

Scilab Textbook Companion for  
Digital Signal Processing  
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# Book Description

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Scilab numbering policy used in this document and the relation to the above book.

**Exa** Example (Solved example)

**Eqn** Equation (Particular equation of the above book)

**AP** Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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# List of Scilab Codes

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# Chapter 1

## Classifications of signals and systems

Scilab code Exa 1.2.a Rectangular wave

```
1 //Example 1.2 (a)
2 clc;clear;
3 t=-5:0.01:5;
4 x=1*(abs(2*t+3)<0.5);
5 plot(t,x);
6 title('x(t)=rect(2t+3)');
```

---

Scilab code Exa 1.2.b Rectangular wave

```
1 //Example 1.2 (b)
2 clc;clear;
3 t=-5:0.01:5;
4 x=2*(abs(t-1/4)<0.5);
5 plot(t,x);
6 title('x(t)=2*rect(t-1/4)');
```

---

### Scilab code Exa 1.2.c Cosine wave

```
1 //Example 1.2 (c)
2 clc;clear;
3 pi=22/7;
4 t=-5:0.01:5;
5 x=cos(2*pi*t-50*pi);
6 plot(t,x);
7 title('x(t)=cos(2*pi*t-50*pi)');
```

---

### Scilab code Exa 1.2.d Ramp wave

```
1 //Example 1.2 (d)
2
3 clc;clear;
4 t=-5:0.01:5;
5 x=-0.5*(t-4);
6 plot(t,x);
7 title('x(t)=r(-0.5t+2)');
8 zoom_rect([-5 0 5 5]);
```

---

## Chapter 2

# Fourier Analysis of Periodic and Aperiodic Continuous Time Signals and Systems

Scilab code Exa 2.1 Fourier Series of Periodic Square Wave

```
1 //Example 2.1
2
3 clc;clear;close;
4 A=1;T=2;
5 w0=2*pi/T;
6
7 //Calculation of trigonometric fourier series co-
  coefficients
8 a0=A/T*(integrate('-1','t',-T/2,-T/4)+integrate('+1',
  't',-T/4,T/4)+integrate('-1','t',T/4,T/2));
9 for n=1:10;
10 a(1,n)=2*A/T*(integrate('-cos(n*w0*t)','t',-T/2,-T
  /4)+integrate('+cos(n*w0*t)','t',-T/4,T/4)+
  integrate('-cos(n*w0*t)','t',T/4,T/2));
11 b(1,n)=2*A/T*(integrate('-sin(n*w0*t)','t',-T/2,-T
  /4)+integrate('+sin(n*w0*t)','t',-T/4,T/4)+
  integrate('-sin(n*w0*t)','t',T/4,T/2));
```

```

12 end
13
14 //Displaying fourier coefficients
15 disp(T, 'fundamental period T= ', A, 'Assumption:
    Amplitude A= ');
16 disp('Trigonometric fourier series coefficients:');
17 disp(a0, 'a0= '); disp(a, 'an= '); disp(b, 'bn= ');
18
19 x=[-A*ones(1,25) A*ones(1,50) -A*ones(1,25)] //
    Function for plotting purpose
20 t=-T/2:0.01*T:T/2-0.01;
21 subplot(311); plot(t,x);
22 title('x(t)'); xlabel('time t');
23 subplot(312); plot2d3(a);
24 title('Coefficients an'); xlabel('n');
25 subplot(313); plot2d3(b);
26 title('Coefficients bn'); xlabel('n');

```

---

### Scilab code Exa 2.2 Fourier Series of Periodic Rectangular Wave

```

1 //Example 2.2
2
3 clc; clear; close;
4 A=1; T=2;
5 w0=2*pi/T;
6
7 //Calculation of trigonometric fourier series co-
    efficients
8 a0=A/T*integrate('1', 't', -T/4, T/4);
9 for n=1:10;
10 a(1,n)=2*A/T*integrate('cos(n*w0*t)', 't', -T/4, T/4);
11 b(1,n)=2*A/T*integrate('sin(n*w0*t)', 't', -T/4, T/4);
12 end
13
14 //Displaying fourier coefficients

```

```

15 disp(T, 'fundamental period T= ', A, 'Assumption:
    Amplitude A= ');
16 disp('Trigonometric fourier series coefficients:');
17 disp(a0, 'a0= '); disp(a, 'an= '); disp(b, 'bn= ');
18
19 x=[zeros(1,25) A*ones(1,50) zeros(1,25)];
20 t=-T/2:0.01*T:T/2-0.01;
21 subplot(311); plot(t,x);
22 title('x(t)'); xlabel('time t');
23 subplot(312); plot2d3(a);
24 title('Coefficients an'); xlabel('n');
25 subplot(313); plot2d3(b);
26 title('Coefficients bn'); xlabel('n');

```

---

### Scilab code Exa 2.3 Fourier Series of Periodic Half Wave Rectified Sine Wave

```

1 //Example 2.3
2
3 clc; clear; close;
4 A=1; T=2;
5 w0=2*pi/T;
6
7 //Calculation of trigonometric fourier series coefficients
8 a0=A/T*integrate('sin(w0*t)', 't', 0, T/2);
9 for n=1:10;
10 a(1,n)=2*A/T*integrate('sin(w0*t)*cos(n*w0*t)', 't',
    ,0, T/2);
11 b(1,n)=2*A/T*integrate('sin(w0*t)*sin(n*w0*t)', 't',
    ,0, T/2);
12 end
13
14 //Displaying fourier coefficients
15 disp(T, 'fundamental period T= ', A, 'Assumption:
    Amplitude A= ');

```

```

16 disp('Trigonometric fourier series coefficients:');
17 disp(a0, 'a0= '); disp(a, 'an= '); disp(b, 'bn= ');
18
19 t=0:0.01*T:T/2;
20 x=[A*sin(w0*t) zeros(1,50)];
21 t=0:0.01*T:T;
22 subplot(311); plot(t,x);
23 title('x(t)'); xlabel('time t');
24 subplot(312); plot2d3(a);
25 title('Coefficients an'); xlabel('n');
26 subplot(313); plot2d3(b);
27 title('Coefficients bn'); xlabel('n');

```

---

#### Scilab code Exa 2.4 Fourier Series of Periodic Triangular Wave

```

1 //Example 2.4
2
3 clc; clear; close;
4 A=1; T=2;
5 w0=2*pi/T;
6
7 //Calculation of trigonometric fourier series co-
  coefficients
8 a0=4*A/T*(integrate('t-0.5*T', 't', -T/2, -T/4)+
  integrate('t', 't', -T/4, T/4)+integrate('-t+0.5*T',
  't', T/4, T/2));
9 for n=1:10;
10 a(1,n)=2*4*A/T*(integrate('(t-0.5*T)*cos(n*w0*t)', 't',
  -T/2, -T/4)+integrate('t*cos(n*w0*t)', 't', -T/4, T/4)+
  integrate('(-t+0.5*T)*cos(n*w0*t)', 't', T/4, T/2));
11 b(1,n)=2*4*A/T*(integrate('(t-0.5*T)*sin(n*w0*t)', 't',
  -T/2, -T/4)+integrate('t*sin(n*w0*t)', 't', -T/4, T/4)+
  integrate('(-t+0.5*T)*sin(n*w0*t)', 't', T/4, T/2));

```

```

12 end
13
14 //Displaying fourier coefficients
15 disp(T, 'fundamental period T= ', A, 'Assumption:
    Amplitude A= ');
16 disp('Trigonometric fourier series coefficients:');
17 disp(a0, 'a0= '); disp(a, 'an= '); disp(b, 'bn= ');
18
19 t=-T/2:0.01*T:T/2;
20 x=[-4*A/T*t(1:25)-2*A 4*A/T*t(26:75) -4*A/T*t
    (76:101)+2*A];
21 subplot(311); plot(t,x);
22 title('x(t)'); xlabel('time t');
23 subplot(312); plot2d3(a);
24 title('Coefficients an'); xlabel('n');
25 subplot(313); plot2d3(b);
26 title('Coefficients bn'); xlabel('n');

