



FIR Low Pass Filter Designing Using Different Window Functions and their Comparison using MATLAB

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ABSTRACT: Digital filters are widely used in the world of communication. A good digital filter performance is important and hence to design a digital finite impulse response filter satisfying all the required conditions is necessary. One of the task is to use proper time window. There are lot of windows with completely different properties in time and frequency domain. Some of these windows are Triangular, Rectangular, Hanning, Hamming and Blackman having different side lobe attenuation and transition width. This paper presents the review of these windows.

KEYWORDS: Rectangular, Hanning, Hamming, Blackman window, FIR Filter, MATLAB

I. INTRODUCTION

Digital filtering is one of the most powerful tools of DSP. Digital filters are capable of performing that specifications which are extremely difficult to achieve with an analog implementation. In addition the characteristics of a digital filter can be easily changed under software control. Many digital systems use signal filtering to remove unwanted noise to provide spectral shaping or to perform signal detection or analysis. Two types of filters provide these functions are finite impulse response (FIR) filters and infinite impulse response (IIR) filters. In actual procedure for designing digital FIR filters first the desired filter responses are characterized and the filter coefficient values are calculated for a causal FIR filter. There are different methods to find the coefficients of digital filter from frequency specifications:-

1. Fourier series method
2. The window method
3. Frequency sampling method
4. Optimal filter design method

A simple and efficient way to design an FIR filter is window method. In the Window Design Method the unit impulse response of ideal filter is obtained by applying Inverse Fourier Transform to the ideal frequency characteristics of digital filter. Then this unit sample response must be truncated at some point, this process is equivalent to multiplying it by a finite length window function. After truncation and windowing, FFT is used to generate the corresponding frequency response of FIR filter. The frequency response can also be modified by choosing different window functions.

A window is a finite array consisting of coefficients selected to satisfy the desirable requirements. While designing digital FIR filter using window function it is necessary to specify a window function to be used and the filter order according to the required specifications (selectivity and stop band attenuation). These two requirements are interrelated. Each function is a kind of compromise between the two following requirements i.e. the higher the selectivity the narrower the transition region and the higher suppression of undesirable spectrum the higher the stop band attenuation. Some frequently used windows are:-

1. Rectangular window

$$W(n) = \begin{cases} 1 & 0 \leq n \leq N - 1 \\ 0 & \text{otherwise} \end{cases}$$



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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Vol. 5, Issue 2, February 2016

2. Triangular window

$$W(n) = \begin{cases} 1 - \frac{2|n - \frac{N-1}{2}|}{N-1} & 0 \leq n \leq N-1 \\ 0 & \text{otherwise} \end{cases}$$

3. Hanning window

$$W(n) = \begin{cases} 0.5 - 0.5 \cos\left(\frac{2\pi n}{N-1}\right) & 0 \leq n \leq N-1 \\ 0 & \text{otherwise} \end{cases}$$

4. Hamming window

$$W(n) = \begin{cases} 0.54 - 0.46 \cos\left(\frac{2\pi n}{N-1}\right) & 0 \leq n \leq N-1 \\ 0 & \text{otherwise} \end{cases}$$

5. Blackman window

$$W(n) = \begin{cases} 0.42 - 0.5 \cos\left(\frac{2\pi n}{N-1}\right) + 0.08 \cos\left(\frac{4\pi n}{N-1}\right) & 0 \leq n \leq N-1 \\ 0 & \text{otherwise} \end{cases}$$

6. Blackman Harris window

$$W(n) = \begin{cases} 0.35875 - 0.48829 \cos\left(\frac{2\pi n}{N-1}\right) + 0.14128 \cos\left(\frac{4\pi n}{N-1}\right) - 0.01168 \cos\left(\frac{6\pi n}{N-1}\right) & 0 \leq n \leq N-1 \\ 0 & \text{otherwise} \end{cases}$$

These are the windows which can be used for designing FIR filters. The main aim of a window function is to provide accurate type of responses with reduced side lobes and comparatively less pass-band and stop-band ripples.

II. LITERATURE SURVEY

For designing FIR digital filters there are several windows available. The order of the digital filter must be kept as small as possible for high speed and low power digital filters. Several Computer Aided Design tools are available to make the digital filter fast and power efficient. Filter design and analysis tool (FDA) is also one of the Computer Aided Design tool available with MATLAB which enables design of the digital filter blocks faster and more accurate.

