ECE 306L - DIGITAL FILTERS - LAB 8
SIMPLE NONRECURSIVE DIGITAL FILTERS

SPRING 2007 **FELZER/KANG**

OBJECTIVE

The objective of this lab is to use Simulink to obtain the frequency responses of some simple nonrecursive digital filters.

PRELAB

1. Given the following 1st order nonrecursive digital filter with difference equation

$$y[n] = x[n] + x[n-1]$$

   a. Find $H(z) = \dfrac{Y(z)}{X(z)}$
   b. Find the poles and zeroes
   c. Sketch the pole-zero diagram
   d. How are the locations of the poles of recursive difference equations different from those of nonrecursive difference equations
   e. Make use of the pole-zero diagram in part (b) to sketch the frequency response for $-f_s/2 \le f \le f_s/2$ when $f_s = 10^4$ samples/sec
   f. Is this filter lowpass, highpass or bandpass. How can you tell
   g. Find the frequency response

$$H\left(e^{j2\pi f/f_s}\right) = H(z)\big|_{z=e^{j2\pi f/f_s}}$$

   h. Use $H\left(e^{j2\pi f/f_s}\right)$ to obtain an equation for the sinusoidal steady state response $y[n]$ when $x(t) = 5\cos(2\pi 2000t)$ sampled at $f_s = 10^4$ samples/sec
   i. Use Matlab to obtain a full graph of the magnitude of the frequency response as follows

$$\left|H\left(e^{j2\pi f/f_s}\right)\right| \quad \text{for} \quad -f_s/2 \le f \le f_s/2$$

   for $f_s = 10^4$ samples/sec
   j. Verify that your results in parts (e) and (i) are the same
   k. Draw a Simulink block diagram for realizing the difference equation for when $x[n]$ is a sinusoid

2. Given a 7th order nonrecursive digital filter with the following zeros

$$z = \frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}} \qquad z = \pm j \qquad z = -\frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}} \qquad z = -1$$

   a. Find the transfer function $H(z)$
   b. Sketch the pole-zero diagram
   c. Make use of the pole-zero diagram to sketch the frequency response for $-f_s/2 \le f \le f_s/2$ when $f_s = 10^4$ samples/sec
   d. Is this filter lowpass, highpass or bandpass. How can you tell
   e. Find the frequency response $H\left(e^{j2\pi f/f_s}\right)$

f. Find the value of b_o so that the gain is equal to one when $f = 0$

g. Use $H\left(e^{j2\pi f/f_s}\right)$ from part (f) to obtain an equation for the sinusoidal steady state response $y[n]$ when $x(t) = 5\cos(2\pi 2000t)$ sampled at $f_s = 10^4$ samples/sec

h. Use Matlab to obtain a full page graph of the magnitude of the frequency response from part (f) as follows

$$\left|H\left(e^{j2\pi f/f_s}\right)\right| \quad \text{for} \quad -f_s/2 \le f \le f_s/2$$

i. Verify that your results in parts (c) and (h) are the same

j. Find the difference equation for this digital filter

k. Draw a Simulink block diagram for realizing the difference equation for $y[n]$ when $x[n]$ is a sinusoid

3. Repeat Problem (2) for the 7th order nonrecursive digital filter with zeroes

$$z = \frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}} \qquad z = \pm j \qquad z = -\frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}} \qquad z = 1$$

Find the value of b_o so that the gain is equal to one when $f = f_s/2$

4. Repeat Problem (2) for the 6th order nonrecursive digital filter with zeroes

$$z = \frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}} \qquad z = -\frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}} \qquad z = \pm 1$$

Find the value of b_o so that the gain is equal to one when $f = f_s/4$

LAB

1. For the difference equation from Problem (1) as follows

$$y[n] = x[n] + x[n-1]$$

with $f_s = 10^4$ samples/sec

a. Use Simulink to obtain the sinusoidal steady state responses at ten representative frequencies. Make at least three screen captures at low, medium and high frequencies

b. Use your Simulink results to calculate $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ for each of your sinusoids

c. Put your values of $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ on your Matlab graph from the prelab

2. For the digital filter of Problem (2) with $f_s = 10^4$ samples/sec

a. Use Simulink to obtain the sinusoidal steady state responses at ten representative frequencies. Put the outputs of your digital filter through an analog lowpass filter to obtain the corresponding sinusoids $y(t)$. Make screen captures that include low, medium and high frequencies

b. Use your Simulink results to calculate $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ for each of your sinusoids

c. Put your values of $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ on your Matlab graph from the prelab

3. For the digital filter of Problem (3) with $f_s = 10^4$ samples/sec
    a. Use Simulink to obtain the sinusoidal steady state responses at ten representative frequencies. Put the outputs of your digital filter through an analog lowpass filter to obtain the corresponding sinusoids $y(t)$. Make screen captures that include low, medium and high frequencies
    b. Use your Simulink results to calculate $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ for each of your sinusoids
    c. Put your values of $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ on your Matlab graph from the prelab

4. For the digital filter of Problem (4) with $f_s = 10^4$ samples/sec
    a. Use Simulink to obtain the sinusoidal steady state responses at ten representative frequencies. Put the outputs of your digital filter through an analog lowpass filter to obtain the corresponding sinusoids $y(t)$. Make screen captures that include low, medium and high frequencies
    b. Use your Simulink results to calculate $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ for each of your sinusoids
    c. Put your values of $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ on your Matlab graph from the prelab

POSTLAB

1. Compare your Matlab and Simulink results for $\left|H\left(e^{j2\pi f/f_s}\right)\right|$ for each of the four filters

2. Why are the orders of nonrecursive digital filters higher than the orders of recursive digital filters that meet the same frequency spec