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 2005

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 ______________(63 max) 2 ______________ (20 max) 3 _______________ (36 max)

4 ______________ (48 max) 5 ______________ (33 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 (63 points)

Describe the following devices and how they work:

1.1 (9 points) PIN photodiode

1.2 (9 points) Light emitting diode (LED)

1.3 (9 points) Metal-foil strain gauge

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1.4 (9 points) Peltier thermoelectric heat pump

1.5 (9 points) Ground fault interrupter (GFI)

1.6 (9 points) Bimetal switch

1.7 (9 points) Ag(AgCl) electrode

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PROBLEM 2 (20 points)

You have a high-impedance amplifier (single input, not differential) with a gain G and an output offset voltage V_{OO} that depends on temperature according to the equation

$$V_{OO} = \left[G\, V_{RTI} + V_{RTO} \right] \exp\left[-\beta \left(\frac{1}{T} - \frac{1}{293} \right) \right]$$

You measure V_{OO} for many temperatures and the best fit values are

$V_{RTI} = -1\ \mu\text{V}$, $V_{RTO} = -100\ \mu\text{V}$ and $\beta = 700\text{K}$.

At higher temperatures this offset can cause the amplifier output to saturate.

Design a circuit that

1 has high input impedance

2 uses a silicon-based thermistor with $\beta = 700\text{K}$ and $R_T = 1\ \text{k}\Omega$ at 20°C

3 avoids saturation by compensating for the offset before the input of the amplifier

2.1 (15 points) Sketch your design below. Provide sufficient detail so that a skilled technician can understand and build it for any specified gain G.

2.2 (5 points) Indicate the values of resistances, currents, and voltages in your circuit at 20°C if G = 100.

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PROBLEM 3 (36 points)

Name a sensors/actuators pair that would be good for the following situations:

3.1 (9 points) sensing and controlling the temperature of a 1 cm^3 environmental chamber from +10 °C to +40°C.

3.2 (9 points) sensing and controlling the temperature of an oven from +100 °C to +500 °C.

3.3 (9 points) sensing and controlling hydrostatic pressure of a fluid from 1 atm to 100 atm.

3.4 (9 points) sensing and controlling angle over 360° to an accuracy of 1°.

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PROBLEM 4 (48 points)

Normal plants grow best with 16 hours of light and 8 hours of darkness per 24 hour day but you have developed a new species of tomato plant that grows even better with constant illumination.

- You want to design a greenhouse that uses natural sunlight as much as possible (to save energy and money) and supplements the light level with artificial illumination as needed to maintain maximal growth. Your design must compensate for changes in natural lighting due to clouds and the darkness of night.
- For simplicity, assume that sunlight and your artificial lights have the same color spectrum and that the average energy per photon is 2 eV.
- You have determined that your plants grow at a rate that is proportional to the amount of light received up to 1000 W/m^2, which is the same as full sunlight. The growth rate does not increase beyond that level.

4.1 (4 points) Your new plant uses chlorophyll, just like normal plants. What does the green color of chlorophyll tell you about the colors of the light that is absorbed? (Hint: consider the colors of the rainbow.)

4.2 (4 points) Which is more energy efficient for producing visible light, incandescent or fluorescent?

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4.3 (20 points) Sketch your photosensor and light control circuit design, showing and labeling all necessary components, signals, and signal levels. Assume that the area of your photosensor is 1 cm^2. Provide sufficient detail so that it could be built by a skilled technician.

4.4 (20 points) Sketch your overall control system design, showing and labeling all necessary components and signals. You can show the greenhouse as a simple room with glass windows, tomato plants on the ground, and artificial lights attached to the glass ceiling.

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PROBLEM 5 (33 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 by a predetermined amount. The user would first turn a switch to a "calibrate" position, then turn the switch to a "toast" position.
(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 (18 points) Sketch your design below. Provide sufficient detail so that a skilled technician can understand and build it.

5.2 (15 points) Describe how your design works