De La Salle University

Electronics and Computer Engineering Department

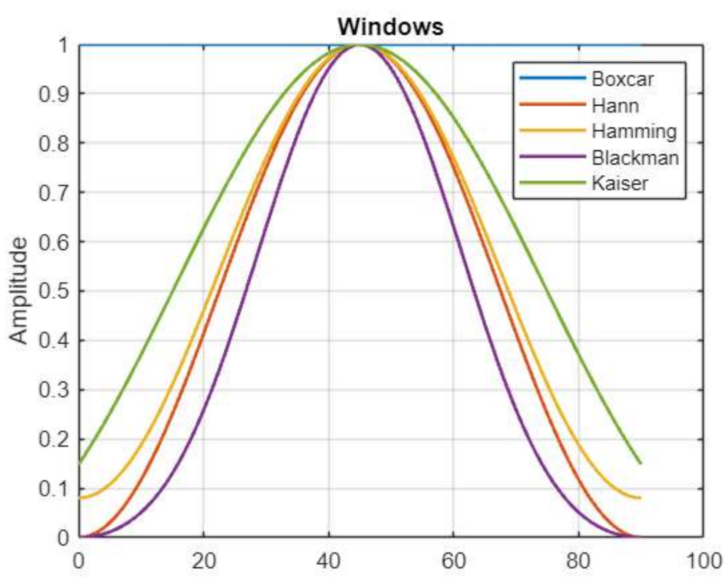
Course : LBYEC4A/LBYCPA4 SECTION : Submitted by : Jared Ong Submitted to : Dr. Edwin Sybingco

Exercise 4 : FIR Filter Note: Check the instructions given in canvas

Task 1

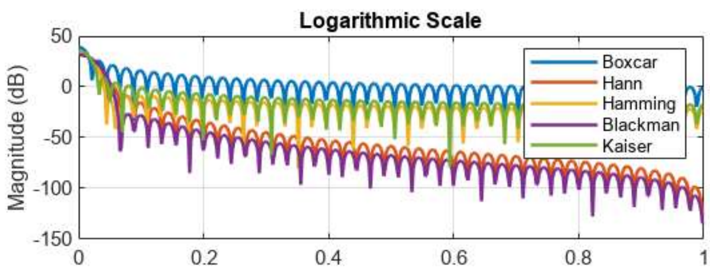
Specify the order of the window

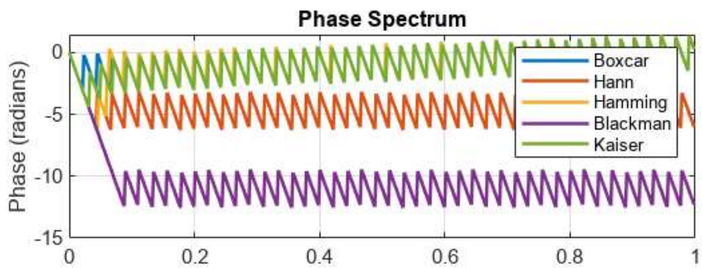
```
M=90;
% Generate the time index
n=0:M;

% Place your code here to generate w
w = zeros(M+1,5);
w(:,1) = rectwin(M+1);
w(:,2) = hann(M+1);
w(:,3) = hamming(M+1);
w(:,4) = blackman(M+1);
w(:,5) = kaiser(M+1, 3.3953);

% Place your code here to calculate W
W = zeros(512,5);
[W(:,1), omega] = freqz(w(:,1), 1, 512);
for k = 2:5
    W(:,k) = freqz(w(:,k), 1, omega);
end

% Place your code here to create the visualization of figure 1
figure(1);
plot(n, w(:,1), n, w(:,2), n, w(:,3), n, w(:,4), n, w(:,5), 'LineWidth', 1.5);
legend('Boxcar', 'Hann', 'Hamming', 'Blackman', 'Kaiser');

ylabel('Amplitude');
title('Windows');
grid on;
```




```
% Place your code here to create the visualization of figure 2
figure(2);
subplot(2,1,1);
plot(omega/pi, 20*log10(abs(W(:,1)) + eps), ...
     omega/pi, 20*log10(abs(W(:,2)) + eps), ...
     omega/pi, 20*log10(abs(W(:,3)) + eps), ...
     omega/pi, 20*log10(abs(W(:,4)) + eps), ...
     omega/pi, 20*log10(abs(W(:,5)) + eps), 'LineWidth', 1.5);
legend('Boxcar', 'Hann', 'Hamming', 'Blackman', 'Kaiser');

ylabel('Magnitude (dB)');
```

```
title('Logarithmic Scale');
grid on;

subplot(2,1,2);
plot(omega/pi, unwrap(angle(W(:,1))), ...
     omega/pi, unwrap(angle(W(:,2))), ...
     omega/pi, unwrap(angle(W(:,3))), ...
     omega/pi, unwrap(angle(W(:,4))), ...
     omega/pi, unwrap(angle(W(:,5))), 'LineWidth', 1.5);
legend('Boxcar', 'Hann', 'Hamming', 'Blackman', 'Kaiser');

ylabel('Phase (radians)');
title('Phase Spectrum');
grid on;
```

