NAME (please print) ______________________________ SID __________________

UNIVERSITY OF CALIFORNIA, BERKELEY
Electrical Engineering and Computer Sciences Department

EECS 145L Electronic Transducer Lab
MIDTERM #2 (100 points maximum)
November 19, 2008

(closed book, calculators OK, equation sheet provided)
(You will not receive full credit if you do not show your work)

PROBLEM 1 (36 points)

Design a thermocouple-based system for measuring the temperature of a furnace (T_f) over the temperature range from 25 °C to 500 °C with an absolute accuracy of 2 °C. Rather than using ice to stabilize the temperature of the reference junction at 0 °C, you decide to leave the reference junction in the air of the room and measure the temperature of the room (T_r) with a solid-state temperature sensor. The correction of the thermocouple output for room temperature will be done by a voltage-summing circuit.

Assume the following:

- The thermocouple sensitivity is 50 μV/°C.
- The solid state temperature sensor passes a current I = (1 μA/K) T where T is its temperature in K and the voltage across it is in the range from 3 to 40 volts.
  Use 0 °C = 273 K.

1.1 (12 points) Sketch a circuit that uses a thermocouple to produce an output V_a = 0.25 V when the temperature difference between the sensing and the reference junction is 25 °C and V_a = 5.00 V when the temperature difference is 500 °C. Label all necessary analog circuit elements and signal lines. Include the thermocouple wires and furnace. (It is not necessary to include analog filtering).

1.2 (12 points) Sketch a circuit that converts the solid-state temperature sensor current into a voltage V_b that has the same sensitivity (V/°C) as the thermocouple circuit in **1.1**. Draw a block diagram and label all necessary analog circuit elements and signal lines. Show where the solid-state temperature sensor is placed in the diagram of part **1.1** above. (It is not necessary to include analog filtering)

1.3 (12 points) Sketch a circuit that combines the outputs of circuits **1.1** and **1.2** to provide a voltage V_c that is proportional to the furnace temperature (0.25 V at 25°C and 5.00 V at 500 °C) and does not depend on the room temperature.

PROBLEM 2 (34 points)

Design a system that converts sound into light for transmission down an optical fiber and then converts the optical signal back into sound.

Assume the following

1 You have a microphone that produces a maximum differential signal of 100 mV p-p (peak-to-peak) at the maximum sound intensity that you need to consider.

2. The microphone wires have 60 Hz electromagnetic pickup of pure 10 mV common mode (for simplicity assume zero differential 60 Hz pickup).

3. You have an light emitting diode (on one end of the optical fiber) that should be driven at 100 mA p-p when the microphone signal is at maximum.

4. You have a photodiode (on the other end of the optical fiber) that produces 1 mA p-p when the light emitting diode is producing its maximum signal (100 mA p-p input).

5. The loudspeaker should be driven at 10 V p-p when the microphone signal is at maximum. The speaker has an input impedance of 10 Ω.

6. Each element in the system should be operated in a linear mode (output proportional to input).

In your design you should provide enough detail so that a skilled technician could be able to build it and understand how it works. Include all necessary components and label all signals with their maximum (p-p) amplitude. You may use any circuit components used in the laboratory exercises or discussed in lecture, but keep it simple.

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PROBLEM 3 (30 points in total)

An experimental system shown in Figure 1 is used to test the properties of human tissues.

(1) The ultrasound probe consists of a PZT transducer with a thin matching layer;

(2) The human tissues have four layers: a fat layer, a muscle layer, a second fat layer and an artery. The direction of the blood flow is perpendicular to the direction of the ultrasound beam.

(3) The ultrasound transducer is fired with a short impulse.

(4) The central frequency of the PZT transducer is $f_0 = 3.5\text{MHz}$.

