International Journal of Electronics and Communication Engineering and Technology (IJECET)
Volume 7, Issue 4, July-August 2016, pp. 91–99, Article ID: IJECET_07_04_011
Available online at
http://www.iaeme.com/IJECET/issues.asp?JType=IJECET&VType=7&IType=4
Journal Impact Factor (2016): 8.2691 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6464 and ISSN Online: 0976-6472

USING OF FIR AND IIR FILTERS FOR NOISE REMOVAL FROM ECG SIGNAL: A PERFORMANCE ANALYSIS

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ABSTRACT

Electrocardiogram (ECG) is a widely used routine and important cardiac diagnostic tool where in electrical signals are measured and recorded to know the functional status of heart. Quiet often, various artifacts corrupt the original ECG signal and reduces it quality. Therefore, there is a need to remove such artifacts from the original signal and improve its quality for better interpretation. ECG signals are very low frequency signals of about 0.5Hz-100Hz and digital filters are used as efficient means for noise removal of such low frequency signals. This paper presents the comparative analysis of FIR and IIR filters and their performances to remove Baseline noises from the ECG signal for proper understanding and display of the ECG signal.

Key words: Baseline Noises, FIR filters, IIR filters

Cite this Article: Gandham Sreedevi and Bhuma Anuradha and Using of Fir and IIR Filters For Noise Removal From ECG Signal: A Performance Analysis, *International Journal of Electronics and Communication Engineering and Technology*, 7(4), 2016, pp. 91–99.
http://www.iaeme.com/IJECET/issues.asp?JType=IJECET&VType=7&IType=4

1. INTRODUCTION

Heart related diseases are among the major causes of human deaths world over. Therefore, to understand the physiological and functional status of heart, clinicians require efficient tools and methods for effective diagnosis of the cardiac disease. Electrocardiography (ECG) is a tool widely used to understand the condition of the heart. In recent years, computerized ECG analysis is considered as a primary and reliable technique for the diagnosis of cardiac related diseases. The ECG recordings obtained by placing electrodes on the subject's chest and limbs get contaminated with different types of artifacts such as Power line interference, Baseline Drift, Motion artifacts, Electrode contact noise, Instrumentation noise caused by electronic devices and Electrosurgical Noise (1-2). Among different noises, Baseline wander elimination is regarded as a classical problem. It is an artifact which significantly influences atrifactual data when measuring the ECG parameters, particularly, the ST segment measures are powerfully affected by this baseline noise (3). In majority of the ECG recording instances, electrode impedance change due to respiration, perspiration and increased body movements are the main causes of the baseline wandering.

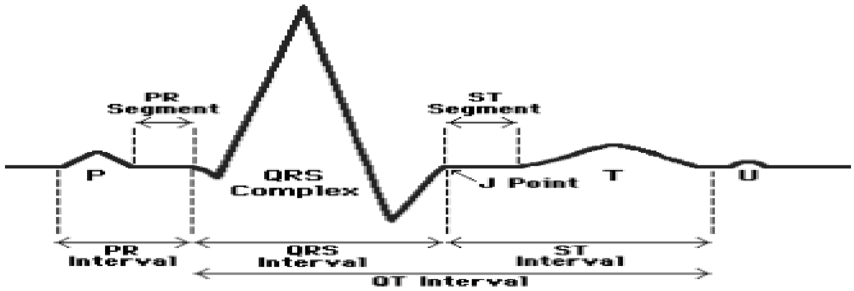

Figure 1 Normal ECG waveform

In this paper, the main aim is to eliminate the baseline noises of the electrocardiogram (ECG) using FIR and IIR filters. Because of Baseline noise interference, it becomes difficult to analyze the ECG records either manually or by automatic means. Especially, with regard to detection of ST-segment deviations, baseline noise interferes significantly. This segment is very important and carries the information related to heart attack. It is necessary that the filters used should remove the baseline noises while preserving the useful clinical information.

