Signal processing - DFT

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Default commands

```
close all;
clear all;
clc;
```

Constants

```
N = 256;
N_w = 32;
P_w = 32*16;
k = 12;
P = 2^k;
M = P - N;
% The signals' characteristics
Amp1 = 1;
Amp2 = 2;
f1 = 10;
f2 = 10*15.5/16;
phi1 = 6;
phi2 = 4;
% Discretize the signals
% We have 16/fe = 256/f1 => fe = 16*f1
fe = 16*f1;
lambda1 = f1/fe;
lambda2 = f2/fe;
t = 1 : N;
% Number of shifted positions
k1 = 1;
k2 = 20;
```

Signals

```
% The original signals
sig1 = Amp1*sin(2*pi*lambda1*t + phi1);
sig2 = Amp2*sin(2*pi*lambda2*t + phi2);

% FFTs of those signals
[magnitude1 phase1 frequency1] = TFDVisu(sig1, fe);
[magnitude2 phase2 frequency2] = TFDVisu(sig2, fe);
```

```
% Comment on plot of these: These have peaks at -f0 and +f0 of each
 signal
% which is understandable because the FFTs of sin waves have the form
% (A/2)*(dirac(f + f0) + dirac(f - f0)). Also this is not affected by
 the
% initial phases because it concerns only the frequency domain.

% Now we shift the signals
sig1_shifted = circshift(sig1,k1);
sig2_shifted = circshift(sig2,k2);
[magnitude1_shifted phase1_shifted frequency1_shifted] =
 TFDVisu(sig1_shifted, fe);
[magnitude2_shifted phase2_shifted frequency2_shifted] =
 TFDVisu(sig2_shifted, fe);
% Comment: The effect of these shifts is that the magnitude of FFT
 will
% stay unchanged while the phase of FFT will be changed. The more the
% delay, the less the phase plot is spread with regards to frequency.

% Now we test some zero padding
sig1_0pad = zeros(1,P);
for i = 1 : (N-1)
    sig1_0pad(1,i) = sig1(i);
end
sig2_0pad = zeros(1,P);
for i = 1 : (N-1)
    sig2_0pad(1,i) = sig2(i);
end
% FFTs of those 0 padding signals
[magnitude1_0pad phase1_0pad frequency1_0pad] =
 TFDVisu_0pad(sig1_0pad, fe, P);
[magnitude2_0pad phase2_0pad frequency2_0pad] =
 TFDVisu_0pad(sig2_0pad, fe, P);

% Now we test the windows
w1 = rectwin(N_w);
w2 = window(@blackmanharris,N_w);
w3 = window(@hamming,N_w);

% Now add 0 padding to the windows
w1_0pad = zeros(1,P_w);
for i = 1 : (N_w - 1)
    w1_0pad(1,i) = w1(i);
end
w2_0pad = zeros(1,P_w);
for i = 1 : (N_w - 1)
    w2_0pad(1,i) = w2(i);
end
w3_0pad = zeros(1,P_w);
for i = 1 : (N_w - 1)
    w3_0pad(1,i) = w3(i);
end

% FFTs of those 0 padding windows
```

```
[magnitude_w1_0pad phase_w1_0pad frequency_w1_0pad] =
 TFDVisu_0pad(w1_0pad, fe, P_w);
[magnitude_w2_0pad phase_w2_0pad frequency_w2_0pad] =
 TFDVisu_0pad(w2_0pad, fe, P_w);
[magnitude_w3_0pad phase_w3_0pad frequency_w3_0pad] =
 TFDVisu_0pad(w3_0pad, fe, P_w);

% Application of window 3 on the 2 signals
sig1_w3 = sig1.*window(@hamming,N)';
sig2_w3 = sig2.*window(@hamming,N)';

% Now we test some zero padding on the filtered signals
sig1_w3_0pad = zeros(1,P);
for i = 1 : (N)
    sig1_w3_0pad(1,i) = sig1_w3(i);
end
sig2_w3_0pad = zeros(1,P);
for i = 1 : (N)
    sig2_w3_0pad(1,i) = sig2_w3(i);
end
% FFTs of those 0 padding signals
[magnitude1_w3_0pad phase1_w3_0pad frequency1_w3_0pad] =
 TFDVisu_0pad(sig1_w3_0pad, fe, P);
[magnitude2_w3_0pad phase2_w3_0pad frequency2_w3_0pad] =
 TFDVisu_0pad(sig2_w3_0pad, fe, P);

% Load the test signal
sig_test = load('SigTest');
sig_test = sig_test.SigTest;
% Apply the 3rd window on it
sig_test_w3 = sig_test.*window(@hamming,length(sig_test))';
% Add zero padding to it
sig_test_w3_0pad = zeros(1,P);
for i = 1 : (N)
    sig_test_w3_0pad(1,i) = sig_test_w3(i);
end
% FFTs of the signal
[magnitude_test_w3_0pad phase_test_w3_0pad frequency_test_w3_0pad] =
 TFDVisu_0pad(sig_test_w3_0pad, fe, P);
```

Plots

```
figure(1);
plot(t,sig1);
grid on;
xlabel('Time (s)');
ylabel('Signal (V)');
title('The signal s1');
legend('The signal s1');

figure(2);
plot(t,sig2);
grid on;
```

