

Scilab Manual for
Digital Signal Processing Lab
by Dr R Kumaraswamy
Electronics Engineering
Siddaganga Institute Of Technology¹

Solutions provided by
Dr R Kumaraswamy
Electronics Engineering
Siddaganga Institute Of Technology

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13.1 Design of a Notch filter to filter noise at a given frequency . 55

Experiment: 1

Discrete-time signals

Scilab code Solution 1.1 Representation of discrete time signals

```
1
2 //scilab 5.5.2 ,OS: Ubuntu 14.04
3 //Generation of signals
4
5 //Unit Sample Sequence
6 clear ;clc ;close ;
7 L = 4; //length= 2*L+1
8 n = -L:L; // Time index
   vector
9 x = [zeros(1,L),1,zeros(1,L) ] ;
10 figure (1);
11 subplot(421),plot2d3(n,x),xlabel('Unit Sample
   sequence ', 'n', 'x_1[n] ');
12
13 //Unit step function
14 //clear ;clc ;close ;
15 n1=0:5
16 x1=[ones(1,6)];
17 subplot(422),plot2d3(n1,x1),xlabel('Unit Step
   sequence ', 'n', 'x_2[n] ');
18 //figure(1); plot2d3(n,x);
```

```

19 //xtitle('Discrete Unit Step Sequence','n','x[n]') ;
20
21 //Unit ramp function
22 //clear ;clc ;close ;
23 L = 4; // Length of the
    sequence
24 n2= -L : L;
25 x2= [zeros(1,L ),0:L ];
26 ,subplot(423),plot2d3(n2,x2),xtitle('Unit Ramp
    sequence','n','x_2[n]')
27 //plot2d3(n,x);
28 //xtitle(' Discrete Unit Ramp Sequence','n','x[n]')
    ;
29
30 //Discrete time Exponential signal
31 //clear ;clc ;close ;
32 a =0.5; //For decreasing a<1 and For increasing
    exponential a>1
33 n3 = 0:10;
34 x3 = (a).^n3 ;
35 subplot(424),plot2d3(n3,x3),xtitle('Exponential
    Sequence','n','x_3[n]')
36 //plot2d3(n,x);xtitle('Exponentially Decreasing
    Signal ','n','x[n]');
37
38
39
40 //Sinusoidal signal
41 //clc;clear;
42 fm=100;// Frequency 100 Hz or input('Enter the input
    signal frequency:'); //100
43 k=3;// Number of cycles:3 or input('Enter the number
    of Cycles of input signal:'); //3
44 A=1; // Unit amplitude or input('Enter the amplitude
    of input signal:'); //5
45 tm=0:1/(fm*k):k/fm;
46 x4=A*cos(2*%pi*fm*tm);
47 subplot(425),plot2d3(tm,x4),xtitle('Sinusoidal

```

```

        Signal ', 'n', 'x_4[n]')
48 //figure(1);plot2d3(tm,x);
49 //title('Graphical Representation of Sinusoidal
    Signal');
50 //xlabel('Time');ylabel('Amplitude');
51 //xgrid(1)
52
53 //Square wave
54 //clc;clear;
55 t=(0:0.1:4*%pi)';
56 x5=4*%pi*squarewave(t);
57 subplot(426),plot2d3(t,x5),xtitle('Square wave', 'n',
    'x_5[n]')
58
59
60 //Triangular wave
61 //clear;clc;
62 A=5//input('enter the amplitude:'); //5
63 K= 2//input('enter number of cycles:'); //2
64 x6 = [0:A A-1:-1:1];
65 x7=x6;
66 for i=1:K-1
67 x7=[x7 x6];
68 end
69 n7=0:length(x7)-1; // Index of the sequence
70 subplot(427),plot2d3(n7,x7);xtitle('Triangular wave'
    , 'time', 'amplitude');
71
72 //Sawtooth wave
73 //clc;clear;
74 A=5//input('enter the amplitude:'); //5
75 K=2; //input('enter number of cycles:'); //2
76 x8 = [0:A];
77 x9=x8;
78 for i=1:K-1
79 x9=[x9 x8];
80 end
81 n9=0:length(x9)-1;

```

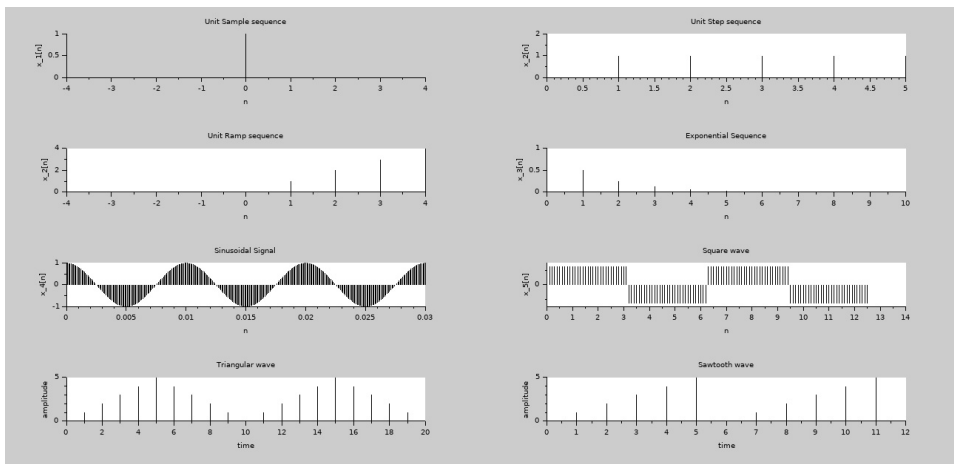


Figure 1.1: Representation of discrete time signals

```

82 subplot(428), plot2d3(n9, x9); xtitle('Sawtooth wave', '
    time', 'amplitude');
83
84 // Complex valued signals
85 clc; clear;
86 n= [-10:1:10];
87 a=-0.1+0.3*%i;
88 x=exp(a*n);
89 figure(2);
90 subplot(221), plot2d3(n, real(x)); xtitle('Complex
    valued signal', 'n', 'Real part');
91 subplot(223), plot2d3(n, imag(x)); xtitle('Imaginary',
    'n');
92 subplot(222), plot2d3(n, abs(x)); xtitle('Magnitude
    part', 'n');
93 theta=(180/%pi)*atan(imag(x), real(x));
94 subplot(224), plot2d3(n, theta); xtitle('Phase part', '
    n');

```

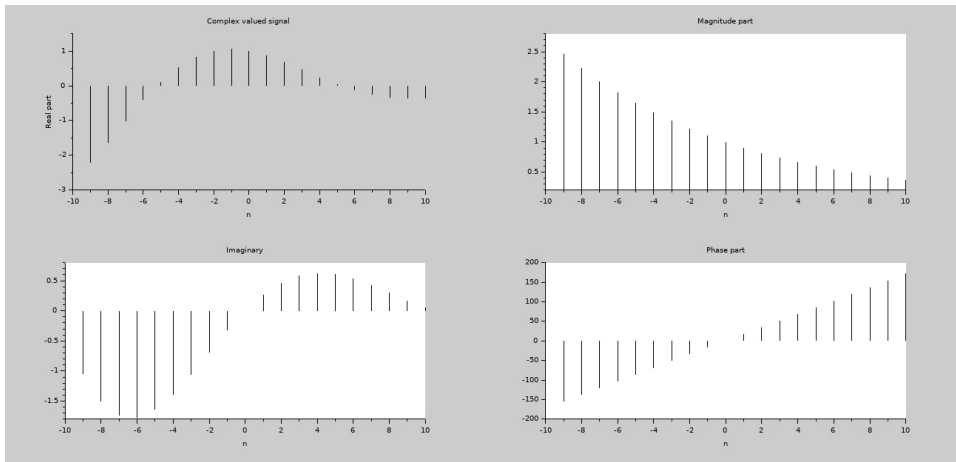


Figure 1.2: Representation of discrete time signals

Experiment: 2

Verification of Sampling Theorem

Scilab code Solution 2.1 To verify Sampling theorem in Time domain

```
1
2 //scilab 5.5.2 , OS: Ubuntu 14.04
3 //Sampling
4 clc; clear;
5 fm=100; //input('Enter the input signal frequency:')
   ; //100
6 k=4; //input('Enter the number of Cycles of input
   signal:'); //2
7 A=1; //input('Enter the amplitude of input signal:');
   //3
8 tm=0:1/(fm*fm):k/fm;
9 x=A*cos(2*%pi*fm*tm);
10 figure(1);
11 subplot(411), plot(tm,x);
12 title('ORIGINAL SIGNAL'); xlabel('Time'); ylabel('
   Amplitude');
13 xgrid(1)
14
15 //Sampling Rate(Nyquist Rate)=2*fm
```

```

16 fnyq=2*fm;
17
18 // UNDER SAMPLING
19 fs=(3/4)*fnyq;
20 n=0:1/fs:k/fm;
21 xn=A*cos(2*%pi*fm*n);
22 //figure(2);
23 subplot(412),plot2d3('gnn',n,xn);
24 plot(n,xn,'r');
25 title('Under Sampling');
26 xlabel('Time');
27 ylabel('Amplitude');
28 legend('Sampled Signal', 'Reconstructed Signal');
29 xgrid(1)
30 //NYQUIST SAMPLING
31 fs=fnyq;
32 n=0:1/fs:k/fm;
33 xn=A*cos(2*%pi*fm*n);
34 //figure(3);
35 subplot(413),
36 plot2d3('gnn',n,xn);
37 plot(n,xn,'r');
38 title('Nyquist Sampling');
39 xlabel('Time');
40 ylabel('Amplitude');
41 legend('Sampled Signal', 'Reconstructed Signal');
42 xgrid(1)
43 //OVER SAMPLING
44 fs=fnyq*10;
45 n=0:1/fs:k/fm;
46 xn=A*cos(2*%pi*fm*n);
47 //figure(4);
48 subplot(414)
49 plot2d3('gnn',n,xn);
50 plot(n,xn,'r');
51 title('Over Sampling');
52 xlabel('Time');
53 ylabel('Amplitude');

