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UNIVERSITY OF CALIFORNIA

College of Engineering
Department of Electrical Engineering and Computer Sciences

EECS 145L: Electronic Transducer Laboratory

FINAL EXAMINATION December 15, 2000 12:30 - 3:30 PM

You have three hours to work on the exam, which is to be taken closed book.
Calculators are OK, use 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 ______________ (30 max) 2 ______________ (45 max) 3 ______________ (45 max)

4 ______________ (40 max) 5 ______________ (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

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PROBLEM 1 (30 points)

1a. (10 points) Sketch a circuit that uses a Pt resistance thermometer to produce an output of 0.0 V at 0 °C and 1.0 V at 100 °C.

Assume that the Pt thermometer resistance is 100 W (1 + 0.004 T) where T is the temperature in °C.

1b. (10 points) Derive the equation that relates temperature to the output voltage of your circuit.

1c. (5 points) What is the output voltage of your circuit at 50 °C?

1d. (5 points) What is the deviation from the linear response at 50 °C in terms of voltage? In terms of temperature?

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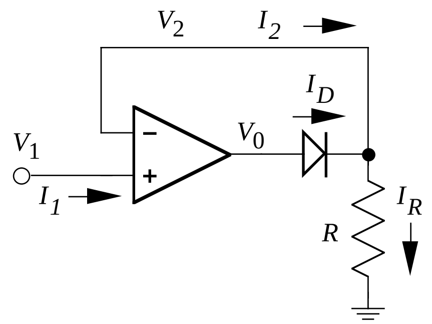
PROBLEM 2 (45 points)

The following op-amp circuit converts a voltage into a current through a light emitting diode (LED).



Assume the following:

- The op-amp is ideal.
- the LED obeys the ideal diode equation $V_D = (86.17\ \mu\text{V/K})\ T \ln(1+I_D/I_S)$, where $V_D = V_0 - V_2$ is the forward voltage across the diode, T is the temperature in degrees K, I_D is the forward current through the diode, and the saturation current $I_S = 10^{-13}$ A.
- At 273 K and $I_D = 30$ mA, $V_D = 0.6217$ V (Given this and the equation above, you should be able to compute V_D for any other T easily).

2a. (5 points) What is the value of R that makes $I_D = 0$ mA at $V_1 = 0.0$ V and $I_D = 30$ mA at $V_1 = 3.0$ V?

2b. (10 points) For $V_1 = 0.0$V and $T = 273$ K, give the values of I_1, I_2, V_2, I_R, I_D, V_D, and V_0.

2c. (15 points) For $V_1 = 3.0$V and $T = 273$ K, give the values of I_1, I_2, V_2, I_R, I_D, V_D, and V_0.

2d. (15 points) For $V_1 = 3.0$V and $T = 173$ K, give the values of I_1, I_2, V_2, I_R, I_D, V_D, and V_0.

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PROBLEM 3 (45 points)

Design a circuit that uses the circuit and assumptions in Problem 2 to sense temperature and produce 0.0 V at 0 °C (273 K) and 1.0 V at –100 °C (173 K). (An LED or a conventional diode would work for this purpose.)

Sketch your design below, and label all essential components. For each conductor in the circuit, show the voltage at 0 °C and –100 °C. Provide enough detail so that a skilled technician would be able to build it and understand how it works.

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PROBLEM 4 (40 points)

Design a circuit that uses (i) an instrumentation amplifier, (ii) a transformer coupled isolation amplifier, and (iii) other circuits as needed to amplify and filter the ECG lead II signal (right arm-left leg) of the human heart.

Assume the following:

- The instrumentation amplifier has differential inputs with 10^{12} W input impedance, a gain that can be set by external resistors, a gain-bandwidth of 10^6, and a CMRR of 10^6.
- The isolation amplifier has a single input with an impedance of 1 kW, a gain of 10, and a bandwidth of 10 kHz
- The impedance of each skin electrode can be as high as 10 kW
- The ECG signal has a differential peak-to-peak amplitude of 20 mV
- The 60 Hz electromagnetic interference on the skin electrodes is 50 mV peak-to-peak (common mode)
- The 60 Hz electromagnetic interference on the skin electrodes is 5 mV peak-to-peak (differential mode)
- The frequency range of the signal is 1 Hz to 1 kHz- you need to eliminate electrode drift (10x rejection at 0.1 Hz), white noise (100x rejection at 10 kHz), and 60 Hz interference (30x rejection).
- The desired signal output is 5 V peak-to-peak

Sketch your design below. Provide enough detail so that a skilled technician would be able to build it and understand how it works. Include all necessary components and label all signals with peak-to-peak voltage values.

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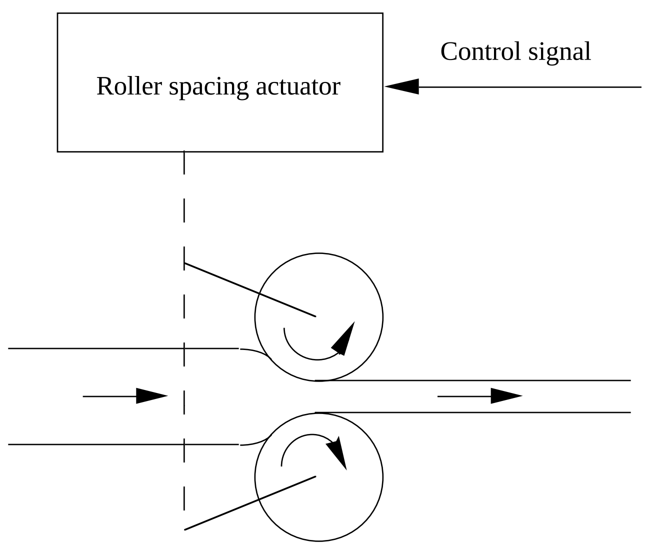
PROBLEM 5 (40 points)

Design a system for controlling the thickness of sheet metal in a rolling mill. To produce sheet metal, thick sheets are pressed between two rollers (see figure below). The distance between the rollers is adjusted to control the thickness of the final product. You plan to use a beta source and a solid-state detector to sense the thickness of the sheet at the output of the rollers and control the distance between the rollers ***so that the thickness is the same as that of a reference sheet***. Since the sheet absorbs some of the beta energy, a thicker sheet will produce less current in the solid state detector than a thinner sheet.

You have:

- Two identical beta sources
- Two identical solid-state detectors that produce a current that is proportional to the beta energy deposited in them
- An interface to the roller mill so that a positive control signal decreases the spacing between the rollers and a negative control signal increases the spacing between the rollers
- The control signal only needs to provide a small current (a few mA)
- Electronic components necessary to generate the control signal

5a (30 points) Sketch you design in the figure below. Provide enough detail so that a skilled technician would be able to build it and understand how it works.



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5b (10 points) Describe how the control system responds when the reference sheet is replaced by a thinner sheet.