

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 collect 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 ± 300 mV 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.

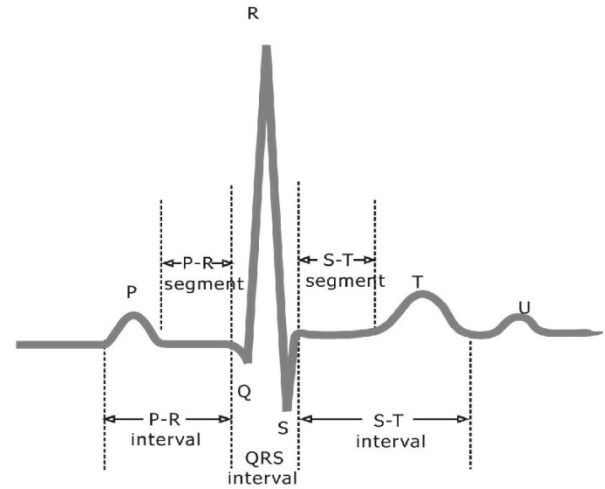


Fig. 1: Basic ECG signal

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 describes 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 raw 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, A_s cannot be varied. The impulse response of low 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]

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

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

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

(a) Blackman window

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

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

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

(b) Hamming window

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

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

(c) Hanning window

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

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

III. ECG ERROR MEASURING PARAMETER

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].

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

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 signal. When using the PRD care must be taken to remove the baseline, or at least, to eliminate the DC level. To avoid this problem, PRDI which independent of the mean value, is used.

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

Where \bar{x} 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].

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

IV. EXPERIMENTAL RESULTS

4.1 FIR filtering results

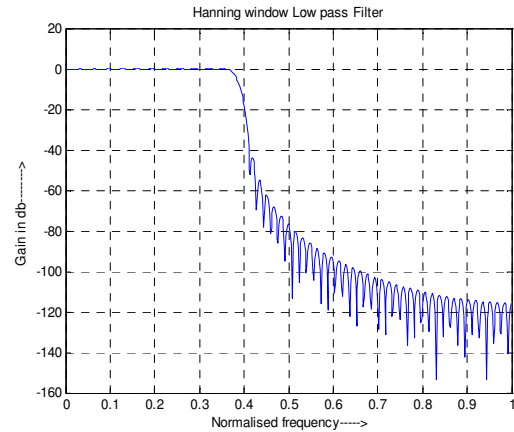


Fig. 2: Low Pass Filter using Hanning Window

Fixed window based low pass FIR filter of order M is designed for normalized pass band frequency is $f_p = 0.180$, Normalized stop band frequency $f_s = 0.205$. MIT-BIH database signals are sampled at 360Hz. The frequency response of designed 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 designed using Hanning window, Hamming window, and Blackman window. These filters are used to remove the Gaussian noise in the ECG signal

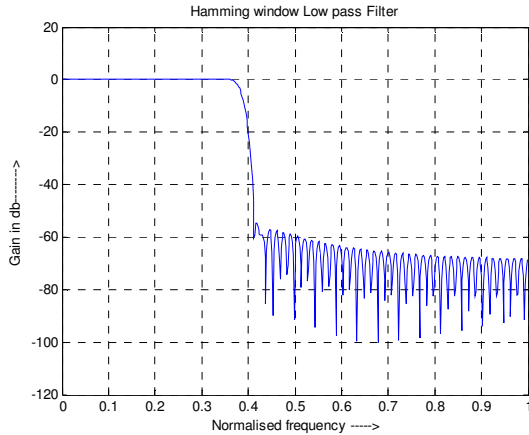


Fig. 3: Low Pass Filter using Hamming Window

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

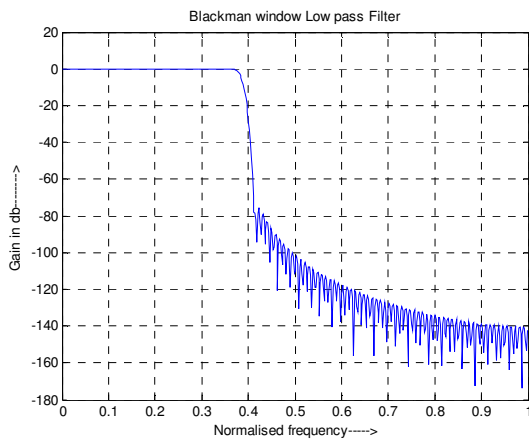


Fig. 4: Low Pass Filter using Blackman Window

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).

