International Engineering Journal For Research & Development

Vol.2
Issue 6

E-ISSN NO:-2349-0721

E-ISSN NO:2349-0721

Impact factor : 2.25

DESIGN OF FILTER TO REMOVE 50-6HZ INTERFERANCE FROM ECG SIGNAL

Kalyani A. Raut[1], Prof.G.N Wazurkar[2] , Prof.D.R.Dandekar[3]

[1] Department of Electronics EngineeringB.D.C.O.E, Sevagram, [2] Department of Electronics Engineering B.D.C.O.E, Sevagram, [3] Department of Electronics Engineering B.D.C.O.E, Sevagram

[1]kalyaniraut28888@gmail.com, [2]girishwazurkar@gmail.com ,[3]d.dandekar@rediffmail.com

ABSTRACT—

ECG signal processing is the emerging need as it is the best way to diagnose the heart condition of a patient. Presence of artifacts in the ECG signal due to power line noise, electroencephalogram, electromyogram and baseline wander make the signal more weak and analysis of required clinical information get distorted. Our objective is to study and design appropriate filter that will remove 50-60 Hz interference. We have studied and implemented different filter structure such as conventional filter, IIR notch filter, Kalman filter and designed Adaptive Kalman filter which works on auto regression algorithm. Comparative study of conventional filter, IIR notch filter, Kalman filter and adaptive kalman filter on basis of MSE, RMSE and SNR is carried out in this paper.The filters are implemented on MATLAB.

***Index Terms*—ECG signal, power line interference, conventional filter, kalman filter, IIR notch filter, Adaptive Kalman filter.**

INTRODUCTION

Signal processing today is performed in the vast majority of systems for ECG analysis and interpretation. ECG (electrocardiogram) is the monitoring interpretation of the electrical activity of the heart over a period of time.ECG is away to measure and diagnose abnormal rhythms of the heart. The objective of ECG signal processing is manifold and comprises the improvement of measurement accuracy and reproducibility (when compared with manual measurements) and the extraction of information not readily available from the signal through visual assessment. The ECG is recorded during ambulatory or strenuous conditions such that the signal is corrupted by different types of noise, sometimes originating from another physiological process of the body in many of the situations. [1]

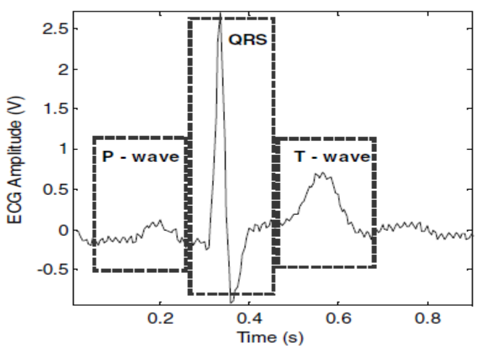


Fig. 1. The shape of ECG signal

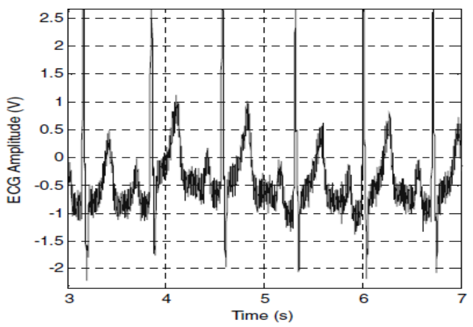


Fig.2. Aquired noisy ECG signal

In order to examine the abnormal activities of heart to prevent heart diseases ECG is required and thus the efficient monitoring of ECG signal is required. The object of signal processing is the improvement of measurement accuracy (when compared with manual measurements) and extraction of information not readily available from the signal through visual assessment. But, it is seen that ECG signal are perturbed by noise.

To avoid signal disruption with these interfering signals from the power electricity supply, we may take some actions:

1. Medical equipment to be correctly connected to ground.

2. Use high quality electrodes.

3. The contact between electrodes and skin to be as good as possible.

4. Where is possible, remove any electrical device near the patient and medical equipment.

5. The collection cables of signals, to be routed in a different manner by power supply cables of medical measuring equipment.

