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Detection of Noise in High Pass Butterworth IIR Filter using MATLAB

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***Abstract*— Filters plays a vital role in every electronic system. The basic need for the filtering is to pass the desired frequencies and reject others. There is a lot of use of filtering in the digital signal processing areas of data communication, digital video, imaging and voice communication. The idea of this paper is to design the high pass Butterworth IIR filter using MATLAB considering different parameters such as cutoff frequencies, order and see the variation of these parameters on noise.**

***Keywords*— IIR, FIR, FDA**

I. Introduction

To fulfill the challenges rising in area of Digital communication system design digital signal processing technique are used. Analog filters are continuous-time systems for which both the input and output are continuous-time signals. Digital filters are discrete-time systems whose input and output are discrete-time signals. A filter is a system or network that selectively changes the wave shape, amplitude-frequency and/or phase-frequency characteristics of a signal in desired manner. Common filtering objectives are to improve the quality of signal (for example, to remove or reduce noise), to extract information from signal or to separate two or more signals.

The term digital filter refers to specific hardware or software routine that perform the filtering algorithm. Digital filters play a vital role in DSP. Compared with analog filters they are preferred in a number of applications (for example data compression, biomedical signal processing, speech processing, Image processing, Data transmission) [1]

Digital filters are broadly divided into two classes, namely infinite impulse response (IIR) and finite impulse response (FIR). The input and output signals to the filter are related by the convolution sum.

$$y(n) = \sum_{k=0}^{\infty} h(k)x(n-k) \qquad (1)$$

$$y(n) = \sum_{k=0}^{N-1} h(k)x(n-k) \qquad (2)$$

Respectively (1) and (2) represent IIR and FIR filters. Noting that x(n),y(n) and h(n) representrespectivelyinput, output and unit impulse response of the filter. N is order of the filter.In practice, it is not feasible to compute the output of the IIR filter using (1) because the length of its impulse response is too long (infinite in theory). Instead, the IIR filtering equation is expressed in recursive form:

$$y(n) = \sum_{k=0}^{\infty} h(k)x(n-k) = \sum_{k=0}^{N} b_k x(n-k) + \sum_{k=1}^{M} a_k y(n-k) \quad ..(3)$$

Where a_k and b_k are the coefficient of the filter [2]. IIR digital filter is ideally design using MATLAB. The digital filter could be divided into FIR digital filter and IIR digital filter according to the unit-impulse response or the reality architecture, could be divided into Chebyshev filter, Butterworth filter and so on. According to the method of design, could be divided into low-pass filter (LPF), high-pass filter (HPF), band-pass filter (BPF) and band-stop filter (BSF) according to the function. [3].There are two major issues that need to be answered before one can develop the digital transfer function. The first and foremost issue is the development of a reasonable frequency response specification from the requirements of the overall system in which the digital filter is to be employed. The second issue is to determine whether an FIR or an IIR digital filter is to be designed. [4]

II. MATHEMATICALANALYSIS OF BUTTERWORTH FILTER DESIGN

Bileneartransformation method is a popular technique for designing of IIR digital filters. Butterworth filter is the simplest of the four classical filters.The Butterworth filter can be realized by using simple first order or biquad stages cascaded together to achieve the desired order, pass band response, and cut-off frequency. The Butterworth filter has a maximally flat response, i.e., no pass band ripple and a roll-off of -20dB per pole.The magnitude function for an Nth-order Butterworth filter with a pass band edge ω_p is given by :

$$|H(j\omega)| = \frac{1}{\sqrt{1+\varepsilon^2\left(\frac{\omega}{\omega_p}\right)^{2N}}} \qquad (4)$$

At $\omega = \omega_p$

$$|H(j\omega_p)| = \frac{1}{\sqrt{1+\varepsilon^2}} \qquad (5)$$

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Thus, the parameter ε determines the maximum variation in passband transmission, Amax,according to

$$A_{max} = 20log\sqrt{1+\epsilon^2} \qquad (6)$$

Conversely, given Amax, the value of ε can be determine from

$$\varepsilon = \sqrt{10^{A_{max}/10} - 1} \qquad (7)$$

Observe that in the Butterworth response the maximum deviation in passband transmission occurs at the passband edge only [5].