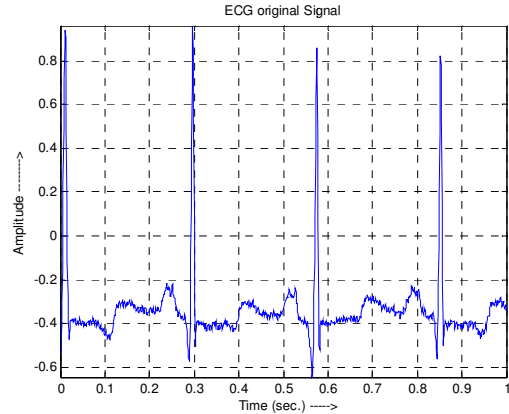


Fig. 5: ECG Original Signal in Time (sec)

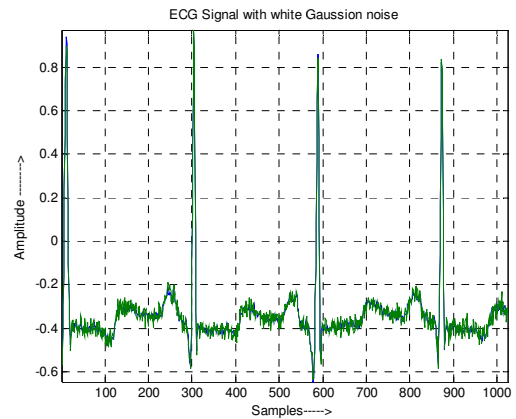


Fig. 6: ECG Signal with SNR = 25dB

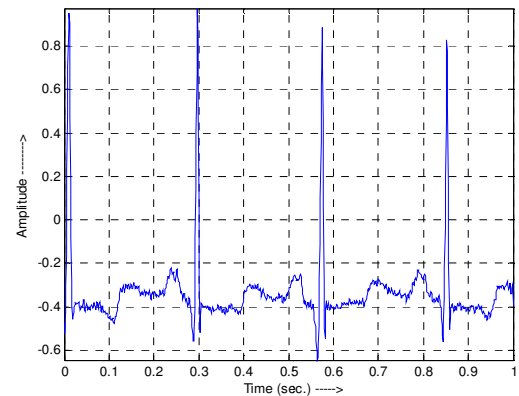


Fig. 7: Filtered ECG Signal using Hamming window

The corrupted ECG signal is filtered using the designed low pass filters. The filtered ECG signal is shown in fig. 8. The results of filtering are shown in Table – I.

Table 1: Noise removal performance of filter with various levels of noise

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

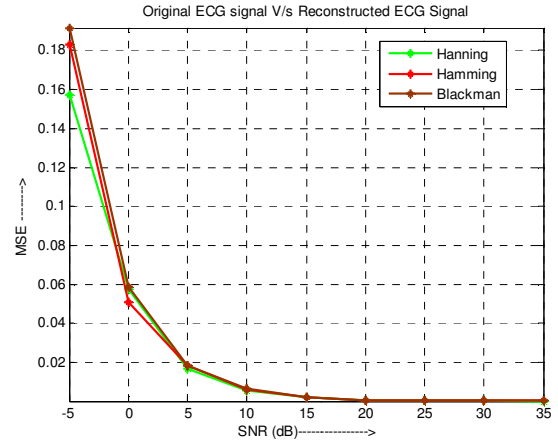


Fig. 9: Comparison of MSE V/s SNR for Hanning, Hamming and blackman window filtered signals.

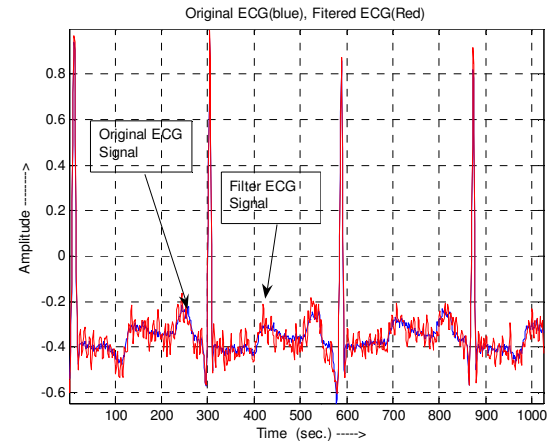


Fig. 10: Comparison of ECG signals (Original Signal and Filtered) at SNR = 15 dB.

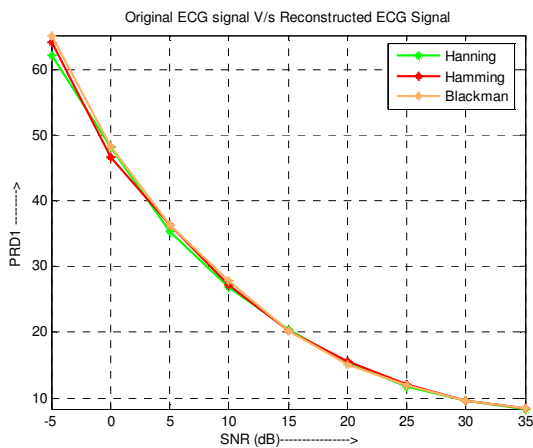


Fig. 8: Comparison of PRD1 V/s SNR for Hanning, Hamming and blackman window filtered signals.

