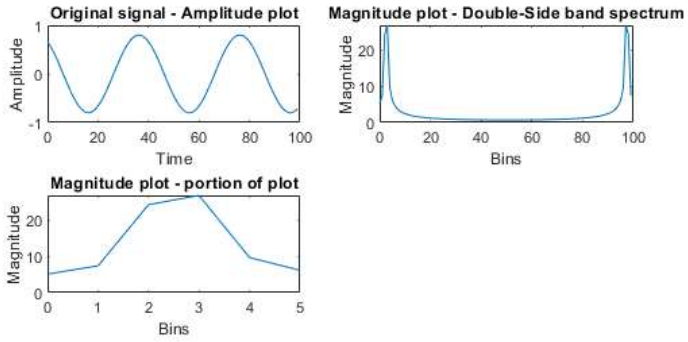
Contents

Adding zero-padding & windowing to reduce the leakage of non-integer frequency value in MATLAB

```
% Remove all global variables from the current workspace
clear;
% Clear all input & output from the command window display
clc;

% Sinusoidal signal with fs=100Hz, 1sec long duration,
% f1=2.5Hz, Sinusoidal Amplitude = 0.8 & Phase = 0.6

% This sinewave has a decimal fraction value frequency of 2.5
% This frequency does not correspond to a DFT bin

fs = 100;     % Sampling frequency = 100Hz
f1 = 2.5;     % Sinusoidal Frequency = 2.5Hz
T = 1/fs;     % Sampling interval
A = 0.8;      % Amplitude = 0.8
P = 0.6;      % Phase = 0.6

t = 0 : T : 1 - T;          % Time vector
x1 = A*cos(2*pi*f1*t + P);  % Sinusoid signal

% Length of x1
L = length(x1);             % Length of signal, 100
```

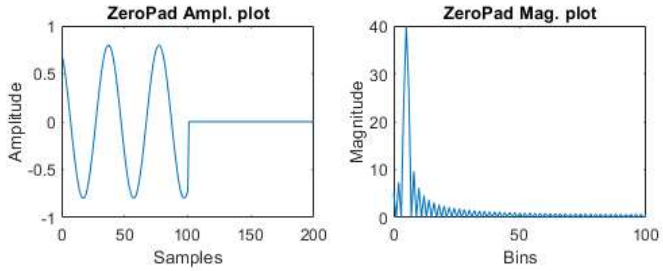
Initially no Zero padding & no windowing is applied

```
% For a non integer value of f1 the Magnitude plot will be different
% There is a spread of spectral energy across a number of bins
% For f1=2.5 most energy is consolidated around bins 2 & 3

subplot(3,2,1)
plot(t*100,x1)
title('Original signal - Amplitude plot');
xlabel('Time');
ylabel('Amplitude');

% Using here capital X1  for frequency content & lower case x1 for time domain content.
% Compute the DFT of x1 using a Fast Fourier Transform (FFT) algorithm
% X1 is a sequence of complex numbers returned by the FFT function

X1 = fft(x1);       % Compute DFT of x1
subplot(3,2,2);
%y1 = length(X1)-1
plot((0:length(X1)-1), abs(X1));
title('Magnitude plot - Double-Side band spectrum');
xlabel('Bins');
ylabel('Magnitude');

subplot(3,2,3);
plot((0:length(X1)-1), abs(X1));
title('Magnitude plot - portion of plot');
xlabel('Bins');
ylabel('Magnitude');

%plot a portion of a plot x-axis 0->5
xlim([0,5]);
```



Adding zero padding (but no windowing yet)

```
% The time domain creates a new signal of 200 samples
% The minimum number of zeros that we can add to the signal is 100 due to L=100
% 100 first samples of sinusoidal signal 2.5 cycles & the rest is padded with 100 zeros to increase it's length to 200 frequency bins in the frequency domain
Z = 100;                    % Number of Zeros
x2 = [x1 zeros(1, Z)];

subplot(2,2,1)
plot(x2)
title('ZeroPad Ampl. plot');
xlabel('Samples');
ylabel('Amplitude');

% Without windowing, FFT Magnitude=[A*L]/2 = 0.8*100/2 = 40
X2 = fft(x2);
subplot(2,2,2);
plot((0:length(X2)-1), abs(X2));
title('ZeroPad Mag. plot');
xlabel('Bins');
ylabel('Magnitude');
%plot a portion of a plot x-axis 0->100
xlim([0,100]);
```



