De La Salle University

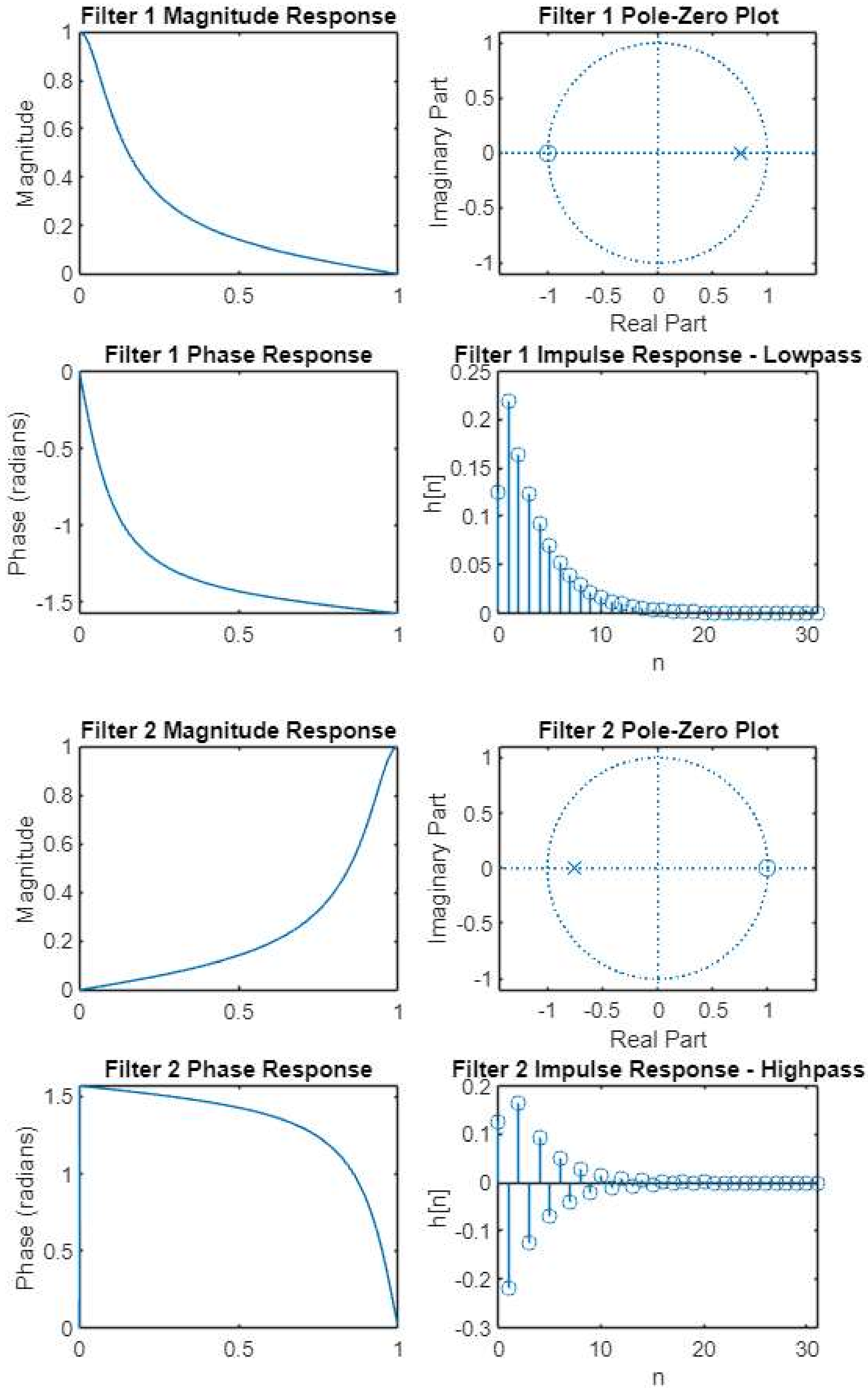
Electronics and Communications Engineering Department Course : LBYCPA4 SECTION : Submitted by : Submitted to : Dr. Edwin Sybingco Exercise 3 : Frequency Representations of Signals and Systems

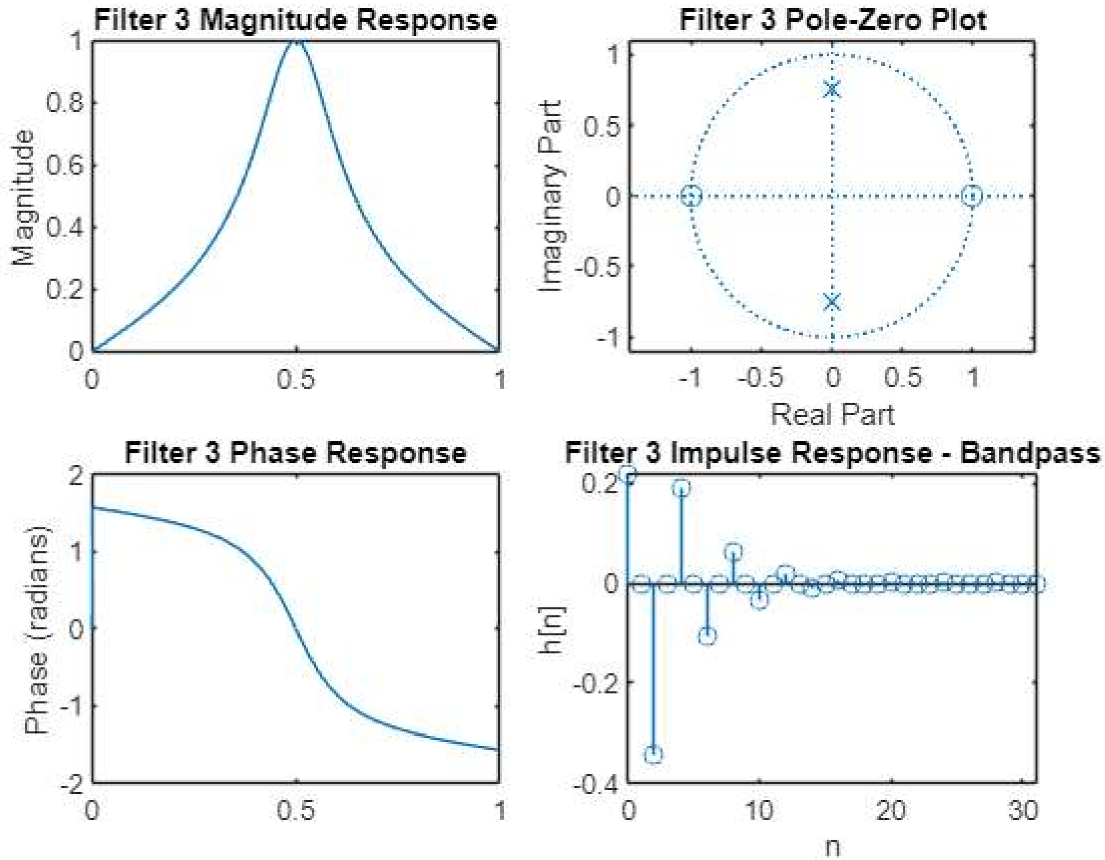
Task 1

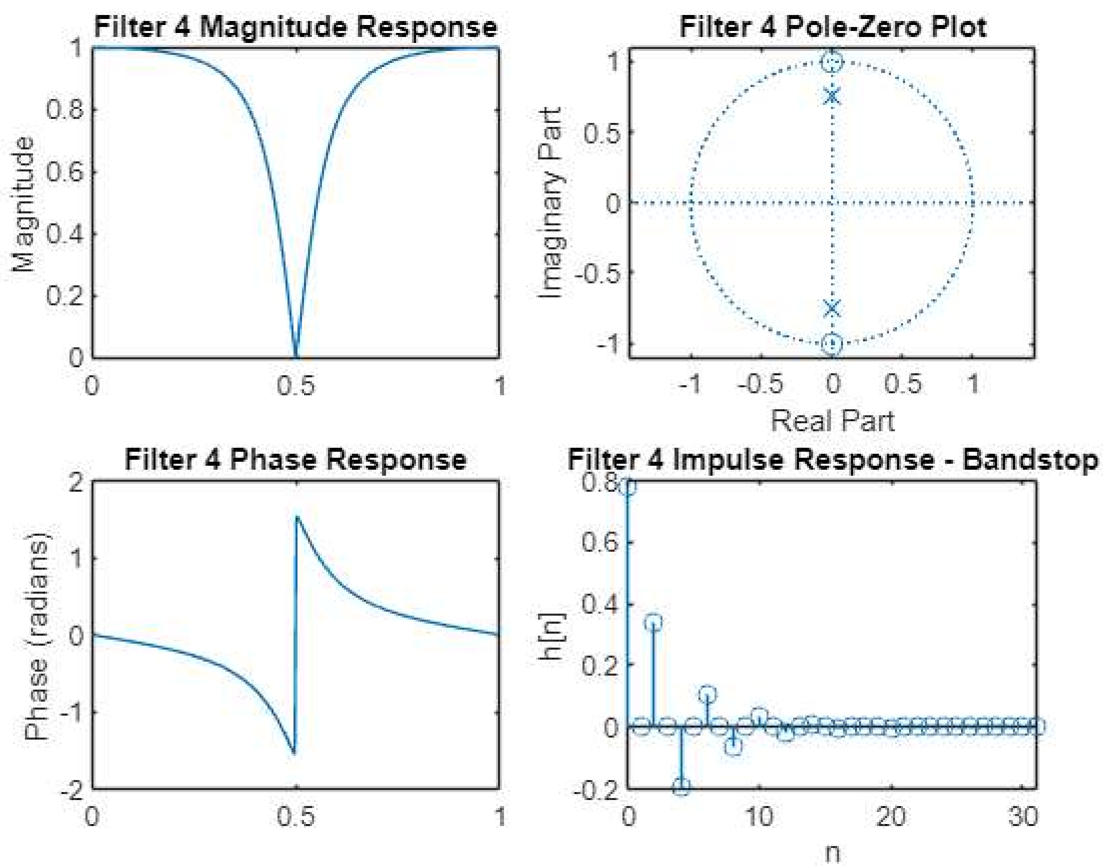
Generate the time index for the impulse response

```
n = 0:31;

% Specify the filter coefficients of filter 1 to 4 using the cell array
% b{k} and a{k} where k = 1,2,3, and 4. Also determine the following
%
% impulse response and store it in h{k}
% Frequency response and store them in H{k}

% Filter 1
b{1} = (1/8)*[1 1];
a{1} = [1 -3/4];

% Filter 2
b{2} = (1/8)*[1 -1];
a{2} = [1 3/4];

% Filter 3
