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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 17, 1992 5:00 - 8:00 PM**

You have three hours to work on the exam, which is to be taken closed book. Calculators are OK, but not needed. Total points = 200 out of 1000 for the course.

1 ______________ (24 max) 2 ______________ (32 max) 3 _______________ (30 max)

4 ______________ (34 max) 5 ______________ (48 max) 6 _______________ (32 max)

TOTAL ______________ (200 max)

COURSE GRADE SUMMARY

LAB REPORTS:

4 __________ 5 __________ 6 __________ 7 __________ 11 __________

12 __________ 13 __________ 14 __________ 15 __________ 16 __________

17 __________ 18 __________ 19 __________

LAB TOTAL =_______ (1000 max) (top 10 lab report grades included- others in parentheses)

LAB TOTAL X 6/10	____________	**(600 max)**	
LAB PARTICIPATION	____________	**(100 max)**	**COURSE LETTER GRADE**
MID-TERM	____________	**(100 max)**	☐
FINAL EXAM	____________	**(200 max)**	
TOTAL COURSE GRADE	____________	**(1000 max)**	

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Problem 1 (24 points)

Give definitions (20 words or less) for the following terms:

1.1 Sensitivity of a sensor

1.2 Actuator

1.3 Strain gauge

1.4 Operational amplifier (ideal)

1.5 Johnson Noise

1.6 Photoconductive mode (of a photodiode)

Problem 2 (32 points)

Describe the components and operation of the following sensors, actuators, and circuits:

2.1 Isolation amplifier (electromagnetic or optical)

2.2 Thermistor

2.3 Thermocouple

2.4 Digital linear position encoder

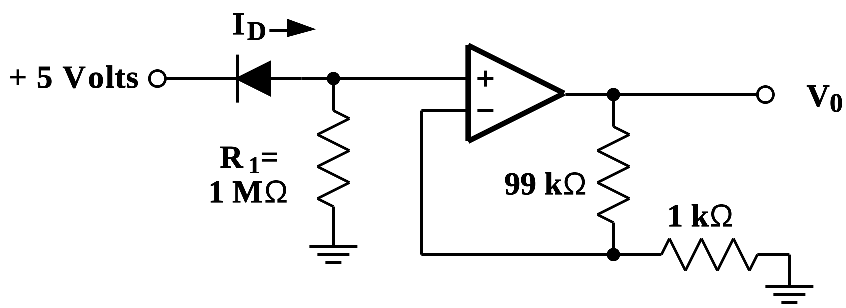
Problem 3 (30 points)

You work as a design engineer for Thermal Manufacturing, Inc. Frequently, prospective customers ask your professional advice whether to use a thermistor or a thermocouple in various situations. For each application below, mark an X to indicate which device is the better choice.

	Thermistor	Thermocouple
Measuring the temperature in a glass furnace		
Measuring small variations in body temperature over a day		
Measuring the temperature difference between sunlit and shaded surfaces on the moon over periods of several years		
A case where linear sensor output (volts vs temperature) is required over a large temperature range		
Accurate temperature measurement where the thermal conductivity of the surrounding medium is frequently changing		
Sensor for a temperature control system in an electrically noisy environment		

Problem 4 (34 points)

You are planning to detect light using a photodiode and an op-amp in the circuit below:



The specifications for the op-amp are :

- **input leakage current difference = 0.1 nA**
- **input offset voltage = 1 mV**
- **rms input noise = 10 nV/Hz$^{-1/2}$ at 90 kHz; 20 nV/Hz$^{-1/2}$ at 9 MHz**
- **rms output noise = 100 nV/Hz$^{-1/2}$ at 90 kHz; 200 nV/Hz$^{-1/2}$ at 9 MHz**
- **R_{in} = 10^9 Ω**
- **Unity gain bandwidth = 9 MHz**

The specifications for the photodiode are :

- **dark current @ 5 V reverse bias = 0.9 nA**

4.1 (10 points) Explain how the circuit converts the current I_D into the output voltage V_0 and give a formula for V_0 as a function of I_D.

4.2 (10 points) What happens if R_1 is taken out of the circuit? Justify your answer.

