DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

ENGINEERING

UNIVERSITY OF MORATUWA

EN2063—SIGNALS AND SYSTEMS

DESIGN OF DIGITAL FILTER (FIR & IIR)

Report

S.N. Pushpakumara

200489H

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Filter specifications

Parameter	Value	Value according to my index
Maximum passband ripple (A_p)	$0.1 + (0.01 \times A)\ dB$	0.14 dB
Minimum stopband attenuation (A_a)	$50 + B\ dB$	58dB
Lower passband edge Ω_{p1}	$(C \times 100) + 400\ rad/s$	$1300\ rad/s$
Upper passband edge Ω_{p2}	$(C \times 100) + 900\ rad/\ s$	$1800\ rad/s$
Lower stopband edge Ω_{s1}	$(C \times 100) + 100\ rad/\ s$	$1000\ rad/s$
Upper stopband edge Ω_{s2}	$(C \times 100) + 1100\ rad/\ s$	$2000\ rad/s$
Sampling frequency Ω_{sm}	$2((C \times 100) + 1500)\ rad/s$	$4800\ rad/s$

(200ABC. is mapped 200489H)

1) Using the ***kaiser window*** method **FIR bandpass digital filter** designing

In order to achieve the required calculations and plotting MATLAB is used here. ***Kaiserord , kaisor , fir1*** are the functions used in order to obtain the values for **the order of the filter,kaiser window** and **filter coefficients** respectively. Beforehand, given parameters (angular frequencies) must be converted into frequencies in Hz. Here it is done using the equation (1).

$$f = \left(\frac{\omega}{2\pi}\right)\ Hz \qquad \text{eq (1)}$$

Lower passband edge Ω_{p1}	1300 rad/s	206.9014 Hz
Upper passband edge Ω_{p2}	1800 rad/s	286.4789 Hz
Lower stopband edge Ω_{s1}	1000 rad/s	159.1549 Hz
Upper stopband edge Ω_{s2}	2000 rad/s	318.3099 Hz
Sampling frequency Ω_{sm}	4800 rad/s	763.9437 Hz

In addition to that, to design a filter, stopband attenuation and passband ripples must be calculated.

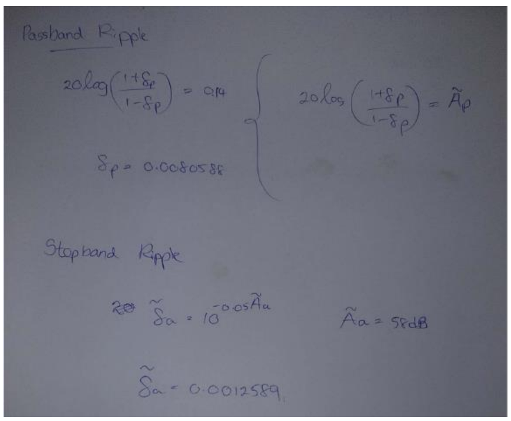

Fig:1 Ripple calculations

a)