```

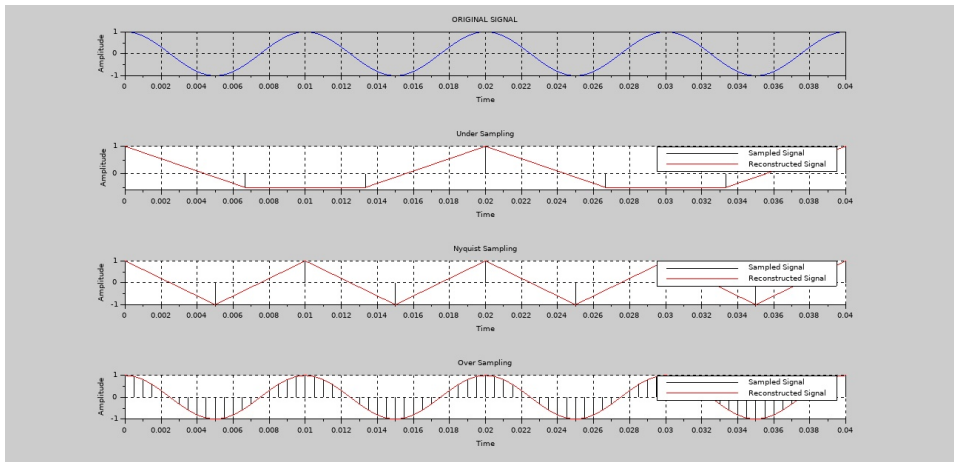


Figure 2.1: To verify Sampling theorem in Time domain

```

54 legend('Sampled Signal', 'Reconstructed Signal');
55 xgrid(1)
56 //Result
57 // Observing plots

```

Experiment: 3

Impulse response of the LTI system

Scilab code Solution 3.1 To determine the impulse response of a system given a difference equation

```
1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 //To determine the impulse response of a LTI system ,
   given the difference equation  $y[n]=b_2 x[n-2]+b_1$ 
    $x[n-1]+ b_0x[n] +a(1)y[n-1]$ 
3 clear all;clc;close;
4 b=input('Enter the coefficients of input x[n]= ');//
   [1]
5 a=input('Enter the coefficients of output y[n]= ');
   //[1 -1 0.9]
6 x=[1 zeros(1,9)];//generate impulse sequence of
   length 10
7 n=0:9;
8 h=filter(b,a,x);
9 figure; plot2d3(n,h),
10 xtitle('Impulse response h[n]','Time index n', 'h[n]
   ',' ');
11 //Example:  $y[n]-y[n-1]+0.9y[n-2]=x[n]$ ; a=[1] b=[1 -1
   0.9]
```

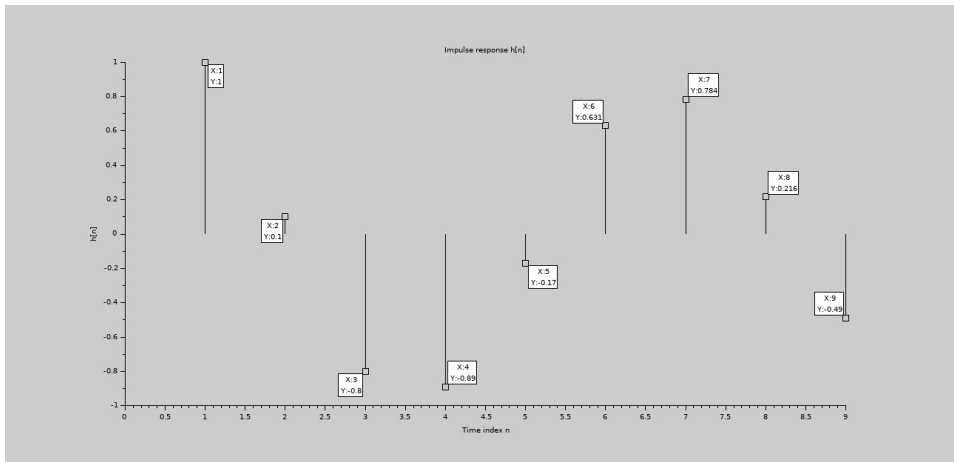


Figure 3.1: To determine the impulse response of a system given a difference equation

- ```

12 //n determines the length of the impulse response
 required
13 //Result:10 samples of h[n
]=[1,1,0.1,-0.8,-0.89,-0.17,0.631,0.784,
 0.216,-0.4895]

```
-

## Experiment: 4

# Frequency response of the LTI system

**Scilab code Solution 4.1** To plot the frequency response of a Digital system

```
1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 //To determine the frequency response of a discrete-
 time system from its difference equation
3
4 //Design steps: Given $y[n] = -a_2 y[n-2] - a_1 y[n-1] + b_0 x[n] + b_1 x[n-1] + b_2 x[n-2]$
5 //1. System function $H(z) = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2}}{1 + a_1 z^{-1} + a_2 z^{-2}}$
6 //2. Put $z = e^{j\omega}$ to get the frequency response
7 //Design example: Plot the magnitude and phase
 response of the system represented by
8 // $6y[n] + 5y[n-1] + y[n-2] = 18x[n] + 8x[n-1]$
9
10
11 clear;clc;
12 close;
13 b=input('Enter the coefficients of x[n] ');// [1 -1]
14 a=input('Enter the coefficients of y[n] ');// [1 -0.5]
```

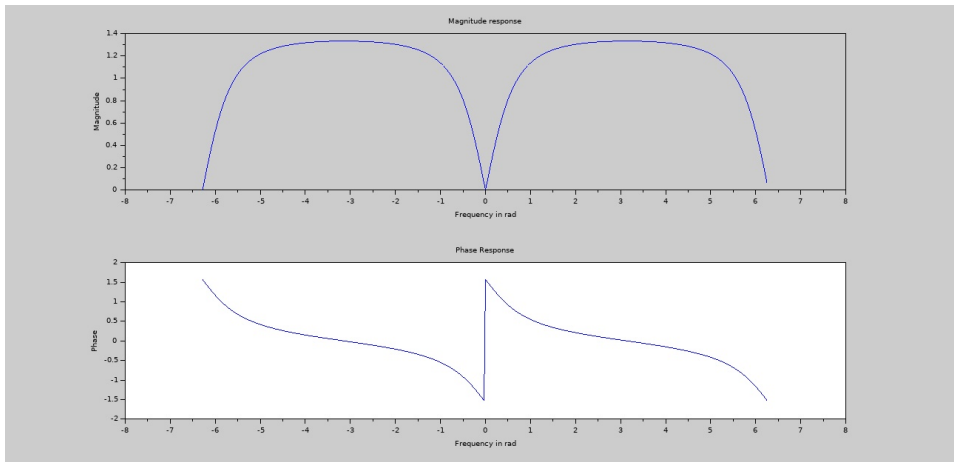


Figure 4.1: To plot the frequency response of a Digital system

```

15 //b=[18, 8];
16 //a=[6 5 1];
17 m= 0: length(b)-1; p=0:length(a)-1;
18 w=-2*%pi:%pi/100:2*%pi;//Plot over a interval of 4pi
 to observe periodicity
19 num = b* exp(-%i*m'*w);
20 den = a*exp(-%i*p'*w);
21 H= num./den;
22 magH = abs(H); angH= atan(imag(H),real(H));
23 figure;
24 subplot(211), plot(w, magH);
25 xtitle('Magnitude response', 'Frequency in rad', '
 Magnitude');
26 subplot(212), plot(w, angH);
27 xtitle('Phase Response', 'Frequency in rad', 'Phase');
28 //Expected result
29 //H = [5,3.5802695 - 1.3881467i,2.6 - i,2.253303 -
 0.4785341i,2.1666667,2.253303 + 0.4785341i,2.6 +
 i,3.5802695 + 1.3881467i,5]

