ISSN No. 2395-0900
IJESTA International Journal of Engineering Studies and Technical Approach

Comparison and Implementation of Different Types of IIR Filters for Lower Order & Economic Rate

Sonal Dwivedi

**PG Student, Department of Electronics & Communication Engineering, MPCT Gwalior, India.*

ABSTRACT*:*

In area of DSP, the function of filters is to eliminate the selected range of signal such as noise or to extract meaningful data from the signal. A filter is a device which is designed to pass frequencies within a specific range while rejecting all other unwanted frequencies that fall outside this range. Filters are widely in use in the field of image processing, communication and signal processing applications such as radar, video operations, audio processing, ECG, EMG, EEG, channel equalization, signal filtering, noise reduction, analyzing of financial and economic data. Depending upon the components used in a filter, they are classified as low pass filter, high pass filter, band pass filter and band stop filter. In this paper, we demonstrate three types of IIR (infinite impulse response) filter namely Butterworth, Chebyshev type 1 and elliptic, applying MATLAB software as it provides figure demonstration. In this paper we analyze all the three variety of filters.

Keywords: IIR Filter, Butterworth, Chebyshev 1, Elliptic filter.

1. INTRODUCTION

The filter plays a vital role in analog and digital signal processing. Analog filters basically consist of resistors, capacitors and inductors which are also called passive components. The digital filter system has two types which includes the IIR or recursive filter and FIR or non-recursive filter. FIR digital filter designed a linear phase digital filter which is convenient for data transmission, telecommunication system and image processing applications. Whereas IIR filter is used much in application such as high speed and low-power communication transceivers systems. As FIR requires large memory in order to store the previous input and previous output but FIR require less memory space to store present and past value of input. IIR pursue following properties that is the width of the pass-band, stop-band, limited ripple at pass-band and limited ripple at stop-band. Each filter (Butterworth, Chebyshev, Elliptic etc.) have different ripples in the pass-band and stop-band, stop-band attenuation and transition width. Here designing of IIR filter with Butterworth, Chebyshev 1 and elliptic became possible with MATLAB software and fundamentals of analog and bilinear transformation. The analog IIR Filter can be designed using Butterworth, chebyshev and elliptic and then transform it into digital IIR filter using Bilinear transformation or optimization method. Filters have much practical usage.

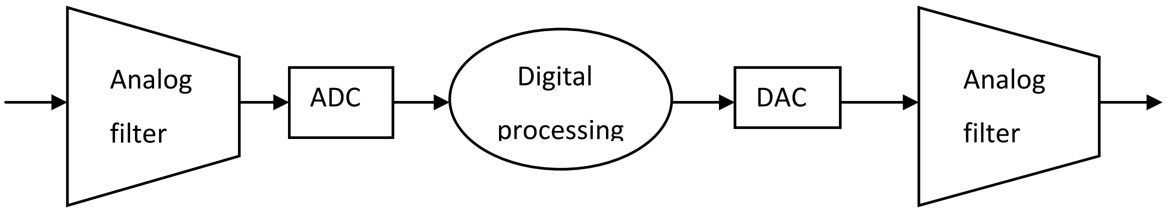

Figure1: Basic digital filter

MATLAB is the one of the strongest scientific computing and graphics software programmer which provides accuracy in mathematical calculations, designing filters and many other formations. It is very convenient in use, so realization of MATLAB program is easy to perform. The hardware requirement is not much in order to implement it ordinary machine. It consists of numerous tool boxes which prove very helpful in designing filters such as FDA tool Box, GA, and PSO etc.

The intent of this paper is to design IIR filter with the Butterworth, Chebyshev 1 and elliptic and comparing all to determine one of the better with low or no ripple, high- speed etc using MATLAB Simulation.

This paper is organized as: Section 2 describe the IIR filter designing. Section 3 describes the differences between IIR and FIR. Section 4 shows the overview of Butterworth, Chebyshev type 1 and elliptic filter. Then results of different filters are evaluated in section 5. And section 6, prescribes the Conclusion followed by references.

2. IIR FILTER

In IIR filter structure there is feedback line pointing from output to input due to which it is also called recursive filter. It consist of present and past values which is described below in the form of equation,

$$\sum_{i=0}^{L} b_i x(n-i) - \sum_{i=1}^{M} a_i y(n-i)$$

$$H(z)=\frac{Y(z)}{X(z)} = \frac{b_0+b_1 z^{-1}+\cdots\ldots\ldots+b_L z^{-L}}{1+a_1 z^{-1}+\cdots\ldots\ldots+a_M b^{-M}}$$

$$\text{Or}\quad H(e^{j\omega}) = \frac{b_0+b_1 e^{-j\omega}+\cdots+b_L e^{-j\omega L}}{1+a_1 e^{-jw}+\cdots+a_M e^{-jwM}},$$

$$\omega = \frac{2\pi f}{f_s}$$

Digital filters are often described and implemented in terms of the difference equation that defines how the output signal is related to the input signal:

$$y(n)= b_0 x(n) + b_1 x(n-1) + b_2 x(n-2) + \cdots + b_M x(n-M) +$$

$$a_0 x(n) + a_1 x(n-1) + a_2 x(n-2) + \cdots ..+ a_N x(n-N)$$

Where:

- M is the feed-forward filter order
- b_m are the feedforward filter coefficients
- N is the feedback filter order
- a_n are the feedback filter coefficients
- X (n) is the input signal
- Y (n) is the output signal.