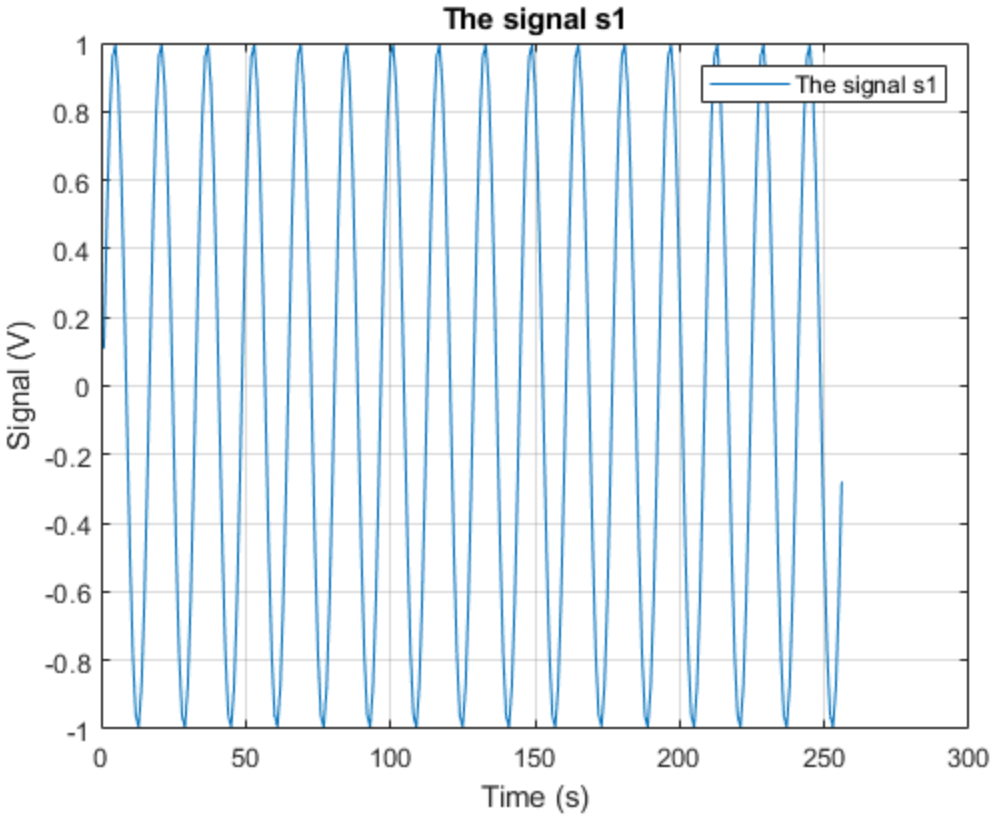
```
xlabel('Time (s)');
ylabel('Signal (V)');
title('The signal s2');
legend('The signal s2');

figure(3);
subplot(211);
plot(frequency1,magnitude1);
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (V)');
title('The magnitude spectrum of signal s1');
legend('The magnitude spectrum of signal s1');
hold on
subplot(212);
plot(frequency1,phase1);
grid on;
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of signal s1');
legend('The phase spectrum of signal s1');

figure(4);
subplot(211);
plot(frequency2,magnitude2);
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (V)');
title('The magnitude spectrum of signal s2');
legend('The magnitude spectrum of signal s2');
hold on
subplot(212);
plot(frequency2,phase2);
grid on;
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of signal s2');
legend('The phase spectrum of signal s2');

figure(5);
subplot(211);
plot(frequency1_shifted,magnitude1_shifted);
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (V)');
title('The magnitude spectrum of signal s1 shifted');
legend('The magnitude spectrum of signal s1 shifted');
hold on
subplot(212);
plot(frequency1_shifted,phase1_shifted);
grid on;
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of signal s1 shifted');
legend('The phase spectrum of signal s1 shifted');

figure(6);
```

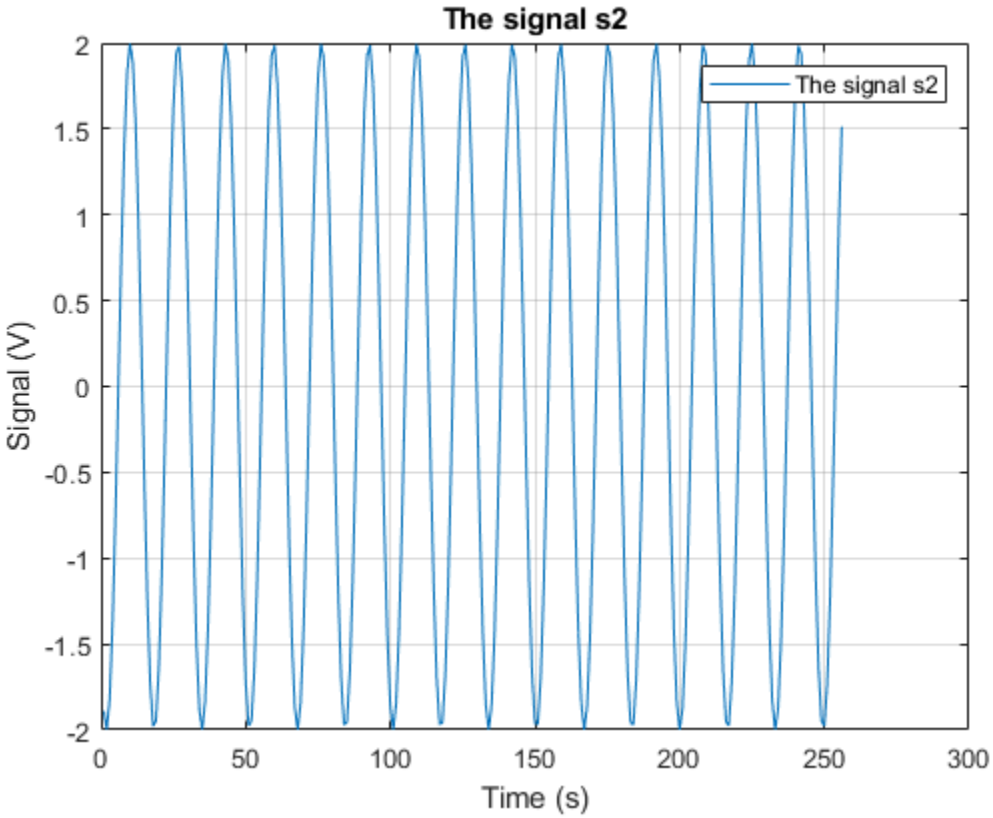
```
subplot(211);
plot(frequency2_shifted,magnitude2_shifted);
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (V)');
title('The magnitude spectrum of signal s2 shifted');
legend('The magnitude spectrum of signal s2 shifted');
hold on
subplot(212);
plot(frequency2_shifted,phase2_shifted);
grid on;
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of signal s2 shifted');
legend('The phase spectrum of signal s2 shifted');

figure(7);
subplot(211);
plot(frequency1_0pad,magnitude1_0pad);
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (V)');
title('The magnitude spectrum of signal s1 with 0 padding');
legend('The magnitude spectrum of signal s1 with 0 padding');
hold on
subplot(212);
plot(frequency1_0pad,phase1_0pad);
grid on;
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of signal s1 with 0 padding');
legend('The phase spectrum of signal s1 with 0 padding');

figure(8);
subplot(211);
plot(frequency2_0pad,magnitude2_0pad);
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (V)');
title('The magnitude spectrum of signal s2 with 0 padding');
legend('The magnitude spectrum of signal s2 with 0 padding');
hold on
subplot(212);
plot(frequency2_0pad,phase2_0pad);
grid on;
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of signal s2 with 0 padding');
legend('The phase spectrum of signal s2 with 0 padding');

figure(9);
subplot(311);
plot(w1);
xlabel('Time (s)');
ylabel('Signal');
title('The plot of window 1');
legend('The plot of window 1');
```