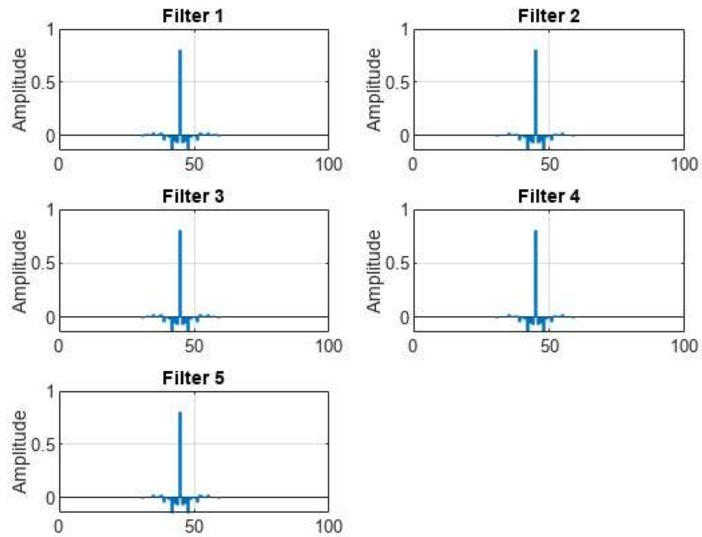




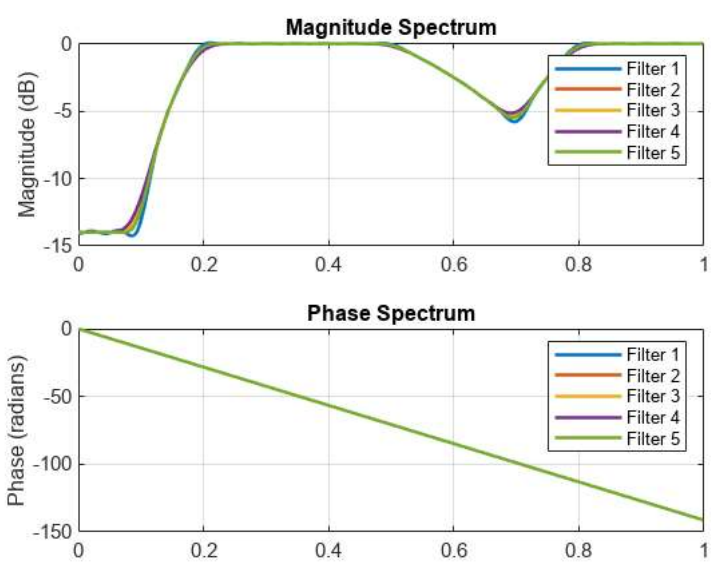
Task 2

specify the parameters of the function fir2 based on the given specifications

```
F = [0, 0.1, 0.2, 0.5, 0.7, 0.8, 1];
A = [0.2, 0.2, 1, 1, 0.5, 1, 1];

% Place your code here to design the five filters and store it in matrix b1
b1 = zeros(5, M+1);
for k = 1:5
    b1(k,:) = fir2(M, F, A, w(:,k));
end

% Place your code here to determine the half frequency frequency representation of the five filters with 512 frequency points. Store the r
H1 = zeros(512,5);
[H1(:,1), omega] = freqz(b1(1,:), 1, 512);
for k = 2:5
    H1(:,k) = freqz(b1(k,:), 1, omega);
end

% Place your code here to create the visualization of figure 3
figure(3);
for k = 1:5
    subplot(3,2,k);
    stem(0:M, b1(k,:), 'Marker', 'none', 'LineWidth', 1.5);
    title(['Filter ', num2str(k)]);

    ylabel('Amplitude');
    grid on;
end
```



