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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 2009

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 ______________ (35 max) 3 _______________ (35 max)

4 ______________ (45 max) 5 ______________ (45 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)

For each of the actuators below describe their construction and how they produce their output.

1.1 Stepping Motor (8 points)

1.2 Resistive Heater (8 points)

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1.3 Incandescent Lamp (8 points)

1.4 Light Emitting Diode (8 points)

1.5 Peltier Thermoelectric Heat Pump (8 points)

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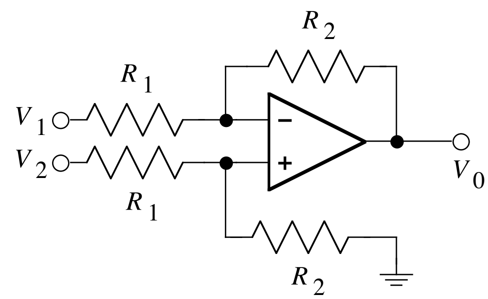
PROBLEM 2 (35 points)

2.1 (20 points) Derive an equation for the output V_0 of the op-amp circuit shown below as a function of the input voltages V_1 and V_2 and the resistors R_1 and R_2. Assume that the op-amp has infinite open loop gain and infinite input impedances.



2.2 (15 points) Using the equation derived in part 2.1, write an equation for the differential and common-mode gains as functions of the resistors R_1 and R_2.

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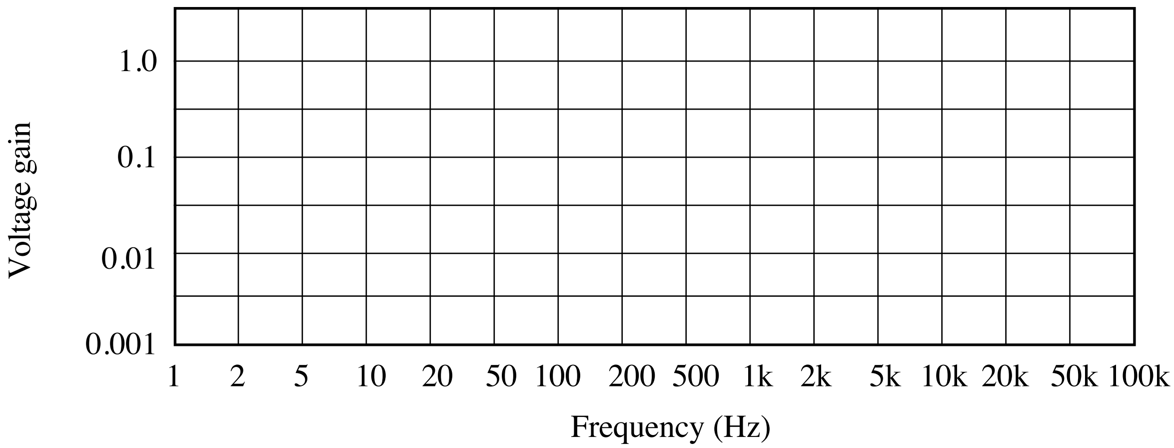
PROBLEM 3 (35 points)

Design an analog filter circuit that has the following properties and the minimum number of active components

- Gain between 0.9 and 1.0 for frequencies between 100 Hz and 10 kHz
- Gain less than 0.001 for frequencies above 30 kHz
- Gain less than 0.003 at 60 Hz
- Gain less than 0.001 for frequencies below 10 Hz

3.1 (10 points) Sketch the required gain vs. frequency below



3.2 (25 points) Design a filtering circuit that meets the requirements above with the minimum complexity and cost. **For each filtering element, give type, corner frequency, and order number.** (Hint: see equation sheet for a table of f/f_c vs. gain and order.) Do not give resistor and capacitor values.

