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UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 145L: Electronic Transducer Laboratory

FINAL EXAMINATION Fall 2007

You have three hours to work on the exam, which is to be taken closed book.

Calculators are OK, equation sheet provided.

You will not receive full credit if you do not show your work.

Use back side of sheet if necessary.

Total points = 200 out of 1000 for the course.

1 _____ (40 max) 2 _____ (40 max) 3 _____ (40 max)

4 _____ (34 max) 5 _____ (46 max) TOTAL _____ (200 max)

COURSE GRADE SUMMARY

LAB REPORTS (500 points max):

[5 short reports (lowest grade dropped)- 100 points max]

[5 full reports (lowest grade dropped)-400 points max]

4 _____ 5 _____ 6 _____ 7 _____ 11 _____
12 _____ 13 _____ 14 _____ 15 _____ 16 _____
17 _____ 18 _____ 19 _____ 25 _____

LAB TOTAL _____ (500 max)

LAB PARTICIPATION _____ (100 max)

MID-TERM #1 _____ (100 max)

MID-TERM #2 _____ (100 max)

FINAL EXAM _____ (200 max)

TOTAL COURSE GRADE _____ (1000 max)

COURSE LETTER
GRADE

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PROBLEM 1 (40 points)

Define the following:

1.1 (8 points) Ideal operational amplifier (Op-amp)

1.2 (8 points) Johnson noise

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1.3 (8 points) Sensitivity (of a sensor)

1.4 (8 points) Actuator

1.5 (8 points) Strain (mechanical)

PROBLEM 2 (40 points)

Design an analog amplification and filtering system for a seismometer. A modern seismometer consists of (1) a heavy permanent magnet that is suspended so that it does not move during an earthquake and (2) thousands of turns of wire (mechanically attached to the ground) that pick up an induced signal from the magnet when the ground moves.

- The seismometer has two output wires and produces a maximum differential signal ± 10 mV which your circuit should amplify to ± 10 V.
- The frequencies of interest are from d.c. to 1000 Hz.
- The seismometer signal has an unwanted 60 Hz component from electromagnetic interference that is ± 10 mV common, ± 0.01 mV differential.
- The instrumentation amplifier that you will use has an input noise $V_{\text{rms}} = 4 \text{ nV Hz}^{-1/2} \sqrt{\Delta f}$, a gain-bandwidth product of 10^7 Hz, and a common mode rejection ratio of 60 dB. Assume zero leakage current, and that the noise at the output = gain x input noise.

Do the following:

2.1 (5 points) What are the gain and bandwidth of the instrumentation amplifier in your design?

2.2 (5 points) What is the instrumentation amplifier noise at its output in that bandwidth?

2.3 (10 points) Design an analog filter (specify type, corner frequency, and order) that has a gain > 0.99 for frequencies of interest and a gain < 0.01 for frequencies above 2 kHz. (Hint: see equation sheet for a table of f/f_c vs. gain and order.) What is the instrumentation amplifier noise at the output of the filter?

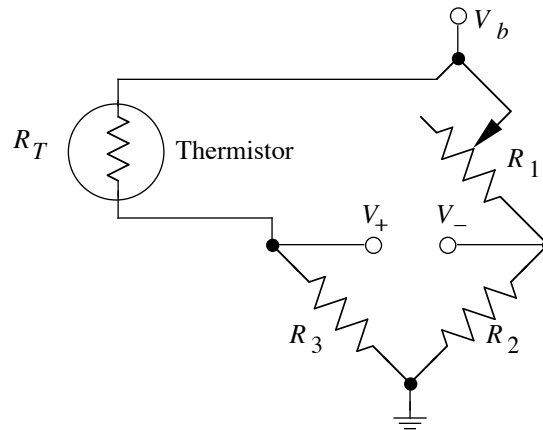
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2.4 (10 points) How would you use analog filtering to minimize the 60 Hz interference with a minimum loss in the signal of interest? What is the 60 Hz output noise before and after the filter (approximate estimate based on what you remember from Lab 6)?

2.5 (10 points) Sketch a block diagram of your amplifier and analog filter circuit in enough detail so that a skilled technician can build it and understand how it meets the design objectives.

