EE123 Spring 2019 Miki Lustig
Digital Signal Processing

Assignment 9

Due April 8^{th} 2019

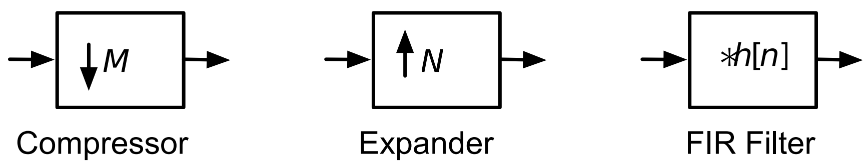
1. Self-grade Homework 8.

2. Read Ch. 5 Oppenheim and Schafer, 3rd ed.

3. Oppenheim and Schafer Exercise 4.61

4. *From Midterm II, sp'11:*
   Design a system that takes a band-limited discrete time input $x[n]$ sampled at a rate $f_{s,1} = 1$ sample/second, and outputs the same signal sampled at $f_{s,2} = 1.5$ samples/second.

   The processing blocks you have are shown below, you can choose to connect them in any order, but you can use each block only once.

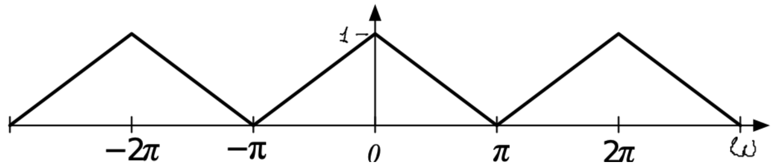


   These are

   - A compressor that reduces the sampling rate by a factor of M. It keeps one out of every M samples, and throws the others away.
   - An expander that increases the sampling rate by a factor of N. It inserts $N-1$ zeros after every input sample.
   - An ideal filter, for which you must specify the frequency response.

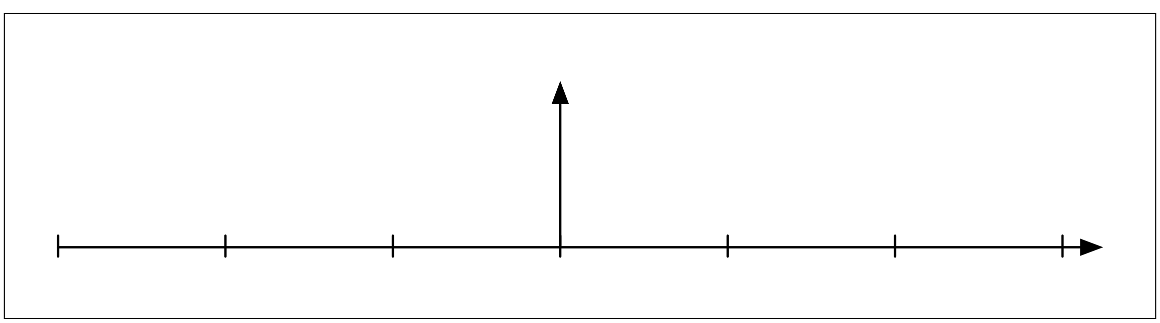
   a) Draw a block diagram of your system, and specify M, N and $H(e^{j\omega})$:

b) The input spectrum looks like this

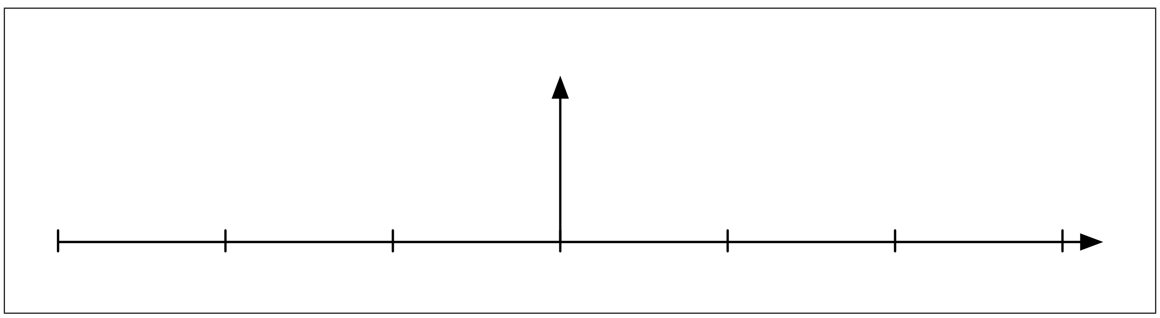


Sketch the output spectrum after each block of your system. Label your axes. Use radian frequencies ω. If aliasing occurs, overlay it with dashed lines.