```

---

# Experiment: 5

## Linear and Circular convolution

Scilab code Solution 5.1 To determine linear convolution

```
1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 // Linear Convolution in time and frequency domain
3
4 clc ;clear all;close ;
5
6 x=[1 2 3 4];//input ('enter the input sequence
 values x(n)= '); // [1 2 3 4]
7 h=[1 -1 0 -1];//input('enter the impulse sequence
 values h(n) = ');..// [1 -1 0 -1]
8
9 L1 = length(x);
10 L2 = length(h);
11
12 //Method 1 Using Direct Convolution Sum Formula
13 for i = 1: L1 +L2 -1
14 conv_sum = 0;
15 for j = 1: i
16 if (((i - j +1) <= L2) &(j <= L1))
17 conv_sum = conv_sum + x (j) * h (i -j +1) ;
18 end ;
19 y(i) = conv_sum ;
```

```

20 end ;
21 end ;
22
23 disp(y, ' Convolution Sum using Direct Formula Method
 = ')
24
25 //Method 2 Using In built Function
26 f = convol(x,h)
27 disp(f, ' Convolution Sum Result using Inbuilt
 Function = ')
28
29 //Method 3 Using frequency Domain multiplication
30 N = L1 +L2 -1; //
 Linear convolution output length
31 x = [x zeros(1 ,N - L1)];
32 h = [h zeros(1 ,N - L2)];
33 f1 = fft(x)
34 f2 = fft(h)
35 f3 = f1.* f2 ; //
 Multiplication in frequency domain
36 f4 = ifft(f3)
37 disp (f4 , 'Convolution Sum Result DFT and IDFT
 method = ')
38
39 //To plot input , impulse and output signals .
40 subplot (5,1,1) ;plot2d3(x);xtitle('Input signal x '
 , 'n' , 'x[n] ');
41 subplot(5,1,2) ;plot2d3(h);xtitle('Impulse signal h'
 , 'n' , 'h[n] ');
42 subplot(5,1,3) ;plot2d3(y);xtitle('Liner Convolution
 using formula', 'n' , 'y1[n] ');
43 subplot(5,1,4) ;plot2d3(f);xtitle('Linear
 Convolution using Inbuilt function', 'n' , 'y2[n] ');
44 subplot(5,1,5) ;plot2d3(f);xtitle('Linear
 Convolution using DFT method', 'n' , 'y3[n] ');
45
46 // Expected result
47 //1. 1. 1. 0. - 6. - 3. - 4.

```

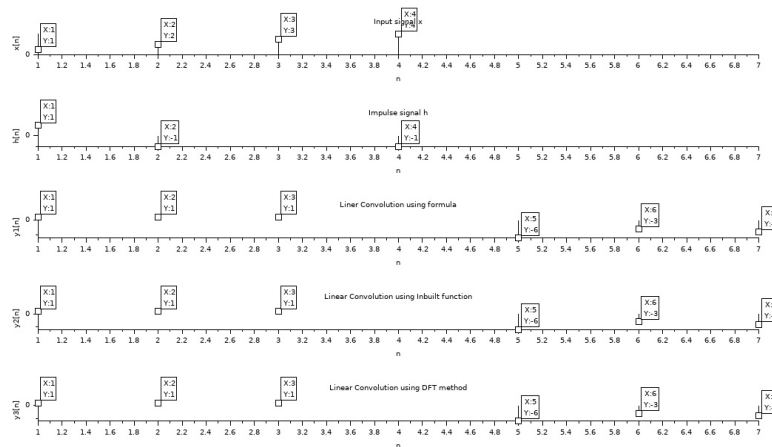


Figure 5.1: To determine linear convolution

### Scilab code Solution 5.2 Circular convolution in time domain and using DFT relations

```

1
2 //scilab 5.5.2 , OS: Ubuntu 14.04
3 // Circular convolution of given discrete sequences
 in time domain (Matrix method)
4 clear;clc;
5 x1=input('enter the first sequence values x1(n)= ');
 ; // [1 2 3 4]
6 x2=input('enter the second sequence values x2(n) = ');
); // [1 -1 0 -1]
7 L1 = length(x1); //length of
 first sequence
8 L2 = length(x2); //length of
 second sequence
9

```

```

10 if (L1 >L2) //To make
 length of x1 and x2 are Equal
11 for i = L2+1:L1
12 x2(i) = 0;
13 end
14 elseif (L2>L1)
15 for i = L1+1:L2
16 x1(i) = 0;
17 end
18 end
19
20 N = length(x1);
21 x3 = zeros(1,N); //x3 =
 Circular convolution result
22 a(1) = x2(1);
23 for j = 2:N
24 a(j) = x2(N-j+2);
25 end
26 for i =1:N
27 x3(1) = x3(1)+x1(i)*a(i);
28 end
29 X(1,:) =a;
30
31 //Calculation of circular convolution
32 for k = 2:N
33 for j =2:N
34 x2(j) = a(j-1);
35 end
36 x2(1) = a(N);
37 X(k,:) = x2;
38 for i = 1:N
39 a(i) = x2(i);
40 x3(k) = x3(k)+x1(i)*a(i);
41 end
42 end
43 disp(X, 'Circular Convolution Matrix x2[n]= ')
44 disp(x3, 'Circular Convolution Result x3[n] = ')
45 // Expected result

```

```

46 //Circular Convolution Matrix x2[n]=
47
48 // 1. - 1. 0. - 1.
49 // - 1. 1. - 1. 0.
50 // 0. - 1. 1. - 1.
51 // - 1. 0. - 1. 1.
52
53 //Circular Convolution Result x3[n] =
54
55 // -5. -2. -3. 0.
56
57 // Circular Convolution in frequency domain (DFT-
 IDFT method)
58 clear all;clc;close;
59 x1=input('enter the first sequence values x1(n)= ');
 ; // [1 2 3 4]
60 x2=input('enter the second sequence values x2(n) = ');
 ; // [1 -1 0 -1]
61 L=input('enter the length of the sequence values L=
 '); //4
62
63 //Computing DFT
64 X1 = fft(x1,-1); // -1 for direct
 FFT
65 X2 = fft(x2,-1);
66 disp(X1,'DFT of x1[n] is X1(k)=')
67 disp(X2,'DFT of x2[n] is X2(k)=')
68
69 //Multiplication of 2 DFTs
70 X3 = X1.*X2;
71 disp(X3,'DFT of x3[n] is X3(k)=')
72 x3 =(fft(X3,1)) //
 Circular Convolution Result ,1 for IFFT
73 disp(x3,'Circular Convolution x3[n]=')
74 //// Expected result
75 //DFT of x1[n] is X1(k)= 10. - 2. + 2.i - 2.
 - 2. - 2.i
76

```

```

77 //DFT of x1[n] is X2(k)= - 1. 1. 3. 1.
78
79 // DFT of x3[n] is X3(k)= - 10. - 2. + 2.i -
 6. - 2. - 2.i
80
81 //Circular Convolution x3[n]= -5. -2.
 -3. 0.
82
83 ////Performing Linear Convolution using Circular
 Convolution
84 clear;clc;
85 x=input ('enter the input sequence values x(n)= ');
 // [1 2 3 4]
86 h=input('enter the impulse sequence values h(n) = ')
 ; // [1 -1 0 -1]
87 N1 = length(x); //Length of input signal
88 N2 = length(h); //Length of impulse response
89
90 N = N1+N2-1 // Length of
 output response
91 disp(N, 'Length of Output Response y(n)')
92
93 //Padding zeros to Make Length of 'h' and 'x' equal
 to length of output response 'y'
94
95 h1 = [h,zeros(1,N-N2)];
96 x1 = [x,zeros(1,N-N1)];
97
98 H = fft(h1,-1);
99 X = fft(x1,-1);
100 //Multiplication of 2 DFTs
101 Y = X.*H
102 y =(fft(Y,1)) //Linear Convolution Result
103
104 disp(X, 'DFT of i/p X(k)=')
105 disp(H, 'DFT of impulse sequence H(k)=')
106 disp(Y, 'DFT of Linear Filter o/p Y(k)=')
107 disp(y, 'Linear Convolution result y[n]=')

```

```

108
109 //Expected output
110 //Length of Output Response y(n) 7.
111
112 //DFT of i/p X(k)= 10. - 2.0244587 -
 6.2239817i , 0.3460107 + 2.4791213i ,
 0.1784479 - 2.4219847i , 0.1784479 +
 2.4219847i , 0.3460107 - 2.4791213i , -
 2.0244587 + 6.2239817i ,
113 //DFT of impulse sequence H(k)= - 1.
 1.2774791 + 1.2157152i , , 0.5990311 +
 0.1930964i , 2.1234898 + 1.4088117i ,
 2.1234898 - 1.4088117i , 0.5990311 -
 0.1930964i , 1.2774791 - 1.2157152i ,
114 //DFT of Linear Filter o/p Y(k)= - 10.
 4.9803857 - 10.412171i , - 0.2714383 +
 1.5518843i , 3.7910526 - 4.8916602i ,
 3.7910526 + 4.8916602i , - 0.2714383 -
 1.5518843i , 4.9803857 + 10.412171i ,
115 //Linear Convolution result y[n]= 1. 1.
 1. 0. -6. -3. -4.

