Exam - PoMS, 23/01/2014

- Write each question on a sheet of paper.
- Write your **name** and **student ID** on each sheet.
- Pay attention to units. A numerical result without a unit will be considered wrong!
- Only a regular calculator is allowed.
- This is NOT an open book exam.
- You are allowed to bring one A4 page with your own notes (one side only).
- You have **3 hours** to complete the exam.
- Note: $\mathscr{L}(t^n\, e^{-\alpha t}) = \frac{n!}{(s+\alpha)^{n+1}}$.

Question 1: General (2 points)

a) What is a *Schmitt trigger* and what is its application? Describe briefly its working principle.

b) Explain the working principle behind a *thermocouple.*

c) The *autocorrelation function* is often used to detect the presence of a period signal buried in random noise. Explain qualitatively what the autocorrelation function embeds and how it can be used to identify the presence of a buried signal.

d) Describe the working principle of a *tachogenerator* in connection to the concept of *reluctance.*

Question 2: A pressure gauge (2 points)

The table below characterises a pressure gauge designed for operation at room temperature (25 °C, standard condition).

Pressure (bar)	1	2	3	4	5	6
I_{out} [mA] (25 °C)	3.9	7.0	10.1	13.2	16.3	19.4
I_{out} [mA] (35 °C)	3.5	7.2	10.9	14.6	18.3	22.0

a) Explain whether the environment variable is modifying, interfering, or both modifying and interfering.

b) Determine the values of K_M, K_I, a, and K associated with the generalized model equation $O = (K + K_M \cdot I_M) \cdot I + a + K_I \cdot I_I$. Note down the units of the parameters!

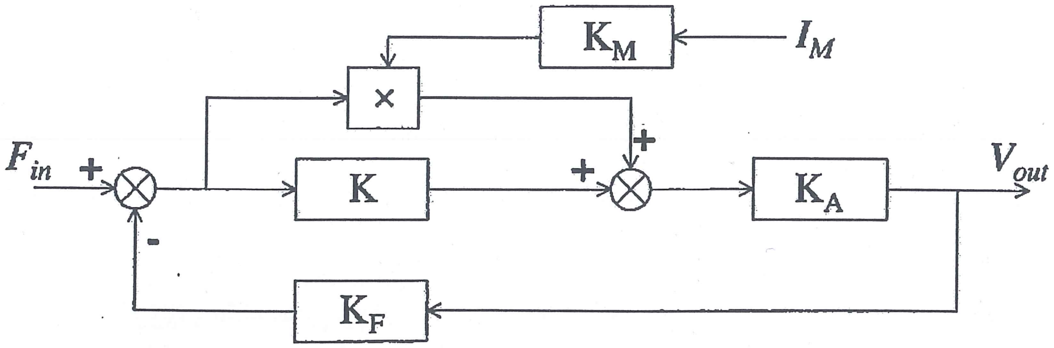

Figure 1: A high-gain negative feedback system.

Question 3: A negative feedback system (2 points)

Figure 1 shows the block diagram of a force transducer (force F_{in} to voltage V_{out}) with a high-gain negative feedback. A sensing element has a sensitivity of K, followed by an amplifier with a high gain K_A, and a feedback element with a sensitivity K_F. The sensing element is influenced by a modifying interference, I_M, with a sensitivity of K_M.

a) Derive the exact equation that describes the static behavior of the system.

b) The high-gain negative feedback system is designed such that the amplifier gain, K_A, is "large". Give an expression that quantifies the meaning of "large", such that $V_{out} \approx F_{in}/K_F$.

c) What is/are the advantage(s) of this technique of "high-gain negative feedback"?

Question 4: A temperature measurement system (2 points)

A temperature measurement system consists of a thermocouple, an amplifier, and a recorder. The thermocouple can be represented by a 1st-order low-pass system with a time constant $\tau = 10$ s and a steady-state sensitivity of 10^{-4} V/°C. The amplifier has a multiplication factor of 10^3 and can be considered as a purely static system. The dynamic response of the *total* measurement system was found to be $G(s) = 1/(1 + 12s + 20s^2)$, where $G(s)$ is the transfer function with s as the Laplace variable (with units sec^{-1}). Note that the steady-state sensitivity of the complete system is unity.

a) Give an expression for the transfer function of the recorder and its steady-state sensitivity.

b) The true temperature changes suddenly by 10 °C from a steady-state condition. Find an expression of the change of the temperature given by the recorder.

c) Estimate the bandwidth of the total measurement system and motivate your answer.

Question 5: Two-element resistance sensor bridge (2+1 points)

Consider a two-element resistance sensor bridge as indicated in Fig. 2. The bridge consists of two identical metal resistance sensors. One sensor is placed at a temperature T_1 (in °C) and the other placed at a fixed reference temperature T_2=0 °C. The formula for resistance as a function of temperature is given in the figure with the temperature coefficient $\alpha=5\times10^{-3}$ °C^{-1} and R_0=100 Ω. The sensor indicated with T_1 operates in a range between 0 and 50 °C.

a) What is the choice for R_3/R_4 such that E_{Th}=0 when $T_1=T_2$ (balanced bridge). Motivate your answer.

b) Take $R_3=R_4=R_0$=100 Ω. The system is calibrated by varying the supply voltage V_S such that E_{Th}=1 V at T_1=50 °C. What value of V_S is required and how large is the non-linearity at T_1=25 °C?

c) What choice for R_3 and R_4 is needed to improve significantly the linearity of the system and to obtain the relation

$$E_{Th} = V_S \left(\frac{R_0}{R_3}\right) \alpha T_1.$$

What price one pays for achieving linearity? Motivate your answers.

d) Take V_S=12 V and $R_3=R_4$=10 kΩ. How large is the maximum power dissipation through sensor R_1?

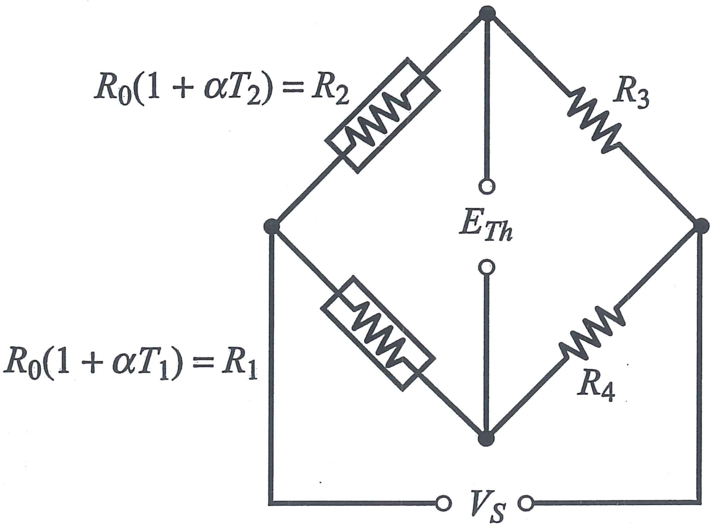

Figure 2: A two-element resistance sensor bridge.