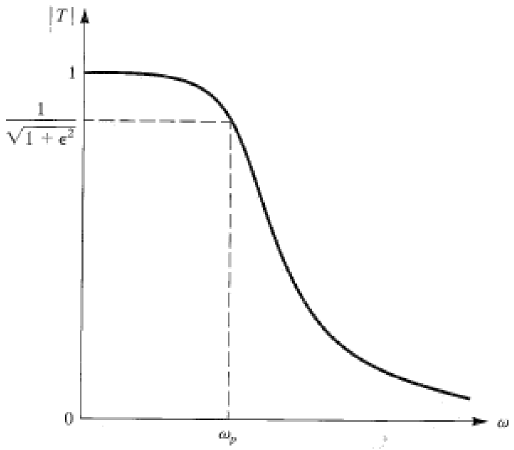

Figure: The magnitude response of Butterworth filter

III. IMPLEMENTATION

As we know that in the processing of signal their is additon of sme noise in it. So this is necessery to remove this noise for the transmission of signal. There noise can be removed by using different techniques. Many of these methods we have to use Butterworth technique of IIR filter for denoising of input signal [6]. In this paper we analyze signal by using MATLAB FDA toolbox. In this paper we have to investigate the unique property of Butterworth High Pass filter in terms of magnitude responses in the pass band, stop band, and transition band regions. In this paper we are designing Butterworth technique of High Pass IIR filter for removing the noise from the signal. For the designing of Butterworth High Pass filter we have to consider different types of parameters such as Cut off frequency, order of filter .We will implement this Butterworth High pass filter using MATLAB FDA toolbox. In the FDA toolbox first we consider the cut off frequency and see the effect of this on noise [7]. For this design other parameters would be assumed constant such parameters are following: Sampling Frequency Fs=48KHZ, Order of filter N=10, Attenuation= 3 db.

