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The Use of FIR Filter for Filtering of ECG Signal and Comparison of Some Parameters

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Abstract — *Electrophysiology and ischemic changes that may occur in heart due to myocardial infarction and arrhythmia can be well studied using electrocardiography (ECG) is often corrupted by different artifacts and noise. For efficient and different artifacts of abnormality, denoising of the acquired ECG signal is essential. Any filtering technique must preserve the important clinical features while providing high attenuation of noise. The ECG signal is the recording of the heart's electrical potential verse time. The present work introduces the implementation of the window filter for the processing of ECG. Electrocardiogram signals are often corrupted by noise which may have electrical or electrophysiological origin. The noise signal tends to alter the signal morphology, thereby hindering the correct diagnosis. In order to remove the unwanted noise, a digital filtering technique based on fixed windows is proposed in this paper. The low pass and notch filter will be designed using windowing method for the ECG signal. The results obtained from different techniques are compared on the basis of popularly used signal error measure like SNR, PRD and MSE.*

Keywords*—Electrocardiogram (ECG), Finite Impulse Response (FIR), Filter bank, Mean Square Error (MSE), Massachusetts Institute of Technology/Beth Israel Hospital (MIT/BIH), Signal-to-Noise ratio (SNR).*

I. Introduction

An Electrocardiogram (ECG) is a recording of the electrical activity on the body surface generated by the heart. Generally the skin electrodes placed at the designated locations on the body collects ECG information.

The ECG signal is characterized by the six peaks and valley labeled with successive letters of the alphabets P, Q, R, S, T, and U as shown in Figure 1. The front end of the ECG must be able to deal with extremely weak signals ranging from 0.5mV to 5mV, combined with DC component of up to ±300mV resulting from electrode skin contact plus common mode component of up to 1.5V, resulting from the potential between ground [1-2].

ECG gets corrupted due to different kinds of the artifacts like power line interference, motion artifacts, base line drift and instruments noise.

Fig. 1: Basic ECG signal

The present work deals with the design of fixed window based FIR low pass filters to reduce the interference present in the ECG signal. ECG signals from MIT-BIH database are used and corrupted with Gaussian noise. This corrupted signal then filtered using designed FIR filter. The obtained results are compared on the basis of popularly used signal error measures like PRD, PRD1, and MSE.

This paper is organized as follows: section 2 describes the FIR filters design, section **3** discusses the ECG error measuring parameters, section 4 shows the experimental results and section 5 is the conclusion.

II. Design Of The Different Digital Filter Using Windows

The present section describer the design of the low pass FIR filters with window techniques to remove the power line inter, motion artifacts, base line drift and instrumental noise from the row ECG signals.

2.1. Windowing Functions

Design of a low pass filter using windowing technique requires four filter parameters –the pass band edge ω_p , the stop band edge ω_s , pass band ripple A_p and stop band attenuation A_s. For fixed window based designs, As cannot be varied. The impulse response of law pass is given by $h_{id}(n).w(n)$. Where w(n) the window is function and $h_{id}(n)$ is the impulse response of the ideal low pass filter [12] ,[14]

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$$h(n)=\frac{\omega_c}{\pi}\left(\frac{\sin \omega_c n}{\omega_c n}\right), -\infty \leq n \leq \infty \quad (1)$$

$$\omega_c \text{ is the cut off frequency}=\frac{(\omega_s+\omega_p)}{2} \quad (2)$$

The window coefficients and the order **M** may be calculated as under:

(a) Blackman window

$$w(n)=0.42+0.5\cos\left(\frac{2\pi n}{2M+1}\right)+0.08\cos\left(\frac{4\pi n}{2M+1}\right), -M \leq n \leq M. \quad (3)$$

$M_{black}= (5.56/\Delta\omega)$

With transition band width is $\Delta\omega = \omega_s - \omega_p$

(b) Hamming window

$$w(n)=0.54+0.46\cos\left(\frac{2\pi n}{2M+1}\right), -M \leq n \leq M \quad (4)$$

$M_{Hamming}= (3.32/\Delta\omega)$

(c) Hanning window

$$w(n)=\frac{1}{2}\left(1+\cos\left(\frac{2\pi n}{2M+1}\right)\right), -M \leq n \leq M. \quad (5)$$

$M_{Hann}= (3.32/\Delta\omega)$

III. Ecg Error Measuring Arameter

Let $x[n]$ and $\hat{x}[n]$ be the original and the reconstructed signal, respectively, of L samples. The PRD formula is defined as: [1],[2],[5].