```

---

### Scilab code Exa 2.5 Fourier Series of Periodic Rectangular Pulse

```

1 //Example 2.5
2
3 clc; clear; close;
4 A=1; T=2; d=0.1;
5 w0=2*pi/T;
6
7 //Calculation of trigonometric fourier series co-
    efficients
8 a0=A/T*integrate('1', 't', -T/4, T/4);
9 for n=1:10;
10 a(1,n)=2*A/T*integrate('cos(n*w0*t)', 't', -d/2, d/2);
11 b(1,n)=2*A/T*integrate('sin(n*w0*t)', 't', -d/2, d/2);
12 end
13
14 //Displaying fourier coefficients

```

```

15 disp(d, 'pulse width d= ', T, 'fundamental period T= ',
    A, 'Assumption: Amplitude A= ');
16 disp('Trigonometric fourier series coefficients:');
17 disp(a0, 'a0= '); disp(a, 'an= '); disp(b, 'bn= ');
18
19 n=round(50*d/T); //
    Variable used for plotting pulses accurately
20 x=[zeros(1,50-n) A*ones(1,2*n+1) zeros(1,50-n)]
21 t=-T/2:0.01*T:T/2;
22 subplot(311); plot(t,x);
23 title('x(t)'); xlabel('time t');
24 subplot(312); plot2d3(a);
25 title('Coefficients an'); xlabel('n');
26 subplot(313); plot2d3(b);
27 title('Coefficients bn'); xlabel('n');

```

---

### Scilab code Exa 2.6 Fourier Series of Square Wave

```

1 //Example 2.6
2
3 clc;clear;close;
4 A=1;T=2;
5 w0=2*pi/T;
6
7 //Calculation of trigonometric fourier series co-
    coefficients
8 a0=A/T*(integrate('-1','t',-T/2,0)+integrate('+1','t',
    ',0,T/2));
9 for n=1:10
10 a(1,n)=2*A/T*(integrate('-cos(n*w0*t)','t',-T/2,0)+
    integrate('+cos(n*w0*t)','t',0,T/2));
11 b(1,n)=2*A/T*(integrate('-sin(n*w0*t)','t',-T/2,0)+
    integrate('+sin(n*w0*t)','t',0,T/2));
12 end
13 a=clean(a);b=clean(b); //Function used to

```



```

        round small entities to zero
14
15 //Calculation of exponential fourier series co-
    efficients
16 function y=f(t),y=complex(cos(n*w0*t),-sin(n*w0*t)),
    endfunction;
17 for n=-10:10
18 c(1,n+11)=A/T*(-1*intc(-T/2,0,f)+intc(0,T/2,f));
19 end
20 c=clean(c); //Function used to
    round small entities to zero
21
22 //Calculation of trigonometric fourier series co-
    efficients from exponential fourie series
    coefficients
23 a01=c(1);
24 a1=2*real(c(12:21));
25 b1=-2*imag(c(12:21));
26
27 //Displaying fourier coefficients
28 disp(T,'fundamental period T= ',A,'Assumption:
    Amplitude A= ');
29 disp('Tigonometric fourier series co-efficients:');
30 disp(a0,'a0= ');disp(a,'an= ');disp(b,'bn= ');
31 disp('Exponential fourier series co-efficients');
32 disp(c(11),'c0= ');disp(c(12:21),'cn= ');disp(c
    (10:-1:1),'c-n= ');
33 disp('Trigonometric fourier series co-efficients from
    exponential coefficients:');
34 disp(a01,'a0= ');disp(a1,'an= ');disp(b1,'bn= ');
35 disp('The co-efficients obtained are same by both
    methods')
36
37 x=[-A*ones(1,50) A*ones(1,51)];
38 t=-T/2:0.01*T:T/2;
39 n=-10:10;
40 subplot(311);plot(t,x);
41 title('x(t)');xlabel('time t');

```

```

42 subplot(312);plot2d3(a);
43 title('Coefficients an');xlabel('n');
44 subplot(313);plot2d3(b);
45 title('Coefficients bn');xlabel('n');
46 figure;
47 subplot(311);plot(t,x);
48 title('x(t)');xlabel('time t');
49 subplot(312);plot2d3(n,abs(c));
50 title('Magnitude of Coefficients |c|');xlabel('n');
51 subplot(313);plot2d3(n,atan(c));
52 title('Phase of Coefficients /_c');xlabel('n');

```

---

### Scilab code Exa 2.8 Complex fourier series representation

```

1 //Example 2.8
2
3 clc;clear;close;
4 t=poly(0,'t');
5 //cn=3/(4+(n*pi)^2)
6 Pt=0.669; //Total energy
7 Preq=0.999*Pt; //Required energy
8 c0=3/(4+(0*pi)^2);
9 disp(c0,'c0=');
10 P=(abs(c0))^2;
11 c=[];n=0;
12 while P<Preq
13     n=n+1;
14     c(n)=3/(4+(n*pi)^2);
15     disp(c(n),'cn=',n,'n=');
16     P=P+2*(abs(c(n)))^2;
17 end
18 disp(Pt,'Total power Pt=');
19 disp(Preq,'99.9% of total power Preq=');
20 disp(n,'To include 99.9% of energy, we need to retain
    n terms where n=');

```



# Chapter 3

## Applications of Laplace Transform to System Analysis

Scilab code Exa 3.10 Poles and Zeros

```
1 //Example 3.10
2
3 clc;clear;close;
4 s=poly(0,'s');
5 I=3*s/(s+2)/(s+4);
6 disp(I,'Given Transfer Function:');
7 zero=roots(numer(I));
8 pole=roots(denom(I));
9 disp(zero,'Zeros of transfer function: ');
10 disp(pole,'Poles of transfer function: ');
11 plzr(I);
```

---

Scilab code Exa 3.11 Poles and zeros

```
1 //Example 3.11
2
```

```
3 clc;clear;close;
4 s=poly(0,'s');
5 F=4*(s+1)*(s+3)/(s+2)/(s+4);
6 disp(F,'Given Transfer Function:');
7 zero=roots( numer(F));
8 pole=roots( denom(F));
9 disp(zero,'Zeros of transfer function: ');
10 disp(pole,'Poles of transfer function: ');
11 plzr(F);
```

---

### Scilab code Exa 3.12 Poles and zeros

```
1 //Example 3.12
2
3 clc;clear;close;
4 s=poly(0,'s');
5 F=10*s/(s^2+2*s+2);
6 disp(F,'Given Transfer Function:');
7 zero=roots( numer(F));
8 pole=roots( denom(F));
9 disp(zero,'Zeros of transfer function: ');
10 disp(pole,'Poles of transfer function: ');
11 plzr(F);
```

---

# Chapter 4

## Z Transforms

Scilab code Exa 4.2 Z transform

```
1 //Example 4.2
2
3 clc;clear;close;
4 z=poly(0,'z');
5 x1=[3 1 2 5 7 0 1];n1=-3:3;
6 X1=x1*(z^-n1)';
7 x2=[2 4 5 7 0 1 2];n2=-2:4;
8 X2=x2*(z^-n2)';
9 x3=[1 2 5 4 0 1]; n3=0:5;
10 X3=x3*(z^-n3)';
11 x4=[0 0 1 2 5 4 0 1];n4=0:7;
12 X4=x4*(z^-n4)';
13 X5=z^0;
14 X6=z^-5;
15 X7=z^5;
16 disp(X1,'x1(n)={3,1,2,5,7,0,1} X1(z)=');
17 disp(X2,'x2(n)={2,4,5,7,0,1,2} X2(z)=');
18 disp(X3,'x3(n)={1,2,5,4,0,1} X3(z)=');
19 disp(X4,'x4(n)={0,0,1,2,5,4,0,1} X4(z)=');
20 disp(X5,'x5(n)=delta(n) X5(z)=');
21 disp(X6,'x6(n)=delta(n-5) X6(z)=');
```

```
22 disp(X7, 'x7(n)=delta(n+5) X7(z)=');
```

---

#### Scilab code Exa 4.4 Z transform

```
1 //Example 4.4
2
3 clc;clear;close;
4 z=poly(0, 'z ');
5 x=[1 3 0 0 6 -1];n=-1:4;
6 X=x*(z^-n)';
7 disp(X, 'x(n)={1,3,0,0,6,-1} X(z)=');
```

---

#### Scilab code Exa 4.13 Convolution

```
1 //Example 4.13
2
3 clc;clear;close;
4 z=poly(0, 'z ');
5 x1=[4 -2 1];n1=0:length(x1)-1;
6 X1=x1*(z^-n1)';
7 x2=[1 1 1 1 1];n2=0:length(x2)-1;
8 X2=x2*(z^-n2)';
9 X3=X1*X2;
10 l=coeff( numer(X3) );
11 x3=l(:, $:-1:1);
12 disp(X1, 'x1(n)={4,-2,1} X1(z)=');
13 disp(X2, 'x2(n)={1,1,1,1,1} X2(z)=');
14 disp(X3, 'Z transform of convolution of the two
           signals X3(z)=');
15 disp(x3, 'Convolution result of the two signals= ');
```

---

### Scilab code Exa 4.14 Convolution

```
1 //Example 4.14
2
3 clc;clear;close;
4 z=poly(0,'z');
5 x1=[2 1 0 0.5];n1=0:length(x1)-1;
6 X1=x1*(z^-n1)';
7 x2=[2 2 1 1];n2=0:length(x2)-1;
8 X2=x2*(z^-n2)';
9 X3=X1*X2;
10 l=coeff( numer(X3));
11 x3=l(:, $:-1:1);
12 disp(X1, 'x1(n)={2,1,0,0.5} X1(z)=');
13 disp(X2, 'x2(n)={2,2,1,1} X2(z)=');
14 disp(X3, 'Z transform of convolution of the two
    signals X3(z)=');
15 disp(x3, 'Convolution result of the two signals=')
```

---

### Scilab code Exa 4.16 Cross correlation

```
1 //Example 4.16
2
3 clc;clear;close;
4 z=poly(0,'z');
5 x1=[1 2 3 4];n1=0:length(x1)-1;
6 X1=x1*(z^-n1)';
7 x2=[4 3 2 1];n2=0:length(x2)-1;
8 X2=x2*(z^-n2)';
9 X2_=x2*(z^n2)';
10 X3=X1*X2_;
11 l=coeff( numer(X3));
12 x3=l(:, $:-1:1);
13 disp(X1, 'x1(n)={4,-2,1} X1(z)=');
14 disp(X2, 'x2(n)={4,-2,1} X2(z)=');
```



```
15 disp(X3, 'Z transform of cross crrelation of the two
    signals X3(z)=');
16 disp(x3, 'Cross correlation result of the two signals
    = ')
```

---

#### Scilab code Exa 4.19 System response

```
1 //Example 4.19
2
3 clc;clear;close;
4 z=poly(0, 'z ');
5 h=[1 2 3];n1=0:length(h)-1;
6 H=h*(z^-n1)';
7 y=[1 1 2 -1 3];n2=0:length(y)-1;
8 Y=y*(z^-n2)';
9 X=Y/H;
10 l=coeff( numer(X));
11 x=l(:, $:-1:1);
12 disp(H, 'h(n)={1,2,3} H(z)=');
13 disp(Y, 'y(n)={1,1,2,-1,3} Y(z)=');
14 disp(X, 'Z transform of input sequence X(z)=');
15 disp(x, 'Inpput Sequence = ')
```

---

# Chapter 5

## Linear Time Invariant Systems

Scilab code Exa 5.20 System response

```
1 //Example 5.20
2
3 clc;clear;close;
4 z=poly(0,'z');
5 x=[-1 1 0 -1];n=0:length(x)-1;
6 X=x*(z^-n)';
7 H=0.2-0.5*z^-2+0.4*z^-3
8 Y=H*X;
9 l=coeff( numer(Y));
10 y=l(:, $:-1:1);
11 disp(X, 'Input sequence x(n)={-1,1,0,-1} X(z)=');
12 disp(H, 'System Transfer Function H(z)=');
13 disp(Y, 'Z transform of output response Y(z)=');
14 disp(y, 'Digital output sequence y=')
```

---

Scilab code Exa 5.21 Poles and zeros

```
1 //Example 5.21
```

```
2  clc;clear;close;
3  z=poly(0,'z');
4  H=(1+z^-1)/(1+3/4*z^-1+1/8*z^-2);
5  pole=roots( numer(H));
6  zero=roots( denom(H));
7  disp(H,'System Transfer Function H(z)=');
8  disp(zero,'System zeros are at ');
9  disp(pole,'System poles are at ');
10 plzr(H);
```

---

# Chapter 6

## Discrete and Fast Fourier Transforms

Scilab code Exa 6.1 Linear and Circular convolution

```
1 //Example 6.1
2 clc;clear;close;
3 x1=[1 1 2 2];
4 x2=[1 2 3 4];
5 ylength=length(x1);
6 //Calculation of linear convolution
7 z=convol(x1,x2);
8 //Calculation of circular convolution
9 for n=1:ylength
10     y(n)=0;
11     for k=1:ylength,
12         l=n-k+1;
13         if l <= 0 then
14             l=1+ylength;
15         end
16         y(n)=y(n)+(x1(k)*x2(l));
17     end
18 end
19 //Calculation of circular convolution using DFT and
```

```

IDFT
20 X1=fft(x1,-1);
21 X2=fft(x2,-1);
22 Y1=X1.*X2;
23 y1=fft(Y1,1);
24 y1=clean(y1);
25 disp(z,'Linear Convolution sequence is z(n): ');
26 disp(y,'Circular Convolution sequence is y(n): ');
27 disp(y1,'Circular Convolution sequence calculated
    using DFT-IDFT method is y(n): ');

```

---

#### Scilab code Exa 6.2 FIR filter response

```

1 //Example 6.2
2
3 clc;clear;close;
4 x=[1 2];
5 h=[1 2 4];
6
7 //Calculation of linear convolution
8 y=convol(x,h);
9 disp(x,'Input Sequence is x(n): ');
10 disp(h,'Impulse response of FIR filter h(n): ');
11 disp(y,'Output sequence is y(n): ');
12 subplot(3,1,1);
13 plot2d3(x);
14 title('Input Sequence x[n]: ');ylabel('Amplitude-->');
    xlabel('n-->')
15 subplot(3,1,2);
16 plot2d3(h);
17 title('Impulse Response h[n]: ');ylabel('Amplitude-->');
    xlabel('n-->')
18 subplot(3,1,3);
19 plot2d3(y);
20 title('Output Sequence y[n]=x[n]*h[n] : ');ylabel('

```

Amplitude—>');xlabel('n—>')

---

### Scilab code Exa 6.3 Convolution

```
1 //Example 6.3
2
3 clc;clear;close;
4 x=[1 1 1];
5 h=[1 1 1];
6
7 //Calculation of linear convolution
8 y=convol(x,h);
9 disp(x,'First Sequence is x(n): ');
10 disp(h,'Second Sequence is h(n): ');
11 disp(y,'Output sequence is y(n): ');
12 subplot(3,1,1);
13 plot2d3(x);
14 title('First Sequence x[n]: ');ylabel('Amplitude—>');
    xlabel('n—>')
15 subplot(3,1,2);
16 plot2d3(h);
17 title('Second Sequence h[n]: ');ylabel('Amplitude—>')
    ;xlabel('n—>')
18 subplot(3,1,3);
19 plot2d3(y);
20 title('Convolution Sequence y[n]=x[n]*h[n] : ');ylabel
    ('Amplitude—>');xlabel('n—>')
```

---

### Scilab code Exa 6.4 Convolution

```
1 //Example 6.4
2
3 clc;clear;close;
```

```

4 a=0.5;
5 n=1:50;
6 x=ones(1,50);
7 h=a^n;
8
9 //Calculation of linear convolution
10 for i=1:50
11     y(1,i)=sum(h(1:i));
12 end
13 disp('First Sequence is x(n)=u(n) ');
14 disp(a,'Second Sequence is h(n)=a^n*u(n) where a= ');
15     ;
16 disp(y,'Output sequence is y(n): ');
17 subplot(3,1,1);
18 plot2d3(x);
19 title('First Sequence x[n]: ');ylabel('Amplitude—>');
20     xlabel('n—>')
21 subplot(3,1,2);
22 plot2d3(h);
23 title('Second Sequence h[n]: ');ylabel('Amplitude—>')
24     ;xlabel('n—>')
25 subplot(3,1,3);
26 plot2d3(y);
27 title('Convolution Sequence y[n]=x[n]*h[n] : ');ylabel
28     ('Amplitude—>');xlabel('n—>')

```

---

#### Scilab code Exa 6.5 Convolution

```

1 //Example 6.5
2 clc;clear;close;
3 x=[1 2 3];xmin=0;nx=xmin:length(x)+xmin-1;
4 h=[1 2 -2 -1];hmin=-1;nh=length(h)+hmin-1;
5
6 //Calculation of linear convolution
7 y=convol(x,h);

```

```

8  ymin=xmin+hmin;ny=ymin:length(y)+ymin-1;
9
10 disp(x,'First Sequence is x(n): ');
11 disp(h,'Second Sequence is h(n): ');
12 disp(y,'Output sequence is y(n): ');
13 subplot(3,1,1);
14 plot2d3(nx,x);
15 title('First Sequence x[n]: ');ylabel('Amplitude—>');
    xlabel('n—>')
16 subplot(3,1,2);
17 plot2d3(nh,h);
18 title('Second Sequence h[n]: ');ylabel('Amplitude—>')
    ;xlabel('n—>')
19 subplot(3,1,3);
20 plot2d3(ny,y);
21 title('Convolution Sequence y[n]=x[n]*h[n] : ');ylabel
    ('Amplitude—>');xlabel('n—>')

```

---

### Scilab code Exa 6.6 Convolution

```

1 //Example 6.6
2
3 clc;clear;close;
4 x=[1 1 0 1 1];xmin=-2;nx=xmin:length(x)+xmin-1;
5 h=[1 -2 -3 4];hmin=-3;nh=length(h)+hmin-1;
6
7 //Calculation of linear convolution
8 y=convol(x,h);
9 ymin=xmin+hmin;ny=ymin:length(y)+ymin-1;
10
11 disp(x,'First Sequence is x(n): ');
12 disp(h,'Second Sequence is h(n): ');
13 disp(y,'Output sequence is y(n): ');
14 subplot(3,1,1);
15 plot2d3(nx,x);

```



```

16 title('First Sequence x[n]: ');ylabel('Amplitude—>');
    xlabel('n—>')
17 subplot(3,1,2);
18 plot2d3(nh,h);
19 title('Second Sequence h[n]: ');ylabel('Amplitude—>')
    ;xlabel('n—>')
20 subplot(3,1,3);
21 plot2d3(ny,y);
22 title('Convolution Sequence y[n]=x[n]*h[n] : ');ylabel
    ('Amplitude—>');xlabel('n—>')

```

---

#### Scilab code Exa 6.8 DFT

```

1 //Example 6.8
2
3 clc;clear;close;
4 L=3;A=1/4;
5 x=A*ones(1,L);
6 //Calculation of DFT
7 X=fft(x,-1);
8 X=clean(X);
9 disp(x,'Given Sequence is x(n): ');
10 disp(X,'DFT of the Sequence is X(k): ');

```

---

#### Scilab code Exa 6.9 DFT

```

1 //Example 6.9
2
3 clc;clear;close;
4 L=3;A=1/5;
5 n=-1:1;
6 x=A*ones(1,L);
7 //Calculation of DFT

```

```

8 X=fft(x,-1);
9 X=clean(X);
10 disp(x,'Given Sequence is x(n): ');
11 disp(X,'DFT of the Sequence is X(k): ');

```

---

### Scilab code Exa 6.10 DFT

```

1 //Example 6.10
2
3 clc;clear;close;
4 x=[1 1 2 2 3 3];
5 //Calculation of DFT
6 X=fft(x,-1);
7 X=clean(X);
8 disp(x,'Given Sequence is x(n): ');
9 disp(X,'DFT of the Sequence is X(k): ');
10 subplot(3,1,1);
11 plot2d3(x);
12 title('Given Sequence x[n]: ');ylabel('Amplitude—&gt;');
13 xlabel('n—&gt;');
14 subplot(3,1,2);
15 plot2d3(abs(X));
16 title('Magnitude Spectrum |X(k)| ');xlabel('k—&gt;');
17 ;
18 subplot(3,1,3);
19 plot2d3(atan(X));
20 title('Phase Spectrum /_X(k) ');xlabel('k—&gt;');

```

---

### Scilab code Exa 6.11 DFT

```

1 //Example 6.11

```

```

2
3 clc;clear;close;
4 N=8;A=1/4;
5 n=0:N-1;
6 x=A^n;
7 //Calculation of DFT
8 X=fft(x,-1);
9 X=clean(X);
10 disp(x,'Given Sequence is x(n): ');
11 disp(N,'N=')
12 disp(X,'N-point DFT of the Sequence is X(k): ');

```

---

#### Scilab code Exa 6.12 DFT

```

1 //Example 6.12
2
3 clc;clear;close;
4 N=4;
5 n=0:N-1;
6 x=cos(%pi/4*n);
7 //Calculation of DFT
8 X=fft(x,-1);
9 X=clean(X);
10 disp(x,'Given Sequence is x(n): ');
11 disp(X,'DFT of the Sequence is X(k): ');

```

---

#### Scilab code Exa 6.13 Inverse DFT

```

1 //Example 6.13
2 clc;clear;close;
3 X=[1 2 3 4];
4 //Calculation of IDFT
5 x=fft(X,1);

```

```
6 x=clean(x);
7 disp(X, 'DFT of the Sequence is X(k): ');
8 disp(x, 'Sequence is x(n): ');
```

---

#### Scilab code Exa 6.14 Inverse DFT

```
1 //Example 6.14
2 clc;clear;close;
3 X=[3 2+%i 1 2-%i];
4 //Calculation of IDFT
5 x=fft(X,1);
6 x=clean(x);
7 disp(X, 'DFT of the Sequence is X(k): ');
8 disp(x, 'Sequence is x(n): ');
```

---

#### Scilab code Exa 6.15 DIT FFT

```
1 //Example 6.15
2
3 clc;clear;
4 x=[1 2 3 4 4 3 2 1];
5 X=clean(fft(x));
6 disp(x, 'x(n)=');
7 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.16 DIT FFT

```
1 //Example 6.16
2
3 clc;clear;
```

```
4 x=[0 1 2 3 4 5 6 7];
5 X=clean(fft(x));
6 disp(x, 'x(n)=');
7 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.17 DIT FFT

```
1 //Example 6.17
2
3 clc;clear;
4 n=0:7;
5 x=2^n;
6 X=clean(fft(x));
7 disp(x, 'x(n)=');
8 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.18 DIT FFT

```
1 //Example 6.18
2
3 clc;clear;
4 x=[0 1 2 3];
5 X=clean(fft(x));
6 disp(x, 'x(n)=');
7 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.19 DIF FFT

```
1 //Example 6.19
2
```

```
3 clc; clear;
4 x=[1 2 3 4 4 3 2 1];
5 X=clean(fft(x));
6 disp(x, 'x(n)=');
7 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.20 DIF FFT

```
1 //Example 6.20
2
3 clc; clear;
4 n=0:7;
5 x=2n;
6 X=clean(fft(x));
7 disp(x, 'x(n)=');
8 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.21 DIF FFT

```
1 //Example 6.21
2
3 clc; clear;
4 n=0:7;
5 x=n+1;
6 X=clean(fft(x));
7 disp(x, 'x(n)=');
8 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.22 DIF FFT

```
1 //Example 6.21
2
3 clc;clear;
4 n=0:3;
5 x=cos(n*pi/2);
6 X=clean(fft(x));
7 disp(x, 'x(n)=');
8 disp(X, 'X(k)=');
```

---

#### Scilab code Exa 6.23 IFFT

```
1 //Example 6.23
2
3 clc;clear;
4 X=[6 -2+2*i -2 -2-2*i];
5 x=clean(ifft(X));
6 disp(X, 'X(k)=');
7 disp(x, 'x(n)=');
```

---

#### Scilab code Exa 6.24 IFFT

```
1 //Example 6.24
2
3 clc;clear;
4 X=[20 -5.828-2.414*i 0 -0.172-0.414*i 0
      -0.172+0.414*i 0 -5.828+2.414*i];
5 x=round(clean(ifft(X)));
6 disp(X, 'X(k)=');
7 disp(x, 'x(n)=');
```

---

### Scilab code Exa 6.25 IFFT

```
1 //Example 6.25
2
3 clc; clear;
4 X=[255 48.63+166.05*%i -51+102*%i -78.63+46.05*%i
      -85 -78.63-46.05*%i -51-102*%i 48.63-166.05*%i];
5 x=round(clean(ifft(X)));
6 disp(X, 'X(k)=');
7 disp(x, 'x(n)=');
```

---

### Scilab code Exa 6.26 IFFT

```
1 //Example 6.26
2
3 clc; clear;
4 X=[36 -4+9.656*%i -4+4*%i -4+1.656*%i -4 -4-1.656*%i
      -4-4*%i -4-9.656*%i ];
5 x=round(clean(ifft(X)));
6 disp(X, 'X(k)=');
7 disp(x, 'x(n)=');
```

---

### Scilab code Exa 6.27 IFFT

```
1 //Example 6.27
2
3 clc; clear;
4 t=0:0.0025:0.0175;
5 f=50;
6 x=sin(2*%pi*f*t);
7 X=clean(fft(x));
8 disp(x, 'x(n)=');
9 disp(X, 'X(k)=');
```



---

Scilab code Exa 6.34 Overlap Add Convolution

```
1 //Example 6.34
2
3 clc;clear;close;
4 h=[2 2 1];
5 x=[3 0 -2 0 2 1 0 -2 -1 0];
6 M=length(h); //length of impulse
   response
7 L=2^M; //length of FFT/IFFT
   operation
8 N=L-M+1;
9 x1=length(x);
10 K=ceil(x1/N); //number of iterations
11 h=[h zeros(1,L-M)];
12 x=[x x(1:K*N-x1)];
13 H=fft(h);
14 y=zeros(1,M-1);
15 for k=0:K-1
16     xk=[x(k*N+1:(k+1)*N) zeros(1,M-1)];
17     Xk=fft(xk);
18     Yk=H.*Xk;
19     yk=ifft(Yk);
20     yk=clean(yk);
21     y=[y(1:k*N) y(k*N+1:k*N+M-1)+yk(1:M-1) yk(M:L)];
22     disp(k+1,'Segment =');
23     disp(xk,'xk(n)=');
24     disp(yk,'yk(n)=');
25 end
26 y=y(1:x1+M-1);
27 disp(y,'Output Sequence is y(n): ');
```

---

### Scilab code Exa 6.35 Overlap Save Convolution

```
1 //Example 6.35
2
3 clc;clear;close;
4 h=[2 2 1];
5 x=[3 0 -2 0 2 1 0 -2 -1 0];
6 M=length(h); //length of impulse
   response
7 L=2^M; //length of FFT/IFFT operation
8 N=L-M+1;
9 x1=length(x);
10 K=ceil(x1/N); //number of iterations
11 h=[h zeros(1,L-M)];
12 x=[zeros(1,M-1) x x(1:K*N-x1)];
13 H=fft(h);
14 for k=0:K-1
15     xk=x(k*N+1:(k+1)*N+M-1);
16     Xk=fft(xk);
17     Yk=H.*Xk;
18     yk=ifft(Yk);
19     yk=clean(yk);
20     y=[yk(1:k*N) yk(M:L)];
21     disp(k+1,'Segment =');
22     disp(xk,'xk(n)=');
23     disp(yk,'yk(n)=');
24 end
25 disp(y,'Output Sequence is y(n): ');
```

---

### Scilab code Exa 6.36 Cross Correlation

```
1 //Example 6.36
2
3 clc;clear;close;
4 x=[1 0 0 1];
```

```

5 h=[4 3 2 1];
6 ylength=length(x)+length(h)-1;
7 xlength=length(x);
8 x=[zeros(1,length(h)-1) x zeros(1,length(h)-1)];
9 y=0;
10 //Calculation of cross correlation
11 for n=1:ylength;
12     y(n)=x*[zeros(1,n-1) h zeros(1,ylength-n)];
           //this instruction performs cross
           correlation of x & h
13 end
14
15 disp(x,'First Sequence is x(n): ');
16 disp(h,'Second Sequence is h(n): ');
17 disp(y,'Correlation Sequence y[n] is ');
18 figure;
19 subplot(3,1,1);
20 plot2d3(x);
21 title('First Sequence x[n]: ');ylabel('Amplitude—>');
    xlabel('n—>')
22 subplot(3,1,2);
23 plot2d3(h);
24 title('Second Sequence h[n]: ');ylabel('Amplitude—>');
    xlabel('n—>')
25 subplot(3,1,3);
26 plot2d3(y);
27 title('Correlation Sequence y[n]: ');ylabel('Amplitude
    —>');xlabel('n—>')

```

---

### Scilab code Exa 6.37 Circular Correlation

```

1 //Example 6.37
2
3 clc;clear;close;
4 x=[1 0 0 1];

```

```

5 h=[4 3 2 1];
6 ylength=length(x);
7 y=0;
8 //Calculation of circular correlation
9 for n=1:ylength,
10     y(n)=0;
11     for k=1:ylength,
12         l=k-n+1;
13         if l <= 0 then
14             l=l+ylength;
15         end
16         y(n)=y(n)+(x(k)*h(l));
17     end
18     y(n)=y(n)/4;
19 end
20
21 disp(x,'First Sequence is x(n): ');
22 disp(h,'Second Sequence is h(n): ');
23 disp(y,'Correlation Sequence y[n] is ');
24 figure;
25 subplot(3,1,1);
26 plot2d3(x);
27 title('First Sequence x[n]: ');ylabel('Amplitude—>');
    xlabel('n—>')
28 subplot(3,1,2);
29 plot2d3(h);
30 title('Second Sequence h[n]: ');ylabel('Amplitude—>')
    ;xlabel('n—>')
31 subplot(3,1,3);
32 plot2d3(y);
33 title('Correlation Sequence y[n]: ');ylabel('Amplitude
    —>');xlabel('n—>')

```

---

# Chapter 7

## Finite Impulse Response Filters

Scilab code Exa 7.3 Low pass filter using fourier series method

```
1 //Example 7.3
2
3 clc;clear;close;
4 fp=2000; //passband frequency
5 F=9600; //sampling frequency
6
7 //Calculation of filter co-efficients
8 a0=1/F*integrate('1','t',-fp,fp);
9 for n=1:10;
10 a(1,n)=2/F*integrate('cos(2*%pi*n*f/F)','f',-fp,fp);
11 end
12 h=[a(:, $:-1:1)/2 a0 a/2];
13
14 //Displaying filter co-efficients
15 disp(F, 'Sampling frequency F= ',fp, 'Assumption:
    Passband frequency fp= ');
16 disp('Filter co-efficients: ');
17 disp(a0, 'h(0)= ');disp(a/2, 'h(n)=h(-n)=');
18
19 n=-10:10;
20 plot2d3(n,h);
```

```
21 title('Filter transfer function h(n)');xlabel('n-->')
    );
```

---

Scilab code Exa 7.4 Low pass filter using Type 1 frequency sampling technique

```
1 //Example 7.4
2
3 clc;clear;close;
4 M=7;w=2*%pi/M;
5
6 //Calculation of filter co-efficients
7 k=[0 1 6];
8 for n=0:M-1
9     h(n+1)=sum(exp(-%i*3*w*k).*exp(%i*w*k*n))/M;
10 end
11 h=clean(h);
12
13 //Displaying filter co-efficients
14 disp(M,'Filter Order M= ');
15 disp('Filter co-efficients:');
16 disp(h,'h(n)= ');
17
18 plot2d3(h);
19 title('Filter transfer function h(n)');xlabel('n-->')
    );
```

---

# Chapter 8

## Infinite Impulse Response Filters

Scilab code Exa 8.1 IIR filter Design by Backward Difference For Derivative method