2. FILTERING TECHNIQUES

Baseline noise wanders between 0.15Hz and 0.5Hz frequencies. The design of a linear, high pass, time-invariant filter, involves several considerations for removal of baseline wander. Among these, the most important ones are the choice of filter cut-off frequency and phase response characteristic. The cut-off frequency has to be selected in such a way that the clinical information in the ECG signals remains undistorted while removing the baseline wander as much as possible (4-6). Hence, it is essential to find the lowest frequency component of the ECG spectrum. In general, the slowest heart rate is considered to describe this particular frequency component while the PQRST waveform is attributed to higher frequencies. If we employ too high cut-off frequency, the output of the high pass filter contains an unwanted, oscillatory component that is strongly correlated to the heart rate. On the basis of Impulse Response, there are generally two types of digital Filters: Infinite Impulse response (IIR) and Finite impulse Response (FIR). Digital Filters are usually described by the generalized discrete differential equation:

$$\sum_{m=0}^{M} a_m \cdot y[n-m] = \sum_{k=0}^{N} b_k \cdot x[n-k]$$

a , b : indicates filter coefficients

x[n] : denotes input signal

y[n] : indicates output signal

M,N : refers to filter order

The right side of the above equation depends only on the inputs x[n] so it is called feed-forward & the left side depends on the previous outputs y[n] i.e. called feed-back. FIR Filters have only feed forward components; they can be calculated non-recursively. IIR Filters have feed-back components also, they are calculated recursively (7). This paper presents the blue print and execution of high pass FIR filter of the order 400 making use of Kaiser Window & IIR Butterworth filter of order 2 . The basic specifications for design of filter are:

1. Cut-off frequency 0.5Hz
2. Sampling frequency 360Hz (MIT/BIH database sampled at 360 Hz)

2.1. IIR Filtering

Digital filters play a crucial role in digital signal processing, e.g., biomedical signal processing. A digital filter refers to a mathematical algorithm executed in hardware/software which works on a digital input signal to generate a digital output signal so as to achieve a filtering objective. The term digital filter employed in this paper refers to the software filter.

Digital IIR filters could be designed to be low pass, high pass, band pass or band stop. One can modify band stop filter to work as a notch filter. Digital IIR filters are developed from its analog counterpart using different methods like impulse invariant, bilinear z-transform or matched z-transform. Some of the important analog counterparts of digital IIR filters include butterworth low pass, butterworth high pass, chebyshev low pass and chebyshev high pass.

In a design problem in which no ripple is acceptable in pass band and stop band, Butterworth filter can be a better choice. But due to no-linear phase response, the waveform becomes distorted. The Magnitude Response and Phase Response of Butterworth low pass and high pass filter is shown in figures 2&3.

