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NOISE REMOVAL FROM ECG SIGNAL BY USING FIR FILTER WITH DIFFERERNT WINDOW TECHNIQUES

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ABSTRACT

Electronic display of bio-signals like electrocardiograms (ECG) requires noise reduction for accurate automatic diagnosis. In this project, FIR filter is going to be implemented on C6713 DSK using different window techniques for noise reduction. The band pass filter consists of low pass filter with subsequent high pass filter. Then signal to noise ratio (SNR) is going to be calculated for different window techniques like Rectangular, Kaiser, Hanning, Hamming, Black-man and Bartlett by the implementation of TMS320C6713 DSK and code composer studio (CC STUDIO). Finally, we conclude that which window technique gives better signal to noise ratio (SNR) for the ECG filtering.

***Keywords**: Electrocardiogram (ECG); EMG noise; Power Line Interference (PLI); Power Spectral Density (PSD); Signal to Noise Ratio (SNR); Normal Sinus Rhythm (NSR); ECG Identification (ID).*

I. INTRODUCTION

Electrocardiogram, ECG is the recording of the electrical behavior of the heart over period of time. It is most recognized biological signal typically used for diagnosis of some diseases by drawing the inference from the signal. The Change in the shape of an ECG waveform is observed due to Abnormalities caused by heart diseases. Each segment of the ECG waveform holds information and their alterations provide relevant evidence for the clinician to reach a proper diagnosis. The ECG signal is influenced by external noises. Therefore, it is mandatory to obtain a noise free ECG signal for processing.

A normal ECG complex contains components, such as P wave, Q, R and S waves (QRS complex), a T wave, finally a U wave. Regular pattern of peaks produced by each heart beat cycle is shown in Fig.1. The P wave signifies the sequential depolarization of right and left atria [1]. It normally has positive polarity with period of less than 120 milliseconds. The spectral characteristic is typically considered to be at low frequency of 10-15 Hz for a normal P wave. The QRS complex relates to depolarization of ventricles (right and left) and mostly lasts for about 70-110 milliseconds in a normal heartbeat. It has the prevalent amplitude of all the ECG waveforms. The frequency content of the QRS complex is high in appraisal to other ECG waves because of its steep slopes, and is fundamentally focused in between 10-40 Hz. The T wave specifies Ventricular repolarisation and it

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expands nearly 300 milliseconds after the QRS complex. The T wave location is strongly reliant on heart rate, being slenderer and adjacent to the QRS complex.

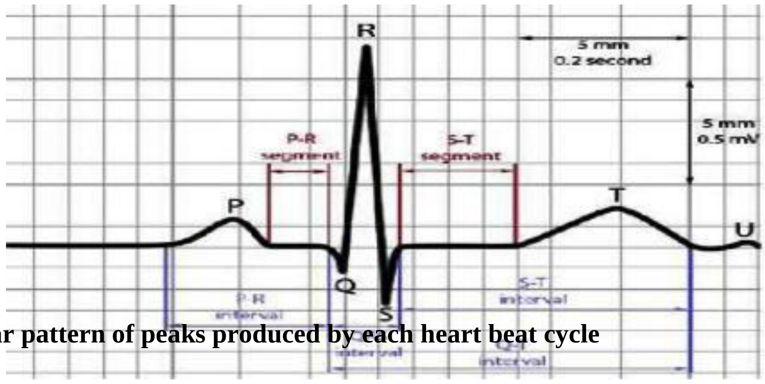

Fig 1: Regular pattern of peaks produced by each heart beat cycle

The Electrocardiogram signal has a frequency range of 0.5Hz to 200Hz. A coherent noise suppression technique plays an important role in further signal analysis of ECG [2, 3]. Removal of noises from ECG signal is a classical problem and hence many researchers are working on signal noise removal by using discrete algorithms and techniques for filtration. The early stage of all ECG signal processing is to suppress Baseline wanders and Power line interference.

ECG Data Base

We have collected ECG data from the laboratories at Boston's Beth Israel Hospital (BIH) and at Massachusetts Institute of Technology (MIT) have supported the research in arrhythmia analysis and related subjects by creating a database.

