UNIVERSITY OF CALIFORNIA  
College of Engineering  
Department of Electrical Engineering and Computer Sciences  

EECS 145L: Electronic Transducer Laboratory  

FINAL EXAMINATION  Fall 2003  

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 ______________ (48 max)  2 ______________ (24 max)  3 ______________ (48 max)  
4 ______________ (34 max)  5 ______________ (46 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  

December 17, 2003  page 1  S. Derenzo
PROBLEM 1 (48 points)

In 50 words or less, define the following terms:

1.1 (8 points) Differential gain (of an instrumentation amplifiers)

1.2 (8 points) Actuator

1.3 (8 points) Electronic ice point (for a thermocouple)
1.4 (8 points) Ground fault interrupter circuit

1.5 (8 points) Low-pass filter

1.6 (8 points) Response curve of a sensor
PROBLEM 2 (24 points)

Consider the following filter circuit, which is a single-stage low pass filter followed by a single-stage high-pass filter:

2.1 (12 points) What are the lower and upper corner frequencies (Gain = 0.707)?

2.2 (12 points) At what two frequencies does the gain = 0.1?

PROBLEM 3 (48 points)

Design 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: \( I(L) = I(0)e^{-kCL} \), \( kC = 0.1 \text{ m}^{-1} \)
• The liquid has a small ionic conductivity (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.
3.1 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using light sensors.

3.2 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using strain gauges.

3.3 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using a digital angle sensor.
3.4 (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).

3.5 (8 points) Describe in about 50 words and/or a simple sketch how you would measure the liquid level using a number of thermistors.

3.6 (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 4 (34 points)
Design a circuit that can be used to measure the current $I_{\text{diode}}$ though the photodiode as a function of the voltage $V_{\text{diode}}$ across it, for both forward and reverse voltages. Assume that only voltages will be measured, using a digital voltmeter with a high input impedance.

4.1 (10 points) Sketch your design below. Include sufficient detail so that a skilled technician could build it.

4.2 (12 points) List the steps necessary for making the voltage measurements and converting them to $V_{\text{diode}}$ and $I_{\text{diode}}$. 
4.3 (12 points) Under conditions of (1) darkness and (2) a light level that produces 1 mA of electron-hole current, plot what you would expect to measure in a figure below and label the axes with numbers and units.
PROBLEM 5 (46 points)

Design a control system for mixing hot and cold water to produce water at a desired temperature. The user can specify any desired temperature between 20°C and 80°C by setting a voltage between 2.0 and 8.0 volts.

You are provided with:

- A voltage-controlled water valve with two water pipe inputs and one water pipe output. By setting the control voltage in the range between −5 and +5 volts, any ratio of hot and cold water can be produced. (See figure below).
- A power op-amp
- A temperature sensor of your choosing
- A cold water temperature of 20°C and a hot water temperature of 80°C.

5.1 (16 points) Sketch a block diagram of your design. Provide enough details so that a skilled technician could understand how it works and build it. Label all essential components and signals and specify the location of your temperature sensor.
5.2 (10 points) Describe the voltages in your control system when the system is controlling at the set point temperature of 20°C.

5.3 (10 points) Describe how the voltages in your control system change after the set point temperature is changed from 20°C to 60°C.

5.4 (10 points) Starting from a state where the system is controlling at a set point temperature of 60°C, describe how the voltages in your control system change after the temperature of the hot water supply is reduced to 70°C.