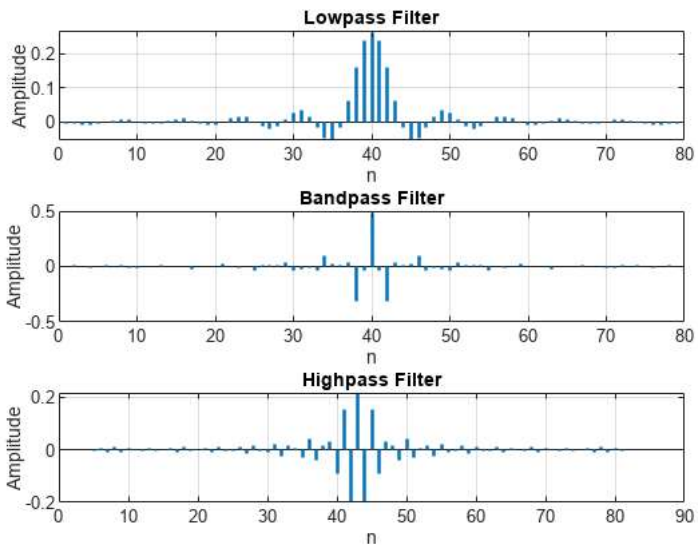

```
% Place your code here to create the visualization of figure 4
figure(4);
subplot(2,1,1);
plot(omega/pi, 20*log10(abs(H1(:,1)) + eps), ...
     omega/pi, 20*log10(abs(H1(:,2)) + eps), ...
     omega/pi, 20*log10(abs(H1(:,3)) + eps), ...
     omega/pi, 20*log10(abs(H1(:,4)) + eps), ...
     omega/pi, 20*log10(abs(H1(:,5)) + eps), 'LineWidth', 1.5);
legend('Filter 1', 'Filter 2', 'Filter 3', 'Filter 4', 'Filter 5');

ylabel('Magnitude (dB)');
title('Magnitude Spectrum');
grid on;

subplot(2,1,2);
plot(omega/pi, unwrap(angle(H1(:,1))), ...
     omega/pi, unwrap(angle(H1(:,2))), ...
     omega/pi, unwrap(angle(H1(:,3))), ...
     omega/pi, unwrap(angle(H1(:,4))), ...
     omega/pi, unwrap(angle(H1(:,5))), 'LineWidth', 1.5);
legend('Filter 1', 'Filter 2', 'Filter 3', 'Filter 4', 'Filter 5');

ylabel('Phase (radians)');
title('Phase Spectrum');
grid on;
```



