Lab 10

Designing FIR Filters

10.1 Introduction

FIR filters are the type of digital filters having a finite impulse response, i.e., the response of the filter (system) decays after some finite time interval. This means that the impulse response sequence of FIR filters has a finite number of non-zero terms. In other words, if the impulse response of a digital filter is determined for some finite number of sample points, then these filters are known as FIR filters.

Let us consider an ideal low pass filter whose frequency response is shown by the figure. The flat frequency response of the system insures equal gain/attenuation to all the frequency components. A sharp cutoff is seen at the cutoff frequencies. The time domain of such a filter is shown by the accompanying Fig. 10.1.

There are two problems in the time domain impulse response of the filter.

1. It is infinite.
2. It is non-causal, making it unsuitable for event-based systems.

Problem 1 is tackled by limiting the time domain impulse response of the system. This is done by multiplying the time domain response by another function that exists between some range around zero. This other function is called a window. Window functions for FIR filter design are given below,

Name of window	Time-domain sequence, $h(n), 0 \le n \le M-1$
Bartlett (triangular)	$1 - \dfrac{2\left\lvert n - \frac{M-1}{2} \right\rvert}{M-1}$
Blackman	$0.42 - 0.5\cos\dfrac{2\pi n}{M-1} + 0.08\cos\dfrac{4\pi n}{M-1}$
Hamming	$0.54 - 0.46\cos\dfrac{2\pi n}{M-1}$
Hanning	$\frac{1}{2}\left(1 - \cos\dfrac{2\pi n}{M-1}\right)$
Kaiser	$\dfrac{I_0\left[\alpha\sqrt{\left(\frac{M-1}{2}\right)^2 - \left(n - \frac{M-1}{2}\right)^2}\right]}{I_0\left[\alpha\left(\frac{M-1}{2}\right)\right]}$
Lanczos	$\left\{\dfrac{\sin\left[2\pi\left(n - \frac{M-1}{2}\right)\Big/(M-1)\right]}{2\pi\left(n - \frac{M-1}{2}\right)\Big/\left(\frac{M-1}{2}\right)}\right\}^L \quad L > 0$
Tukey	$1, \left\lvert n - \frac{M-1}{2} \right\rvert \le \alpha\frac{M-1}{2} \quad 0 < \alpha < 1$ $\frac{1}{2}\left[1 + \cos\left(\dfrac{n - (1+\alpha)(M-1)/2}{(1-\alpha)(M-1)/2}\pi\right)\right]$ $\alpha(M-1)/2 \le \left\lvert n - \frac{M-1}{2} \right\rvert \le \frac{M-1}{2}$

Problem 2 is handled by shifting the restricted time domain impulse response such that the first term of the time domain impulse response occurs at time zero.

By introducing such remedies to the problems, frequency response of the system is no more ideal. The windows are of different types and each of them contributes a specific advantage to the frequency response. For example, some window function produces sharp cutoff, but at the same time the stop band attenuation decreases.

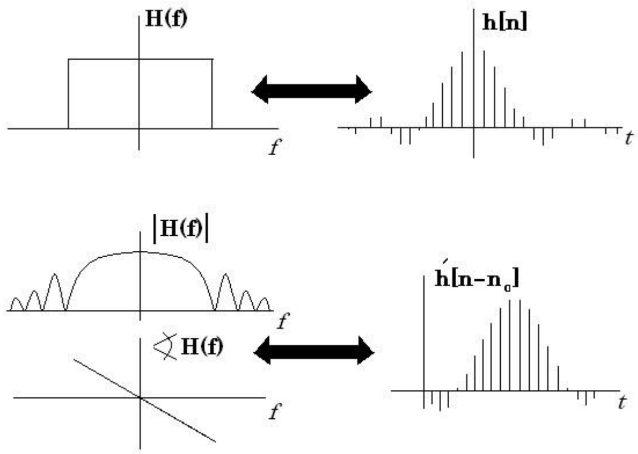

Figure 10.1: Design procedure of an FIR filter. The ideal response is changed

10.1.1 MATLAB's FDATool

MATLAB's fdatool is specifically designed for filter design and its analysis. Using this tool, we can do anything from making digital FIR, IIR filters to realizing the models. The filter coefficients can be exported to MATLAB's workspace, to scripts or to Simulink models. As shown in Fig. 10.2, we see that there are different variations of FIR and IIR filters from which we can chose our design like equiripple, window based, maximally flat etc.

