

Scilab Manual for
Digital Signal Processing
by Mr Vijay P Sompur
Electronics Engineering
Visvesvraya Technological University¹

Solutions provided by
Mr. R.Senthilkumar- Assistant Professor
Electronics Engineering
Institute of Road and Transport Technology

July 16, 2024

¹Funded by a grant from the National Mission on Education through ICT, <http://spoken-tutorial.org/NMEICT-Intro>. This Scilab Manual and Scilab codes written in it can be downloaded from the "Migrated Labs" section at the website <http://scilab.in>

Contents

List of Scilab Solutions	4
1 Verification of Sampling theorem.	6
2 Impulse response of a given system	11
3 Linear Circular convolution of two given sequences	14
4 Autocorrelation of a given sequence and verification of its properties.	18
5 Cross correlation of given sequences and verification of its properties.	21
6 Solving a given difference equation.	24
7 Computation of N point DFT of a given sequence and to plot magnitude and phase spectrum.	26
8 Linear convolution of two sequences using DFT and IDFT.	30
9 Circular convolution of two given sequences using DFT and IDFT	33
10 Design and implementation of FIR filter to meet given specifications.	35
11 Design and implementation of IIR filter to meet given specifications.	39

List of Experiments

Solution 1.1	Verification of Sampling Theorem	6
Solution 2.2	Program to find impulse response and Frequency Response of a system	11
Solution 3.1	Program to Compute the Convolution of Two Sequences	14
Solution 4.1	Program to Compute the Autocorrelation of a Sequence And verification of Autocorrelation property	18
Solution 5.1	Program to Compute the Crosscorrelation of a Sequence And verification of crosscorrelation property	21
Solution 6.1	Solving Difference Equation Direct Form II Realization	24
Solution 7.1	Program to find the spectral information of discrete time signal Calculation of DFT and IDFT	26
Solution 8.1	Linear Convolution using Circular Convolution DFT IDFT method	30
Solution 9.1	Circular Convolution using DFT IDFT method	33
Solution 10.1	To Design an Low Pass FIR Filter	35
Solution 11.1	To obtain Digital IIR Butterworth low pass filter Frequency response	39
Solution 11.2	To obtain Digital IIR Chebyshev low pass filter Frequency response	43
Solution 12.1	Program to perform circular convolution of two sequences	49

List of Figures

1.1	Verification of Sampling Theorem	9
1.2	Verification of Sampling Theorem	10
2.1	Program to find impulse response and Frequency Response of a system	12
3.1	Program to Compute the Convolution of Two Sequences	15
7.1	Program to find the spectral information of discrete time signal Calculation of DFT and IDFT	27
8.1	Linear Convolution using Circular Convolution DFT IDFT method	31
10.1	To Design an Low Pass FIR Filter	36
11.1	To obtain Digital IIR Butterworth low pass filter Frequency response	40
11.2	To obtain Digital IIR Chebyshev low pass filter Frequency response	44

Experiment: 1

Verification of Sampling theorem.

Scilab code Solution 1.1 Verification of Sampling Theorem

```
1 //Caption: Verification of Sampling Theorem
2 //[1]. Right Sampling [2]. Under Sampling [3]. Over
   Sampling
3 clc;
4 close;
5 clear;
6 fm=input('Enter the input signal frequency:');
7 k=input('Enter the number of Cycles of input signal:
   ');
8 A=input('Enter the amplitude of input signal:');
9 tm=0:1/(fm*fm):k/fm;
10 x=A*cos(2*%pi*fm*tm);
11 figure(1);
12 a = gca();
13 a.x_location = "origin";
14 a.y_location = "origin";
15 plot(tm,x);
16 title('ORIGINAL SIGNAL');
17 xlabel('Time');
```

```

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

```



```
56 figure(4);
57 a = gca();
58 a.x_location = "origin";
59 a.y_location = "origin";
60 plot2d3('gmn',n,xn);
61 plot(n,xn,'r');
62 title('Over Sampling');
63 xlabel('Time');
64 ylabel('Amplitude');
65 legend('Sampled Signal', 'Reconstructed Signal');
66 xgrid(1)
67 //Result
68 //Enter the input signal frequency:100
69 //
70 //Enter the number of Cycles of input signal:2
71 //
72 //Enter the amplitude of input signal:2
```