```

---

# Experiment: 6

## Spectral analysis using DFT

Scilab code Solution 6.1 To demonstrate spectral leakage

```
1
2 //scilab 5.5.2 , OS: Ubuntu 14.04
3 // Spectral Leakage
4 //Check the result for the following cases
5 //case(1): fm=10;fs=125;m=1;m=number of cycles
6 //case(2): fm=10;fs=125;m=2;
7 //case(3): fm=200;fs=10000;m=2.5;
8 //case(4): fm=75;fs=250;m=3;
9
10 clc;clear;close;
11 //fm=input('Enter the frequency of the input signal
 ');//message frequency in Hz
12 //fs=input('Enter the sampling frequency');//
 sampling frequency in Hz
13 //m=input('Enter the number of cycles of the input
 signal');// Number of cycles
14 //Case2:No spectral leakage
15 fm=10;fs=125;m=2;//Oversampling and integer number
 of cycles
16 t=0.0001:1/fs:m/fm;
17 x=3*cos(2*%pi*fm*t); //signal
```

```

18 N=(m*fs/fm); //should be non-
 integer to obtain spectral leakage
19 for k=1:N
20 X1(k)=0;
21 for n=1:length(x)
22 X1(k)=X1(k)+x(n).*exp((-i).*2.*pi.*(n-1).*(k-1)
 ./N);
23 end
24 end
25 k=0:N-1
26 f=k*fs/N; //frequency axis in Hz
27 figure(1), subplot(221), plot2d3(t,x), xlabel('time'),
 ylabel('x(n)'), title('No leakage: m=2, f=10 and
 Fs=125 Hz'), subplot(223), plot2d3(f,abs(X1)),
 xlabel('freq in Hz'), ylabel('Mag'); //Case 3:
 Spectral leakage
28 fm=10; fs=125; m=2.5; //Oversampling and integer
 number of cycles
29 t=0.0001:1/fs:m/fm;
30 x=3*cos(2*pi*fm*t); //signal
31 N=(m*fs/fm); //should be non-
 integer to obtain spectral leakage
32 for k=1:N
33 X1(k)=0;
34 for n=1:length(x)
35 X1(k)=X1(k)+x(n).*exp((-i).*2.*pi.*(n-1).*(k-1)
 ./N);
36 end
37 end
38 k=0:N-1
39 f=k*fs/N; //frequency axis in Hz
40 figure(1), subplot(222), plot2d3(t,x), xlabel('time'),
 ylabel('x(n)'), title('Spectral leakage: m=2.5, f
 =10 and Fs=125 Hz'), subplot(224), plot2d3(f,abs(X1
)), xlabel('freq in Hz'), ylabel('Mag')

```

---

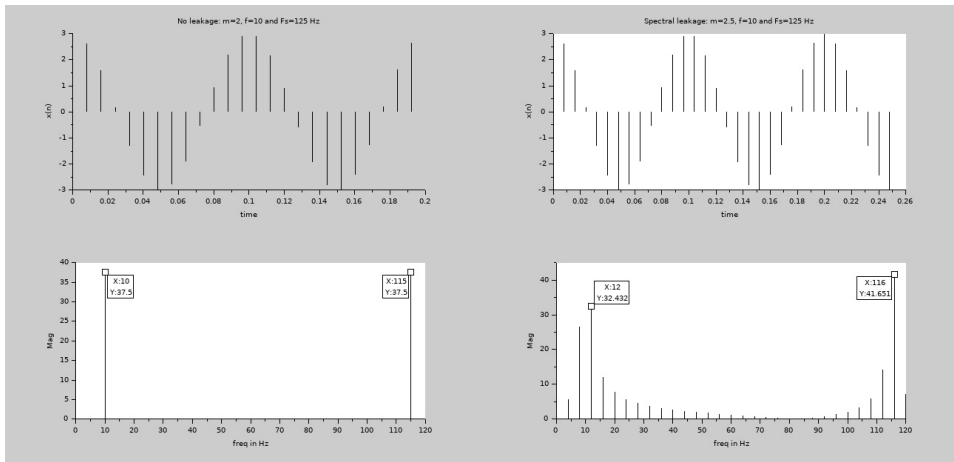


Figure 6.1: To demonstrate spectral leakage

**Scilab code Solution 6.2** To demonstrate effects of zeropadding and zero insertion on the spectrum

```

1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 //Effect of zero padding and interpolation
3 // Effect of Zero padding
4 clc;clear;close;
5 x= input ('enter the input sequence values x(n)= ');
 // [1 2 3 4]
6 k= input ('enter the number of zeros to be padded= ');
 // 1020 (For 1024 point DFT)
7 N=length(x);
8 x_pad=[x zeros(1,k)];
9 N1=length(x_pad);
10 f=0:N-1;
11 f1=0:N1-1;
12 X=abs(fft(x));

```

```

13 X_pad= abs(fft(x_pad));
14 figure(1);
15 subplot(221),plot2d3(x),title(' Original sequence '),
 subplot(223),plot2d3 (f,X), title('Spectrum of
 Original sequence ');
16 subplot(222),plot2d3(x_pad),title('Zero-padded
 sequence '),subplot(224), plot2d3 (f1,X_pad),title
 ('Spectrum of Zero-padded sequence ')
17 //// Effect of inserting zeros in between samples (
 Interpolation)
18 x= input ('enter the input sequence values x(n)= ');
 //[1 2 3 4]
19 k= input ('enter the number of zeros to be inserted=
 ');//2 (Vary and observe effect of zero
 interpolation)
20 x_mod=[];
21 N=length(x);
22 //
23 for i= 1: N
24 x_mod=[x_mod, x(i), zeros(1,k)];
25 end
26 N1=length(x_mod);
27 f=0:N-1;
28 f1=0:N1-1;
29 X=abs(fft(x));
30 X_mod= abs(fft(x_mod));
31 figure(2);subplot(221),plot2d3(x),title(' Original
 sequence '),subplot(223),plot2d3 (f,X), title('
 Spectrum of Original sequence ');
32 subplot(222),plot2d3(x_mod),title('Zero-interpolated
 sequence '),subplot(224), plot2d3 (f1,X_mod),
 title('Spectrum of Zero-inserted sequence ')

```

---

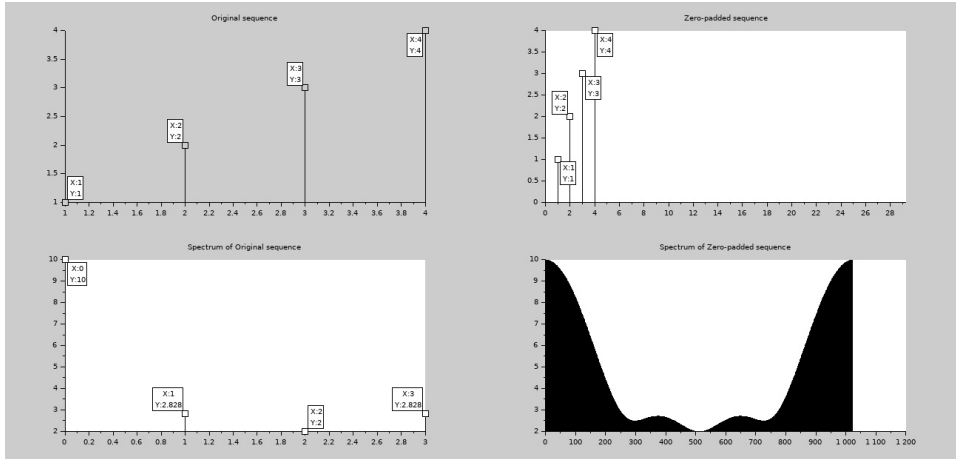


Figure 6.2: To demonstrate effects of zero-padding and zero insertion on the spectrum

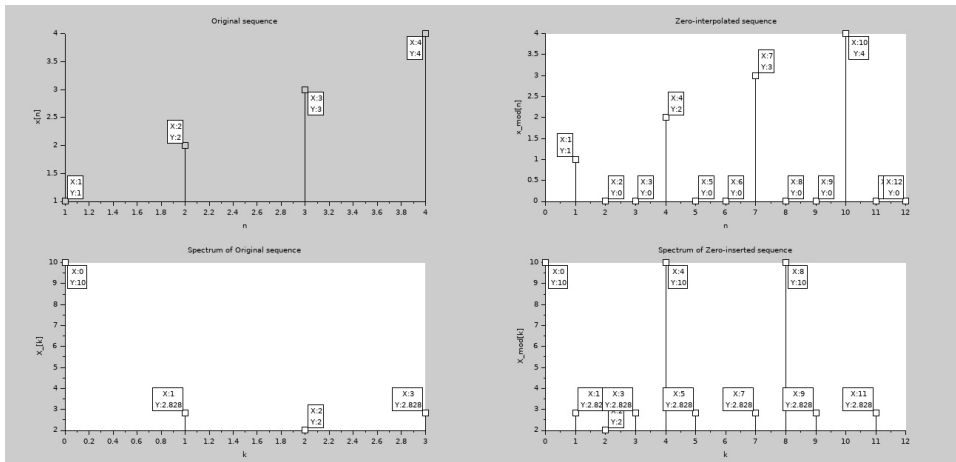


Figure 6.3: To demonstrate effects of zero-padding and zero insertion on the spectrum

