New Mexico State University
Klipsch School of Electrical Engineering

EE395 - Introduction to Digital Signal Processing

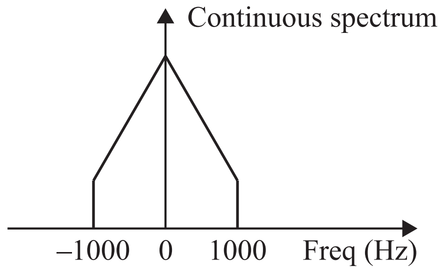
Fall 2010
Exam #1 Part 1

Name: ____________________

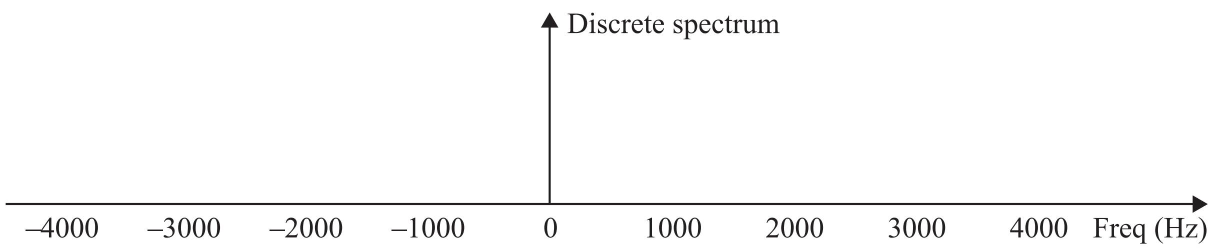
Prob. 1	/ 16 points
Prob. 2	/ 17 points
Prob. 3	/ 17 points
Total	/ 50 points

Prob. 1

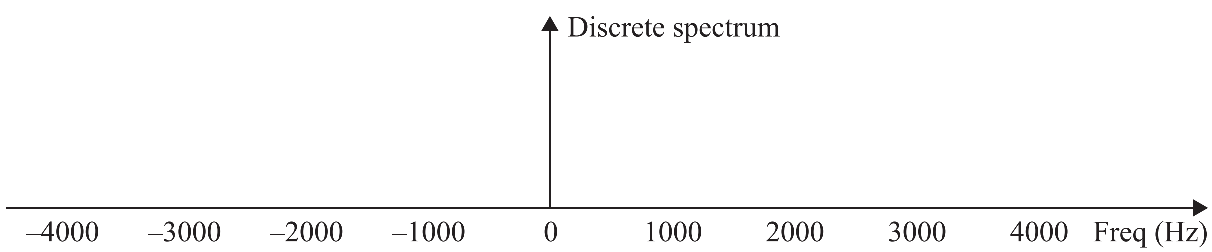
Consider the *baseband* spectrum $X(f)$ of a continuous-time signal shown below. Sketch the spectrum of the discrete-time signal for the given sample rates. Also indicate whether the discrete-time signal is aliased.



