EE 3310/5310 • Exam V • 2 December 2022 18 pts NAME SOLUTION

1) An NTC thermistor is to be used in a fault-detection circuit to warn the user when a commercial refrigerator is operating outside normal parameters. The thermistor has the following specs:

- **β = 5002 K**
- **R_0 = 890 Ω @ T_0 = 40°F**

Design a circuit that achieves a LOW to HIGH state change on a 5V Arduino Uno when the temperature rises from 0 to 55°F. Note: °C = 5/9 (°F−32). Draw your circuit, clearly showing the position of the thermistor, and choose an E24 external resistor value. Verify that the voltages of your circuit at the two temperatures constitute LOW and HIGH inputs.

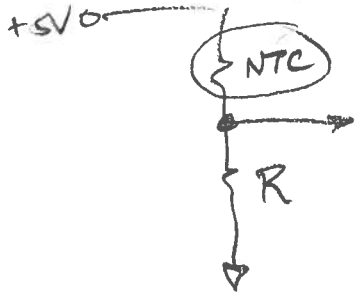
$$R_t = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

$$T_0 = \frac{5}{9}(0-32) + 273.15 = 255.4\,K$$

$$T = \frac{5}{9}(55-32) + 273.15 = 285.9\,K \quad (+2)$$

$$R_t = 890\, e^{5002\left(\frac{1}{285.9} - \frac{1}{255.4}\right)} = 110.2\,\Omega \quad (+1)$$

This configuration goes LOW to HIGH when T ↑ [because R_{NTC} ↓]:



(+2)

$$R \overset{N}{=} \sqrt{110.2 \cdot 890} = 313.2\,\Omega \quad (+1); \quad \text{use } R = 300\,\Omega \quad (+1)$$

Check: $V_0 = 5\left[\frac{R}{R+R_0}\right] = 5\left[\frac{300}{300+890}\right] = 1.26\,V$ (+1) = yes, LOW

$$V_t = 5\left[\frac{R}{R+R_t}\right] = 5\left[\frac{300}{300+110.2}\right] = 3.66\,V$$ (+1) = yes, HIGH

2) A *strain gage* is a type of sensor that changes resistance with applied deformation; thus, it requires an external voltage source to create a changing voltage. Is this a *modulating* or *generating* sensor?

+1

A strain gage in a bridge circuit has an output voltage of **2.254 V**. To what level is this voltage quantized in a **12-bit, 3.3V** system?

12-bit system $\Rightarrow 2^{12} = 4096$ levels (+1)

∴ possible values: 0 to 4095 (+1)

$\therefore 2.254\,V \left(\frac{4095}{3.3\,V}\right) = 2797.00909$

$\therefore$ 2797 (+1)

in binary: 101011101101 (+1)

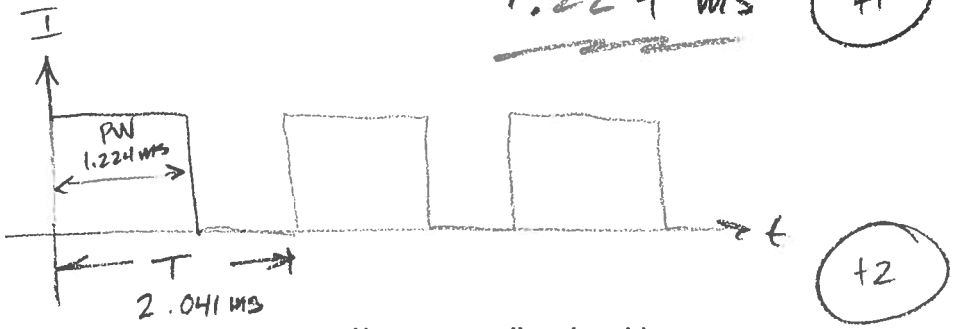
An LED warning light is driven from a PWM signal furnished by an Arduino Uno at the standard frequency of 490 Hz. If "normal" brightness is achieved at 100% duty cycle, what duty cycle will reduce the apparent brightness by 40%? To what pulse width in milliseconds does this correspond? Draw the signal, showing the pulse width and period.

100% · (1 − 40%) = 60% duty cycle (+1)

$T = \frac{1}{490} = 0.002040816$ or 2.041 ms (+1)

∴ Pulse width is 0.6 · 2.041

= 1.224 ms (+1)



(+2)

Have an excellent break!