$$PRD=\sqrt{\frac{\sum_{n=1}^{L}\left(x[n]-\hat{x}[n]\right)^2}{\sum_{n=1}^{L}\left(x[n]\right)^2}}\times 100 \quad (6)$$

This parameter as quality measurement can mask the real performance of an algorithm since the

PRD depends a lot on the mean value of the original si**g**nal. When using the PRD care must be taken to remove **t**he baseline, or at least, to eliminate the DC level. To av**o**id this problem, PRD1 which independent of the mean v**a**lue, is used.

$$PRD1 = \sqrt{\frac{\sum_{n=1}^{L}\left[x[n] - \hat{x}[n]\right]^2}{\sum_{n=1}^{L}\left[x[n] - \bar{x}[n]\right]^2}} \times 100 \qquad (7)$$

Where $\bar{x}[n]$ is the mean value of the signal $x[n]$

3.2 Mean square error (MSE)

The average of the square of the difference between the original and the reconstructed signal output, respectively, of L samples. The *MSE* formula is defined as: [1].

$$MSE = \frac{1}{L}\sum_{n=1}^{L}\left|x[n] - \hat{x}[n]\right|^2 \qquad (8)$$

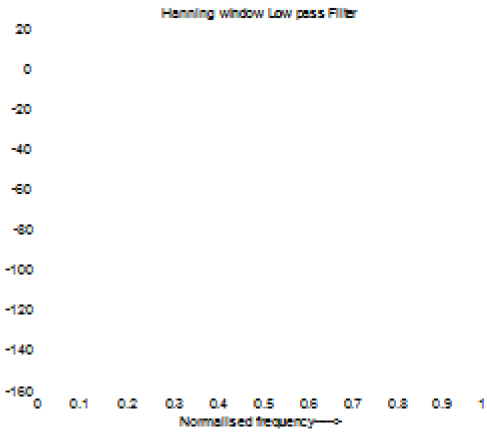


Fig. 2: Low Pass Filter us**i**ng Hanning Window

Fixed window based low pas**s** FIR filter of order M is designed for normalized pas**s** band frequency is fp= 0.180, Normalized stop band **f**requency fs=0.205., MIT-BIH database signals are sampled at 360Hz.The frequency response of designe**d** filter is show in fig, 1-3. For the given design, obtained M for Blackman window, Hamming window and Hanning window is 223, 133 and 125 respectively.

Different FIR LPF is designe**d** using Hanning window, Hamming window, and Black**m**an window. These filters are used to remove the Gaussi**a**n noise in the ECG signal

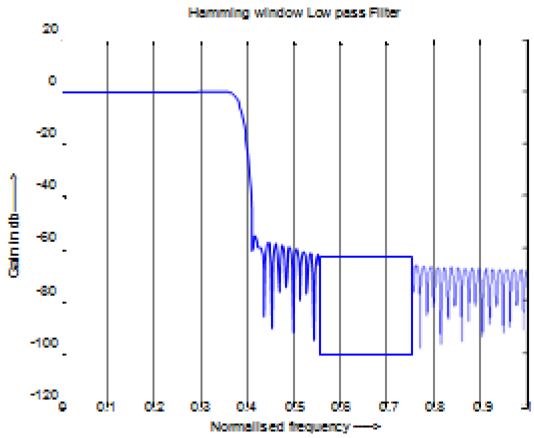


Fig. 3: Low Pass Filter using Hamming Window

Let x[n] and x[n] be the original ECG signal and reconstructed ECG signal, respectively, and $x_{Noise}[n]$ is noisy ECG signal.

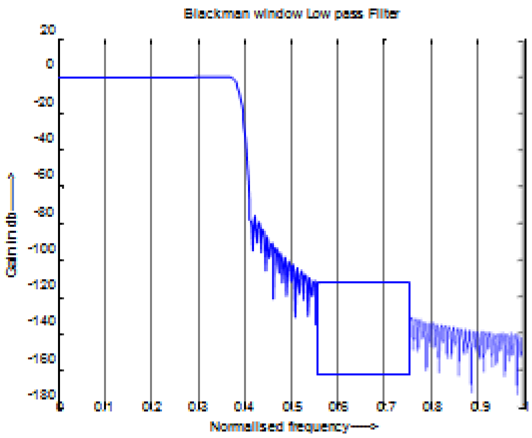


Fig. 4: Low Pass Filter using Blackman Window

MIT-BIH arrhythmia database is used to carry out tests. Fig. 3 shows the initial 1024 signal samples of record 100 from MIT-BIT database.
For experiment, the ECG signal is corrupted with zero mean white Gaussian noise (fig.7) with S/N ranging from 0 dB to 35dB (Low Noise).

