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UNIVERSITY OF CALIFORNIA
Electrical Engineering and Computer Sciences

EECS 145L Electronic Transducer Lab
MIDTERM #2 (100 points maximum)

(closed book, calculators OK- note formulas on last page)
(You will not receive full credit if you do not show your work)

PROBLEM 1 (25 points)

Suppose you have a force transducer with a single resistance strain gauge as was used in the lab

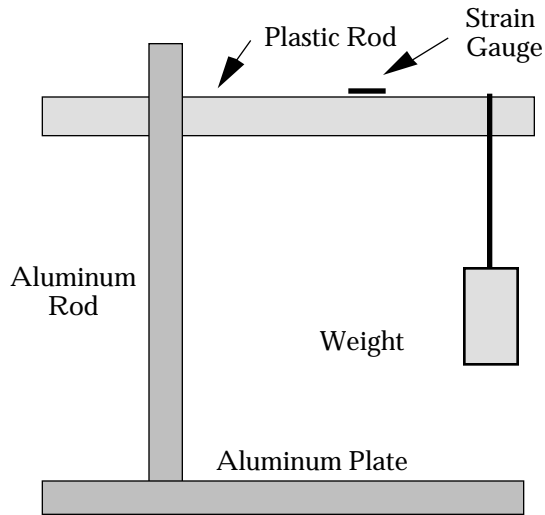


Figure 1. Force transducer. Strain gauge has resistance R_S and gauge factor $G_S = 2$.

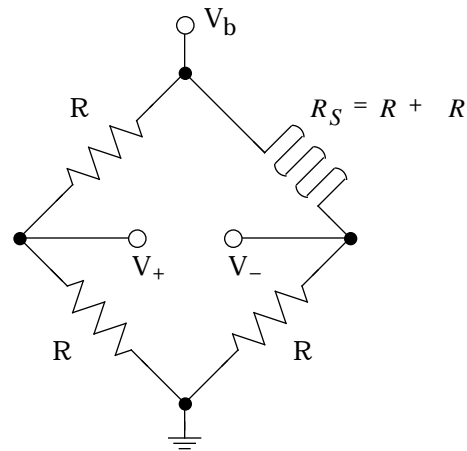


Figure 2. Bridge circuit. $R_S = R$ when bar is unloaded. $V_b = 1$ volt.

You may approximate the bridge output as

$$V_0 = V_+ - V_- = V_b \frac{R}{R+R} - \frac{R}{R+R_S} = V_b \frac{1}{2} - \frac{1}{2 + R/R}$$

$$= \frac{V_b}{2} \left[1 - \frac{1}{1 + R/(2R)} \right] = \frac{V_b}{2} \left[\frac{R/(2R)}{R/(2R)} \right] = \frac{V_b}{4} \frac{R}{R}$$

1a (5 points) What is V_0 when the bar is unloaded?

1b (5 points) What is V_0 when a 1 kg weight is hung from the bar such that the top of the bar increases in length by 3%?

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1c (5 points) Suppose that the coefficient of thermal expansion of the bar is $(\Delta L/L)/(\Delta T) = 5 \times 10^{-4}/\text{C}^\circ$. If the temperature of the room increases by 10C° , what is V_0 for the case of the unloaded bar (1a)?

1d (5 points) As 1c, but for the case of the loaded bar (1b)?

1e (5 points) If the temperature of the room increases by 10C° and you did not notice or correct for it, what would the error in the weight measurement be (expressed in g)?

PROBLEM 2 (50 points)

2a (10 points) Show in Figure 3 below how you would use two identical strain gauges to counteract the effects of temperature change and increase the sensitivity for measuring the load.

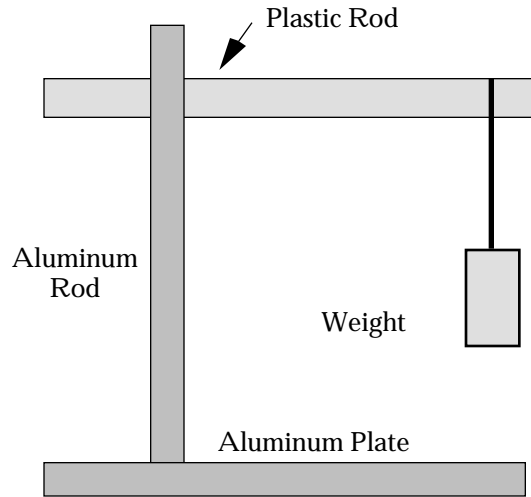


Figure 3. Force transducer.

2b (10 points) Sketch below the bridge circuit that you would use.

