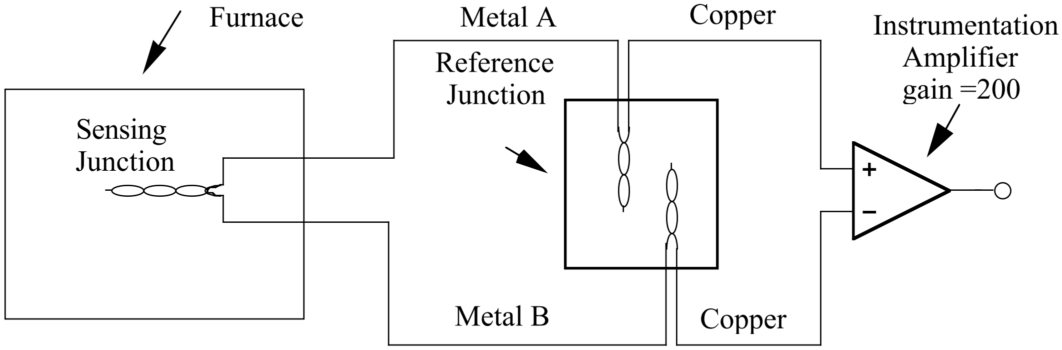
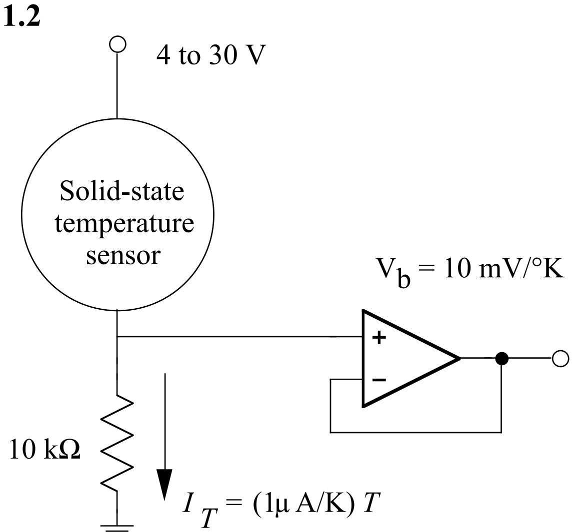
Midterm #2 Solutions – EECS 145L Fall 2008

1.1



Since the thermocouple has a sensitivity of 50 μV/°C, we need a differential gain of 200 to get the required 10 mV/°C
[2 points off for gain =20 or 2000]
[4 points off for not calculating a gain]
[3 points off for not producing 10 mV/C°]

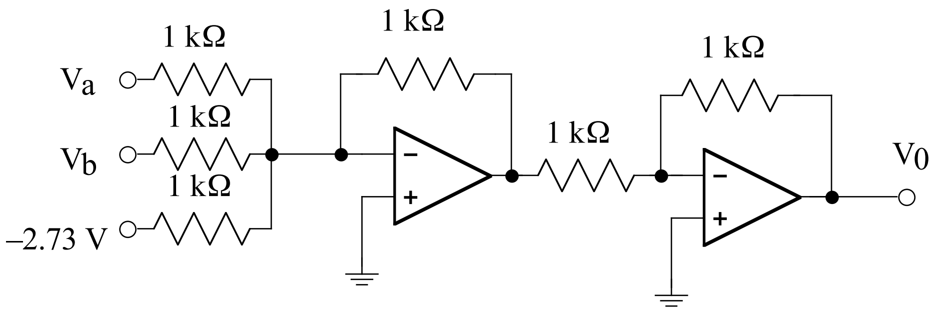
1.2



Note: this sensor is placed near the reference junction above

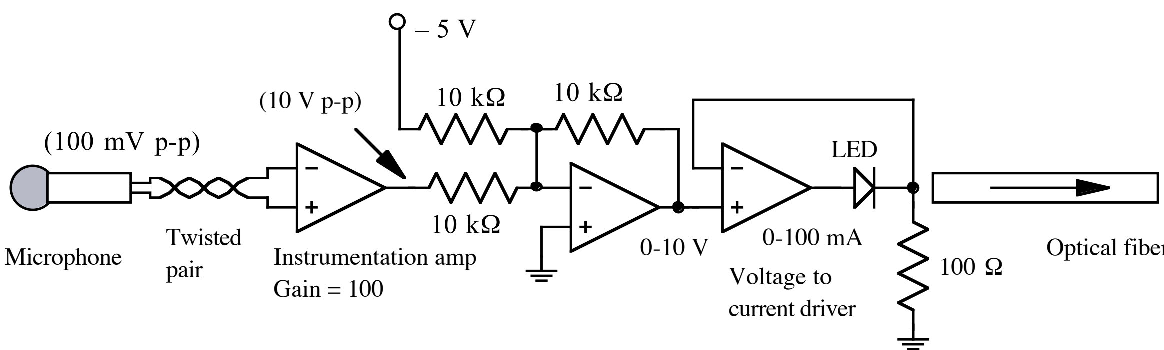
With a sensitivity of 1 μA/K, a series resistor of 10 kΩ will give us the required 10 mV/K. The buffer amplifier prevents loading of the summing amplifier.
[3 points off for not producing 10 mV/C°]