b{3} = (7/32)*[1 0 -1];
a{3} = [1 0 9/16];

% Filter 4
b{4} = (25/32)*[1 0 1];
a{4} = [1 0 9/16];

% Complete the table below by categorizing the filter type as lowpass,
% highpass, bandpass, or bandstop

t = table([1;2;3;4], 'VariableName', {'FilterNumber'});
t.FilterType(1) = {'Lowpass'};
t.FilterType(2) = {'Highpass'};
t.FilterType(3) = {'Bandpass'};
t.FilterType(4) = {'Bandstop'};

% Frequency and impulse responses with visualization
H = cell(4,1);
h = cell(4,1);
for k = 1:4
    % Frequency response
    [H{k}, w] = freqz(b{k}, a{k}, 512);
    % Impulse response
    h{k} = impz(b{k}, a{k}, length(n));
```

```
    % Visualization
    figure(k);
    subplot(2,2,1); % Top left - Magnitude response
    plot(w/pi, abs(H{k}));
    title(['Filter ', num2str(k), ' Magnitude Response']);
    ylabel('Magnitude');

    subplot(2,2,2); % Top right - Pole-zero plot
    zplane(b{k}, a{k});
    title(['Filter ', num2str(k), ' Pole-Zero Plot']);

    subplot(2,2,3); % Bottom left - Phase response
    plot(w/pi, angle(H{k}));
    title(['Filter ', num2str(k), ' Phase Response']);
    ylabel('Phase (radians)');

    subplot(2,2,4); % Bottom right - Impulse response
    stem(n, h{k});
    xlabel('n');
    ylabel('h[n]');
    title(['Filter ', num2str(k), ' Impulse Response - ', t.FilterType{k}]);
end
```

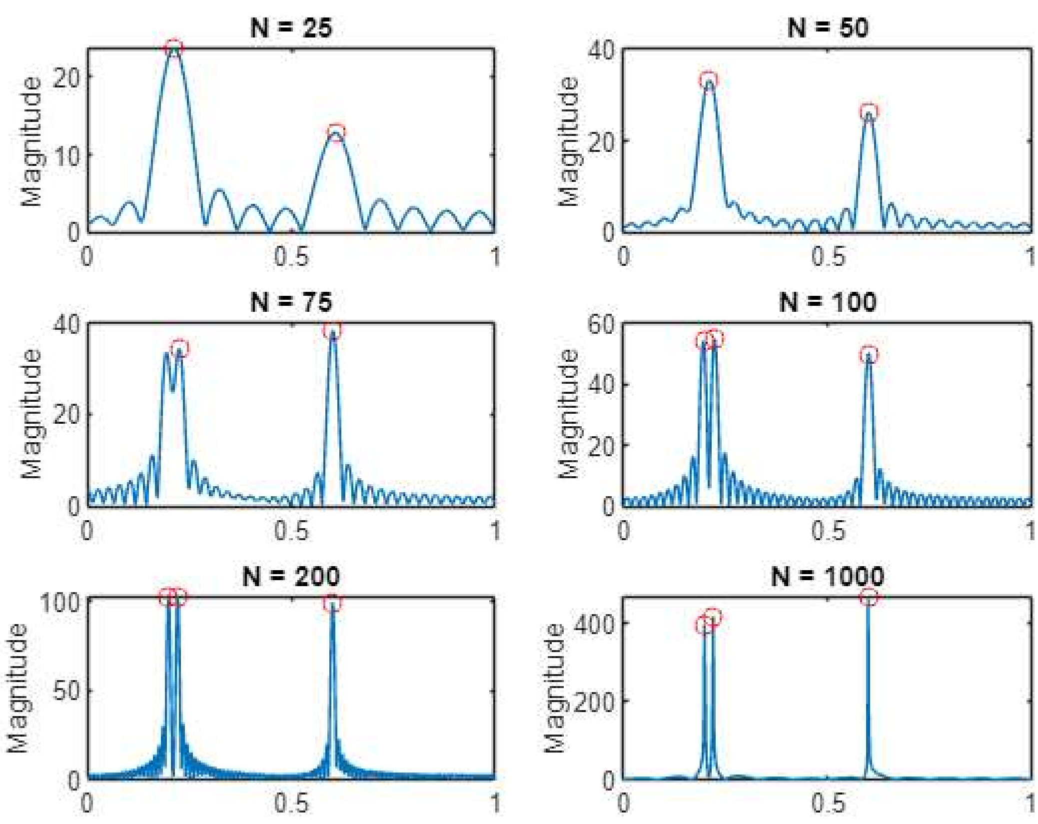

Filter 1 Magnitude Response
Magnitude
Filter 1 Pole-Zero Plot
Imaginary Part
Real Part
Filter 1 Phase Response
Phase (radians)
