NAME (please print) ______________________________ SID ___________________

UNIVERSITY OF CALIFORNIA

College of Engineering

Department of Electrical Engineering and Computer Sciences

EECS 145L: Electronic Transducer Laboratory

FINAL EXAMINATION Fall 2002

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 ______________ (60 max) 2 ______________ (40 max) 3 ______________ (60 max)

4 ______________ (40 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

NAME (please print) ______________________________ SID ____________________

PROBLEM 1 (60 points)

In 50 words or less, describe the ***essential differences*** between the following pairs

1a (10 points) **Johnson noise** vs. **shot noise**

1b (10 points) **sensor** vs. **actuator**

1c (10 points) **Thompson emf** vs. **Peltier emf**

1d (10 points) **thermocouple** vs. **Peltier thermoelectric heat pump**

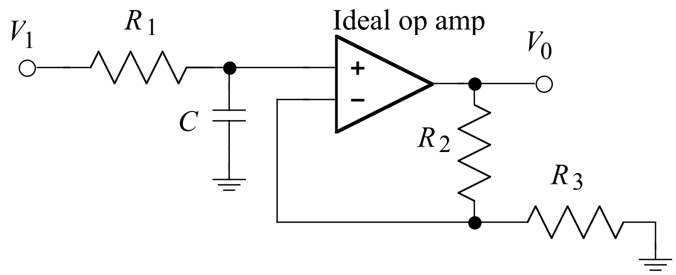
1e (10 points) **electromyogram (EMG)** vs. **electrocardiogram (ECG)**

1f (10 points) **beta ray** vs. **x-ray**

NAME (please print) ______________________________ SID ___________________

PROBLEM 2 (40 points)

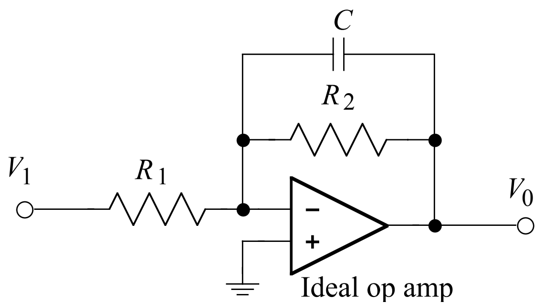
2a (15 points) Derive the voltage gain vs. frequency formula for the following circuit. Hint: the impedance of a capacitor is given by 1/(jωC).



2b (5 points) For voltage gains of 10.00 at 0 Hz and 7.07 at 1 kHz, specify suitable values for R_1. R_2, R_3, and C. (Hint: For RC = 0.159 ms, 1/(2πRC) = 1 kHz)

NAME (please print) ______________________________ SID ___________________

2c (15 points) Derive the voltage gain vs. frequency formula for the following circuit.



2d (5 points) For voltage gains of 10.00 at 0 Hz and 7.07 at 1 kHz, specify suitable values for R_1. R_2, and C.

NAME (please print) ______________________________ SID ___________________

PROBLEM 3 (60 points)

Design a thermocouple-based system for measuring the temperature inside a furnace with an absolute accuracy of 2 °C over the range from 25 °C to 500 °C, without the need to provide a constant supply of ice to keep the reference junction at 0 °C. Instead, you decide to leave the reference junction in the room air outside the furnace, measure its temperature with a platinum resistance thermometer, and correct the thermocouple signal using ***analog circuits of your design***.

To simplify the calculations, assume the following:

- The sensitivity of the thermocouple is 50.00 μV/C°.
- The platinum resistance thermometer has a resistance given by the equation
  $R(T) = 100.0\ \Omega\ (1 + 0.004\ T)$, where T is the temperature in °C.

3a (15 points) Design a circuit that converts the thermocouple output into a voltage V_{tc} so that $V_{tc} = \Delta T$ (10 mV/C°), where $\Delta T = T_{sens} - T_{ref}$. Draw a block diagram and label all necessary analog circuit elements and signal lines. Include the thermocouple wires. (It is not necessary to include analog filtering)

3b (15 points) Design a circuit that converts the platinum resistance into a suitable voltage V_{pt} so that $V_{pt} = T_{rm}$ (10 mV/C°), where T_{rm} is the room temperature in C°. Draw a block diagram and label all necessary analog circuit elements and signal lines. Show where the platinum resistance thermometer is placed in the diagram of part **3a** above. (It is not necessary to include analog filtering)

NAME (please print) ______________________________ SID ___________________

3c (10 points) Sketch the thermocouple voltage V_{tc} as a function of the temperature difference $\Delta T = T_{sens} - T_{ref}$. Label the axes with numbers and units.

3d (10 points) Sketch the platinum resistance circuit voltage V_{pt} as a function of the temperature T_{rm}. Label the axes with numbers and units.

3e (10 points) Sketch your design for converting V_{tc} and V_{rm} into a voltage V_{out}, where $V_{out} = T_{sens}$ (10 mV/C°), independent of room temperature.

NAME (please print) ______________________________ SID ___________________

PROBLEM 4 (40 points)

After considering how sensitive strain gauges are to the thermal expansion of the element to which they are bonded, you invent a new temperature sensor that consists of two resistive strain gauges cemented to a small aluminum plate.

Assume the following:

- You use the two strain gauges in a bridge circuit
- The two strain gauges have unstrained resistance 100 Ω, gauge factor = 2
- The thermal expansion coefficient of aluminum is 23 ppm/°C (ppm = parts per million)
- The maximum power that the strain gauges can dissipate is 250 mW
- You use an instrumentation amplifier with a noise level of 10 $nV/Hz^{1/2}$ (relative to the input)

4a (8 points) Sketch your circuit design, including all components and wires.

4b (8 points) Derive the equation that relates bridge output voltage to the resistance of the two strain gauges.

4c (8 points) What bridge bias voltage gives the maximum bridge sensitivity?

4d (8 points) At the bias voltage from part **4c**, what is the bridge output sensitivity in mV/C°?

4e (8 points) Assuming the sensitivity from part **4d**, what is the noise level in terms of C° at 1M Hz and 1 Hz bandwidths?