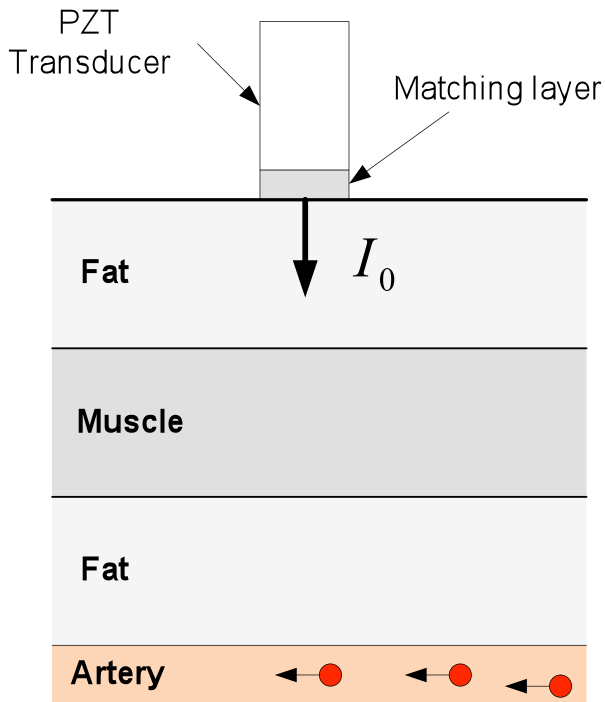

Figure 1

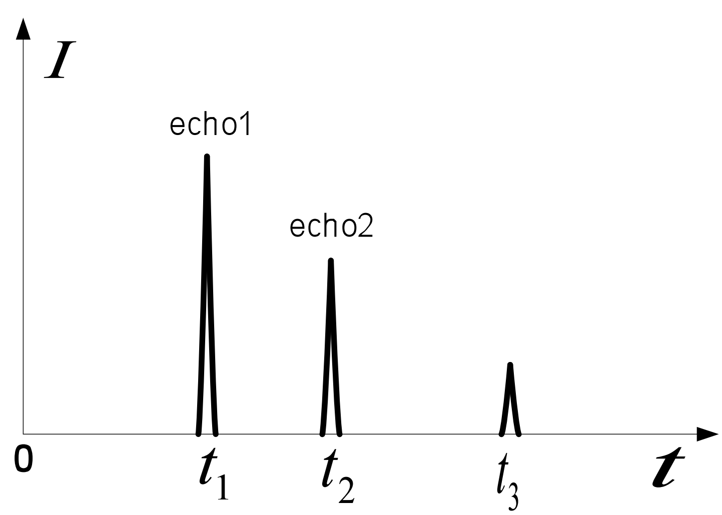

Figure 2

3.1 (5 points)
The received ultrasound echoes are shown in Figure 2 ($t_1 = 69\mu s$, $t_2 = 107\mu s$). The speed of sound in fat: 1450m/s. The speed of sound in muscle: 1580m/s. What is the thickness of the first fat layer and the muscle layer?

3.2 (5 points)
If the speed of the blood flow in the artery is 0.3m/s, what is the Doppler frequency shift of the received echoes? The speed of ultrasound in blood is 1570m/s.

3.3 (10 points)
If the intensity of the ultrasound wave incident to the first fat layer is I_0, what is the intensity of echo 1 received by the transducer (ignore the reflections between the fat and the matching layer, and between the matching layer and PZT).
The attenuation coefficient of the fat is $\alpha_{\text{fat}} = 0.6\text{dBcm}^{-1}\text{MHz}^{-1}$.
The attenuation coefficient of the muscle is $\alpha_{\text{muscle}} = 1.8\text{dBcm}^{-1}\text{MHz}^{-1}$.
The acoustic impedance of the fat is: $Z_{\text{fat}} = 1.3\times10^{-6}\,\text{kg}\cdot\text{m}^{-3}\cdot s^{-1}$
The acoustic impedance of the muscle is: $Z_{\text{muscle}} = 1.7\times10^{-6}\,\text{kg}\cdot\text{m}^{-3}\cdot s^{-1}$

3.4 (10 points)
Determine the acoustic impedance of the matching layer to maximize the transmitted ultrasound intensity to the fat. Acoustic impedance of the transducer: $Z_T = 8\times10^{-6}$ kg m^{-3} s^{-1}