# Experiment: 7

## FIR filter design

Scilab code Solution 7.1 Design of FIR filter using Windowing method

```
1
2 //scilab 5.5.2 , OS: Ubuntu 14.04
3 //Design of FIR filters using windowing
4 // Design a digital FIR low pass filter with
 following specifications.
5 //a) Pass band cut-off frequency :wp=
 -----radians
6 //b) Pass band ripple :rp=-----dB
7 //c) Stop band cut-off frequency :ws=
 -----radians
8 //d) Stop band attenuation :rs=
 -----dB
9 //Choose an appropriate window function and
 determine impulse response and provide a plot of
 frequency response of the designed filter.
10
11 //Design example:
12 //Design a digital FIR low pass filter with
 following specifications.
13 //a) Pass band cut-off frequency :0.3 rad
14 //b) Pass band ripple :0.25 dB
```

```

15 //c) Stop band cut-off frequency :0.45 rad
16 //d) Stop band attenuation : 50 dB
17 clc;
18 clear;
19 close;
20 wp=input('enter the pass band edge in rad');
21 ws=input('enter the stop band edge in rad');
22 rs=input('enter the stop band ripple in dB');
23 freq_points=1024;
24 freq_divs=(freq_points/2)-1;
25 k=4; //Hamming window (decided based on stop band
 attenuation)
26 trw=ws-wp;
27 N=(k*2*%pi/trw);
28 N=ceil(N);
29 remainder=N-fix(N./2).*2
30 if remainder==0
31 N=N+1;
32 end
33
34 wc=wp;
35 aph=(N-1)/2;
36 for n=0:N-1
37 if n==aph
38 hdn_minusalph(n+1)=wc/%pi;
39
40 else
41 hdn_minusalph(n+1)= sin(wc.*(n-aph))./(%pi.*(n-
 aph));
42
43 end
44 end
45 n=0:N-1;
46 wndw=window('hm',N);
47
48 hn=hdn_minusalph.*wndw';
49 figure(1);subplot(311);plot2d3(n,wndw);xlabel('n');
 ylabel('wndw');title('Hamming Window function');

```

```

50 subplot(312); plot2d3(n,hdn_minusalph);xlabel('n');
 ylabel('hdn_minusalph');title('Impulse response
 of IIR filter');
51 subplot(313); plot2d3(n,hn);xlabel('n');ylabel('hn')
 ;title('Impulse response of FIR filter');
52 //omega=0:%pi/freq_divs:%pi;
53 h=[hn' zeros(1,freq_points-length(hn))];; //For a
 1024 point DFT
54 H=fft(h);
55 H_mag=20*log10(abs(H));
56 H_ang=atan(imag(H),real(H));
57 H_phase=unwrap(H_ang);
58 w=(0:freq_divs)./(freq_points);
59 w1=w*pi;
60 figure(2);subplot(211),plot2d(w1,H_mag(1:512));
61 xtitle('Magnitude response','w (rad)','Magnitude(dB)
 ');
62 subplot(212),plot2d(w1,H_phase(1:512));
63 xtitle('Phase Response','w (rad)','Phase (rad)');
64
65
66
67 //Problems:
68
69 //1. Design a digital FIR low pass filter with
 following specifications.
70 //a) Pass band cut-off frequency :0.4 rad
71 //b) Pass band ripple :0.25 dB
72 //c) Stop band cut-off frequency :0.6 rad
73 //d) Stop band attenuation : 44 dB
74
75 //2. Design a digital FIR low pass filter with
 following specifications.
76 //a) Pass band cut-off frequency :0.25 rad
77 //b) Pass band ripple :0.25 dB
78 //c) Stop band cut-off frequency :0.3 rad
79 //d) Stop band attenuation : 50 dB

```

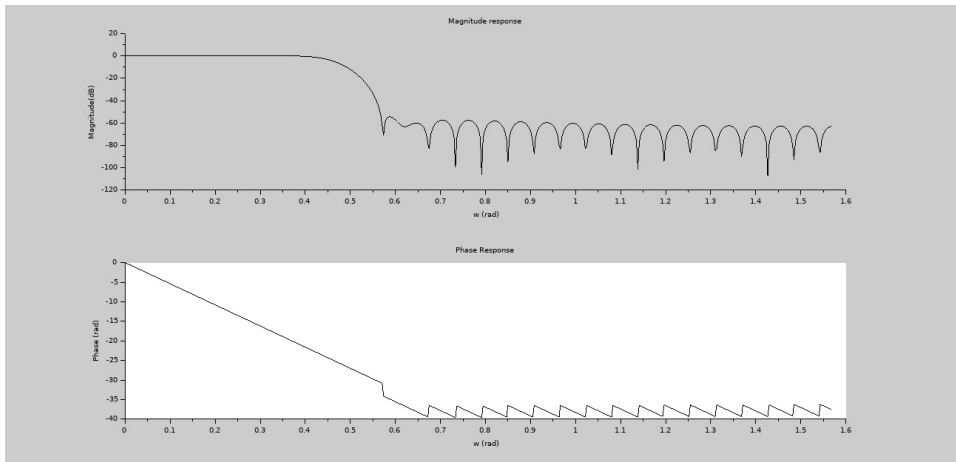


Figure 7.1: Design of FIR filter using Windowing method

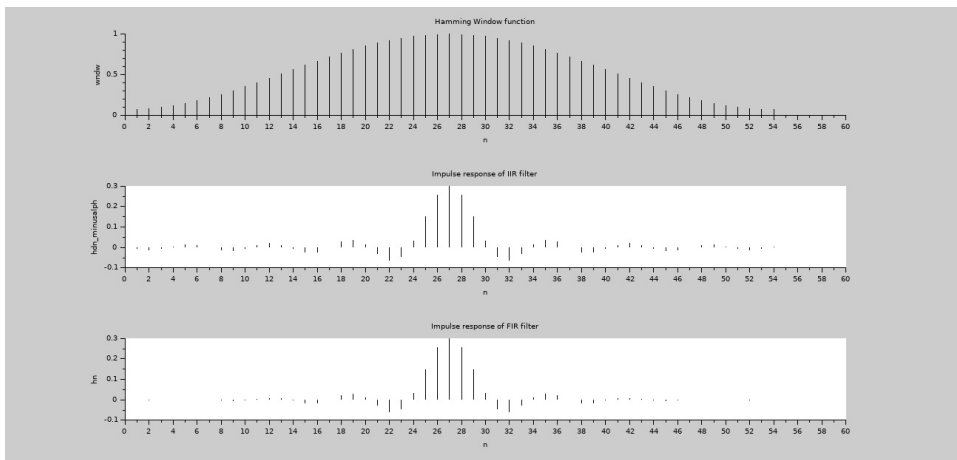


Figure 7.2: Design of FIR filter using Windowing method

## Experiment: 8

# Design of Hilbert transformer using FIR filter

Scilab code Solution 8.1 Design of a digital Hilbert Transformer using FIR filter

```
1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 //Design a differentiator using a Hamming window of
 length N=21. Plot the time and frequency domain
 responses.
3 //Design a length-25 digital Hilbert transformer
 using a Hann window.
4
5 //Design of Hilbert transformer
6 //The ideal frequency response of a linear phase
 Hilbert transformer is given by
7 //Hd(ejw) = -j e(-j w) , 0 < w < pi
8 // j e(-j w) , -pi < w < 0
9
10 //The ideal impulse response is given by
11
12 //hd(n-)= 2/pi (sin2 pi(n)/2) / (n
),
13 // 0, n=
```

```

14
15
16 //Scilab Program
17 //Inputs: Window length and type of window
18 clc; clear; close;
19
20 N = 41; //input("enter the window length"); //55
21 freq_points=1024;
22 windowfn = window('hm',N); // Hamming window ()Window
 type can be changed here)
23 m = 0:N-1;
24 aph = (N-1)/2;
25 for n=0:N-1
26 if n==aph
27 hd(n+1)=0;
28
29 else
30 hd(n+1)=(2/%pi)*((sin((%pi/2)*(n-aph)).^2)./(n-
 aph));
31
32 end
33 end
34 n=0:N-1;
35 hn = hd.*windowfn';
36
37 omega=-%pi:2*%pi/(freq_points-1):%pi;
38
39 z=%z;
40 den1=real(z^(N-1));
41 num=0;
42 for n=0:N-1
43 num=num+(hn(n+1).*z^(N-n-1));
44 end
45 num1=real(num);
46 Hz=num1./den1;
47 w=exp(%i*omega);
48 rep=freq(Hz("num"),Hz("den"),w);
49 magH=abs(rep);

