UNIVERSITY OF MORATUWA

DEPARTMENT OF **E**LECTRONICS AND **T**ELECOMMUNICATION **E**NGINEERING

EN2063—SIGNALS AND SYSTEMS

FIR and IIR Filter Design

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Specification	Symbol	Value	Units
Maximum pass-band ripple	$\tilde{A}_p$	0.1	dB
Maximum stop band attenuation	$\tilde{A}_a$	56	dB
Lower pass band edge	Ω_{p1}	800	$rads^{-1}$
Upper pass band edge	Ω_{p2}	1300	$rads^{-1}$
Lower stop band edge	Ω_{s1}	500	$rads^{-1}$
Upper stop band edge	Ω_{s2}	1500	$rads^{-1}$
Sampling frequency	Ω_{sm}	3800	$rads^{-1}$

The specifications of the digital filter

1. **Design an FIR bandpass digital filter Using the windowing method in conjunction with the Kaiser window.**

a) Impulse response of FIR bandpass digital filter

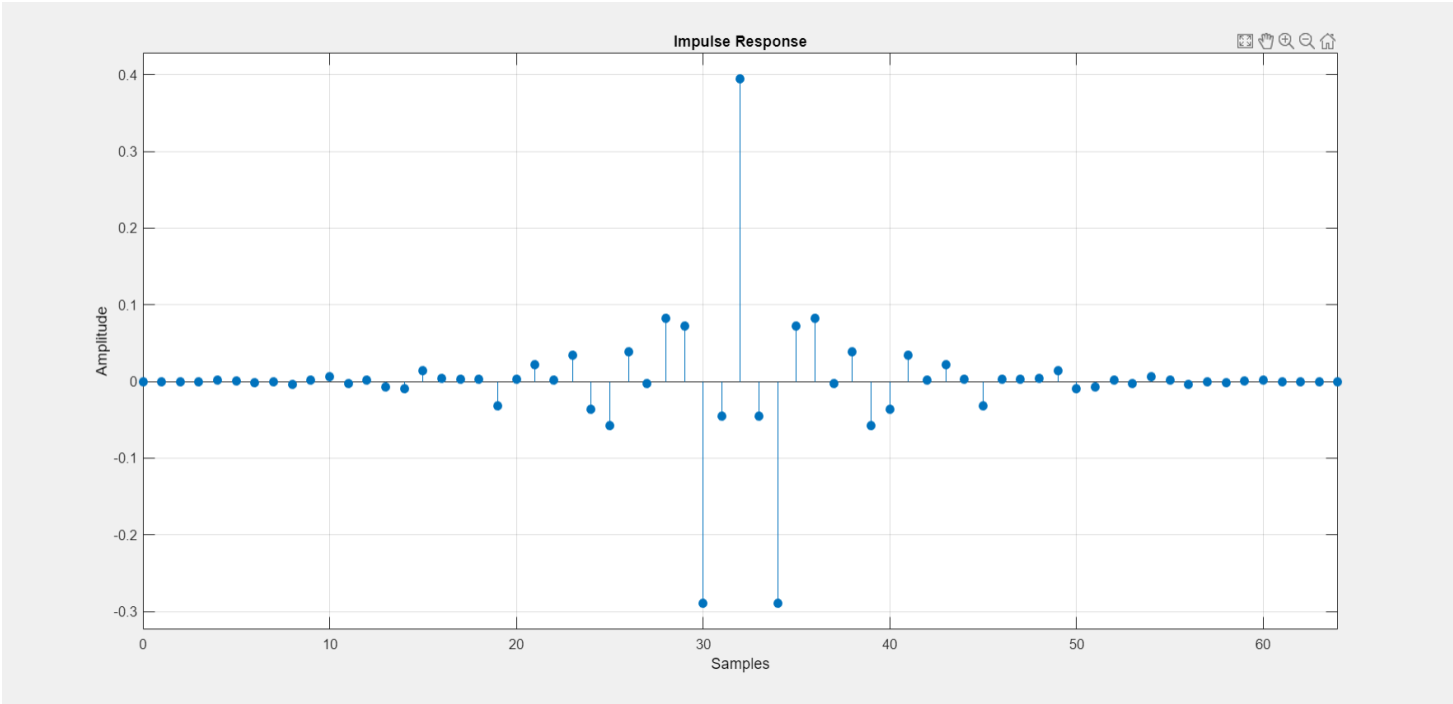

Figure 1: Impulse response

b) Magnitude response of FIR bandpass digital filter for $\pi \leq \omega < \pi$ rad/sample.

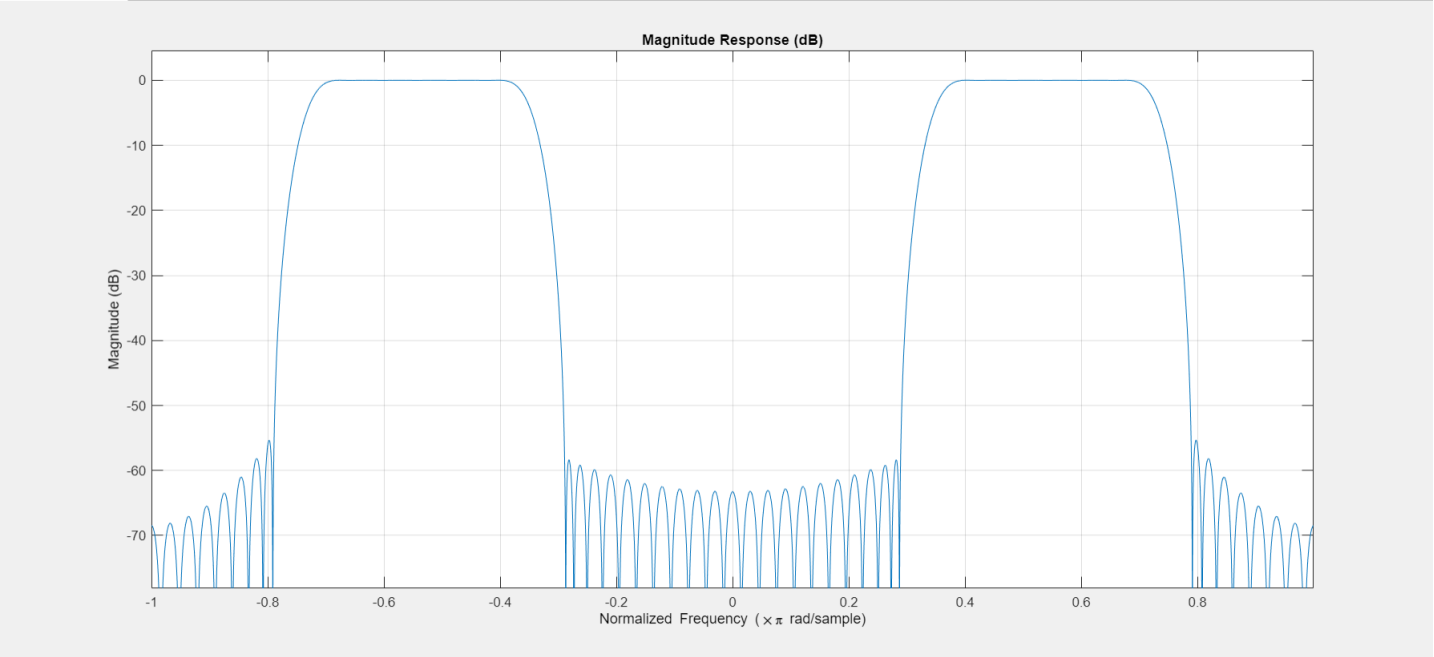

Figure 2: Magnitude response

c) Magnitude response for ($\omega p1 \leq \omega \leq \omega p2$) FIR bandpass digital filter