PROBLEM 3 (40 points)

You wish to measure air temperatures near 20°C using the thermistor bridge shown below.



Assume the following:

- $R_2 = R_3 = 10 \text{ k}\Omega$.
- You use an instrumentation amplifier with a gain of 5: $V_0 = 5 (V_+ - V_-)$.
- The thermistor resistance R_T is $10.0 \text{ k}\Omega$ at 20°C
- $dR_T/dT = -300 \text{ }\Omega/^\circ\text{C}$ at 20°C .

You then perform a series of experiments to explore the thermistor self-heating of your system.

Experiment 1: With $V_b = 1$ volt and the thermistor in **water** at 20°C , you adjust R_1 to make the amplifier output $V_0 = 0.000$ volts. (Assume that there is no self heating in water)

3.1 (4 points) What are the values of R_1 and R_T ?

3.2 (8 points) What electrical power is produced in the thermistor?

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Experiment 2: You then move the thermistor to **air** at 20 °C, wait a while, and find that the amplifier output $V_0 = 0.05$ volts ($V_b = 1$ volt).

3.3 (8 points) What is the thermistor resistance R_T ?

3.4 (7 points) What is the temperature of the thermistor?

3.5 (7 points) What electrical power is produced in the thermistor?

3.6 (6 points) What is the thermal dissipation coefficient in W per C°?

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PROBLEM 4 (36 points)

Design a circuit that can be used to measure the current I_{diode} through the photodiode as a function of the voltage V_{diode} across it, for both forward and reverse voltages. Assume that only voltages will be measured, using a digital voltmeter with a high input impedance.

4.1 (10 points) Sketch your design below. Include sufficient detail so that a skilled technician could build it

4.2 (12 points) List the steps necessary for making the voltage measurements and converting them to V_{diode} and I_{diode} .

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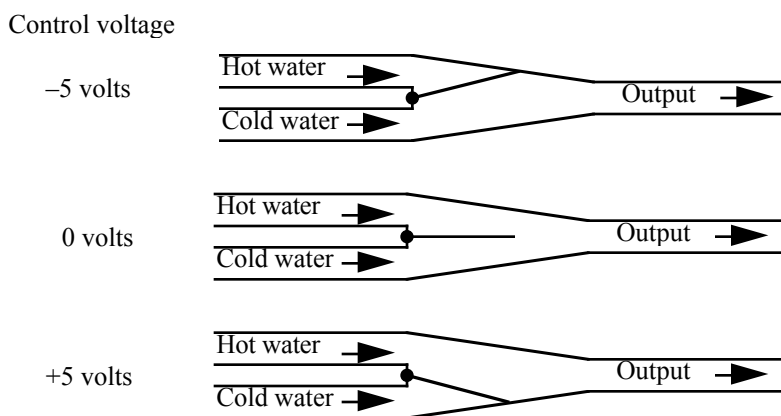
- 4.3** (12 points) Under conditions of (1) darkness and (2) a light level that produces 1 mA of electron-hole current, plot what you would expect to measure in a figure below and label the axes with numbers and units.

PROBLEM 5 (46 points)

Design a control system for mixing hot and cold water to produce water at a desired temperature. The user can specify any desired temperature between 20C and 80C by setting a voltage between 2.0 and 8.0 volts.

You are provided with:

- A voltage-controlled water valve with two water pipe inputs and one water pipe output. By setting the control voltage in the range between -5 and $+5$ volts, any ratio of hot and cold water can be produced. (See figure below).
- A power op-amp
- A temperature sensor of your choosing
- A cold water temperature of 20C and a hot water temperature of 80C.



5.1 (16 points) Sketch a block diagram of your design. Provide enough details so that a skilled technician could understand how it works and build it. Label all essential components and signals and specify the location of your temperature sensor.

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5.2 (10 points) Describe the voltages in your control system when the system is controlling at the set point temperature of 20C.

5.3 (10 points) Describe how the voltages in your control system change after the set point temperature is changed from 20C to 60C.

5.4 (10 points) Starting from a state where the system is controlling at a set point temperature of 60C, describe how the voltages in your control system change after the temperature of the hot water supply is reduced to 70C