Filter 1 Impulse Response - Lowpass
h[n]
n
Filter 2 Magnitude Response
Magnitude
Filter 2 Pole-Zero Plot
Imaginary Part
Real Part
Filter 2 Phase Response
Phase (radians)
Filter 2 Impulse Response - Highpass
h[n]
n





Task 2: Frequency Resolution

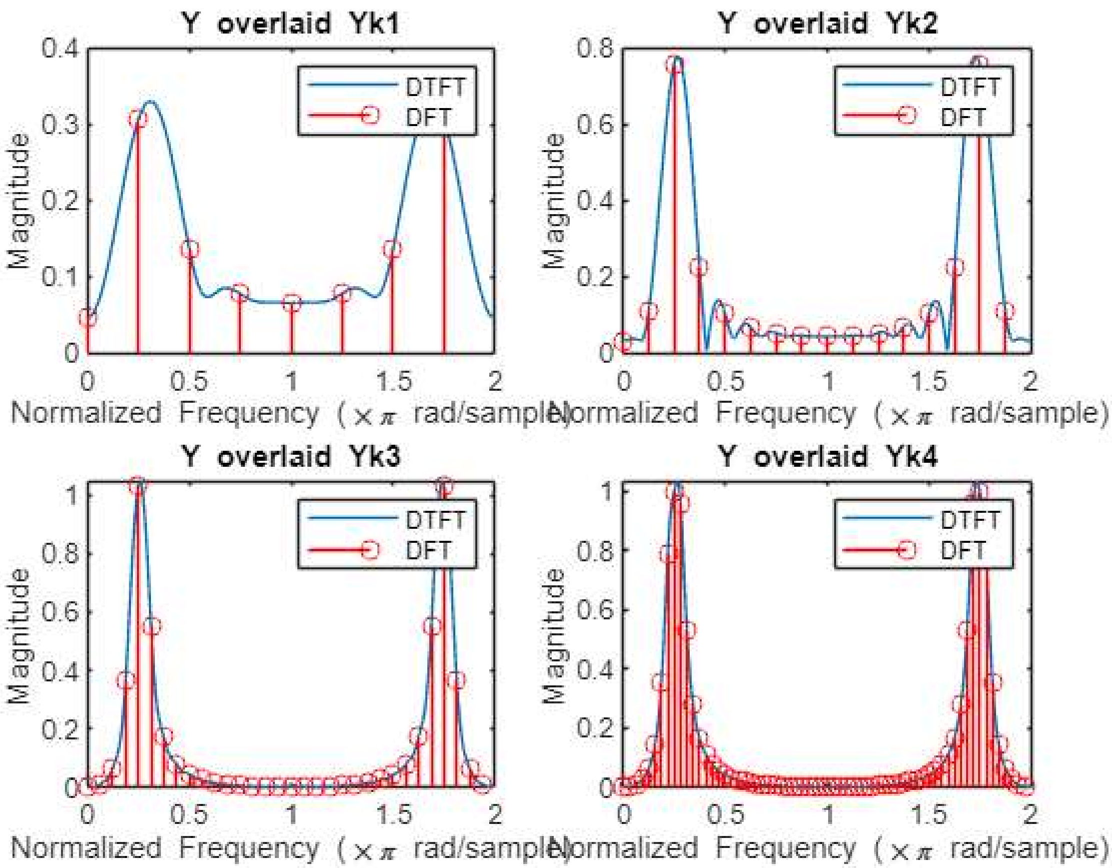
```
N = [25, 50, 75, 100, 200, 1000];
X = cell(1, length(N));

for k = 1:length(N)
    n = 0:N(k)-1;
    x{k} = cos(0.2*pi*n) + cos(0.22*pi*n) + cos(0.6*pi*n);
    X{k} = fft(x{k}, 1024);
     X{k} = X{k}(1:512);

    % Visualization
    figure(5);
    subplot(3, 2, k);
    w = linspace(0, pi, 512);
    plot(w/pi, abs(X{k}))
    title(['N = ', num2str(N(k))])
    ylabel('Magnitude')
    [pks, locs] = findpeaks(abs(X{k}), 'MinPeakProminence', max(abs(X{k}))/2);
