Full Name: ______________________________

EEL 3135 (Spring 2025) – Lab #08

Question #1: *(Z-transform, Filtering, and Magnitude Response)*

Download `EEL3135_lab08_comment.m` from Canvas, replace each of the corresponding comments with the corresponding descriptions. This is designed to show you how to visualize the IIR filters in the z-domain in MATLAB.

Note: You should run the code to help you understand how it works and help you write your comments. You will use elements of this MATLAB code for the rest of the lab assignment.

Question #2: *(Designing Basic Filters in Z-Domain)*

In this question, you will study filters in z-domain.

(a) For the following transfer function, plot the magnitude response and pole-zero plots for $\omega_a = 0, \pi/2,$ and π with $a = 0.9$

$$H_a(z) = \frac{1}{(1 - ae^{j\omega_a}z^{-1})(1 - ae^{-j\omega_a}z^{-1})}$$

(b) For the following transfer function, plot the magnitude response and pole-zero plots for $\omega_a = 0, \pi/2,$ and π with $b = 1$

$$H_b(z) = (1 - be^{j\omega_b}z^{-1})(1 - be^{-j\omega_b}z^{-1})$$

(c) **Answer in your comments:** State if each filter above is an FIR filter or an IIR filter.

(d) **Answer in your comments:** How does changing ω_0 affect the poles and zeros?

(e) **Answer in your comments:** As ω_0 changes, what kind of filters do $H_a(z)$ and $H_b(z)$ (i.e., when are they a low-pass filter, high-pass filter, band-pass filter, band-stop (or notch) filter, all-pass filter, or none-of-the-above as ω changes?)

Question #3: *(IIR Filters in Z-Domain)*

In this problem, we will use this concept to design several different types of IIR filters. For each filter, consider the signal x defined in the skeleton code. We will also refer to the two filters defined in Question #2.

In this problem, we will extensively use the cascading simple filters, for example,

$$H(z) = H_0(z)H_1(z)\cdots H_{M-1}(z)$$

or equivalently in time

$$x[n] = x_0[n] * x_1[n] * \ldots * x_{M-1}[n]\ .$$

As you will see, cascading is a powerful tool to make complex filters from simple filters.

(a) *(Filter 1)* Apply the input signal `x` to a cascade of four filters:
- $H_b(z)$ with $b = 1/0.999$ and $\omega_a = 5\pi/8$
- $H_a(z)$ with $a = 0.999$ and $\omega_b = 5\pi/8$
- $H_b(z)$ with $b = 1/0.999$ and $\omega_a = 6\pi/8$
- $H_a(z)$ with $a = 0.999$ and $\omega_b = 6\pi/8$

Plot the time-domain input and output. Plot the magnitude of the DTFT before and after applying the filter and plot the plot-zero plot for the filter. You may also want to listen to the output using `soundsc` with a sampling rate of 2000.

(b) **Answer in your comments:** Is the filter an all-pass, low-pass, high-pass, or none-of-the-above? How does the filter change the signal?

(c) *(Filter 2)* Apply the input signal `x` to a cascade of seven filters:
- $H_a(z)$ with $a = 0.8$ and $\omega_a = \pi/2$
- $H_b(z)$ with $b = 1$ and $\omega_b = 0$
- $H_b(z)$ with $b = 1$ and $\omega_b = \pi/4$
- $H_b(z)$ with $b = 1$ and $\omega_b = 3\pi/8$
- $H_b(z)$ with $b = 1$ and $\omega_b = 5\pi/8$
- $H_b(z)$ with $b = 1$ and $\omega_b = 6\pi/8$
- $H_b(z)$ with $b = 1$ and $\omega_b = pi$

Plot the time-domain input and output and plot the magnitude of the DTFT before and after applying the filter and plot the plot-zero plot for the filter.. You may also want to listen to the output using `soundsc` with a sampling rate of 2000.

(d) **Answer in your comments:** Is the filter an all-pass, low-pass, high-pass, or none-of-the-above? What role does the $H_a(z)$ filter play (hint: what changes if these are not included)?

(e) *(Filter 3)* Apply the input signal `x` to a cascade of three filters:
- $H_b(z)$ with $b = 1$ and $\omega_b = \pi$
- $H_a(z)$ with $a = 0.66$ and $\omega_a = \pi/8$
- $H_a(z)$ with $a = 0.66$ and $\omega_a = \pi/8$

Plot the time-domain input and output and plot the magnitude of the DTFT before and after applying the filter and plot the plot-zero plot for the filter.. You may also want to listen to the output using `soundsc` with a sampling rate of 2000.

(f) **Answer in your comments:** Is the filter an all-pass, low-pass, high-pass, or none-of-the-above?

(g) *(Notch filter)* In the previous Lab 6, we designed a simple FIR notch filter. However, We can do better with an IIR filter. Apply the input signal `x` to a cascade of two filters:
- $H_b(z)$ with $b = 1$ and $\omega_b = \pi/4$
- $H_a(z)$ with $a = 0.95$ and $\omega_a = \pi/4$

Plot the time-domain input and output and plot the magnitude of the DTFT before and after applying the filter and plot the plot-zero plot for the filter.. You may also want to listen to the output using `soundsc` with a sampling rate of 2000.

(h) Return back to `noisy2.wav` from Lab 6 (although little different), design your improved cascade of notch filters to remove the noisy frequencies. **Submit the output as a .wav file along with your PDF.**

(i) **Answer in your comments:** What is the difference between the results from Lab 6 and these new results?