LULEÅ UNIVERSITY OF TECHNOLOGY
Dept. of Computer Science and Electrical Engineering

Course	E0004E (SME101)
Date	2007-12-17
Time	9.00–13.00

Exam in: **Measurement & Instrumentation**
Teacher: Johan Carlson, Ext. (ankn.). 2517
Problems: 5 (5 points per problem)
Tools allowed: BETA (Mathematics Handbook), Physics handbook,
Language dictionary, calculator
Text book: Principles of Measurement Systems, by John Bentley

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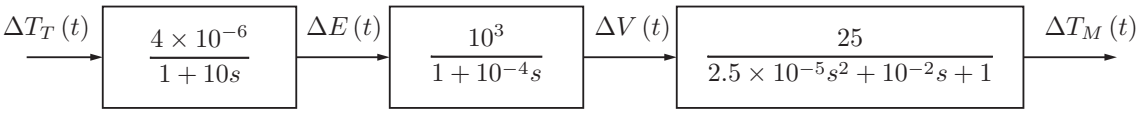
1. A potentiometer has a total length of 10 cm and a resistance of 100 Ω.
   (a) Calculate the supply voltage so that the power dissipation = 1 W. (1p)
   (b) Draw the Thévenin equivalent circuit for 7 cm displacement. (2p)
   (c) The potentiometer is connected to a recorder with a resistance R_L. Find R_L such that the recorder output is 5% less than the open circuit voltage at 7 cm displacement. (2p)

2. A thermocouple sensor has an electromotive force (e.m.f.) in microvolts (μ V)
$$E(T) = 38.74T + 3.319 \times 10^{-2}T^2 + 2.071 \times 10^{-4}T^3 - 2.195 \times 10^{-7}T^4,$$
for the range 0 to 400 °C. For $T = 0$ °C, $E(T) = 0$ μV and for $T = 400$ °C, $E(T) = 28\,442$ μV.
   (a) Derive an expression for the ideal straight line relationship, $E(T) = K \cdot T$. (1p)
   (b) Determine the sensitivity of the sensor (as a function of the temperature). (1p)
   (c) Determine the maximum non-linearity of the system, as a percentage of the full-scale deflection (400 °C). (3p)

3. A turbine flowmeter consists of an assembly of four ferromagnetic blades rotating at an angular velocity ω rad/s given by
$$\omega = 4.5 \times 10^4 Q,$$
where Q m^3/s is the volume flow rate of the fluid. The total flux N linked by the coil of the magnetic transducer is given by
$$N = 3.75 + 0.88 \cos 4\theta \text{ milliwebers},$$
where θ is the angle between the blade assembly and the transducer. The range of the flowmeter is 0.15×10^{-3} to 3.15×10^{-3} m^3/s. Calculate the amplitude and frequency of the transducer output at minimum and maximum flows. (5p)

4. A temperature measurement system is given in the figure below, with transfer functions of the individual elements as in the figure.



   (a) Calculate the dynamic error $E(T)$ of the system. Which element in the system is the dominant cause of this error? (3p)

   (b) Assume that the input temperature is varying as

$$T_T(t) = 5\sin(10^{-2}t) + 2\sin(50t).$$

   What is the output of the system? Explain this behavior. (2p)

5. Consider a measurement system that generates a time-varying voltage with a range of 0–1 Volts. The voltage signal is sampled using an 8 bit analog-to-digital converter (ADC) at a sampling frequency of 10 kHz. The input range of the ADC is set to 0–8 Volts. Assume that the input to the ADC has a standard deviation, $\sigma_I = 0.01$ V.

   (a) What is the maximum quantization error of the system (in Volts), using the current settings of the ADC, expressed as a percentage of the maximum input signal level? (2p)

   (b) What is the maximum possible frequency of the input voltage the system can manage? How can this be guaranteed, even in the presence of noise? (1p)

   (c) How much can the total uncertainty of the system be reduced by changing the input range of the ADC? Motivate your answer clearly. (2p)