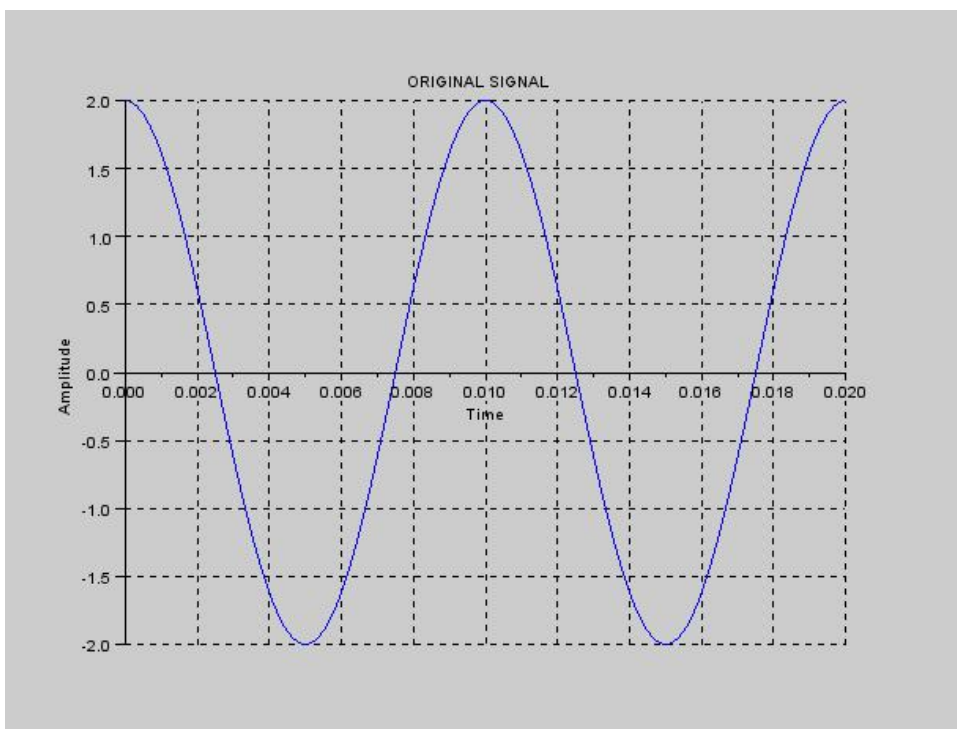


Figure 1.1: Verification of Sampling Theorem

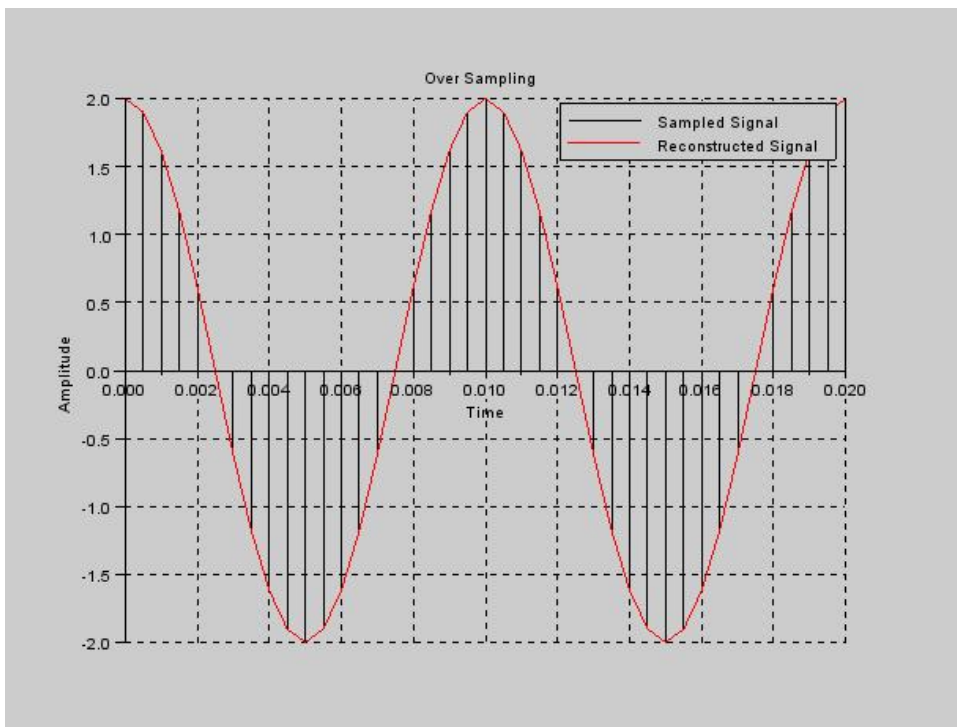


Figure 1.2: Verification of Sampling Theorem

Experiment: 2

Impulse response of a given system

Scilab code Solution 2.2 Program to find impulse response and Frequency Response of a system

```
1 //Caption: Program to find impulse response and
2 //Frequency Response of a system
3 //y[n] = a*y[n-1]+x[n]
4 //Assume y[n] = h[n], x[n]=delta[n]=unit impulse
   response
5 //a = 0.9
6 //h[n] = 0.9*h[n-1]+delta[n]
7 clc;
8 clear;
9 close;
10 a = 0.9; //constant a = 0.9 less than 1
11 h0 = 1;
12 h1 = a; //first two values of impulse response
13 h = [h0,h1,zeros(1,100)];
14 for i = 1:100
15     h(i+2) = ((a)^(i+1))*h(i+1); //impulse response
```

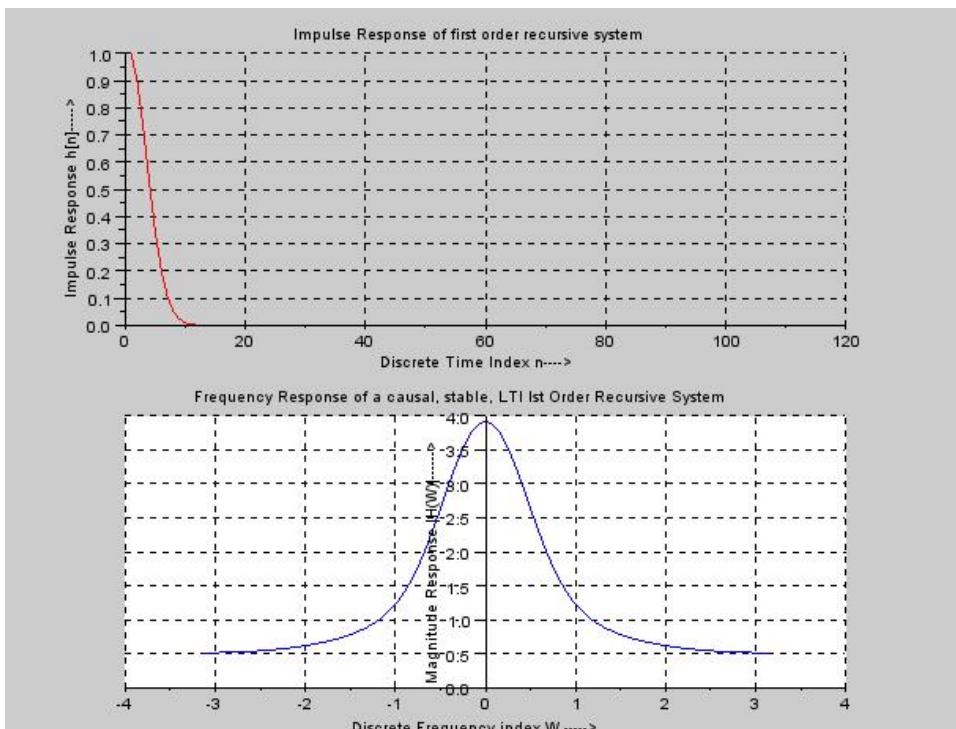


Figure 2.1: Program to find impulse response and Frequency Response of a system

```

16 end
17 [HW,W] = frmag(h,512); //frequency response
18 figure(1)
19 subplot(2,1,1)
20 a = gca();
21 a.x_location = 'origin';
22 a.y_location = 'origin';
23 plot([1:length(h)],h,'r');
24 xlabel('Discrete Time Index n——>');
25 ylabel('Impulse Response h[n]————>');
26 title('Impulse Response of first order recursive
        system');
27 xgrid(1)
28 subplot(2,1,2)
29 a = gca();
30 a.x_location = 'origin';
31 a.y_location = 'origin';
32 plot([mtlbfliplr(-2*pi*W),2*pi*W(2:$)],[
        mtlb_fliplr(abs(HW)),abs(HW(2:$))])
33 xlabel('Discrete Frequency index W————>')
34 ylabel('Magnitude Response |H(W)|————>')
35 title('Frequency Response of a causal, stable, LTI
        1st Order Recursive System');
36 xgrid(1)

```

Experiment: 3

Linear Circular convolution of two given sequences

Scilab code Solution 3.1 Program to Compute the Convolution of Two Sequences

```
1 //Caption: Program to Compute the Convolution of Two
   Sequences
2 clc;
3 clear;
4 close;
5 x = input('Enter the input Sequence:= ');
6 m = length(x);
7 lx = input('Enter the lower index of input sequence
   := ');
8 hx = lx+m-1;
9 n = lx:1:hx;
10 h = input('Enter impulse response sequence:= ');
11 l = length(h);
12 lh = input('Enter the lower index of impulse
   response:= ');
13 hh = lh+l-1;
```

