ECE 6140 | HW01 | Brendon Simonsen

1. Passive and Active Sensors
   a) Alcohol thermometer **(Passive)**
   b) Thermostat in a car **(Passive)**
   c) pH meter in an aquarium
      i. **(Passive)** if it is just the chemical reaction with colors
      ii. **(Active)** if it is a digital pH meter
   d) Pressure sensor in the lid of a jar **(Passive)**
   e) Microphone in a cell phone **(Active)**
   f) Water level sensor in dishwasher **(Active)**
   g) Temperature sensor in a refrigerator **(Active)**
   h) Acceleration sensor in a car **(Active)**

2. Classification of sensors
   a) Both, this thermometer is measuring temperature. It is observing or reading a value. It then moves a dial to display the temperature.
   b) Passive
   c) The first transduction mechanism is the bimetal strip. It changes the energy from the heat, to expand the different metals, which could be considered kinetic energy. There is also a mechanism for taking the energy of expanding the metal and converting it to energy for moving the dial
3. Classification of a sensor
   i. This is an active sensor because it is sending out a stimulus to the hot wire with the expectation of a change to the wire temperature.
   ii. This is a relative sensor because it is using the relative power needed to keep the wire hot to determine the mass air flow.
   iii. Physical sensor because it uses the heat of the wire to determine if more current is needed to keep the wire hot. The current needed is then correlated with the mass air flow.
   iv. Thermoelectric. This sensor uses a correlation between heat, the temperature of the wire, and the voltage and current needed to maintain that temperature.
4. Acoustic pressure and dB.
   a) 120 dB
   b) Assuming that the attenuation is to avoid the threshold of pain, you would need 47.96 or ~48dB of attenuation. I would assume that for ear protection, you may err on the side of caution and use hearing protection with a greater amount of attenuation.
5. Simple RTD
   a) 54.7 m

b) 0.29 m

c) R(-45) = 89.58 Ω

R(120) = 166.8 Ω

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(4) $2\times10^{-5}\,Pa$ (LOWEST) $\rightarrow 20\,Pa$ (HIGHEST) $\quad Pa \Leftrightarrow dB \quad dB\ SPL = 20\log_{10}\left(\frac{P}{P_0}\right)$

(a) $20\log_{10}\left(\frac{2\times10^{-5}\,Pa}{2\times10^{-5}\,Pa}\right) = 0\,dB \qquad (120-0) = 120\,dB$

$20\log_{10}\left(\frac{20\,Pa}{2\times10^{-5}}\right) = 20\log_{10}(10^6) = 120\,dB$

(b) 5,000 Pa ⇒ dB $\quad 20\log_{10}\left(\frac{5000}{2\times10^{-5}}\right) = 167.96\,dB$

$20\log(5000) - 20\log(20) = 20\log\left(\frac{5000}{20}\right) = 47.96\,dB \simeq 48\,dB$

(5) 0.1 mm THICK $\quad 120\,\Omega$ @ $20^\circ C \quad A_{circle} = \pi r^2$

a) $R = \frac{L}{\sigma A} \Leftrightarrow L = R\sigma A \quad L = 120(5.8\times10^7)\left(\pi\left(\frac{0.1E-3}{2}\right)^2\right) = \boxed{54.7\,m}$

$R(t) = R_0(1+\alpha[T-T_0])$

b) $C = \pi D = \pi(0.006) = 0.01885\,m \qquad \frac{L_{WIRE}}{C} = \frac{54.7\,m}{0.01885\,m} = 2.9E3$ TURNS

WIRE THICKNESS = 0.0001 m

$\underbrace{(0.0001)}_{m}\underbrace{(2.9E3)}_{TURN} = 290.19\,mm \Rightarrow 0.29\,m$

c) $-45^\circ C \quad +120^\circ C$

$R(t) = R_0(1+\alpha[T-T_0])$

$\alpha = 0.0039$

$T_0 = 20^\circ C$

$R_0 = 120\,\Omega$

$R(-45^\circ C) = 120(1+0.0039[-45-20]) = \boxed{89.58\,\Omega}$

$R(+120^\circ) = 120(1+0.0039[120-20]) = \boxed{166.8\,\Omega}$

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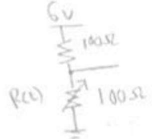
6) $-200°C$ to $+600°C$ @ $0°C$ $R = 100\,\Omega$