ISSN No. 2395-0900
International Journal of
Engineering Studies and Technical Approach

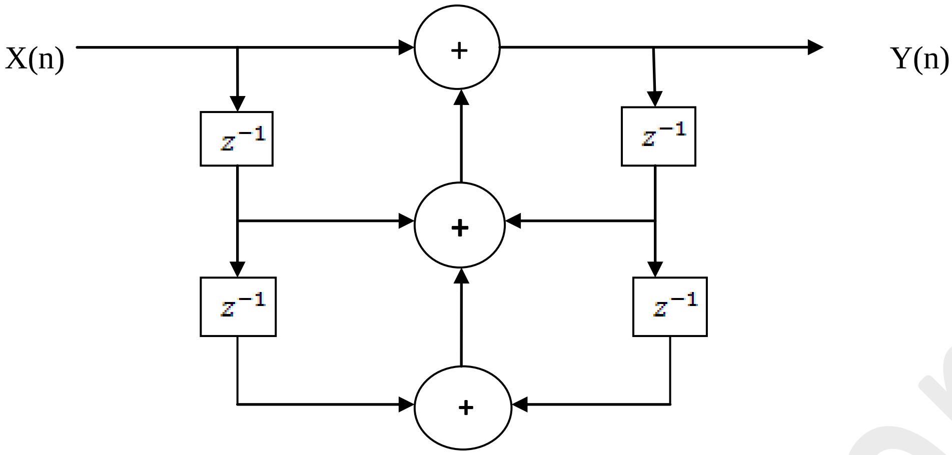

Figure 2: IIR Filter

3. DIFFERENTIATE BETWEEN FIR AND IIR FILTER

As we have gone through various techniques for designing purpose of both the filters IIR & FIR. So one wonders to choose which of the filter will be suitable whether IIR or FIR and which procedure should be select to design appropriate filter for given application. However, it is possible to attempt some meaningful comparisons between these two filters.

Advantages of IIR Filter over IIR Filter-

1. IIR can achieve a given filtering characteristic using less memory and calculations than a similar FIR filter.
2. In the stop-band of IIR filter it contains less number of side lobes.
3. Shorter or no time delay in IIR filter than the FIR filter.
4. In designing the same filter, IIR requires low order than the FIR.
5. It can achieve all the desired specification by low computational cost.
6. Long impulse response with feedback.

4. BUTTERWORTH FILTER

The Butterworth filters have monotonically response which indicates that the magnitude response of the pass-band and stop-band has maximally flat. It can be notice that by increasing the order of filter N, it approximates to the ideal response. However, the phase response of the Butterworth filter becomes more non-linear with increasing.

The Butterworth filters low-pass filter has a magnitude response given by:

$$|H(j\omega)|^2 = \frac{1}{1+(\frac{\omega}{\omega_c})^{2N}}$$

Attenuation,

$$A = -10\log\left(1 + (\frac{\omega}{\omega_c})^{2N}\right)$$

www.ijesta.com

Here ω_c is 3db cut-off frequency and N is the order of filter. Compared to the other filter like chebyshev and elliptic, the Butterworth filter has more linear phase response in the pass-band.

5. CHEBYSHEV TYPE 1 & 2- FILTER

Here we have two types of chebyshev filters which are called chebyshev type-1 (regular) filter and the chebyshev type-2 (inverse) filter. First, we will discuss about chebyshev type-1 filter in which it have equiripple in pass-band and no-ripples in stop-band whereas in chebyshev type-2 it have equiripple in stop-band and no-ripples in pass-band. It is noted that, we can obtain a lower order filter by choosing a chebyshev filter which is characterized by equiripple rather than a Butterworth filter that is characterized by monotonic behavior or maximally flat magnitude response for the same specification as for the chebyshev

The magnitude response of chebyshev is given below-

$$|H(j\omega)|^2 = \frac{1}{1+\varepsilon^2 c_N^2(\frac{\omega}{\omega_c})}$$

$$|H(j\omega)| in\ dB = -10 \log(1 + \varepsilon^2 c_N^2(\frac{\omega}{\omega_c}))$$

Where ε = amount of ripple in magnitude, $c_n = chebyshev\ coefficient$

$c_N = \cosh(n\cosh^{-1} \frac{\omega}{\omega_c})$, if $\frac{\omega}{\omega_c} \geq 1$.

When $c_N(\frac{\omega}{\omega_c})$ tends to zero in pass-band, then magnitude response is in its peak stage.

Then $H(j\omega) = \frac{1}{1+\varepsilon^2}$

Similarly to design the equation for chebyshev type-2, put $\omega_c = \omega_c$ in the equation of chebyshev type-1. As equiripples is present in stop-band of chebyshev type-2.

Then $H(j\omega) = \frac{\varepsilon^2}{1+\varepsilon^2}$

If equiripple are allowed in pass-band then to match the same specification, the Chebyshev filter's order will be lower than the desired Butterworth filter. This means that components required to build Chebyshev filter is lesser than the Butterworth filter. So it concluded that higher the percent of ripple permitted the lower order filter is required.

6. ELLIPTIC FILTER

This type of filter contains ripple behavior in both the pass-band and stop-band. They have similar magnitude response characters as FIR ripple filter does. It achieves minimum order of filter N, and it also has minimum transition bandwidth. It is very difficult to design and

www.ijesta.com

ISSN No. 2395-0900
IJESTA International Journal of Engineering Studies and Technical Approach

analyze. It is not so easy to design them with simple tools, program or tables. Sometimes it is also called Cauer Filter.

