15-19 ✓ 8, 10-12 ✓
1-6 ✓ 13 & 14 ✓

CPE 381 **Final Exam** *Spring 2021*

Student name: Nolan Andersson

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

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 150Hz.

See work Below!

✓ **Q1: What is the minimum sampling frequency of the signal?**

✓ **Q2: What is the minimum voltage of the signal if the expected range of temperatures is 40-80 °F?**

✓ **Q3: What is the maximum voltage of the signal if the expected range of temperatures is 40-80 °F?**

✓ **Q4: How many seconds of the signal you can buffer on the microcontroller without optimization? (Check Canvas for the amount of available memory).**

✓ **Q5: How many seconds of the signal you can buffer on the microcontroller with optimization? (Check Canvas for the amount of available memory).**

✓ **Q6: What is the quantization step of the AD converter in milivotls [mV]?**

Q7: 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?

✓ **Q8: What is the output of the AD converter when the temperature is 60°F?**

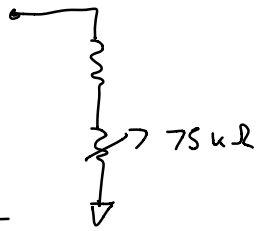
Q9: The embedded microcontroller runs at clock speed of 10MHz and spends 240 cycles to process each sample. Total data acquisition time is 0.2 ms and sampling frequency is 40 Hz. In addition, every 1,024 samples the controller is running the FFT analysis which takes <check Canvas> instructions. What is the ratio of average processing time (including data acquisition time) and sampling interval Ts?

✓ **Q10: Can system run in real-time?**

#1 $2 \times 150 = \boxed{300\,Hz}$

#2 $R(80) = 161 \times e^{-0.013(80)}$

$56.906 / 56.906 + 75 \times 3 = \boxed{1.2942\,v}$



#3 $R(40) = 161 e^{-0.013(40)} =$

$= 95.72 / 95.72 + 75 \times 3 = \boxed{1.6820\,v}$

#4 $12/8 = 1.5 \rightarrow 2$ $\quad 300\,Hz \times 2\,BPS = 600\,BPS$ $\quad 8000/600 = \boxed{13.3333}$

#5 $12/8 = 1.5$ $\quad 300 \times 1.5 = 450$ $\quad 8000/450 = \boxed{17.7778}$

#6 $2.5 - 0 = 2.5$ $\quad 2.5/2^{12} = .000610352 = 6.1035E-4V$

$.000610352\,V = 0.6104\,mV$ $\quad .6104mV$

$.000610352$ $\boxed{0.6104\,mV}$

#7 $115200\,bps$ $\quad 10$ bits for 1 set of data ???

$\boxed{11520\,s}$

$14400\,Bps$

$1.25\,B$ per sample

#8 $R(60) = 161e^{-0.013(60)} = 73.8034$ $\quad .000610352$

$73.8034 / 73.8034 + 75 \times 3 = 1.4879$

$1.4879 - 0 / 0.6104\,mV = \boxed{2437.8}$

#9 $\left[\frac{240}{10{,}000{,}000} \cdot 40\right] + \left[.2\text{ms} \cdot 40\text{Hz}\right] + \frac{\left(\frac{82{,}000}{1024}\right)}{10{,}000{,}000} \times 40$

$.00096 \quad + .008 \quad + .0003203$

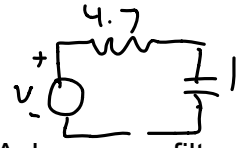
$= .0092803135 = 9.2803\text{ ms}$???

$9.2803 / .025 = \boxed{0.3712}$

#10 **NO!**

$0.3712 > .025 \rightarrow 1/40$

So no, it cannot work in real time.



$1/1+RCs \quad s = 500 \times 2\pi j$

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).

$|H(500)| = 1/\sqrt{1+(4.7\times1\times1000\pi j)^2} = 1/14.7943 = .0676$

Q11: What is the magnitude of the transfer function at frequency 500 Hz? ?

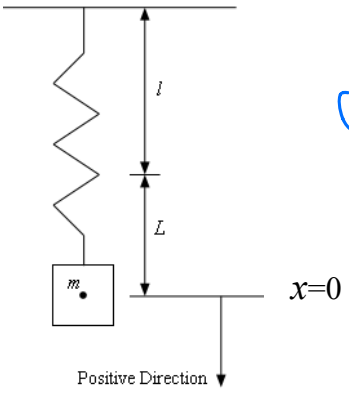
3. Let x[n] = [0.1 0.3 0.24 0.39 0.41 0.3 0.23 -0.2 -0.15 0.2 0.4] and h[n]=[-0.1 0.2 -0.05] Compute and plot the convolution y[n] = x[n] * h[n].

