EE 5340
Oct. 24, 1997
Instructor: C. Davila

Name:________________
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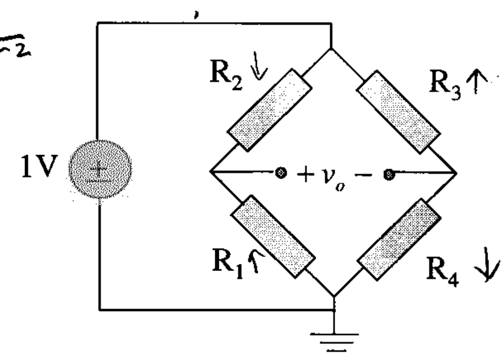
EE 5340 Exam I

1. Each resistor in the resistive bridge forms part of an unbonded strain gauge. At equilibrium, each resistance is ~~1Ω~~. Assume each resistance is cylindrically shaped, and has a diameter of 1 mm, a length of 10 mm, and a resistivity of 1 Ω-mm. Determine the sensitivity in V/mm of the unbonded strain gauge. Assume resistivity and resistor diameter remain constant during stretching.

$$R = \rho\frac{L}{A} = \frac{10}{\pi r^2}$$



$R_1 = R + \Delta R$
$R_2 = R - \Delta R$
$R_3 = R + \Delta R$
$R_4 = R - \Delta R$

$$V_0 = \frac{R_1}{R_1+R_2} - \frac{R_4}{R_3+R_4}$$

$$= \frac{R+\Delta R}{2R} - \frac{R-\Delta R}{2R} = \frac{\Delta R}{R}$$

$$\Delta R = \rho\frac{\Delta L}{A} = \frac{\Delta L}{\pi r^2}$$

$$V_0 = \frac{\Delta R}{R} = \frac{\Delta L/\pi r^2}{10/\pi r^2} = \frac{\Delta L}{10}$$

$$\text{SENSITIVITY} = \frac{\Delta V_0}{\Delta L} = \frac{1}{10}\ \text{V/mm}$$

[1] I hereby agree to abide by the terms of the Honor Code at Southern Methodist University.

2. A thermistor R_T is linearized with a parallel resistor, R_p. The operating temperature of the linearized sensor is $T_m = 310\ ^oK$. Assume that $\beta = 3000\ ^oK$, and $R_0 = 1000\ \Omega$ at $T_0 = 298\ ^oK$. (a) Determine R_p. (b) Find the sensitivity of the linearized sensor at T_m.

$$R_{eq} = \frac{R_p R_T}{R_p + R_T}, \quad R_p = R_{T_m} \frac{\beta - 2T_m}{\beta + 2T_m}$$

$T_m = 310\ ^oK$

$$R_T = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)} \; ; \; R_{T_m} = 10^3 e^{3000\left(\frac{1}{310} - \frac{1}{298}\right)} = 677.3\ \Omega$$

a) $$R_p = 677.3 \frac{(3000 - 2 \times 310)}{(3000 + 2 \times 310)} = \underline{\underline{445.3\ \Omega}}$$

b) SENSITIVITY OF R_T $$= \frac{dR_T}{dT} = R_0 \beta(-1/T^2) e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)} = -\frac{R_0 \beta}{T^2} e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

$$\left.\frac{dR_T}{dT}\right|_{T=T_m} = \frac{-1000 \times 3000}{310^2} e^{3000\left(\frac{1}{310} - \frac{1}{298}\right)}$$

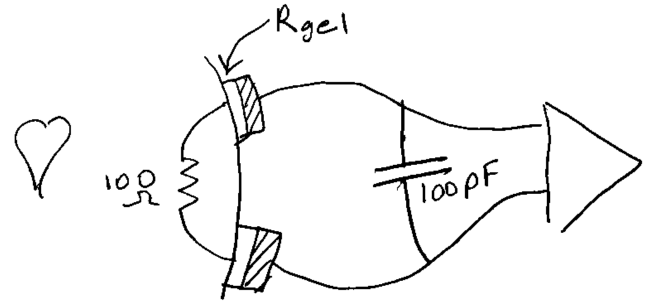
$$= -21.1\ \Omega/^oK = R_T'$$

SENSITIVITY OF R_T' $$= \left.\frac{(R_p + R_T) R_p R_T' + R_p R_T (R_T')}{(R_p + R_T)^2}\right|_{T=T_m}$$

$$= \frac{(445.3 + 677.3)(445.3)(-21.1) + 677.3(445.3)(-2}{(445.3 + 677.3)^2}$$

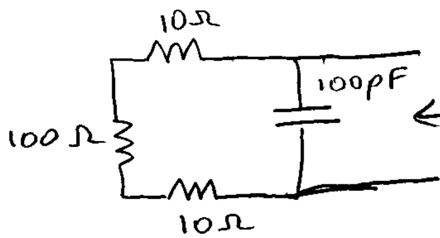
$$= -13.4\ \Omega/^oK$$

4. Suppose that two ideal non-polarizable EKG electrodes are positioned on the chest. The electrodes have a surface area of 1 cm^2. Assume that the electrolyte gel occupies a 1 mm thick layer and has a resistivity of 100 Ω-cm. The tissue resistance between the electrodes can be modeled with a 100 Ω resistor. The electrode leads have zero resistance but there exists a 100 pF parasitic capacitance between them. Determine the impedance between the two electrode leads and sketch a Bode plot of the impedance as a function of frequency.



1 mm = 0.1 cm

$$R_{gel} = \frac{100\,\Omega\text{-cm} \times 0.1\,\text{cm}}{1\,\text{cm}^2} = 10\,\Omega$$



$$\leftarrow Z = \frac{\frac{1}{j\Omega C}\cdot 120}{120 + 1/j\Omega C} = \frac{120}{1 + j\Omega \cdot 120C}$$

$$= \frac{120}{1 + j\,\Omega\,120\times10^{-10}}$$

$$= \frac{120}{1 + j\,\frac{\Omega}{\Omega_c}}$$

$$\Omega_c = \frac{1}{120\times10^{-10}} = 8.\overline{33}\times10^{7}\ \text{RAD/S}$$