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 2004

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 ______________ (40 max) 2 ______________ (24 max) 3 _______________ (56 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 (40 points)

In 50 words or less, define the following terms:

1.1 (8 points) Ideal operational amplifier (op-amp)

1.2 (8 points) Precision rectifier (full wave) (just consider input and output)

1.3 (8 points) PID (Proportional, Integral, Differential) control

1.4 (8 points) Electromagnetic isolation amplifier

1.5 (8 points) Thermistor

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PROBLEM 2 (24 points)

A waveform contains two signals at discrete frequencies plus a large background at other frequencies.

- Signal 1 is at 1 kHz and has an amplitude from 0 to 10 mV p-p (peak-to-peak)
- Signal 2 is at 2 kHz and has an amplitude from 0 to 10 mV p-p
- There are also other signals and random white noise from d.c. to 1 MHz with a combined amplitude of 1 volt p-p

Design a circuit for extracting signal 1 and signal 2 on separate outputs. You may use any components covered in this course.

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PROBLEM 3 (56 points)

Design an analog amplification and filtering system for a seismometer. A modern seismometer consists of (1) a heavy permanent magnet that is suspended so that it does not move during an earthquake and (2) thousands of turns of wire (mechanically attached to the ground) that pick up an induced signal from the magnet when the ground moves.

- The seismometer has two output wires and produces a maximum differential signal ±10 mV which your circuit should amplify to ±10 V.
- The frequencies of interest are from d.c. to 1000 Hz.
- The seismometer signal has an unwanted 60 Hz component from electromagnetic interference that is ±10 mV common, ±0.01 mV differential.
- The instrumentation amplifier that you will use has an input noise $V_{rms} = 4 \text{ nV Hz}^{-1/2} \text{sqrt}(\Delta f)$, a gain-bandwidth product of 10^7 Hz, and a common mode rejection ratio of 60 dB. Assume zero leakage current, and that the noise at the output = gain x input noise.

Do the following:

3a (5 points) What are the gain and bandwidth of the instrumentation amplifier in your design?

3b (5 points) What is the noise at the output of the instrumentation amplifier in that bandwidth?

3c (16 points) Design an analog filter (specify type, corner frequency, and order) that has a gain >0.99 for frequencies of interest and a gain <0.01 for frequencies above 2 kHz. (Hint: see equation sheet for a table of f/f_c vs. gain and order.) What is the noise at the output of the filter?

3d (15 points) How would you use analog filtering to minimize the 60 Hz interference with a minimum loss in the signal of interest? What is the 60 Hz output noise before and after the filter (approximate estimate based on what you remember from Lab 6)?

3e (15 points) Sketch a block diagram of your amplifier and analog filter circuit in enough detail so that a skilled technician can build it and understand how it meets the design objectives.

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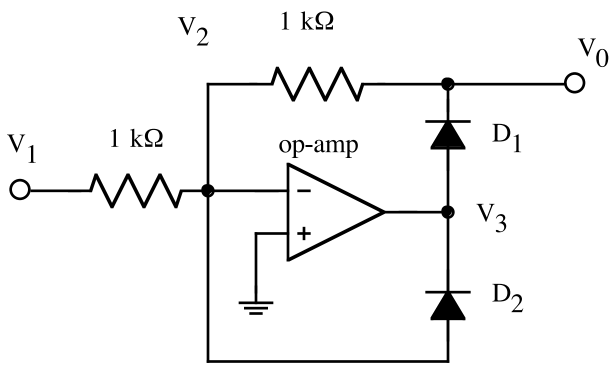
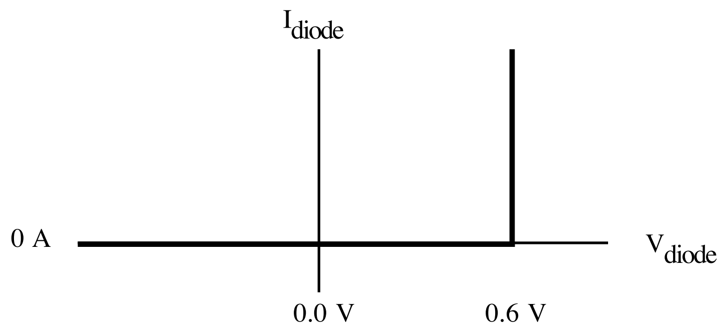
PROBLEM 4 (40 points)

Consider the following half-wave rectifier circuit:



Assume the following:

- The op-amp is ideal
- The diodes are ideal with 0.6V threshold



4.1 (20 points) For $V_1 < 0$, what are V_2, V_3, and V_0 in terms of V_1?

4.2 (20 points) For $V_1 > 0$, what are V_2, V_3, and V_0 in terms of V_1?

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PROBLEM 5 (40 points)

Design a system for automatic control of the temperature of a chemical reaction in a large tank.

- Initially the contents of the tank need to be heated to 50C to start the chemical reaction
- Once the chemical reaction is started, it produces significant heat and the contents of the tank needs to be cooled to keep the tank at 50C
- When the reaction is complete, heating is again required to maintain the contents at 50C
- You have a heating unit that can be proportionally controlled by a voltage between 0 and +10 volts
- You have a cooling unit that can be proportionally controlled by a voltage between 0 and +10 volts
- Coils containing a heat exchange fluid pass through the tank, the heating unit and the cooling unit.

5.1 (25 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 electrical and fluid connections and signals.

5.2 (15 points) Describe how your design controls the temperature during the various stages of he reaction.