```

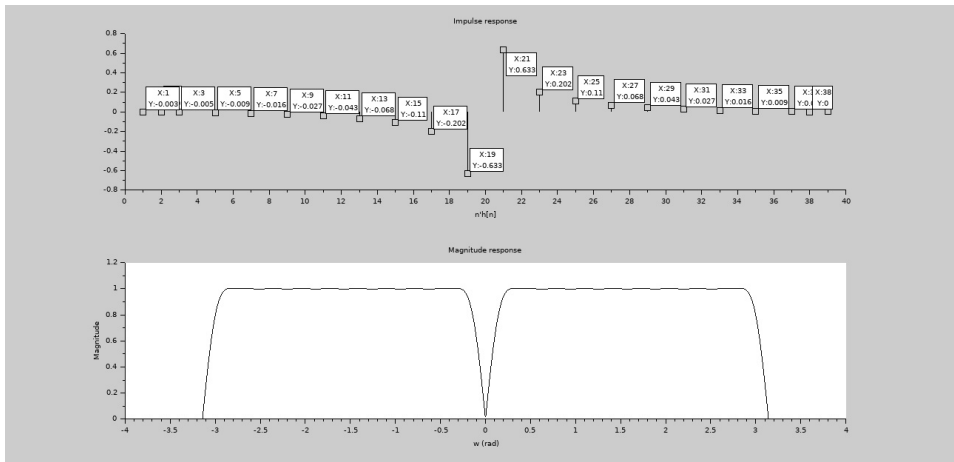


Figure 8.1: Design of a digital Hilbert Transformer using FIR filter

```

50 figure; subplot(211), plot2d3(m, hn), xtitle('Impulse
 response', 'n', 'h[n]')
51 , subplot(212), plot2d(omega, magH);
52 xtitle('Magnitude response', 'w (rad)', 'Magnitude');
53 //Expected result
54 //Magnitude response graph

```

---

## Experiment: 9

# Design of digital differentiator using FIR filter

Scilab code Solution 9.1 Design of Digital Differentiator using a FIR filter

```
1
2 11//scilab 5.5.2 , OS: Ubuntu 14.04
3 //Design a differentiator using a Hamming window of
 length N=21. Plot the time and frequency domain
 response
4 //Inputs: Window length and Type of window
5 //The frequency response of a linear-phase ideal
 differentiator is given by
6 //Hd(ejw) = j , 0 < w <
7 // -jw, -π < w < 0
8 //The ideal impulse response of a digital
 differentiator shifted by π with linear phase is
 given by
9 //hd(n) = cos(πn/2) / (n - 1), n
10 // 0, n =
11
12 //Scilab Program:
```

```

13 clc; clear; close;
14 N = 41; // input("enter the window length"); //55
15 freq_points=1024;
16 windowfn = window('hm',N); //Hamming wuindow (Try with
 different windows)
17 m = 0:N-1;
18 aph = (N-1)/2;
19 for n=0:N-1
20 if n==aph
21 hd(n+1)=0;
22
23 else
24 hd(n+1)= cos(%pi*(n-aph)) ./ (n-aph);
25
26 end
27 end
28 n=0:N-1;
29 hn = hd.*windowfn';
30
31 omega=-%pi:2*%pi/(freq_points-1):%pi;
32
33 z=%z;
34 den1=real(z^(N-1));
35 num=0;
36 for n=0:N-1
37 num=num+(hn(n+1).*z^(N-n-1));
38 end
39 num1=real(num);
40 Hz=num1./den1;
41 w=exp(%i*omega);
42 rep=freq(Hz("num"),Hz("den"),w);
43 magH=abs(rep);
44 figure; subplot(211), plot2d3(m, hn), xtitle('Impulse
 response', 'n', 'h[n]'), subplot(212), plot2d(omega,
 magH);
45 xtitle('Magnitude response', 'w (rad)', 'Magnitude');
46 //Expected result
47 //Magnitude response graph

```

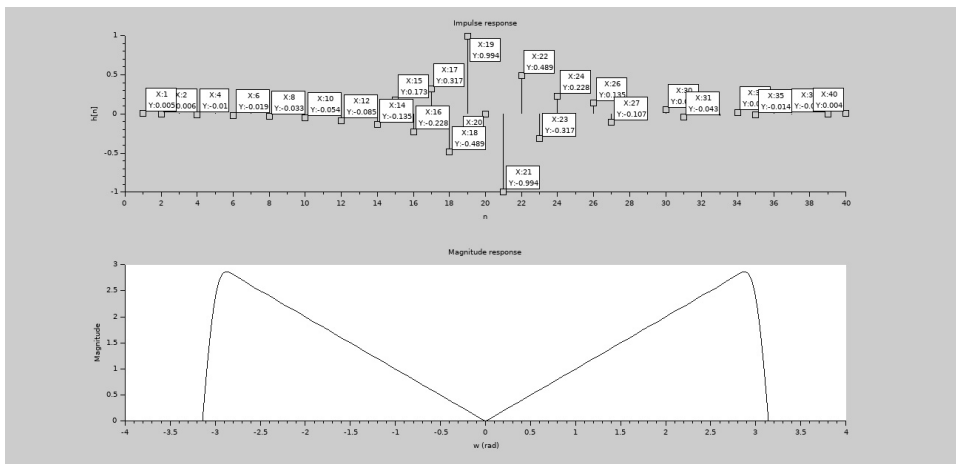


Figure 9.1: Design of Digital Differentiator using a FIR filter

# Experiment: 10

## Design of IIR filter

Scilab code Solution 10.1 Design of digital Butterworth lowpass filter

```
1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 //Program To Design the Digital Butterworth IIR
 Filter
3 //Design a digital IIR low pass filter with
 following specifications.
4 //a) Pass band cut-off frequency :1000 Hz
5 //b) Pass band ripple : -1 dB
6 //c) Stop band cut-off frequency :3000 Hz
7 //d) Stop band attenuation : -15 dB
8 //Sampling frequency: 15000 Hz
9
10 clear all;clc;close;
11 f1=1000;//input('Enter the pass band edge(Hz)= ');
12 f2=3000;//input('Enter the stop band edge(Hz)= ');
13 k1=-1;//input('Enter the pass band attenuation(dB)=
 ');
14 k2=-15;//input('Enter the stop band attenuation(dB)=
 ');
15 fs=10000;//input('Enter the sampling rate(Hz)= ');
16
17 //Digital filter specifications(rad)
```

```

18 w1=2*%pi*f1*1/fs;
19 w2=2*%pi*f2*1/fs;
20
21 //Pre warping
22 o1=2*fs*tan(w1/2)
23 o2=2*fs*tan(w2/2)
24
25 //Design of analog filter
26 n=log10(((10.^(-k1/10))-1)/((10.^(-k2/10))-1))./(2*
 log10(o1/o2));
27 n=round(n);
28 wn= o2./((10.^(-k2/10)-1).^1/(2*n));
29
30 // [h, poles , zeros , gain]=analpf(n, 'butt ', [0 0], wn)hb.
 dt = 'c';
31 // [fr , hr]=repfreq (hb, fmin , fmax)
32
33 h=buttmag(n, wn, 1:2*%pi*fs);
34 mag=20*log10(h)';
35
36
37 //Converting analog to digital filter
38 hz=iir(n, 'lp', 'butt', 0.25, [])
39 //g*poly(z, 'z')/poly(p, 'z')
40
41 [hzm, fr]=frmag(hz, 256);
42 magz=20*log10(hzm)';
43
44 subplot(2,1,1), plot2d((1:2*%pi*fs)', mag), xtitle('
 Analog IIR filter: lowpass', 'Analog frequency in
 rads/sec', 'dB', ' '); subplot(2,1,2), plot2d(fr,
 magz); xtitle('Digital IIR filter: lowpass 0 < fr
 < 0.5', 'frequency', 'dB', ' ');
45
46 //note: Use zoom/axis commands to verify the design.

```

---

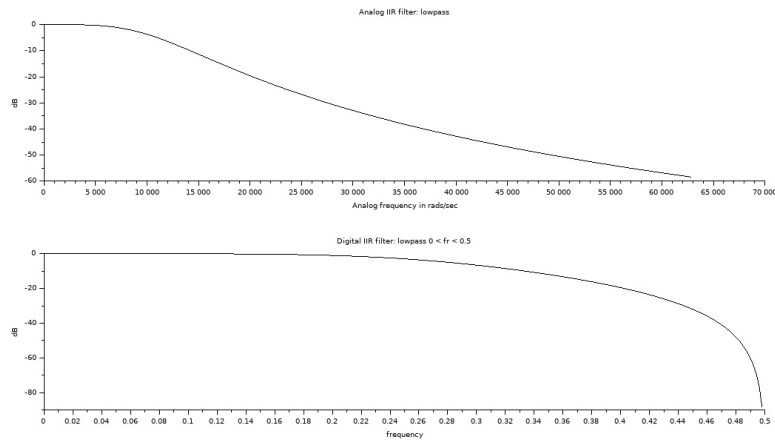


Figure 10.1: Design of digital Butterworth lowpass filter

### Scilab code Solution 10.2 Design of Digital Chebyshev lowpass filter

```

1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 //Program To Design the Digital Chebyshev IIR Filter
3 ////Design example:
4 //Design a digital IIR low pass filter with
 following specifications.
5 //a) Pass band cut-off frequency :1000 Hz
6 //b) Pass band ripple : -1 dB
7 //c) Stop band cut-off frequency :3000 rad
8 //d) Stop band attenuation : -15 dB
9 //Sampling frequency: 15000 Hz
10
11 clear all;clc;close;
12 f1=1000;//input('Enter the pass band edge(Hz)= ');
13 f2=3000;//input('Enter the stop band edge(Hz)= ');
14 rp=-1;//input('Enter the pass band ripple(dB)= ');