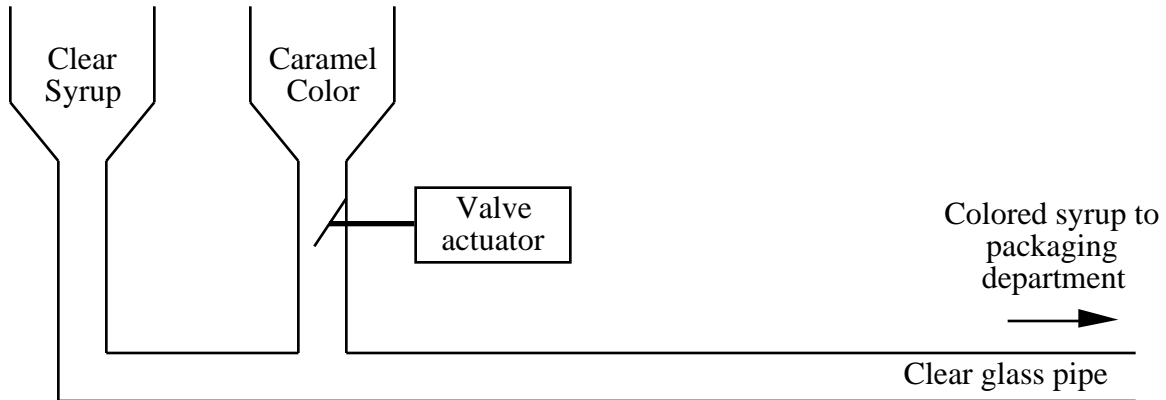
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- 2c** (10 points) Derive the formula for your bridge output V_0 as a function of the change in the strain gauge resistances.
- 2d** (10 points) What is V_0 when a 1 kg weight is hung from the bar such that the top of the bar increases in length by 3%?
- 2e** (10 points) If the coefficient of thermal expansion of the bar is $(\Delta L/L)/(\Delta T) = 5 \times 10^{-4}/\text{C}^\circ$, the temperature of the room increases by 10C° , and you did not notice or correct for it, what would the error in the weight measurement be (expressed in g)?

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PROBLEM 3 (25 points)

The Coca-Cola company has hired you to design a system to add "caramel coloring" to soda syrup. The plumbing is already designed and looks like the following:



3a (15 points) Design a system that continuously measures the color of the processed syrup, and uses negative feedback to control the flow of the "caramel color" to maintain a consistent color in the finished syrup. Sketch your design in the diagram **above**, including all sensor, actuator, and circuit components.

Note 1: Assume that the flow of the clear syrup is constant, regulated by an existing system that is not shown.

Note 2: The actuator closes the valve at 0 volts, and fully opens the valve at 5 volts and 5 amperes.

Note 3: The color of the finished syrup must be adjustable by the user.

Note 4: Provide sufficient detail so that your design could be built by a student who has taken 145L.

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- 3b** (10 points) Imagine that the system has been running a while and that the "caramel color" feed bucket is nearly empty. What happens if a new batch of **darker** "caramel color" is added? Explain qualitatively how the system reacts to control the color of the final product.

Equations, some of which you may need:

$$R(T) = R(T_0) \exp\left(\frac{1}{T} - \frac{1}{T_0}\right) \quad I = I_0 e^{-kLC} \quad V_{\text{rms}} = \sqrt{B[(D_1 G)^2 + (D_0)^2]}$$

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

$$|G| = \frac{1}{\sqrt{1 + (f/f_c)^{2n}}} \quad \tan \frac{\phi}{n} = \frac{f}{f_c} \quad f_c = \frac{1}{2RC}$$

$$|G| = \frac{(f/f_c)^n}{\sqrt{1 + (f/f_c)^{2n}}} \quad E = \frac{F/A}{L/L}$$

$$x = e^{-\alpha t} [A \cos(\omega t) + B \sin(\omega t)] = R e^{-\alpha t} \cos(\omega t + \phi) \quad V = q/C$$

$$v = v_0 + at \quad x = x_0 + v_0 t + 0.5 at^2 \quad (\text{constant } a) \quad g = 10 \text{ m s}^{-2}$$

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

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

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

$$N(x) = N(0)e^{-x\mu} \quad \text{“CMRR”} = \frac{G_\pm}{G_c} \quad \text{“CMR”} = 20 \log_{10} \frac{G_\pm}{G_c}$$

$$R = L/A \quad \frac{R}{R} = G_s \frac{L}{L} \quad x = \frac{V}{dV/dx}$$

$$V_T = V_{\text{BE2}} - V_{\text{BE1}} = \frac{kT}{q} \ln \frac{I_1}{I_2} \quad k/q = 86.17 \mu\text{V/K}$$

$$P_R = AT^4 = 5.6696 \times 10^{-8} \text{ W m}^{-2} \text{ K}^4$$

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

$$= \frac{T_{n+2} - T_{n+1}}{T_{n+1} - T_n} \quad T_{\text{equ}} = T_{n+1} + \frac{T_{n+2} - T_{n+1}}{1 - \dots} \quad T = T_2 - (T_2 - T_1)e^{-t/\tau}$$

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

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

$$f = \sqrt{\frac{f_{a1}^2}{a_1^2} + \frac{f_{a2}^2}{a_2^2} + \dots + \frac{f_{an}^2}{a_n^2}}$$

Johnson noise = 129 μV for 1 MHz and 1 M

Iron+Constantan - 52.6 μV/°C

W+W(Rh) - 16.0 μV/°C