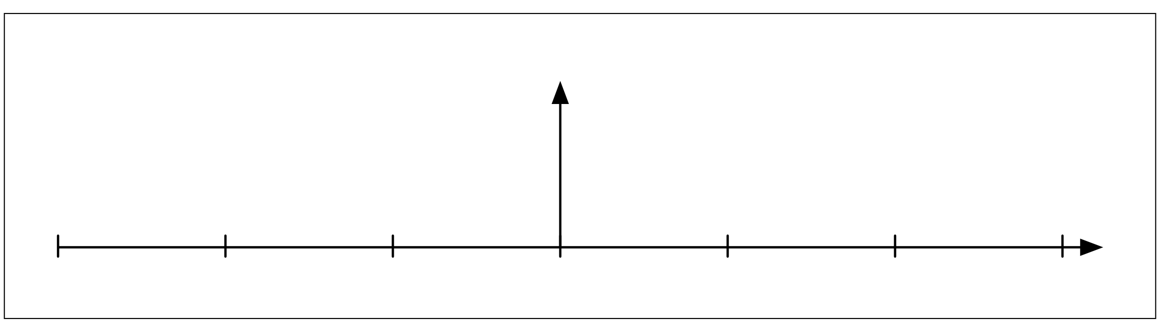
i) Spectrum after Block 1:



ii) Spectrum after Block 2:



iii) Spectrum after Block 3:



c) Find the impulse response $h[n]$ of the filter. You can assume it is ideal instead of an FIR.

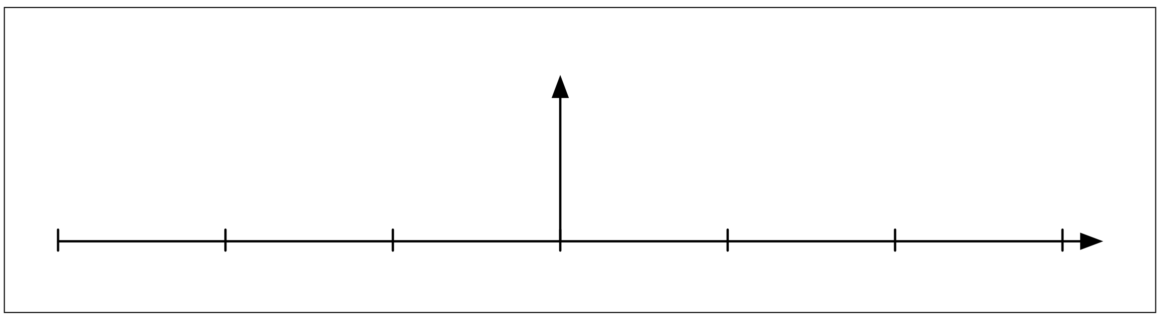
$h[n] =$

d) Instead of using the ideal $h[n]$ FIR filter, you decide to use a triangular window (linear interpolation) with a gain a.

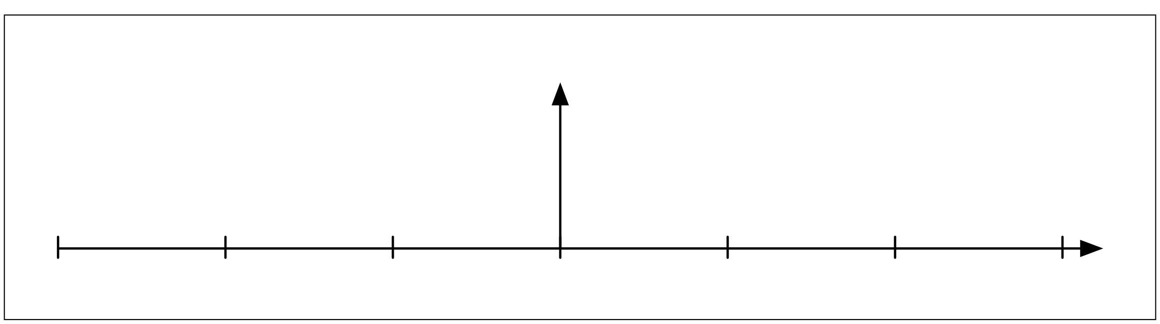
$$h[n] = \begin{cases} a(1 - |n/N|) & |n| < N \\ 0 & \text{otherwise} \end{cases}, \qquad H(e^{j\omega}) = a\frac{\sin^2(\frac{\omega}{2}(N+1))}{(N+1)\sin^2(\frac{\omega}{2})}$$