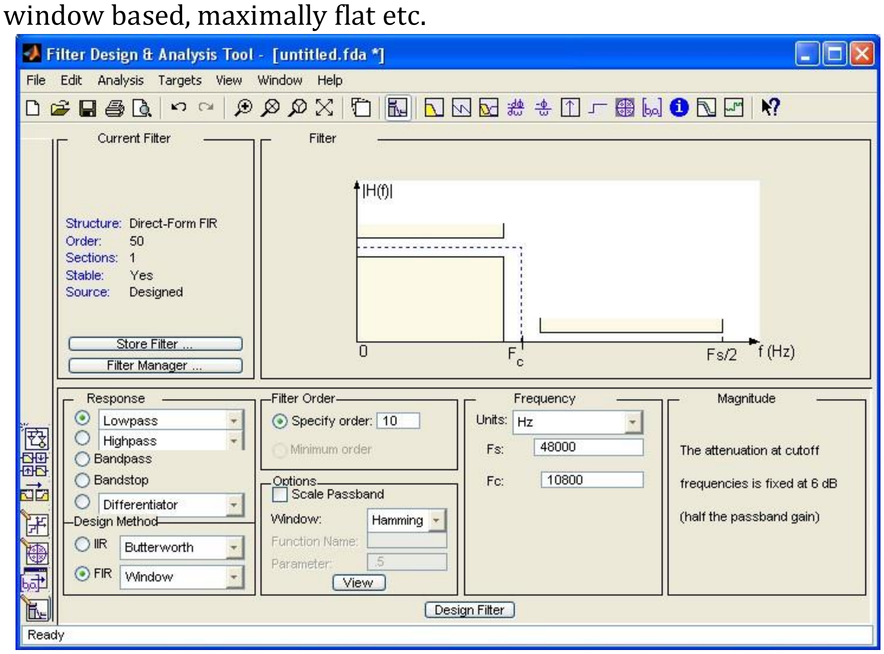

Figure 10.2: Screen shot of the MATLAB's FDATool

10.2 Practical

Using the FDATool of MATLAB, obtain the coefficients of 3rd order, 7th order and 10th order FIR low pass filter with a cutoff frequency of 4000 Hz, sampled at 8000 Hz. The simulation of a filter is shown in Fig. 10.3. Perform the procedure for rectangular, hamming, hann, Barlett, Flat Top and Kaiser Windows. Generate a signal composed of three sinusoids of 10, 20 and 50 Hz and contaminate the signal with noise. Using the above filters, eliminate the noise. Draw time and frequency domain plots of the signals.

10.3 Hints

Invoke the FDATool by typing fdatool in MATLAB. Use the function *sos2tf*(). Save the filters with different names for future reference.

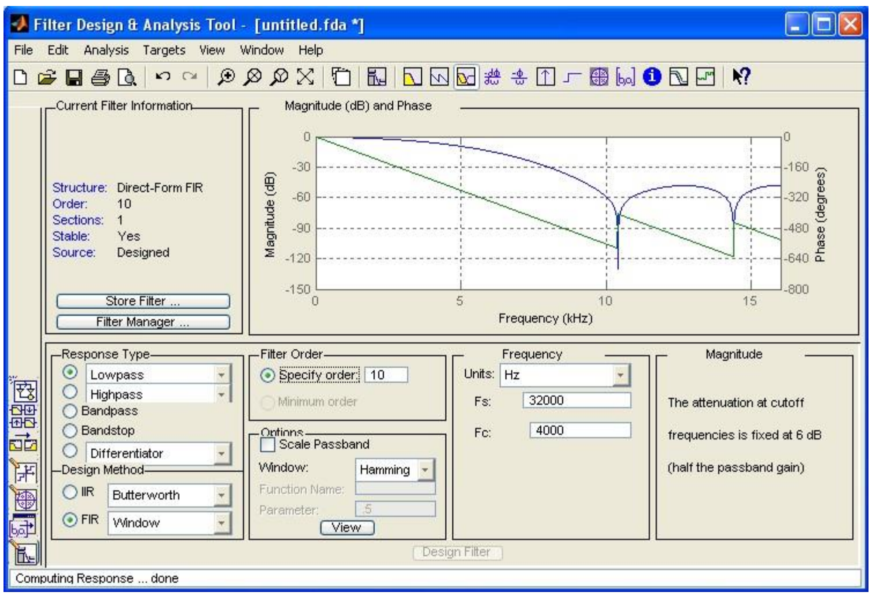

Figure 10.3: Generation of a low pass FIR filter using FDATool

9.4 Questions

1. Which type of the above windows produces the sharpest cutoff in frequency domain in a 10th order FIR filter?
2. What is the significance of Kaiser Window upon the other window functions?
3. What is the value of denominator of filter impulse response obtained for all the windows? Why?
4. Do the numerator coefficients of filter impulse response show any type of periodicity?
5. Design a linear-phase lowpass FIR filter with the following specifications: passband edge= 2 kHz and sampling rate of 10 kHz. Compare its performance to a moving-average filter.