The magnitude response is given by:

$$|H(\omega)|^2 = \frac{1}{1+\varepsilon^2 U_N(\omega/\omega_c)}$$

Where U_N (x) is the order of Jacobean elliptic function

N = order of filter

ε= constant related to pass-band ripple.

7. SIMULATION RESLULTS

For purpose of designing digital filter such as lowpass, highpass, bandpass and bandstop with different specifications such as Butterworth, Chebyshev1, Chebyshev2 and Elliptical ,we are using some frequency parameters which help us in determining digital filter's responses, pole-zero etc. By obtaining all the characters of different specifications, we able to decide which specification is best or more suitable in particular area. In table 1 all the frequency parameters are given through which obtained result is given below.

Table 1:- Digital filter frequency parameters

FILTER TYPE	R_p	R_s	W_s		W_p	
Low pass filter	3	60	0.3		0.1	
High pass filter	3	60	0.3		0.1	
Band pass filer	3	60	0.2	0.3	0.1	0.4
Band stop filter	3	60	0.2	0.3	0.1	0.4

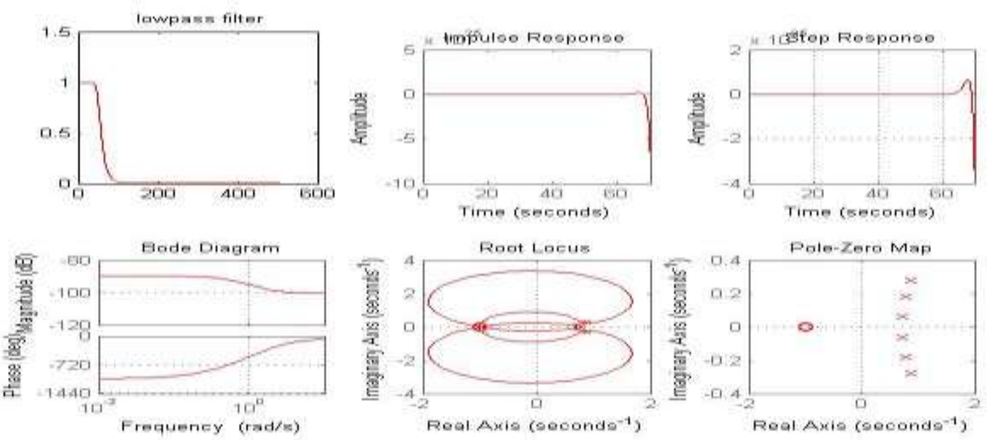

Figure 3: Butterworth Low-pass Filter

www.ijesta.com

ISSN No. 2395-0900

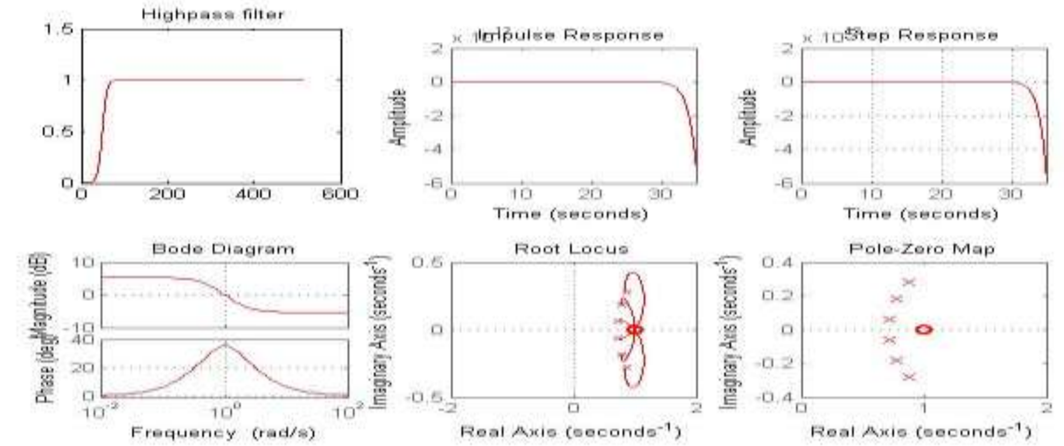

Figure 4: Butterworth High-pass Filter

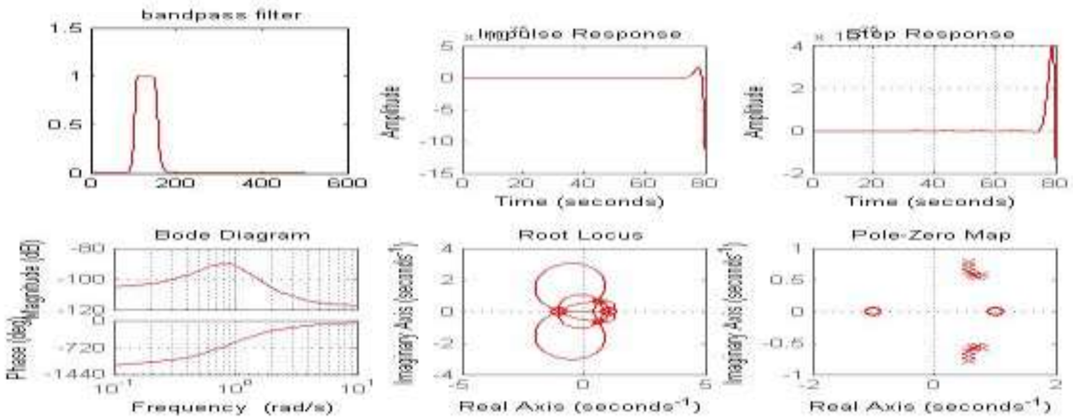

Figure 5: Butterworth Band-pass Filter

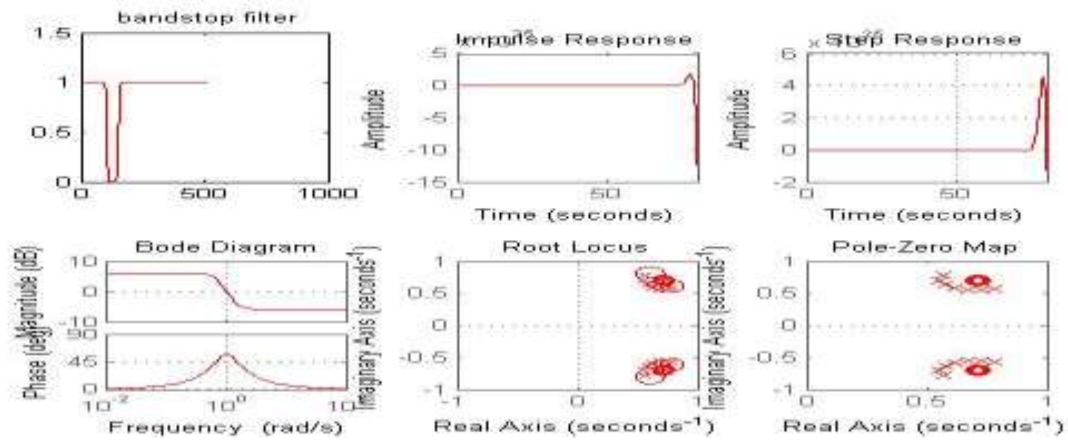

Figure 6: Butterworth Band-stop Filter

International Journal of Engineering Studies and Technical Approach
ISSN No. 2395-0900

