UNIVERSITY OF CALIFORNIA
Electrical Engineering and Computer Sciences

145L MIDTERM #2 (in class, closed book)
November 17, 1993

(100 points total)

Problem 1 (24 points)

Give definitions (30 words or less) for the following terms:

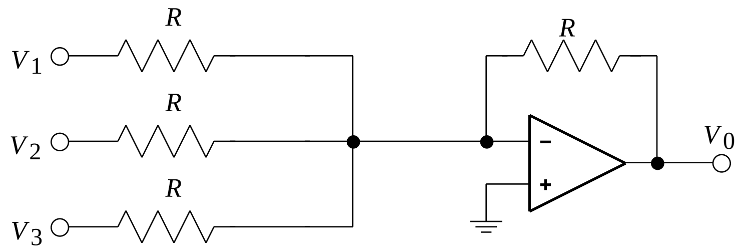
1.1 (8 points) Accuracy of a sensor

1.2 (8 points) Thermoelectric heat pump

1.3 (8 points) Thompson emf

Problem 2 (26 points)

Analyze the op-amp circuit shown below (assume infinite open-loop gain):



2.1 (8 points) What are the currents flowing through each of the three input resistors?

2.2 (8 points) What is the current flowing through the op-amp feedback resistor?

2.3 (10 points) What is V_0 in terms of the quantities R, V_1, V_2, and V_3?

Problem 3 (50 points)

Your assignment is to design a thermocouple-based temperature system for measuring the temperature of a furnace over the 25 °C to 500 °C range with an absolute accuracy of 2 °C but you do not want the requirement of providing ice to stabilize the temperature of the reference junction. Instead, you decide to leave the reference junction in the air of the room and measure the temperature of the room (maximum range 10 to 45 °C) with a thermistor, which would provide sufficient accuracy. The correction of the thermocouple output for room temperature will be done by a microcomputer program.

3.1 (10 points) Design a circuit that converts the thermocouple output into a suitable voltage V_{tc} (–5 to +5 volts) for input to a microcomputer. Draw a block diagram and label all necessary analog circuit elements and signal lines. (It is not necessary to include analog filtering)

3.2 (10 points) Design a circuit that converts the thermistor output into a suitable voltage V_{tm} (–5 to +5 volts) for input to a microcomputer. Draw a block diagram and label all necessary analog circuit elements and signal lines. Show where the thermistor is placed in the diagram 3.1 above. (It is not necessary to include analog filtering)

3.3 (10 points) Sketch below the thermocouple voltage V_{tc} as a function of the temperature difference ΔT.

3.4 (10 points) Sketch below the thermocouple voltage V_{tm} as a function of the thermistor temperature T_{tm}.

3.5 (10 points) Describe in a flow chart, a list of steps, or a sentence or two what the microcomputer program would have to do to convert V_{tc} and V_{tm} into the temperature T_s of the sensing junction in °C.

Equations, some of which you may need:

$$\frac{V_1}{V_1 + V_2} = \frac{R_1}{R_1 + R_2} \qquad R(T) = R(T_0)\exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right] \qquad V_{rms} = \sqrt{B\left[(D_1 G)^2 + (D_0)^2\right]}$$

$$V(t) = V_0 \sin(\omega t) \qquad \omega = 2\pi f \qquad V_0 = A(V_+ - V_-)$$

$$|G| = \frac{1}{\sqrt{1 + (f/f_c)^{2n}}} \qquad \tan\left(\frac{\varphi}{n}\right) = \frac{f}{f_c} \qquad N(x) = N(0)e^{-x\mu}$$

$$x = e^{-\alpha t}\left[A\cos(\omega t) + B\sin(\omega t)\right] = R\,e^{-\alpha t}\cos(\omega t + \delta)$$

$$T = T_2 - (T_2 - T_1)e^{-t/\tau} \qquad I = I_0 e^{-kLC} \qquad \Delta x = \frac{\Delta V}{dV/dx}$$

$$I_{rms} = \sqrt{2qI(F_2 - F_1)}$$ $q = 1.60 \times 10^{-19}$ Coulombs

$$V_{rms} = \sqrt{4kTR(F_2 - F_1)}$$ $k = 1.38 \times 10^{-23}$ Volt^2 sec ohm^{-1} °K^{-1}

$$R_T = R_3 \frac{V_b R_1 - V_0(R_1 + R_2)}{V_b R_2 + V_0(R_1 + R_2)} \qquad V_0 = G_{\pm}(V_+ - V_-) + G_c(V_+ + V_-)/2$$

$$f_c = \frac{1}{2\pi RC} \qquad \text{“CMRR”} = \frac{G_{\pm}}{G_c} \qquad \text{“CMR”} = 20\log_{10}\left(\frac{G_{\pm}}{G_c}\right)$$

$$R = \rho A/L \qquad \frac{\Delta R}{R} = G\frac{\Delta L}{L} \qquad V_0 = V_b\, G\left(\frac{\Delta L}{L}\right)$$

$$V_T = V_{BE2} - V_{BE1} = \frac{kT}{q}\ln\left(\frac{I_1}{I_2}\right) \qquad k/q = 86.17\ \mu V/K$$

$$P_R = \sigma A T^4 \quad \sigma = 5.6696 \times 10^{-8}\ W\,m^{-2}\,K^4$$

$$E = hc/\lambda \quad hc = 1240\ eV\ nm \qquad \lambda_{max} = (2.8978 \times 10^6\ nm\ K)/T$$

$$\eta = \frac{T_{n+2} - T_{n+1}}{T_{n+1} - T_n} \qquad T_{equ} = T_{n+1} + \frac{T_{n+2} - T_{n+1}}{1 - \eta}$$

$$Q = \pi I + I^2 R/2 + K_p(T_s - T_0) + K_a(T_a - T_0) \qquad T_{equ} = \frac{\pi I + I^2 R/2 + K_p T_s + K_a T_a}{K_p + K_a}$$

$$\mu \approx \bar{a} = \frac{1}{m}\sum_{i=1}^{m} a_i \qquad \sigma_a^2 = \frac{1}{m-1}\sum_{i=1}^{m}(a_i - \bar{a})^2 \qquad \sigma_{\bar{a}} = \frac{\sigma_a}{\sqrt{m}}$$

$$\sigma_f = \sqrt{\left(\frac{\partial f}{\partial a_1}\right)^2 \sigma_{a1}^2 + \left(\frac{\partial f}{\partial a_2}\right)^2 \sigma_{a2}^2 + \cdots + \left(\frac{\partial f}{\partial a_n}\right)^2 \sigma_{an}^2}$$