Measurement Systems

Problem set n° 2

Sensors and signal conditioning circuits

Exercise 1 (Temperature compensation)

a) Four strain gauges are mounted in a Wheatstone bridge according to figure 1 and are used to measure deformations. These deformations induce a variation of the resistances ΔR. The resistances R of the strain gauges also vary with a change in temperature according to the following relationship:

$$R = R_o + \Delta R_T = R_o \cdot (1 + \alpha_T \cdot \Delta T) \qquad (\alpha_T\text{: temperature coefficient})$$

In which condition is the system insensitive to temperature?

b) We define a new system according to figure 2, with a piezoresistive sensor mounted in a Wheatstone bridge to measure the deformation. Its gauge factor K_T varies as a function of temperature T according to equation :

$$K_T = K_o \cdot \exp[-\beta_T \cdot T]$$

- Express the sensitivity of the bridge S ($S = dU_{ab}/d\varepsilon$) and the relative change in sensitivity $\Delta S/S$ as a function of a change in temperature ΔT.
- Calculate the change in sensitivity $\Delta S/S$ with $\Delta T = 10$ K, $K_o = 200$ and $\beta_T = 0.005$.

c) In order to **compensate for temperature variations**, we add a thermistor R_T in series with the voltage power supply U_i (figure 3). The resistance of the strain gauge will increase with temperature. To compensate this, we use thermistors because their resistance decreases as a function of temperature. These two can then cancel each other out within a certain range of temperatures.

- Determine the temperature coefficient γ_T ($\gamma_T = \frac{1}{R_T} \cdot \frac{\Delta R_T}{\Delta T}$) of the thermistor in order to compensate the change in sensitivity $\Delta S/S$ due to the change of the strain gauge resistance as a function of temperature. (Hint: express $\Delta S/S$ as a function of ΔK_T and ΔU_p. Proper temperature compensation meads that $\frac{\Delta S}{S} = 0$)

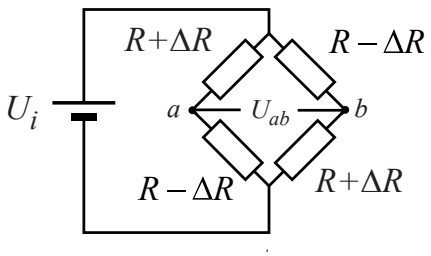

Figure 1: Circuit with T compensation

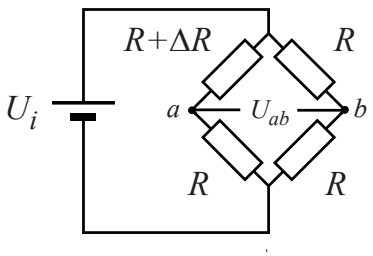

Figure 2: Circuit without compensation

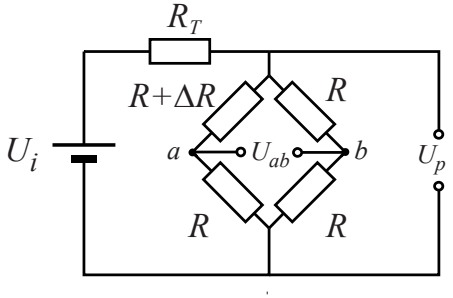

Figure 3: Circuit with compensation

Exercise 2 (***Desired quantity, modifying and interfering inputs***)

We have a strain gauge with resistance $R + \Delta R$ and gauge factor K conditioned according to figure 4. Take into account the resistance of the wires connecting the gauge $R_{c,1}$, $R_{c,2}$ and $R_{c,3}$. We know that the current $i_{c,2}$ is very low.

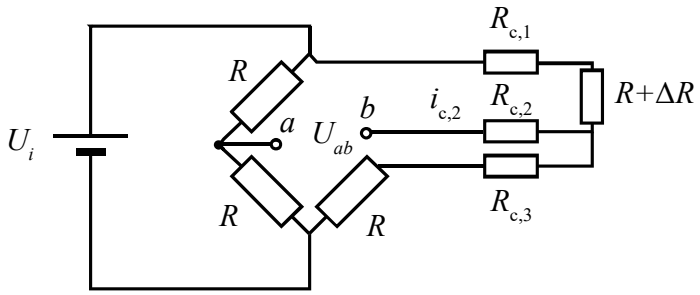

Figure 4: Wheatstone bridge conditioning a strain gauge, taking into account the resistance of the gauge wires

1. Express how **the resistance of wires interfere and/or alter** the measurement of the deformation ϵ.
2. Knowing that the wires have the same cross-section S and the same resistivity ρ, give the condition to limit their effect on the measurement of the deformation. Is the effect of the wires in this case a modifying and/or an interfering input?