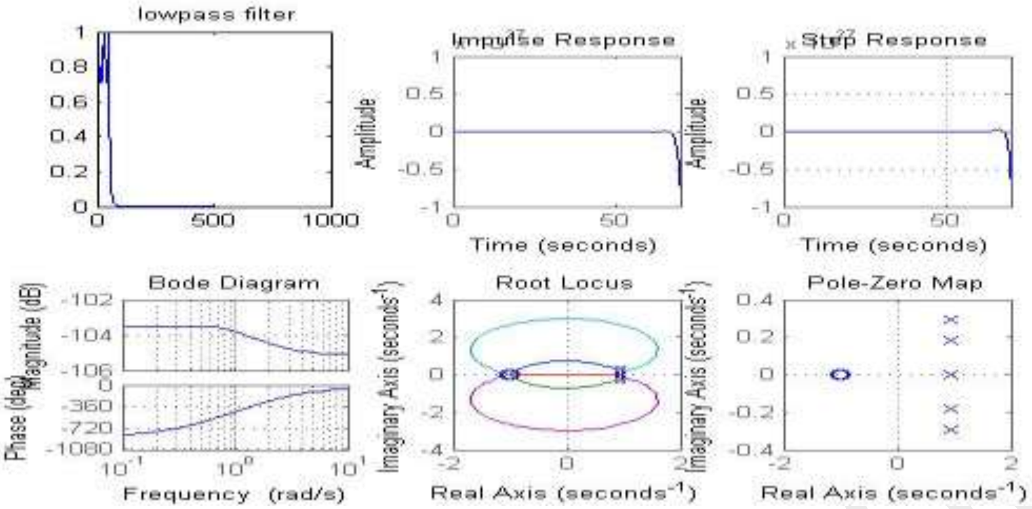

Figure 7 : Chebydshev1 Low-pass Filter

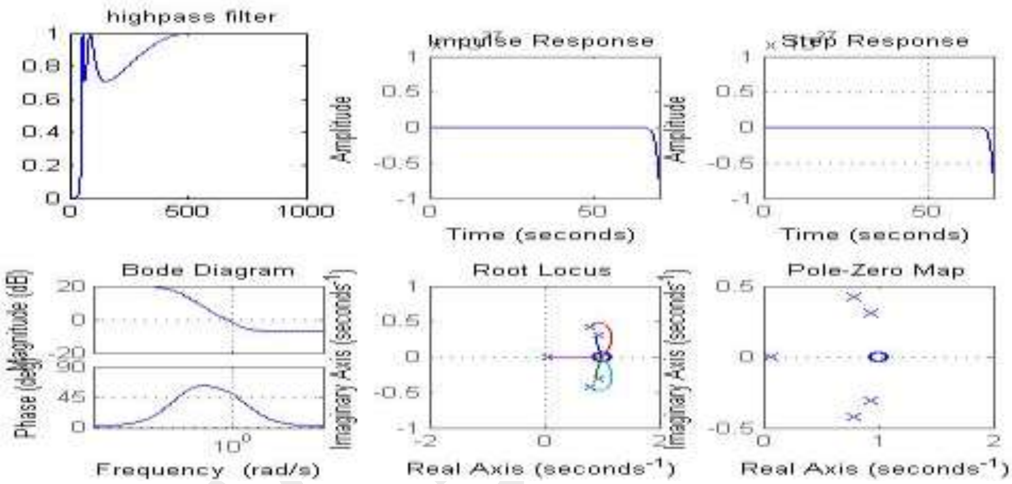

Figure 8: Chebyshev1 High-pass Filter

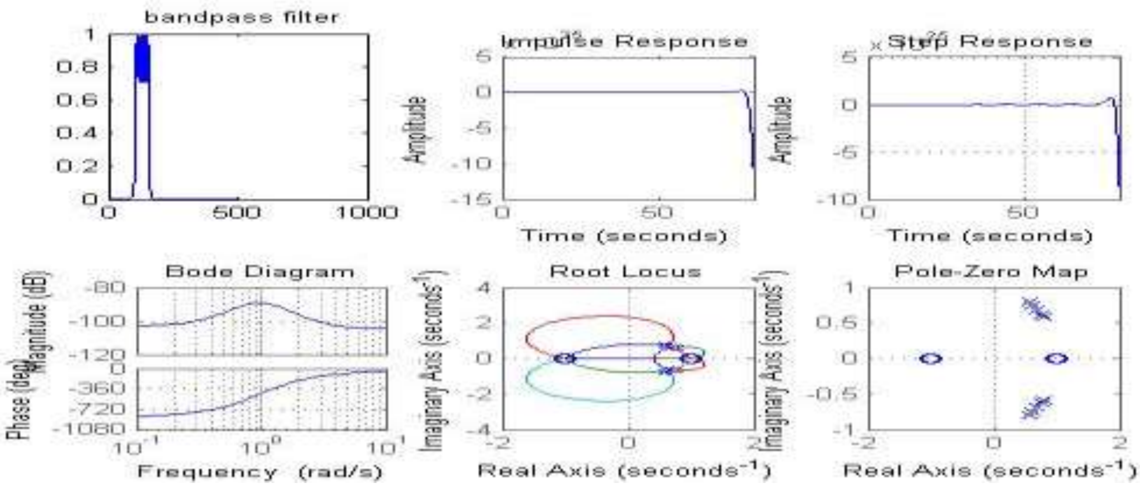

Figure 9: Chebyshev1 Band-pass Filter

IJESTA International Journal of Engineering Studies and Technical Approach
ISSN No. 2395-0900

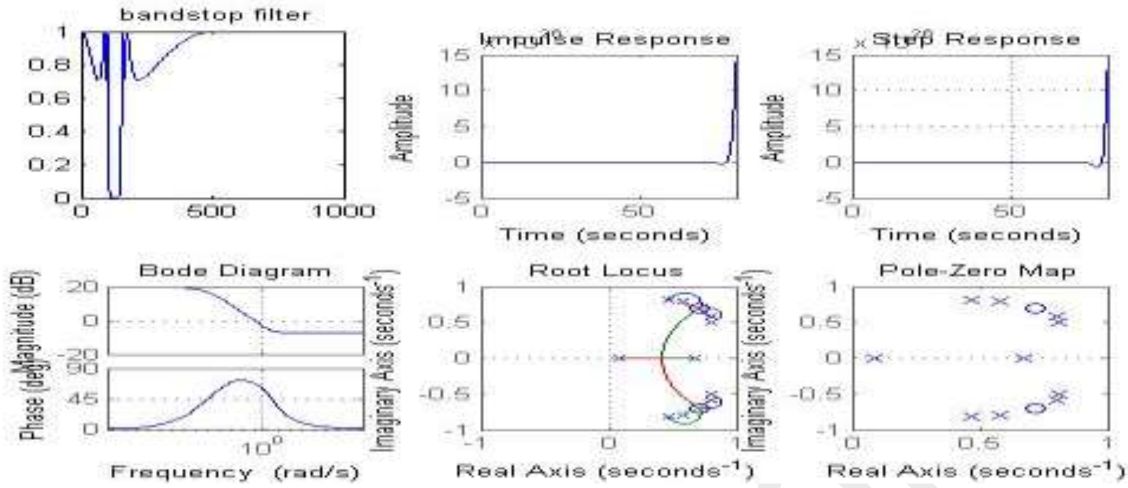

Figure 10: Chebyshev1 Band-stop Filter

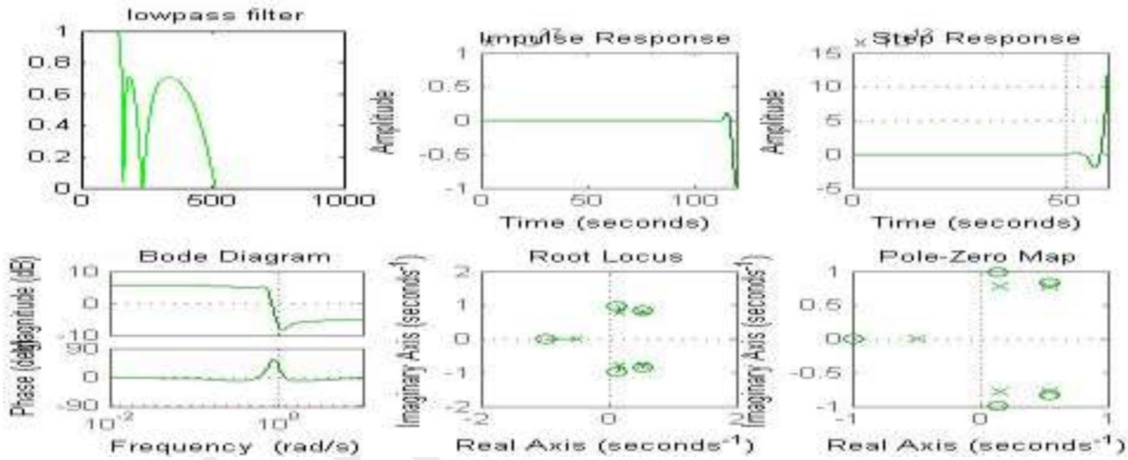

Figure 11: Chebyshev2 Low-pass Filte

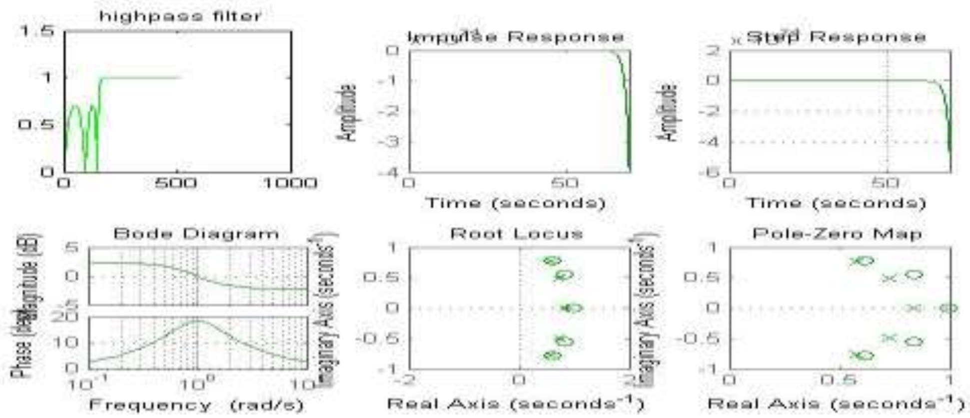

Figure 12: Chebyshev2 High-pass Filter

International Journal of
Engineering Studies and Technical Approach
ISSN No. 2395-0900

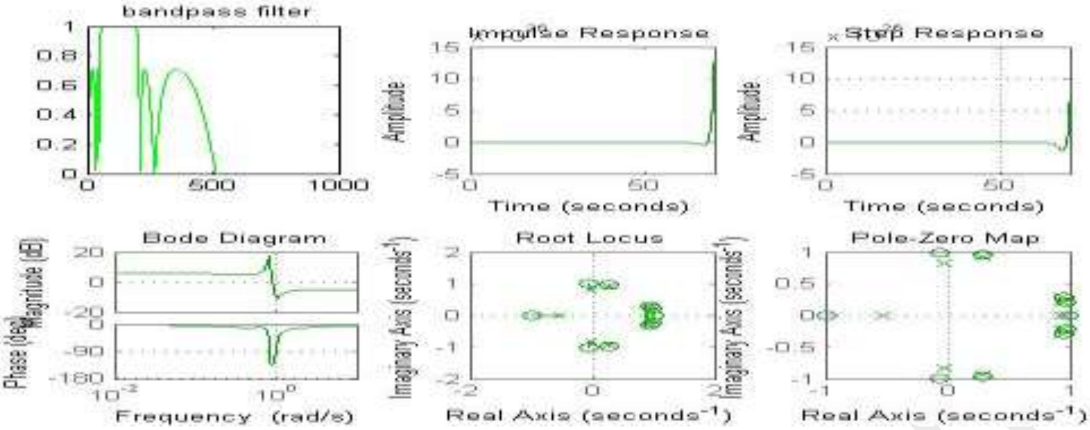

Figure 13: Chebyshev2 Band-pass Filter

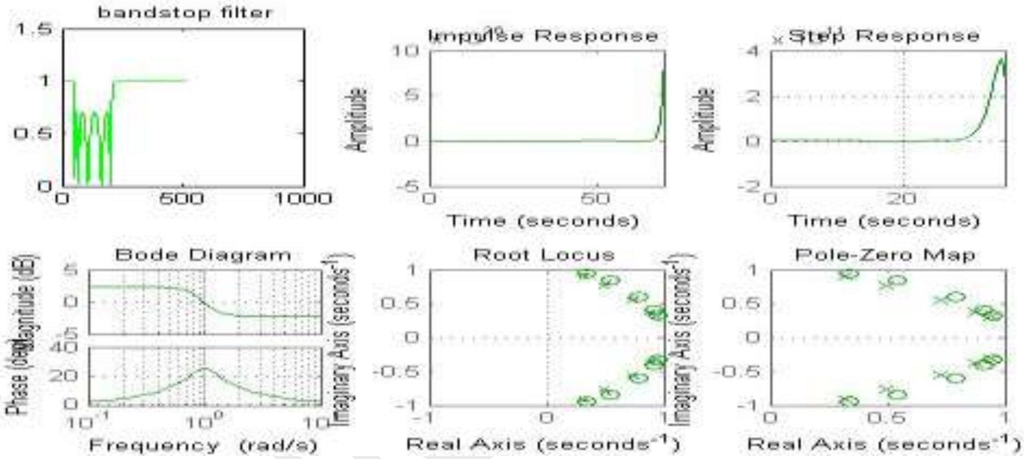

Figure 14: Chebyshev2 Band-stop Filter

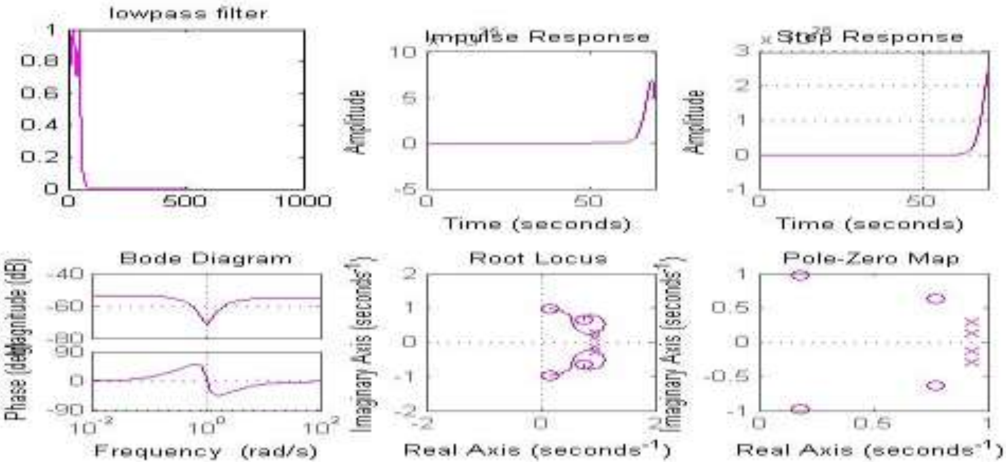

Figure 15: Elliptic Low-pass Filter

ISSN No. 2395-0900
International Journal of
Engineering Studies and Technical Approach