(a) $f_s = 2500$ samples/s. Aliased: YES / NO

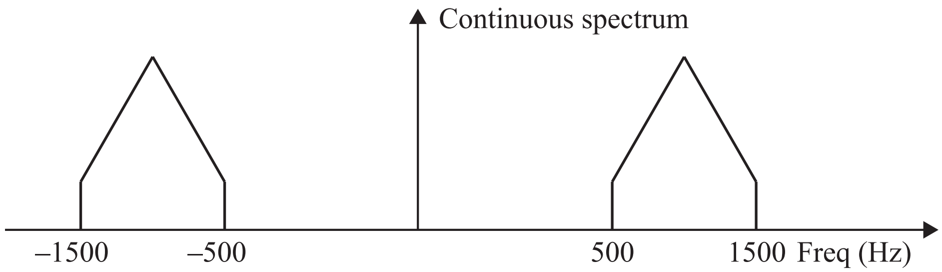


(b) $f_s = 1000$ samples/s. Aliased: YES / NO

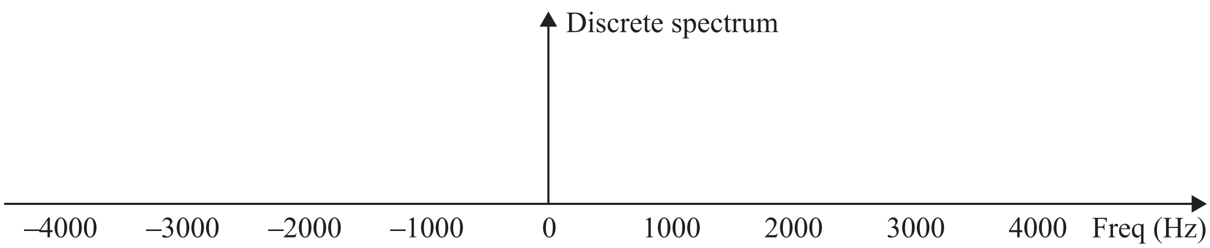


Prob. 1 (cont.)

Consider the *bandpass* spectrum $X(f)$ of a continuous-time signal shown below. Sketch the spectrum of the discrete-time signal for the given sample rates. Also indicate whether the discrete-time signal is aliased.



(c) $f_s = 2500$ samples/s. Aliased: YES / NO



Prob. 2

Consider the Discrete Fourier Transform (DFT)

$$X(m) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi mn/N} \tag{2.1}$$

for $0 \leq m \leq N-1$. Now suppose the length of $x(n)$ is $L < N$. Show that computing

$$Y(m) = \sum_{n=0}^{L-1} x(n) e^{-j2\pi mn/N} \tag{2.2}$$

for $0 \leq m \leq N-1$ is the same as zero-padding $x(n)$ with $N-L$ zeros and computing (2.1).

Prob. 3

The following magnitude spectrum plots (next page) were computed using a DFT

$$X(m) = \sum_{n=0}^{N-1} x(n)e^{-j2\pi mn/N} \quad (3.1)$$

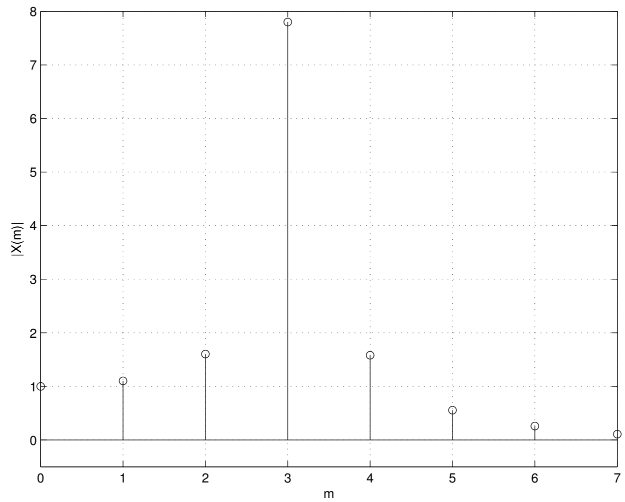
for $0 \leq m \leq N-1$ under the following conditions:

- Either a rectangular or Hamming window is used
- Either one or two cosine waves (same amplititude) are present in the signal and $f_s =$ 1000 samples/s.
- The cosine waves may only have a frequency 100, 200, 250, or 400 Hz.