    hold on
    plot(w(locs)/pi, pks, 'ro')
    hold off
end
```



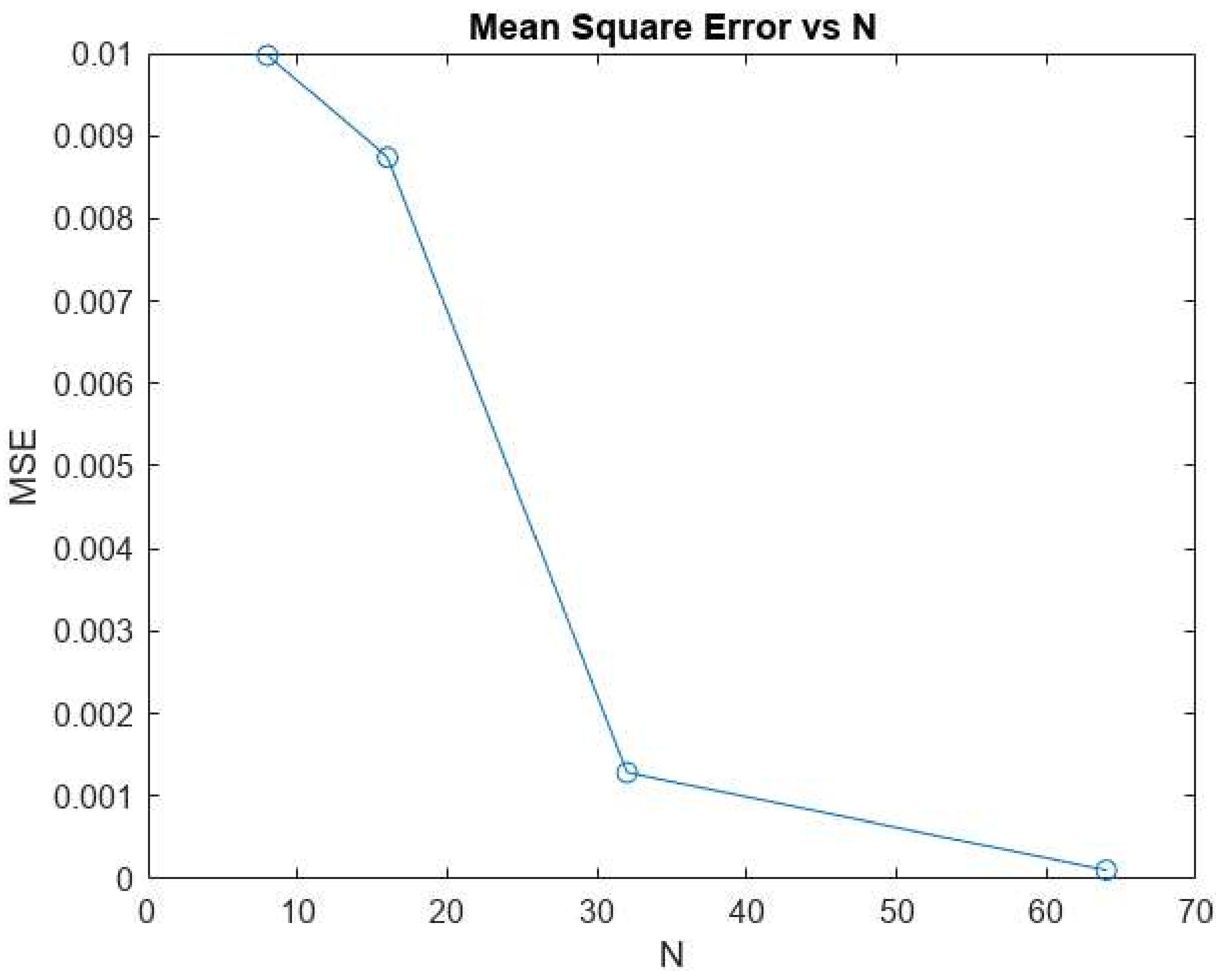
Task 3: MSE of DTFT and DFT/FFT

```
b1 = 0.0168 * [1 0 -2 0 1];
a1 = [1 -2.5333 3.2089 -2.0520 0.6561];
N = [8 16 32 64];
```

```
Y = cell(1, length(N));
Yk = cell(1, length(N));
y = cell(1, length(N));
MSE = zeros(1, length(N));

for k = 1:length(N)
    y{k} = filter(b1, a1, [1 zeros(1, N(k)-1)]);

    % Compute DTFT
    [Y{k}, wF] = freqz(y{k}, 1, 1024, "whole");

    % Compute DFT with N(k) points
    Yk{k} = fft(y{k}, N(k));

     Yint = interp1(2*pi*(0:N(k)-1)/N(k), abs(Yk{k}), wF, 'linear', 'extrap');
    % Compute MSE
    MSE(k) = mean((abs(Y{k}) - Yint).^2);


    % Visualization of DTFT and DFT (Figure 6)
    figure(6);