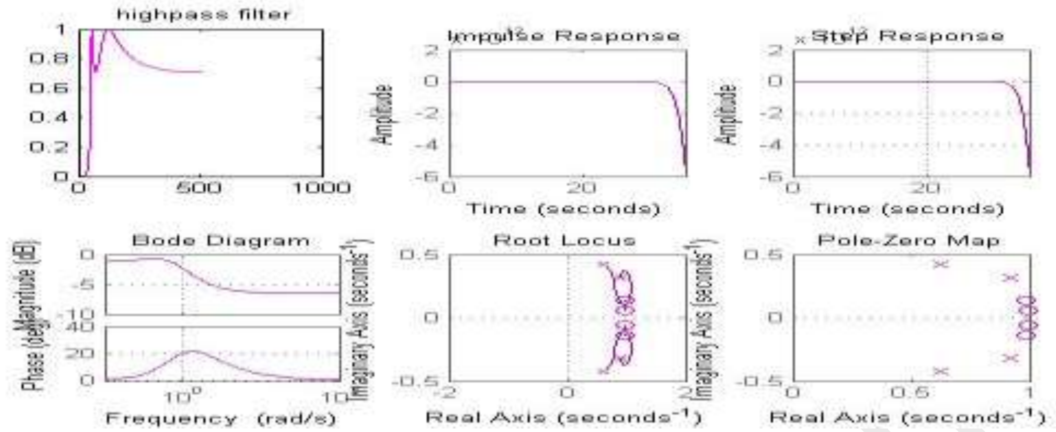

Figure 16: Elliptic High-pass Filter

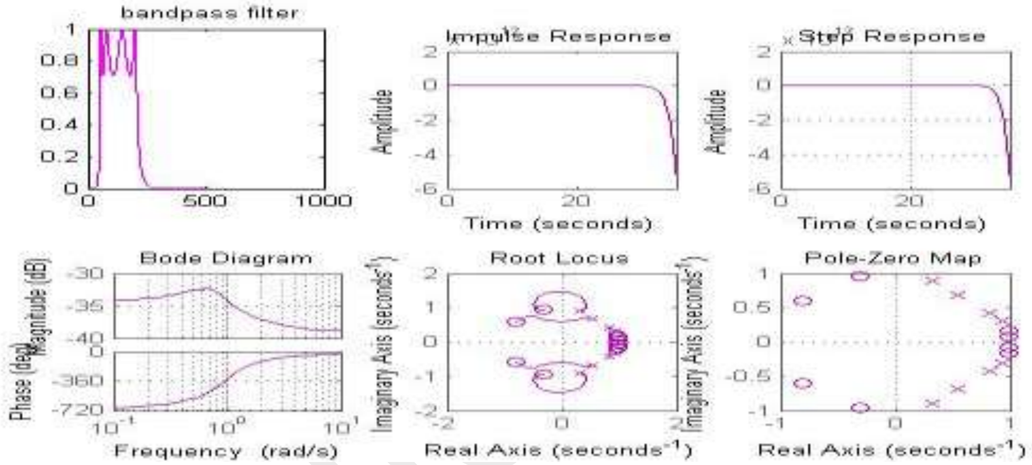

Figure 17: Elliptic Band-pass Filter

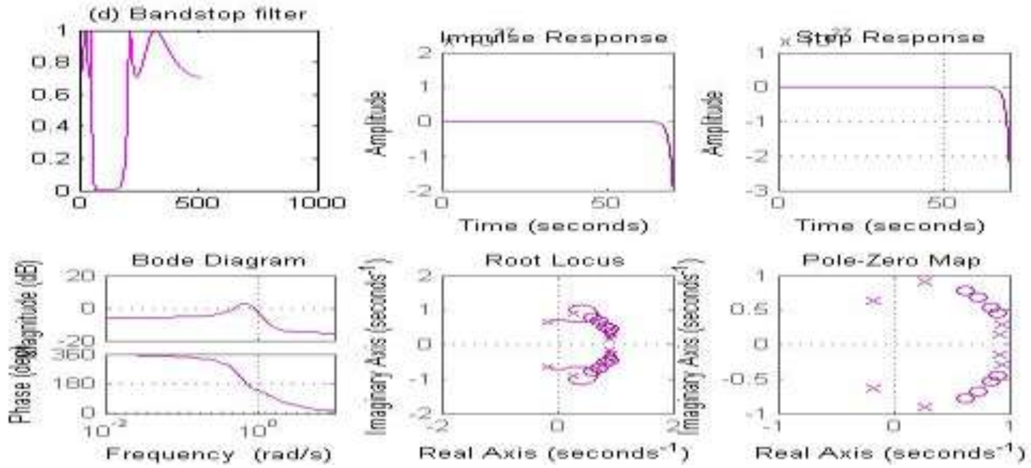

Figure 18: Elliptic Band-stop Filter

CONCLUSION

For LPF, HPF, BPF & BSF Butterworth filter there is no attenuation in pass-band and stop-band as shown in fig. 3, 4, 5 & 6 which denotes it has good phase response but the order is 6 which is high as compare to others. The frequency response output shows no or zero ripple. The condition of roll off is poor. Whereas in case of Chebyshev1, 2 the attenuation is possible, so the ripple increases. The order of Chebyshev1, 2 filters is 5 which are lower than Butterworth filter so it decreases the large requirement of components and computational cost. The fig. 7, 8, 9, 10, 11, 12, 13 & 14 shows LPF, HPF, BPF & BSF Chebyshev1, 2. In elliptic filter there are high non-linear responses due to having both pass-band and stop-band ripple which makes it very difficult to implement. In spite of having lower order then Butterworth and Chebyshev1, 2 which is 4, it is practically difficult to design. The transition region of elliptic filter is smaller than chebyshev1 filter. The fig. 15, 16, 17 & 18 represents the LPF, HPF, BPF and BSF of Elliptic Filter.

In this paper among all the above specifications the Chebyshev1, 2 are the best in terms of order and computational or economic purpose. The magnitude responses, phase responses, pole-zero, root locus, step response and impulse response is designed for all type of filters all performed by using MATLAB tool box. It has been found that chebyshev is better in all terms as an average. The output responses prove the better performance of chebyshev with respect to others.

REFERENCES

i. Julius Orion Smith , “” Introduction to Digital Filters”, 2007

ii. Dag Stanneby, “ Digital Signal Processing-DSP Application”, Butterworth-Heinemann, Oxford, 2001

iii. “Survey paper on digital IIR filter uses GA” paper published in the international journal of innovative research in computer and communication engineering- IJIRCCE volume 3, issue 6, June 2015.

iv. lngle, Vinay K. and John G. Proakis, (1997), “DIGITAL SIGNALP ROCESSING USING MATLAB V.4”, PWS Publishing Company and International Thomson Publishing Inc.