```
1 //Example 8.1
2 clc;clear;close;
3 s=poly(0,'s');
4 z=poly(0,'z');
5 T=1;
6 Hs=1/(s+2);
7 Hz=horner(Hs,(1-1/z)/T);
8 disp('Using Backward difference formula for
      derivative:')
9 disp(Hs,'H(s)=');
10 disp(Hz,'H(z)=');
```

---

Scilab code Exa 8.2 IIR filter Design by Backward Difference For Derivative method

```
1 //Example 8.2
2 clc;clear;close;
```

```

3 s=poly(0, 's');
4 z=poly(0, 'z');
5 T=1;
6 Hs=1/(s^2+16);
7 Hz=horner(Hs, (1-1/z)/T);
8 disp('Using Backward difference formula for
      derivative:')
9 disp(Hs, 'H(s)=');
10 disp(Hz, 'H(z)=');

```

---

**Scilab code Exa 8.3** IIR filter Design by Backward Difference For Derivative method

```

1 //Example 8.3
2 clc;clear;close;
3 s=poly(0, 's');
4 z=poly(0, 'z');
5 T=1;
6 Hs=1/((s+0.1)^2+9);
7 Hz=horner(Hs, (1-1/z)/T);
8 disp('Using Backward difference formula for
      derivative:')
9 disp(Hs, 'H(s)=');
10 disp(Hz, 'H(z)=');

```

---

**Scilab code Exa 8.4** IIR filter Design by Impulse Invariant method

```

1 //Example 8.4
2 clc;clear;close;
3 s=poly(0, 's');
4 z=poly(0, 'z');
5 T=1;
6 Hs=(s+0.2)/((s+0.2)^2+9);
7 Hz=horner(Hs, (1-1/z)/T);

```



```
8 disp('Using Impulse Invariant Technique:')
9 disp(Hs, 'H(s)=');
10 disp(Hz, 'H(z)=');
```

---

Scilab code Exa 8.5 IIR filter Design by Impulse Invariant method

```
1 //Example 8.5
2 clc;clear;close;
3 s=poly(0, 's');
4 z=poly(0, 'z');
5 T=1;
6 Hs=1/(s+1)/(s+2);
7 Hz=horner(Hs, (1-1/z)/T);
8 disp('Using Impulse Invariant Technique:')
9 disp(Hs, 'H(s)=');
10 disp(Hz, 'H(z)=');
```

---

Scilab code Exa 8.6 IIR filter Design by Impulse Invariant method

```
1 //Example 8.6
2 clc;clear;close;
3 s=poly(0, 's');
4 z=poly(0, 'z');
5 T=1;
6 Hs=1/(s+0.5)/(s^2+0.5*s+2);
7 Hz=horner(Hs, (1-1/z)/T);
8 disp('Using Impulse Invariant Technique:')
9 disp(Hs, 'H(s)=');
10 disp(Hz, 'H(z)=');
```

---

Scilab code Exa 8.7 IIR filter Design by Bilinear Transformation method

```
1 //Example 8.7
2 clc;clear;close;
3 s=poly(0,'s');
4 z=poly(0,'z');
5 T=0.276;
6 Hs=(s+0.1)/((s+0.1)^2+9);
7 Hz=ss2tf(cls2dls(tf2ss(Hs),T));
8 disp('Using Bilinear Transformation:');
9 disp(Hs,'H(s)=');
10 disp(Hz,'H(z)=');
```

---

Scilab code Exa 8.8 IIR filter Design by Bilinear Transformation method

```
1 //Example 8.8
2 clc;clear;close;
3 s=poly(0,'s');
4 z=poly(0,'z');
5 T=0.1;
6 Hs=2/(s+1)/(s+2);
7 Hz=ss2tf(cls2dls(tf2ss(Hs),T));
8 disp(Hs,'H(s)=');
9 disp(Hz,'H(z)=');
```

---

Scilab code Exa 8.9 IIR filter Design by Bilinear Transformation method

```
1 //Example 8.9
2 clc;clear;close;
3 s=poly(0,'s');
4 z=poly(0,'z');
5 T=0.1;
6 wr=0.25*%pi; //Given cut off frequency
```

```

7 fc=2/T*tan(wr/2);
8 Hs=fc/(s+fc);
9 Hz=ss2tf(cls2dls(tf2ss(Hs),T));
10 disp('Using Bilinear Transformation:');
11 disp(Hs,'H(s)=');
12 disp(Hz,'H(z)=');

```

---

Scilab code Exa 8.10 IIR filter Design by Bilinear Transformation method

```

1 //Example 8.10
2 clc;clear;close;
3 s=poly(0,'s');
4 z=poly(0,'z');
5 T=0.1;
6 Hs=1/(s+1)^2;
7 Hz=ss2tf(cls2dls(tf2ss(Hs),T));
8 disp('Using Bilinear Transformation:');
9 disp(Hs,'H(s)=');
10 disp(Hz,'H(z)=');

```

---

Scilab code Exa 8.11 Butterworth Filter using Impulse Invariant transformation

```

1 //Example 8.11
2 clc;clear;close;
3 rp=0.707 //passband ripple
4 rs=0.2 //stopband ripple
5 wp=%pi/2; //passband frequency
6 ws=3*%pi/4; //stopband frequency
7 T=1;
8 fp=wp/T;
9 fs=ws/T;
10 s=poly(0,'s');
11 z=poly(0,'z');

```

```

12 hs=1;
13 //Calculating the order of filter
14 num=log((rs^-2 -1)/(rp^-2 -1));
15 den=2*log(fs/fp);
16 N=ceil(num/den);
17
18 //Calculation of cut-off frequency
19 fc=fp/(rp^-2 -1)^(0.5/N);
20
21 //Calculating filter response
22 if modulo(N,2)==1 then
23     b=-2*sin(%pi/(2*N));
24     hs=hs*fc/(s+fc);
25 end
26 for k=1:N/2
27     b=2*sin((2*k-1)*%pi/(2*N));
28     hs=hs*fc^2/(s^2+b*fc*s+fc^2);
29 end
30 hs=clean(hs);
31 sys=syslin('c',hs);
32 hz=horner(ss2tf(dscr(sys,T)),1/z);           //
      converting H(s) to H(z)
33
34 //Displaying filter response
35 [hzm,fr]=frmag(hz,256);
36 disp(hz,'Filter Transfer function: ');
37 plot(fr,hzm);
38 title('Lowpass Butterworth Filter Response');ylabel(
      'Amplitude—>');xlabel('Normalised frequency f/fs
      —>');

```

---

Scilab code Exa 8.12 Butterworth Filter using Bilinear transformation

```

1 //Example 8.12
2 clc;clear;close;

```

```

3  rp=0.9                                     //passband ripple
4  rs=0.2                                     //stopband ripple
5  wp=%pi/2;                                 //passband frequency
6  ws=3*%pi/4;                               //stopband frequency
7  T=1;
8  fp=2/T*tan(wp/2);
9  fs=2/T*tan(ws/2);
10 s=poly(0, 's');
11 z=poly(0, 'z');
12 hs=1;
13 //Calculating the order of filter
14 num=log((rs^-2 -1)/(rp^-2 -1));
15 den=2*log(fs/fp);
16 N=ceil(num/den);
17
18 //Calculation of cut-off frequency
19 fc=fp/(rp^-2 -1)^(0.5/N);
20
21 //Calculating filter response
22 if modulo(N,2)==1 then
23     hs=hs*fc/(s+fc);
24 end
25 for k=1:N/2
26     b=2*sin((2*k-1)*%pi/(2*N));
27     hs=hs*fc^2/(s^2+b*fc*s+fc^2);
28 end
29 hs=clean(hs);
30 sys=syslin('c',hs);
31 hz=ss2tf(cls2dls(tf2ss(sys),T));           //converting
      H(s) to H(z)
32
33 //Displaying filter response
34 [hzm,fr]=frmag(hz,256);
35 disp(hz,'Filter Transfer function: ');
36 plot(fr,hzm);
37 title('Lowpass Butterworth Filter Response');ylabel(
      'Amplitude—>');xlabel('Normalised frequency f/fs
      —>');

```

---

Scilab code Exa 8.14 Filter transformation