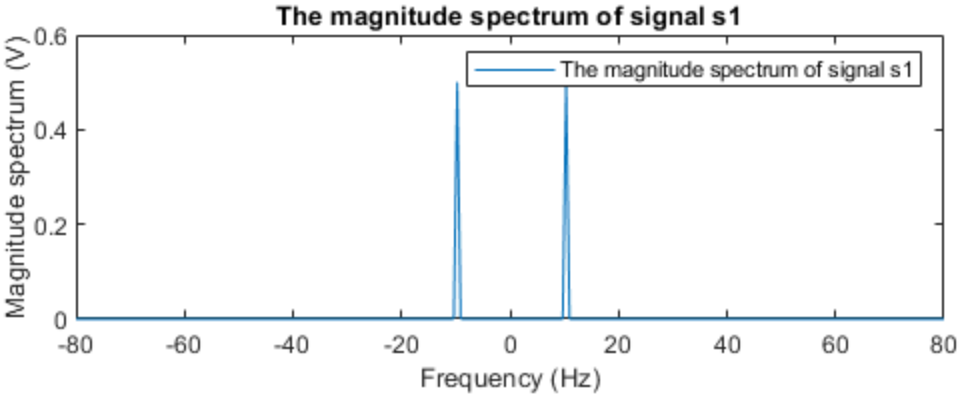
```
hold on
subplot(312);
plot(w2);
grid on;
xlabel('Time (s)');
ylabel('Signal');
title('The plot of window 2');
legend('The plot of window 2');
hold on
subplot(313);
plot(w3);
grid on;
xlabel('Time (s)');
ylabel('Signal');
title('The plot of window 3');
legend('The plot of window 3');

figure(10);
subplot(321);
plot(frequency_w1_0pad,magnitude_w1_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (Rad)');
title('The magnitude spectrum of window 1 with 0 padding');
legend('The magnitude spectrum of window 1 with 0 padding');
hold on
subplot(322);
plot(frequency_w1_0pad,phase_w1_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of window 1 with 0 padding');
legend('The phase spectrum of window 1 with 0 padding');
hold on
subplot(323);
plot(frequency_w2_0pad,magnitude_w2_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (Rad)');
title('The magnitude spectrum of window 2 with 0 padding');
legend('The magnitude spectrum of window 2 with 0 padding');
hold on
subplot(324);
plot(frequency_w2_0pad,phase_w2_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of window 2 with 0 padding');
legend('The phase spectrum of window 2 with 0 padding');
hold on
subplot(325);
plot(frequency_w3_0pad,magnitude_w3_0pad);
grid on
xlabel('Frequency (Hz)');
```

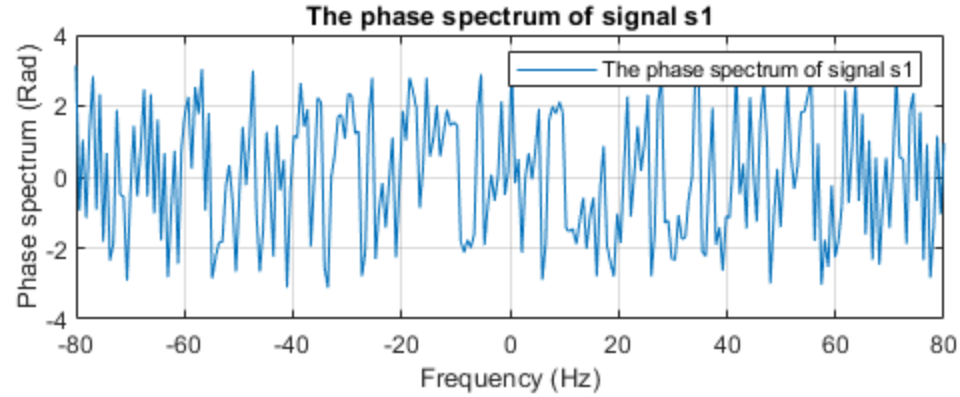
```
ylabel('Magnitude spectrum (Rad)');
title('The magnitude spectrum of window 3 with 0 padding');
legend('The magnitude spectrum of window 3 with 0 padding');
hold on
subplot(326);
plot(frequency_w3_0pad,phase_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of window 3 with 0 padding');
legend('The phase spectrum of window 3 with 0 padding');

figure(11);
subplot(211);
plot(t,sig1_w3);
grid on;
xlabel('Time (s)');
ylabel('Signal (V)');
title('The signal s1 with window 3 applied');
legend('The signal s1 with window 3 applied');
subplot(212);
plot(t,sig2_w3);
grid on;
xlabel('Time (s)');
ylabel('Signal (V)');
title('The signal s2 with window 3 applied');
legend('The signal s2 with window 3 applied');

figure(12);
subplot(221);
plot(frequency1_w3_0pad,magnitude1_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (Rad)');
title('The magnitude spectrum of sig1 with w3 with 0 padding');
legend('The magnitude spectrum of sig1 with w3 with 0 padding');
hold on
subplot(222);
plot(frequency1_w3_0pad,phase1_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of sig1 with w3 with 0 padding');
legend('The phase spectrum of sig1 with w3 with 0 padding');
hold on
subplot(223);
plot(frequency2_w3_0pad,magnitude2_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (Rad)');
title('The magnitude spectrum of sig2 with w3 with 0 padding');
legend('The magnitude spectrum of sig2 with w3 with 0 padding');
hold on
subplot(224);
```

