UNIVERSITY OF MORATUWA, SRI LANKA

Faculty of Engineering

Department of Electronic and Telecommunication Engineering

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EN2063-SIGNALS AND SYSTEMS

Project

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`1 FIR Bandpass Digital Filter Design

1.1 Filter Specifications

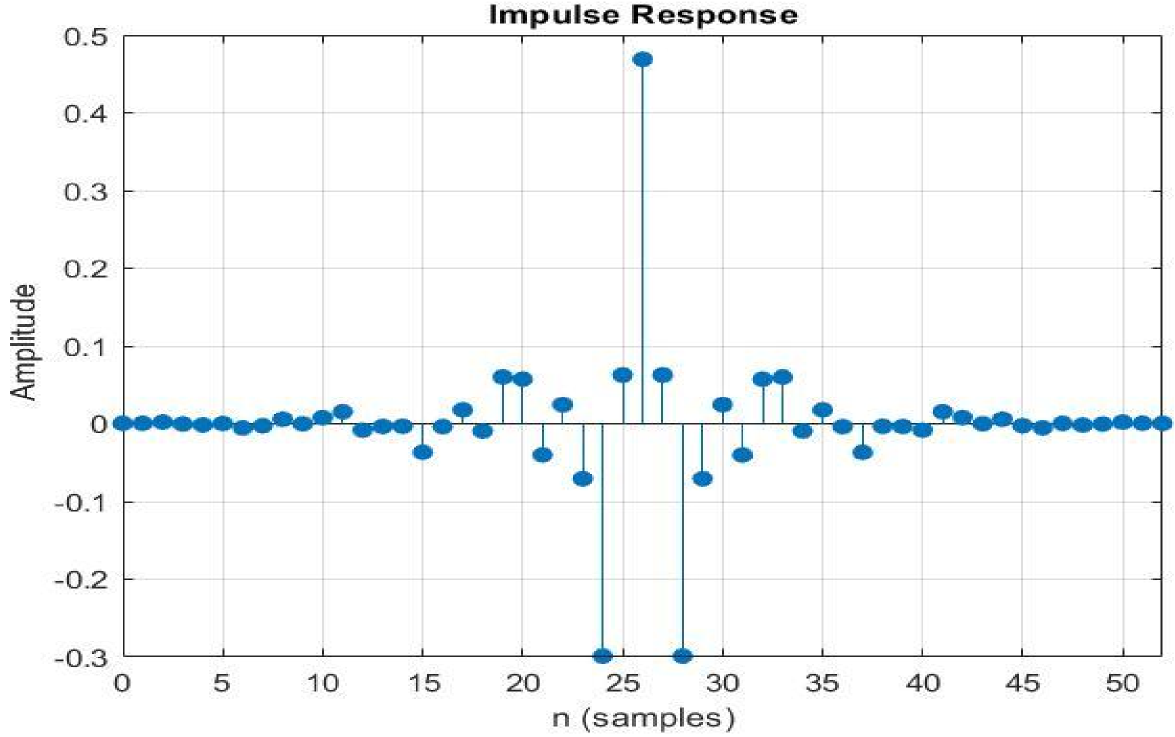
- A=6
- B=4
- C=1

Parameter (Analog Domain)	**Value**
Maximum passband ripple, A˜ p	0.1 + (0.01 × A) dB = 0.16dB
Minimum stopband attenuation, A˜ a	50 + B dB =54dB
Lower passband edge, Ωp1	(C × 100) + 400 rad/s =500rad/s
Upper passband edge, Ωp2	(C × 100) + 900 rad/s =1000rad/s
Lower stopband edge, Ωs1	(C × 100) + 100 rad/s =200rad/s
Upper stopband edge, Ωs2	(C × 100) + 1100 rad/s =1200rad/s
Sampling frequency, Ωsm	2((C × 100) + 1500) rad/s =3200rad/s

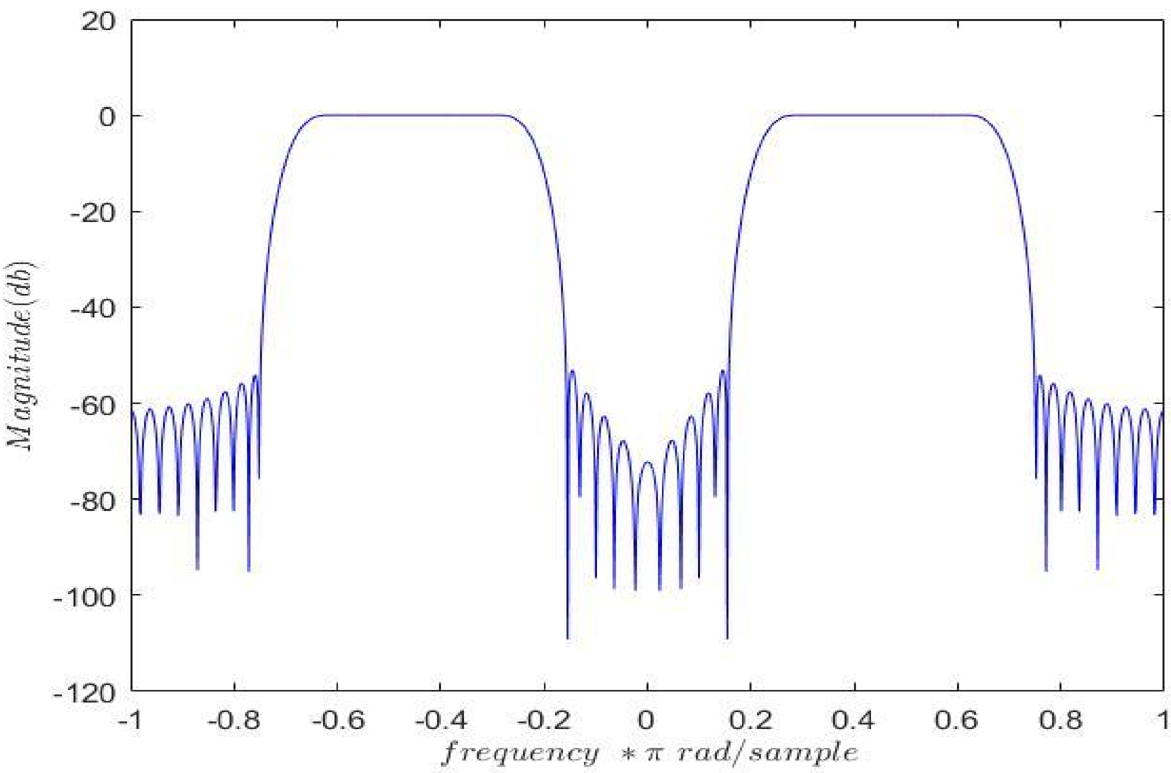
$$\omega = \frac{2\pi\Omega}{\Omega sm}$$

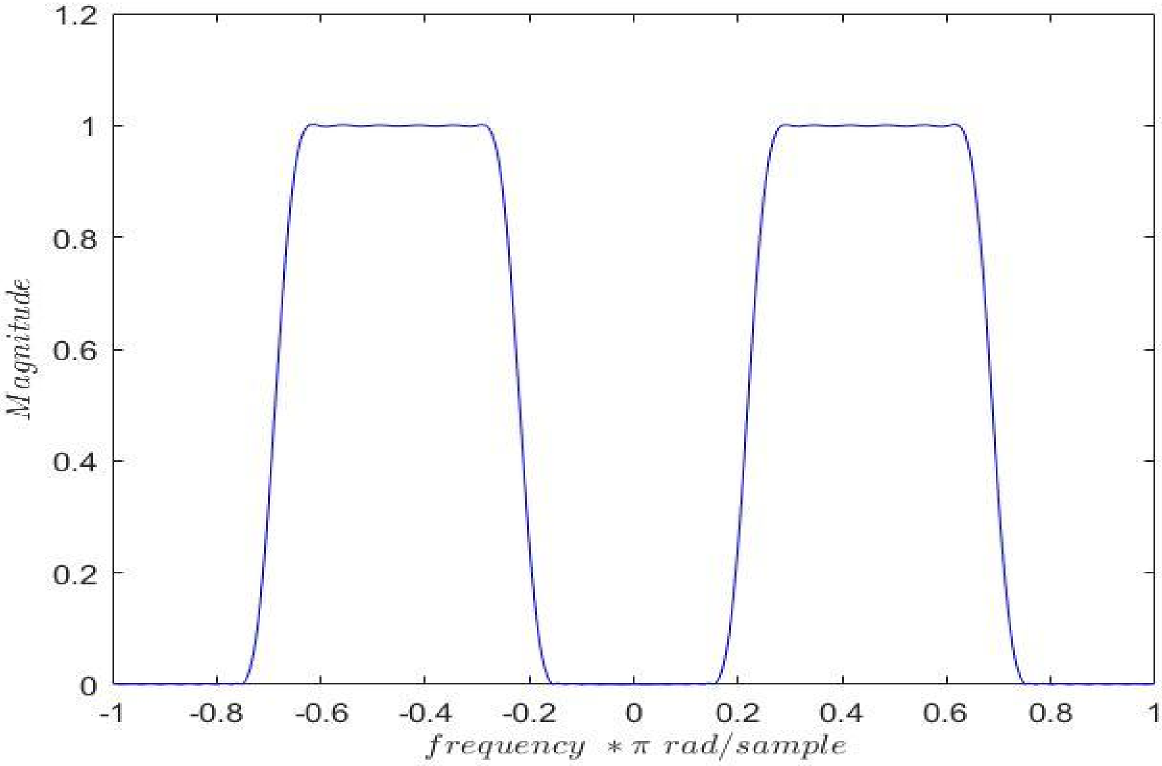
Parameter (Digital Domain)	**Value**
Lower passband edge,ωp1	5π/16
Upper passband edge, ωp2	10π/16
Lower stopband edge, ωs1	2π/16
Upper stopband edge, ωs2	12π/16

1.2 Impulse Response of the FIR FIlter

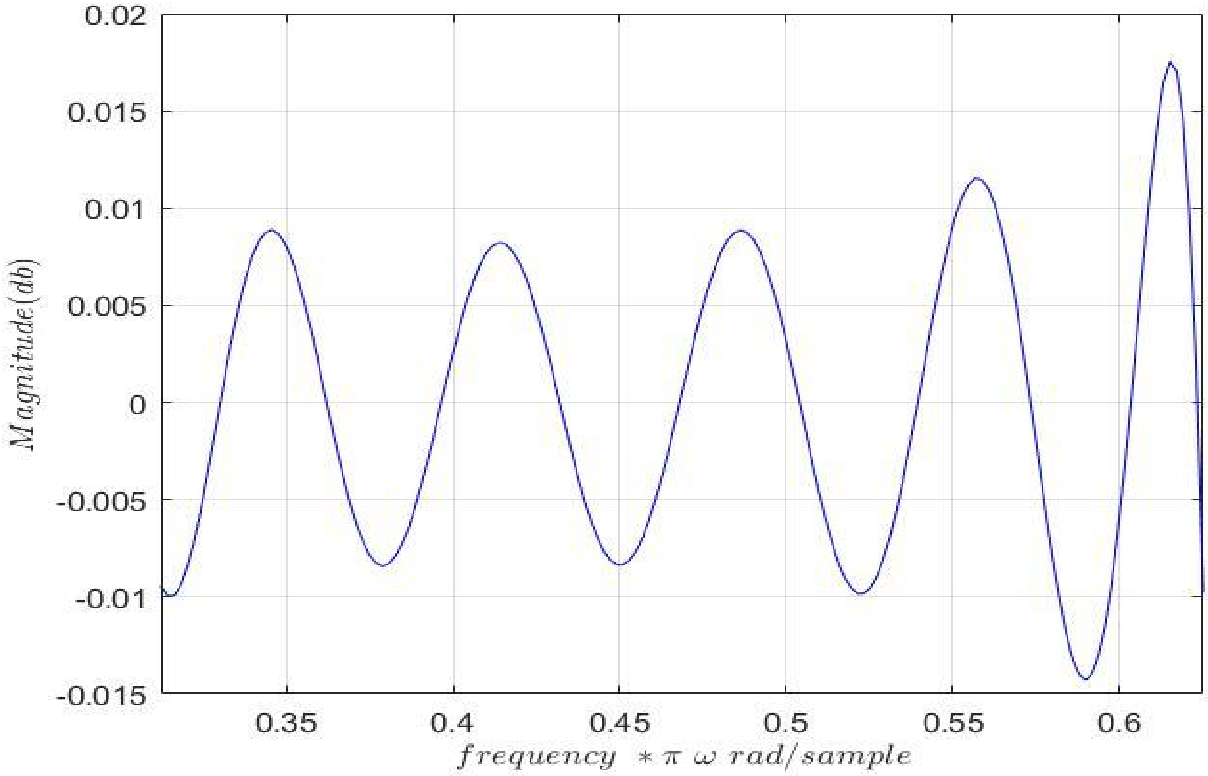


1.3 Magnitude Response of the FIR Filter for -π ≤ ω < π rad/sample





1.3 Magnitude Response of the FIR Filter for ωp1 ≤ ω ≤ ωp2 rad/sample



2 IIR Bandpass Digital Filter Design

D=1%4 =1

Approximation method is Chebyshev .

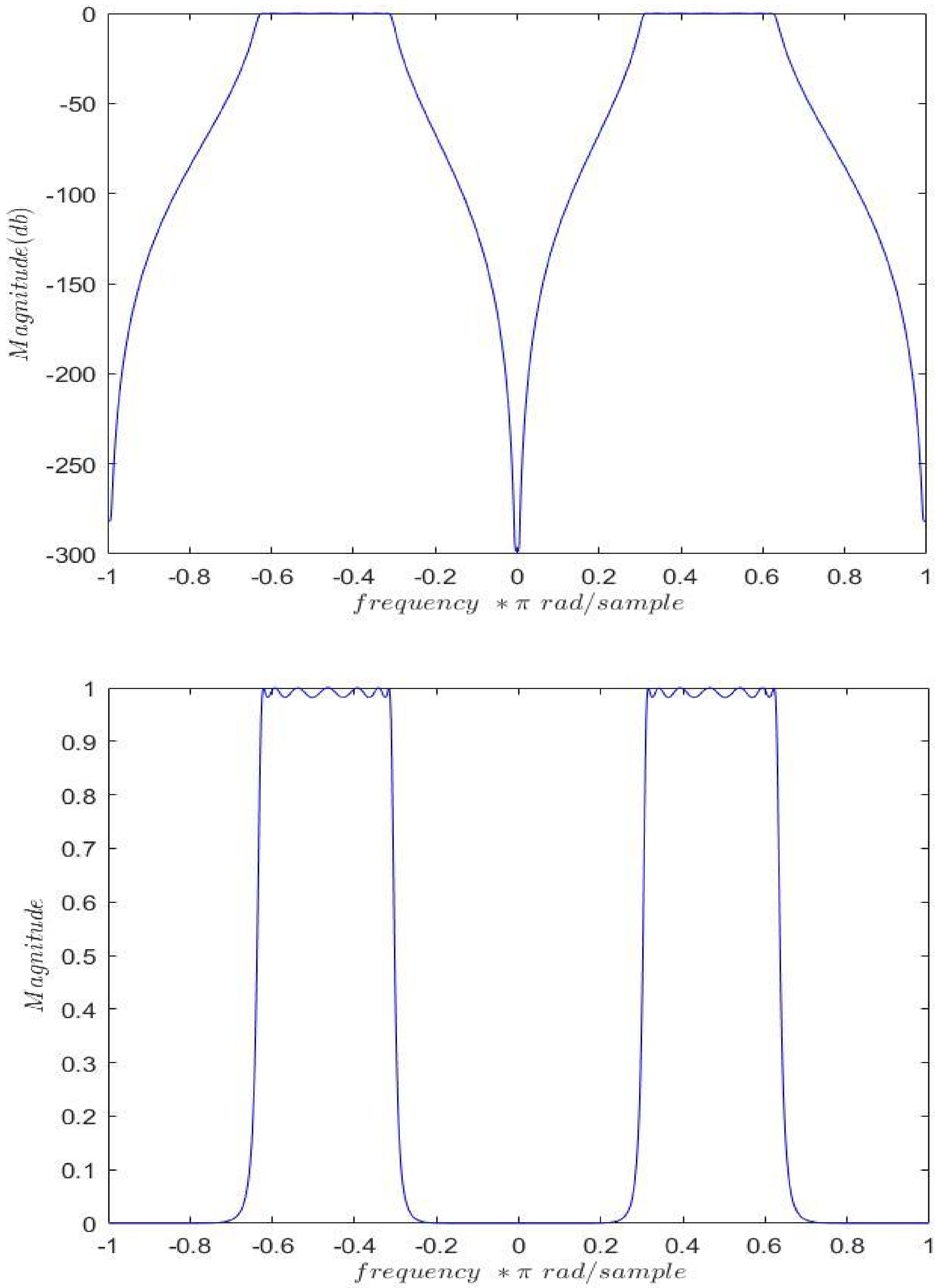
Transfer function of the IIR filter is in the form of;