4.3 (14 points) What is the amplifier output V_0 (compute both the average value and rms noise) when no light reaches the photodiode? Show work.

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Problem 5 (48 points)

You have just been hired by an engineering firm that provides instrumentation to large industrial corporations. Your first problem is designing a system for measuring the liquid level in a large tank.

- **The liquid level is to be sensed electronically and the electrical signal is to be connected to the analog input of a microcomputer for display and storage**
- **the tank is 10 meters in diameter and 10 meters high.**
- **The liquid absorbs green light with an absorption of 10% per meter**
  ($I(L) = I(0)e^{-kCL}$, $kC = 0.1\ m^{-1}$)
- **The liquid is slightly conductive**
  (A column of liquid with area A and length L has resistance $R = \rho A/L$)
- **The liquid is non-flammable.**
- **The liquid level is to be measured to an accuracy of 0.1 meter.**

5.1 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using light sensors.

5.2 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using strain gauges.

5.3 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using a digital angle sensor.

5.4 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using ideal electrodes. (Hint: ideal electrodes transform ionic conductivity in a solution into simple electrical conductivity).

5.5 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using thermistors.

5.6 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using sound (speaker and microphone).

Problem 6 (32 points)

Design a simple *analog* temperature control system using the following components

- **a thermistor**
- **a thermoelectric heat pump and heat sink (one surface heats or cools, depending on input voltage polarity; the other surface is kept at room temperature by the heat sink)**
- **a power amplifier (single input- single output, requires ±10 volt supply)**
- **a ±10-volt power supply**
- **a steel box insulated with glass fibers**
- **any components or circuits used in the 145L lab**

Note: **Do not use a computer or analog filtering**

Your system should do the following:

- **keep the inside of the box at a chosen temperature**
- **allow the chosen temperature to be varied**

6.1 (12 points) Sketch below a block diagram for the system.

- **Include and label all essential components and include all interconnections.**
- **Show typical voltage and current levels at all important points.**

6.2 (12 points) Do part 5.1 again, replacing the thermoelectric heat pump with a high-wattage, high-temperature resistor

6.3 (8 points) List the relative advantages and disadvantages of the two systems described above

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Equations, some of which you may need:

$$\frac{V_1}{V_1 + V_2} = \frac{R_1}{R_1 + R_2} \qquad R(T) = R(T_0)\exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right] \qquad V_{rms} = \sqrt{B\left[(D_1 G)^2 + (D_0)^2\right]}$$

$$V(t) = V_0 \sin(\omega t) \qquad \omega = 2\pi f \qquad V_0 = A(V_+ - V_-)$$

$$T = T_2 - (T_2 - T_1)e^{-t/\tau} \qquad I = I_0 e^{-kLC} \qquad \Delta x = \frac{\Delta V}{dV/dx}$$

$$I_{rms} = \sqrt{2qI(F_2 - F_1)} \qquad V_{rms} = \sqrt{4kTR(F_2 - F_1)}$$

$q = 1.60 \times 10^{-19}$ Coulombs $\qquad k = 1.38 \times 10^{-23}$ Volt^2 sec ohm^{-1} °K^{-1}

$$R_T = R_3 \frac{V_b R_1 - V_0(R_1 + R_2)}{V_b R_2 + V_0(R_1 + R_2)} \qquad V_0 = G_\pm(V_+ - V_-) + G_c(V_+ + V_-)/2$$

$$f_c = \frac{1}{2\pi RC} \qquad \text{“CMRR”} = \frac{G_\pm}{G_c} \qquad \text{“CMR”} = 20\log_{10}\left(\frac{G_\pm}{G_c}\right)$$

$$R = \rho A/L \qquad \frac{\Delta R}{R} = G\frac{\Delta L}{L} \qquad V_0 = V_b\, G\left(\frac{\Delta L}{L}\right)$$

$$\eta = \frac{T_{n+2} - T_{n+1}}{T_{n+1} - T_n} \qquad T_{equ} = T_{n+1} + \frac{T_{n+2} - T_{n+1}}{1 - \eta}$$