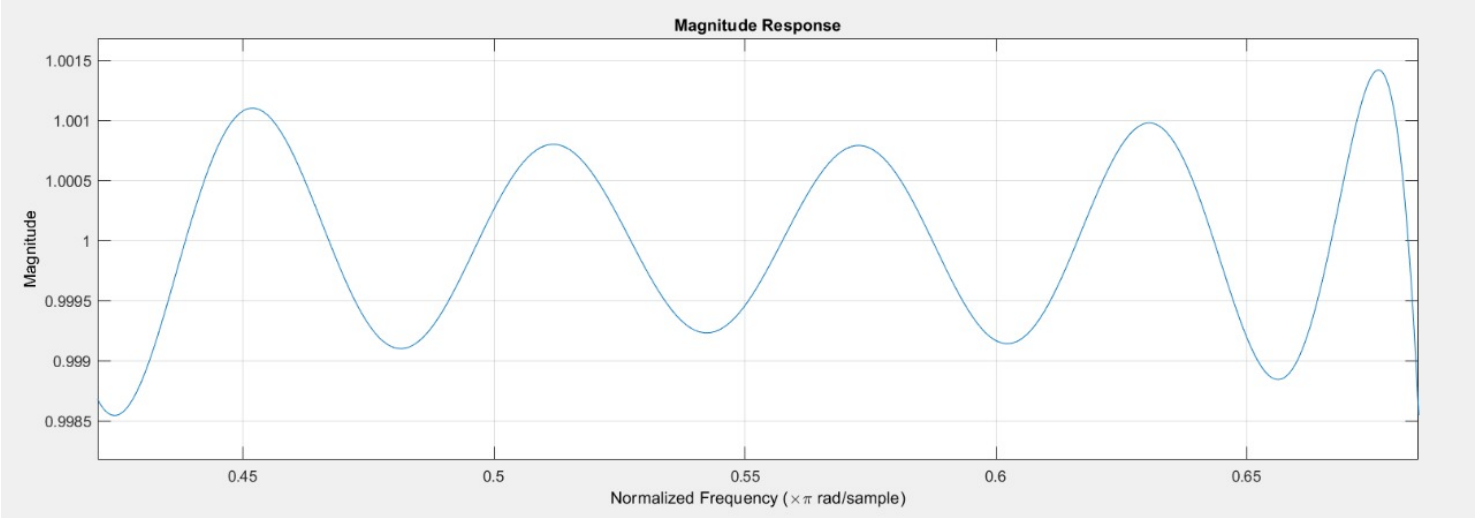

Figure 3: Magnitude response in the passband

2) Design an IIR bandpass digital filter Using the bilinear transformation method (Butterworth Approximation method).

a) Coefficients of the transfer function of the IIR filter

Value	Count	Percent
0	22	47.83%
1	1	2.17%
11442	1	2.17%
8.86063e+07	1	2.17%
4.86966e+11	1	2.17%
2.15774e+15	1	2.17%
7835336893841715 20	1	2.17%
2.42048e+22	1	2.17%
6.40433e+25	1	2.17%
1.47414e+29	1	2.17%
2.95782e+32	1	2.17%
2.13439e+35	1	2.17%
5.21179e+35	1	2.17%
8.0572e+38	1	2.17%
1.09669e+42	1	2.17%
1.30968e+45	1	2.17%
1.37349e+48	1	2.17%
1.25562e+51	1	2.17%
9.98577e+53	1	2.17%
6.80194e+56	1	2.17%
3.94157e+59	1	2.17%
1.87183e+62	1	2.17%
7.16683e+64	1	2.17%
1.94742e+67	1	2.17%
3.58141e+69	1	2.17%

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b) Magnitude response of the IIR digital filter for ($\pi \leq \omega < \pi$) rad/sample.