Rick M. Roark proposed a paper “*Design of FIR filters with exceptional Passband and Stopband smoothness using a new transitional window*”. In this he discussed about a new transitional window to design FIR filters with exceptional pass-band and stop-band smoothness. He demonstrated that FIR filters with excellent pass-band and stop-band smoothness can be obtained when sharp transition edges in the ideal filter replaced with a spline. In this research a new parameter p was used which adjusts the degree of flatness at the transition edge. He varied the values of p and compared the results. He also compared Kaiser window filter with principally flat filter along with varying the value of p .

Zhenhe Sun, Wei Yu and Chen He presented a paper “*FIR digital filter design and MATLAB simulation*”. In this paper, window function method was used to design digital filters. Band-pass filter was designed by using MATLAB which possesses superior characteristics of devising filters in a fast and effective way when using window functions originated in it and the filter was applied to a mixed sine wave signal. Simulation model established by using MATLAB and the waveforms from oscilloscopes observed in order to verify the performance. So this paper concludes that superior



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properties can be achieved by using MATLAB to deal with the link of design and simulation such as good practicability, altering parameters at any time by contrasting characteristics of the filter in order to achieve the optimal design of the filter.

Sonika Gupta and Aman Panghal in their research paper “*Performance analysis of FIR Filter Design by using Rectangular, Hanning and Hamming Window methods*” provided the information that FIR filter design by using hamming is stable as compare to rectangular and hanning windows. In their paper, they used filter order 61. It was concluded that ripples in pass band are less in hamming as compare to other two techniques and it has high stability, linear phase as compare to rectangular and hanning windows.

Shalu Pandey et al., introduced a paper “*FIR filter implementation and its performance analysis*” that illustrates practical aspects of FIR filter design. This paper gives a short review of best windowing technique for implementing the FIR filter and also reviews on how to apply multirate techniques for constructing digital FIR filter. They discussed the windowing technique and compared the magnitude and phase response of Bartlett window, Hamming window and Kaiser window (Filter order = 20 & $f_c = 0.6$). They also observed that Kaiser window shows the best possible result than the other windowing techniques. Process of decimation and interpolation had also been discussed in this paper to increase or decrease the sampling frequency.

Subhadeep Chakraborty demonstrated a comparative study between Blackman and hamming window in “*Advantages of Blackman Window over Hamming Window method for designing FIR filter*”. The output response of these two windows was compared and the results showed that Blackman window technique is more powerful, perfect and useful than Hamming window. Throughout the paper it was also shown that Blackman window has more terms compared to the Hamming window. More term in calculation indicates more accuracy in result. There are extra cosine terms in Blackman function. This extra term reduces the side lobes and hence increases less losing power. For FIR low pass filter design, there are four side lobes exist in Hamming window but for same specification and filter order, in Blackman window, there exists only two side lobes. Similar thing found in other filters (high pass filter, band pass and band stop filter) and for this reason the result and simulation both are more accurate in Blackman window.

Alia Ahmed Eleti and Amer R. Zerek put forward a paper “*FIR Digital Filter Design By Using Windows Method With MATLAB*”. The work reported in this paper deals with Finite Impulse Response (FIR) digital filter designed by using window method. Also some common windows Triangular, Hamming, Hanning and Blackman had also been discussed and their response was compared by simulating these in MATLAB software. The results of this paper shows that window method is simple to apply and easy to understand.

III. SIMULATION USING MATLAB

While designing FIR filter in MATLAB using different windows filter order is taken as 70, cut-off frequency 10800 Hz and sampling frequency 48000 Hz.