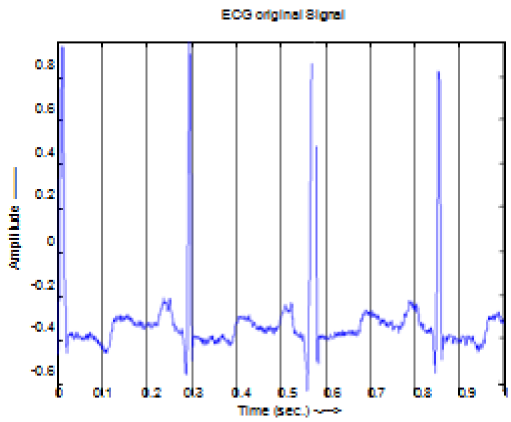


Fig. 5: ECG Original Signal in Time (sec)

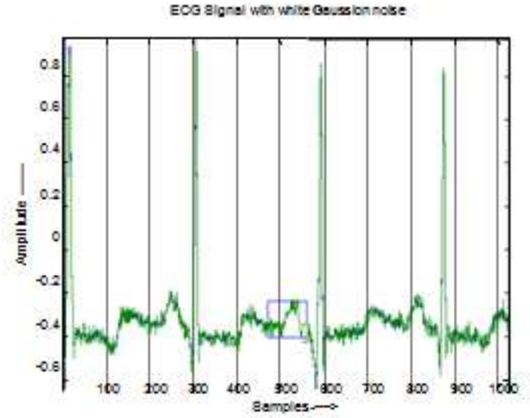


Fig. 6: ECG Signal **w**ith SNR = 25dB

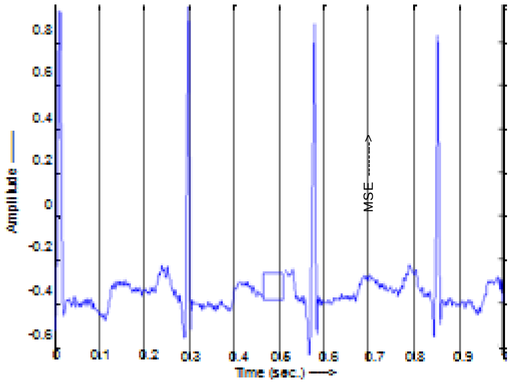
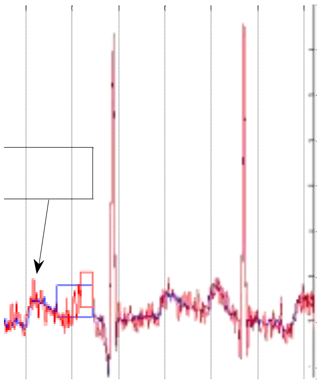


Fig. 7: Filtered ECG Signal using Hamming window

The corrupted ECG signal is **f**iltered using the designed low pass filters. The filtered E**C**G signal is shown in fig. 8. The results of filtering are s**h**own in Table – I.



SNR (dB)	Window	PRD1	MSE
-5	Hanning	62.0657	1.5702
	Hamming	64.1444	1.83 e-01
	Blackman	65.2232	1.91 e-01
0	Hanning	48.1868	5.73 e-02
	Hamming	46.6405	5.07 e-02
	Blackman	48.3566	5.83 e-02
5	Hanning	35.3445	1.63 e-02
	Hamming	36.4425	1.85 e-02
	Blackman	36.3725	1.83 e-02
10	Hanning	26.8874	5.47 e-03
	Hamming	27.2071	5.70 e-03
	Blackman	27.9363	6.38 e-03
15	Hanning	20.3753	1.80 e-03
	Hamming	20.2018	1.74 e-03
	Blackman	20.3066	1.78 e-03
20	Hanning	15.3830	5.86e-004
	Hamming	15.5304	6.09e-004
	Blackman	15.1226	5.48e-004
25	Hanning	11.8104	2.03e-004
	Hamming	12.0795	2.23e-004
	Blackman	11.8599	2.07e-004
30	Hanning	9.5285	8.63e-005
	Hamming	9.5420	8.68e-005
	Blackman	9.5884	8.85e-005
35	Hanning	8.3436	5.07e-005
	Hamming	8.4045	5.22e-005
	Blackman	8.4622	5.37e-005

