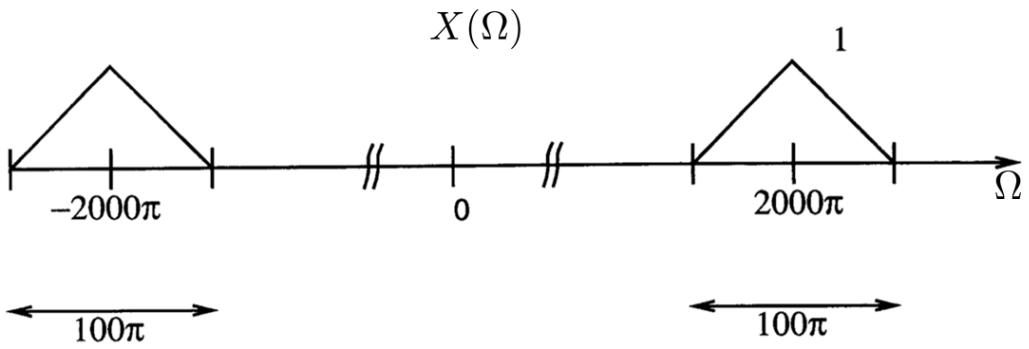
EE123 Spring 2019 Miki Lustig
Digital Signal Processing

Assignment 7

Due March 18^{th} 2019

1. Self-grade Homework 6.
2. Read Chapter 4.1-4.4 Oppenheim and Schafer, 3rd ed.
3. Problem 4.7 Oppenheim and Schafer, 3rd ed.
4. Problem 4.9 Oppenheim and Schafer, 3rd ed.
5. Problem 4.21 Oppenheim and Schafer, 3rd ed.
6. *Sampling basics*
   A continuous-time signal has the following spectrum:



   a) What is the Nyquist frequency for this signal?
   b) You sample $x(t)$ at a rate of 500 Hz. Sketch the spectra of $x_s(t)$ (the continuous-time signal multiplied by the sampling impulse train), and $x[n]$, the new discrete signal with $x[n] = x(nT)$, $T = 1/500$.
   c) Why can you sample $x(t)$ at a rate lower than the Nyquist frequency without losing information?

7. *From Final, fall '11: Dual Tone – Multi Frequency (DTMF)* In touch-tone systems two frequencies are played at the same time, which is technically a DTMF generator. One frequency encodes the row of the keys and another corresponds to the columns. The frequencies are given below. For example, when the button 6 is pressed, the result is the signal

$$y[nT] = \cos(2\pi 770 nT) + \cos(2\pi 1477 nT).$$

   to indicate that key 6 is in the second row, and third column.

		f_c		
		1209	1336	1477
	697	1	2	3
f_r,	770	4	5	6
	852	7	8	9
	941	*	0	#

Sound command in Matlab uses a default sampling rate of 8192 Hz. However, this is not the lowest rate possible.

a) What is the Nyquist sampling rate for DTMF signals?

Nyquist rate:

b) Your friend says that the Nyquist rate is overrated and he can decode DTMF even at much lower rates than Nyquist. For example, he suggests using $F_s = 288$Hz. What property of DTMF signals is your friend relying on? Briefly Explain.

Property of DTMF:

c) Design a system using filter banks to decode DTMF signals sampled at 288 Hz. What is the approximate filter length, M, of the Hanning window that you need to use, and what are the bandpass filters frequencies (in Hz) . (HINT: Hanning window is TBW=2)

Filter length: $M =$
Frequencies: 1) 2) 3) 4) 5) 6) 7)