$TCR = 0.00385/°C$

SELF HEAT = $0.07\ °C/mW$

POWER SOURCE

6V 100Ω RESISTOR



$R(t) = R_0(1 + \alpha[T - T_0])$

$I(0) = \frac{V_1}{R} = \frac{6V}{(100+100)\Omega} = 0.03\,A$

$P = I^2 R(t)$

$P = (0.03A)^2(100\Omega) = 0.09\,W$

$SH = (0.07\ °C/mW)(P_{mW})$

$P_{SH} = (0.07\ °C/mW)(90E\text{-}3) = \boxed{6.3°C}$

100°C

$R(100) = 100(1 + 0.00385[100 - 0]) = 138.5\,\Omega$

$I(100) = \frac{V}{R} = \frac{6V}{(100+138.5)} = 25.16E\text{-}3\,A$ $\quad P = (25.16E\text{-}3A)^2(138.5) = 87.65E\text{-}3\,W$

$SH = (0.07)(87.65mW) = \boxed{6.1355°C \text{ ERR}}$

80°C $R(80) = 100(1 + 0.00385[80 - 0]) = 130.8\,\Omega$ $\quad I(80°) = \frac{6V}{(100+130.8)} = 25.94 \approx 26E\text{-}3\,A$

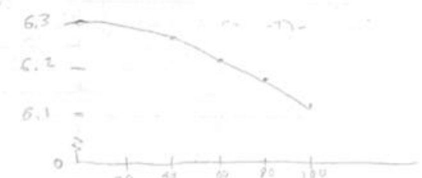
$P = (26E\text{-}3A)^2(130.8) = 88.4E\text{-}3\,W$ $\quad SH = (0.07)(88.4) = 6.19°C$ ERR

60°C $R(60) = 100(1 + 0.00385[60 - 0]) = 123.1\,\Omega$ $\quad I(60°) = \frac{6V}{(100+123.1)} = 26.9E\text{-}3\,A$

$P = (26.9E\text{-}3)^2(123.1) = 89.04E\text{-}3\,W$ $\quad SH = (0.07)(89.04) = 6.2328°C$ ERR

40°C $R(40) = 100(1 + 0.00385[40 - 0]) = 115.4\,\Omega$ $\quad I(40) = \frac{6V}{100+115.4} = 27.86E\text{-}3\,A$

$P = (27.86E\text{-}3A)^2(115.4\Omega) = 89.5E\text{-}3\,W$ $\quad SH = (0.07)(89.5) = 6.265°C$ ERR



7) $R(t) = R_0(1+\alpha[T-T_0])$ $\quad \sigma = 1.8 \times 10^7 \quad TCR = 0.0056$

22Ω @ $20°C$ $\quad$ 120V, 100W LIGHT BULB

a) TEMP OF FILAMENT WHEN BULB IS LIT $\qquad P = \frac{V^2}{R} \iff R = \frac{V^2}{P}$

$R(t) = \frac{120^2}{100} = 144$

$$\left(\frac{\frac{R(t)}{R_0} - 1}{\alpha}\right) + T_0 \Rightarrow \left(\frac{\frac{144}{22\Omega} - 1}{0.0056}\right) + 20 \boxed{= 1.01E3°C}$$

b) ONE SOURCE OF ERROR COULD BE THAT THE SURFACE AREA OF THE FILAMENT MAY VARY WHICH COULD CHANGE THE RESISTANCE OF THE WIRE.

THE ENVIRONMENT MAY NOT ALWAYS BE 20°C. OUR CALCULATIONS USE THE RESISTANCE OF THE WIRE AT 20°C.

