ECE 5210 Midterm 2

Week of: March 26, 2025

Student's name: ______________________________

Instructor:
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You have 2.5 hours for 5 problems.

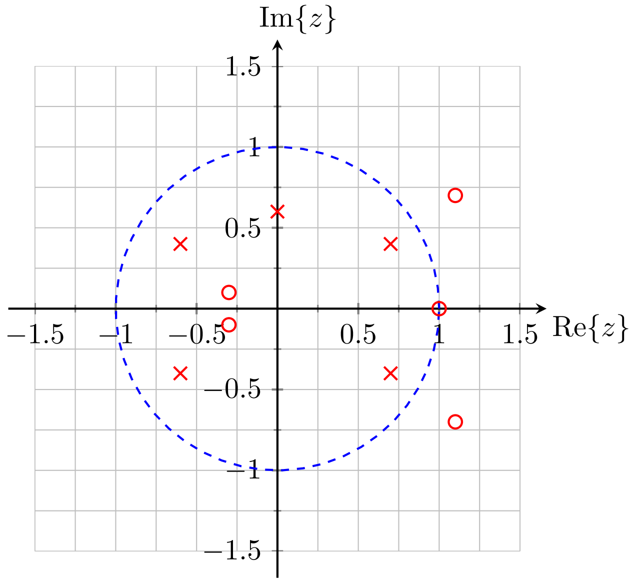
- Show enough (neat) work in the clear spaces on this exam to convince us that you derived, not guessed, your answers.
- Put your final answers in the boxes at the bottom of the page.

You are allowed TWO pages of notes (front and back) for this exam. You may use a graphing calculator of your choice. Consulting with any third party is considered cheating.

Problem	Score	Possible Points
1		20
2		20
3		20
4		20
5		20
Total score		100

1 Short answer

(a) Consider the pole-zero plot for some system $H(z)$.



(i) Is this system IIR or FIR?

IIR FIR

(ii) Is the system stable?

stable unstable

(iii) Does the system have minimum phase?

yes no

(iv) Does the system have linear phase? If so, what type of linear phase filter is this?

Type I Type II Type III Type IV Not linear phase

(v) Is the system causal?

yes no cannot be determined

(vi) Are the coefficients of the system real or complex?

real	complex

(b) Suppose you have a signal that you have quantized that has an SNR_{Q} of 85 dB but you really want 110 dB. How many bits would you need to add to your quantization?

(c) If a FIR system has a zero at $z = 0.8e^{j\pi/4}$, has three taps in total, and has real-valued coefficients, what is the phase of the system at $\omega = \pi/4$?

$\angle H(e^{j\omega}) =$

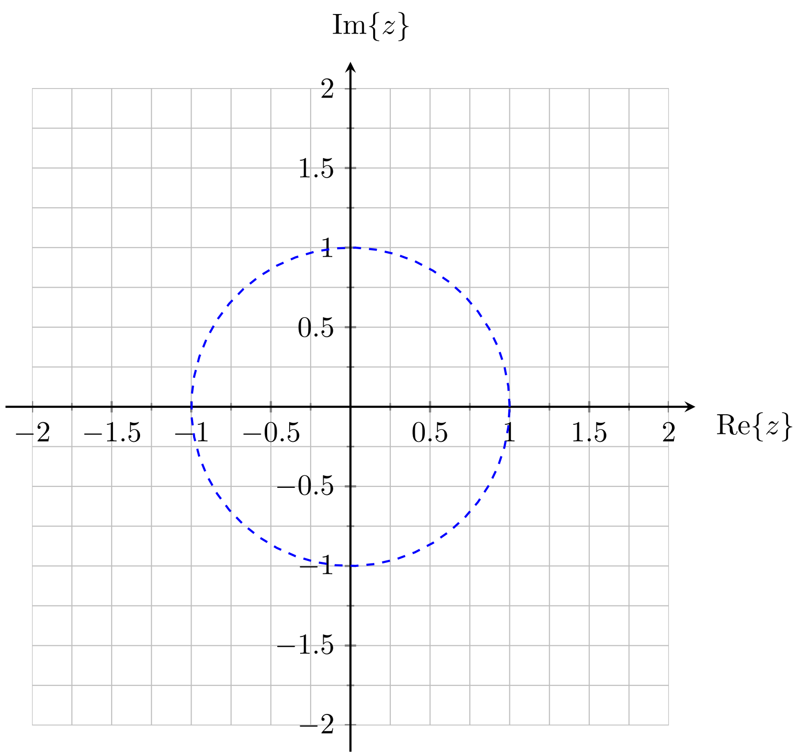
(d) Is the system described by the impulse function $h[n] = 0.9^n(u[n] - u[n-10])$ FIR or IIR?