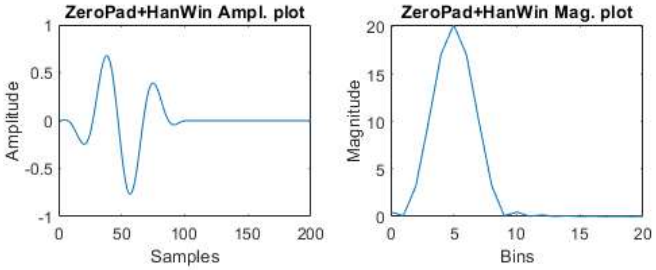
Adding a window function

```
% Hanning window
x3 = x1.*hanning(length(x1))';

% Hamming window
%x3 = x1.*hamming(length(x1))';

% Kaiser window with different beta values
%x3 = x1.*kaiser(length(x1), 1)';
%x3 = x1.*kaiser(length(x1), 4)';
%x3 = x1.*kaiser(length(x1), 9)';

% Rectangular window
%x3 = x1.*rectwin(length(x1))';
```

```
% Blackman-Harris window
%x3 = x1.*blackmanharris(length(x1))';

% Flat-Top window
%x3 = x1.*flattopwin(length(x1))';
```

+ zero padding

```
x3 = [x3 zeros(1, Z)];

subplot(2,2,1)
plot(x3);
title('ZeroPad+HanWin Ampl. plot');
xlabel('Samples');
ylabel('Amplitude');
xlim([0,200]);

X3 = fft(x3);
subplot(2,2,2);
plot((0:length(X3)-1), abs(X3));
title('ZeroPad+HanWin Mag. plot');
xlabel('Bins');
ylabel('Magnitude');
%plot a portion of a plot x-axis 0->20
xlim([0,20]);
```

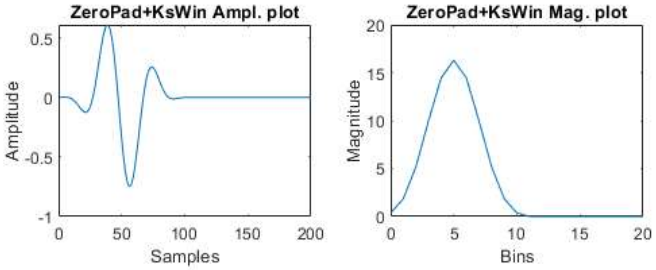


Adding Kaiser (beta=9) windowing

```
% Kaiser window with different beta values
% As beta increases, the relative sidelobe atennuation decreases and the mainlope width increases

%x4 = x1.*kaiser(length(x1), 1)';
%x4 = x1.*kaiser(length(x1), 4)';
x4 = x1.*kaiser(length(x1), 9)';
```

+ zero padding

```
x4 = [x4 zeros(1, Z)];

subplot(2,2,1)
plot(x4)
title('ZeroPad+KsWin Ampl. plot');
xlabel('Samples');
ylabel('Amplitude');
xlim([0,200]);

X4 = fft(x4);
subplot(2,2,2);
plot((0:length(X4)-1), abs(X4));
title('ZeroPad+KsWin Mag. plot');
xlabel('Bins');
ylabel('Magnitude');
%plot a portion of a plot x-axis 0->20
xlim([0,20]);
```



Analyse the magnitude frequency information of eg X3 (Hanning windowing & zero-padding) above

```
% To determine the Amplitude/Frequency & Phase of the sinusoids present

% To get the Magnitude of the DFT main lobe, 20.1959
%    6 here refers to bin no. 5 due to MATLAB indexing issues
%    MATLAB indexes start at no.1 whereas mathematically we normally start at 0
%    This is half (ie 40/2) on what we get when we apply without windowing
%    Note: For Z=1100, m = abs(X3(31)) = 20.1959 for bin no.30
m = abs(X3(6))         % For Z=100, m=20.1959 for bin no. 5

% Actual Amplitude of the simnusoid, a=0.8078
%  Little bit out. It depends on the window function that we use
a = abs(X3(6))/(L/4)

% Phase of sinusoid, p = 0.6
p = angle(X3(6))

% Original frequency, f = 2.5
f = 5*fs/(Z + 100)           % (Bin_number * fs) / No_of_Bins
```

```
m =

   20.1959


a =

    0.8078


p =

    0.6003


f =

    2.5000
```

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