$$H_z(z)=\frac{Y(z)}{X(z)}=\frac{b_0+\cdots+b_{N-1}z^{-N+1}}{1+\cdots+a_{M-1}z^{-M+1}}$$

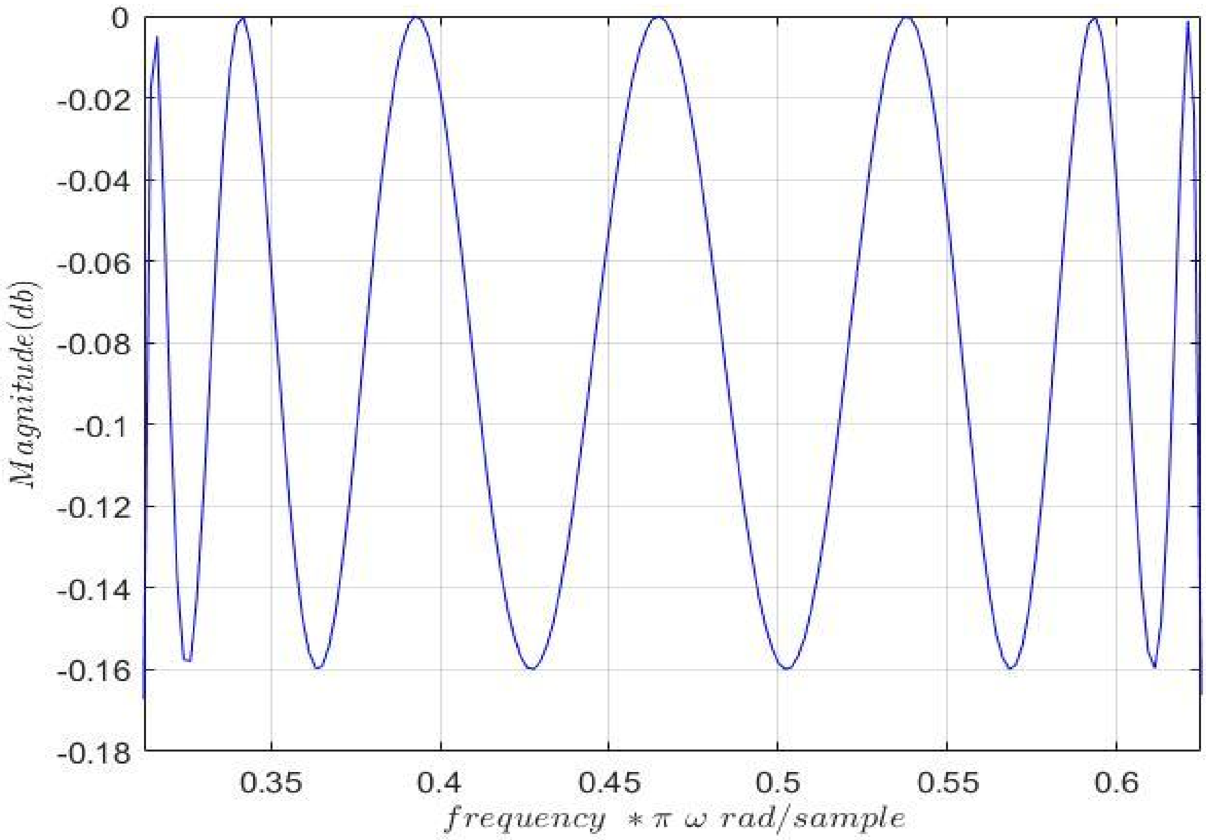
2.1 coefficients of the transfer function of the IIR filter