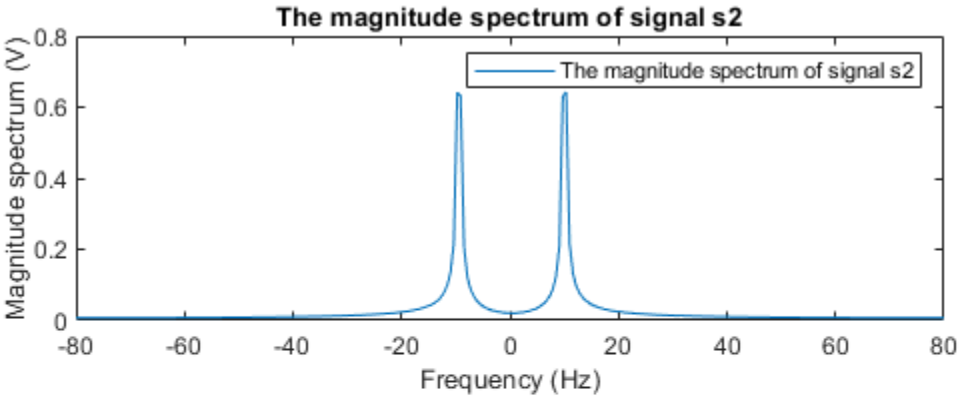
```
plot(frequency2_w3_0pad,phase2_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of sig2 with w3 with 0 padding');
legend('The phase spectrum of sig2 with w3 with 0 padding');

figure(13);
subplot(221);
plot(sig_test);
grid on
xlabel('Time(s)');
ylabel('Signal');
title('The test signal');
legend('The test signal');
hold on
subplot(222);
plot(sig_test_w3);
grid on
xlabel('Time(s)');
ylabel('Signal');
title('The test signal with w3');
legend('The test signal w3');
hold on
subplot(223);
plot(frequency_test_w3_0pad,magnitude_test_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Magnitude spectrum (Rad)');
title('The magnitude spectrum of test sig with w3 with 0 padding');
legend('The magnitude spectrum of test sig with w3 with 0 padding');
hold on
subplot(224);
plot(frequency_test_w3_0pad,phase_test_w3_0pad);
grid on
xlabel('Frequency (Hz)');
ylabel('Phase spectrum (Rad)');
title('The phase spectrum of test sig with w3 with 0 padding');
legend('The phase spectrum of test sig with w3 with 0 padding');
```

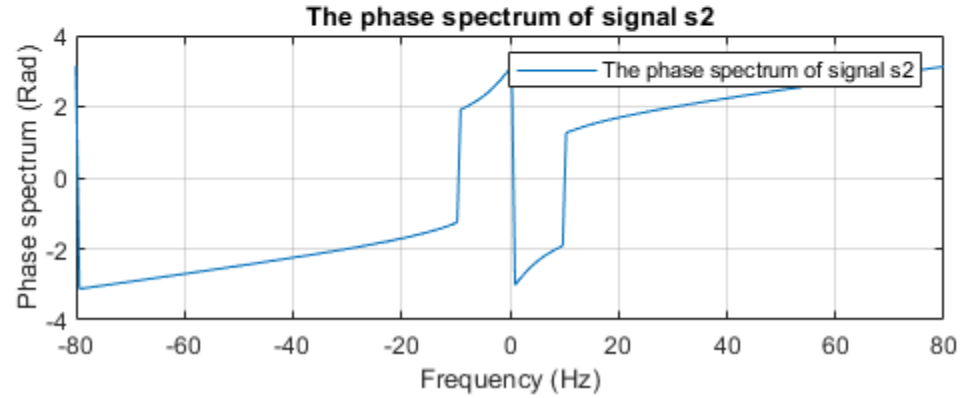

The signal s1
The signal s1
Signal (V)
Time (s)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
50
100
150
200
250
300

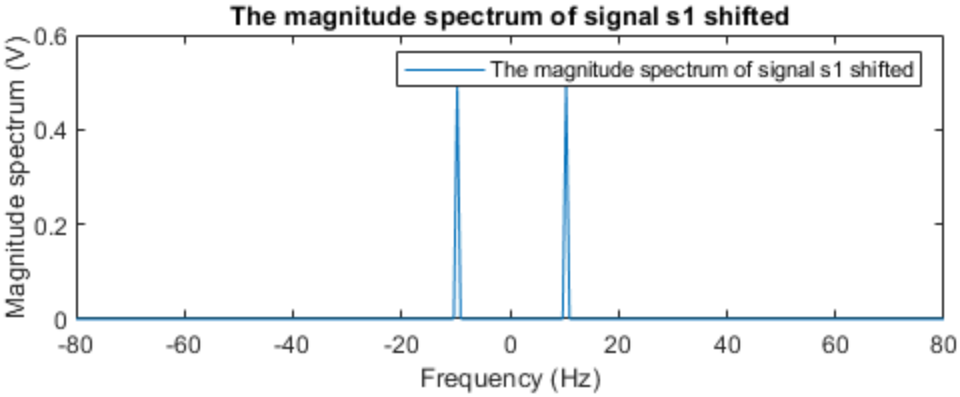

The signal s2
The signal s2
Signal (V)
Time (s)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
50
100
150
200
250
300

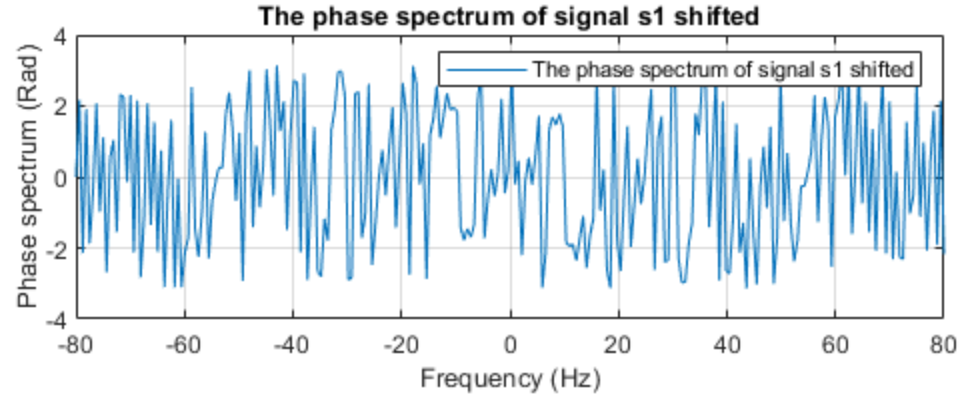

The magnitude spectrum of signal s1
Magnitude spectrum (V)
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The magnitude spectrum of signal s1