Types of noises in ECG:

Generally, the ECG signal is affected by different types of noises that can be within the frequency band of ECG signal. The corruption of ECG signal is due to following major noises.

a) Baseline wander noise (0.1-0.5 Hz)

b) Power line Interference (50/60 Hz)

c) Electromyogram noise (100 Hz)

a) Baseline Wander noise

It is caused by variations in the position of the heart with respect to the electrodes and changes in the propagation medium between the heart and the electrodes. This causes sudden changes in the amplitude of the ECG signal, as well as low frequency (0.1-0.5) baseline shifts, as shown in Fig2. These changes can be reduced by window based high pass filter with cut off frequency 0.5 Hz.

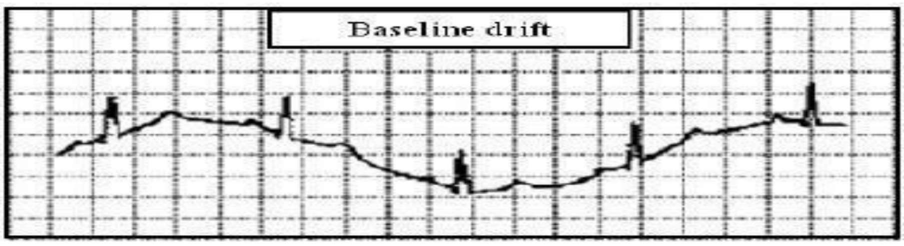

Fig2: ECG signal with Baseline drift

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b) Power line Interference(60hz)

Power line interference as shown in Fig3 is primarily caused due to inappropriate grounding of the ECG equipment. It degrades the signal quality and affects the tiny features, which can be critical for signal processing, monitoring and clinical diagnosis as a whole. Actually, it is a narrow-band noise with bandwidth not more than 1 Hz and the focus of 50 Hz or 60 Hz. This changes can be reduced by window based stop band filter with cut off frequencies Fc1=59.5 Hz and fc2=60.5 Hz.

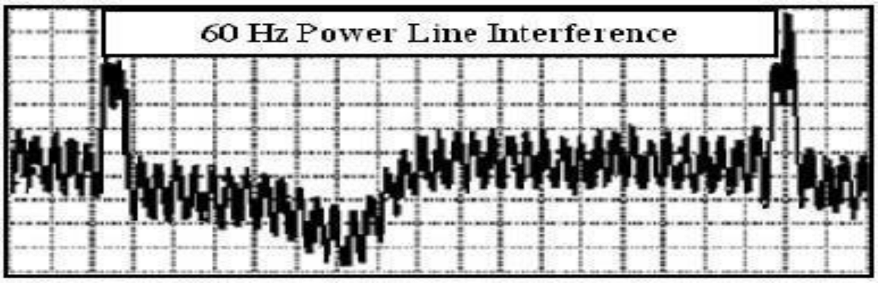

Fig3: ECG signal with power line interference

c) Electromyography Noise (EMG noise)

Electromyography noise as shown in Fig4 is caused by the contraction of other muscles besides the heart. The extent of the crosstalk depends on the amount of muscular contraction and the quality of the probes. The frequency of this EMG noise is in between 100-500 Hz. This can be reduced by using window based low pass filter with cut off frequency (<100).