Sketch the output spectrum after the second and third blocks of your system. Label your axes. If aliasing occurs, overlay it with dashed lines.

i) Spectrum after Block 2:



ii) Spectrum after Block 3:

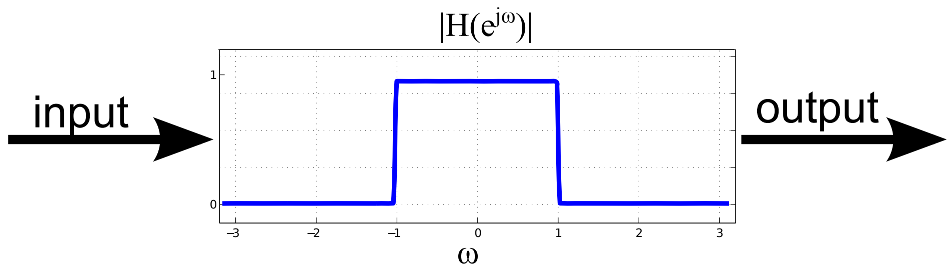


5. Problem 5.24, Oppenheim and Schafer, 3rd ed.

6. Problem 5.45, Oppenheim and Schafer, 3rd ed. Part (e) is optional.

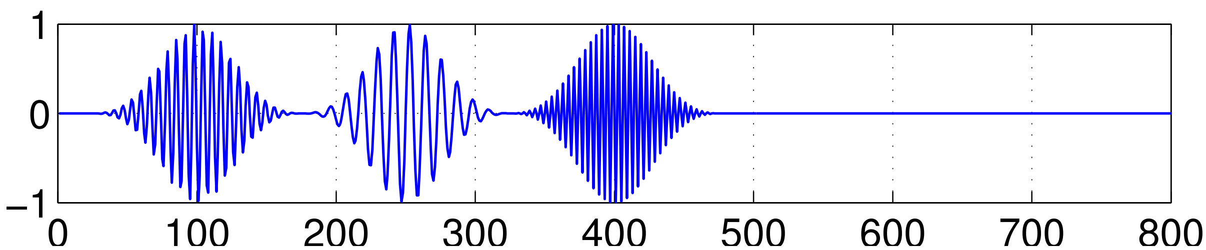
7. *From Final, Fall 11:*

   Consider a **causal LTI** with the following **magnitude** frequency response:

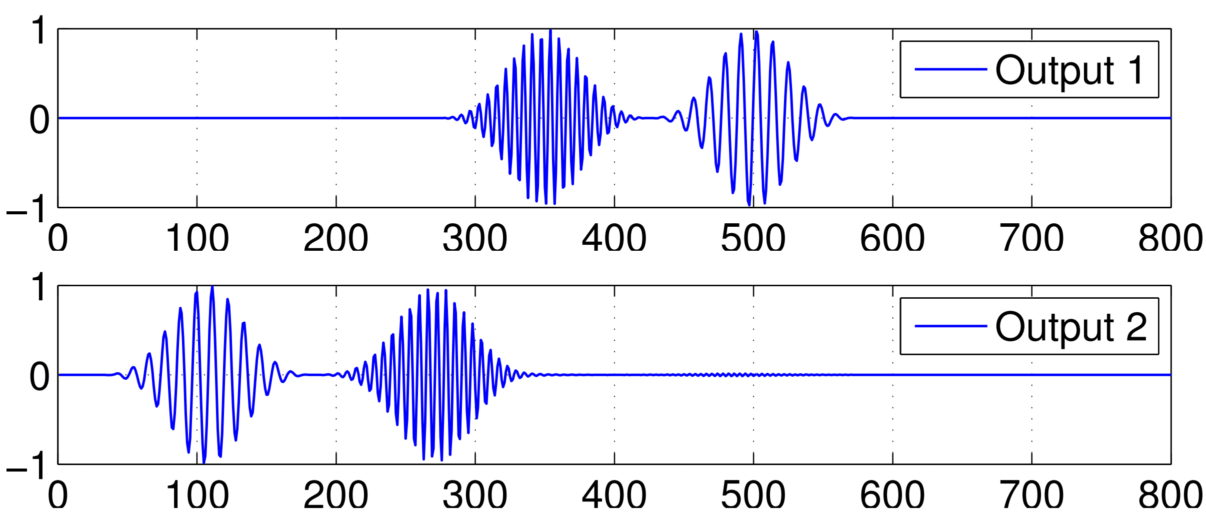


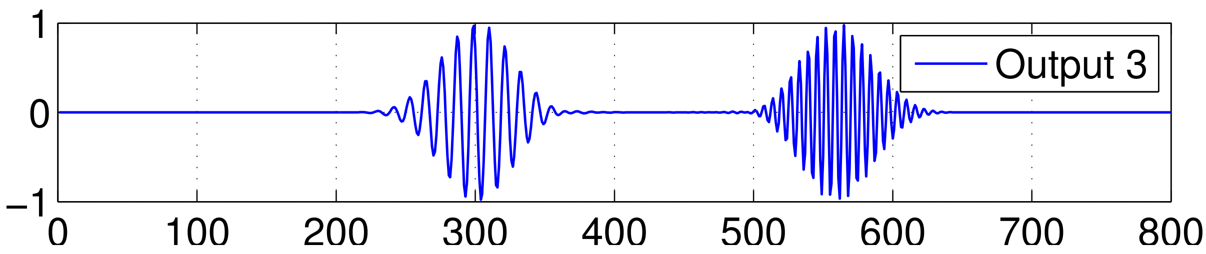
   The system is an **order** $M = 500$ **FIR** filter.

   The following signal, composed of narrowband pulses is passed through the system. The x-axis is samples.



   The following signals are possible outputs of the system:



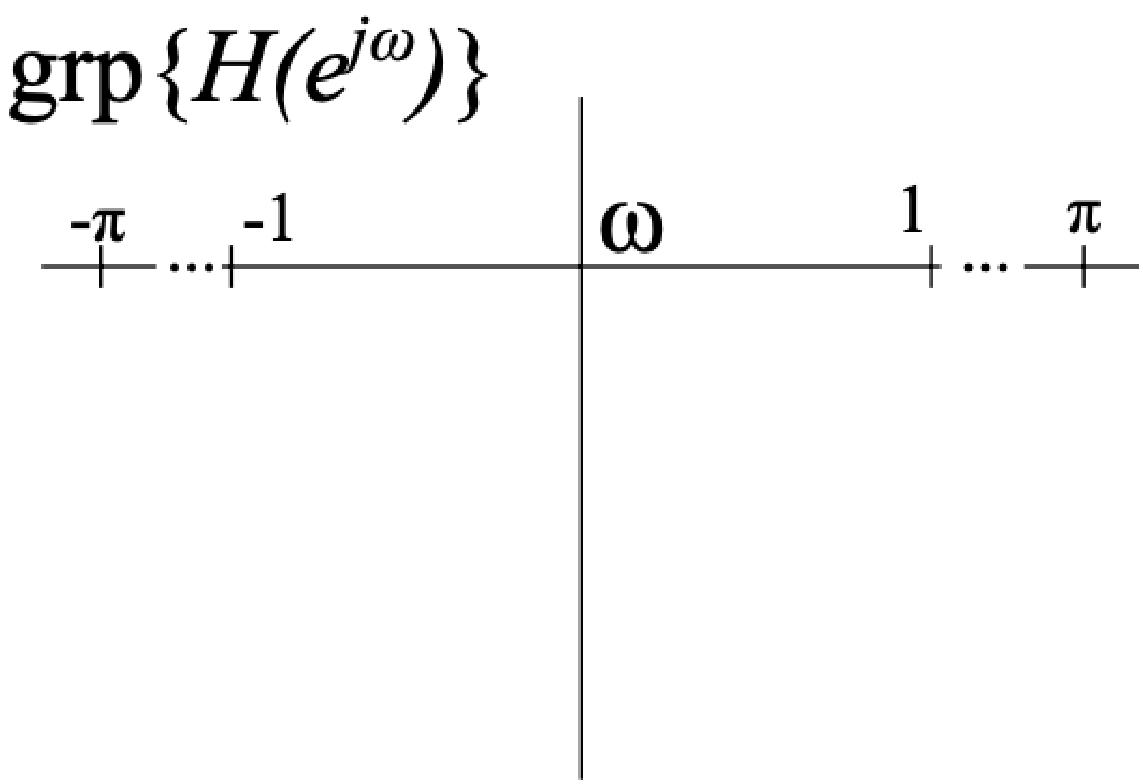


a) Is Output 1 a valid output of the system? Explain why.

valid / not valid

* If the output is valid, draw the group-delay grp$\{H(e^{j\omega})\}$. Explain!

group delay:

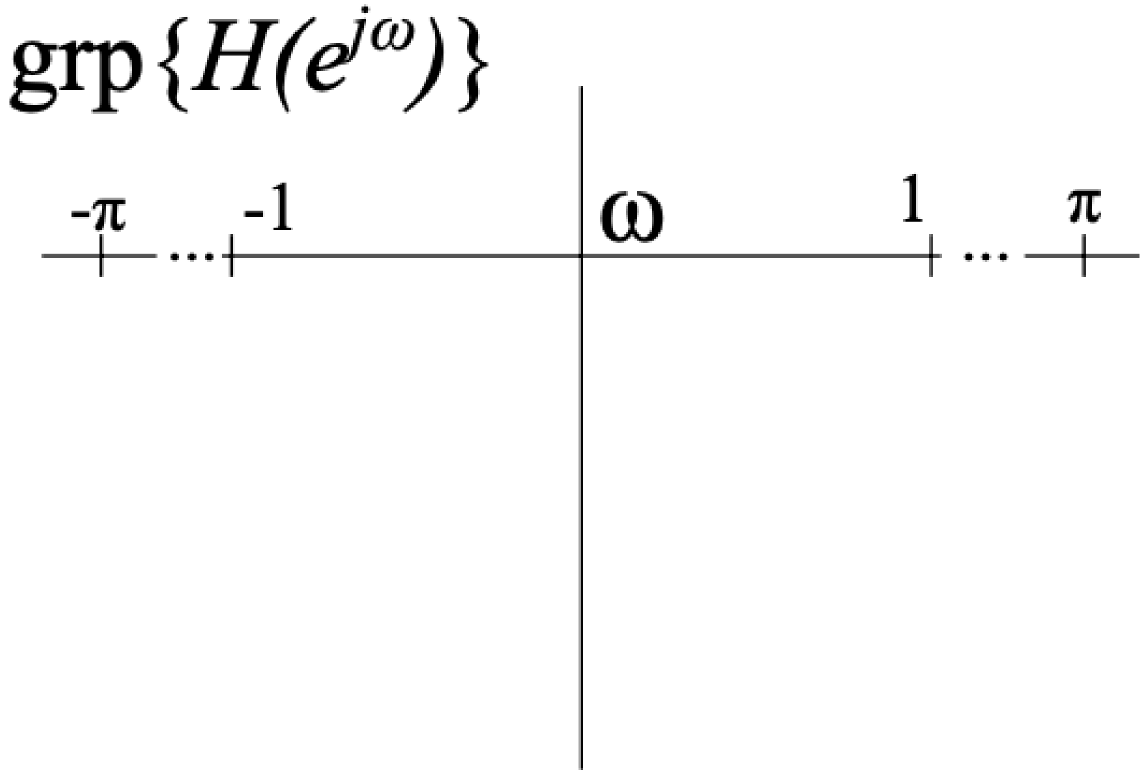


b) Is Output 2 a valid output of the system? Explain why.

valid / not valid

* If the output is valid, draw the group-delay grp$\{H(e^{j\omega})\}$. Explain!

group delay:



c) Is Output 3 a valid output of the system? Explain why.

valid / not valid

* If the output is valid, draw the group-delay grp$\{H(e^{j\omega})\}$. Explain!

group delay: