

Designing of Basic Types of Filters using Standard Tool

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Abstract - In today's communication large amount of data can be transferred from one place to another place without any large communication issues. The data is in the form of audio, video, image, text and multimedia information. Different modulation techniques and networking infrastructures can able to make the communication more effective. During the data transmission many major data loss issues come in to existence, adding noise to original signal is one of the major and most common issue in information transmission. In this paper we focused on removing the unwanted signal from the original signal while data transfer using the basic filters. The filters are designed using MATLAB, and FDA tool using standardized mathematical and signal processing standards.

Key Words: Cut-off frequency; Attenuation; Bandwidth; Stopband; Passband;

1. INTRODUCTION

Filters are the electronic circuits which can able to attenuate the unwanted frequency of the signal, noises, and any other disturbances. The filters are mainly classified as active filters and passive filters. Active filters are designed using resistor and capacitor with op-amp. Passive filters are designed using resistor and capacitor and inductor. The filters can be further classified on the basis of frequency selection are: Low pass filter, high pass filter, band pass filter and band rejection filter

1.1 Requirement:

1.1.1 Matlab: Matlab is a multi-disciplinary mathematical computing tool which performs all the numerical computations. It is basically a software which is designed to perform all sorts of numerical computations and additionally it analyses the data and gives the plots of the computed data. In this we have two windows one is editor (script) window and the other is command window. In editor window we write program for the computation that we want and for the plots. In command window we will get the results of the computation. We can directly write the code in command window even it will work in the same manner and provides results but it has a disadvantage if we write program in command window when once computation is done if we want to perform the same for different values we cannot edit we have to clear and rewrite the program where as in editor window the code can be edited and used further for different data and we can make changes and do different computations. The steps results which we do not display in command window will be stored in work space. In this we have an integrated tool called Simulink which is used to compute and obtain models (mathematical model).

1.1.2 Fdatool: fdatool or filter designing and analysis tool which is used to design and analyze the filters. Fdatool enables us to design FIR and IIR filters by setting filter performance parameters and specifications, by importing data directly from matlab workspace or by setting filter coefficients. This tool also enables us to analyze the performance parameters of filters with respect to plots such as magnitude plot, phase plot and phase-magnitude plot. This tool also enables us to create the model of filter using required equipments. Fdatool is a separate window in the matlab for analyzing filters and designing filters.

2. Difference between passive and active filters

Table -1: Passive vs active filters

Feature	Passive RLC network	Active RC network
Realizably	Can be realized only a class of real function ,which is on right side of the s-plane	No restrictions .It can be realized with any real rational function
Requiemet of inductors	Inductors are required in almost all cases	Inductors are not required
applicability	Used in fixed frequency response application	Used in both fixed frequency and variable frequency applications

Signal source	Suitable only for resistive load impedances	Very low output impedance can be achieved
Frequency range	Above 200 Hz	Below 100kHz
Stability	Absolute stable	Unstable, due to varying process conditions in fabrications
Sensitivity	The ladder type of filter is less sensitive	Active filter are more sensitive.

3. Filters

3.1. LOW PASS FILTERS:

A low pass filter that passes frequency lower than a certain cut-off frequency and attenuates other frequency above the cut-off frequency.

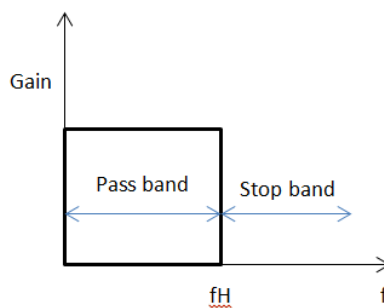


Fig.1 LPF graph

The range of frequency from 0 to higher cut off frequency f_H is called pass band and the range of frequencies above f_H is called stopband.