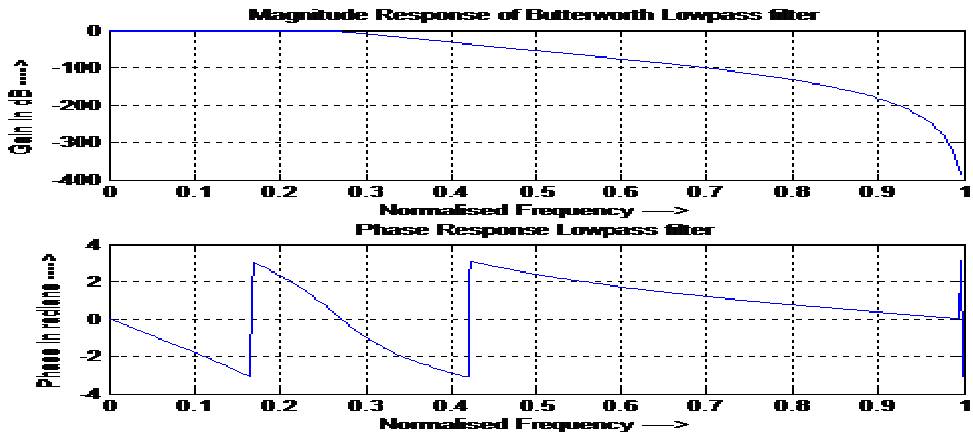

Figure2 Magnitude Response & Phase Response of Butterworth Low Pass Filter

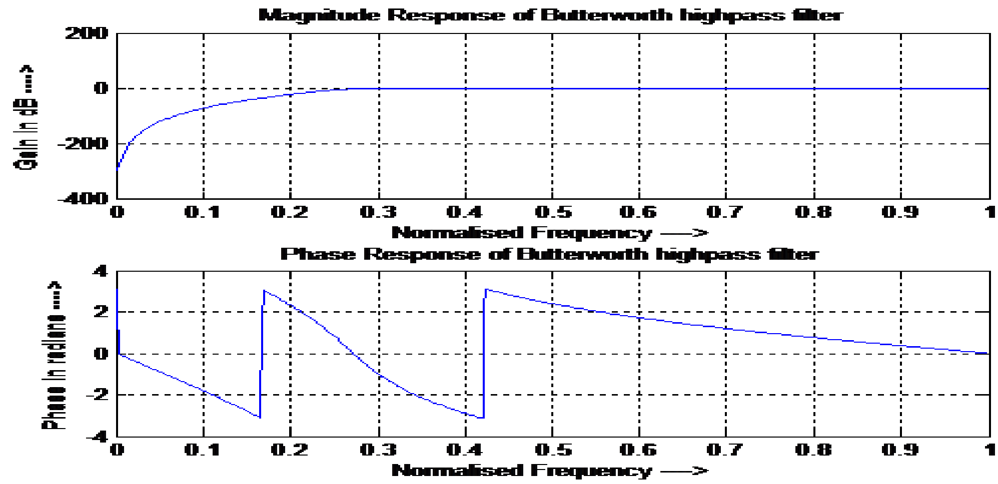

Figure3 Magnitude Response & Phase Response of Butterworth High Pass Filter

2.2. FIR filtering

Here, the high pass FIR filter is designed by using Kaiser window. The fundamental principle involved in the window design method is to truncate the ideal response with a finite length window. In the filters design using windows like Bartlett, Hanning, Rectangular, Hamming and Blackman, it is noticed that, a trade off exists between the main lobe width and the side lobe amplitude. The main lobe width is found to be inversely proportional to the N order of the filter. A raise in the window length decreases the transition band of the filter. However, for the minimum stop band reduction and pass band ripple, the designer must locate a window with an appropriate side lobe level and then select order to obtain the prescribed transition width. In this process, the designer may often have to settle for a window with undesirable design specifications. To surpass this problem Kaiser has chosen a class of windows that are based on the portable Speriodal functions. The Kaiser window is given by following equation.

$$w_k = \frac{I_0[\alpha\sqrt{1-[\frac{2n}{N-1}]^2}]}{I_0(\alpha)} \quad for\ |n| \leq \frac{N-1}{2}$$

$= 0$ otherwise

3. EVALUATION PARAMETERS

In Signal processing, Fast Fourier transforms (FFT), Power spectral density (PSD) has emerged as an important tool to provide an improved diagnosis of cardiovascular pathologies. The power spectral density (PSD) of a signal denotes how the power of a signal is distributed with in the frequency domain, which means, it gives the energy spectrum of the signal. The power spectrum of the heart rate variability can be divided into three parts: the very low frequency (VLF) component (0.001-0.04 Hz), the low frequency (LF) component [0.04-0.15 Hz] and high frequency (HF) component (0.15-0.4 Hz) [6]. The HF is associated with the respiratory cycle and the LF component has been shown to be associated with parasympathetic and sympathetic activity (7-9). Both of these components could be affected during cardiovascular pathologies. In the current problem, we used FFT and PSD to differentiate ECG signals of normal subjects from those with having ventricular arrhythmias who eventually had sudden cardiac arrest. The ECG signals are obtained from the database collection provided by http://www.physionet.org/physiobank.

4. EXPERIMENTAL RESULTS

The important parameters to check the suppression of Baseline noises is Power Spectral density.

Power Spectral Density (PSD)

The periodogram power spectrum estimate represents the distribution of the signal power over frequency. From the spectrum the frequency content of the signal can be estimated directly. Power spectral density (PSD) of ECG signal is calculated as follows:

$$S(f) = \frac{1}{FsN}\left|\sum_{n=1}^{N} x_n e^{-j(2\pi f/Fs)n}\right|^2$$

where Fs is sampling frequency.

The periodogram is an estimate of the PSD of the signal defined by the sequence [x1,...., xN]. Periodogram uses an nfft point FFT to compute the power spectral density (10).

4.1. FIR-Equiripple-conventional and zerophase filter

ECG signal is taken from the standard MITBIH data base. These original signals were first corrupted with noise. Then, to remove these noises a low pass FIR equiripple filter was first constructed and filtered the noisy waveform by using both zero-phase and conventional filtering. Because the filter is an all-zero (FIR) filter, the denominator equals 1. Zero-phase filtering reduces noise in the signal and preserves the QRS complex at the same time it occurs in the original signal. Conventional filtering reduces noise in the signal, but delays the QRS complex (12-15).

