

Figure 10.1: Rectangular Window for Lowpass Filter

w = 0:pi/100:pi/6; %bounds of the original filter

W = pi/6; %max frequency

n = 0:1:24; %number of samples

N = 25; % also the number of samples

subplot(3,1,1);

hd = ideal\_lp(W,N);%generates the ideal lowpass filter in time domain

plot(hd);%plots the ideal response of the filter in time from 0-24

title('Ideal Response for Lowpass Filter');

xlabel('n');

ylabel('hd(n)');

subplot(3,1,2);

wn = round(heaviside(n)); %rectangular window can be modeled as amplitude 1

h = hd.\*wn; %calculates the actual response of the filter using the window

plot(h); % plots the actual response of the fitler

title('Actual Lowpass Response for Rectangular Window');

xlabel('n');

ylabel('h(n)');

subplot(3,1,3);

f = [0 1/6 1/6 1];

m = [1 1 0 0];

b1 = fir2(25,f,m, rectwin(26)); %calculates the ideal lowpass filter

[db,mag,pha,grd,w] = freqz\_m(b1,1); %finds the frequency response of the filter

plot(w/pi,db)

xlabel('\omega / \pi');

title('Frequency Response for Rectangular Window');

ylabel('|H(w)|dB');



Figure 10.2: Hanning Window for Lowpass Filter

w = 0:pi/100:pi/6; %bounds of the original filter

W = pi/6; %max frequecy

n = 0:1:24; %number of samples

N = 25; % also the number of samples

subplot(3,1,1);

hd = ideal\_lp(W,N);%generates the ideal lowpass filter in time domain

plot(hd);%plots the ideal response of the filter

title('Ideal Response for Lowpass Filter');

xlabel('n');

ylabel('hd(n)');

subplot(3,1,2);

wn = 0.5\*(1-cos((2\*pi\*n)/(N-1))); %hanning method approx from book

h = hd.\*wn; %calculates the actual response of the filter using the window

plot(h); % plots the actual response of the fitler

title('Actual Lowpass Response for Hanning Window');

xlabel('n');

ylabel('h(n)');

subplot(3,1,3);

f = [0 1/6 1/6 1];

m = [1 1 0 0];

b1 = fir2(25,f,m, hann(26)); %calculates the ideal lowpass filter

[db,mag,pha,grd,w] = freqz\_m(b1,1); %finds the frequency response of the filter

plot(w/pi,db)

xlabel('\omega / \pi');

title('Frequency Response for Hanning Window');

ylabel('|H(w)|dB');



Figure 10.3: Hamming Window for Lowpass Filter

w = 0:pi/100:pi/6; %bounds of the original filter

W = pi/6; %max frequecy

n = 0:1:24; %number of samples

N = 25; % also the number of samples

subplot(3,1,1);

hd = ideal\_lp(W,N);%generates the ideal lowpass filter in time domain

plot(hd);%plots the ideal response of the filter

title('Ideal Response for Lowpass Filter');

xlabel('n');

ylabel('hd(n)');

subplot(3,1,2);

wn = 0.54 - 0.46\*cos((2\*pi\*n)/(N-1)); %hamming method approx from book

h = hd.\*wn; %calculates the actual response of the filter using the window

plot(h); % plots the actual response of the fitler

title('Actual Lowpass Response for Hamming Window');

xlabel('n');

ylabel('h(n)');

subplot(3,1,3);

f = [0 1/6 1/6 1];

m = [1 1 0 0];

b1 = fir2(25,f,m, hamming(26)); %calculates the ideal lowpass filter

[db,mag,pha,grd,w] = freqz\_m(b1,1); %finds the frequency response of the filter

plot(w/pi,db)

xlabel('\omega / \pi');

title('Frequency Response for Hamming Window');

ylabel('|H(w)|dB');



Figure 10.4: Bartlett Window for Lowpass Filter

w = 0:pi/100:pi/6; %bounds of the original filter

W = pi/6; %max frequecy

n = 0:1:24; %number of samples

N = 25; % also the number of samples

subplot(3,1,1);

hd = ideal\_lp(W,N);%generates the ideal lowpass filter in time domain

plot(hd);%plots the ideal response of the filter

title('Ideal Response for Lowpass Filter');

xlabel('n');

ylabel('hd(n)');

subplot(3,1,2);

wn = 1-((2\*abs(n-((N-1)/2)))/(N-1)); %Bartlett method approx from book

h = hd.\*wn; %calculates the actual response of the filter using the window

plot(h); % plots the actual response of the fitler

title('Actual Lowpass Response for Bartlett Window');

xlabel('n');

ylabel('h(n)');

subplot(3,1,3);

f = [0 1/6 1/6 1];

m = [1 1 0 0];

b1 = fir2(25,f,m, bartlett(26)); %calculates the ideal lowpass filter

[db,mag,pha,grd,w] = freqz\_m(b1,1); %finds the frequency response of the filter

plot(w/pi,db)

xlabel('\omega / \pi');

title('Frequency Response for Bartlett Window');

ylabel('|H(w)|dB');



