<u>EEEE678</u> DIGITAL SIGNAL PROCESSING

MATLAB project #1

1. Consider the system function given by equation 5.15 in section 5.1.2 (page 278) of the Oppenheim and Schafer text. There appears to be a scaling problem with the gain and I needed to adjust the overall gain by a factor of 3.0955 in order to get the same plots as the book (I think the text has made a slight mistake in calculating the gain):

$$H(z) = \frac{1}{3.0955}\left(\frac{\left(1-.98e^{j.8\pi}z^{-1}\right)\left(1-.98e^{-j.8\pi}z^{-1}\right)}{\left(1-.8e^{j.4\pi}z^{-1}\right)\left(1-.8e^{-j.4\pi}z^{-1}\right)}\right)\prod_{k=1}^{4}\left(\frac{\left(c_k^*-z^{-1}\right)\left(c_k-z^{-1}\right)}{\left(1-c_k z^{-1}\right)\left(1-c_k^* z^{-1}\right)}\right)^2$$

where, $c_k = 0.95e^{j(.15\pi+.02\pi k)}$, for k = 1, 2, 3, 4. Consider the input $x[n]$, as defined in equations 5.16 through 5.18 of the text:

$$x[n] = x_3[n] + x_1[n-M-1] + x_2[n-2M-2]$$

$$x_1[n] = w[n]\cos(0.2\pi n),$$

$$x_2[n] = w[n]\cos(0.4\pi n - \pi/2),$$

$$x_3[n] = w[n]\cos(0.8\pi n + \pi/5),$$

$$w[n] = \begin{cases} 0.54 - 0.46\cos\left(\dfrac{2\pi n}{M}\right), & 0 \le n \le M, \\ 0. & \text{otherwise} \end{cases}$$

We wish to reproduce the results depicted in Figures 5.2 through 5.6 of section 5.1.2 to gain insight into the concepts of frequency response and group delay.

a. Plot the pole-zero diagram for the filter (Figure 5.2 of text).

b. Plot both the Principle value of the phase, ARG[$H(e^{j\omega})$], and the continuous phase, arg[$H(e^{j\omega})$], for the filter (Figure 5.3).

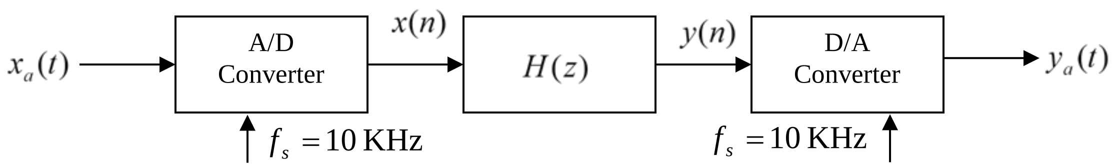
c. Plot the Group delay function, grd[$H(e^{j\omega})$], and the magnitude of the frequency response, $|H(e^{j\omega})|$ (Figure 5.4).

d. Plot the input signal, $x[n]$, and the magnitude of its corresponding DTFT, $|X(e^{j\omega})|$ (Figure 5.5).

e. Calculate and plot the output signal, $y[n]$ (Figure 5.6).

f. As suggested in the text, in order to gain a better understanding of the frequency response and group delay, experiment with several variations to the input signal such as increasing or decreasing the window length, or changing the frequencies of the input sinusoids. In each case, try to first predict what would happen to the output and then verify your prediction by calculating the actual output. Briefly report on at least one such experiment.

2. Consider the system shown below,



where , $$H(z) = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2} + \cdots + b_{M-1} z^{-M+1}}{1 + a_1 z^{-1} + a_2 z^{-2} + \cdots + a_{N-1} z^{-N+1}} \qquad N = M = 15$$

$$\begin{aligned}
a_1 &= -6.6814 \\
a_2 &= 21.8365 \\
a_3 &= -45.7544 \\
a_4 &= 68.2005 \\
a_5 &= -76.1361 \\
a_6 &= 65.4106 \\
a_7 &= -43.8106 \\
a_8 &= 22.9357 \\
a_9 &= -9.3222 \\
a_{10} &= 2.8911 \\
a_{11} &= -0.6625 \\
a_{12} &= 0.1059 \\
a_{13} &= -0.0106 \\
a_{14} &= 0.0005
\end{aligned}$$

$$b_i = G \frac{(N-1)!}{i!(N-1-i)!}, \quad i = 0, 1, \cdots, N-1$$

$$G = 1.91486834935659 \times 10^{-7}$$

a) Is filter $H(z)$ stable?

b) Plot $|H(j2\pi f)|$ as a function frequency over the frequency range of 0 to 5 KHz.

c) Find the 3-dB cutoff frequency of the filter.

d) Find the output signal $y_a(t)$ if the input signal is

$$x_a(t) = 1 + \cos(2\pi \times 10^3 t) + \cos(6\pi \times 10^3 t)$$

e) Find the ratio of the output signal power to the input signal power.