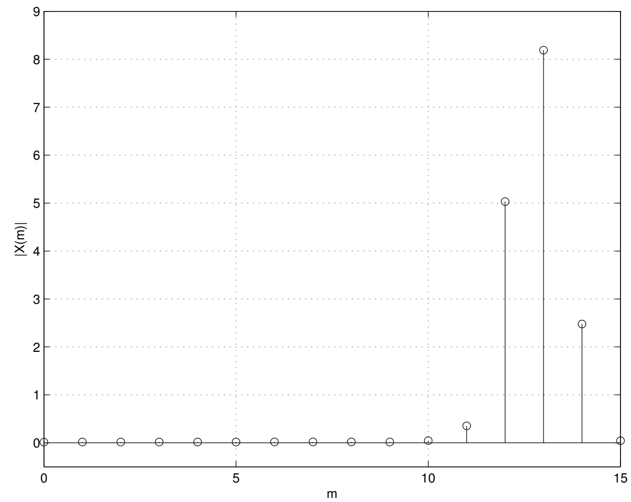
Only the positive frequencies are plotted. Fill in the empty elements in the table.
Note: If a unique value cannot be determined, write "cannot be determined."

Figure	N	Window	# of Cosines	Frequency(s)
(a)				
(b)				
(c)				
(d)				

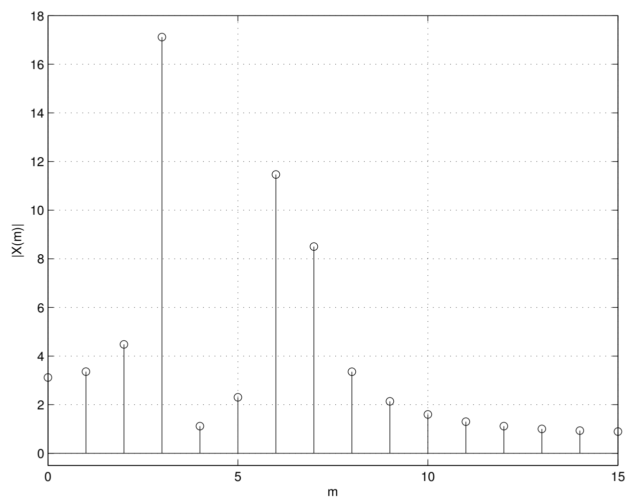
Prob. 3 (cont.)



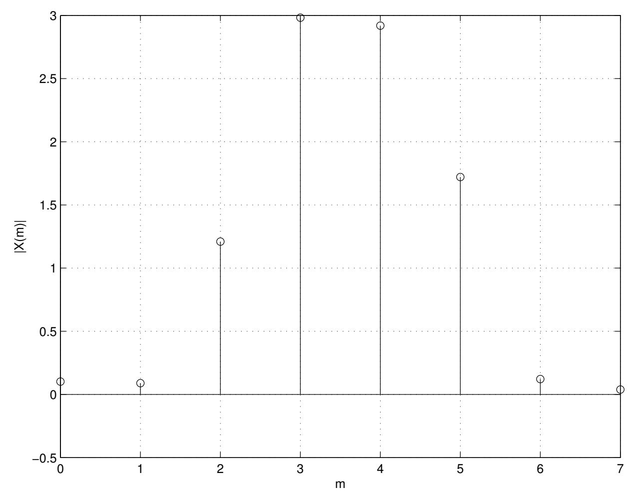
(a)



(b)



(c)



(d)

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EE395 - Introduction to Digital Signal Processing

Fall 2010
Exam #1 Part 2

(Solution due in GA160G 10:30am Fri., Sep. 24, 2010)

"The attached solution is due entirely to my own, individual efforts. I have not discussed this project with any other student nor have I consulted with anyone other than (possibly) the instructor of this course in creating these solutions."

Signature: ______________________ Date: ______________

Prob. 1	/ 16 points
Prob. 2	/ 17 points
Prob. 3	/ 17 points
Total	/ 50 points

Directions

For each problem, please write a MATLAB code which produces the required plots. Name your main codes prob1.m, prob2.m, and prob3.m. Please submit the cover sheet of this exam and a hardcopy of your solutions to the problems. In addition, please send (before the due date) an email to `pdeleon@nmsu.edu` with a .zip file archive containing the three main codes and a directory called "DSP_toolkit" containing your tools.