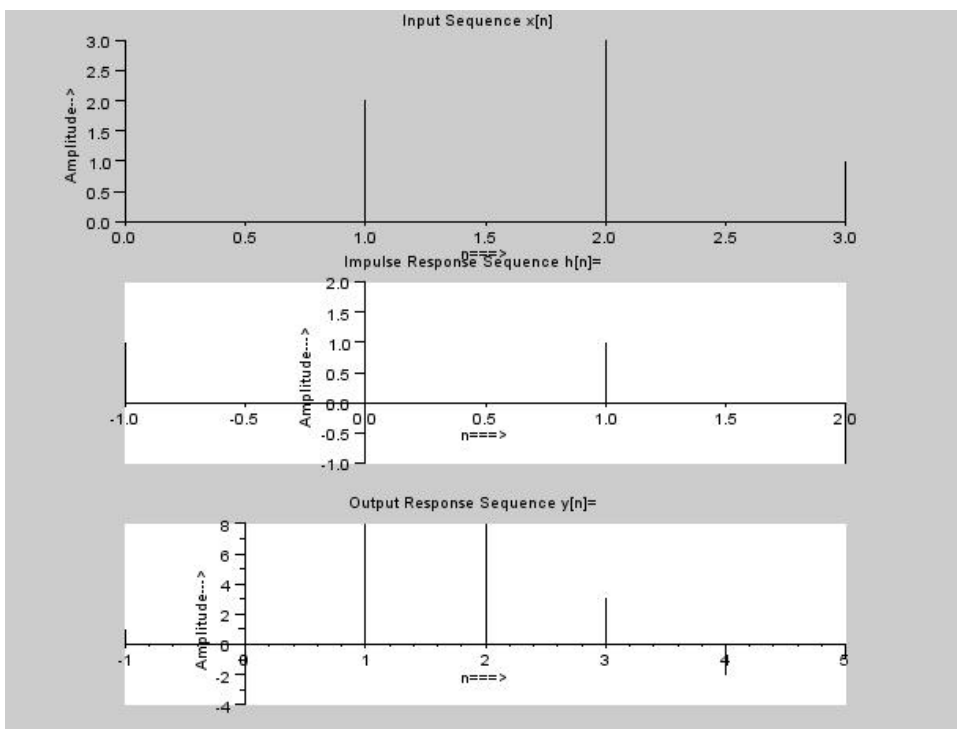


Figure 3.1: Program to Compute the Convolution of Two Sequences


```

14 g = lh:1:hh;
15 nx = lx+lh;
16 nh = nx+m+1-2;
17 y = convol(x,h)
18 r = nx:nh;
19 figure(1)
20 subplot(3,1,1)
21 a = gca();
22 a.x_location = "origin";
23 a.y_location = "origin";
24 plot2d3('gmn',n,x)
25 xlabel('n====>')
26 ylabel('Amplitude—>')
27 title('Input Sequence x[n]')
28 subplot(3,1,2)
29 a = gca();
30 a.x_location = "origin";
31 a.y_location = "origin";
32 plot2d3('gmn',g,h)
33 xlabel('n====>')
34 ylabel('Amplitude—>')
35 title('Impulse Response Sequence h[n]=')
36 subplot(3,1,3)
37 a = gca();
38 a.x_location = "origin";
39 a.y_location = "origin";
40 plot2d3('gmn',r,y)
41 xlabel('n====>')
42 ylabel('Amplitude—>')
43 title('Output Response Sequence y[n]=')
44 //Example
45 //Enter the input Sequence:=[1,2,3,1]
46 //
47 //Enter the lower index of input sequence:=0
48 //
49 //Enter impulse response sequence:=[1,2,1,-1]
50 //
51 //Enter the lower index of impulse response:=-1

```

```
52 //  
53 //  
54 //→y  
55 // y =  
56 //  
57 // 1. 4. 8. 8. 3. - 2. - 1.  
58 //
```

Experiment: 4

Autocorrelation of a given sequence and verification of its properties.

Scilab code Solution 4.1 Program to Compute the Autocorrelation of a Sequence And verification of Autocorrelation property

```
1 //Caption: Program to Compute the Autocorrelation of
  a Sequence
2 //And verification of Autocorrelation property
3 clc;
4 clear;
5 close;
6 x = input('Enter the input Sequence:=');
7 m = length(x);
8 lx = input('Enter the lower index of input sequence
  :=')
9 hx = lx+m-1;
10 n = lx:1:hx;
11 x_fold = x($:-1:1);
12 nx = lx+lx;
13 nh = nx+m+m-2;
14 r = nx:nh;
```

```

15 Rxx = convol(x,x_fold);
16 disp(Rxx,'Auto Correlation Rxx[n]:=')
17 //Property 1: Autocorrelation of a sequence has even
    symmetry
18 //Rxx[n] = Rxx[-n]
19 Rxx_flip = Rxx([$:-1:1]);
20 if Rxx_flip==Rxx then
21     disp('Property 1:Auto Correlation has Even
        Symmetry');
22     disp(Rxx_flip,'Auto Correlation time reversed
        Rxx[-n]:=');
23 end
24 //Property 2: Center value Rxx[0]= total power of
    the sequence
25 Tot_Px = sum(x.^2);
26 Mid = ceil(length(Rxx)/2);
27 if Tot_Px == Rxx(Mid) then
28     disp('Property 2:Rxx[0]=center value=max. value=
        Total power of i/p sequence');
29 end
30 subplot(2,1,1)
31 plot2d3('gnn',n,x)
32 xlabel('n====>')
33 ylabel('Amplitude-->')
34 title('Input Sequence x[n]')
35 subplot(2,1,2)
36 plot2d3('gnn',r,Rxx)
37 xlabel('n====>')
38 ylabel('Amplitude-->')
39 title('Auto correlation Sequence Rxx[n]')
40 //Example
41 //Enter the input Sequence:=[2,-1,3,4,1]
42 //
43 //Enter the lower index of input sequence:=-2
44 //
45 // Auto Correlation Rxx[n]:=
46 //
47 //      2.      7.      5.      11.      31.      11.      5.

```

```

    7.      2.
48 //
49 // Property 1:Auto Correlation has Even Symmetry
50 //
51 // Auto Correlation time reversed Rxx[-n]:=
52 //
53 //      2.      7.      5.      11.      31.      11.      5.
    7.      2.
54 //
55 // Property 2:Rxx[0]=center value=max. value=Total
    power of i/p sequence

```

Experiment: 5

Cross correlation of given sequences and verification of its properties.