    subplot(2, 2, k);
    plot(wF/pi, abs(Y{k}))
    hold on
    stem(2*pi*(0:N(k)-1)/N(k)/pi, abs(Yk{k}), 'r')
    hold off
    title(['Y overlaid Yk{', num2str(k), '}'])
    xlabel('Normalized Frequency (\times\pi rad/sample)')
    ylabel('Magnitude')
    legend('DTFT', 'DFT')
end
```

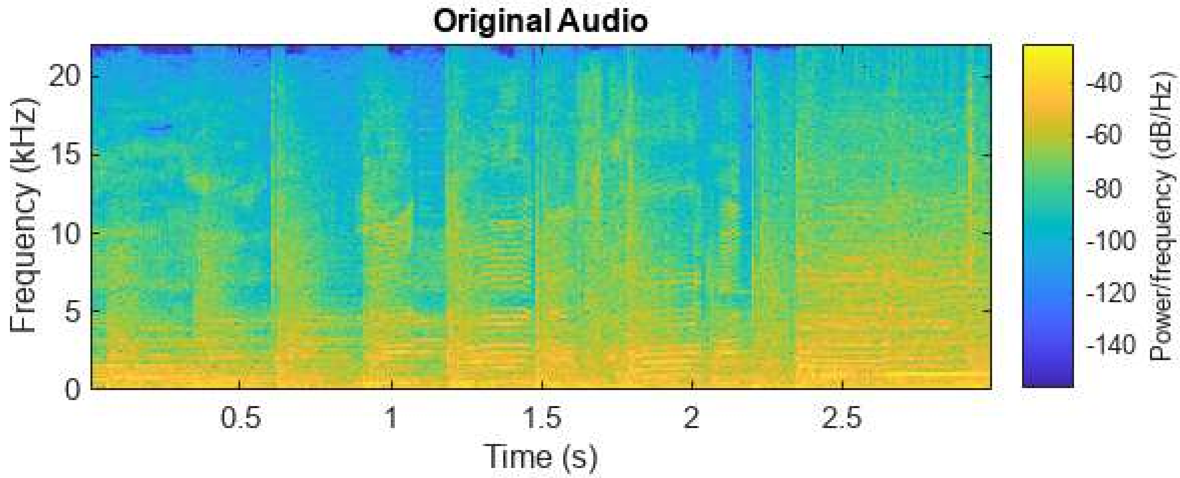


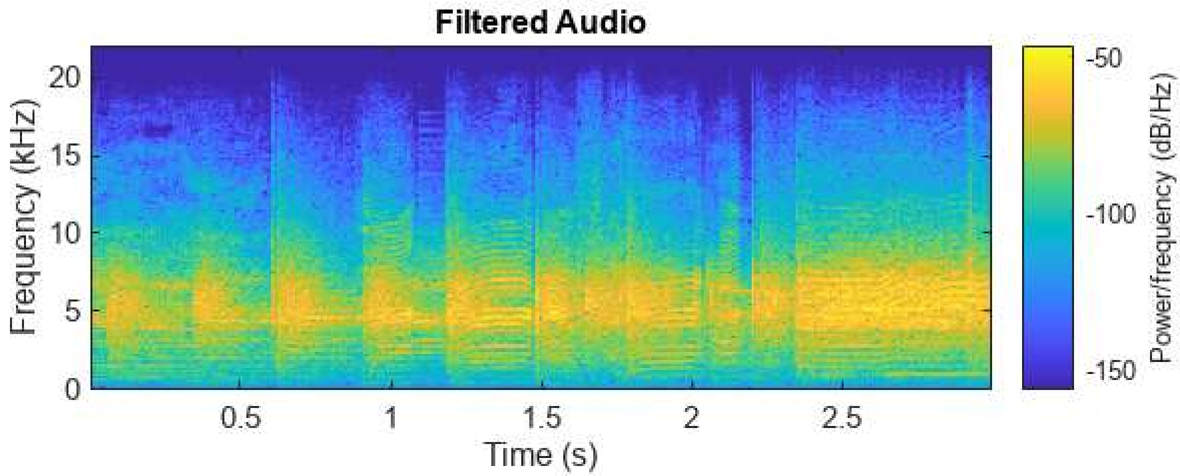

```
% Visualization of MSE (Figure 7)
figure(7);
plot(N, MSE, '-o'); title('Mean Square Error vs N');
xlabel('N'); ylabel('MSE');
```



Task 4: Time-Frequency Representation

```
[s, Fs] = audioread('RollingInTheDeep.wav');
so = filter(b1, a1, s);

figure(8);
subplot(2, 1, 1);
spectrogram(s, hanning(512), 128, 512, Fs, 'yaxis'); title('Original Audio');
subplot(2, 1, 2);
spectrogram(so, hanning(512), 128, 512, Fs, 'yaxis'); title('Filtered Audio');
```





Task 5: Image Processing

```
h2 = 0.142 * [0 1 2; -1 0 1; -2 -1 0];
H2f = fftshift(fft2(h2, 512, 512));

I = imread('lena_gray.tiff');
Is = fftshift(fft2(I));
If = imfilter(I, h2, 'conv');

min_val = min(If(:));
If = If - min_val; % Shift so minimum is zero
If = uint8(If);

Isf = fftshift(fft2(If));

% Visualization of spectra
figure(9)
subplot(2,3,1)
mesh(abs(H2f))
title('Spectrum of the Filter')
subplot(2,3,2)
mesh(abs(Is))
title('Spectrum of the Original Image')
subplot(2,3,3)
```

```
mesh(abs(Isf))
title('Spectrum of the Filtered Image')
subplot(2,3,4)
imshow(I)
title('Original Image')
subplot(2,3,5)
imshow(If)
title('Filtered Image')
```