Table 1: Noise removal performan**c**e of filter with various levels of noise

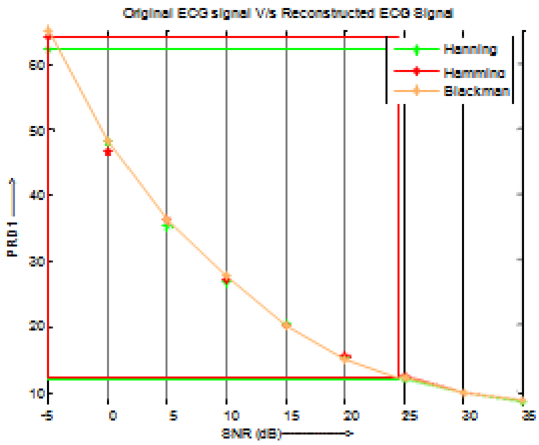


Fig. 8: Comparison of PRD1 V/s SNR for Hanning, Hamming and blackman **w**indow filtered signals.

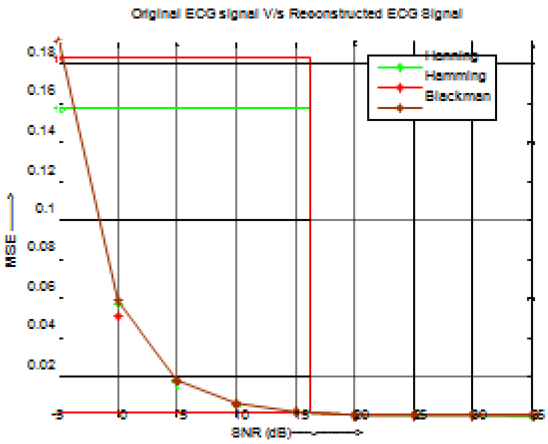


Fig. 9: Comparison of MS**E** V/s SNR for Hanning, Hamming and blackman wi**n**dow filtered signals.

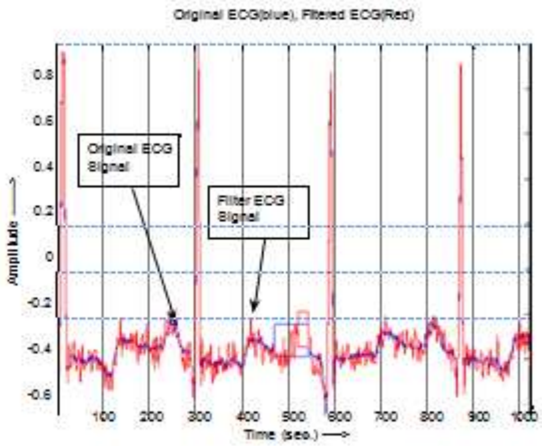


Fig. 10: Comparison of ECG signals (Original Signal and Filtered) at SNR = 15 dB.

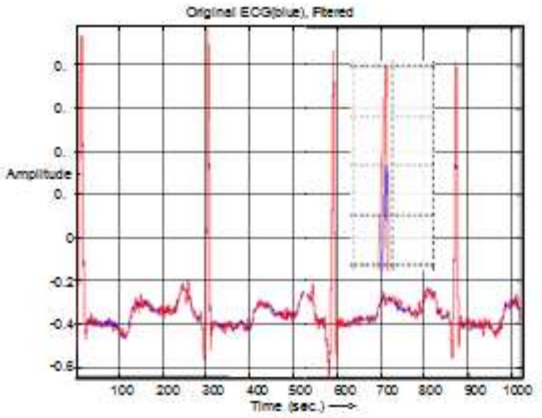


Fig. 11: Comparison of **E**CG signals (Original Signal and Filtered) at **S**NR = 25 dB. Using Hamming window. Inset: Z**o**om view of R peak.

IV. Conclusion

In this work FIR based filtering tec**h**niques for ECG signal is presented; windowing techni**q**ues are used to develop various filters. Fixed window f**u**nctions are used to developed low pass filter. It has bee**n** well established that ECG signal are low frequen**c**y signals, low amplitude periodic signals. However **t**hese signals are susceptible to external electrical conta**m**ination as well as artifacts. This may seriously af**f**ect the clinical diagnosis. In this work we have exper**i**mented with the response of FIR filter in suppressing th**e** high frequency noise. It can be concluded, quantitativ**e**ly as well as by visual inspection that ECG waveform **s**hows (table – I) significant improvement in quality wit**h** the use of high attenuation low pass filter. This can **e**xtract the ECG signal from noise, thus enabling car**d**iac experts for reliable and dependable clinical diagnos**i**s.

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