FIR	IIR

2 Linear phase filters

A linear phase filter has a frequency response with $H(e^{j0}) = 0$ and $H(e^{j\pi}) = 0$. There is a zero at $z = 0.8e^{j\pi/4}$.

(a) Sketch the pole-zero plot of this system.



(b) What is the transfer function $H(z)$ of the overall system? You do not need to simplify the transfer function beyond second-order stages.

$H(z) =$

(c) What type of linear phase filter is this?

Type I	Type II	Type III	Type IV

(d) Decompose this system to a minimum phase system $H_{\text{min}}(z)$ and an all-pass system $H_{\text{ap}}(z)$.

$H_{\text{min}}(z) =$

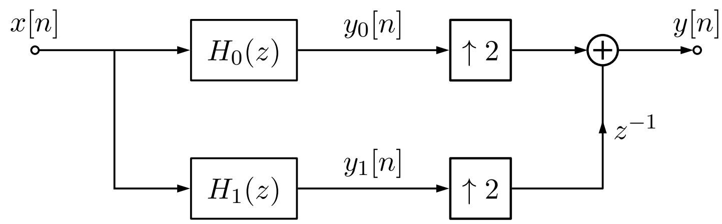
$H_{\text{ap}}(z) =$

3 Interpolation

Consider the system below where $y_0[n]$ and $y_1[n]$ are generated by the difference equations

$$y_0[n] = x[n] - 2x[n-1] + x[n-2]$$
$$y_1[n] = 1.5x[n] + 1.5x[n-1]$$

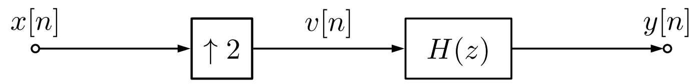
.



(a) Find expressions for $H_0(z)$ and $H_1(z)$.

$H_0(z) =$ $H_1(z) =$

(b) The decimation filter can also be implemented as shown below. Find $H(z)$.



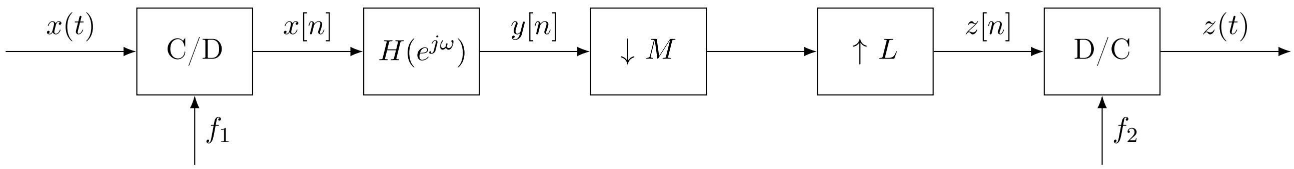
$H(z) =$

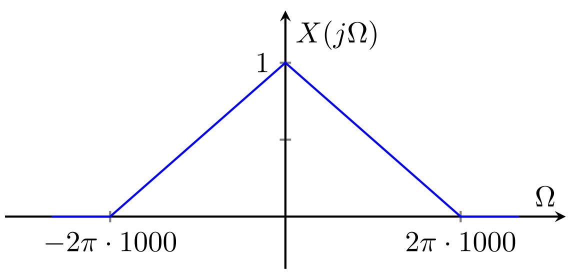
(c) In the implementation above, $y[n] = a_0 v[n] + a_1 v[n-1] + a_2 v[n-2] + a_3 v[n-3] + a_4 v[n-4]$. Find a_k for $k = 0, 1, \ldots, 4$

