Western Michigan University
Electrical and Computer Engineering Dep
ECE4550/ECE5550-Digital Signal Proce

SPRING 2024

Final Exam

Show all your work! Failure to show your work steps will result in a major loss of your

Due 11 pm on Monday 4/22/2024

Answer all problems as best as you can. Write clearly!

Submit one pdf file for all your work. Number your pages and upload to eLearning dropbox. Image files must be converted to pdf before uploading

Name (last name 1st): ....

This cover sheet must be scanned and used as a cover sheet with your submission

PROBLEM 1 (25)	
PROBLEM 2 (25)	
PROBLEM 3 (30)	
TOTAL (100)	

Make sure to clearly label all axes of all your graph

PROBLEM #1 (25 Points) Filter Design/Analysis (Chapter 5 content)

Design a filter that completely blocks the frequency of $\boldsymbol{\omega_o = \frac{\pi}{3}}$, , by placing its poles and zeros in the z-plane. The designed filter should yield real output, given the input is real. Clearly and show all your work, answer the following:

1) Draw poles and zeros of the filter in the Z-plane, clearly showing magnitude and phase.
2) Write the expression for the transfer function, $H(z)$ associated with the filter you designed per your pole-zero plot. You can use K=1 for a scaling constant.
3) Write an expression for $H(\omega)$, $and\ give\ its\ magnitude\ and\ phase$.
4) Plot the magnitude of $H(\omega)$ (**not the Bode plot**), that is $|H(\omega)|\ versus\ frequency\ \omega$. **You can use any software.**
5) Discuss this filter stability in sight of your choice of its poles and zeros.
6) Determine the output y(n), if the input signal to the filter is given by

$$\boldsymbol{x(n) = 6 + 3\cos\left(\frac{\pi}{3}n\right) + \sin\left(\frac{\pi}{6}n + \frac{\pi}{2}\right) + 2\cos\left(\frac{\pi}{2}n\right) \quad -\infty < n < \infty}$$

7) What type of a filter can this be used for, and why?
8) Based on the filter's type, explain the relation between $y(n)\ and\ x(n)\ in\ part\ 6$.

PROBLEM #2 (25 points) FIR DESIGN USING WINDOWING METHOD

Use the specifications of the following ideal filter to design a BP FIR Filter, answer the following questions:

$$H_{IDEAL}(F) = \begin{cases} 1 & 10 \leq |F| \leq 15 \\ 0 & otherwise \end{cases}$$

With sampleig frequency $\boldsymbol{F_s = 50kHz}$ ***and all given*** $\boldsymbol{F}$ ***values above are in*** $\boldsymbol{kHz}$.

And using,

$$W_{hamming}(n) = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi n}{M}\right) & 0 \leq n \leq M \\ 0 & otherwise \end{cases}$$

1) Sketch the frequency response for the desired filter using your hand drawing.
2) Using the above window, determine the impulse response of FIR filter which approximates this frequency response.
3) Compute *the first 4 coefficients of the impulse response h(n) coefficients*.
4) Use MATLAB to plot both the desired h(n), and the frequency response magnitude and phase of the filter you designed.
5) Comment on the expected performance of the filter you designed, and verify that it holds.
6) Comment on the nature of the filters phase.
7) Discuss how this window would be a better choice over the rectangular window.

PROBLEM #3 (30 Points) IIR Design Methods Using Analog Filters.

Consider the following filter $H(s)$

$$\boxed{H(s) = \frac{1}{s}}$$

Using $Fs = 10Hz$, design an IIR filter using these methods.

- ***Method 1: Impulse Invariant***
- ***Method 2: Bilinear Transformation***

In your design, address these questions

1) Give the model for $H(z)$ *and* $H(\omega)$ for each method.
2) Sketch the magnitude frequency response of $\boldsymbol{H(\Omega)}, \boldsymbol{H_i(\omega)}$ ***of each of the methods listed above.*** You can use any tools.
3) Discuss the performance of both designs in how they approximate the analog filter for certain frequencies, that is discuss filter performance for low range frequencies, and high frequencies in comparison to the analog filter.
4) What type of a filter is this? Explain you answer.
5) Does you answer in part 4 align with the advantages and disadvantages of these two design methods? Keep you answer short and precise statements.
6) Discuss warping effect on $H_2(\omega)$ *if any.*