↳ see matlab below Pg. 5 (also manually did it)!

Q12: What is the value of the sixth sample of the result?

0.0325

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/s^2. All forces, velocities, and displacements in the upward direction will be negative, according to the Figure below.



work on next page 6

Q13: What is the value of position x at t=1.6s?

Q14:What is the steady state value of x(t)?

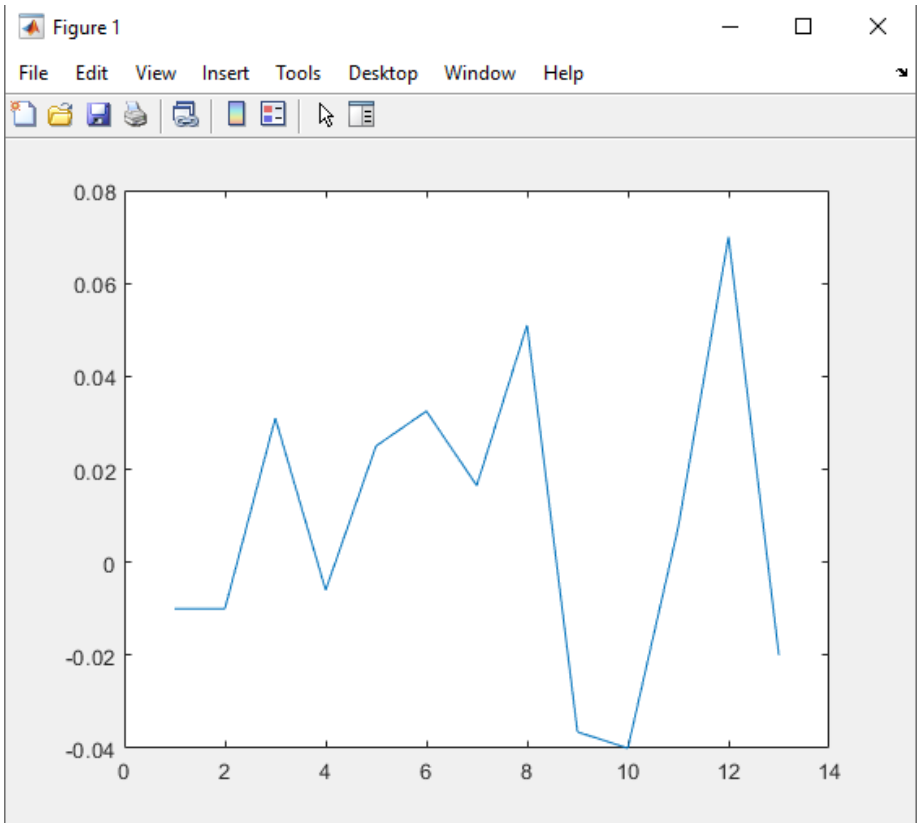
$x(1.6) = 0.2064$

$x(t)$ steady $= 0$

#12

	0	1	2	3	4	5	6				
	.1	.3	.24	.39	.41	.3	.23	-.2	-.15	.2	.4
-.1	-.01	-.03	-.024	-.034	-.041	-.03	-.023	.02	.015	-.02	-.04
.2	.02	.06	.048	.078	.082	.06	.046	-.04	-.03	.04	.08
-.05	-.005	-.015	-.012	-.0195	-.0205	-.015	-.0115	.01	.0075	-.01	-.02

{-.0100, -.0100, .0310, -.0060, .0250, .0325,
.0165, .0510, -.0365, -.0400, .0700,
-.0200}



#13) 14 work

$k = \frac{m \times g}{2} = \frac{1\,kg \times 10\,m/s}{10/17} = 17\,n/m$

EQ: $m\,d^2x/dt^2 + kx + c\frac{dx}{dt} = 0$

$\mathcal{L}\left[\; 1 \cdot \ddot{y}(t) + 17x + 2\dot{y} = 0 \;\right]$

$s^2X(s) - s\,x(0^-)^{1} - x'(0)^{0} + 17X(s) + 2sX(s) - 2x(0^-)^{1} = 0$

$s^2X(s) - s + 17X(s) + 2sX(s) - 2x = 0$

$X(s)\left[s^2 + 2s + 17\right] - s - 2 = 0$

$X(s) = \frac{s+2}{s^2+2s+17}$ $\quad \mathcal{L}^{-1}\left[\frac{s+2}{s^2+2s+17}\right]$ ↓ get into this form!