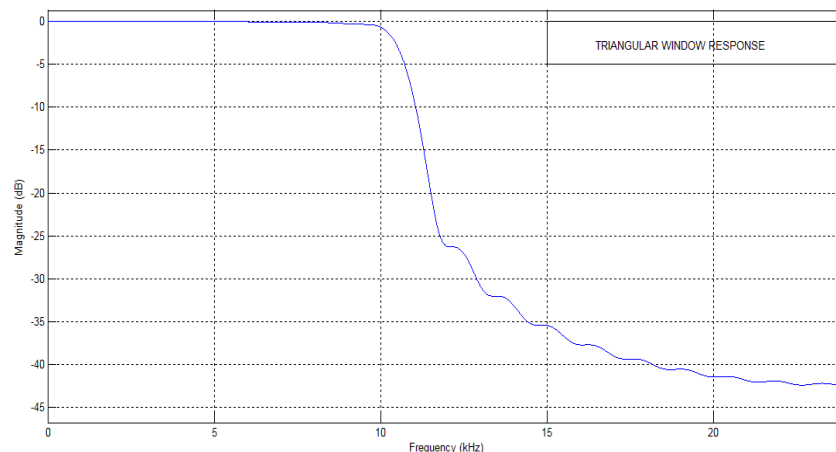


Fig.1 TRIANGULAR WINDOW RESPONSE

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 2, February 2016

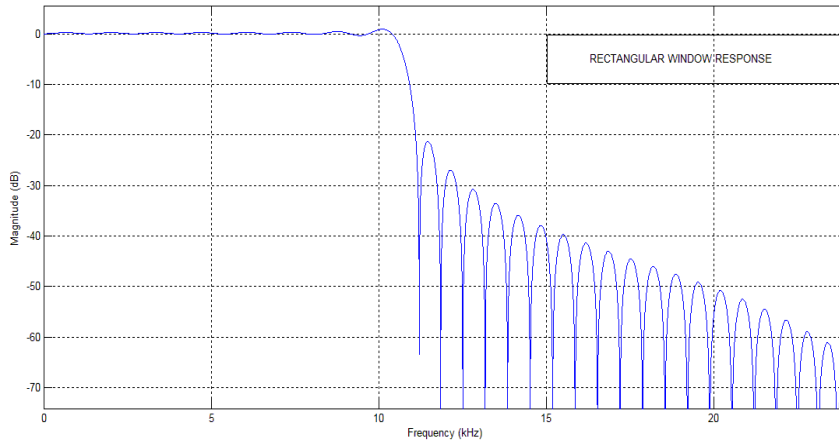


Fig.2 RECTANGULAR WINDOW RESPONSE

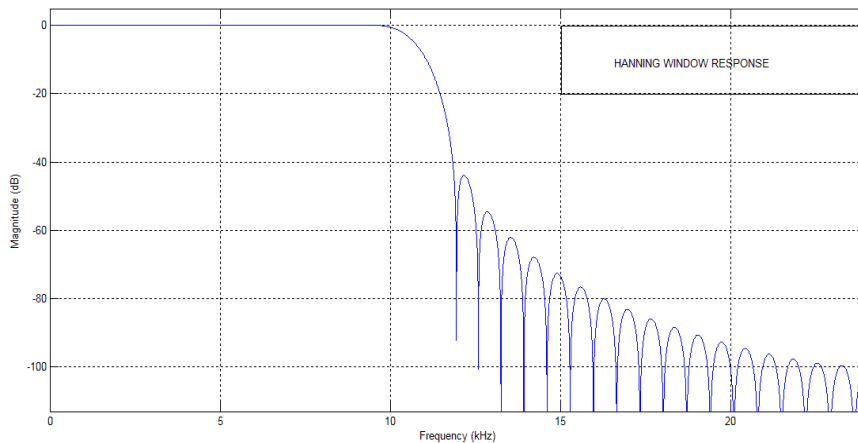


Fig.3 HANNING WINDOW RESPONSE

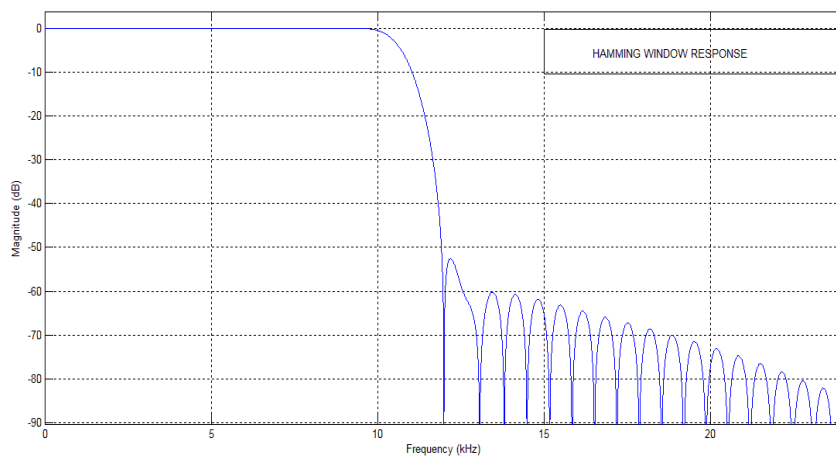


Fig.4 HAMMING WINDOW RESPONSE

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

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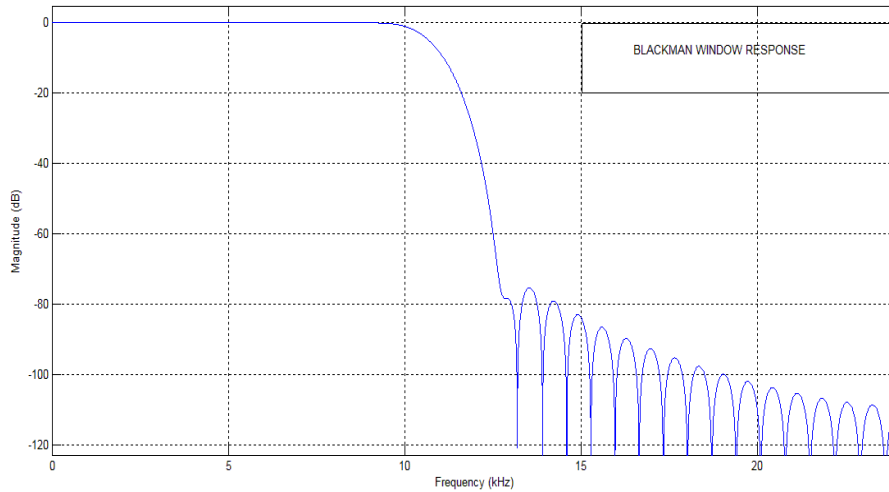


Fig.5 BLACKMAN WINDOW RESPONSE

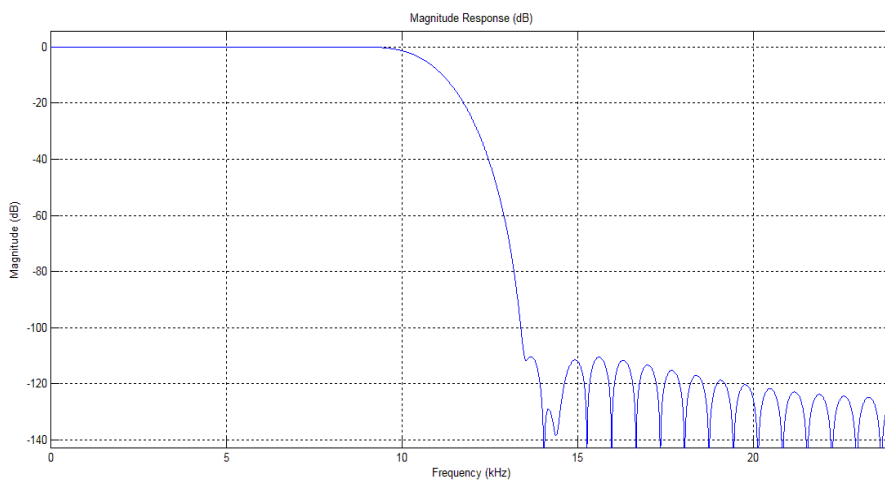


Fig.5 BLACKMAN-HARRIS WINDOW RESPONSE

COMPARISON OF ABOVE FIGURES:-

WINDOW FUNCTION	LEAKAGE FACTOR (%)	RELATIVE SIDELobe ATTENUATION (dB)	MAINLOBE WIDTH (-3dB)
TRIANGULAR WINDOW	0.28	-26.5	0.035156
RECTANGULAR WINDOW	9.39	-13.3	0.023438
HANNING WINDOW	0.05	-31.5	0.041016
HAMMING WINDOW	0.04	-42.5	0.037109
BLACKMAN WINDOW	0	-58.1	0.046875
BLACKMAN HARRIS WINDOW	0	-92.1	0.054688



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Vol. 5, Issue 2, February 2016

IV.CONCLUSION

From simulation it is clear that triangular window is not a good choice as compare to Rectangular window because firstly the transition region is high and secondly attenuation in stop band is less. Hanning window produces small ripples in both passband and stopband. But at higher frequencies Hamming window generates less oscillations in the side lobes than the Hanning window that's why for the same main lobe width the Hamming window is preferred.

Blackman window has more terms compared to Hamming window and Hanning window. More terms in calculation indicates more accuracy in result. For this reason the result and the simulation are more accurate in this window. The extra cosine term in Blackman window reduces the side lobes. Further more Blackman Harris window has three cosine terms and side lobes are even less than Blackman window. Leakage factor of this window is also zero. So it is clear that Blackman Harris window technique is more powerful and perfect than the FIR filter designed with other windows i.e. Rectangular, Triangular, Hamming and Hanning.

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