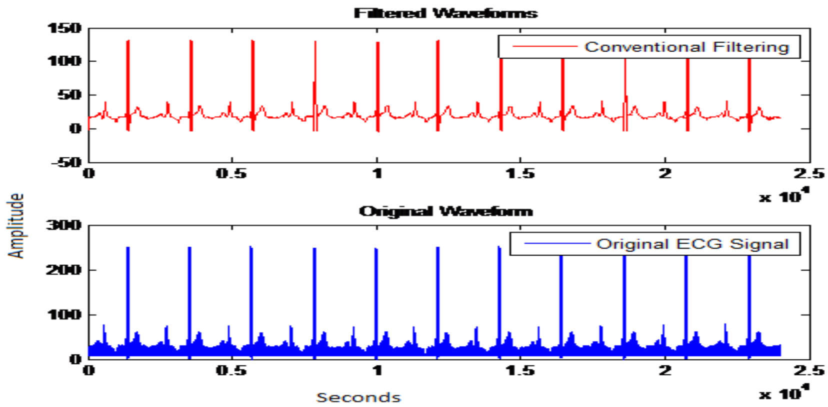

Figure 4.1 FIR-Equitripple-Conventional filter

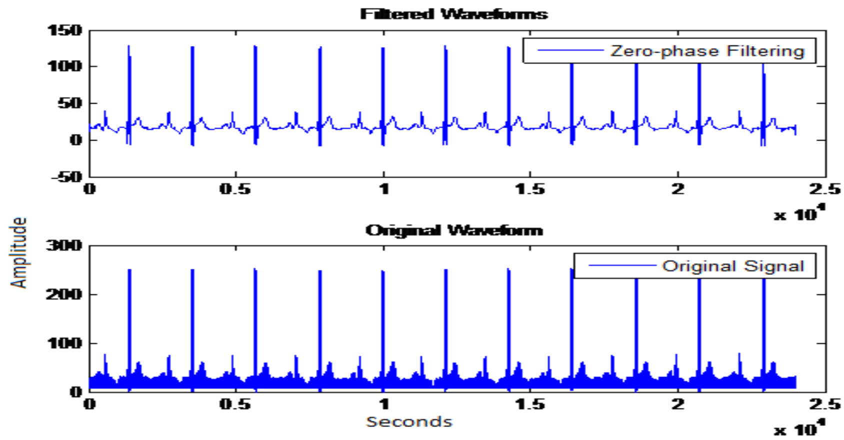

Figure 4.2 FIR-Equitripple zero phase wave forms

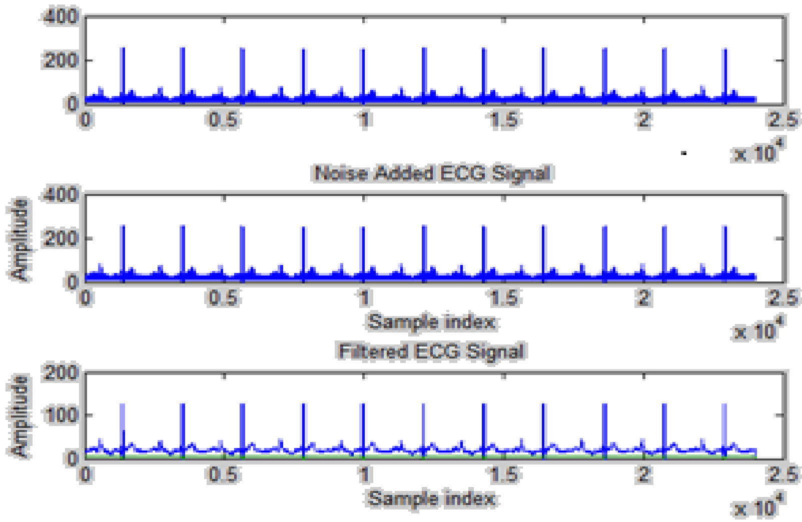

Figure 4.3 ECG Signal Filtering By Median Filter

4.4. FIR Chebshev-high pass filter

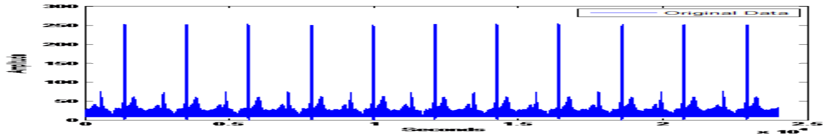

Figure 4.4.1 FIR Chebshev -high pass filter input signal

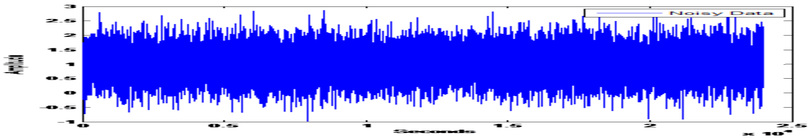

Figure 4.4.2 FIR Chebshev - high pass filter noisy signal

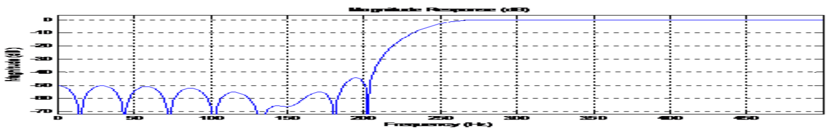

Figure 4.4.3 FIR Chebshev -high pass filter Magnitude response

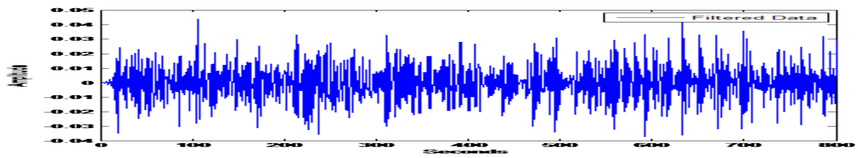

Figure 4.4.4 FIR Chebshev - high pass filter response

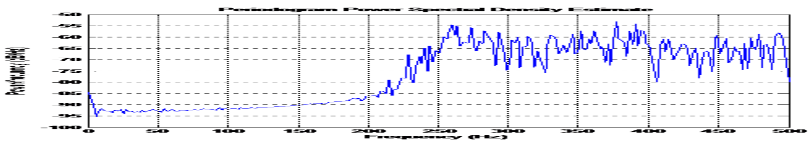

Figure 4.4.5 FIR Chebshev -high pass filter PSD waveform

4.5. FIR kaiser - low pass filter

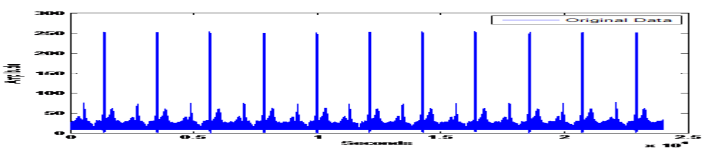

Figure 4.5.1 FIR Kaiser- low pass filter input signal

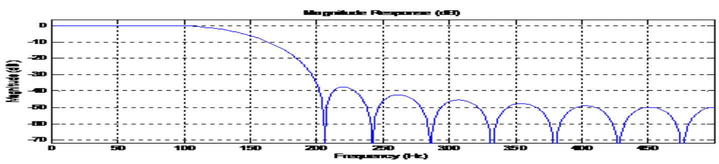

Figure 4.5.2 FIR kaiser -low pass filter Magnitude response

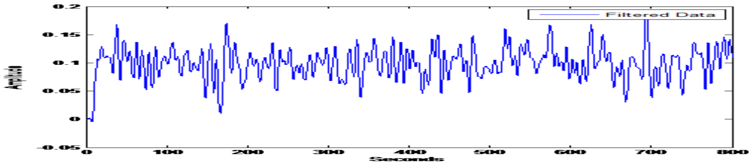

Figure 4.5.3 FIR kaiser - low pass filtered data

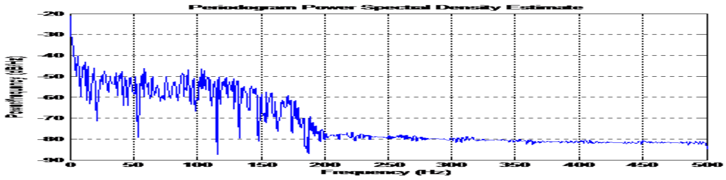

Figure 4.5.4 FIR kaiser - low pass filter PSD waveform

4.6. Savitzky- Golay based ECG signal filtering

Savitzky- Golay filtering is also called as digital smoothing polynomial filters or least squares smoothing filters. Such filters are employed to "smooth out" a noisy signal whose frequency span is large. In this type of application, Savitzky- Golay smoothing filters perform much better than standard averaging FIR filters, which tend to filter out a significant portion of the signal's high frequency content along with the noise (16). Although Savitzky- Golay filters are more effective at preserving the pertinent high frequency components of the signal, they are less successful than standard averaging FIR filters at rejecting noise (17-20). Table-1shows the ccomparison of FIR and IIR filters for removal of Baseline drift and table-2 shows signal to noise ratio before and after filtering.

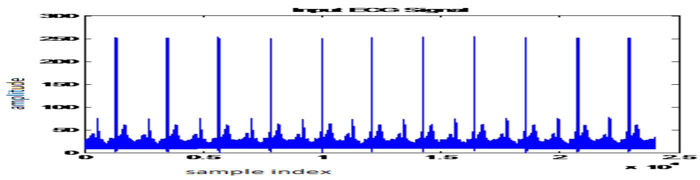

Figure 4.6.1 Original signal

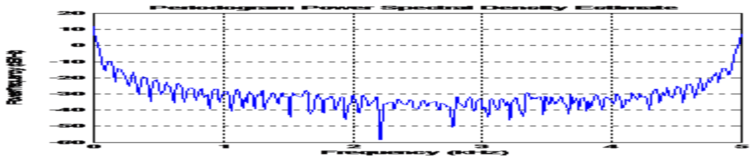

Figure 4.6.2 PSD waveform

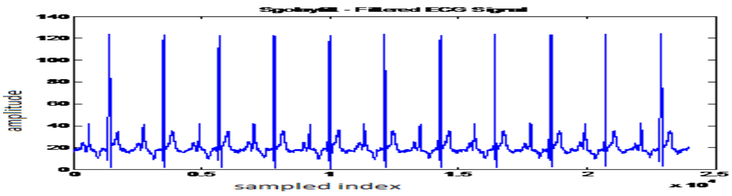

Figure 4.6.3 filtered ECG Signal

Table 1 Comparison of FIR and IIR filters for Removal of Baseline drift.

S.No	Methods	PSD before Filtering	PSD after Filtering
1.	Equiripple conventional filter	76.7297	71.640
2.	Equiripple zero phase	76.7297	70.888
3.	Chebshev high pass filter	76.7297	59.192
4.	Chebshev low pass filter	76.7297	42.988
5.	kaiser high pass filter	76.7297	40.353
6.	kaiser low pass filter	76.7297	24.240
7.	Butter Worth low pass filter	76.7297	21.421
8.	Butter Worth high pass filter	76.7297	8.543

Table2 Using Signal to Noise Ratio before and after Filtering

S.No	SNR before filtering	SNR after filtering	Noise
1.	1.99	1.52	3.1881e-36

5. CONCLUSIONS

The order of performed IIR filter is 2 and it is a recursive filter. Thus, IIR filters require less computation-power, and their implementation is easier than that of FIR filters. The transition band is very narrow (0.1 Hz) as compared to FIR filters. The phase delay is also approximately zero. However, IIR filters have a phase distortion that is caused by nonlinear phase response of IIR filters. If we increase the order of filter then infinite oscillations can get produced. But to remove Baseline noise we require only filter of order 2 at which there are only small oscillations at the starting of waveform which is called Ringing effect. This problem can be solved by applying the IIR filter to the ECG signal in both directions. Table 1 shows the comparison of complexity between FIR and IIR filters. FIR and IIR filters both have removed the baseline noises at the expense of some ringing effect at the starting of waveform. But their comparison shows that due to large order of FIR filter there is a phase delay in FIR filtered waveforms. The computational complexity of FIR filter is far greater than IIR filters. It increases the memory requirement and power dissipation of FIR filter. So, IIR filters can be the better choice for removal of Baseline noises.