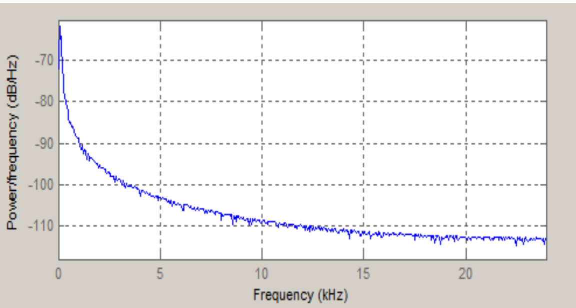

Figure 1: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=100Hz

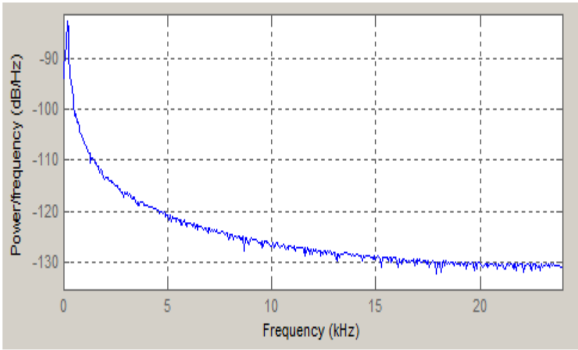

Figure 2: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=200Hz

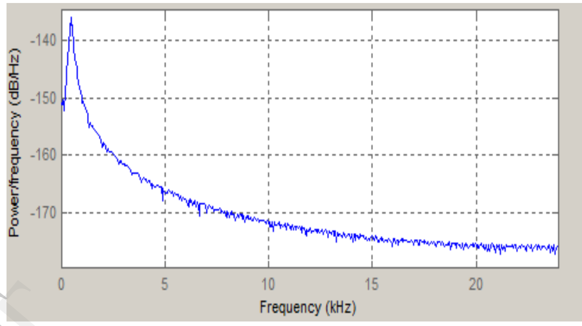

Figure 3: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=500Hz

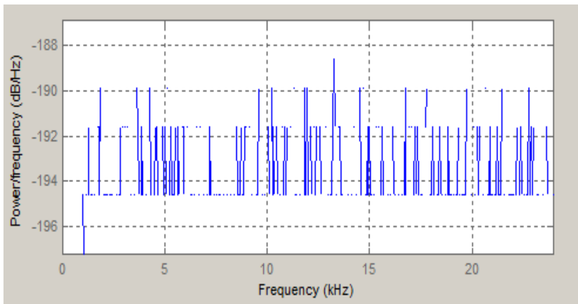

Figure 4: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=1Khz

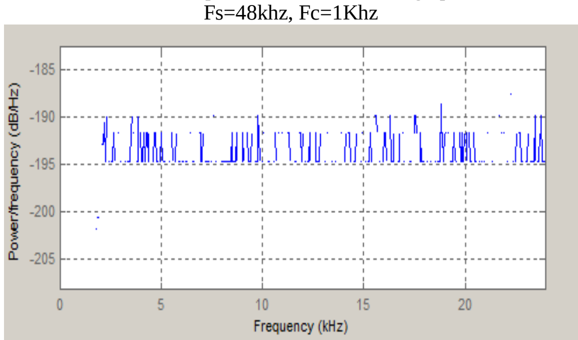

Figure 5: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=2Khz

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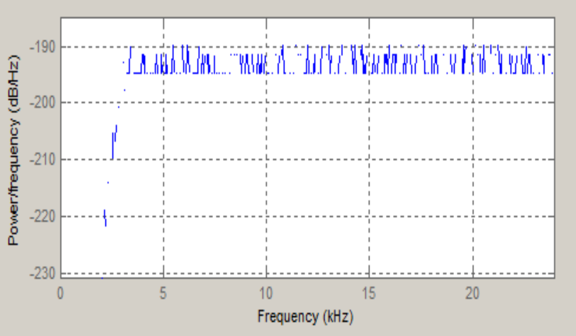

Figure 6: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=3Khz

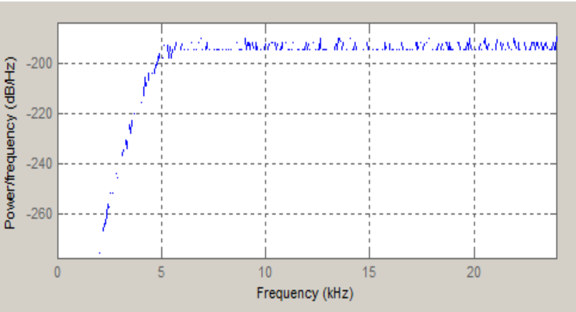

Figure 7: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=5Khz

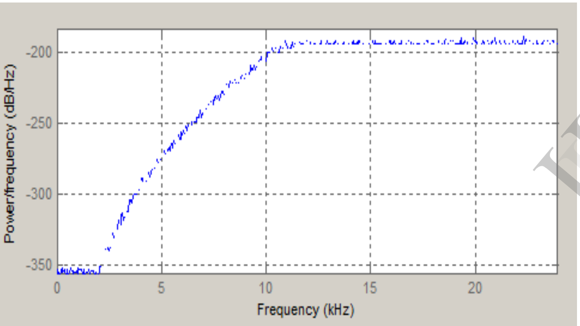

Figure 8: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=10.8Khz

The second parameter is order of the filter. Now we see the variation of noise with the order of Butterworth high pass filter by using MATLAB FDA Toolbox. For this other parameters would be remain constant such as :
Cut off Frequency Fc= 10.8 khz,Sampling Frequency Fs=48 khz, Attenuation= 3db

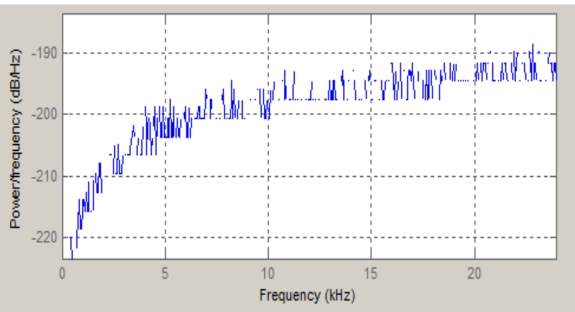

Figure 9: Round off noise response of Butterworth High pass filter with N=1, Fs=48khz, Fc=10.8 khz