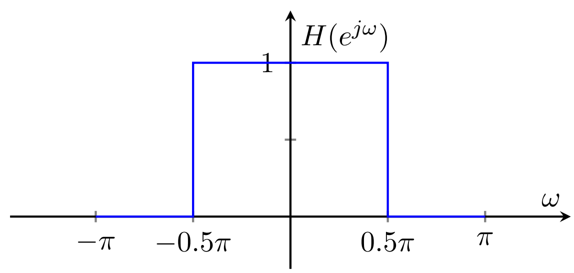
$a_0 =$ $a_1 =$ $a_2 =$ $a_3 =$ $a_4 =$

4 DT processing of CT signals

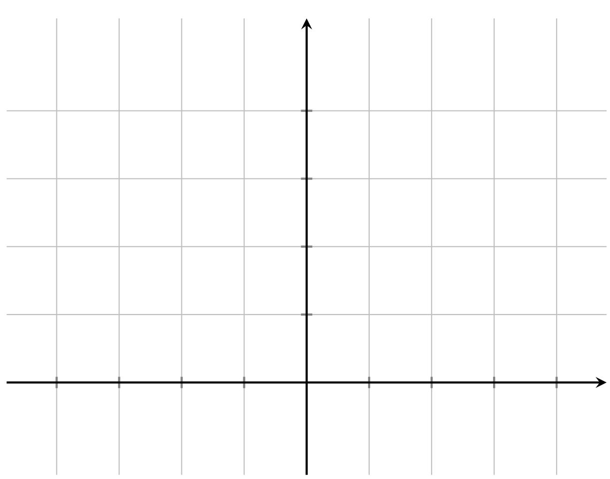
The discrete-time filtering system comprises a C/D converter sampling at rate $f_1 = 2\,\text{kHz}$, a filter with frequency response $H(e^{j\omega})$, a resampler that resamples at a rate of $M : L$ (downsample by M immediately followed by upsample by L with no filtering in between the two operations) and an ideal D/C converter at rate f_2. Ideal means that the D/C converter contains an ideal lowpass reconstruction filter with a bandwidth of f_2 and a gain of $1/f_2$. The spectrum of the input, $X(j\Omega)$, and frequency response, $H(e^{j\omega})$, are shown below.

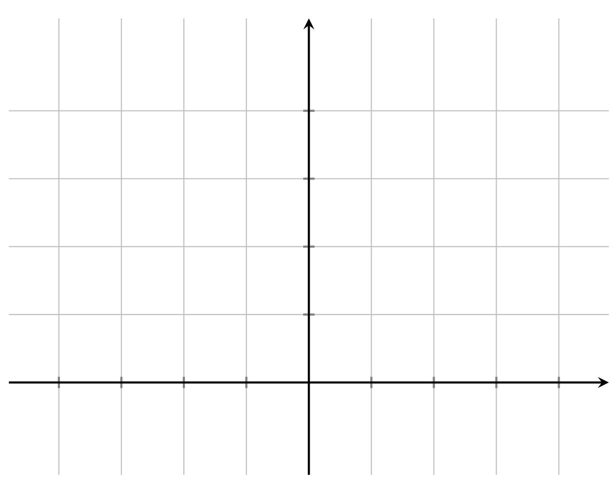




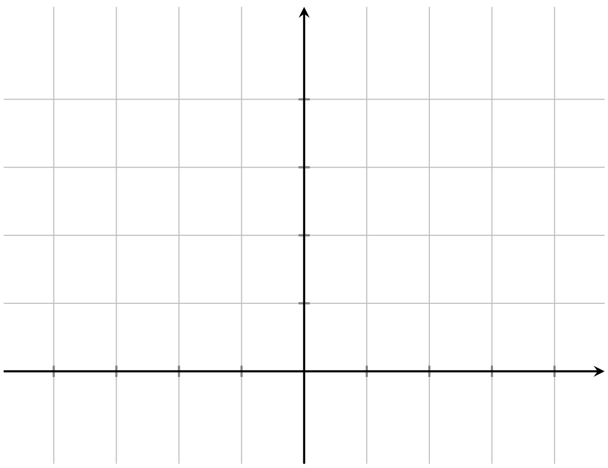
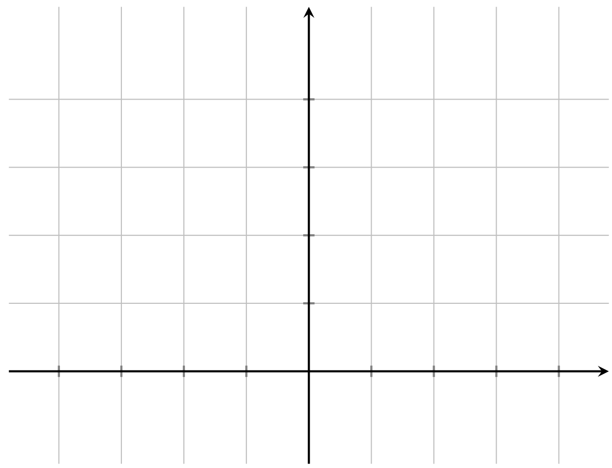


(a) Plot the spectra $X(e^{j\omega})$ and $Y(e^{j\omega})$. Label all axes and relevant features. Plot the DTFTs from $\omega = -\pi$ to π.

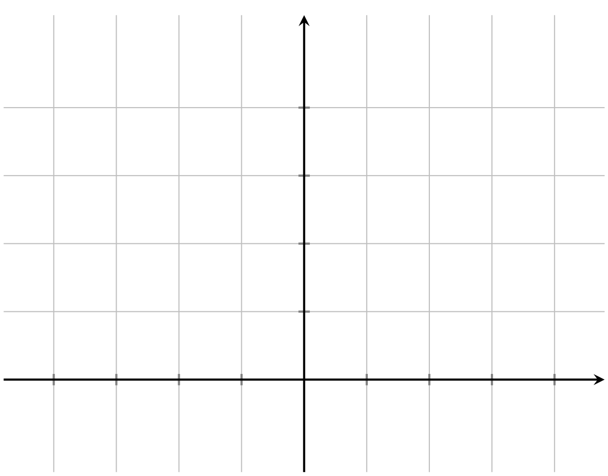
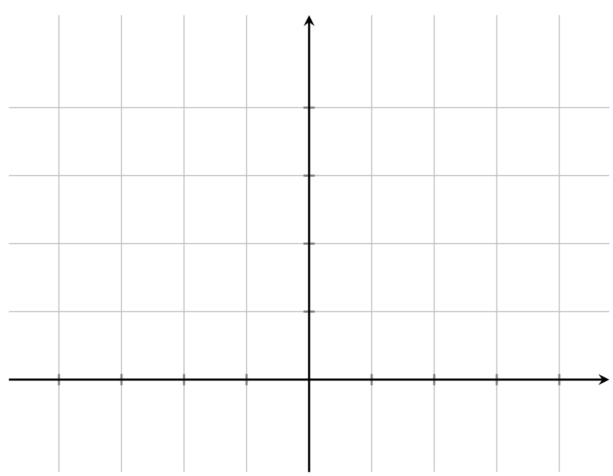




(b) Given $f_2 = 1\,\text{kHz}$, $M = 2$, and $L = 1$, plot the spectra $Z(e^{j\omega})$ and $Z(j\Omega)$. Label all axes and relevant features. Plot the continuous-time Fourier transform such that the entire signal bandwidth is represented. Plot the DTFT from $\omega = -\pi$ to π.

(c) Given $f_2 = 4\,\text{kHz}$, $M = 1$, and $L = 2$, plot the spectra $Z(e^{j\omega})$ and $Z(j\Omega)$. Label all axes and relevant features. Plot the DTFT from $\omega = -\pi$ to π. Plot the continuous-time Fourier transform such that the entire signal bandwidth is represented. Plot the DTFT from $\omega = -\pi$ to π.

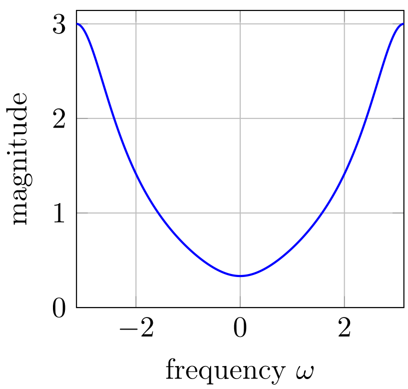
5 Frequency response

For each $H(z)$ in the table below, select the matching magnitude response from the magnitude response plots below. Write the plot ID number (e.g., "M1") next to the matching transfer function. You may use each plot once, more than once, or not at all.

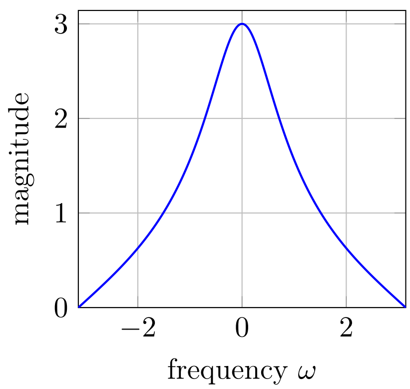
Hint: it might be helpful to check the values of each $H(z)$ at a few select points.

$H(z)$	Magnitude response
$z-2$	
$\frac{3}{2}\frac{1+jz}{z-j}$	
$2\left(z+\frac{1}{2}\right)$	
$\frac{3}{2}\frac{z+1}{2z-1}$	
$\frac{3}{2}(z-1)$	
$z+2$	

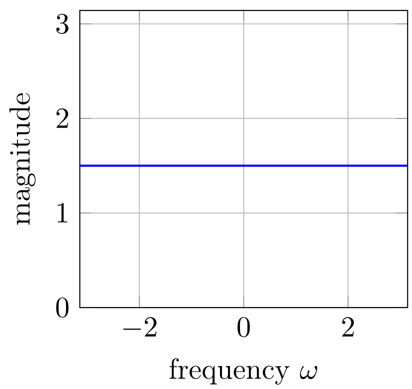
M1



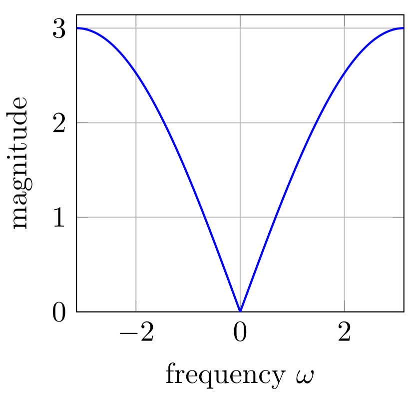
M2



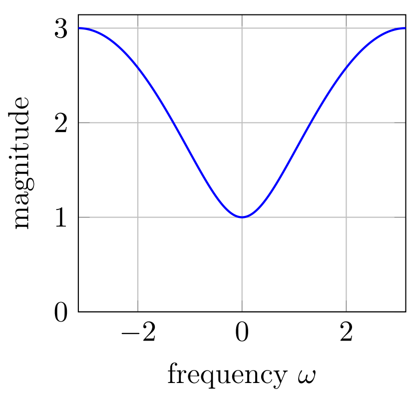
M3



M4



M5



M6