Figure 10.5: Blackman Window for Lowpass Filter

w = 0:pi/100:pi/6; %bounds of the original filter

W = pi/6; %max frequecy

n = 0:1:24; %number of samples

N = 25; % also the number of samples

subplot(3,1,1);

hd = ideal\_lp(W,N);%generates the ideal lowpass filter in time domain

plot(hd);%plots the ideal response of the filter

title('Ideal Response for Lowpass Filter');

xlabel('n');

ylabel('hd(n)');

subplot(3,1,2);

wn = 0.42 - 0.5\*cos((2\*pi\*n)/(N-1)) + 0.08\*cos((4\*pi\*n)/(N-1)); %Blackman method approx from book

h = hd.\*wn; %calculates the actual response of the filter using the window

plot(h); % plots the actual response of the fitler

title('Actual Lowpass Response for Blackman Window');

xlabel('n');

ylabel('h(n)');

subplot(3,1,3);

f = [0 1/6 1/6 1];

m = [1 1 0 0];

b1 = fir2(25,f,m, blackman(26)); %calculates the ideal lowpass filter

[db,mag,pha,grd,w] = freqz\_m(b1,1); %finds the frequency response of the filter

plot(w/pi,db)

xlabel('\omega / \pi');

title('Frequency Response for Blackman Window');

ylabel('|H(w)|dB');



Figure 10.6: Rectangular Window for BandStop Filter

f = [0 1/6 1/6 1/3 1/3 1];

m = [1 1 0 0 1 1];

b1 = fir2(25,f,m, rectwin(27)); %calculates the ideal bandstop filter

subplot(3,1,1);

plot(b1);%plots the ideal band stop filter

title('Ideal Response for Bandstop Filter');

xlabel('n');

ylabel('hd(n)');

b2 = fir2(25,f,m, rectwin(27));%calculates the bandstop with rectangular window

subplot(3,1,2);

plot(b2);%plots the windowed filter

title('Actual Response for Rectangular Window');

xlabel('n');

ylabel('h(n)');

[db,mag,pha,grd,w] = freqz\_m(b2,1); %finds the frequency response of the filter

subplot(3,1,3);

plot(w/pi,db);

title('Frequency Response for Rectangular Window');

xlabel('\omega / \pi');

ylabel('|H(w)|dB');



Figure 10.7: Hanning Window for BandStop Filter

f = [0 1/6 1/6 1/3 1/3 1];

m = [1 1 0 0 1 1];

b1 = fir2(25,f,m, rectwin(27)); %calculates the ideal bandstop filter

subplot(3,1,1);

plot(b1); %plots the ideal band stop filter

title('Ideal Response for Bandstop Filter');

xlabel('n');

ylabel('hd(n)');

b2 = fir2(25,f,m, hann(27)); %calculates the bandstop with hanning window

subplot(3,1,2);

plot(b2); %plots the windowed filter

title('Actual Response for Hanning Window');

xlabel('n');

ylabel('h(n)');

[db,mag,pha,grd,w] = freqz\_m(b2,1); %finds the frequency response of the filter

subplot(3,1,3);

plot(w/pi,db);

title('Frequency Response for Hanning Window');

xlabel('\omega / \pi');

ylabel('|H(w)|dB');

 Figure 10.8: Hamming Window for BandStop Filter

f = [0 1/6 1/6 1/3 1/3 1];

m = [1 1 0 0 1 1];

b1 = fir2(25,f,m, rectwin(27)); %calculates the ideal bandstop filter

subplot(3,1,1);

plot(b1); %plots the ideal band stop filter

title('Ideal Response for Bandstop Filter');

xlabel('n');

ylabel('hd(n)');

b2 = fir2(25,f,m, hamming(27)); %calculates the bandstop with hamming window

subplot(3,1,2);

plot(b2); %plots the windowed filter

title('Actual Response for Hamming Window');

xlabel('n');

ylabel('h(n)');

[db,mag,pha,grd,w] = freqz\_m(b2,1); %finds the frequency response of the filter

subplot(3,1,3);

plot(w/pi,db);

title('Frequency Response for Hamming Window');

xlabel('\omega / \pi');

ylabel('|H(w)|dB');



Figure 10.9: Bartlett Window for BandStop Filter

f = [0 1/6 1/6 1/3 1/3 1];

m = [1 1 0 0 1 1];

b1 = fir2(25,f,m, rectwin(27)); %calculates the ideal bandstop filter

subplot(3,1,1);

plot(b1); %plots the ideal band stop filter

title('Ideal Response for Bandstop Filter');

xlabel('n');

ylabel('hd(n)');

b2 = fir2(25,f,m, bartlett(27)); %calculates the bandstop with bartlett window

subplot(3,1,2);

plot(b2); %plots the windowed filter

title('Actual Response for Bartlett Window');

xlabel('n');

ylabel('h(n)');