Scilab code Solution 5.1 Program to Compute the Crosscorrelation of a Sequence And verification of crosscorrelation property

```
1 //Caption: Program to Compute the Crosscorrelation
  of a Sequence
2 //And verification of crosscorrelation property
3 clc;
4 clear;
5 close;
6 x = input('Enter the First input Sequence:= ');
7 y = input('Enter the second input Sequence:= ');
8 mx = length(x);
9 my = length(y);
10 lx = input('Enter the lower index of first input
  sequence:= ');
11 ly = input('Enter the lower index of second input
  sequence:= ');
12 hx = lx+mx-1;
13 n = lx:1:hx;
```

```

14 x_fold = x($:-1:1);
15 y_fold = y($:-1:1);
16 nx = lx+ly;
17 ny = nx+mx+my-2;
18 r = nx:ny;
19 Rxy = convol(x,y_fold);
20 Ryx = convol(x_fold,y);
21 disp(Rxy,'Cross Correlation Rxy[n]:=')
22 count =1;
23 //Property 1: crosscorrelation of a sequence has
    Antisymmetry
24 //Rxy[n] = Ryx[-n]
25 Ryx_flip = Ryx([$:-1:1]);
26 for i = 1:length(Rxy)
27     if (ceil(Ryx_flip(i))==ceil(Rxy(i))) then
28         count = count+1;
29     end
30 end
31 if (count==length(Rxy)) then
32     disp('Property 1:Cross Correlation has
        AntiSymmetry: Rxy[n]=Ryx[-n]');
33 end
34 //Property 2:% Verification of Energy Property of
    Rxy
35 Ex = sum(x.^2);
36 Ey = sum(y.^2);
37 E = sqrt(Ex*Ey);
38 Mid = ceil(length(Rxy)/2);
39 if (E >= Rxy(Mid)) then
40     disp('Property 2:Energy Property of Cross
        Correlation verified')
41 end
42 subplot(2,1,1)
43 plot2d3('gnn',n,x)
44 xlabel('n====>')
45 ylabel('Amplitude—>')
46 title('Input Sequence x[n]')
47 subplot(2,1,2)

```

```

48 plot2d3('gnn',r,Rxy)
49 xlabel('n====>')
50 ylabel('Amplitude-->')
51 title('Cross correlation Sequence Rxy[n]')
52 //Example
53 //Enter the First input Sequence:=[1,2,1,1]
54 //Enter the second input Sequence:=[1,1,2,1]
55 //Enter the lower index of first input sequence:=0
56 //Enter the lower index of second input sequence:=0
57 //Cross Correlation Rxy[n]:=
58 //      1.      4.      6.      6.      5.      2.      1.
59 //Property 1:Cross Correlation has AntiSymmetry: Rxy
      [n]=Ryx[-n]
60 //
61 // Property 2:Energy Property of Cross Correlation
      verified

```

Experiment: 6

Solving a given difference equation.

Scilab code Solution 6.1 Solving Difference Equation Direct Form II Realization

```
1 //Caption: Solving Difference Equation
2 //Direct Form-II Realization
3 //Finding out the Output Response of the first order
4 //system(Filter)
5 clc;
6 clear;
7 close;
8 x =
    [1,1/2,1/4,1/8,1/16,1/32,1/64,1/128,1/256,1/512];
9 b = [3,-4/3]; //numerator polynomials
10 a = [1,-1/3]; //denominator polynomials
11 p = length(a)-1;
12 q = length(b)-1;
13 pq = max(p,q);
14 a = a(2:p+1);
15 w = zeros(1,pq);
16 for i = 1:length(x)
17     wnew = x(i)-sum(w(1:p).*a);
```

```
18     w = [wnew,w];
19     y(i) = sum(w(1:q+1).*b);
20 end
21 disp(y,'Output Response y[n]= ');
22 //Result
23 //Output Response y[n]=
24 //      3.
25 //      1.1666667
26 //      0.4722222
27 //      0.1990741
28 //      0.0871914
29 //      0.0394805
30 //      0.0183685
31 //      0.0087270
32 //      0.0042111
33 //      0.0020547
```

Experiment: 7

Computation of N point DFT of a given sequence and to plot magnitude and phase spectrum.

Scilab code Solution 7.1 Program to find the spectral information of discrete time signal Calculation of DFT and IDFT

```
1 //Caption: Program to find the spectral information
   of discrete time signal
2 //Calculation of DFT and IDFT
3 //Plotting Magnitude and Phase Spectrum
4 clc;
5 close;
6 clear;
7 xn = input('Enter the real input discrete sequence x
   [n]= ');
8 N = length(xn);
9 XK = zeros(1,N);
10 IXK = zeros(1,N);
11 //Code block to find the DFT of the Sequence
12 for K = 0:N-1
```

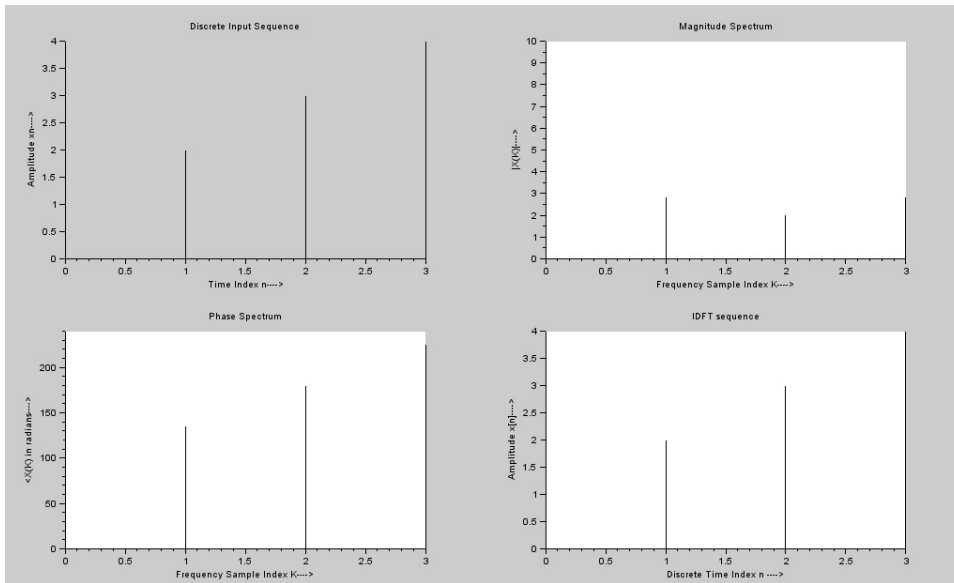


Figure 7.1: Program to find the spectral information of discrete time signal
Calculation of DFT and IDFT

```

13     for n = 0:N-1
14         XK(K+1) = XK(K+1)+xn(n+1)*exp(-%i*2*%pi*K*n/
           N);
15     end
16 end
17 [phase,db] = phasemag(XK)
18 disp(XK,'Discrete Fourier Transform X(k)=')
19 disp(abs(XK),'Magnitude Spectral Samples=')
20 disp(phase,'Phase Spectral Samples=')
21 n = 0:N-1;
22 K = 0:N-1;
23 figure(1)
24 subplot(2,2,1)
25 a = gca();
26 a.x_location = "origin";
27 a.y_location = "origin";
28 plot2d3('gnn',n,xn)
29 xlabel('Time Index n——>')

