Student name:

	1 37	2 5	3 12	4 20	5 6	6 5	7 15	Total

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1. An embedded microcontroller program is used to measure temperature with thermistor with the following characteristics:

$$R(t) = 161 \cdot e^{-0.013*t} \ [K\Omega]$$

where *t* is temperature in degrees Fahrenheit [°F]. Thermistor is used in voltage divider configuration with fixed resistor of 75 KΩ connected to power supply and thermistor connected to the ground. Microcontroller uses a 12 bit AD converter with 2.5V positive reference and ground as negative reference. Signal conditioning circuit uses power supply of 3V. Maximum expected frequency of the signal is 100Hz.

Q1.1. (2 points) What is the minimum sampling frequency of the signal?

Q1.2. (2 points) What is the minimum voltage of the signal if the expected range of temperatures is 40-80 °F?

Q1.3. (2 points) What is the maximum voltage of the signal if the expected range of temperatures is 40-80 °F?

Q1.4. (2 points) How many seconds of the signals you can buffer on the microcontroller without optimization?

Q1.5. (2 points) How many seconds of the signals you can buffer on the microcontroller with optimization?

Q1.6. (5 points) What is the quantization step of the AD converter in millivolts [V]?

Q1.7. (5 points) The system transmits data using UART with 8 data bits, 1 start bit, 1 stop bit, and bit rate of 115,200 bps. What is the maximum sampling frequency that allows real-time transmission of samples using UART?

Q1.8. (5 points) What is the output of the AD converter when the temperature is 60°F?

Q1.9. (10 points) The embedded microcontroller runs at clock speed of 10MHz and spends 240 cycles to process each sample. Total data acquisition time is 0.2 ms and sampling frequency is 40 Hz. In addition, every 1,024 samples the controller is running the FFT analysis which takes 15,500 instructions. What is the ratio of average processing time (including data acquisition time) and sampling interval Ts?

Q1.10. (2 points) Can system run in real-time?

2. A low-pass filter is implemented using R=4.7$K\Omega$ and C = 1 μF (series of resistor and capacitor, and capacitor is parallel to output).


Q2.1. (5 points) What is the magnitude of the transfer function at frequency 500 Hz?

3. Let x[n] = [0.1 0.35 0.24 0.39 0.41 0.3 0.23 -0.12 -0.15 0.2 0.4] and h[n]=[-0.1 0.2 -0.05]

Compute and plot the convolution y[n] = x[n] * h[n].

Q3.1. (12 points) What is the value of the fifth sample of the output (y[4*Ts])?

4. A 1 kg weight is hung on the end of a vertically suspended spring, thereby stretching the spring $L= \frac{10}{17}$ [m]. The weight is pulled 1m below its equilibrium position and released from rest at time t=0. The damping coefficient is $c = 2$. Find the displacement x of the weight from its equilibrium position at time t. Use g=10m/s². All forces, velocities, and displacements in the upward direction will be negative, according to the Figure below.
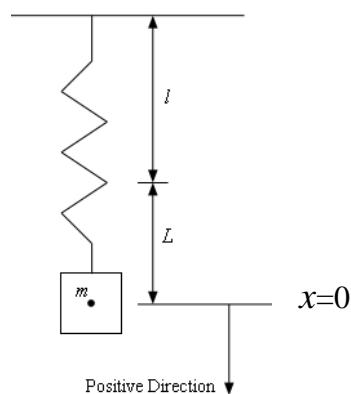
Q4.1. (17 points) What is the value of the step response x(t) at time t=1.8 s?

Q4.2. (3 points) What is the steady state value of x(t)?

5. A and B are vectors with coefficients of a 5-point averaging filter in C program.

Q5.1. (3 points) What is the value of A[0]?

Q5.2. (3 points) What is the value of B[2]?

6. Signal is sampled at Fs=500 Hz and discrete Fourier transform is performed by using N=2048 point window.

Q6.1. (5 points) What is the frequency resolution of the result - Δf ?

7. Load **fintest.mat** from Canvas/final_exam. Signal x is sampled at Fs=200 Hz. Analyze signal using Matlab function **fft** and NFFT=1024 point window and a 1024 point **hanning** window. Plot the spectrum and publish the file

Q7.1. (6 points) How many discrete frequency components do you have in spectrum of the real signal x?

Q7.2. (9 points) What is the frequency of the second largest component in spectrum of x?