```

```

15 rs=-15; //input('Enter the stop band attenuation (dB)=
 ');
16 fs=10000; //input('Enter the sampling rate(Hz)= ');
17 //Digital filter specifications(rad)
18 w1=2*pi*f1*1/fs
19 w2=2*pi*f2*1/fs
20 //Pre warping
21 o1=2*fs*tan(w1/2)
22 o2=2*fs*tan(w2/2)
23 or=o2/o1; //Stop-band edge of normalized lowpass
 filter
24 A2 =10.^(-rs/10);
25 A=sqrt(A2);
26 epsilon2 = (10.^(-rp/10)-1);
27 epsilon=sqrt(epsilon2)
28 g=((A2-1).^0.5./epsilon)
29
30 N = (acosh(g))/(acosh(or))
31 N = ceil(N)
32 oc=o1;
33 // [pols ,gn] = zpch1(N,epsilon ,o1)
34 //Hs = poly(gn, 's', 'coeff')/real(poly(pols, 's'))
35 h=cheb1mag(N,oc,epsilon,1:2*pi*fs);
36 mag=20*log10(h)';
37 //plot2d((1:1000)',mag,[2],"011", " ", [ymax,ymin ,fmax
 ,fmin])
38 //gain=20*log10(abs(h_s)); %Verify the specification
 [k1,k2] at prewarped frequencies
39 //subplot(211);
40 //plot(omega ,gain);
41 //xlabel(frequency in rad/sec);
42 //Converting analog to digital filter
43 fc=w1/(2*pi);
44 delta1=(1-(1./A2));
45 //1-ripple in passband
46 hz=iir(N, 'lp', 'cheb1', [fc],[delta1 0]);
47 //for cheb1 filters 1-delta(1)<ripple<1 in passband
48 //g*poly(z, 'z')/poly(p, 'z')

```

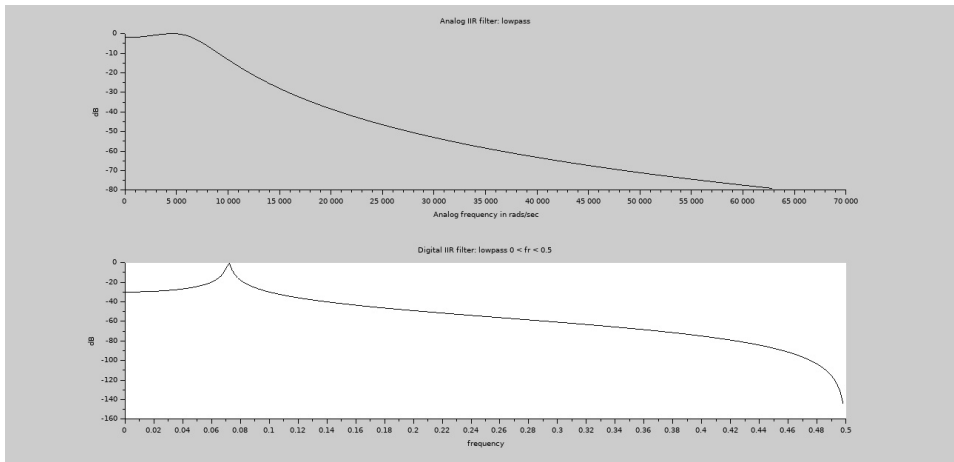


Figure 10.2: Design of Digital Chebyshev lowpass filter

```

49 [hzm, fr]=frmag(hz, 256);
50 magz=20*log10(hzm)';
51 figure(1); subplot(2,1,1), plot2d((1:2*%pi*fs)', mag),
 xtitle('Analog IIR filter: lowpass', 'Analog
 frequency in rads/sec', 'dB', ' '); subplot(2,1,2),
 plot2d(fr, magz); xtitle('Digital IIR filter:
 lowpass 0 < fr < 0.5', 'frequency', 'dB', ' ');

```

---

# Experiment: 11

## Application of IIR filter

**Scilab code Solution 11.1** To design a digital IIR Butterworth filter to suppress noise

```
1 //scilab 5.5.2 , OS: Ubuntu 14.04
2 // This program will suppress noise at f=4000 Hz
 using Butterworth prototype
3 //pass band edge=f1=1500Hz
4 //stop band edge=f2=2000 Hz
5 //sampling rate =Fs=10000 Hz = 1/Ts
6 //passband attenuation = -1db
7 //stop attenuation = -3 db
8
9 clear all;clc;close;
10 f1=input('Enter the pass band edge(Hz)= ');
11 f2=input('Enter the stop band edge(Hz)= ');
12 k1=input('Enter the pass band attenuation(dB)= ');
13 k2=input('Enter the stop band attenuation(dB)= ');
14 fs=input('Enter the sampling rate(Hz)= ');
15
16 signal_fo=1000;
17 noise_fo=4000;
18
19 //Digital filter specifications(rad)
```

```

20 w1=2*%pi*f1*1/fs;
21 w2=2*%pi*f2*1/fs;
22
23 //Pre warping
24 o1=2*fs*tan(w1/2)
25 o2=2*fs*tan(w2/2)
26
27 //Design of analog filter
28 n=log10(((10.^(-k1/10))-1)/((10.^(-k2/10))-1))./(2*
 log10(o1/o2));
29 n=round(n);
30 wn= o2./((10.^(-k2/10)-1).^1/(2*n));
31
32 // [h, poles , zeros , gain]=analpf(n, 'butt', [0 0], wn)hb.
 dt = 'c';
33 // [fr , hr]=repfreq (hb, fmin , fmax)
34
35 h=buttmag(n, wn, 1:2*%pi*fs);
36 mag=20*log10(h)';
37 //plot2d((1:2*%pi*fs)', mag)
38 //xtitle('Analog IIR filter: lowpass', 'Analog
 frequency in rads/sec', 'dB', ' ');
39
40 //Converting analog to digital filter
41 hz=iir(n, 'lp', 'butt', 0.25, [])
42 //g*poly(z, 'z')/poly(p, 'z')
43
44 [hzm, fr]=frmag(hz, 256);
45 magz=20*log10(hzm)';
46 fr1=fr*fs;
47 //figure; plot2d(fr1', magz'); xtitle('Digital IIR
 filter: lowpass 0 < fr < 0.5', 'frequency', 'dB', '
 ');
48
49 ///////note: Use zoom/axis commands to verify the
 design.
50 //These coefficients are to be read from variable hz
 (line 41, output of iir function)

```

```

51 num=[0.2928 0.5858 0.2928];
52 den=[1 0 0.1716]; // In negative powers of z
53
54 //Signal generation (sine wave of frequency 1000 Hz)
 of length 1 second
55 t=0:1/fs:10/signal_fo; //10 cycles of input
56 original_signal=sin(2*%pi*signal_fo*t);
57
58 //Noise generation (sine wave of frequency 4000 Hz)
 of length 1 second
59 t=0:1/fs:10/signal_fo;
60 noise=sin(2*%pi*noise_fo*t);
61
62 noisy_signal=original_signal+noise;
63
64 filter_output=filter(num,den,noisy_signal);
65
66 //Plot original, noisy and filtered outputs
67
68 figure;subplot(3,1,1), plot2d(t,original_signal),
 xtitle('Original_signal','t','x(t)'),
69 subplot(3,1,2), plot2d(t,noisy_signal),xtitle('
 Noisy_signal','t','n(t)'),
70 subplot(3,1,3), plot2d(t,filter_output),xtitle('
 Filtered_signal','t','y(t)'),
71 l1=length(original_signal);
72 l2=length(noisy_signal);
73 N=512;
74 x=[original_signal zeros(1,N-l1)]; //To make it of
 length 512
75 n=[noisy_signal zeros(1,N-l1)];
76 y=[filter_output zeros(1,N-l1)];
77 X=fft(x);
78 N=fft(n);
79 Y=fft(y);
80 f=(0:511)*fs;
81 figure;
82 subplot(3,1,1), plot2d(f,abs(X)),xtitle('