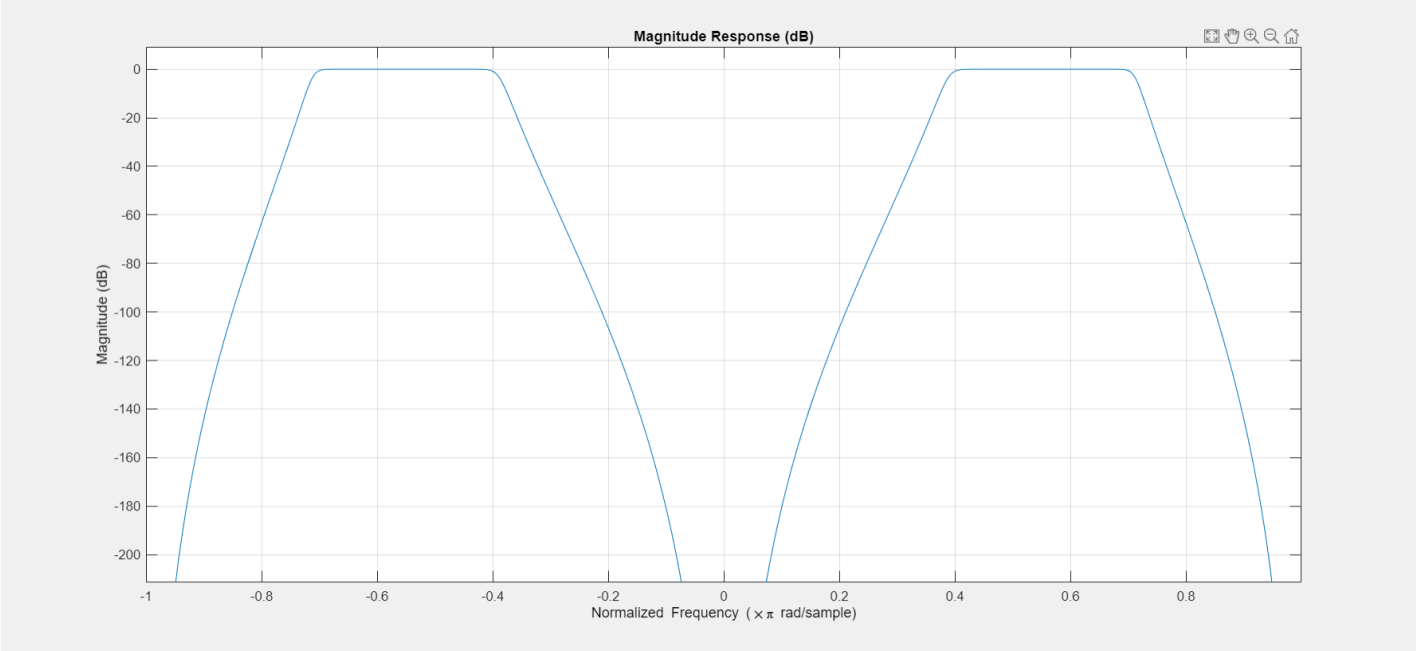

Figure 4: Magnitude response

c) Magnitude response for ($\omega p1 \leq \omega \leq \omega p2$) IIR bandpass digital filter

