YOUR NAME: ______________________ ID:_s__________ DOB: ____/____/19__

Department/Program: TN / TBK / BMT / ...

Final Exam
Principles of Measurement Systems
(NAPMS.2007-2008.1a)
Thursday, April 10, 2008 (9:00-12:00)

Please write your name, student ID number and date of birth on this or the first page, only your name on all subsequent pages, and number the pages. Don't forget to hand in all relevant paperwork.

This is not an open-book exam, so please remove all other documents.

Read carefully. Pay attention to units. A numerical result without, or with wrong units, will be considered incorrect. You may assume that I know the answer to the questions posed; Therefore, give derivations and/or motivate your answers as appropriate! If you cannot answer the first part of a question, make a (educated) guess, and continue with the rest... Success!

Question 1

Table I gives the results of a laboratory calibration of an unknown pressure sensor.

Table I. Calibration results of unidentified pressure sensor.

p [bar]	0	1	2	3	4	5
V_{out} [V]	-12.84	-9.22	-4.92	+2.19	+6.03	+9.56

a. Graph the behavior of V_{out} in the pressure range from 0 to 5 bar. Interpolate between the data points, assuming a relatively smooth sensor response.

b. Determine the ideal straight line parameters a and K in: $O = a + K \cdot I$

c. Estimate the maximum non-linearity, in absolute units, and expressed as a percentage of the full-scale deflection.

d. Estimate the output voltage for p = 2.5 bar.

Question 2

A pressure sensor with built-in current transmitter (characterized by its Norton equivalent circuit: current source i_N with shunt resistance R_N) is read out by a recorder with load resistance R_L. The capacitive coupling to a nearby power cable and earth plane can be described by the parasitic capacitors C_1, C_2, C_3, and C_4, as shown in Figure 2.

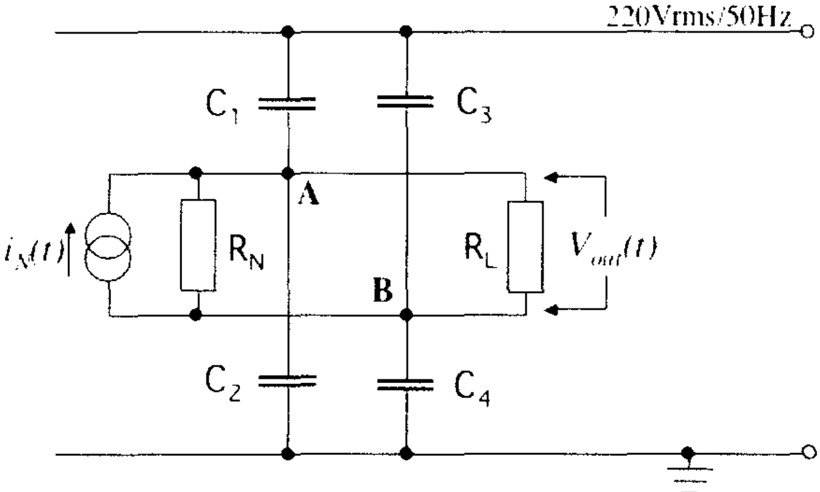


Figure 2. Equivalent circuit of pressure transducer and recorder, showing capacitive coupling to power cable and earth plane. R_N=100 kΩ, R_L=1 kΩ, C_1=50 pF, C_2=55 pF, C_3=80 pF, C_4=85 pF

Assume for the moment that $i_N \sim 0$ A.

a. Derive an expression for the common mode voltage (rms) seen by the recorder, and evaluate it numerically.

b. Derive an expression for the series mode voltage (rms) seen by the recorder, and evaluate it numerically.

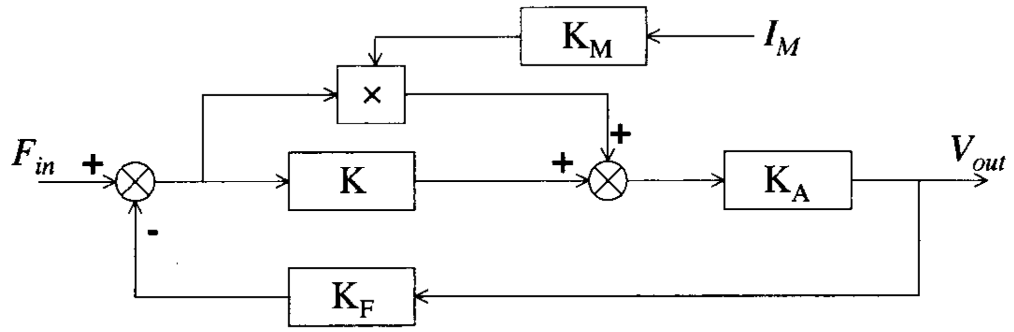
The current is given by $i_N(t) = c \cdot sin(\omega t)$, with c = 6.3 mA and ω=1 kHz.

c. Ignoring the influence of the capacitive coupling, calculate the rms signal registered by the recorder.

d. Discuss strategies for reduction of the capacitive coupling.

e. Estimate the signal-to noise ratio of the measurement, provided that the recorder has a CMRR=60 dB and that the sole source of noise is the capacitive coupling to the power cable.