```
1 //Example 8.14
2 clc;clear;close;
3 s=poly(0,'s');
4 fc=1; //Assumed cut off frequency
5 Q=10;f0=2; //Given data
6 Hs=1/(s^2+2*s+1);
7 l=fc*(s^2+f0^2)/(s*f0/Q);
8 Hs1=horner(Hs,l);
9 disp(Hs,'Low pass filter H(s)=');
10 disp(Hs1,'Band pass filterH(s)=');
```

---

Scilab code Exa 8.15 Filter transformation

```
1 //Example 8.15
2 clc;clear;close;
3 s=poly(0,'s');
4 fc=1; //Assumed cut off frequency of
   low pass filter
5 f0=5; //Assumed cut off frequency of
   high pass filter
6 Hs=fc/(s+fc);
7 Hs1=horner(Hs,fc*f0/s);
8 disp(Hs,'H(s)=',fc,'Low pass filter with fc=');
9 disp(Hs1,'H(s)=',f0,'High pass filter with fc=');
```

---

# Chapter 9

## Realisation of Digital Linear Systems

Scilab code Exa 9.4 Cascade Realisation

```
1 //Example 9.4
2 clc;clear;close;
3 z=poly(0,'z');
4 Hz=2*(z+2)/(z*(z-0.1)*(z+0.5)*(z+0.4));
5 H=dscr(Hz,0.1);
6 disp(Hz,'System Function H(z)=');
7 disp(H,'System Function for cascade realisation Hk(z
   )=');
```

---

Scilab code Exa 9.5.a Parallel Realisation

```
1 //Example 9.5.a
2 clc;clear;close;
3 z=poly(0,'z');
4 s=poly(0,'s');
5 Hz=3*(2*z^2+5*z+4)/(2*z+1)/(z+2);
```

```

6 H=pfss(Hz/z);
7 for k=1:length(H)
8     H(k)=clean(H(k));
9     H1(k)=z*horner(H(k),z);
10 disp(H1(k), 'System Function for parallel realisation
    Hk(z)=');
11 end
12 disp(Hz, 'System Function H(z)=');

```

---

#### Scilab code Exa 9.5.b Parallel Realisation

```

1 //Example 9.5.b
2 clc;clear;close;
3 z=poly(0, 'z ');
4 s=poly(0, 's ');
5 Hz=3*z*(5*z-2)/(z+1/2)/(3*z-1);
6 H=pfss(Hz/z);
7 for k=1:length(H)
8     H(k)=clean(H(k));
9     H1(k)=z*horner(H(k),z);
10 disp(H1(k), 'System Function for parallel realisation
    Hk(z)=');
11 end
12 disp(Hz, 'System Function H(z)=');

```

---



# Chapter 10

## Effects of Finite Word Length in Digital Filters

Scilab code Exa 10.2 Output Quantisation Noise

```
1 //Example 10.2
2
3 clc;clear;close;
4 z=poly(0,'z');
5 H=0.5*z/(z-0.5);
6 B=8;
7 pn=2^(-2*B)/12; //Noise power
8 X=H*horner(H,1/z)/z;
9 r=roots(denom(X));
10 r1=length(r);
11 rc=coeff(denom(X))
12 q1=[];q2=[];
13 for n=1:r1 //Loop to separate poles
    inside the unit circle
14     if (abs(r(n))<1) then
15         q1=[q1 r(n)];
16     else
17         q2=[q2 r(n)];
18     end
```

```

19 end
20 P=numer(X)/rc(length(rc));
21 Q1=poly(q1, 'z');
22 Q2=poly(q2, 'z');
23 I=residu(P,Q1,Q2);           //Residue Calculation
24 po=pn*I;                   //Output Noise power
25 disp(pn, 'Input Noise power');
26 disp(po, 'Output Noise power');

```

---

### Scilab code Exa 10.3 Deadband Interval

```

1 //Example 10.3
2
3 clc; clear;
4 //y(n)=0.9y(n-1)+x(n)
5 //Input x(n)=0
6 n=-1;y=12;           //Initial Condition y(-1)=12
7 flag=1;
8 while n<8
9     n=n+1;
10    y=[y 0.9*y(n+1)];
11    yr=round(y);
12 end
13 disp(n, 'n=');
14 disp(y, 'y(n)-exact');
15 disp(yr, 'y(n)-rounded');
16 disp([-yr(n+2) yr(n+2)], 'Deadband interval ');

```

---

### Scilab code Exa 10.4 Deadband Interval

```

1 //Example 10.4
2
3 clc; clear;

```

```

4 //y(n)=0.9y(n-1)+x(n)
5 a=0.9;
6 l=ceil(0.5/(1-abs(a)));
7 disp([-1 l], 'Deadband interval ')

```

---

Scilab code Exa 10.5 Output Quantisation Noise for Cascade realisation

```

1 //Example 10.5
2
3 clc;clear;close;
4 x=poly(0,'x'); //x=2^-2B
5 z=poly(0,'z');
6 H1=1/(1-0.9/z);
7 H2=1/(1-0.8/z);
8 H=H1*H2;
9 pn=x/12; //Input Noise power
10
11 //Calculation of output noise for H1(z)
12 X1=H*horner(H,1/z)/z;
13 r1=roots(denom(X1));
14 rc1=coeff(denom(X1));
15 q1=[];s1=[];
16 for n=1:length(r1) //Loop to separate
    poles inside the unit circle
17     if (abs(r1(n))<1) then
18         q1=[q1 r1(n)];
19     else
20         s1=[s1 r1(n)];
21     end
22 end
23 P1=numer(X1)/rc1(length(rc1));
24 Q1=poly(q1,'z');
25 S1=poly(s1,'z');
26 I1=abs(residu(P1,Q1,S1)); //Residue
    Calculation

```

```

27 po1=pn*I1;                               //Output Noise power
28
29 //Calculation of output noise for H2(z)
30 X2=H2*horner(H2,1/z)/z;
31 r2=roots(denom(X2));
32 rc2=coeff(denom(X2));
33 q2=[];s2=[];
34 for n=1:length(r2)                         //Loop to separate
      poles inside the unit circle
35     if (abs(r2(n))<1) then
36         q2=[q2 r2(n)];
37     else
38         s2=[s2 r2(n)];
39     end
40 end
41 P2=numer(X2)/rc2(length(rc2));
42 Q2=poly(q2,'z');
43 S2=poly(s2,'z');
44 I2=abs(residu(P2,Q2,S2));                 //Residue
      Calculation
45 po2=pn*I2;                               //Output Noise
      power
46
47 po=po1+po2;
48 disp(pn,'Input Noise power');
49 disp(I1,'I1=');disp(I2,'I2=');
50 disp(po1,'Output Noise power for H1(z)');
51 disp(po2,'Output Noise power for H2(z)');
52 disp(po,'Total Output Noise power');

```

---

# Chapter 11

## Multirate Digital Signal Processing

Scilab code Exa 11.1 Time Decimation

```
1 //Example 11.1
2
3 clc;clear;close;
4 x=[0:6 0:6];
5 y=x(1:3:length(x));
6 disp(x,'Input signal x(n)=');
7 disp(y,'Output signal of decimation process by
   factor three y(n)');
8 subplot(2,1,1);
9 plot2d3(x);title('Input signal x(n)');
10 subplot(2,1,2);
11 plot2d3(y);title('Output signal y(n)');
```

---

Scilab code Exa 11.2 Interpolation

```
1 //Example 11.2
```

```

2
3 clc; clear; close;
4 x=0:5;
5 y=[];
6 for i=1:length(x)
7     y(1,2*i)=x(i);
8 end
9 disp(x, 'Input signal x(n)=');
10 disp(y, 'Output signal of interpolation process with
    factor two y(n)');
11 subplot(2,1,1);
12 plot2d3(x); title('Input signal x(n)');
13 subplot(2,1,2);
14 plot2d3(y); title('Output signal y(n)');

```

---

#### Scilab code Exa 11.4 Polyphase Decomposition