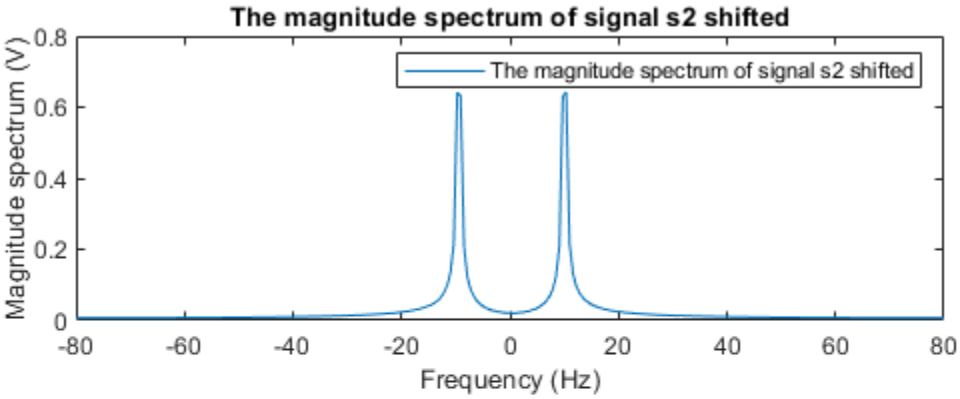

The phase spectrum of signal s1
Phase spectrum (Rad)
4
2
0
-2
-4
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The phase spectrum of signal s1

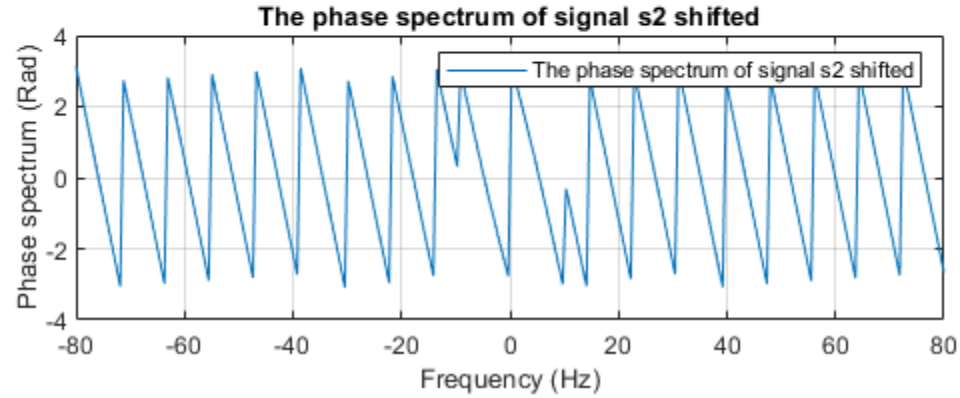

The magnitude spectrum of signal s2
Magnitude spectrum (V)
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The magnitude spectrum of signal s2

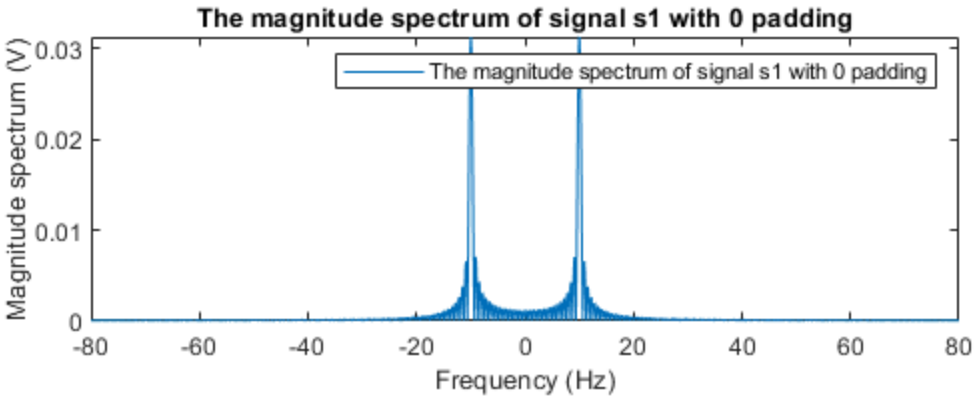

The phase spectrum of signal s2
Phase spectrum (Rad)
4
2
0
-2
-4
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The phase spectrum of signal s2

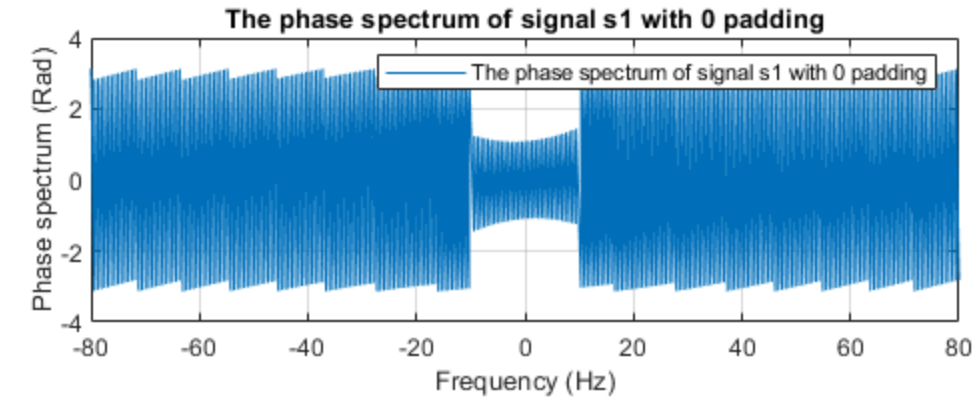

The magnitude spectrum of signal s1 shifted
Magnitude spectrum (V)
Frequency (Hz)
The magnitude spectrum of signal s1 shifted

