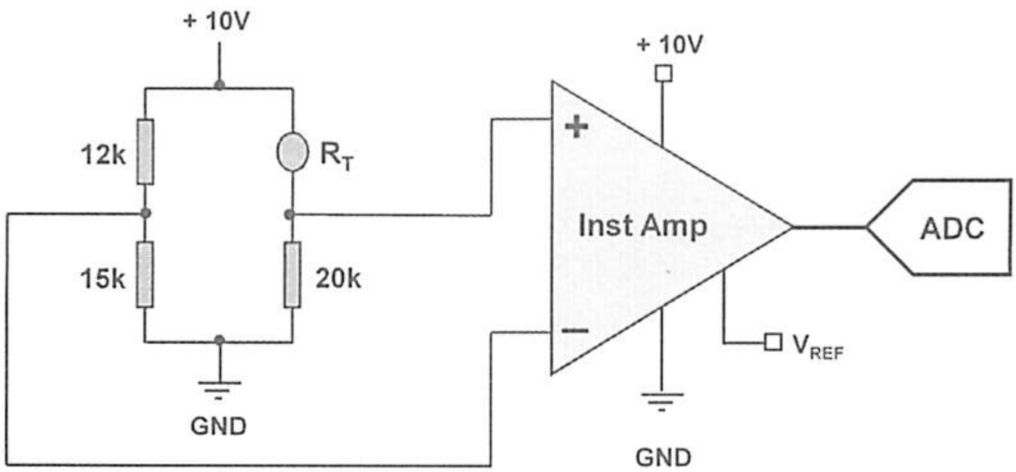
BME/ECE 386 QUIZ (W20) NAME: Solutions

1 problem for 20 pts

Temperature Measurement

You are asked to design a temperature measurement system that operates from 10 °C to 45 °C with a sensitivity of 0.05 °C. You decide to use a thermistor R_T in a quarter bridge as shown in the figure below. Both the bridge and instrumentation amplifier are powered by +10V and GND. You can assume the amplifier has a max and min output of 9V and 1V, respectively. The reference voltage is V_{REF} = 5V. The ADC operates from 0 to 10V with 12 bits. The thermistor properties are the following:

- T = 10 °C: R_T = 41.8 kohm α = -4.47 %/°C
- T = 25 °C: R_T = 22.0 kohm α = -4.10 %/°C
- T = 45 °C: R_T = 10.1 kohm α = -3.67 %/°C



a) You must choose between an amplifier gain of Ad = 1, 1.5, 2, 2.5, 3, or 3.5. Which is the best choice? Show all work!

b) Suppose the measurement system has a noise voltage of V_N = 1 mV_{RMS}. Does the temperature sensitivity at T = 45 °C satisfy the design requirement? Show all work!

(a) $V_{Meas} = V_{Ref} + A_d \Delta V$

$= 5 + A_d \cdot 10 \cdot \left(\frac{20K}{20K + R_T} - \frac{15K}{15K + 12K} \right)$

↑ Limited by amplifier for both max and min?

Max 9V ← $T = 45°C$ $(R_T = 10.1K)$, $\Delta V \uparrow$

Ref 5V

Min 1V ← $(R_T = 41.8K)$ $T = 10°C$

$5 + A_d\, 10 \left(\frac{20K}{20K + 10.1K} - \frac{15K}{27K} \right) < 9$

$\Rightarrow A_d < 3.67$ (+5)

(extra sheet for work)

$T = 10^\circ C \; (R_T = 41.8K)$, $\Delta V \downarrow$

$$5 + A_d \cdot 10\left(\frac{20K}{20K + 41.8K} - \frac{15K}{27K}\right) > 1$$

+2

$\Rightarrow A_d < \underline{1.72}$ ← This limits the gain!

+5

Choose $A_d = 1.5$

(b)

$$\Delta T_{MIN} = \frac{\Delta V_{MIN}}{\frac{\partial V_{Meas}}{\partial T}}$$

$$\Delta V_{ADC} = \frac{10V}{2^{12} - 1} = .0024V$$ ← ΔV_{MIN}!

$V_N = .001V$

$$\frac{\partial V_{Meas}}{\partial R_T} \cdot \alpha R_T = \left[-A_d \cdot 10 \cdot \frac{20K}{(20K + R_T)^2}\right] \cdot \alpha R_T$$

$$= \left[-1.5 \times 10 \cdot \frac{20K}{(20K + 10.1K)^2}\right] (-.0367\ {}^1/_{^\circ C})(10.1K)$$

$$= \underline{0.123\ V/^\circ C}$$

$$\text{So, } \Delta T_{MIN} = \frac{.0024V}{.123\ V/^\circ C} = \boxed{.0195\ ^\circ C} < .05^\circ C \checkmark$$

YES

+8

:)