[db,mag,pha,grd,w] = freqz\_m(b2,1); %finds the frequency response of the filter

subplot(3,1,3);

plot(w/pi,db);

title('Frequency Response for Bartlett Window');

xlabel('\omega / \pi');

ylabel('|H(w)|dB');



Figure 10.10: Blackman Window for BandStop Filter

f = [0 1/6 1/6 1/3 1/3 1];

m = [1 1 0 0 1 1];

b1 = fir2(25,f,m, rectwin(27)); %calculates the ideal bandstop filter

subplot(3,1,1);

plot(b1); %plots the ideal band stop filter

title('Ideal Response for Bandstop Filter');

xlabel('n');

ylabel('hd(n)');

b2 = fir2(25,f,m, blackman(27)); %calculates the bandstop with blackman window

subplot(3,1,2);

plot(b2); %plots the windowed filter

title('Actual Response for Blackman Window');

xlabel('n');

ylabel('h(n)');

[db,mag,pha,grd,w] = freqz\_m(b2,1); %finds the frequency response of the filter

subplot(3,1,3);

plot(w/pi,db);

title('Frequency Response for Blackman Window');

xlabel('\omega / \pi');

ylabel('|H(w)|dB');

**i. Compare the five FIR filters in Problems 10.1 and 10.3 as follows. Which magnitude**

**response has the smallest width of the main lobe? Which has the smallest transition**

**bandwidth? Which has the smallest side lobes? Use your plots and the material in the**

**textbook to support your conclusions. Refer to the pages/tables/figures in the book and**

**your plots by number.**

The magnitude response for the rectangular window has the smallest width of the main lobe because the rectangular window is the same as the ideal response. The magnitude response for the rectangular window has the smallest transition bandwidth this is also because the rectangular window is ideal. The magnitude response for the Blackman window has the smallest side lobes. See Figure 10.5. Table 10.2 on page 668 suggests that Blackman would produce the smallest side lobes along with the example plots given on pages 667 and 670 in the book.

**ii. Suppose you had to choose one actual filter (from all lowpass FIR filters that you have**

**generated) that approximates well the ideal lowpass frequency response (in Problem**

**10.1). Which filter would you choose? Give short justification of your choice.**

Besides the obvious rectangular which is the ideal filter, the actual filter that best approximates the ideal lowpass frequency response is the Hanning. This is seen by looking at the frequency responses of the Hanning and rectangular windowed lowpass filters. The Hanning’s magnitude in the spectrum most closely models the ideal filter as seen in Figures 10.1 and 10.2.

**iii. Discuss briefly the characteristics of the stopband FIR filters in Problems 10.2 and 10.4. In particular, address the width of the transition region (from passband to stopband) and the stopband attenuation qualitatively. Discuss whether these filters provide good approximation to the ideal stopband frequency response in problem 10.2. Which parameter in the filter design would you change to improve this approximation? Explain and justify your answer by referring to the pages/tables/figures in the book.**

Rectangular:

The width of the transition band is narrow. The stopband attenuation is narrow and severe. This is shown in Figure 10.6 where the half power point in the signal happens very abruptly. It accurately cuts off the frequencies within the given range pi/6 to pi/3.

Hanning:

The width of the transition band is wider than the ideal frequency response transition band as the signal takes longer to get to the half power point so more of the signal gets through. The stopband attenuation is wider than the ideal frequency response stopband with a less severe attenuation, thus letting some of the signal through due to the gain being greater than the ideal response. In comparison with the other window techniques, the Hanning method has a similar wide transition band, but the gain of the frequency response is lowest, so less of the signal will get through.

Hamming:

The width of the transition band is wider than the ideal frequency response transition band as the signal takes longer to get to the half power point so more of the signal gets through. The stopband attenuation is wider than the ideal frequency response stopband with a less severe attenuation, thus letting some of the signal through due to the gain being greater than the ideal response.

Bartlett:

The width of the transition band is wider than the ideal frequency response transition band as the signal takes longer to get to the half power point so more of the signal gets through. The stopband attenuation is wider than the ideal frequency response stopband with a less severe attenuation, thus letting some of the signal through due to the gain being greater than the ideal response.

Blackman:

The width of the transition band is wider than the ideal frequency response transition band as the signal takes longer to get to the half power point so more of the signal gets through. The stopband attenuation is wider than the ideal frequency response stopband with a less severe attenuation, thus letting some of the signal through due to the gain being greater than the ideal response.

For the Hamming, Bartlett, and Blackman window methods, they all seem to have similar wide transition widths in terms of frequency response and these three specifically have very similar gain values at around -13dB.

None of the windows (excluding rectangular) provide a good approximation to the ideal stopband frequency response. To improve the approximation, the length of the window should be increased to provide a larger filter. Evidence of the increase in window size adding to the accuracy of the filter can be seen on pg. 668 in the book, especially Table 10.2 on that page which shows the relation of transition width in the main lobe to gain due to the window size.