```

```

30 ylabel('Amplitude xn——>')
31 title('Discrete Input Sequence')
32 subplot(2,2,2)
33 a = gca();
34 a.x_location = "origin";
35 a.y_location = "origin";
36 plot2d3('ggn',K,abs(XK))
37 xlabel('Frequency Sample Index K——>')
38 ylabel('|X(K)|——>')
39 title('Magnitude Spectrum')
40 subplot(2,2,3)
41 a = gca();
42 a.x_location = "origin";
43 a.y_location = "origin";
44 plot2d3('ggn',K,phase)
45 xlabel('Frequency Sample Index K——>')
46 ylabel('<X(K) in radians——>')
47 title('Phase Spectrum')
48 //Code block to find the IDFT of the sequence
49 for n = 0:N-1
50     for K = 0:N-1
51         IXK(n+1) = IXK(n+1)+XK(K+1)*exp(%i*2*%pi*K*n
52             /N);
53     end
54 end
55 IXK = IXK/N;
56 ixn = real(IXK);
57 subplot(2,2,4)
58 a = gca();
59 a.x_location = "origin";
60 a.y_location = "origin";
61 plot2d3('ggn',[0:N-1],ixn)
62 xlabel('Discrete Time Index n ——>')
63 ylabel('Amplitude x[n]——>')
64 title('IDFT sequence')
65 //Example
66 //Enter the real input discrete sequence x[n

```

```

    ]=[1,2,3,4]
67 //
68 // Discrete Fourier Transform X(k)=
69 //
70 //      10. - 2. + 2.i - 2. - 9.797D-16i - 2. - 2.i
71 //
72 // Magnitude Spectral Samples=
73 //
74 //      10.      2.8284271      2.      2.8284271
75 //
76 // Phase Spectral Samples=
77 //
78 //      0.      135.      180.      225.
79 //

```

Experiment: 8

Linear convolution of two sequences using DFT and IDFT.

Scilab code Solution 8.1 Linear Convolution using Circular Convolution
DFT IDFT method

```
1 //Caption: Linear Convolution using Circular
   Convolution
2 //DFT-IDFT method
3 clc;
4 clear;
5 close;
6 x = input('Enter the input discrete sequence:=')
7 h = input('Enter the impulse discrete sequence:=')
8 N1 = length(x);
9 N2 = length(h);
10 N = N1+N2-1; //Linear Convolution result length
11 h = [h, zeros(1, N-N2)];
12 x = [x, zeros(1, N-N1)];
13 //Computing DFT-IDFT
```

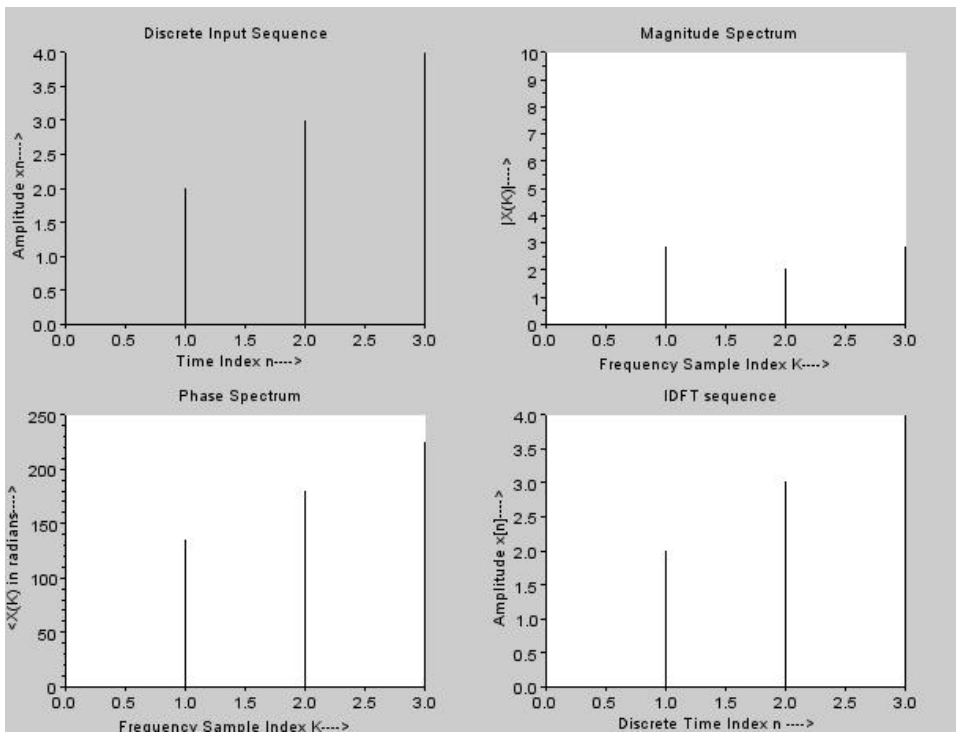


Figure 8.1: Linear Convolution using Circular Convolution DFT IDFT method


```

14 XK = dft(x,-1); //N point DFT of i/p sequence
15 HK = dft(h,-1); //N point DFT of impulse sequence
16 //Multiplication of 2 DFT's
17 YK = XK.*HK;
18 //Linear Convolution result
19 yn = dft(YK,1); //IDFT of Y(K)(o/p sequence)
20 disp(real(yn), 'Linear Convolution result y[n]:= ')
21 //Example
22 //Enter the input discrete sequence:= [1,2,3]
23 //Enter the impulse discrete sequence:=[1,2,2,1]
24 //Linear Convolution result y[n]:=
25 //
26 //      1.
27 //      4.
28 //      9.
29 //     11.
30 //      8.
31 //      3.

```

Experiment: 9

Circular convolution of two given sequences using DFT and IDFT

Scilab code Solution 9.1 Circular Convolution using DFT IDFT method

```
1 //Caption: Circular Convolution using DFT-IDFT
  method
2 clc;
3 clear;
4 close;
5 L = 4; // Length of the sequence
6 N = 4; //N-point DFT
7 x1 = input('Enter the first discrete sequence:x1[n]=
  ')
8 x2 = input('Enter the second discrete sequence:x2[n
  ]=')
9 //Computing DFT
10 X1K = dft(x1,-1);
11 X2K = dft(x2,-1);
12 //Multiplication of 2 DFT's
13 X3K = X1K.*X2K;
14 x3 = dft(X3K,1); //IDFT of X3(K)
```

```
15 x3 = real(x3);
16 disp(x3, 'Circular Convolution result:x3[n]= ');
17 //Example
18 //Enter the first discrete sequence:x1[n]= [2,1,2,1]
19 //Enter the second discrete sequence:x2[n]=
    [1,2,3,4]
20 //
21 // Circular Convolution result:x3[n]=
22 //
23 //      14.
24 //      16.
25 //      14.
26 //      16.
```

Experiment: 10

Design and implementation of FIR filter to meet given specifications.