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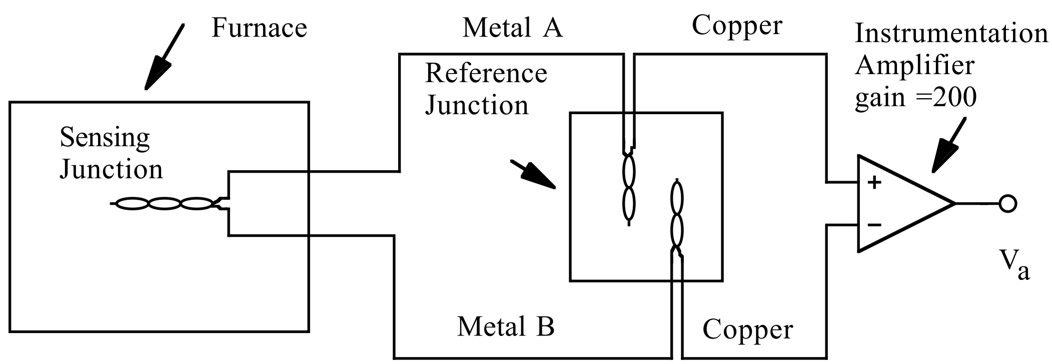
PROBLEM 4 (45 points)

You are given the following circuits for two temperature sensors. The thermocouple sensing junction is in a furnace. The thermocouple reference junction and the solid-state temperature sensor are at room temperature.
The sensitivity of the thermocouple is 50 μV per centigrade degree.
The sensitivity of the solid-state temperature sensor is 1 μA per centigrade degree.
All temperatures in degrees Celsius.

4.1 (15 points) Derive the equation for the output voltage V_a of the instrumentation amplifier as a function of the furnace temperature T_f and the room temperature T_r.



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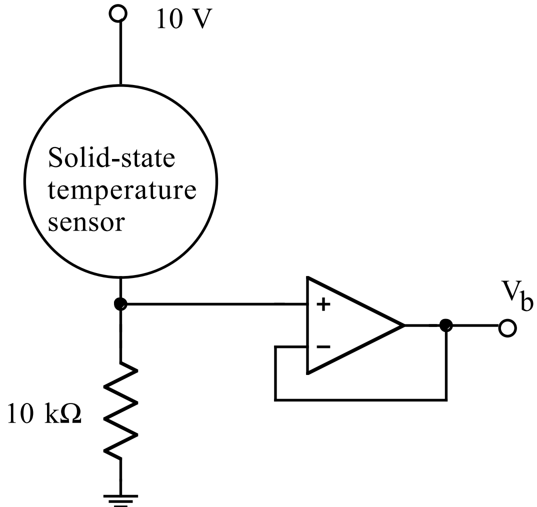
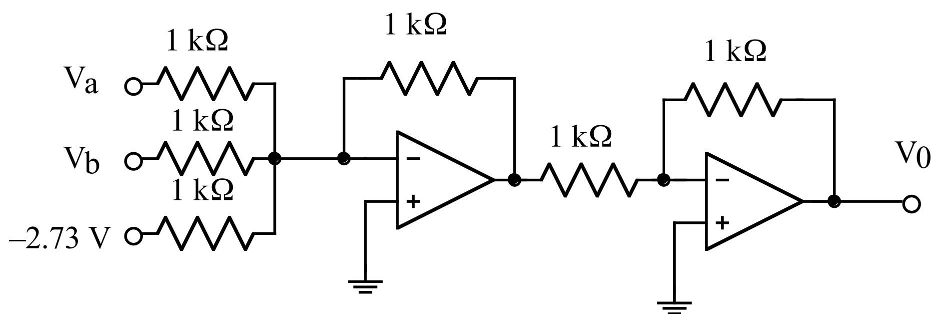
4.2 (15 points) Derive the equation for the output voltage V_b of the solid-state temperature sensing circuit as a function of the room temperature T_r.



4.3 (15 points) Derive the equation for the output voltage V_0 in the circuit below as a function of the furnace temperature T_f and the room temperature T_r.



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PROBLEM 5 (45 points)

Design a toaster that senses the color of the bread (or muffin, frozen waffle, etc.) and stops the toasting process when the color darkens to a preset level. The user places a color standard into a slot and turns on the toaster. When the darkness of the toast is the same as that of the color standard, the toasting stops. The toaster heater element requires 110 V at 10A.
Hint: combine (1) what you know about the light sensing laboratory exercise, (2) negative feedback control, and (3) the high-power switching portion of the ground fault interrupter circuit.

(Note that almost all toasters are controlled by time or the temperature near the heating coil- this is why they are so inaccurate)

5.1 (25 points) Sketch your design below. Provide sufficient detail so that a skilled technician could understand and build it.

5.2 (20 points) Describe how your design works to produce perfectly toasted toast.