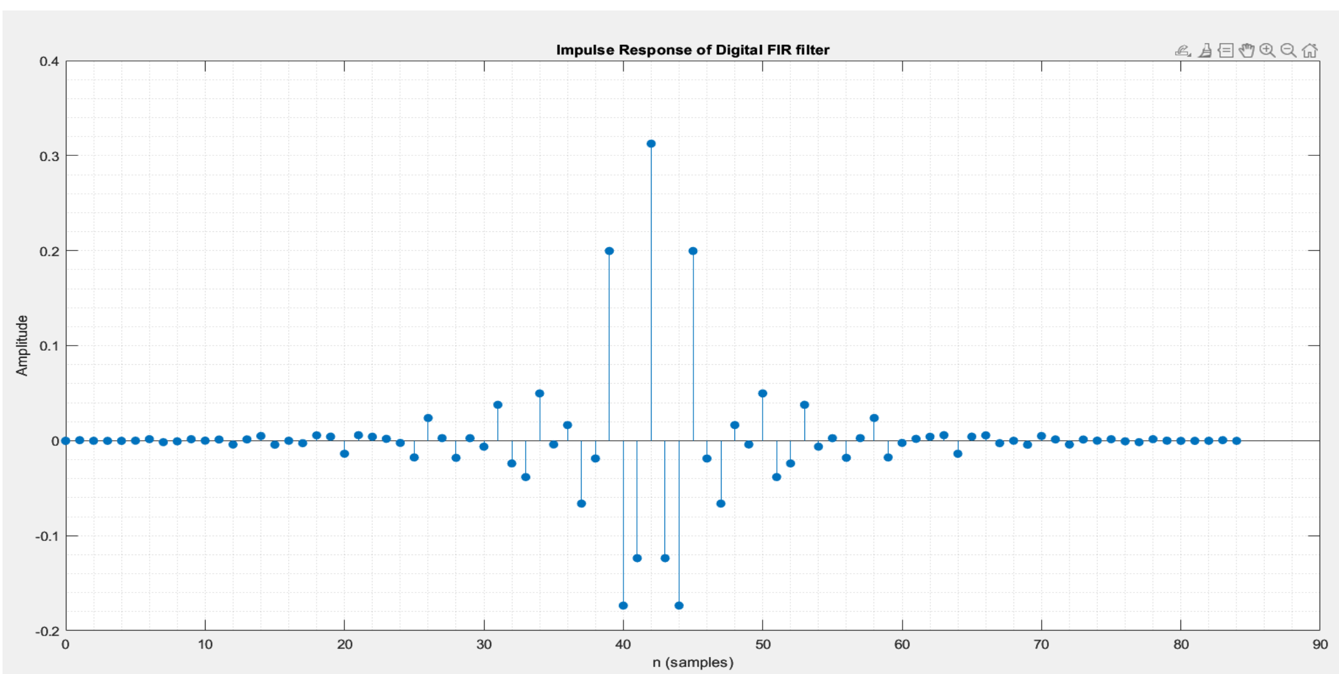

Fig2: Impulse Response

b) magnitude response of the digital filter for $-\pi \leq \omega < \pi\ rad/sample$