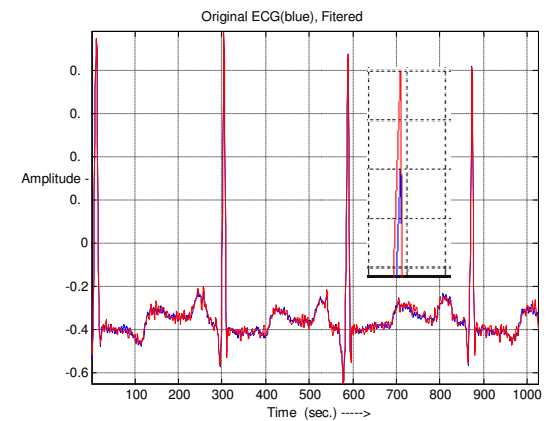


Fig. 11: Comparison of ECG signals (Original Signal and Filtered) at SNR = 25 dB. Using Hamming window. Inset: Zoom view of R peak.

V. CONCLUSION

In this work FIR based filtering techniques for ECG signal is presented; windowing techniques are used to develop various filters. Fixed window functions are used to developed low pass filter. It has been well established that ECG signal are low frequency signals, low amplitude periodic signals. However these signals are susceptible to external electrical contamination as well as artifacts. This may seriously affect the clinical diagnosis. In this work we have experimented with the response of FIR filter in suppressing the high frequency noise. It can be concluded, quantitatively as well as by visual inspection that ECG waveform shows (table – I) significant improvement in quality with the use of high attenuation low pass filter. This can extract the ECG signal from noise, thus enabling cardiac experts for reliable and dependable clinical diagnosis.

REFERENCES

- [1] Ashutosh Datar, Alok Jain and PC Shama “Performance of Blackman window family in M channel Cosine Modulated Filter Bank for ECG signals”, IMPACT-2009
- [2] Wei Zhang, Xu Wang, Linlin Ge2 ,et .al, “Noise Reduction in ECG Signal Based on Adaptive Wavelet Transform” , Proc. 27th IEEE Conf. Engineering in Medicine and Biology (EMB) Shanghai, China, September 1-4, 2005.
- [3] Manuel Blanco-Velasco, Fernando Cruz-Roldan, Ignacio Godino-Llorente et. al., “On the use of PRD and CR parameters for ECG compression” Medical Engineering & Physics, 27 (2005), pp. 798–802.
- [4] Ch. Renumadhavi, Dr. S. Madhavan Kuamar, Dr. A. G. Ananth, et.al, “A New Approach for evaluation SNR of ECG signal and its implementation” Proceeding.
- [5] Yong Lian and Jiang Hong Yu “The Reduction of noises in ECG signal using a frequency response masking based FIR filter” IEEE International workshop on Biomedical circuits & system, 2004
- [6] Stuart W.A. Bergen, Andreas Antoniou, “An efficient closed –form design method for cosine –modulated filter banks using window functions” Department of Electrical and Computer Engineering of Victoria P.O.Box 3055STN CSC Victoria, BC, Canada, 7 August 2006.
- [7] Prajakta S Gokhale, “ECG Signal De-noising using Discrete Wavelet Transform for removal of 50Hz PLI noise”, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 5, May 2012
- [8] S.K. Jagtop, M. S. Chavan, R. C. Wagnekar and M.D.Uplane “Application of the digital filter for noise reduction in electrocardiogram” JI of Instrum. Soc. of India vol.40 No.2, June 2010.
- [9] T-YM Slonim, MA Slonim, EA Ovsyscher “The use of Simple FIR Filters for Filtering of ECG Signals and a NEW method for Post-Filter Signal reconstruction” Electrical and Computer engineering Department ,Cardiology Department Ben-Gurion University of the Negev ,Beer-sheva,Israel, 1993 IEEE.
- [10] Yaniv Zigel*, Arnon Cohen, and Amos Katz, “ECG Signal Compression Using Analysis by Synthesis Coding”, IEEE Transaction on Biomedical Engineering vol.47, 10, October 2000
- [11] John W. Clark, Michael R. Neuman, Walter H. Olson et .al, “Medical Instrumentation Application and Design” 3rd edition, John Wiley & Sons Inc., New York, 2001.
- [12] C. Ifeachor and B.W. Jervis, Digital Signal Processing-A Practical

Approach, Asea Pearson, New Delhi, 2002.

- [13] R. M. Rangayyan, “Biomedical Signal Analysis- A case study approach”, EMB, WSE, Wiley, 2002.
- [14] W. J. Tompkins, “Biomedical Digital Signal Processing”, PHI, 2nd edition, 2002.
- [15] S. K Mitra, “Digital Signal Processing-A Computer based Approach”, Mc Graw Hill, New Delhi, 2nd edition, 2001.
- [16] D. J. Defatta, “Digital Signal Processing-a System design approach”, WSE, Wiley and Sons, 1988.

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