

Name: _____

Section: 2111

EE432 Fall 2011 Exam 1

Problem	Possible Points	Score
1	25	
2	25	
3	25	
4	25	
Total	100	

- Turn this in by Friday, Sep. 30, 2011 at the **beginning** of class.
- This is an open book, open notes and open computer exam. **USE ONLY YOUR COURSE TEXTBOOK** (“Fundamentals of Digital Signal Processing”), your notes from this course, and MATLAB Help. Do NOT talk to anyone else about this exam.
- You **must show your work** to get full credit for problems. Don’t just write answers. Use additional sheets as necessary.
- Label your plots carefully, and turn in all of your code when using MATLAB.
- If you are stuck on a problem, you may ask for guidance...but it might cost you in points. You ask your question, and I will let you know how much it will cost. Then you can agree to obtain the guidance for the specified number of points off of your final score, if you wish.

1. (25 pts) Sampling. An analog signal contains five frequencies : 23.5 kHz, 70 kHz, 160 kHz, 240 kHz, and 280 kHz, and is input to an A/D.

a. When converting this signal to digital, what is the minimum sample frequency to prevent aliasing?

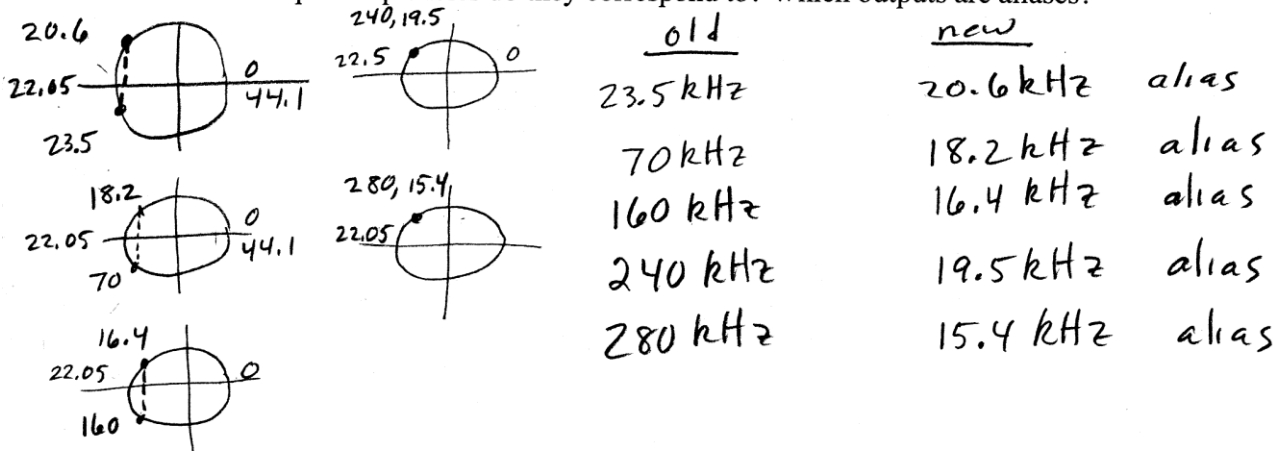
$$2 f_{max} = 2 (280 \text{ kHz}) = \boxed{560 \text{ kHz}}$$

b. If the signal is sampled at 125 kHz, what is the Nyquist frequency and Nyquist range?

$$f_N = f_s/2 = \boxed{62.5 \text{ kHz}}$$

$$\text{Nyquist Range} = [0, f_s/2] = [0, 62.5 \text{ kHz}]$$

c. If the analog signal is sampled at 44.1 kHz, what frequencies will appear out of the A/D and what input frequencies do they correspond to? Which outputs are aliases?



d. If the analog signal is sampled at 44.1 kHz, what is the maximum frequency that can appear out of the A/D?

$$\frac{f_s}{2} = \boxed{22.05 \text{ kHz}}$$

e. If the analog signal is sampled at 500 Hz, what frequencies will appear out of the A/D?