```

1 //Example 11.4
2
3 clc; clear;
4 z=poly(0, 'z');
5 num=1-4*z^-1;
6 den=1+5*z^-1;
7 H=num/den;
8 num1=num*(1-5*z^-1);
9 den1=den*(1-5*z^-1);
10 H1=num1/den1;
11 c=coeff(numer(num1));
12 clength=length(c);
13 c=[c zeros(1, pmodulo(clength,2))]; //make
    length of 'c' multiple of 2
14 c0=[]; c1=[];
15 for n=1:ceil(clength/2) //loop to
    separate even and odd powers of z
16     c0=[c0 c(2*n-1) 0];

```

```

17     c1=[c1 c(2*n) 0];
18 end
19 E0=poly(c0,'z','coeff')/z^n/den1;
20 E1=poly(c1,'z','coeff')/z^(n-2)/den1;
21 disp('Polyphase Components')
22 disp(E0,'E0(z)');
23 disp(E1,'E1(z)');

```

---

### Scilab code Exa 11.5 Decimator implementation

```

1 //Example 11.5
2
3 clc;clear;
4
5 function [N,R]=func(Fs,Fp,Ft,Fti,dp,ds,M)
6     dF=(Fs-Fp)/Ft;
7
8     //
9     Normalised transition bandwidth
10    N=round((-20*log10(sqrt(dp*ds))-13)/(14.6*dF))
11    ; //FIR Filter length
12
13    R=N*Fti/M;
14
15    //
16    Number of Multiplications per second
17
18 endfunction
19
20 Ft=20000; //Sampling rate of input signal
21 Fp=40; //Passband frequency
22 Fs=50; //Stopband frequency
23 dp=0.01; //Passband ripple
24 ds=0.002; //Stopband ripple
25 M=100; //Decimation Factor
26 Fti=Ft; //Input sampling rate
27 //Single stage implementation
28 [N1,R1]=func(Fs,Fp,Ft,Fti,dp,ds,M);
29
30

```

```

21 //Two stage implementation
22 //Stage 1 F(z) with decimation factor 50
23 Fpf=Fp;           //Passband frequency
24 Fsf=190;          //Stopband frequency
25 dpf=0.005;        //Passband ripple
26 dsf=0.002;        //Stopband ripple
27 Mf=50;            //Decimation Factor
28 Fti=Ft;           //Input sampling rate
29 [N2f, R2f]=func(Fsf, Fpf, Ft, Fti, dpf, dsf, Mf);
30
31 //Stage 2 G(z) with decimation factor 2
32 Fpg=50*Fp;        //Passband frequency
33 Fsg=50*Fs;        //Stopband frequency
34 dpg=0.005;        //Passband ripple
35 dsg=0.002;        //Stopband ripple
36 Mg=2;             //Decimation Factor
37 Fti=Ft/50;        //Input sampling rate
38 [N2g, R2g]=func(Fsg, Fpg, Ft, Fti, dpg, dsg, Mg);
39 N2=N2f+50*N2g+2; //Total filter length
40 R2=R2f+R2g;       //Total Number of
    Multiplications per second
41 disp(R1, 'Number of Multiplications per second =', N1,
    'FIR filter length =', 'For Single stage
    implementation:');
42 disp('For Two stage implementation:');
43 disp(R2f, 'Number of Multiplications per second =',
    N2f, 'FIR filter length =', 'For F(z):');
44 disp(R2g, 'Number of Multiplications per second =',
    N2g, 'FIR filter length =', 'For G(z):');
45 disp(R2, 'Total Number of Multiplications per second
    =', N2, 'Overall FIR filter length =');

```

---

Scilab code Exa 11.6 Decimator implementation

```
1 //Example 11.6
```



```

2
3 clc;clear;
4
5
6 function [N,R]=func(Fs,Fp,Ft,Fti,dp,ds,M)
7     dF=(Fs-Fp)/Ft;
8
9     Normalised transition bandwidth //
10    N=round((-20*log10(sqrt(dp*ds))-13)/(14.6*dF))
11    ; //FIR Filter length
12    R=N*Fti/M;
13
14    Number of Multiplications per second //
15 endfunction
16
17 Ft=10000; //Sampling rate of input signal
18 Fp=150; //Passband frequency
19 Fs=180; //Stopband frequency
20 dp=0.002; //Passband ripple
21 ds=0.001; //Stopband ripple
22 M=20; //Decimation Factor
23 Fti=Ft; //Input sampling rate
24 //Single stage implementation
25 [N1,R1]=func(Fs,Fp,Ft,Fti,dp,ds,M);
26
27 //Two stage implementation
28 //Stage 1 F(z) with decimation factor 50
29 Fpf=Fp; //Passband frequency
30 Fsf=720; //Stopband frequency
31 dpf=0.001; //Passband ripple
32 dsf=0.001; //Stopband ripple
33 Mf=10; //Decimation Factor
34 Fti=Ft; //Input sampling rate
35 [N2f,R2f]=func(Fsf,Fpf,Ft,Fti,dpf,dsf,Mf);
36
37 //Stage 2 G(z) with decimation factor 2
38 Fpg=10*Fp; //Passband frequency
39 Fsg=10*Fs; //Stopband frequency

```

```

35 dpg=0.001;           //Passband ripple
36 dsg=0.001;           //Stopband ripple
37 Mg=2;                //Decimation Factor
38 Fti=Ft/10;           //Input sampling rate
39 [N2g,R2g]=func(Fsg,Fpg,Ft,Fti,dpg,dsg,Mg);
40 N2=N2f+10*N2g+2;     //Total filter length
41 R2=R2f+R2g;          //Total Number of
    Multiplications per second
42
43 disp(R1,'Number of Multiplications per second =',N1,
    'FIR filter length =','For Single stage
    implementation:');
44 disp('For Two stage implementation:');
45 disp(R2f,'Number of Multiplications per second =',
    N2f,'FIR filter length =','For F(z):');
46 disp(R2g,'Number of Multiplications per second =',
    N2g,'FIR filter length =','For G(z):');
47 disp(R2,'Total Number of Multiplications per second
    =',N2,'Overall FIR filter length =');

```

---

# Chapter 12

## Spectral Estimation

Scilab code Exa 12.2 Power Spectrum

```
1 //Example 12.2
2 clc;clear;close;
3 N=8;n=0:N-1;
4 f1=0.6;f2=0.62;
5 x=cos(2*%pi*f1*n)+cos(2*%pi*f2*n);
6 L1=8;
7 for k=0:L1-1
8     P1(k+1)=1/N*abs(x*(cos(%pi*n*k/L1)-%i*sin(%pi*n*
9         k/L1)))^2
10 end
11 L2=16;
12 for k=0:L2-1
13     P2(k+1)=1/N*abs(x*(cos(%pi*n*k/L2)-%i*sin(%pi*n*
14         k/L2)))^2;
15 end
16 L3=32;
17 for k=0:L3-1
18     P3(k+1)=1/N*abs(x*(cos(%pi*n*k/L3)-%i*sin(%pi*n*
19         k/L3)))^2;
20 end
21 subplot(311);
```

```
19 plot2d3(0:L1-1,P1);title('L=8');
20 subplot(312);
21 plot2d3(0:L2-1,P2);title('L=16');
22 subplot(313);
23 plot2d3(0:L3-1,P3);title('L=32');
```

---

#### Scilab code Exa 12.4 Frequency resolution

```
1 //Example 12.4
2 clc;clear;close;
3 N=1000;
4 Q=10;
5 disp(N,'Length of sample sequence N=',Q,'Quality
   factor Q=');
6 f_bart=Q/(1.11*N);
7 f_w=Q/(1.39*N);
8 f_bt=Q/(2.34*N);
9 disp(f_bart,'Bartlett Frequency resolution =');
10 disp(f_w,'Welch Frequency resolution =');
11 disp(f_bt,'Blackman Turkey Frequency resolution =');
```

---