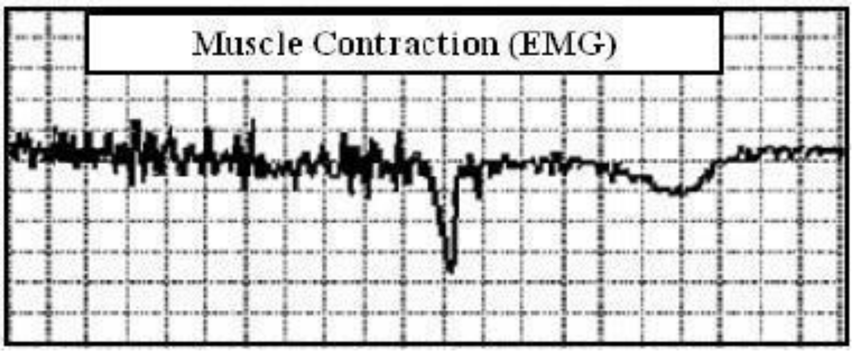

Fig4: ECG signal with Muscle contraction

II. DIGITAL FILTER IMPLEMENATION

A digital filter is a system that performs mathematical operations on a sampled, discrete-time signal to reduce or enhance certain aspects of that signal. FIR filters are digital filters with finite impulse response. They are also known as non-recursive digital filters as they do not have the feedback, even though recursive algorithms can be used for FIR filter realization. The design of FIR filters is preferred due to the following advantages: Exact linear phase, Always stable, Design methods are linear and Can be realized efficiently in hardware.

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Window Method

In this method, we start with the desired frequency response specification $Hd(\omega)$ and the corresponding unit sample response $hd(n)$ is determined using inverse Fourier transform. The relation between $Hd(\omega)$ and $hd(n)$ is as follows : $h(n) = hd(n)\, w(n)$ Now, the multiplication of the window function $w(n)$ with $hd(n)$ is equivalent to convolution of $Hd(\omega)$ with $W(\omega)$, where $W(\omega)$ is the frequency domain representation (Fourier transform) of the window function. By using appropriate window functions method, which is time function, we can reduce Gibbs oscillations.

Window functions

Using appropriate window functions which are time domain function, we can reduce Gibb's oscillations and to precondition the impulse response. The following window functions are most commonly used:

1. Rectangular window
2. Hanning window and hamming window
3. Blackman window
4. Kaiser window

The FIR filter design procedure with window functions method can be classified to different stage:

- Determining a window function according to the filter and defining the filter characteristics
- Calculating the filter order required for a given set of characteristics
- Computing the window function coefficients
- Calculating the ideal filter coefficients according to the filter order
- Computing FIR filter coefficients according to the gain window function and ideal filter coefficients.
- If the resulting filter has too wide or too narrow transition area, it is required to change the filter order by increasing or decreasing it according to de-noising of ECG signal.

Filter implementation

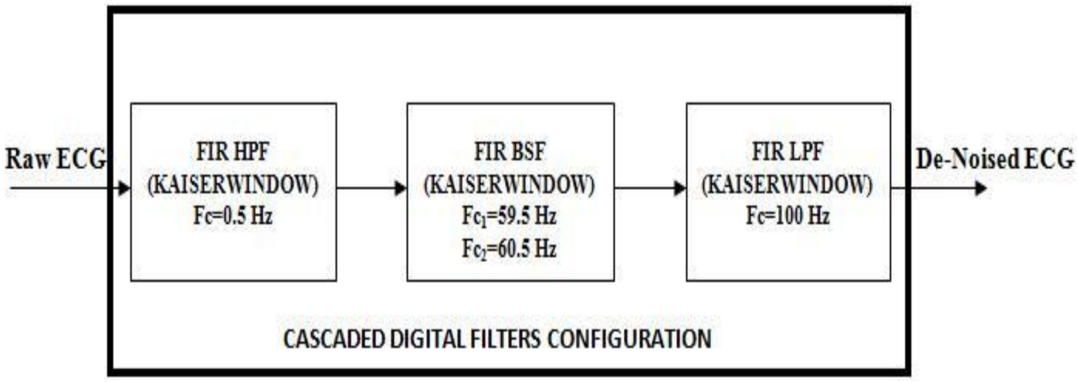

Fig5: Denoising of ECG signal using FIR filter implementation

1. In first step with the help of FDA (filter design and analysis) Tool in MATLAB software design FIR with high pass filter cut off frequency 0.5 Hz based on window to removing baseline wander noise from noisy ECG signal.