REFERENCES

[1] Mahesh S. Chavan, R.A.Aggarwala, M.D.Uplane, Design and implementation of Digital FIR Equiripple notch Filter on ECG signal for removal of Power line Interference ‘WSEAS Transactions on Signal Processing, 2008; 4:4, 221–30.

[2] G. K. Singh, A. Sharma, S. Velusami, A Research Review on Analysis and Interpretation of Arrhythmias using ECG Signals. IJMST. 2009, 2(3), 37–55.

[3] Wikipedia the free encyclopedia http://en.wikipedia.org/wiki/Electrocardiogram.

[4] M. Friesen, Gary et al., Comparison of noise sensitivity of QRS Detection Algorithms, IEEE Transactions on Biomedical Engineering, 1990: 37, 1.

[5] Zahoor-uddin, ‘Baseline Wandering Removal from Human Electrocardiogram Signal using Projection Pursuit Gradient Ascent Algorithm’, International Journal of Electrical & Computer Sciences IJECS/IJENS. 2009; 9: 9, 11–13.

[6] Mahesh S. Chavan, Ra.Agarwala, M.D.Uplane, Interference Reduction in ECG using Digital FIR Filters based on rectangular window, WSEAS Transactions on Signal Processing. 2008; 5:4, 340–49.

[7] V. S. Chouhan and S. S. Mehta, Total Removal of Baseline Drift from ECG Signal, International Conference on Computing: Theory and Applications-ICCTA '07. 2007, Accession No: 9420611.

[8] Lisheng Xu, David Zhang, And Kuanquan Wang, Wavelet- Based Cascaded Adaptive Filter For Removing Baseline Drift In Pulse Waveforms', IEEE Transactions On Biomedical Engineering. 2005; 52:11, 1973-75.

[9] M. S. Chavan, R.A.Agarwala, M.D.Uplane, Comparative Study of Chebyshev I and Chebyshev II Filter used For Noise Reduction in ECG Signal, International Journal of Circuits, Systems and Signal Processing, 2008; 1:2, 1–17.

[10] IT-BIH Arrhythmia database directory, 3rd Edition, Harvard- MIT Division of Health Science and Technology, July, 1992.

[11] Matlab Mathworks. http://www mathworks.com/ Technikum Wien, 'Microprocessor based Design for Biomedical Applications', MBE 3 – MDBA VII: Digital Signal Processing Basics & Applications. 2011; 1-7.

[12] Seema rani et al, / (IJCSIT) International Journal of Computer Science and Information Technologies. 2011; 2 (3): 1105-1108.

[13] Cromwell, F.J. Weibell, E.A. Pfeiffer (2005) Biomedical Istrumentation and Measurements, Prentice Hall of India, New Delhi.

[14] Rashmi Panda and Umesh C. Pati, ―Removal of Artifacts from Electrocardiogram Using Digital Filter‖ , Proc. Of 2012 IEEE Students' Conference on Electrical, Electronics and Computer Science. 2012; 1-4.

[15] R. Acharya, J. S. Suri, J. A.E. Spaan and S .M. Krishnan, Advances in Cardiac Signal Processing, 2007 edition, *Springer Berlin Heidelberg, New York*, ISBN: 3-540-36674-1.

[16] S.K. Jagtap, M.S. Chavan, R.C. Wagvekar and M.D. Uplane, "Application of the digital filter for noise reduction in electrocardiogram". Journal of Instrumentation. 2010; 40:2, 83–86.

[17] http://www.physionet.org/physiobank/database/mitdb/

[18] MIT-BIH Database distribution, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge.

[19] Carson K. S. Pun, S. C. Chan, K. S. Yeung, and K. L. Ho, On the design and implementation of FIR and IIR digital filters with variable frequency characteristics, IEEE transactions on circuits and systems-II: analog and digital signal processing, 2002; 49:11, 689 – 703.

[20] Mohammed Salman Ullah Khan And Prof. F.I. Shaikh, Suppression of Power Line Interference Correction of Baseline Wanders And Denoising Ecg Signal Based On Constrained Stability Least Mean Square Algorithm, *International Journal of Electronics and Communication Engineering and Technology*, 4(3), 2013, pp. 185–192.

[21] Rashmi Panda, Umesh C. pati, Removal of artifacts from electrocardiogram using digital filter, Proceedings of IEEE Students' Conference on Electrical, Electronics and Computer Science, 2012; 1–4.