The derivation for cut off frequency and gain for R-C filter first order:

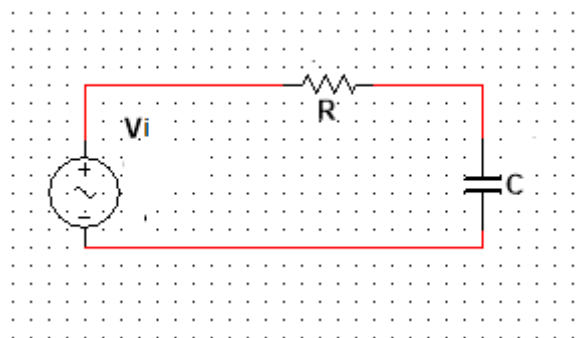


Fig.2 LPF circuit

$$\frac{|V_o|}{|V_i|} = \frac{1}{1+j\omega RC}$$

$$\frac{|V_o|}{|V_i|} = \frac{1}{\sqrt{1+(\omega RC)^2}}$$

$$\theta = \tan^{-1} \omega RC$$

At cut off frequency gain = $\frac{1}{\sqrt{2}}$

$$\omega_c = \frac{1}{RC}$$

Similarly for R-L low pass filter:

$$\omega_c = \frac{R}{L}$$

3.2 HIGH PASS FILTERS:

High pass filters that passes frequencies higher than certain cut-off frequency and attenuates low frequencies.

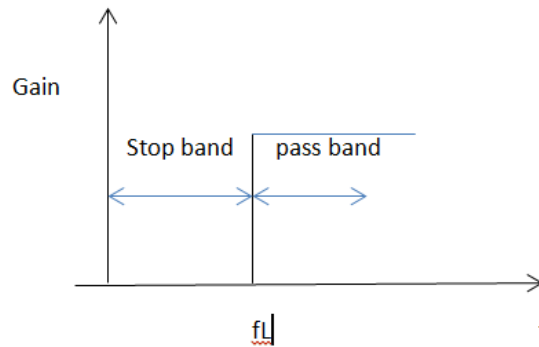


Fig.3 HPF graph

The range of frequency from 0 to f_L is called stop band and range above the f_L is called pass band .

The derivation for R-C first order filter to find gain is:

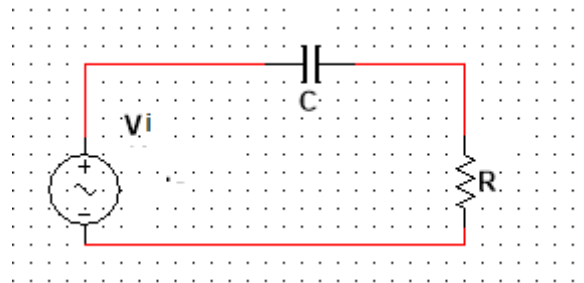


Fig.4 HPF circuit

Cut -off frequency= $f_c = \frac{1}{2\pi RC}$

Phase shift = $\phi = \tan^{-1}(\frac{1}{2\pi fRC})$

$$\frac{V_o}{V_i} = \frac{R}{\sqrt{R^2 + X_C^2}} = \frac{R}{Z}$$

At low frequency, $X_C \rightarrow \infty, v_{out} = 0$

At high frequency, $X_C \rightarrow 0, V_{out} = V_{in}$

3.3 BAND PASS FILTERS:

Band pass filter is a filter which passes certain ranges of frequencies, that range is called as band. It is a combination of high pass and low pass filters in cascaded form.

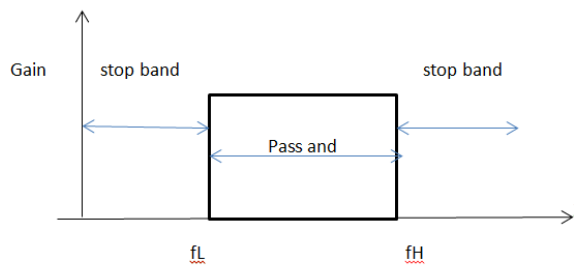


Fig.5 BPF graph

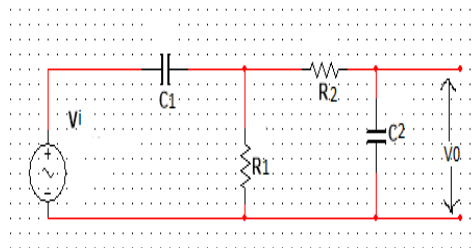


Fig.6 BPF circuit

It has two stop band in the range of frequencies between 0 to f_L and beyond f_H . The band between the cut off frequencies is called pass band .Hence its bandwidth

$$\text{Centre frequency } = f_r = \sqrt{f_H + f_L}$$

Where, f_H = higher cut off frequency

f_L = lower cut off frequency

$$B = f_H - f_L$$

$$Q = \frac{f_r}{f_H - f_L}$$

$$f_L = \sqrt{\frac{B^2}{4} + f_r^2} - \frac{B}{2}$$

3.4 BAND STOP FILTER

It is a filter which blocks certain range of frequencies and allows other frequencies, it is a combination of low pass and high pass filter which are connected in parallel form.

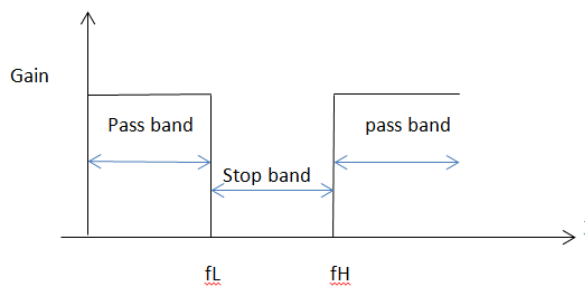


Fig.7 BSF graph

There are two pass band from 0 to fl and also fh to maximum frequency. And stop band is present between fl and fh.

Gain for the band stop is shown below

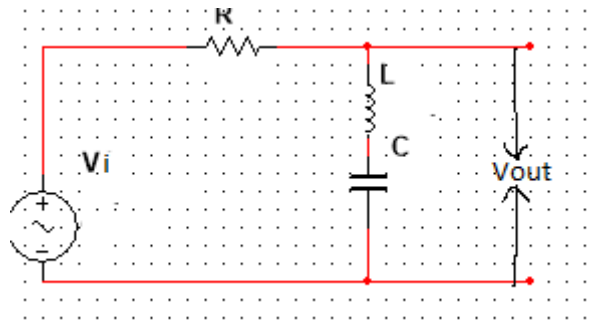


Fig.8 BSF circuit

$$\frac{V_o}{V_i} = \frac{j(\omega L - \frac{1}{\omega C})}{(R + j(\omega L - \frac{1}{\omega C}))}$$

3.5 IIR FILTERS:

IIR filters are designed by the infinite sample of impulse response. Direct design of IIR is not possible because processing of infinite samples is not possible in digital domain .So IIR filter is designed through analog filter. It is a non linear phase filter. IIR filters have feedback.

There are two commonly used types of IIR filters:

- Butterworth
- Chebyshev (type I , type II)

In this paper we are going to concentrate mainly on Butterworth filter.

3.6 FIR FLITERS:

FIR (finite impulse response) is a filter whose impulse response has finite duration .FIR filters are inherently stable and have linear phase. FIR fliters need higher order for similar magnitude response compare to IIR filters.

Linear phase filter – linear phase refers to condition where phase response of the filter is linear function of frequency. This results in delay through the filter being the same all frequency.

There are 4 types of FIR filters based on impulse response:

- Type I and type II- symmetric
- Type III and type IV –asymmetric

Design techniques

- Window method
- Frequency sampling method
- Optimal filter design (CAD)

Window method is commonly used method in FIR filter design. There are number of windowing techniques available .In this paper we are going to concentrate particularly on HAMMING WINDOW.