v. Er. Daljit singh bajwa, karamjeet singh, navpreet kaur chahal” survey paper of digital IIR filter design”, IJARCSSE, vol. 4, issue 4, april 2014.

vi. “Designing of IIR filter with multi-objective GA” Paper Published in international journal of modern trends in engineering and research (IJMTER), volume 2, issue 4, April 2015.

vii. “Using multi-objective GENETIC ALGORITHM Designing High- pass IIR filter” paper published in International publisher for advanced scientific journals- IIJEC may 2015.

viii. Yaduvir Singh, Sweta tripathi and Manoj “ Analysis of Digital IIR Filter with Lab VIEW International Journal of Computer Applications, Vol. No. 06, pp.23-30, 2010.

ix. Samarjeet Singh and Uma Sharma, “ MATLAB based Digital IIR filter design”, International Journal Electronics and Computer Science Engineering, Vol. No. 01, ISSN 2277-1956,pp.74-83.

www.ijesta.com

x. Prajoy Podder, Md. Mehedi Hasan "Design and implementation of butterworth, chebyshev and elliptic filter for speech signal analysis", International Journal of Computer Application. Vol. 98-No.7, july 2014.

xi. Wazir Muhammad Laghari, Mohammad Usman Baloch, Muhammad Abid Mengal, Syed Jalal Shah "Performance Analysis of Analog Butterworth Low Pass Filter as Compared to Chebyshev Type-I Filter, Chebyshev Type-II Filter and Elliptical Filter", Vol.5 No.9(2014), Article ID:49253,8 pages.

xii. Abderrahmane ouadi" optimal multi-objective design of digital filters using spiral optimization technique", springer plus 2013,2:461.

xiii. Wei- der chang " coefficient estimation of IIR filter by a multiple crossover genetic algorithm", ELSEVIER (2006), 1437-1444.

xiv. Raaed faleh Hassan, ali subhi abbood" design of finite impulse response filters based on genetic algorithm", diyala journal of engineering sciences, vol. 06, no. 03, pp. 28-39, September 2013.

xv. Pardeep kaur, simarpreet kaur," to improve the magnitude response, phase variation and phase delay in FIR filters using GA", IJAIEM, vo. 2, issue 1, January 2013.

xvi. Karaboga, Nurhan and Bahadir Cetinkaya, (2004), "Performance comparison of Genetic Algorithm based design methods of digital filters with optimal magnitude response and minimum phase", IEEE. PP. 644-647.

www.ijesta.com