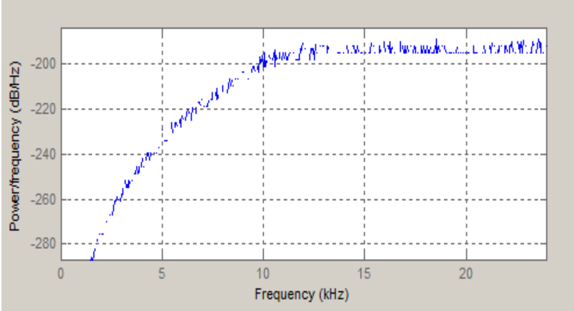

Figure 10: Round off noise response of Butterworth High pass filter with N=5, Fs=48khz, Fc=10.8 khz

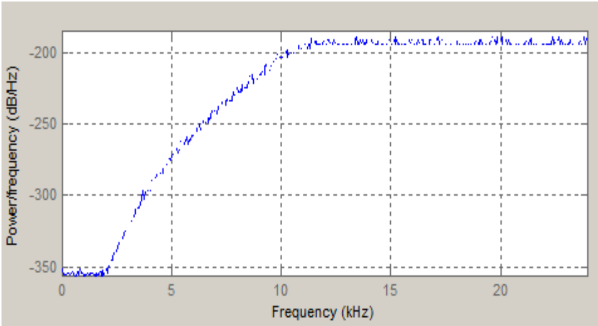

Figure 11: Round off noise response of Butterworth High pass filter with N=10, Fs=48khz, Fc=10.8 khz

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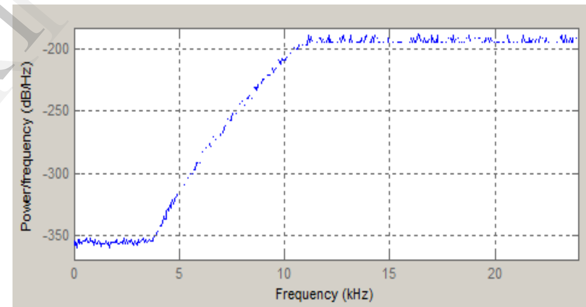

Figure 12: Round off noise response of Butterworth High pass filter with N=15, Fs=48khz, Fc=10.8 khz

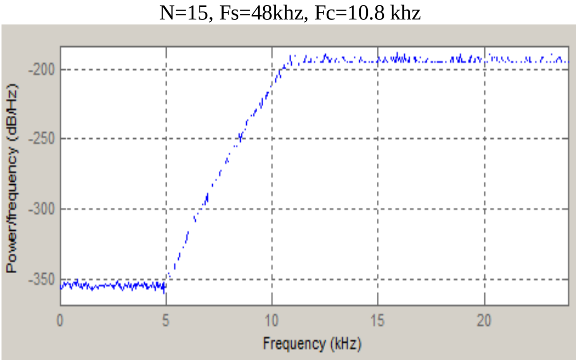

Figure 13: Round off noise response of Butterworth High pass filter with N=20, Fs=48khz, Fc=10.8 khz

IV. CONCOLUSION

Judging the variation of noise for different cut off frequencies, it can be said that from fig-1 to fig-3 the noise is decreasing, if we increase the cut off frequency the noise is increased as shown in fig-4, further if we increase the frequency the noise is reduced. So we can conclude that cut off frequency is not the exact value which separates the pass band and stop band, basically cut off frequency is a range which means it would take some values to separate the pass band and stop band.

We can also analyze the variation of noise with the order of filter. The order of filter is an important parameter for designing of any filter. We will see here that how these order of filter effects the noise in the signal. We can analyze from fig9 that when the order of filter, N=1 then noise in the signal is very high. As we increased the order of filter, the noise in the signal is reduced as we can see from fig 10 to 13 where the order of filter N= 5, 10, 15 and 20 respectively.

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