k	b_k	a_k
0	0.000301994810908868	0.000301994810908868
1	$-2.66453525910038\times10^{-15}$	$-2.66453525910038\times10^{-15}$
2	-0.00211396367635608	-0.00211396367635608
3	$-2.66453525910038\times10^{-15}$	$-2.66453525910038\times10^{-15}$
4	0.00634189102909666	0.00634189102909666
5	$-4.44089209850063\times10^{-14}$	-4.44089209850063e-14
6	-0.0105698183817093	-0.0105698183817093
7	$-1.17239551400417\times10^{-13}$	$-1.17239551400417\times10^{-13}$
8	0.0105698183819296	0.0105698183819296
9	$-1.07469588783715\times10^{-13}$	$-1.07469588783715\times10^{-13}$
10	-0.00634189102901317	-0.00634189102901317
11	$-3.06421554796543\times10^{-14}$	$-3.06421554796543\times10^{-14}$
12	0.00211396367638228	0.00211396367638228
13	$-6.66133814775094\times10^{-15}$	$-6.66133814775094\times10^{-15}$
14	-0.000301994810906620	-0.000301994810906620

2.2 Magnitude Response of the IIR Filter for -π ≤ ω < π rad/sample



2.3 Magnitude Response of the IIR Filter for ωp1 ≤ ω ≤ ωp2 rad/sample



3 Comparison of FiR and IIR filters

FIR Filter	**IIR Filter**
FIR filter is a non recursive filter; Difference equation of a non recursive filter is given by ; **y[n] =** $\sum_{k=0}^{m} b_k$**x[n-k]** Due to the symmetric property **y[n] =** $\sum_{k=0}^{m/2-1} b_k$**(x[n-k]+x[n-(m-k)])** $+b_{m/2}$**x[n-m/2]** Order of the filter = m=52 Number of adders required = m=52 Number of multipliers required = m/2+1=27 Group delay = m/2 =26	IIR filter is a recursive filter; Difference equation of a recursive filter is given by ; **y[n] =** $\sum_{k=0}^{m} b_k$**x[n-k] +** $\sum_{k=1}^{n} a_k$**y[n-k]** Since we have used bilinear transformation m=n; Order of the filter = m=14 Number of adders required =2*m=28 Number of multipliers required = 2m+1=2x14+1=29 Group delay = m/2 =7