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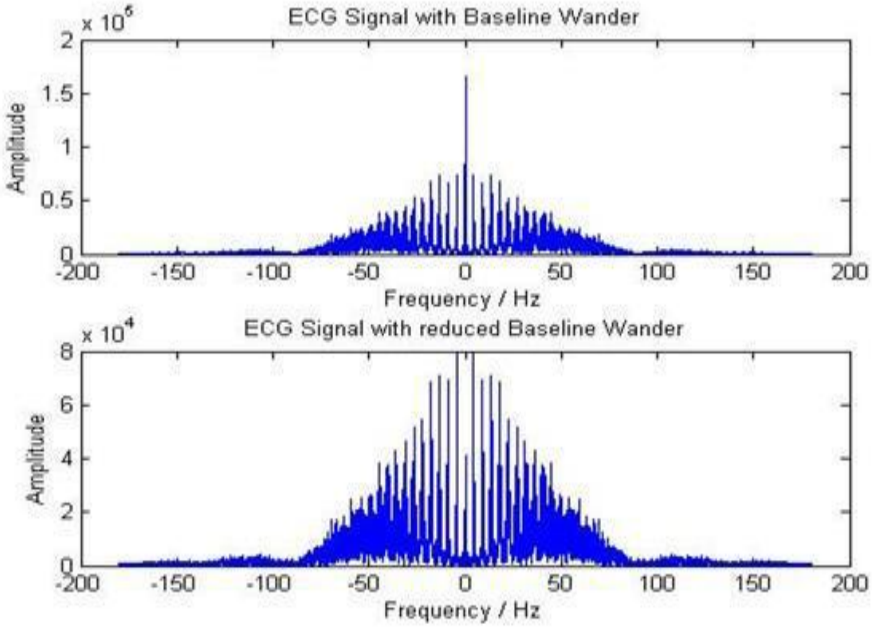
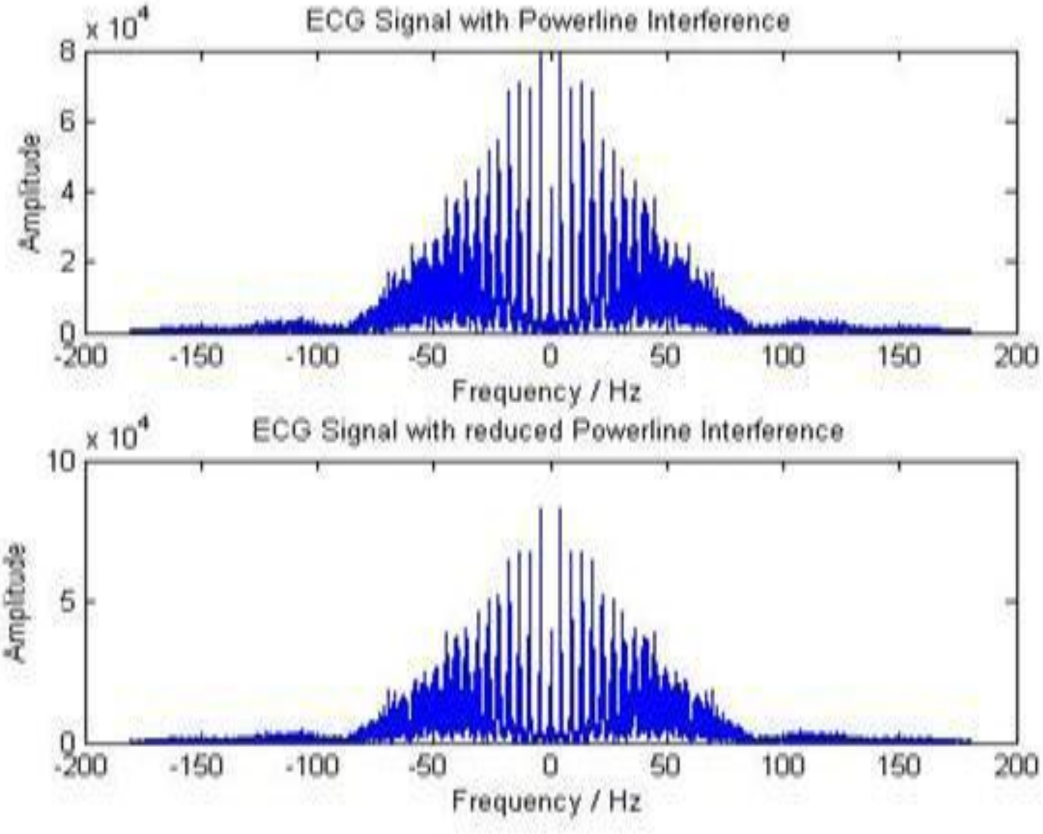


2. In second step removing power line interference (50/60 Hz) by band stop with cut off frequency (59.5Hz-60.5 Hz).



3. In third step we deleting EMG noise by applying low pass filter with cut off frequency 100Hz. Finally moving average filter to smooth the ECG waveform. The task was accomplished in various orders.