4. METHODOLOGY:

4.1 IIR BUTTERWORTH

4.1.1 low pass filter

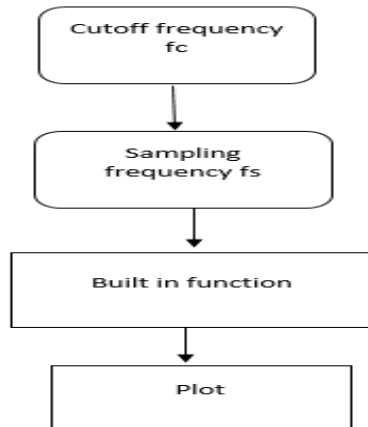


Fig.9 flowchart IIR LPF

4.1.2 high pass filter

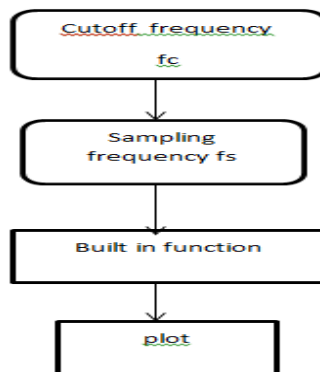


Fig.10 flowchart IIR HPF

4.1.3 band pass filter

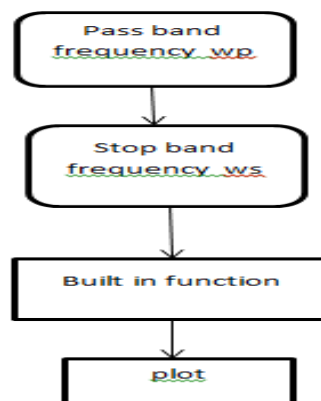


Fig.11 flowchart IIR BPF

4.1.4 Band stop filter

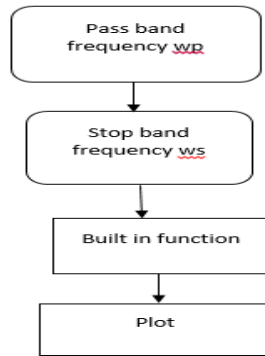


Fig.12 flowchart IIR BSF

4.2 FIR HAMMING WINDOW :

4.2.1 low pass filter

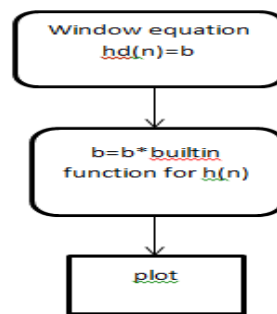


Fig.13 flowchart FIR LPF

4.2.2 high pass filter

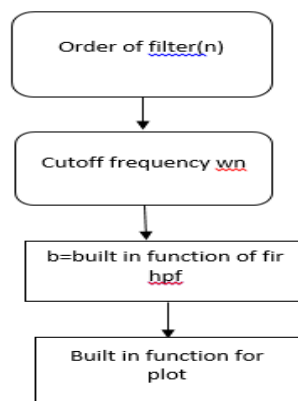


Fig.14 flowchart FIR HPF

4.2.3 band pass filter

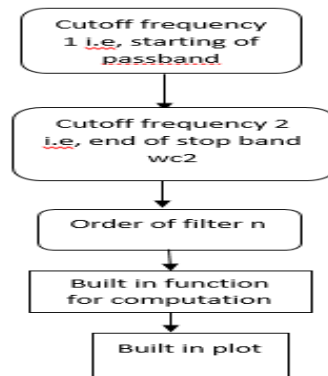


Fig.15 flowchart FIR BPF

4.2.4 Band stop filter

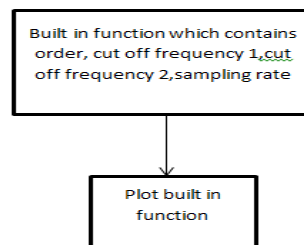


Fig.16 flowchart FIR BSF

5. RESULTS AND DISCUSSION:

5.1 IIR BUTTERWORTH FILTER:

5.1.1 Low pass filter

```

fc = 300;% cut off freq
fs = 1000; % sampling freq
[b,a] = butter(6,fc/(fs/2));
freqz(b,a)
    
```

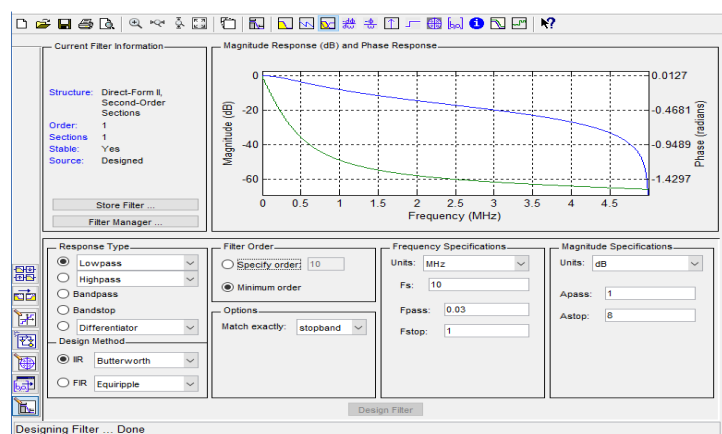
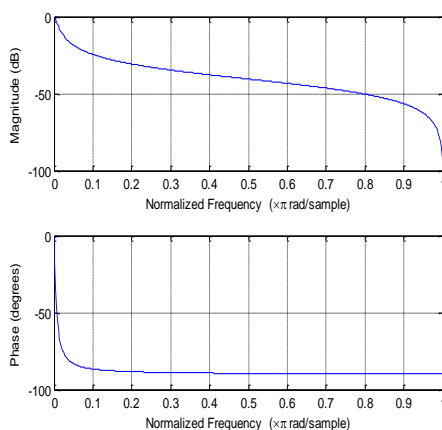


Fig.17 IIR LPF Matlab and FDA output.

5.1.2 Highpass filter

```
fc = 0.5*10^6;
fs = 10*10^6;
[b,a] = butter(1,fc/(fs/2),'high');
freqz(b,a)
```

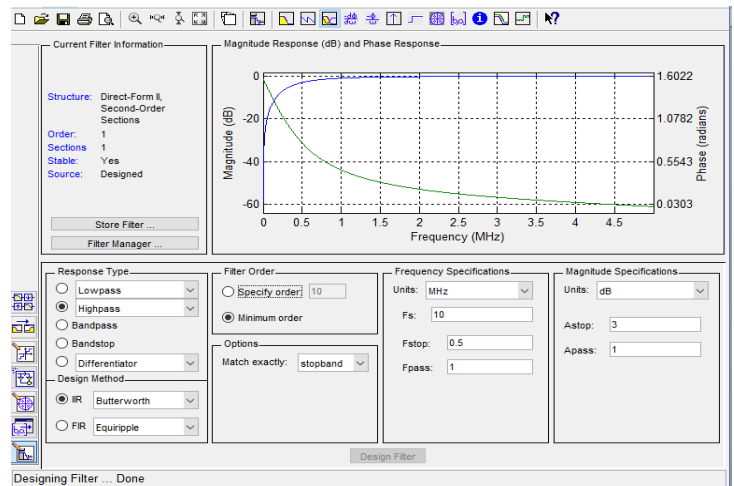
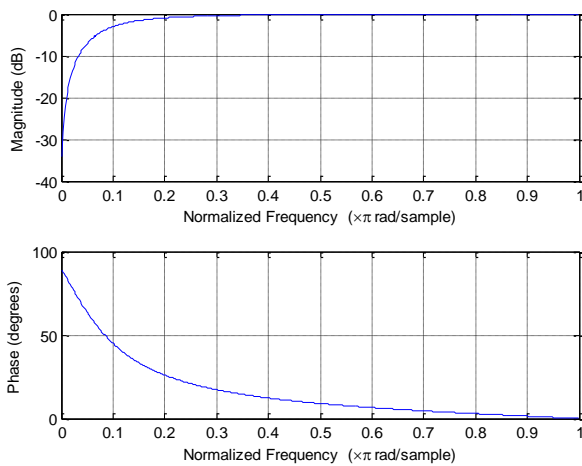


Fig.18 IIR HPF Matlab and FDA output.

5.1.3 Band pass filter

```
wp=67*10^-2;%wp is start of pass band
ws=98*10^-2;%ws is end of pass band
[b,a] = butter (4, [wp ws],'bandpass'); % 4 is the order of filter
freqz(b, a)
```

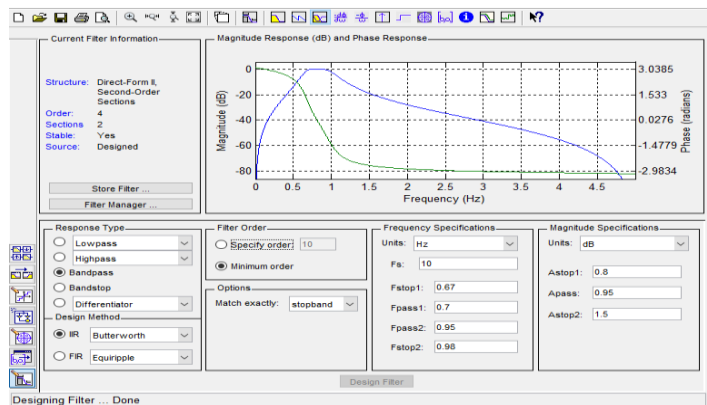
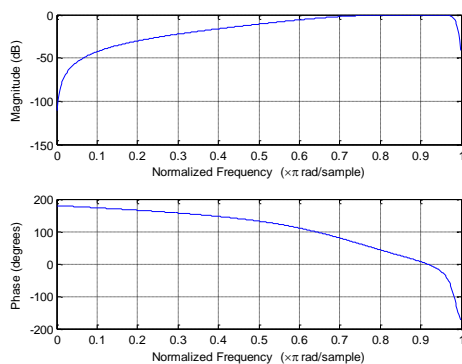


Fig.19 IIR BPF Matlab and FDA output.

5.1.4 bandstop filter.

```
wp=5*10^-1; %wp is start of stop band
ws=8*10^-1; %ws is end of stop band
[b, a] = butter (2, [wp ws],'stop'); % 2 is the order of filter
freqz(b, a)
```

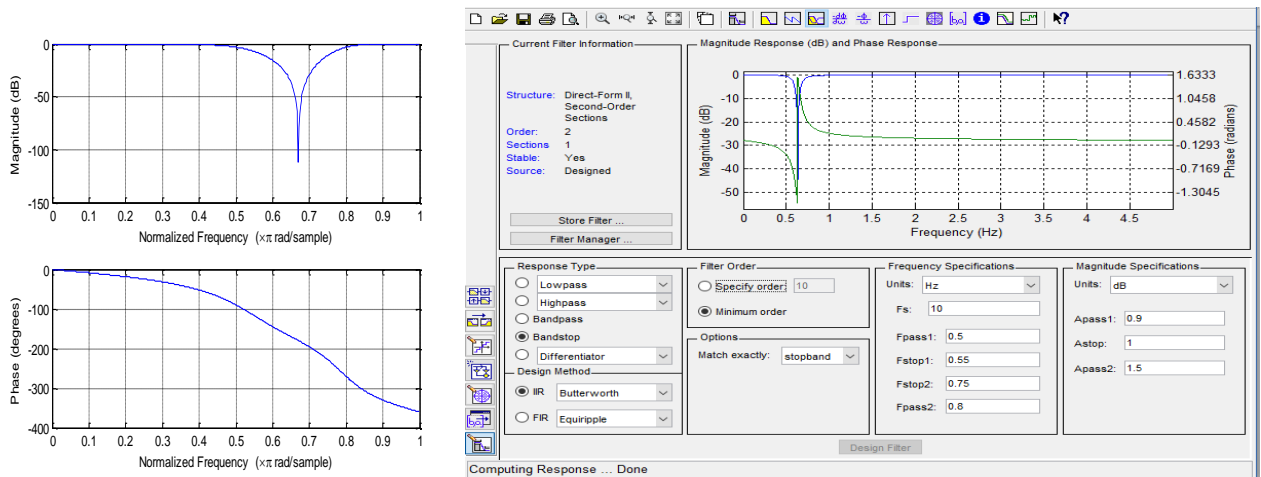


Fig.20 IIR BSF Matlab and FDA output.

5.2 FIR HAMMING WINDOW :

5.2.1 Low pass filter.

$b = 0.5 * \text{sinc}(0.5 * (-5:5));$ %0.5 is cut off freq , -5 to 5 is range

$b = b * \text{hamming}(11)';$ % 11 is n, where n is order of filter

`fvtool(b,1)`

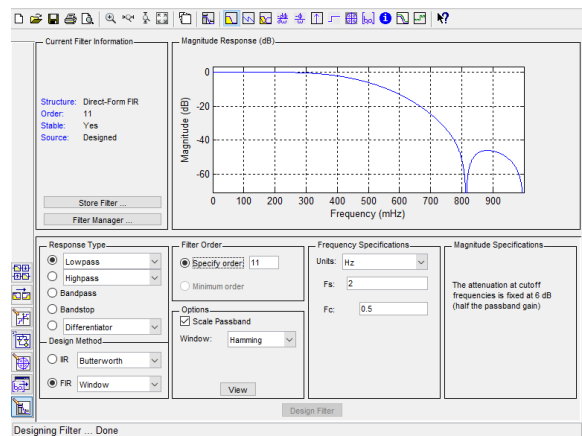
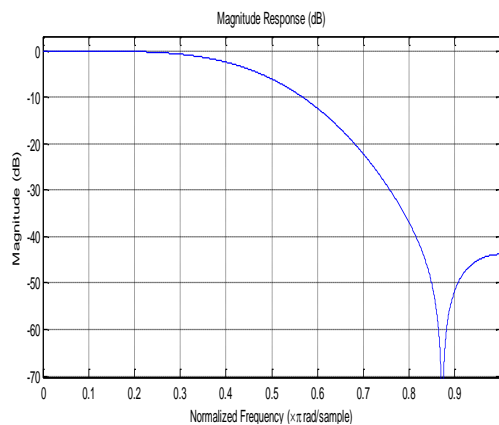


Fig.21 FIR LPF Matlab and FDA output.

5.2.2 high pass filter

$n = 10;$ % 10 is order

$Wn = 0.4;$ % 0.4 is cut off freq in rad/sample

$b = \text{fir1}(n, Wn, 'high');$

`fvtool(b,1)`

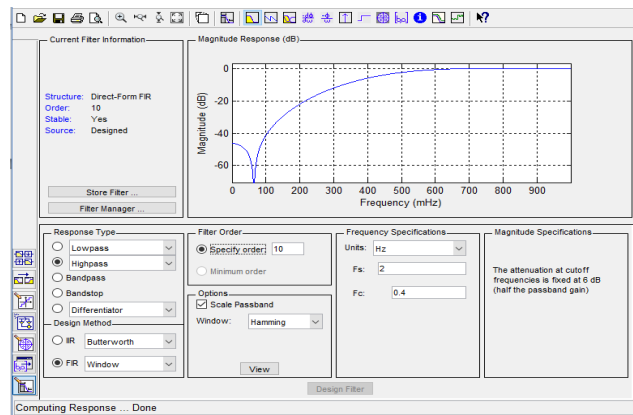
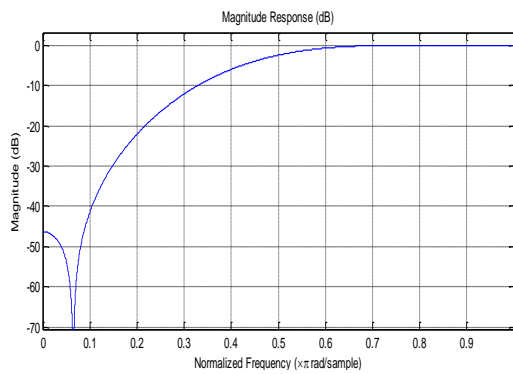


Fig.22 FIR HPF Matlab and FDA output

5.2.3 Band pass filter.

```

wc1=0.35;% start freq of band which needs to be passed
wc2=0.65; % stop freq of band which needs to be passed
n=83; % n =order
a = fir1 (n, [wc1 wc2]);
freqz (a, 1, 5)
    
```

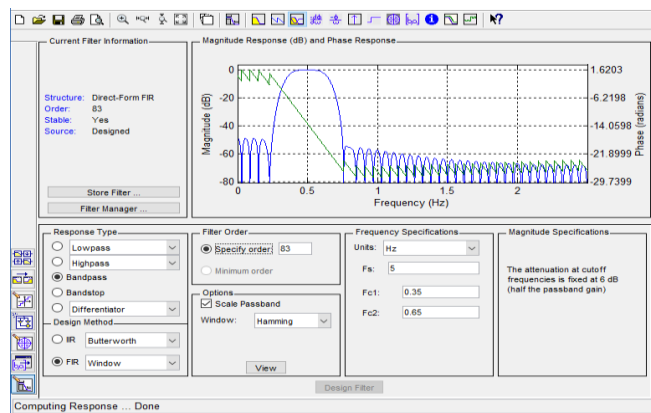
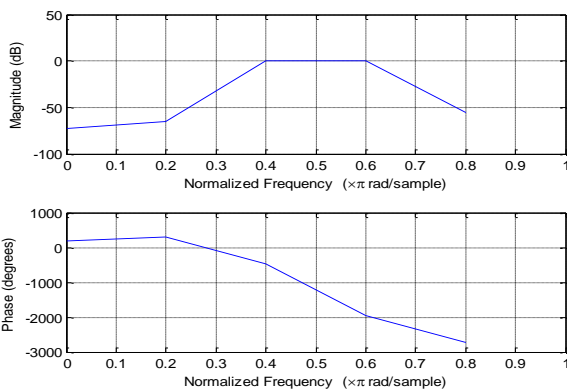


Fig.23 FIR BPF Matlab and FDA output

5.2.4 band stop filter

```

bsFilt = designfilt('bandstopfir','FilterOrder',350, ...
    'CutoffFrequency1',2.4*10^9,'CutoffFrequency2',5.4*10^9, ...
    'SampleRate', 15*10^9);
fvtool(bsFilt)
    
```

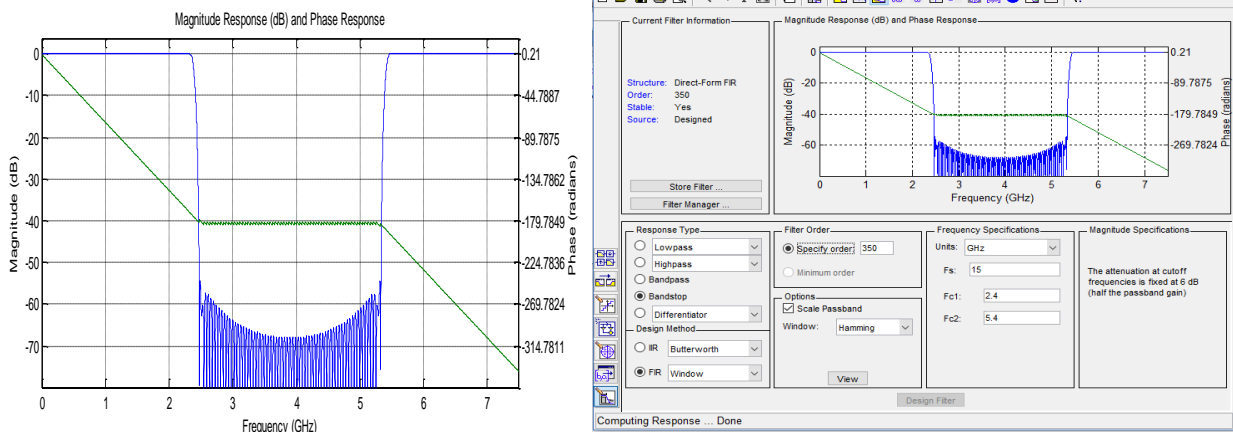


Fig.24 FIR BSF Matlab and FDA output

6. CONCLUSIONS

In this paper we have discussed about active filters and passive filters , and also different types of analog filters like butterworth iir filter and window method in fir filter .We have designed different types of filters using matlab and also by using FDAtool .In FDAtool we have given the cutoff frequency, passband frequency, stopband frequency and sampling frequencies to obtain the required filter responses

Future scope

now a days we are developing various kinds of new communication technologies of which the basic necessity is filters so many manufacturers are trying to develop different kinds of filters based on their applications for all those the basic models are the above mentioned filters. Filters are widely used in communication systems, instrumentation systems, audio systems and biomedical systems.

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