Final Exam
Principles of Measurement Systems

(NAPMS05E.2010-2011)
Wednesday 10/10/2010 (09:00-12:00)

- Write your **name, student ID number and date of birth on the first page.**
- Write your **name on all pages and number the pages**
- This is **NOT an open book exam** - only a regular calculator is allowed.
- Pay attention to units. A numerical result without a unit will be considered wrong !
- You have **2 hours to complete the exam.**
- Answers must be **readable, short, clear and to the point.**

1.
(a) Draw a simple Thevenin and Norton equivalent circuit with one load attached. Write down the expression for the voltage over this load in both cases. Show what specifications one needs to impose on the load impedance to obtain optimal transmission of the signal.
(b) Why are current sources preferred in industrial applications ? Short answer in one sentence.
(c) A sinusoidal signal of 1 mV is overwhelmed by white noise with total power of 10 mW. What is the rms voltage of the noise if we assume that the average noise value is zero. What device can one use to determine the signal frequency ?
(d) what is the difference between a thermistor and a thermocouple (one sentence!) and indicate the main benefit of a thermocouple.
(e) What is the preferred value of ξ to obtain a flat amplitude ratio and no peak at the natural frequency in second order transfer function ? Sketch this transfer function (i.e. : the amplitude ratio) for the "preferred value of ξ. How does this figure change when ξ is lower then the preferred value ?
(f) A temperature sensor operates between 0 and 100 °C and gives a perfectly linear output voltage between 0 and 1 V. If this voltage is digitized with a 14-bit digitizer, what is the maximum error on the temperature measurement ?

2.
A sensor consists of a current source with a parallel resistance (150 Ω) and capacitance (3 pF). The sensor is connected to a recorder, consisting of a 10kΩ resistance with a 50 cm cable (with capacitance 100 pF). Fig. 1 gives a an overview of this measurement system.
(a) Show that the transfer function $G(s) = \dfrac{\Delta V_L(s)}{\Delta i_N(s)}$ is of the following form :

$G(s) = \dfrac{a}{1+bs}$. Determine a and b and indicate their units !
Evaluate the transfer function at the frequency (f) of 63.7 MHz
(i.e. : $|G(s)|_{f=63.7MHz}$)
(b) Sketch the amplitude ratio $|G(s)|$ with appropriate values on each axis (i.e. : angular frequency on the X-axis and Amplitude Ratio $|G(s)|$ on Y-axis). Indicate the bandwidth of this system (frequency range).
(c) Is this system suitable to measure signals at this frequency ?

3.
A temperature measurement system consists of an NTC temperature sensor, a voltage divider network and a recorder. The three elements are described by the following equations, resp. :

$$R(T) = R_\infty \exp(\beta/T),\ V(R) = V_0 \frac{R_0}{R_0 + R(T)},\ T_M(V) = K.V(R) + a$$

Mean value	standard deviation (σ)
$R_\infty = 1.6770 \times 10^{-2}\ \Omega$	$10^{-5}\ \Omega$
β = 3965.0 K	0 K
V_0 = 10 V	5 mV
R_0 = 10 kΩ	0 Ω
K = 8.9678 K/V	0.001 K/V
a = 253.315 K	0 K

Assuming all probability distributions are normal, calculate for an input temperature of 300 K:
(a) the mean of the measured temperature
(b) the standard deviation of the corresponding error probability density function
(c) which parameter contributes most significantly to the measured uncertainty?

4.
(a) Draw a deflection bridge with four general impedances Z_1, Z_2, Z_3, Z_4 and derive an expression for the Thevenin voltage E_{Th}.
(b) Two of these impedances are replaced by the following inductances :
$Z_i = \frac{L_0}{1+\alpha(a-x)}$, $Z_j = \frac{L_0}{1+\alpha(a+x)}$. Indicate which impedances in your drawing should be replaced by these $Z_{i,j}$ to obtain a Thevenin voltage E_{Th} which is linear in "x".
(c) How is this particular sensor, consisting of two inductances, called ?
Draw a sketch of this sensor and indicate what is measured with this sensor.

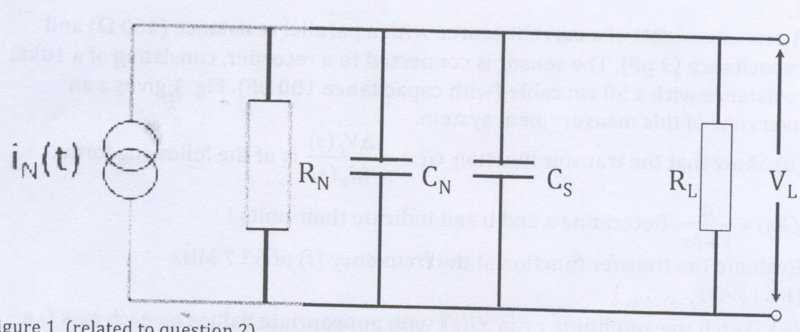

Figure 1 (related to question 2)