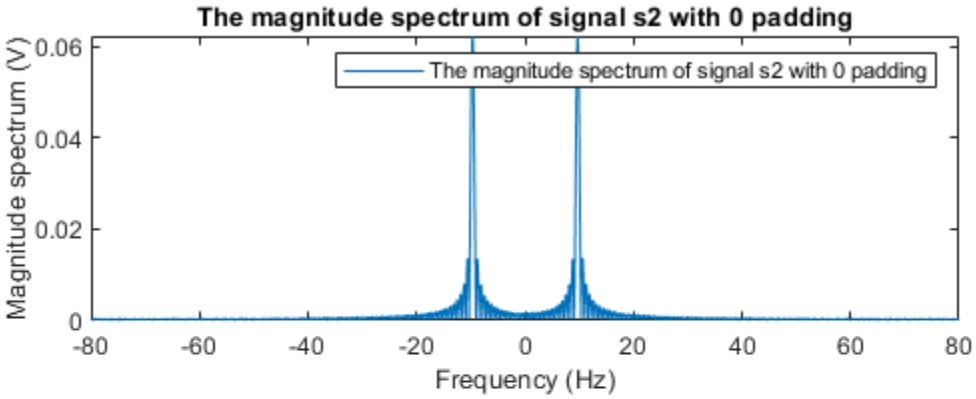

The phase spectrum of signal s1 shifted
Phase spectrum (Rad)
Frequency (Hz)
The phase spectrum of signal s1 shifted

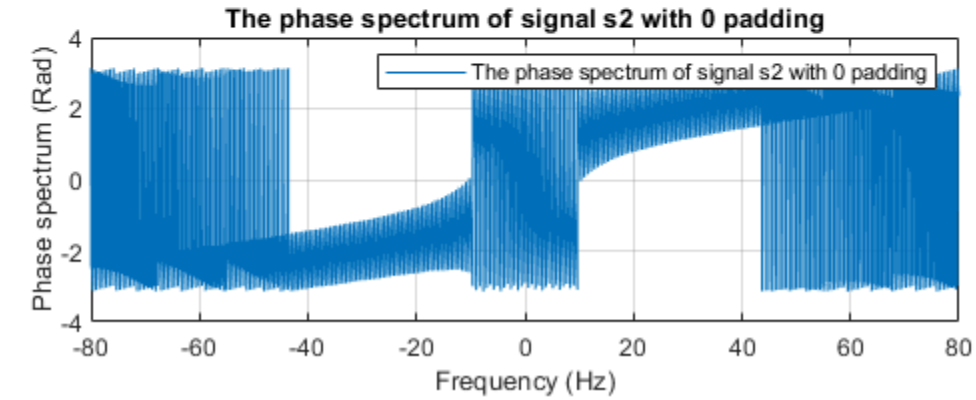

The magnitude spectrum of signal s2 shifted
Magnitude spectrum (V)
Frequency (Hz)
The magnitude spectrum of signal s2 shifted

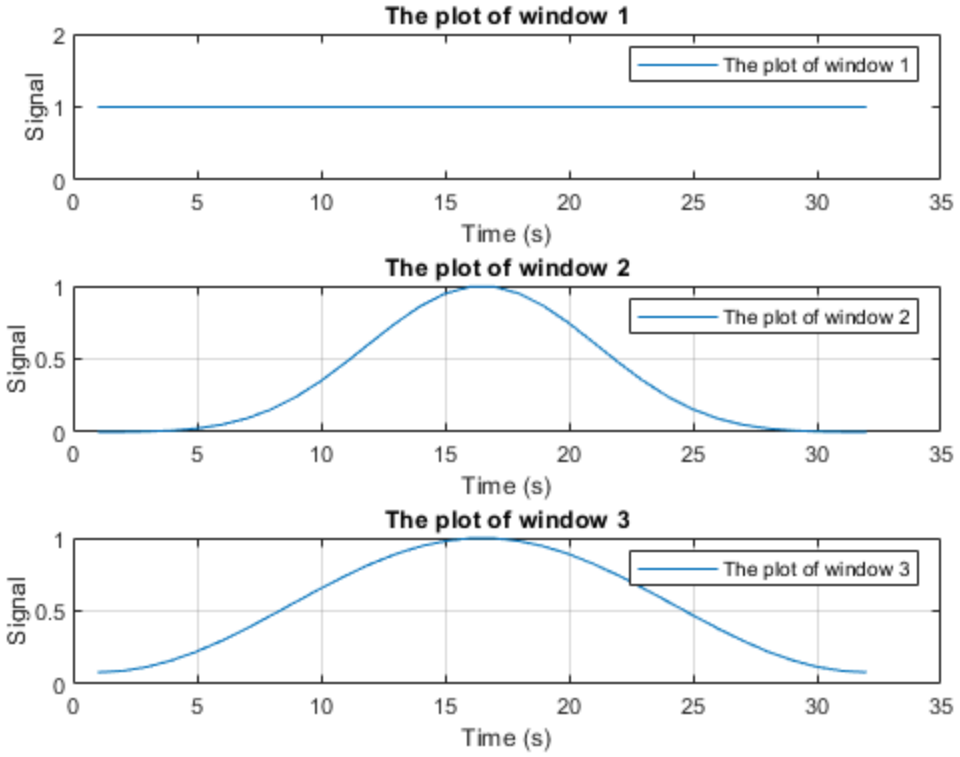

The phase spectrum of signal s2 shifted
Phase spectrum (Rad)
Frequency (Hz)
The phase spectrum of signal s2 shifted