Scilab code Solution 10.1 To Design an Low Pass FIR Filter

```
1 //Caption: To Design an Low Pass FIR Filter
2 clc;
3 clear;
4 close;
5 wp= input('Enter the pass band edge (rad)= ');
6 ws= input('Enter the stop band edge (rad)= ');
7 ks= input('Enter the stop band attenuation (dB)= ');
8 //If 43<Ks<54 choose hamming window.
9 //To select N,order of filter.
10 N= (2*%pi*4)./(ws-wp); // k=4 for Hamming window.
11 N= ceil(N); //To round-off N to the next integer.
12 wc=(wp+(ws-wp)/2)./%pi
13 // To obtain FIR filter Impulse Response 'wft'
14 //And FIR Filter Frequency response 'wfm'
15 [wft,wfm,fr]=wfirm('lp',N+1,[wc/2,0],'hm',[0,0]);
```

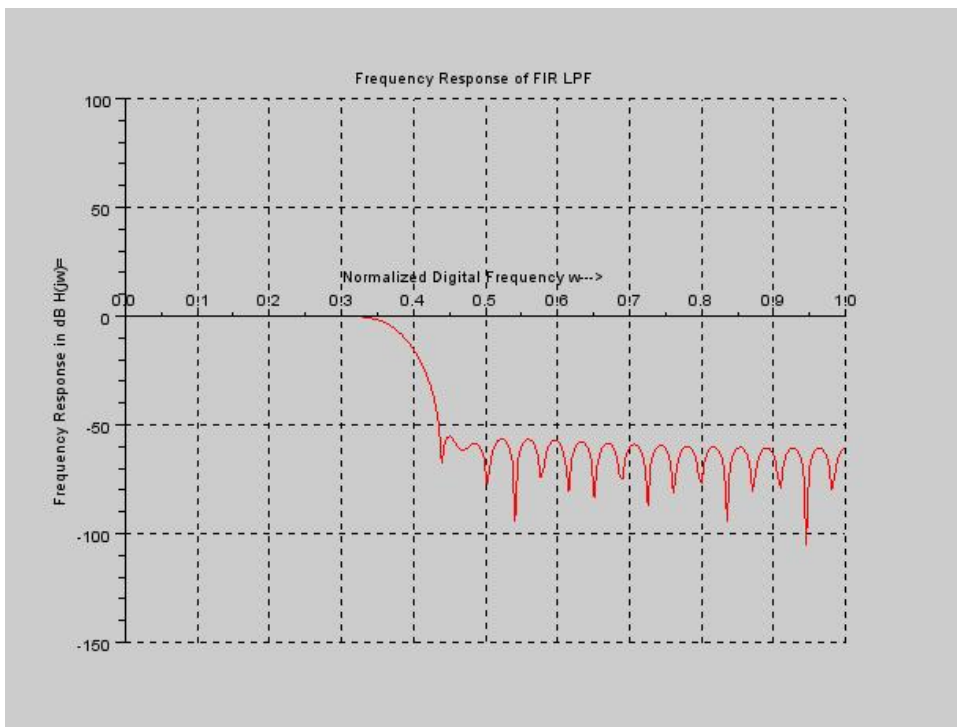


Figure 10.1: To Design an Low Pass FIR Filter

```

16 figure(1)
17 a = gca();
18 a.x_location = "origin";
19 a.y_location = "origin";
20 a.data_bounds = [0,-150;1,50];
21 plot(2*fr,20*log10(wfm),'r')
22 xlabel('Normalized Digital Frequency w—>')
23 ylabel('Frequency Response in dB H(jw)=')
24 title('Frequency Response of FIR LPF')
25 xgrid(1)
26 //Result
27 //Enter the pass band edge (rad)= 0.3*%pi
28 //Enter the stop band edge (rad)= 0.45*%pi
29 //Enter the stop band attenuation (dB)= 50
30 //N = 54.
31 //—>wc
32 // wc = 0.375
33 //—>disp(wft,'Impulse Response of FIR LPF=')
34 // Impulse Response of FIR LPF=
35 // column 1 to 7
36 // 0.0003609 - 0.0007195 - 0.0010869 1.575D
// -18 0.0016485 0.0015927 - 0.0010883
37 // column 8 to 14
38 // - 0.0035703 - 0.0017009 0.0038764
0.0061896 - 5.965D-18 - 0.0090208 - 0.0082516
39 // column 15 to 21
40 // 0.0053105 0.0164428 0.0074408 -
0.0162551 - 0.0251602 1.191D-17 0.0359480
41 // column 22 to 28
42 // 0.0334760 - 0.0225187 - 0.0756838 -
0.0394776 0.1111441 0.2931653 0.375
43 // column 29 to 35
44 // 0.2931653 0.1111441 - 0.0394776 -
0.0756838 - 0.0225187 0.0334760 0.0359480
45 // column 36 to 42
46 // 1.191D-17 - 0.0251602 - 0.0162551
0.0074408 0.0164428 0.0053105 - 0.0082516
47 // column 43 to 49

```

```
48 // - 0.0090208 - 5.965D-18 0.0061896
      0.0038764 - 0.0017009 - 0.0035703 - 0.0010883
      column 50 to 55
49 // 0.0015927 0.0016485 1.575D-18 -
      0.0010869 - 0.0007195 0.0003609
```

Experiment: 11

Design and implementation of IIR filter to meet given specifications.

Scilab code Solution 11.1 To obtain Digital IIR Butterworth low pass filter Frequency response

```
1 //Caption: To obtain Digital IIR Butterworth low
  pass filter
2 //Frequency response
3 clc;
4 clear;
5 close;
6 fp= input('Enter the pass band edge (Hz) = ');
7 fs= input('Enter the stop band edge (Hz) = ');
8 kp= input('Enter the pass band attenuation (dB) = ')
  ;
9 ks= input('Enter the stop band attenuation (dB) = ')
  ;
10 Fs= input('Enter the sampling rate samples/sec = ')
  ;
```