```

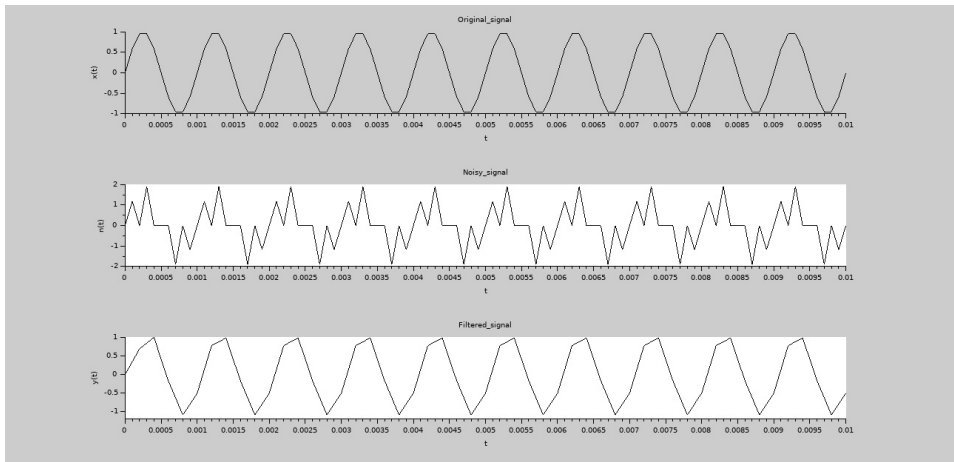


Figure 11.1: To design a digital IIR Butterworth filter to suppress noise

```

Original_signal', 'F', 'X(f) '),
83 subplot(3,1,2), plot2d(f,abs(N)), xtitle('
 Noisy_signal', 'F', 'N(f) '),
84 subplot(3,1,3), plot2d(f,abs(Y)), xtitle('
 Filtered_signal', 'F', 'Y(f) ');

```

---

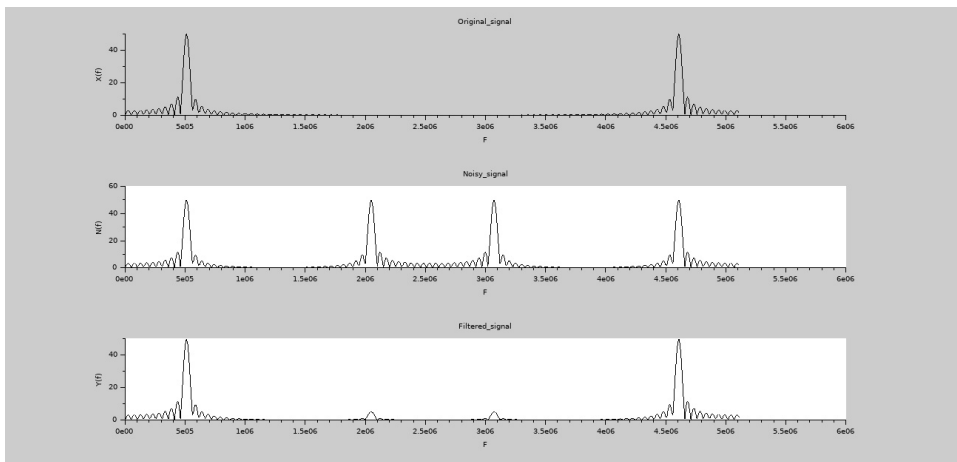


Figure 11.2: To design a digital IIR Butterworth filter to suppress noise

# Experiment: 12

## Design of Notch filter

**Scilab code Solution 12.1** Suppression of noise at a given frequency using Notch filter

```
1
2 //scilab 5.5.2 , OS: Ubuntu 14.04
3 //Program To Design a simple notch filter and verify
4 // Design a simple notch filter to stop a
 disturbance with frequency F_0=3.5 kHz and a
 sampling frequency F_s=8 kHz.
5 //Also, verify the notch filter operation by adding
 a sinewave of F_0 Hz to a speech signal, filter
 and verify.
6
7 //Scilab Program:
8 clc;clear;close;
9 f=3500;//input("Enter the frequency in Hz");
 //3500
10 fs=8000;//input("Enter the sampling rate");
 //8000
11 r=0.98;//input("Enter the radius of the pole in the
 z-plane"); //0.98
12 w=2*%pi*f/fs;
13 z1=exp(%i*w);
```

```

14 z2=exp(-%i*w);
15 p1=r*exp(%i*w);
16 p2=r*exp(-%i*w);
17 z=%z;
18 num1=(real((z-z1)*(z-z2)))
19 den1=(real(((z-p1)*(z-p2))))
20 Hz=num1./den1
21 //figure(1);plzr(Hz);zgrid()
22 [h1 fr]=frmag(Hz,512)
23 figure(1);plot2d(fr*fs,h1);xlabel('Magnitude
 response','frequency in Hz','Mag');
24
25 //Noise generation
26
27 original_signal=wavread('home/hyrkswamy/kswamy/
 Coursework/SAP/wav/mask.wav');
28 t=0:1/fs:(length(original_signal)-1)/fs;
29 noise=sin(2*pi*f*t);
30 noisy_signal=original_signal+noise;
31
32 filter_output=filter(num1,den1,noisy_signal);
33
34 //Play back the original, noisy and filtered outputs
35 playsnd(original_signal,fs);
36 pause;
37 playsnd(noisy_signal,fs);
38 pause;
39 playsnd(filter_output,fs);

```

---

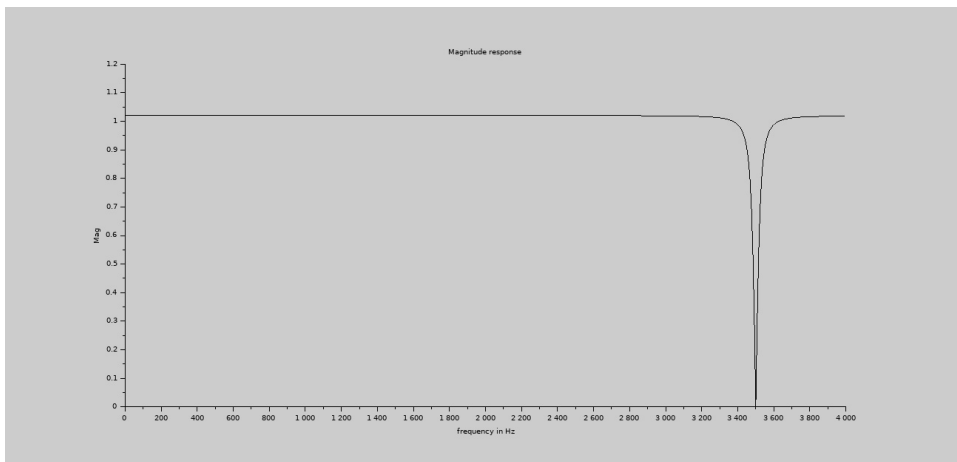


Figure 12.1: Suppression of noise at a given frequency using Notch filter

# Experiment: 13

## Design of Resonator

**Scilab code Solution 13.1** Design of a Notch filter to filter noise at a given frequency

```
1
2 //scilab 5.5.2 , OS: Ubuntu 14.04
3 //Design a digital resonator that resonates at 1000
 Hz. Assume Fs=8000 Hz.
4 // Calculate the pole location
5 //w=2*pi*f/fs;
6 //Complex conjugate pair of poles at w=pi/4 and -pi
 /4
7 //Assume radius=0.98 (near to unit circle but inside
 the unit circle)
8
9 //Scilab Program:
10 clc;
11 clear;
12 close;
13 f=1000;//input("Enter the frequency in Hz");
 //1000
14 fs=8000;//input("Enter the sampling rate");
 //8000
15 r=0.98;//input("Enter the radius of the pole in the
```

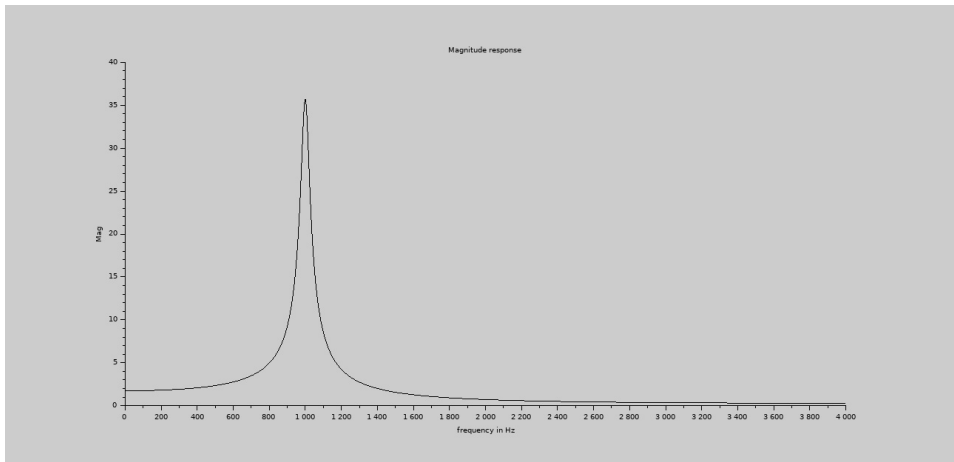


Figure 13.1: Design of a Notch filter to filter noise at a given frequency

```

 z-plane"); //0.98
16 w=2*%pi*f/fs;
17 pole1=r*exp(%i*w);
18 pole2=r*exp(-%i*w);
19
20 z=%z;
21
22 num1=real(z^(2));
23 den1=real(z^(2)-1.3859293*z+0.9604);
24 Hz=num1./den1;
25 //figure;
26 //plzr(Hz);
27 [h1 fr]=frmag(Hz,1024);
28 figure;
29 plot2d(fr*fs,h1);
30 xtitle('Magnitude response','frequency in Hz','Mag')
 ;

```

---