Please also return Homework #2 for regrading.

Assistance

- You are free to email any questions to Prof. De Leon during the project period. Email may include a request to examine code.
- Extended office hours will be held on Thu., Sep. 23, 9:00–11:00am and 3:00–5:00pm.

Prob. 1

For the following magnitude spectra plots, please label the y-axis $|X(f)|$ or $|Y(f)|$, label the x-axis f (Hz), use a grid, and title your plots. Since the signals are real-valued, plot only the positive frequencies, i.e. $0 \leq f \leq f_s/2$.

(a) Use the DFT to compute the magnitude spectrum of

$$x(n) = \cos\left(\frac{2\pi f_1}{f_s}n\right) + \cos\left(\frac{2\pi f_2}{f_s}n\right) \tag{1.1}$$

for $f_1 = 1125$ Hz, $f_2 = 1525$ Hz, $f_s = 8000$ samples/s, and $0 \leq n \leq 199$. What is the frequency resolution of your DFT? Plot the magnitude spectrum.

(b) Repeat (a) for $f_1 = 1125$ Hz, $f_2 = 1205$ Hz.

(c) Repeat (a) for $f_1 = 1125$ Hz, $f_2 = 1145$ Hz.

(d) Comment on your plot results in (a)–(c) paying particular attention to resolvability of the two cosine waves, DFT leakage, and sidelobe structure.

(e) Use the DFT to compute the magnitude spectrum of

$$y(n) = w(n)\left[\cos\left(\frac{2\pi f_1}{f_s}n\right) + \cos\left(\frac{2\pi f_2}{f_s}n\right)\right] \tag{1.2}$$

where $w(n)$ is the Hamming window for $f_1 = 1125$ Hz, $f_2 = 1525$ Hz, $f_s = 8000$ samples/s, and $0 \leq n \leq 199$. What is the frequency resolution of your DFT? Plot the magnitude spectrum.

(f) Repeat (e) for $f_1 = 1125$ Hz, $f_2 = 1205$ Hz.

(g) Repeat (e) for $f_1 = 1125$ Hz, $f_2 = 1145$ Hz.

(h) Comment on your plot results in (e)–(g) paying particular attention to resolvability of the two cosine waves, DFT leakage, sidelobe structure, and comparison to (d).

Prob. 2

Read the following Wikipedia entry on Dual-Tone Multifrequency (DTMF) and note the DTMF keypad frequencies

http://en.wikipedia.org/wiki/Dual-tone_multi-frequency_signaling

Download the following DTMF signal

http://www.ece.nmsu.edu/~pdeleon/Teaching/EE395/dtmf.wav

and listen to it in MATLAB (or other media player).

(a) Plot a 10 ms section of each DTMF pulse using the following code example

```
[x,fs,bits] = wavread('dtmf.wav');
start = round(0.3125*fs);
stop = round(start+0.010*fs); % pointers to the second pulse
plotcsig(x(start:stop),fs);
```

(b) Describe your approach to decoding the DTMF including signal segmentation, DFT calculation, windowing, and spectral peak detection. [You may need to answer (c) before you answer(b)].

(c) Determine the telephone number which is dialed. Include any plots you used in determining the DTMF frequencies.

You may be interested to know that if you hold the microphone of an analog telephone set to the PC speaker and play the dtmf.wav file, the phone number will be dialed. Asking the answerer for their telephone number is <u>not</u> the way to solve (c).

Prob. 3

Let

$$x(n) = \begin{cases} 1, & 4 \leq n \leq 14 \\ 0, & 0 \leq n \leq 3 \text{ and } 15 \leq n \leq 19. \end{cases} \tag{3.1}$$

Compute the DFT and plot the magnitude and phase response. Show that your response agrees with theory by superimposing the magnitude and phase of equation (3-43) on your plots with the appropriate substitutions for $n_0,\ K,\ N$.