2. (25 pts) Quantization. An analog signal with a voltage range of $[-3.3, +12.7]$ is to be converted to digital using a quantizer designed for this voltage range. This quantizer has the smallest max quantization error.

a. If it is desired that this signal be quantized with 16 bits, what is the resolution and the maximum expected quantization error?

$$Q = \frac{12.7 - (-3.3)}{2^{16}} = 2.4414 \times 10^{-4} \quad Q/2 = 1.2207 \times 10^{-4}$$

b. If this signal is to be digitized such that the resolution of the quantizer is less than 8 mV. What is the minimum number of bits for this quantizer and what is the resulting resolution?

$$0.008 \geq \frac{12.7 - (-3.3)}{2^n} \quad \text{need } 2^n \geq 2000$$

$$2^n \geq \frac{16}{0.008} = 2000 \quad \text{so } n = 11 \quad Q = \frac{16 \text{ V}}{2^{11}} = 0.0078 \text{ V}$$

c. Fill out the following table for the 4-bit quantizer for this problem.

$Q = \frac{16}{16} = 1 \text{ V}$

Digital Code (bits)	Decimal Value	Quantization Voltage Level
0000	0	-2.8V
0001	1	-1.8V
0010	2	-0.8V
0011	3	0.2V
0100	4	1.2V
0101	5	2.2V
0110	6	3.2V
0111	7	4.2V
1000	8	5.2V
1001	9	6.2V
1010	10	7.2V
1011	11	8.2V
1100	12	9.2V
1101	13	10.2V
1110	14	11.2V
1111	15	12.2V

d. Using your quantizer from step c, what would an analog sample value of -0.67 volts be quantized to?

-0.8V (closest Quant level)

e. What is the dynamic range for the quantizer in step c (in dB)?

$$DR = 20 \log_{10} \frac{V_{\max} - V_{\min}}{2^n} = 20 \log_{10} \left(\frac{16 \text{ V}}{16} \right) = 0 \text{ dB}$$

3. (25 pts) Difference Equations, Convolution and Filtering.

- a. For the system defined as follows, determine the 1st six non-zero values of the impulse response.

$$2.4y[n-1] - 2x[n] + 2y[n] + 0.6x[n-1] = 0.$$

$$y[n] = x[n] - 0.3x[n-1] - 1.2y[n-1]$$

n	$x[n] = \delta[n]$	$-0.3x[n-1]$	$-1.2y[n-1]$	$y[n] = h[n]$
0	1	0	0	1
1	0	-0.3	-1.2	-1.5
2	0	0	1.8	1.8
3	0	0	-2.16	-2.16
4	0	0	2.592	2.592
5	0	0	-3.1104	-3.1104

↑ answer

- b. For the system defined by $y[n] = \frac{1}{4}x[n] + y[n-1] - 0.25x[n-4]$, demonstrate whether FIR or IIR, recursive or non-recursive, and whether it is BIBO stable or not.

Find $h[n]$

n	$\frac{1}{4}x[n] = h[n]$	$-0.25x[n-4]$	$y[n-1]$	$y[n] = h[n]^*$	recursive equation - current output is a function of prior outputs
0	1/4	0	0	1/4	
1	0	0	1/4	1/4	
2	0	0	1/4	1/4	
3	0	0	1/4	1/4	
4	0	-0.25	1/4	0	
5	0	0	0	0	

FIR Filter - $h[n]$ has only 4 non-zero terms

BIBO stable $\sum_{n=-\infty}^{\infty} |h[n]| = 1/4 + 1/4 + 1/4 + 1/4 = 1 < \infty$

- d. For the system with an impulse response that follows, use convolution to determine the step response using a table (by hand). $h[n] = -\delta[n-2] + \delta[n-3] + \delta[n-4] - \delta[n-5]$.