$\mathcal{L}\left[\frac{s+1}{(s+1)^2+16} + 1 \cdot \frac{1}{(s+1)^2+16}\right]$

19. $e^{at}\sin(bt)$	$\frac{b}{(s-a)^2+b^2}$
20. $e^{at}\cos(bt)$	$\frac{s-a}{(s-a)^2+b^2}$

↓ ↳

$e^{-t}\cos(4t)$ $\quad \frac{1}{4}e^{-t}\sin(4t)$

$X(t) = e^{-t}\cdot\left[\cos(4t) + \frac{\sin(4t)}{4}\right]$ ✓ with matlab

$X(1.6) = e^{-1.6}\cdot\left[\cos(4(1.6)) + \frac{\sin(4\cdot 1.6)}{4}\right]$ → mat lab Calc.

$\boxed{X(1.6) = 0.2064}$

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

$$y[n] = .2\,x[n] + .2\,x[n-1] + .2\,x[n-2] + .2\,x[n-3] + .2\,x[n-4]$$

✓ **Q15: What is the value of A[0]?**

$$\frac{}{1}$$

1

✓ **Q16: What is the value of B[3]?**

$1/5 = 0.2$

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

✓ **Q17: What is the frequency resolution of the result - df ?**

$500/2048 = 0.2441$

7. Load **`final.mat`** from `Canvas` using the link in the problem description. 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

✓ **Q18: How many discrete frequency components do you have in spectrum of the real signal x? Please explain your answer!?**

3 - there are 3 spikes on the graph (see below)

✓ **Q19: What is the frequency of the component with the maximum magnitude in spectrum of x? Please use 4 decimal digits in your answer.**

5.8594 (5.85938)

Header

Table of Contents

Nolan Anderson CPE 381 Final Exam Final.m Plots the spectrum using a hanning function and input .mat file.

Load and initialize

```
load('fintest.mat');

Fs = 200; %sampling frequency
NFFT = 1024; %NFFT
H = 1024; %Hanning window size
Window = transpose(hann(H));
```

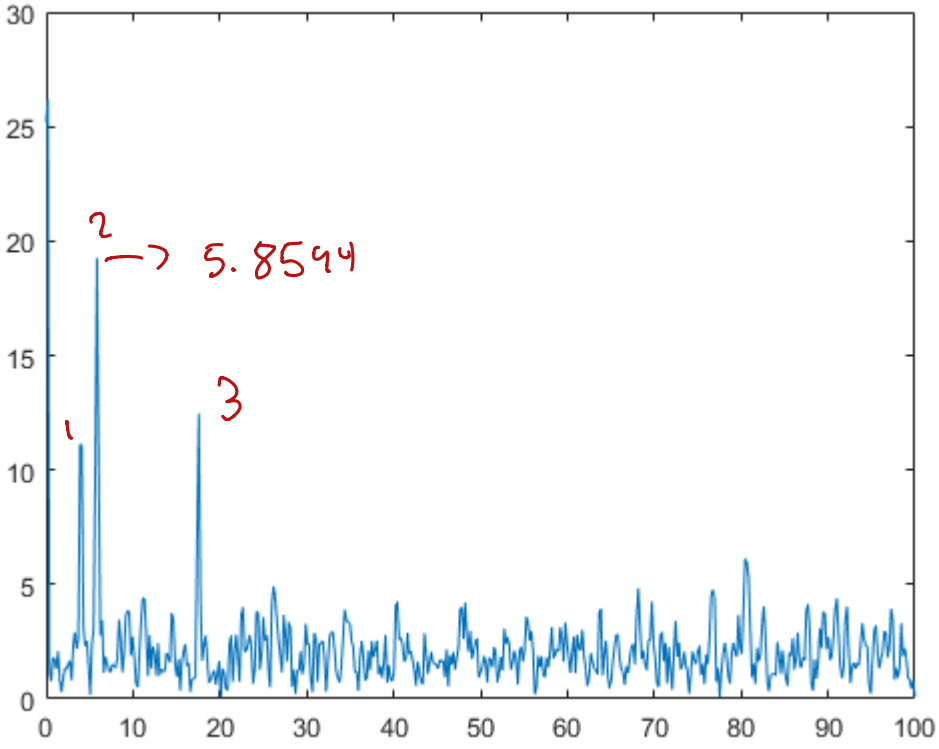
Calculate and Plot

```
x = x .* Window;

out = fft(x, NFFT);
f = Fs*(0:(NFFT/2))/NFFT; % Half samp freq.

sp2 = abs(out / NFFT);
sp1 = sp2(1:NFFT/2+1);
sp1(2:end-1) = 2*sp1(2:end-1);

plot(f,sp1)
```



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