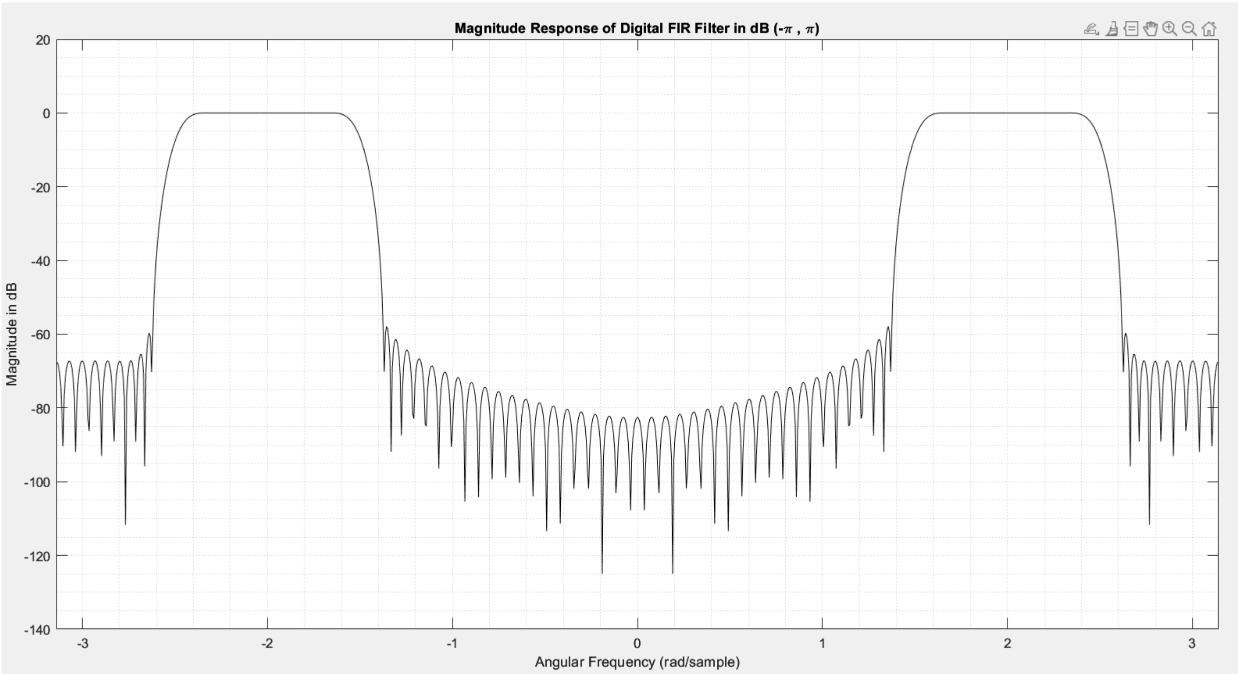

Fig3: Magnitude Response

c) magnitude response for $\omega_{p1} \leq \omega \leq \omega_{p2}$ (passband)

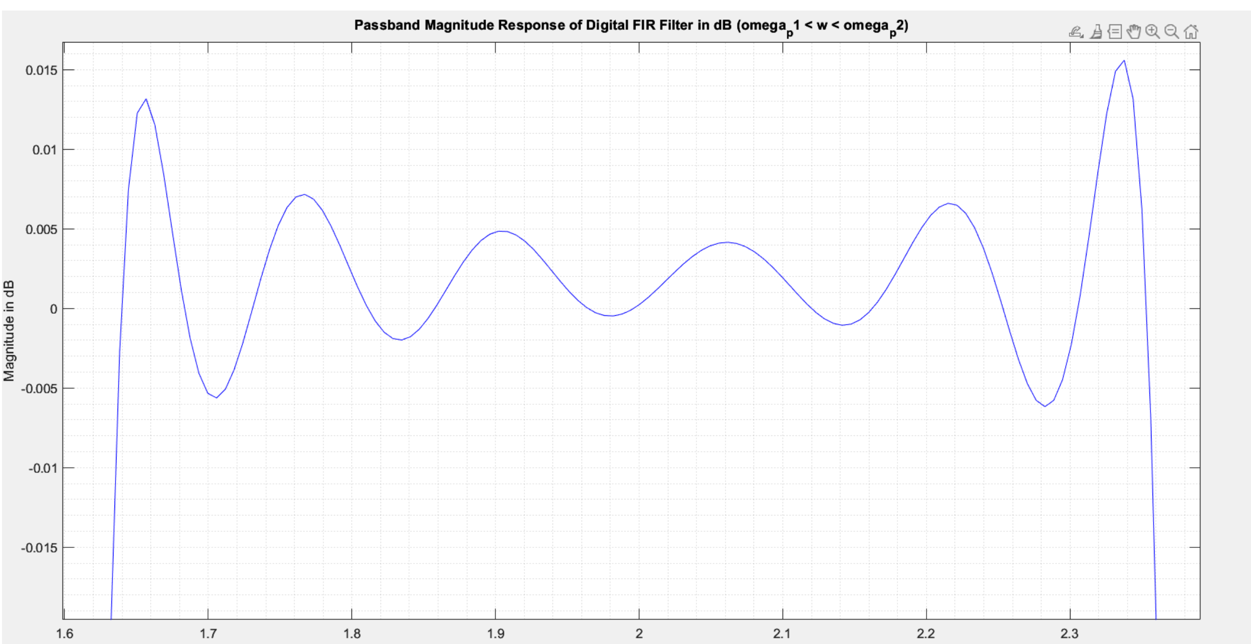

Fig4: Magnitude Response (Passband)

APPENDIX 1: MATLAB code (FIR Filter Design)

```
%specifications/prescribed
f_sample = 763.9437; %sample rate
f_edges = [159.1549 206.9014 286.4789 318.3099]; % passband edges and stopband edges in Hz
magnitudes = [0 1 0];
rip_n_att = [0.0080588 0.0012589 0.0080588]; % passband ripple and stopband attenuation
           %[stop_ripple  passband_ripple stop_ripple]
[order, Wn, beta, filter_type] = kaiserord(f_edges, magnitudes, rip_n_att, f_sample); %calculate kaiser window parameters

%filter design
filter_length = order + rem(order,2) ;
FIR = fir1(filter_length, Wn, filter_type, kaiser(filter_length + 1, beta));
disp(FIR)

%(a)impulse response
figure(1);
[m,t]=impz(FIR,1);
stem(t,m,'filled')
title('Impulse Response of Digital FIR filter')
xlabel('n (samples)')
ylabel('Amplitude')
grid("minor")

%(b)magnitude response
figure(2);
[h,omega]=freqz(FIR,1);
omega = [-omega omega];
plot(omega,mag2db(abs(h)),"black")
title('Magnitude Response of Digital FIR Filter in dB (-\pi , \pi)')
xlabel('Angular Frequency (rad/sample)')
ylabel('Magnitude in dB')
xlim([-pi,pi])
grid("minor")

%(c)magnitude response of the passband
figure(3);
plot(omega,mag2db(abs(h)),"blue")
title('Passband Magnitude Response of Digital FIR Filter in dB (omega_p1 < w < omega_p2)')
xlabel('Angular Frequency (rad/sample)')
ylabel('Magnitude in dB')
xlim([(1300*2*pi)/(4800),(1800*2*pi)/(4800)])
grid("minor")
```

2.) Using **Bilinear Transform** method designing **IIR bandpass digital filter**

Index number 200489H -----> remainder of 9 /4 = 1 (Chebyshev)

Considering the prescribed specification given, it is needed to obtain the mapped ω values corresponding to the Ω values using the equation given below.

$$\omega = \frac{2\pi\Omega}{\Omega s} \qquad \boxed{\text{eq (2)}}$$

But When the Warping effect is considered, it is essential to do Prewarping. Prewarping is done by the equation given below.

$$\frac{2}{T} Tan(\omega/2) = \Omega \text{ ; where T is sampling period} \qquad \boxed{\text{eq (3)}}$$

$$\begin{array}{ccc} \Omega & \xrightarrow{\text{mapping using eq (2)}} & \omega \\ & & \Big\downarrow \text{Prewarping using eq (3)} \\ & & \Omega \text{ (Prewarped)} \end{array}$$

After the prewarping , Ω values (Prewarped) are corresponding to the ω values of the actual filer which is being designed. Then using MATLAB minimum order required for the given prescribed specifications can be found. Now the analog filter should be design for the prewarped values for frequencies. After that, **Bilinear Transform** can be performed in order to obtain the **Transfer function** (in Z domain) using equation (4)

$$S = \frac{T}{2}\frac{(z-1)}{(z+1)} \qquad \boxed{\text{eq (4)}}$$

a) Table of coefficient of the Transfer function of IIR digital filter

```
>> Q2_IIR_NIPUN
>> Coefficient_table

Coefficient_table =

  15×2 table

    Numerator_coefficient    Denominator_coefficient
    _____________________    _______________________

          2.2068e-05                      1
                   0                 5.7461
         -0.00015448                 19.589
                   0                 46.618
          0.00046343                 86.006
                   0                 127.21
         -0.00077238                 155.32
                   0                 157.71
          0.00077238                 134.16
                   0                 94.876
         -0.00046343                 55.365
                   0                 25.879
          0.00015448                 9.3743
                   0                  2.368
         -2.2068e-05                0.35673
```

b) Plot the magnitude response of the digital filter for -π ≤ ω < π rad/sample.