$x[n] = u[n]$

index k	-2	-1	0	1	2	3	4	5	6	7	8
$h[k]$					-1	1	1	-1			
$x[-k]$	1	1	1								\vdots
$x[1-k]$	1	1	1	1							$y[1] = 0$
$x[2-k]$	1	1	1	1	1						$y[2] = -1$
$x[3-k]$	1	1	1	1	1	1					$y[3] = 0$
$x[4-k]$	1	1	1	1	1	1	1				$y[4] = 1$
$x[5-k]$	1	1	1	1	1	1	1	1			$y[5] = 0$
											$y[6] = 0$
											\vdots

$$s[n] = -\delta[n-2] + \delta[n-4]$$

4. (25 pts) Fun with MATLAB.

Download the file called "EE432-Exam01-anmbhz89.wav" from the course website. This is a file from a seismometer in New Mexico that recorded the 1989 San Francisco earthquake. An earthquake signal consists of a recording of significant motion of the earth (tremors, or vibrations). The first part of the earthquake consists of initial tremors, and is followed by the largest tremor which eventually dies away. Use MATLAB to answer the following questions about these files. DO NOT attempt to listen to it.

- a. For this file, fill in the following table. State how you did come up with your answers. Include any plots and code you create with this exam. Also, find the bit rate generated in the recording.

Find:	Your Answer:
Earthquake tremors started (sec)	437 sec
Total duration of earthquake (sec)	1263 sec
Time (sec) largest jolt (tremor) began	730 sec
Estimate the period of the largest jolt (sec)	15 sec
Max possible frequency that could appear in this signal based on its A/D (Hz)	$f_s/2 = 10 \text{ Hz}$
Bit rate (bps) of recording	480 bps

Explanations: I plotted the signal, and zoomed in as necessary

Tremors started- Background noise was very small until time 437 sec, when tremors started

Total duration-

stop
 $1700 - 437 = 1263 \text{ sec}$
 Tremors stopped at $\sim 1700 \text{ sec}$

Time of largest jolt-

730 sec
 Looked at plot, saw when the largest sinusoidal variation happened.

Period of largest jolt-

$$748 - 733s = 15s$$

The start + stop of largest oscillation

Max possible frequency in signal-

f_s for this file was 20 Hz, so the Nyquist freq is $f_s/2 = 10$ Hz.

Bit rate- $24 \frac{\text{bits}}{\text{sample}} \times 20 \frac{\text{samples}}{\text{sec}} = 480 \text{ bps}$

nbits for this file is 24 bits/sample .

- b. Produce a properly labeled stem plot of 20 seconds worth of this file centered on the largest tremor.

see attached

- c. If this signal were to be quantized with a 16-bit quantizer that was designed for its range of voltage, that has the smallest possible max quantization error, what would be the quantization voltage levels corresponding to:

Digital Code (bits): Quantization Voltage Level

00000000 00000000

-0.999985

11111111 11111111

0.966282

$\leftarrow V_{min} + Q/2$
 $\leftarrow V_{max} - Q/2$

$$V_{max} = 0.9663 \text{ V}$$

$$V_{min} = -1$$

$$Q = \frac{V_{max} - V_{min}}{2^{16}} = 3.0003e-5 \text{ V}$$

$$Q/2 = 1.5002e-5 \text{ V}$$

% I used the following code to generate a plot of the earthquake, then zoomed in as needed to answer questions.

```
[a,fs,nb]=wavread('EE432-Exam01-anmbhz89.wav');  
t=(0:length(a)-1)*1/fs;  
figure(1),plot(t,a),xlabel('time (sec)'),ylabel('Amplitude (V)')  
title('San Francisco Earthquake-1989'),grid on
```

% I used the following code to generate the stem plot, after determining that the largest jolt was centered around 740 seconds.

```
figure(2),stem(t,a),axis([730 750 -1 1]),xlabel('time (sec)'),ylabel('Amplitude (V)')  
title('20 Seconds of Earthquake Centered at Largest Jolt')
```