4 Appendices


```
%sampling frequency

fsampling = 3200/(2*pi);

% Filter specifications

bandedges = [200/(2*pi) 500/(2*pi) 1000/(2*pi) 1200/(2*pi)];
magnitudes = [0 1 0];
deviations = [10^(-54/20) 10^(0.16/20) 10^(-54/20)];

%obtaining the FIR filter related to the given specifications

[n,Wn,beta,filter_type] = kaiserord(bandedges,magnitudes,deviations,fsampling);
n = n + rem(n,2);
hn = fir1(n,Wn,filter_type,kaiser(n+1,beta),'noscale');

%plot impulse response

figure('name','Impulse Response of the FIR Filter');
impz(hn,1);
grid on;

% Magnitude response in between [-pi,pi]
figure('name','Magnitude response of the FIR filter');
[H,f] = freqz(hn,1);
plot(f/pi,20*log10(abs(H)),'b');
hold on;
plot(-f/pi,20*log10(abs(H)),'b');
xlabel("$frequency \ *\pi  \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude  (db)$","Interpreter","Latex");

% Magnitude response in between [-pi,pi]
figure('name','Magnitude response of the FIR filter');
[H,f] = freqz(hn,1);
plot(f/pi,abs(H),'b')
hold on
plot(-f/pi,abs(H),'b')
xlabel("$frequency \ *\pi  \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude$","Interpreter","Latex");

% Magnitude response in between [Wp1,Wp2]
figure('name','Magnitude response of the FIR filter for [Wp1,Wp2]');
plot(f/pi, 20*log10(abs(H)),'b')
xlim([(5/16) (10/16)])
xlabel("$frequency \ *\pi \ \omega \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude  (db)$","Interpreter","Latex");
grid on;
```

```
%Sampling interval
Tsm = (2*pi)/3200;

%Spceification of the Analog FIlter
Wp = [abs((2/Tsm)*tan((5*pi)/32)) abs((2/Tsm)*tan((10*pi)/32))];
Ws = [abs((2/Tsm)*tan(pi/16)) abs((2/Tsm)*tan((12*pi)/32))];
Rp = 0.16;
Rs = 54;


% obtain the analog filter according to the above specification
[n,W] = cheb1ord(Wp,Ws,Rp,Rs,'s');

%obtaining the transfer function of the analog filter
[b,a] = cheby1(n,Rp,W,'s');


%obtaining the transfer function of the digital filter using the bilinear
%transformation
[zd,zp]=bilinear(b,a,1/Tsm);

[H,f]= freqs(b,a);
[A,w] = freqz(zd,zp);



% Magnitude response of analog filter
figure('name','Magnitude response of the analog filter');
plot(f,20*log10(abs(H)),'b');
hold on;
plot(-f,20*log10(abs(H)),'b');
xlabel("$frequency \ *\pi  \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude  (db)$","Interpreter","Latex");



% Magnitude response of Analog filter
figure('name','Magnitude response of the analog filter');
plot(f,abs(H),'b')
hold on
plot(-f,abs(H),'b')
xlabel("$frequency \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude$","Interpreter","Latex");



% Magnitude response in between [-pi,pi]
figure('name','Magnitude response of the IIR filter');
plot(w/pi,20*log10(abs(A)),'b');
```

```
hold on;
plot(-w/pi,20*log10(abs(A)),'b');
xlabel("$frequency \ *\pi  \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude  (db)$","Interpreter","Latex");

% Magnitude response in between [-pi,pi]
figure('name','Magnitude response of the IIR filter');
plot(w/pi,abs(A),'b')
hold on
plot(-w/pi,abs(A),'b')
xlabel("$frequency \ *\pi  \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude$","Interpreter","Latex");

% Magnitude response in between [Wp1,Wp2]
figure('name','Magnitude response of the IIR filter for [Wp1,Wp2]');
plot(w/pi, 20*log10(abs(A)),'b')
xlim([(5/16) (10/16)])
xlabel("$frequency \ *\pi \ \omega \ rad/sample$","Interpreter","Latex");
ylabel("$Magnitude  (db)$","Interpreter","Latex");
grid on;
```