Question 3
The figure here below shows the block diagram of a force transducer with high-gain negative feedback.



a. Derive the exact equation that describes the static behavior of the system.
b. High-gain negative feedback implies that K_F is "large". But large with respect to what? Give an expression that quantifies the meaning of "large" in this case.
c. Show that, if the expression you just derived holds, $V_{out} \approx F_{in}/K_F$.
d. What is/are the advantage(s) of this technique of "high-gain negative feedback"?

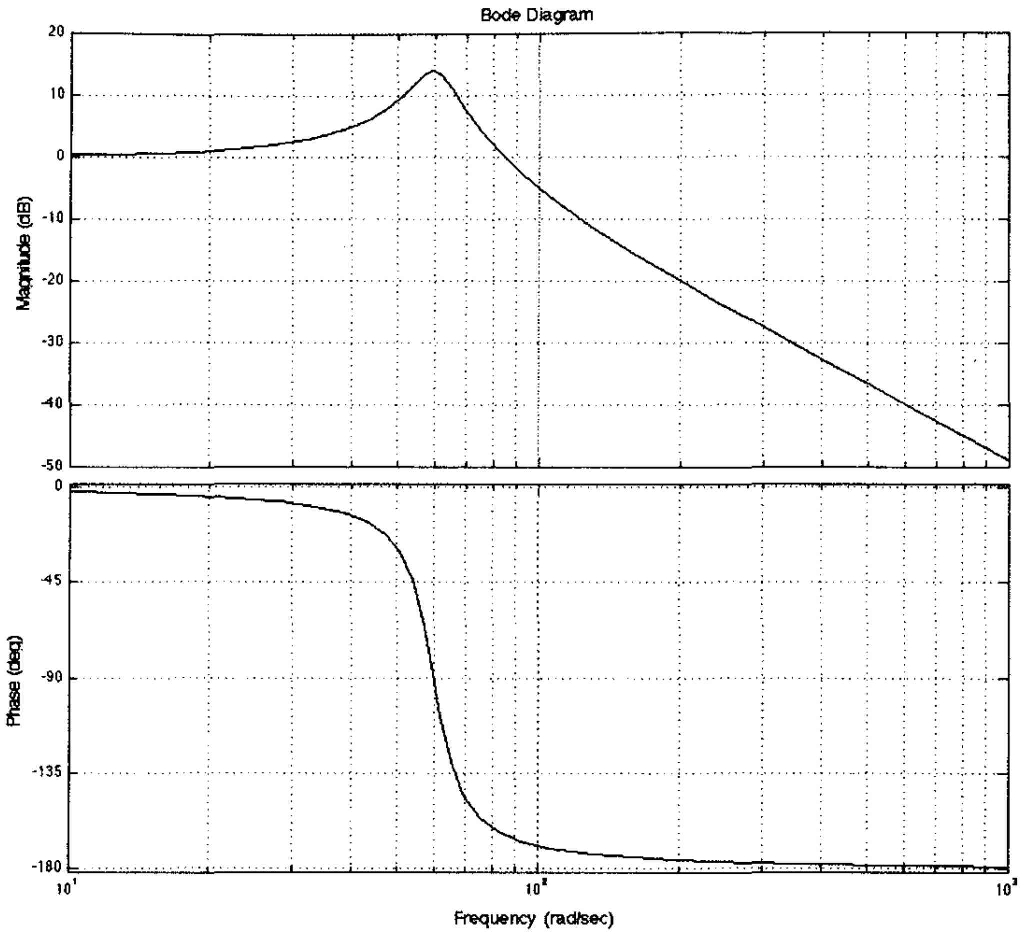
Question 4
The figure on the following page gives the Bode diagrams (magnitude and phase) of a 2nd order mechanical system with transfer function:

$$G(s) = \frac{1/k}{\left(\frac{s}{\omega_n}\right)^2 + \frac{2\xi s}{\omega_n} + 1}$$

a. Determine the numerical values of the natural frequency, damping ratio, and stiffness from the Bode diagram (pay attention to units!).

Remember that $\omega_n = \sqrt{k/m}$ and $\lambda / k = 2\xi / \omega_n$. Then:

b. Draw a schematic representation of a mechanical (sensor) system for which the above transfer function describes the relation between ΔF and Δx, the deviations of the applied input force and the resulting displacement from initial steady-state conditions. Label each element, and give the parameter that specifies it, as well as the corresponding numerical value (including units).
c. Give the differential equation describing the mechanical system.



... End of the Exam.