Task 3

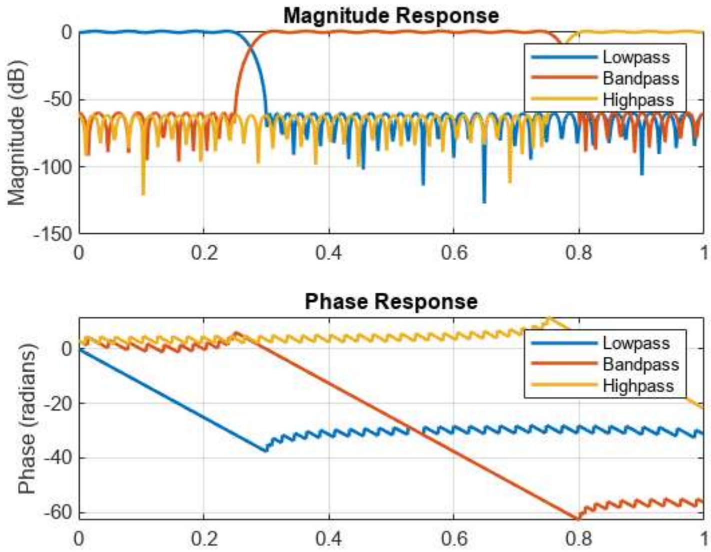
Place your code here to design the lowpass filter

```
delta1 = 0.0575; delta2 = 0.0009;
Wp = 0.25 * pi; Ws = 0.3 * pi;
[N_lp, Fo, Ao, W] = firpmord([Wp/pi, Ws/pi], [1, 0], [delta1, delta2]);
N_lp = N_lp + rem(N_lp, 2);
b_lp = firpm(N_lp, Fo, Ao, W);

% Place your code here to design the bandpass filter
Wp = [0.3, 0.75] * pi; Ws = [0.25, 0.8] * pi;
[N_bp, Fo, Ao, W] = firpmord([Ws(1)/pi, Wp(1)/pi, Wp(2)/pi, Ws(2)/pi], [0, 1, 0], [delta2, delta1, delta2]);
N_bp = N_bp + rem(N_bp, 2);
b_bp = firpm(N_bp, Fo, Ao, W);

% place your code here to design the highpass filter
Wp = 0.8 * pi; Ws = 0.75 * pi;
[N_hp, Fo, Ao, W] = firpmord([Ws/pi, Wp/pi], [0, 1], [delta2, delta1]);
N_hp = N_hp + rem(N_hp, 2);
b_hp = firpm(N_hp, Fo, Ao, W);

% Place your code here to determine the frequency response of the three filters
b2 = zeros(3, max([N_lp, N_bp, N_hp]) + 1);
b2(1,1:N_lp+1) = b_lp;
b2(2,1:N_bp+1) = b_bp;
b2(3,1:N_hp+1) = b_hp;

H2 = zeros(512, 3);
[H2(:,1), omega] = freqz(b2(1,1:N_lp+1), 1, 512);
[H2(:,2), ~] = freqz(b2(2,1:N_bp+1), 1, omega);
[H2(:,3), ~] = freqz(b2(3,1:N_hp+1), 1, omega);

% Place your code here to create the visualization (impulse response) of figure 5
figure(5);
subplot(3,1,1); stem(0:N_lp, b_lp, 'Marker', 'none', 'LineWidth', 1.5);
title('Lowpass Filter'); xlabel('n'); ylabel('Amplitude'); grid on;
subplot(3,1,2); stem(0:N_bp, b_bp, 'Marker', 'none', 'LineWidth', 1.5);
title('Bandpass Filter'); xlabel('n'); ylabel('Amplitude'); grid on;
subplot(3,1,3); stem(0:N_hp, b_hp, 'Marker', 'none', 'LineWidth', 1.5);
title('Highpass Filter'); xlabel('n'); ylabel('Amplitude'); grid on;
```



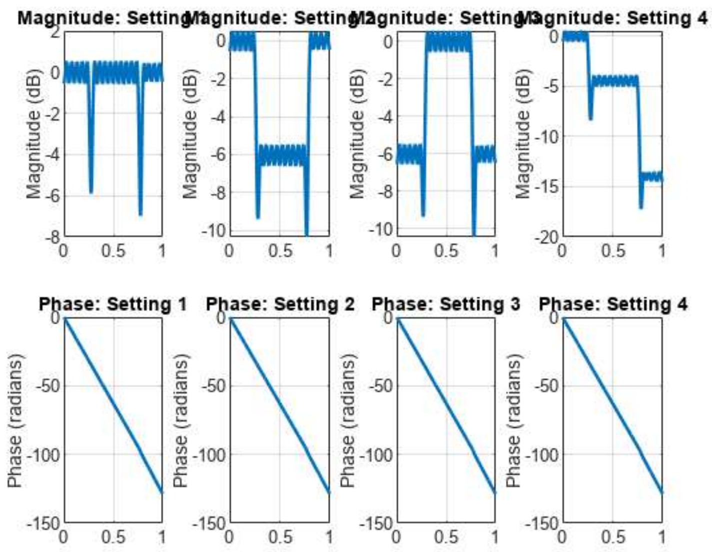

```
% Place your code here to create the visualization (magnitude and phase spectrum of figure 6
figure(6);
subplot(2,1,1);
plot(omega/pi, 20*log10(abs(H2(:,1)) + eps), ...
     omega/pi, 20*log10(abs(H2(:,2)) + eps), ...
     omega/pi, 20*log10(abs(H2(:,3)) + eps), 'LineWidth', 1.5);
legend('Lowpass', 'Bandpass', 'Highpass');

ylabel('Magnitude (dB)');
title('Magnitude Response');
grid on;

subplot(2,1,2);
plot(omega/pi, unwrap(angle(H2(:,1))), ...
```

```
    omega/pi, unwrap(angle(H2(:,2))), ...
    omega/pi, unwrap(angle(H2(:,3))), 'LineWidth', 1.5);
legend('Lowpass', 'Bandpass', 'Highpass');

ylabel('Phase (radians)');
title('Phase Response');
grid on;
```