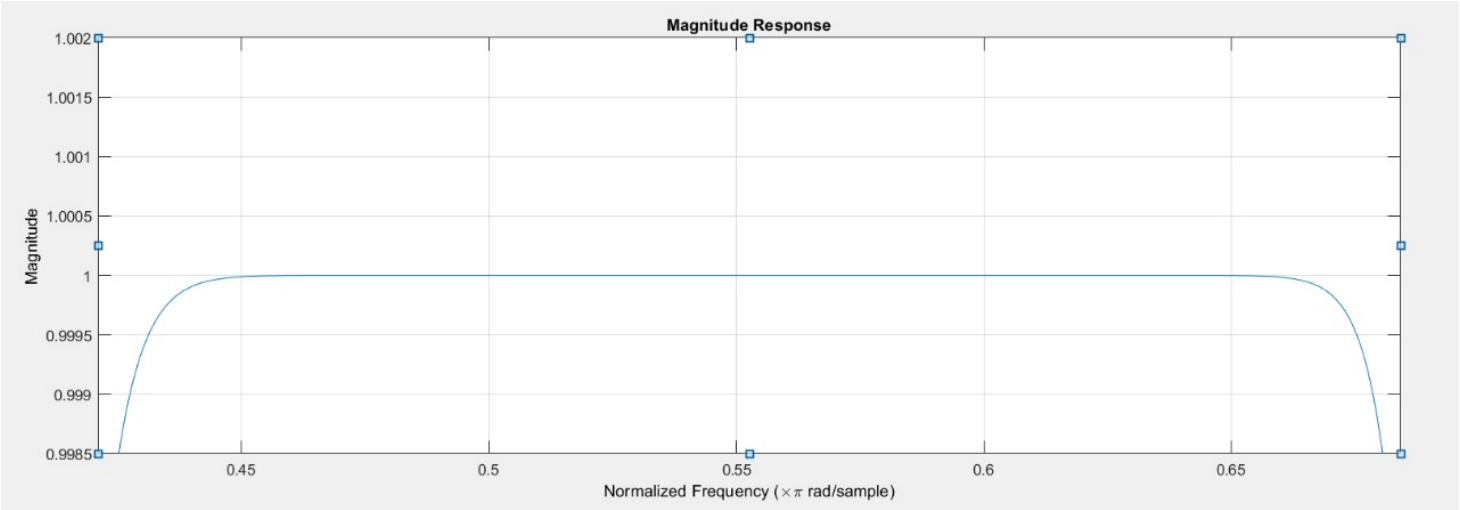

Figure 5: Magnitude response in the passband

3) Order and the number of multiplications and additions required to process a sample by the two designed filters

FIR Filter

```
Discrete-Time FIR Filter (real)
-------------------------------
Filter Structure   : Direct-Form II Transposed
Numerator Length   : 65
Denominator Length : 1
Stable             : Yes
Linear Phase       : Yes (Type 1)

Implementation Cost
Number of Multipliers          : 65
Number of Adders               : 64
Number of States               : 64
Multiplications per Input Sample : 65
Additions per Input Sample       : 64
```

IIR Filter

```
Discrete-Time IIR Filter (real)
-------------------------------
Filter Structure   : Direct-Form II Transposed
Numerator Length   : 23
Denominator Length : 23
Stable             : Yes
Linear Phase       : No

Implementation Cost
Number of Multipliers          : 45
Number of Adders               : 44
Number of States               : 22
Multiplications per Input Sample : 45
Additions per Input Sample       : 44
```

APPENDIX

MATLAB code for FIR filter

```
fsamp = 3800/(2*pi);
fedges = [500/(2*pi) 800/(2*pi) 1300/(2*pi) 1500/(2*pi)];

mags = [0 1 0];
devs = [0.01157945426 0.00154893192 0.01157945426];

c = kaiserord(fedges,mags,devs,fsamp,'cell');

bcell = fir1(c{:});
hfvt = fvtool(bcell,1,'Fs',fsamp);
```

MATLAB code for IIR filter

```
CT_w_given =[800 1300 500 1500]/(2*pi);
fs=3800/(2*pi);

DT_w=2*pi*CT_w_given/fs;
CT_w_prewarpped=2*fs*tan(DT_w/2);
wp=CT_w_prewarpped(1:2);
ws=CT_w_prewarpped(3:4);
Rp=0.1;
Rs=56;
[n,wn]=buttord(wp,ws,Rp,Rs,'s');
[b,a]=butter(n,wn,'s');
[numd,dend]=bilinear(b,a,fs);

fvtool(numd,dend);

tabulate([b,a])
```