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 2006

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 ______________(50 max) 2 ______________ (30 max) 3 _______________ (45 max)

4 ______________ (45 max) 5 ______________ (30 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 (50 points)

Define the following and explain their operation in fundamental terms:

1.1 (10 points) Virtual short (of an op-amp using negative feedback)

1.2 (10 points) Electromagnetic isolation amplifier

NAME (please print) ______________________________ SID ___________________

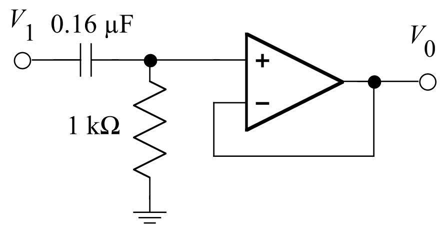
1.3 (10 points) Digital angle encoder

1.4 (10 points) PID controller

1.5 (10 points) smoke detector (with internal alpha source)

NAME (please print) ______________________________ SID ____________________

PROBLEM 2 (30 points)
Consider the high-pass one-pole filter circuit shown below.

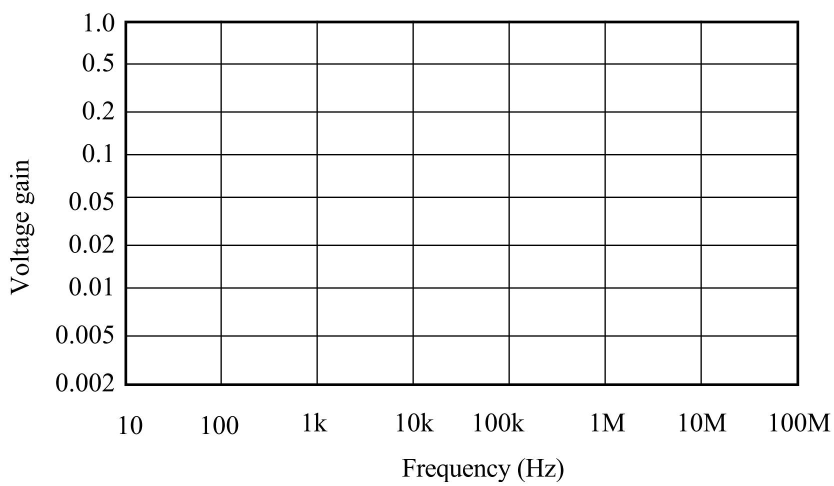


The op amp specifications are

- Infinite input impedance, no input leakage currents
- The open-loop gain A varies as 1/frequency and reaches unity gain at 10^6 Hz

2.1 (15 points) At what frequencies is the gain 0.1?

2.2 (15 points) Sketch the Bode gain plot below.



NAME (please print) ______________________________ SID ___________________

PROBLEM 3 (45 points)

You are designing a thermocouple-based system for measuring the temperature of a furnace (T_f) over the temperature range from 25 °C to 500 °C with an absolute accuracy of 2 °C and do not want to provide ice to stabilize the temperature of the reference junction at 0 °C. Instead, you decide to leave the reference junction in the air of the room and measure the temperature of the room (T_r) with a solid-state temperature sensor. The correction of the thermocouple output for room temperature will be done by a voltage-summing circuit.

Assume the following:

- The thermocouple sensitivity is 50 µV/°C.
- The solid state temperature sensor passes a current I = (1 µA) T where T is its temperature in K and the voltage across it is in the range from 3 to 40 volts. Note that 0 °C = 273 K.

3.1 (15 points) Sketch a circuit that uses a thermocouple to produce an output V_a = 0.25 V when the temperature difference between the sensing and the reference junction is 25 °C and V_a = 5.00 V when the temperature difference is 500 °C. Label all necessary analog circuit elements and signal lines. Include the thermocouple wires and furnace. (It is not necessary to include analog filtering).

3.2 (15 points) Sketch a circuit that converts the solid-state temperature sensor current into a voltage V_b that has the same sensitivity (V/°C) as the thermocouple circuit **a**. Draw a block diagram and label all necessary analog circuit elements and signal lines. Show where the solid-state temperature sensor is placed in the diagram of part **3.1** above. (It is not necessary to include analog filtering)

3.3 (15 points) Sketch a circuit that combines the outputs of circuits **3.1** and **3.2** to provide a voltage V_c that is proportional to the furnace temperature (0.25 V at 25°C and 5.00 V at 500 °C) and does not depend on the room temperature.

NAME (please print) ______________________________ SID ___________________

PROBLEM 4 (45 points)

4.1 (10 points) Design and sketch a circuit for using a metal film strain gauge (gauge factor 2) to convert a strain from $\Delta L/L = -10^{-5}$ to $+10^{-5}$ into a voltage from –1 to + 1 volt.

4.2 (15 points) Design and sketch a circuit for using a thermistor (10 kΩ at 0°C, 5 kΩ at 25°C, 2 kΩ at 50°C) to convert a temperature from 0°C to 50°C into a voltage from 0 to + 5 volts with maximum sensitivity at midrange.

4.3 (10 points) Design and sketch a circuit for using a PIN photodiode (quantum efficiency 50%) to convert a narrow light beam from 0 to 6.241 x 10^9 photons/s into a voltage from 0 to 1 V. (*Hint:* 6.241 x 10^{18} electrons = 1 Coulomb)

4.4 (10 points) Design and sketch a circuit for using Ag(AgCl) skin electrodes and optical isolation to convert a –1 to +1 mV ECG signal into a voltage from 0 to 1 V to be connected to a computer without any possibility of electrical shock to the patient.

NAME (please print) ______________________________ SID ___________________

PROBLEM 5 (30 points)

Design a circuit for powering an incandescent lamp (light bulb) in a photographic exposure system that requires a constant light source. Over time, some of the lamp filament evaporates and coats the inside of the glass envelope with a metal film that absorbs light. As the filament becomes thinner, variations in its diameter become more important, and cooler and hotter sections develop. Consequently, the relationship between voltage and light output over the life of the lamp is complicated and difficult to predict.

Technical requirements:

1 Constant light output over the lifetime of the lamp and during minor changes in the wall outlet voltage.

2 The ability to adjust the light output

3 Sufficient power for a 100 watt lamp with a maximum voltage of 10 volts.

5.1 (20 points) Sketch your design below. Provide enough detail so that a skilled technician would be able to build it and understand how it works. Include and label all necessary components. Label all signals with typical voltage and current values. You may use any circuit components from the laboratory exercises, textbook, or lectures, but keep it simple.

(Hint: Use an op-amp with negative feedback)

5.2 (10 points) Describe how the circuit responds to the gradual development of a metal film on the inside of the glass envelope.