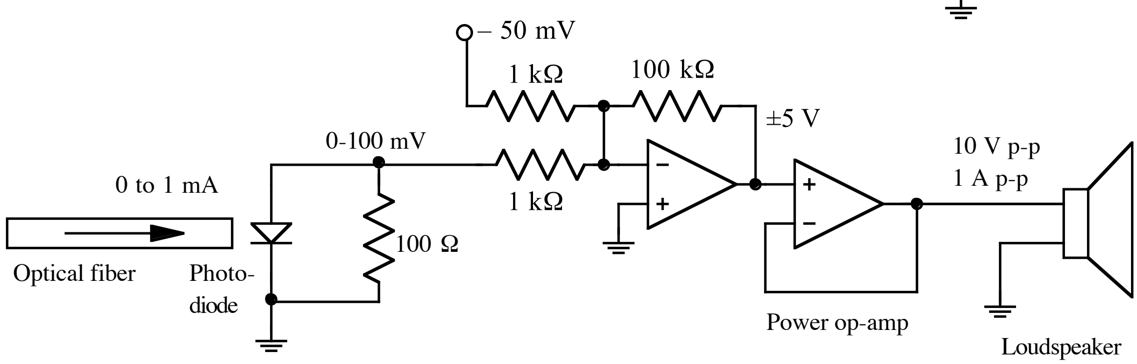
1.3



The output $V_0 = V_a + V_b - 2.73$ V.
As a check, consider the following situation: The sensing and the reference junction are both at 0 °C, so Va = 0.0 V. The solid state temperature sensor is at 273K and V_b = 2.73V. The above circuit produces V_0 = 0.0 V, as desired.
[2 points off for omitting the 2.73 volt bias or not converting solid state sensor K to C°]

2





[4 points off for no microphone differential amplifier (the microphone had differential output and the common mode 60 Hz pickup of 10 mV needed to be eliminated)]

[2 points off for using 60 Hz notch filter since it rejects 60 Hz microphone signals]

[5 points off for not using a voltage controlled current driver for the LED]

[3 points off if it was not clear how the circuit converts 100 mV from the microphone into 100 mA into the LED]

[3 points off for using a 10 kΩ resistor to convert photodiode 1 mA to 10V since a photodiode cannot produce 10 V]

[3 points off if it was not clear how the circuit converts a 1 mA photodiode current into a 10 V, 1A speaker signal]

Midterm #2 Solutions – EECS 145L Fall 2008

Note: Since the microphone waveform oscillates about zero, it is necessary to level shift before driving the LED and after the photodiode current to voltage converter. This was not required for full credit.

3.1

The thickness of the first fat layer:

$$d_1 = \frac{c_{fat} \cdot t_1}{2} = \frac{1450 \times 69 \times 10^{-6}}{2} = 0.05\text{m}$$

The thickness of the muscle layer:

$$d_2 = \frac{c_{muscle} \cdot (t_2 - t_1)}{2} = \frac{1580 \times (107 - 69) \times 10^{-6}}{2} = 0.03\text{m}$$

3.2

$$\Delta f = f - f_0 = \frac{2v_s \cos\theta}{c} f_0 = \frac{2v_s \cos 90^\circ}{c} f_0 = 0$$

The frequency shift is 0, because the speed vector of the blood flow is perpendicular to the direction of the ultrasound beam.

3.3

The intensity of the first echo is determined by:

(1) The acoustic attenuation in the fat

$$\text{Attenuation}_{\text{fat}} = e^{-\beta \times f_0 \times 2d_1} = e^{-0.23 \times \alpha \times f_0 \times 2d_1} = e^{-0.23 \times 0.6 \times 3.5 \times 5} = 0.79\%$$

Or: $\text{Attenuation}_{\text{fat}}(\text{in dB}) = -\alpha_{\text{fat}} \times 2d_1 \times f_0 = -0.6 \times 10 \times 3.5 = -21\text{dB}$

(2) And the reflection ratio between the interface of the first fat layer and the muscle layer.

$$\text{Reflection}_{\text{fat-muscle}} = \frac{(Z_{muscle} - Z_{fat})^2}{(Z_{fat} + Z_{muscle})^2} = \left(\frac{1.7 - 1.3}{1.7 + 1.3}\right)^2 = 1.8\%$$

$$\text{Reflection}_{\text{fat-muscle}}(\text{in dB}) = 10 \times \log_{10}\left(\frac{(Z_{muscle} - Z_{fat})^2}{(Z_{fat} + Z_{muscle})^2}\right) = 10 \times \log_{10}\left(\left(\frac{1.7 - 1.3}{1.7 + 1.3}\right)^2\right) = -17.5\text{dB}$$

The intensity of the first echo is: $I_1 = I_0 \times \text{Attenuation}_{\text{fat}} \times \text{Reflection}_{\text{fat-muscle}} = 1.42 \times 10^{-4} I_0$

Or $I_1 = I_0 - 21\text{dB} - 17.5\text{dB} = I_0 - 38.5\text{dB}$

3.4

The ratio of the intensity of the ultrasound incident to the fat (I_0) and the ultrasound produced by the transducer (I_i):

$$\frac{I_0}{I_i} = \frac{I_{t-match}}{I_i} \cdot \frac{I_0}{I_{t-match}} = \frac{4Z_T Z_M}{(Z_T + Z_M)^2} \frac{4Z_M Z_{fat}}{(Z_M + Z_{fat})^2}$$

To maximize $\frac{I_0}{I_i}$,

$$Z_M = \sqrt{Z_T Z_S} = \sqrt{8 \times 1.3} = 3.2 \times 10^{-6} \text{kg} \cdot \text{m}^{-3} \cdot s^{-1} \quad Z_S = Z_{\text{fat}}$$

145L midterm #2 grade distribution:

Problem	
1	25.0 (10.2 rms) (36 max)
2	25.7 (9.12 rms) (34 max)
3	21.6 (6.6 rms) (30 max)

maximum score = 100
average score = 72.3 (19.5 rms)

30-39	3	F
40-49	4	F
50-59	2	D
60-69	2	C
70-79	9	B
80-89	4	B
90-94	6	A
95-99	3	A
100	0	