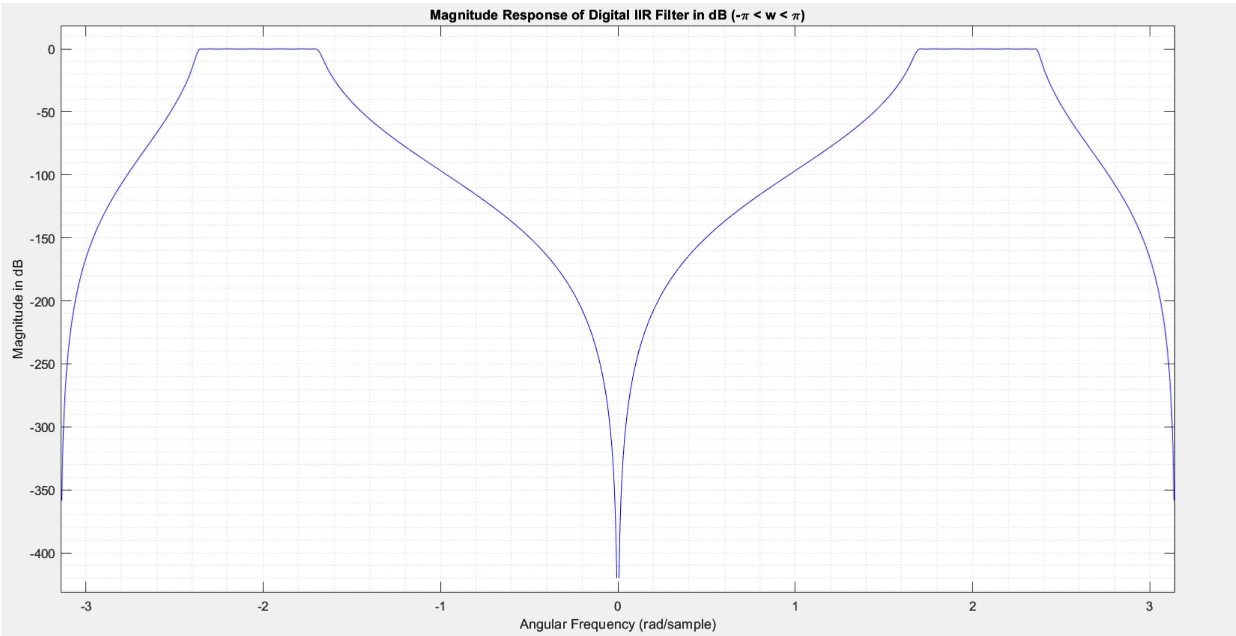

Fig:6 Magnitude Response

c) Plot the magnitude response for $\omega_{p1} \le \omega \le \omega_{p2}$ (passband)

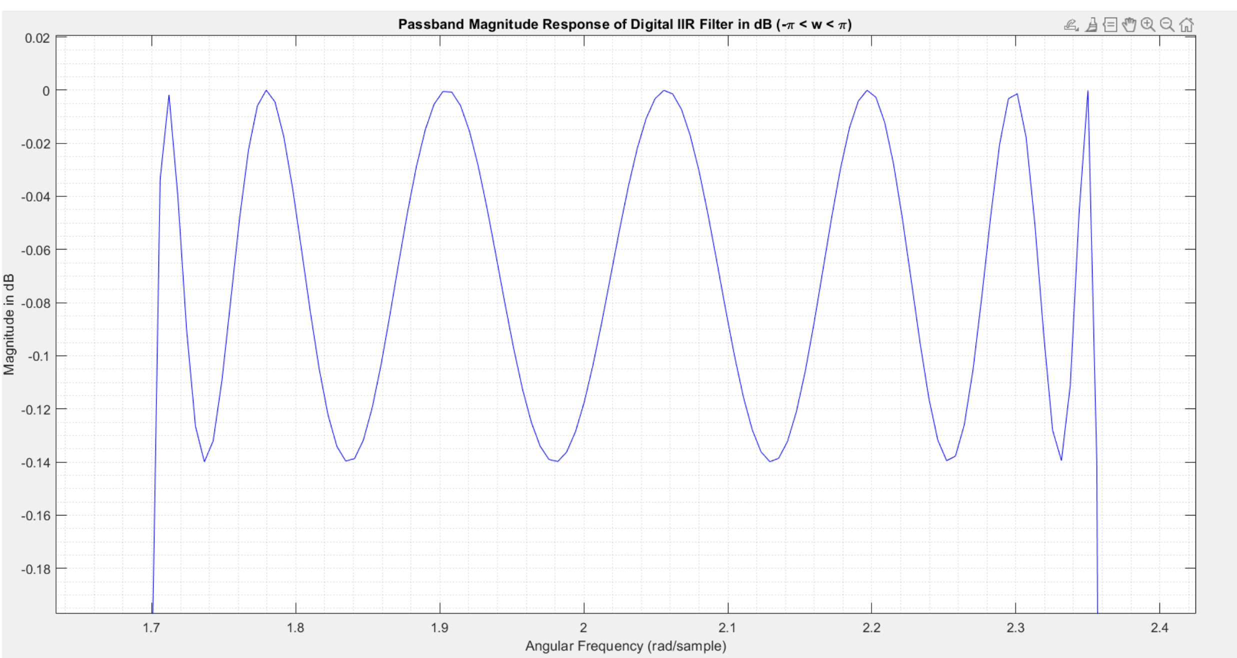

Fig7: Magnitude Response (Passband)

APENDIX 2: MATLAB code (IIR Filter Design)

```
%IIR filter

%specifications of IIR filter
f_sample = 763.9437; %sample Hz
Fpass_edges = [1742.221 3688.647]; % passband Prewarping done manually
Fstop_edges = [1172.389 5702.154]; % stopband Prewarwping done manually
Rpass = 0.14;%passband ripple in dB
Rstop = 58;%stop band ripple in dB

%calculate the order of chebyshev analog filter
[order , Fpass_edges] = cheb1ord(Fpass_edges,Fstop_edges,Rpass,Rstop,'s');

%analog filter design
[b,a] = cheby1(order,Rpass,Fpass_edges,'s');
freqz(b,a)
%calculating the zeros and poles
[zero_analog,pole_analog,gain_analog] = tf2zp(b,a);
%taking the bilinear transform
[zero_digital,pole_digital,gain_digital] = bilinear(zero_analog,pole_analog,gain_analog,f_sample);
%(a)coefficient of Digital IIR Filter
[Numerator,Denominator] = zp2tf(zero_digital,pole_digital,gain_digital);
Numerator_coefficient=Numerator(:);
Denominator_coefficient=Denominator(:);
Coefficient_table=table(Numerator_coefficient,Denominator_coefficient);%getting the coefficints as a table

%ploting the filter
%(b)magnitude response
figure(1)
[h,omega]=freqz(Numerator,Denominator);
omega = [-1*omega omega];
plot(omega,mag2db(abs(h)),"blue")
title('Magnitude Response of Digital IIR Filter in dB (-\pi < w < \pi)')
xlabel('Angular Frequency (rad/sample)')
ylabel('Magnitude in dB')
xlim([-pi,pi])
grid("minor")

%(c)magnitude response of the passband
figure(2)
plot(omega,mag2db(abs(h)),"blue")
title('Passband Magnitude Response of Digital IIR Filter in dB (-\pi < w < \pi)')
xlabel('Angular Frequency (rad/sample)')
ylabel('Magnitude in dB')
xlim([(1300*2*pi)/(4800),(1800*2*pi)/(4800)])
grid("minor")
```

3) Compare the order and the number of multiplications and additions required to process a sample by the two designed filters. Assume that the two filters are implemented using the difference equations, and the symmetry of coefficients can be exploited to reduce the number of multiplications.

Using MATLAB, the results (order, the number of multiplications and additions required) can be illustrate as follows

Parameters	**FIR Filter**	**IIR Filter**
order	84	7
No. of co-efficient in numerator of the transfer function	85	15
No. of co-efficient in denominator of the transfer function	0	15
No. of Multiplications in numerator (considering symmetry of coefficients)	43	8
No. of Multiplications in denominator (considering symmetry of coefficients)	0	15
No. of addition in numerator (considering symmetry of coefficients)	42	8
No. of addition in denominator (considering symmetry of coefficients)	0	15
Total number of multiplications	43	23
Total number of additions	43	23