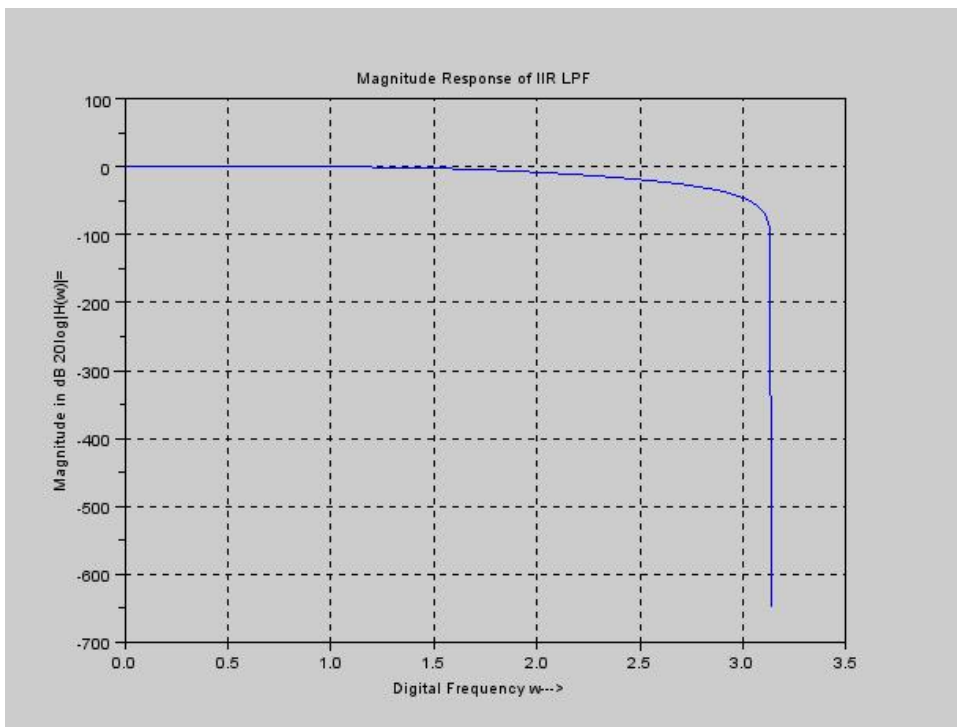



Figure 11.1: To obtain Digital IIR Butterworth low pass filter Frequency response

```

11 d1 = 10^(kp/20);
12 d2 = 10^(ks/20);
13 d = sqrt((1/(d2^2))-1);
14 E = sqrt((1/(d1^2))-1);
15 //Digital filter specifications(rad/samples)
16 wp=2*pi*fp*1/Fs;
17 ws=2*pi*fs*1/Fs;
18 disp(wp,'Digital Pass band edge freq in rad/samples
        wp=')
19 disp(ws,'Digital Stop band edge freq in rad/samples
        ws=')
20 //Pre warping
21 op=2*Fs*tan(wp/2);
22 os=2*Fs*tan(ws/2);
23 disp(op,'Analog Pass Band Edge Freq. in rad/sec op='
        )
24 disp(os,'Analog Stop band Edge Freq. in rad/sec os='
        )
25 N = log10(d/E)/log10(os/op);
26 oc = op/((E^2)^(1/(2*N)));
27 N = ceil(N);//rounded to nearest integer
28 disp(N,'IIR Filter order N =');
29 disp(oc,'Cutoff Frequency in rad/seconds OC = ')
30 [pols,gn] = zpbutt(N,oc);
31 disp(gn,'Gain of Analog IIR Butterworth LPF Gain =')
32 disp(pols,'Poles of Analog IIR Butterworth LPF Poles
        =')
33 HS = poly(gn,'s','coeff')/real(poly(pols,'s'));
34 disp(HS,'Transfer function of Ananlog IIR
        Butterworth LPF H(S)=')
35 z = poly(0,'z')
36 Hz = horner(HS,(2*Fs*(z-1)/(z+1)))
37 num = coeff(Hz(2))
38 den = coeff(Hz(3))
39 Hz(2)= Hz(2)./den(3);
40 Hz(3) = Hz(3)./den(3);
41 disp(Hz,'Transfer function of Digitla IIR
        Butterworth LPF H(Z)=')

```

```

42 [Hw,w] = frmag(Hz,256);
43 figure(1)
44 plot(2*w*pi,20*log10(abs(Hw)));
45 xlabel('Digital Frequency w—>')
46 ylabel('Magnitude in dB 20log |H(w)|=')
47 title('Magnitude Response of IIR LPF')
48 xgrid(1)
49 //Result
50 //Enter the pass band edge (Hz) = 1500
51 //
52 //Enter the stop band edge (Hz) = 2000
53 //
54 //Enter the pass band attenuation (dB) = -1
55 //
56 //Enter the stop band attenuation (dB) = -3
57 //
58 //Enter the sampling rate samples/sec = 8000
59 //
60 // Digital Pass band edge freq in rad/samples wp=
61 //
62 // 1.1780972
63 //
64 // Digital Stop band edge freq in rad/samples ws=
65 //
66 // 1.5707963
67 //
68 // Analog Pass Band Edge Freq. in rad/sec op=
69 //
70 // 10690.858
71 //
72 // Analog Stop band Edge Freq. in rad/sec os=
73 //
74 // 16000.
75 //
76 // IIR Filter order N =
77 //
78 // 2.
79 //

```

```

80 // Cutoff Frequency in rad/seconds OC =
81 //
82 //     16022.769
83 //
84 // Gain of Analog IIR Butterworth LPF Gain =
85 //
86 //     2.567D+08
87 //
88 // Poles of Analog IIR Butterworth LPF Poles =
89 //
90 //     - 11329.809 + 11329.809 i     - 11329.809 -
91 //     11329.809 i
92 // Transfer function of Analog IIR Butterworth LPF
93 // H(S)=
94 //
95 //     2.567D+08
96 //     -----
97 //           2
98 //     2.567D+08 + 22659.618 s + s
99 // Transfer function of Digital IIR Butterworth LPF
100 // H(Z)=
101 //
102 //           2
103 //     0.2933099 + 0.5866197 z + 0.2933099 z
104 //     -----
105 //           2
106 //     0.1715734 + 0.0016661 z + z

```

Scilab code Solution 11.2 To obtain Digital IIR Chebyshev low pass filter Frequency response