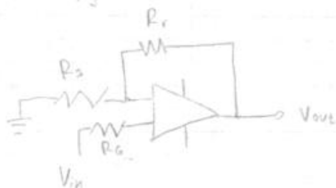
8) RANGE → 0 AND 100μV $\quad$ OUTPUT 0V → 5V $\quad Z_{IN} = 10M\Omega$ $\quad$ OPEN LOOP $G = 10^6$

$V_{out} = 0 \to 5V \qquad V_{in} = 0 - 100\mu V \qquad G = \frac{5V}{100\mu V} = 50E3$

$G = 1 + \frac{R_F}{R_S}$

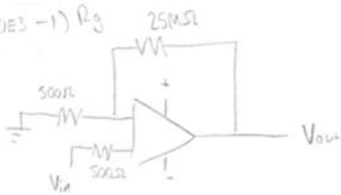
$R_S = R_g$

$$\boxed{\begin{array}{l} R_g = 500\Omega \\ R_F = 25M\Omega \end{array}}$$



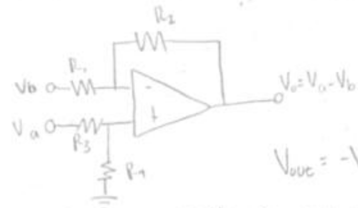
$R_F = (G-1)R_g \Rightarrow R_F = (50E3 - 1)R_g$

R_g	R_F
100k	~5E9
200k	~10E9
100	~5M
500	~25M



(9) FOR $V_{out} = V_a - V_b$ IF $\underbrace{R_1 = R_2 = R_3 = R_4}_{1}$ $V_a = 0$

IF $R_1 = R_2 = R_3 = R_4$ THEN



V_{OUT} EQUATION FOR SUBTRACTING AMPLIFIER:

$$V_{out} = -V_b\left(\frac{R_2}{R_1}\right) + V_a\left(\frac{R_4}{R_3+R_4}\right)\left(\frac{R_1+R_2}{R_1}\right)$$

USING SUPERPOSITION

$V_{out} = V_a - V_b$

IF $V_b = 0$ AND $R_1 = R_2 = R_3 = R_4$

$V_{out} = V_a$

IF $V_a = 0$ AND $R_1 = R_2 = R_3 = R_4$

$V_{out} = -V_b$

b) $V_{out} = 5(V_a - V_b)$

IF $R_2 = 5$ AND $R_1 = 1$ $\quad V_{out} = -V_b(5) + V_a\left(\frac{R_4}{R_3+R_4}\right)\left(\frac{1+5}{1}\right)$

$5 = \left(\frac{R_4}{R_3+R_4}\right)(6) \Rightarrow \frac{5}{6} = \left(\frac{R_4}{R_3+R_4}\right)$ $\quad R_4 = 5$ AND $R_3 = 1$ $\quad \frac{5}{1+5} = \frac{5}{6}$

$\boxed{\text{IF } R_1 = 1\Omega,\ R_2 = 5\Omega,\ R_3 = 1\Omega,\ R_4 = 5\Omega}$

(10) $1K\Omega$ @ $25°C$ MATERIAL CONSTANT $\beta = 3{,}200K$ $\quad$ 0.2 mA CURRENT SOURCE

TEMP RANGE $0°C$-$50°C$ $\quad 25°C = 298.15K$ $\quad R(T) = R_0 \cdot e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$

a) CALC ERROR IN TEMP $\quad 50°C = 323.15K$ $\quad R_0 = 1k\Omega$ $\quad T = 323.15K$ $\quad T_0 = 298.15K$

$R(50°C) = R(323.15K) = 1k\Omega \cdot e^{3200K\left(\frac{1}{323.15} - \frac{1}{298.15}\right)} \Rightarrow \underline{R(50°C) = 435.9\Omega}$

$$T = \frac{\beta}{\ln\left(\frac{R(T)}{R_0 e^{-\beta/T_0}}\right)} = \frac{3200}{\ln\left(\frac{435.9}{1000 \cdot e^{-3200/298.15}}\right)} = 323.09K \Leftrightarrow 49.94°C$$