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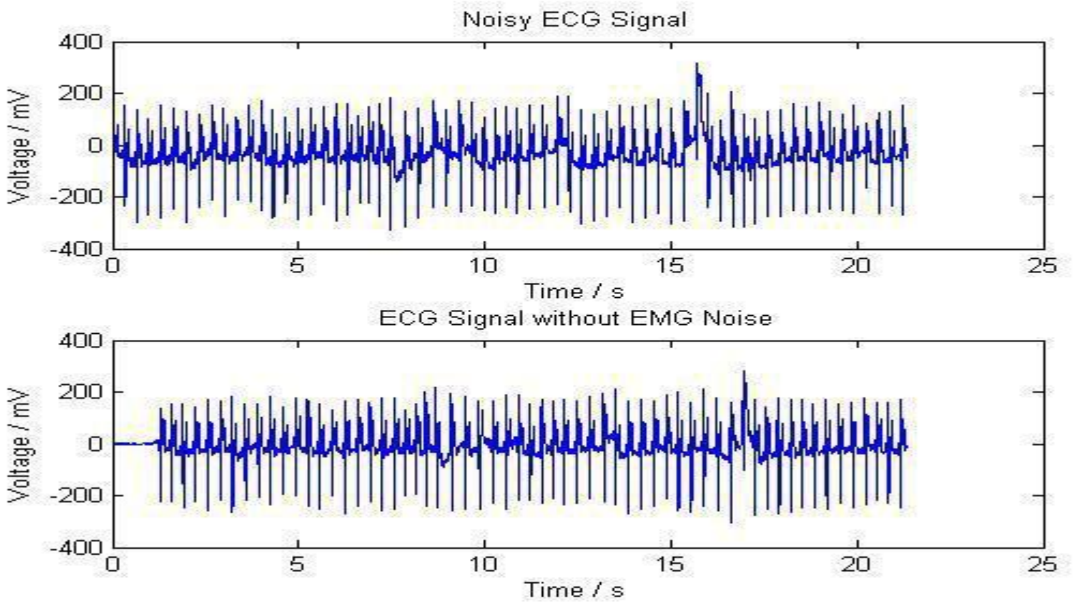

III. RESULTS

On implementation of above designed filters on ECG signals with noise, the following results are obtained.

Table 1: performance comparison of FIR filter using different windows.

FIR Filter	Order of filter	Spectral density before filtration (dB/Hz)	Spectral density after filtration (dB/Hz)	Average power (dB)	Ringing effect
FIR Equiripple	320	40.74	16.83	37.5	Small
Kaiser	450	40.74	27.72	38.78	Small
Rectangular	450	40.74	26.89	38.84	Small
Hamming	1200	40.74	27.47	38.74	Large
Hanning	1200	40.74	28.12	38.74	Large
Blackmann	1500	40.74	27.61	38.87	Large

When the signal to noise ratio is calculated by equation (1), it is found that the SNR is least for FIR Equiripple filter and highest for FIR filter with Hanning window implementation for removing the HF / LF noise present in ECG signal.

$$Signal\ to\ Noise\ ratio\ (SNR) = \frac{\text{Spectral density after filtering}}{spectral\ density\ before\ filtering} \qquad \text{---------(1)}$$

IV. CONCLUSION

As the noise-removal of ECG is a compulsory task to find the heart rate and for the cardiac diagnosis, here we have done an experimental study on noise removal by the implementation of FIR filter using different window techniques. The results evaluated by waveforms and power spectrums density (PSD), for various FIR filters are given in Table1. Finally, it is found the signal to noise ratio (SNR), where the Hanning Window gives the best SNR ratio.

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