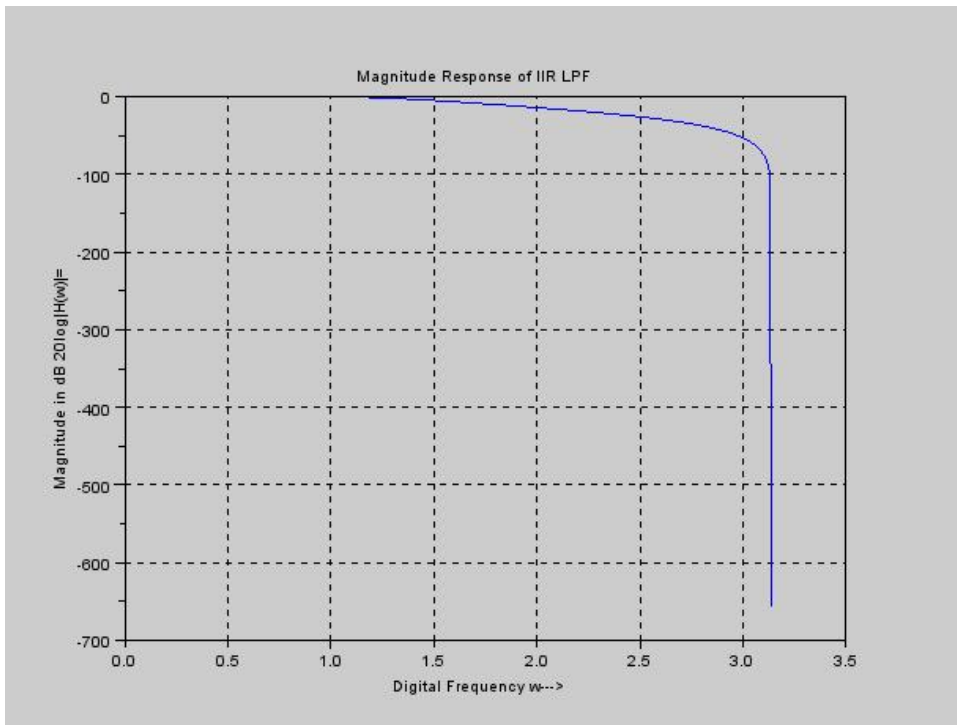


Figure 11.2: To obtain Digital IIR Chebyshev low pass filter Frequency response

```

1 //Caption: To obtain Digital IIR Chebyshev low pass
  filter
2 //Frequency response
3 clc;
4 clear;
5 close;
6 fp= input('Enter the pass band edge (Hz) = ');
7 fs= input('Enter the stop band edge (Hz) = ');
8 kp= input('Enter the pass band attenuation (dB) = ');
  ;
9 ks= input('Enter the stop band attenuation (dB) = ');
  ;
10 Fs= input('Enter the sampling rate samples/sec = ');
  ;
11 d1 = 10^(kp/20);
12 d2 = 10^(ks/20);
13 d = sqrt((1/(d2^2))-1);
14 E = sqrt((1/(d1^2))-1);
15 //Digital filter specifications(rad/samples)
16 wp=2*%pi*fp*1/Fs;
17 ws=2*%pi*fs*1/Fs;
18 disp(wp,'Digital Pass band edge freq in rad/samples
  wp=')
19 disp(ws,'Digital Stop band edge freq in rad/samples
  ws=')
20 //Pre warping
21 op=2*Fs*tan(wp/2);
22 os=2*Fs*tan(ws/2);
23 disp(op,'Analog Pass Band Edge Freq. in rad/sec op='
  )
24 disp(os,'Analog Stop band Edge Freq. in rad/sec os='
  )
25 N = acosh(d/E)/acosh(os/op);
26 oc = op/((E^2)^(1/(2*N)));
27 N = ceil(N);//rounded to nearest integer
28 disp(N,'IIR Filter order N =');
29 disp(oc,'Cutoff Frequency in rad/seconds OC = ')
30 [pols,gn] = zpchl(N,E,op);

```

```

31 disp(gn, 'Gain of Analog IIR Chebyshev Type-I LPF
    Gain =')
32 disp(pols, 'Poles of Analog IIR Chebyshev Type-I LPF
    Poles =')
33 HS = poly(gn, 's', 'coeff')/real(poly(pols, 's'));
34 disp(HS, 'Transfer function of Analog IIR Chebyshev
    Type-I LPF H(S)=')
35 z = poly(0, 'z')
36 Hz = horner(HS, (2*Fs*(z-1)/(z+1)))
37 num = coeff(Hz(2))
38 den = coeff(Hz(3))
39 Hz(2) = Hz(2) ./ den(3);
40 Hz(3) = Hz(3) ./ den(3);
41 disp(Hz, 'Transfer function of Digital IIR Chebyshev
    LPF H(Z)=')
42 [Hw, w] = frmag(Hz, 256);
43 figure(1)
44 plot(2*w*pi, 20*log10(abs(Hw)));
45 xlabel('Digital Frequency  $\omega \rightarrow$ ')
46 ylabel('Magnitude in dB  $20 \log |H(\omega)|$ =')
47 title('Magnitude Response of IIR LPF')
48 xgrid(1)
49 //Result
50 //Enter the pass band edge (Hz) = 1500
51 //
52 //Enter the stop band edge (Hz) = 2000
53 //
54 //Enter the pass band attenuation (dB) = -1
55 //
56 //Enter the stop band attenuation (dB) = -3
57 //
58 //Enter the sampling rate samples/sec = 8000
59 //
60 // Digital Pass band edge freq in rad/samples wp=
61 //
62 // 1.1780972
63 //
64 // Digital Stop band edge freq in rad/samples ws=

```

```

65 //
66 //      1.5707963
67 //
68 // Analog Pass Band Edge Freq. in rad/sec op=
69 //
70 //      10690.858
71 //
72 // Analog Stop band Edge Freq. in rad/sec os=
73 //
74 //      16000.
75 //
76 // IIR Filter order N =
77 //
78 //      2.
79 //
80 // Cutoff Frequency in rad/seconds OC =
81 //
82 //      17642.912
83 //
84 // Gain of Analog IIR Chebyshev Type-I LPF Gain =
85 //
86 //      1.123D+08
87 //
88 // Poles of Analog IIR Chebyshev Type-I LPF Poles =
89 //
90 //      - 5867.861 + 9569.6927i   - 5867.861 - 9569.6927i
91 //
92 // Transfer function of Analog IIR Chebyshev Type-I
93 // LPF H(S)=
94 //
95 //      1.123D+08
96 //      -----
97 //                                 2
98 //      1.260D+08 + 11735.722s + s
99 // Transfer function of Digital IIR Chebyshev LPF H(
100 // Z)=

```


Experiment: 12

Circular convolution of two given sequences

Scilab code Solution 12.1 Program to perform circular convolution of two sequences

```
1 //Caption: Program to perform circular convolution
  of two sequences
2 clc;
3 clear;
4 close;
5 x1 = input('Enter the first discrete sequence:=')
6 x2 = input('Enter the second discrete sequence:=')
7 m = length(x1); //length of first sequence
8 n = length(x2); //length of second sequence
9 //To make length of x1 and x2 are equal
10 if(m>n)
11     for i = n+1:m
12         x2(i)=0;
13     end
14 elseif(n>m)
15     for i = m+1:n
16         x1(i)=0;
17     end
```

```

18 end
19 N = length(x1);
20 x3 = zeros(1,N); //circular convolution result
    initialized to zero
21 a(1) = x2(1);
22 for j = 2:N
23     a(j) = x2(N-j+2);
24 end
25 for i = 1:N
26     x3(1) = x3(1)+x1(i)*a(i);
27 end
28 X(1,:) = a;
29 //Calculation of circular convolution
30 for k =2:N
31     for j = 2:N
32         x2(j) = a(j-1);
33     end
34 x2(1) = a(N);
35 X(k,:) = x2;
36     for i = 1:N
37         a(i) = x2(i);
38         x3(k) = x3(k)+x1(i)*a(i);
39     end
40 end
41 disp(x3, 'Circular Convolution Result x3[n]= ')
42 //Example
43 //Enter the first discrete sequence:= [2,1,2,1]
44 //Enter the second discrete sequence:= [1,2,3,4]
45 //Circular Convolution Result x3[n]=
46 //     14.     16.     14.     16.
47 //

```