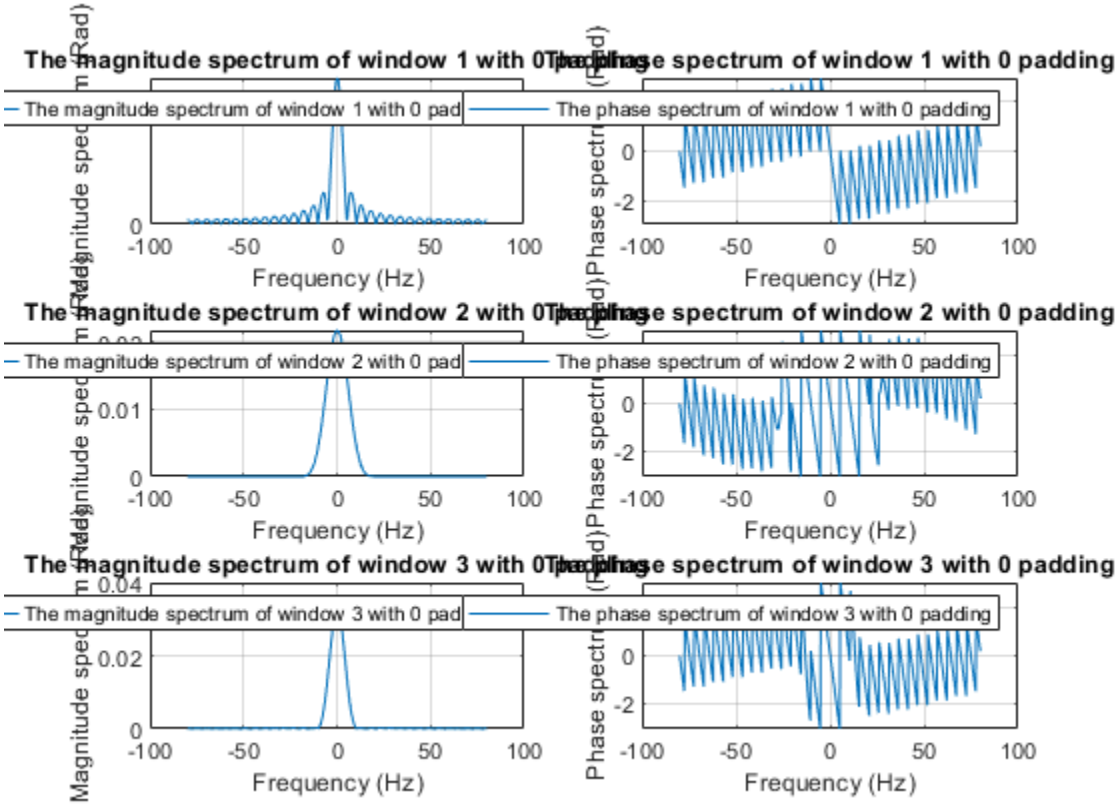

The magnitude spectrum of signal s1 with 0 padding
Magnitude spectrum (V)
0.03
0.02
0.01
0
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The magnitude spectrum of signal s1 with 0 padding

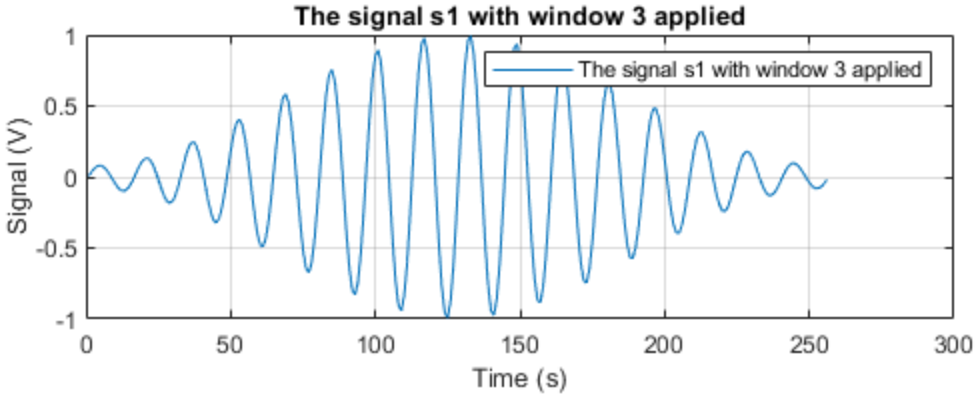

The phase spectrum of signal s1 with 0 padding
Phase spectrum (Rad)
4
2
0
-2
-4
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The phase spectrum of signal s1 with 0 padding

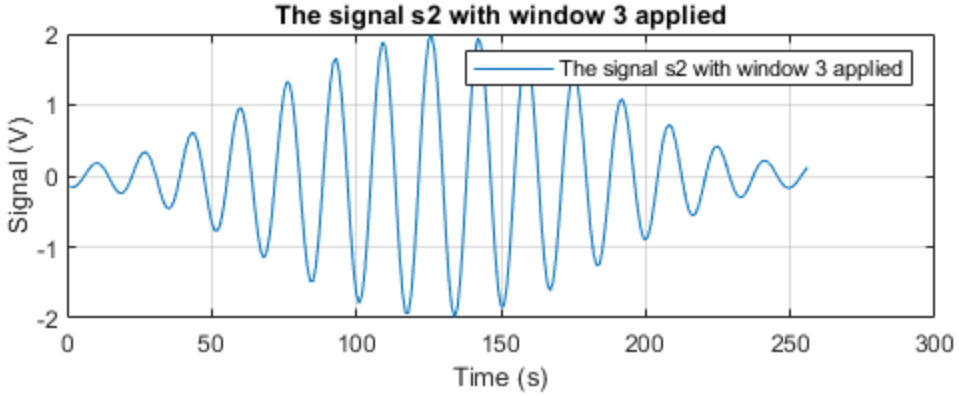

The magnitude spectrum of signal s2 with 0 padding
Magnitude spectrum (V)
0.06
0.04
0.02
0
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The magnitude spectrum of signal s2 with 0 padding

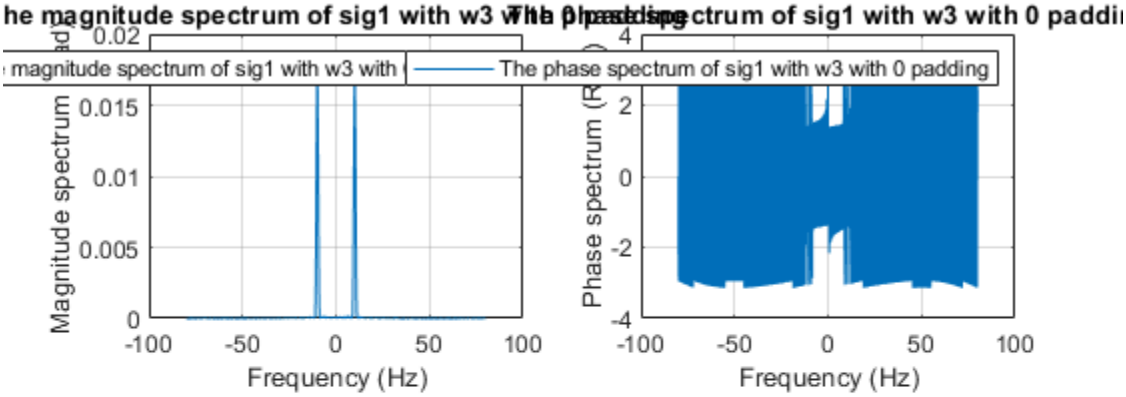

The phase spectrum of signal s2 with 0 padding
Phase spectrum (Rad)
4
2
0
-2
-4
-80
-60
-40
-20
0
20
40
60
80
Frequency (Hz)
The phase spectrum of signal s2 with 0 padding