4

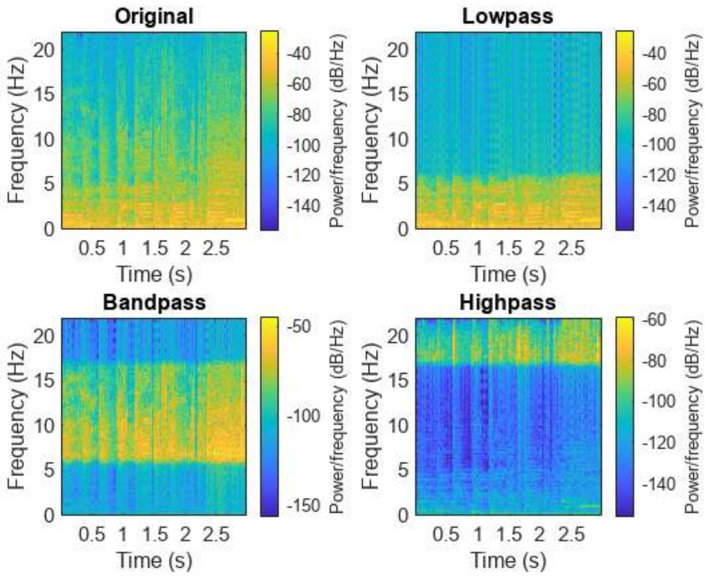
```
alpha = [1 1 1; 1 0.5 1; 0.5 1 0.5; 1 0.6 0.2];
% Place your code here to compute for H3
H3 = zeros(512,4);
for i = 1:4
    H3(:,i) = alpha(i,1)*H2(:,1) + alpha(i,2)*H2(:,2) + alpha(i,3)*H2(:,3);
end

% Place your code here to create the visualization (magnitude and phase spectrum of figure 7
figure(7);
for i = 1:4
    subplot(2,4,i);
    plot(omega/pi, 20*log10(abs(H3(:,i)) + eps), 'LineWidth', 1.5);

    ylabel('Magnitude (dB)');
    title(['Magnitude: Setting ', num2str(i)]);
    grid on;

    subplot(2,4,i+4);
    plot(omega/pi, unwrap(angle(H3(:,i))), 'LineWidth', 1.5);

    ylabel('Phase (radians)');
    title(['Phase: Setting ', num2str(i)]);
    grid on;
end
```



5

Read the audio file and store it in the first column of y

```
[y(:,1),Fs] = audioread('RollingInTheDeep.wav');

% Place your code here to generate y1, y2, and y3 and store them in the 2nd, 3rd, and 4th column of y
y(:,2) = filter(b2(1,1:N_lp+1), 1, y(:,1));
y(:,3) = filter(b2(2,1:N_bp+1), 1, y(:,1));
y(:,4) = filter(b2(3,1:N_hp+1), 1, y(:,1));

% Place your code here to calculate the spectrogram of y and store them in the three-dimensional matrix S
S = zeros(257, 1032, 4);
window = kaiser(256, 3.3953);
noverlap = 128;
nfft = 512;
for k = 1:4
    [S(:,:,k), ~, ~] = spectrogram(y(:,k), window, noverlap, nfft, Fs);
end

% Place your code here to create the visualization (spectrogram) of figure 8
figure(8);
for i = 1:4
    subplot(2,2,i);
    spectrogram(y(:,i), window, noverlap, nfft, Fs, 'yaxis');
    switch i
        case 1
            title('Original');
        case 2
            title('Lowpass');
        case 3
            title('Bandpass');
        case 4
            title('Highpass');
    end
    xlabel('Time (s)');
    ylabel('Frequency (Hz)');
end
```



Original
Lowpass
Bandpass
Highpass
Frequency (Hz)
Time (s)
Power/frequency (dB/Hz)