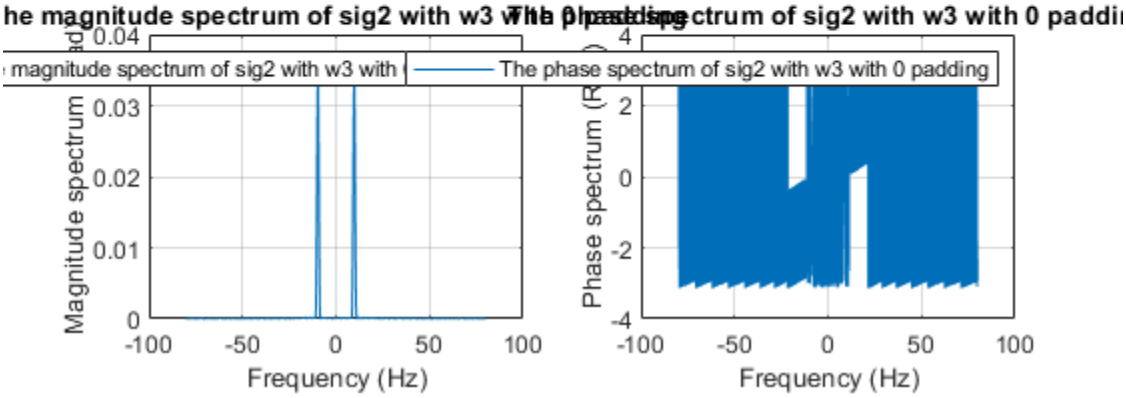

The plot of window 1
The plot of window 1
Signal
Time (s)
The plot of window 2
The plot of window 2
Signal
Time (s)
The plot of window 3
The plot of window 3
Signal
Time (s)

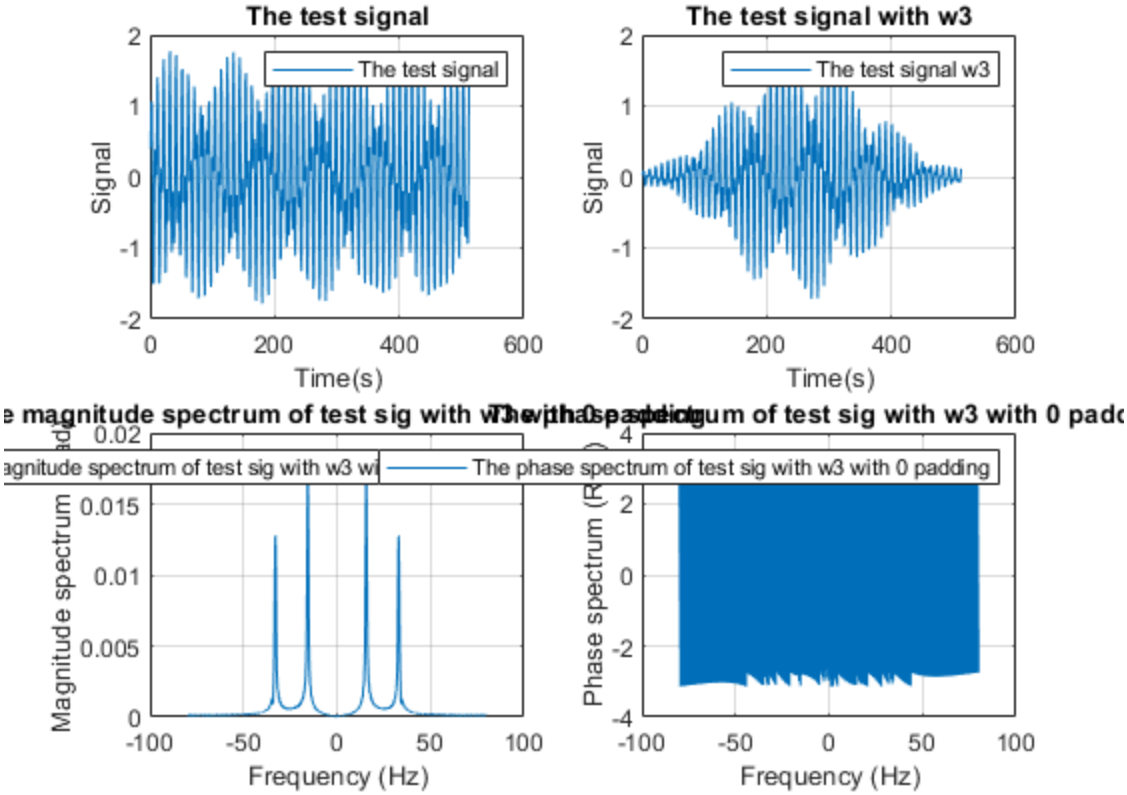

The magnitude spectrum of window 1 with 0 pad
The phase spectrum of window 1 with 0 padding
Frequency (Hz)
The magnitude spectrum of window 2 with 0 pad
The phase spectrum of window 2 with 0 padding
Frequency (Hz)
The magnitude spectrum of window 3 with 0 pad
The phase spectrum of window 3 with 0 padding
Frequency (Hz)


The signal s1 with window 3 applied
The signal s1 with window 3 applied
Signal (V)
Time (s)


The signal s2 with window 3 applied
The signal s2 with window 3 applied
Signal (V)
Time (s)


The phase spectrum of sig1 with w3 with 0 padding
Magnitude spectrum
Phase spectrum (R
Frequency (Hz)
Frequency (Hz)


magnitude spectrum of sig2 with w3 with
The phase spectrum of sig2 with w3 with 0 padding
Magnitude spectrum
Phase spectrum (R
Frequency (Hz)
Frequency (Hz)



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