6. Avoid the patient's muscle contractions, due to appear irregularities of the frequency and amplitude.

7. And finally, avoid harmful electromagnetic fields near the chamber for collecting the signals.[8-11]

But, only this method do not assure optimum performance.[12-13] The important step represented is ECG signal processing interpreting the signal shape. The main factors that produce damage on signal shape are AC power-supply interferences, Radio Frequency interferences produced by medical surgery equipment and the implanted devices like pace makers can also produce major impact on accuracy of ECG acquisition. In literature was specified that are four main sources of noise that affect the ECG signal

1. At low frequency appear an affect called Baseline Wander

2. Power line interferences (50 Hz or 60 Hz plus harmonics)

3. Muscle noise which are produced in the same area of collected ECG. To remove this noise it can be done in software correction.

4. Other interferences like radio frequency produced by medical surgery equipment.

Hence, noise reduction represents another important objective of ECG signal processing; sometime, the waveforms of interest are heavily masked by noise that their presence can only be revealed once appropriate signal processing has first been applied. Electrocardiographic signals may be recorded on a long timescale (i.e., several days) for the purpose of identifying intermittently occurring disturbances in the heart rhythm. The objective of the paper is to show the comparison of various filters such as IIR filter, FIR filter and various algorithm that are used to implement it. Also its implementation on FPGA is studied.

LITERATURE REVIEW

[Applications of Adaptive Filtering to ECG Analysis: Noise Cancellation and Arrhythmia Detection is presented by Nitish V. Thakor and Yi-Sheng Zhu[2]. In this paper several adaptive filter structures are proposed for noise cancellation and arrhythmia detection. The adaptive filter essentially minimizes the mean-squared error between a primary input, which is the noisy ECG, and a reference input, which is either noise that is correlated in some way with the noise in the primary input or a signal that is correlated only with ECG in the primary input. Different filter structures are presented to eliminate the diverse forms of noise: baseline wander, 60 Hz power line interference, muscle noise, and motionartifact. An adaptive recurrent filter structure is proposed for acquiring the impulse response of the normal *QRS* complex. The primary input of the filter is the ECG signal to be analyzed, while the reference input is an impulse train coincident with the *QRS* complexes. Two limitations of the ARF technique are apparent. The first problem is that the reference impulse must be exactly coincident with the signal complex. When this is done independently by detecting *QRS* complexes, there is the possibility of uncertainty and error. *QRS* detection, especially in the presence of noise and artifact, can be inaccurate. The proposed adaptive filters onlyform one step in a complex strategy to detect arrhythmias.

Power Line Interference Removal from ECG Signalusing SSRLS Algorithm is presented by Maryam Butt, Nauman Razzaq, Ismail Sadiq, Muhammad Salman, Tahir Zaidi. In this paper State Space Recursive Least Squares (SSRLS) filter based method for removal of 50Hz PLI noise from an ECG signal is discussed[3]. The results are encouraging when compared with notch filter of varying attenuation levels. Under varying PLI noise levels, the SSRLS filter is seen to show superior performance as compared to notch filter. A new class of RLS filter, the State-Space Recursive Least Squares (SSRLS) to remove 50Hz PLI noise from ECG signal. The SSRLS filter requires knowledge of the PLI noise frequency. SSRLS effectively tracks the PLI in the ECG signal. The PLI estimated by SSRLS is subtracted from the noisy ECG signal, leading to clean ECG signal. For comparison, multiple 50Hz notch filters with varying attenuation levels were used for the PLI noise removal from ECG signal. Computer simulations show that SSRLS filter performs better than conventional notch filter in many aspects discussed in detail in computer simulations section.

Digital *Q*-Varying Notch IIR Filter With Transient Suppression is presented by Jacek Piskorowski. This paper presents a new concept of digital IIR notch filters, whose quality factor changes with time[4]. Owing to a temporary change in the value of the quality factor, the transient can considerably be reduced. Simulations verifying the effectiveness of the proposed *Q*-varying IIR notch filter are presented and compared with the performance of the traditional *Q*-constant filter using ECG signals with unwanted sinusoidal interference as a study case. In this paper, the parameter-varying technique has been used to generate a new class of digital *Q*-varying IIR notch filters with transient suppression. The proposed *Q*-varying digital notch filters possess selective magnitude response and transient response of short duration. It was demonstrated that this new class of filters achieved a considerable reduction of the duration of the transient response compared with the traditional time invariant filter, which was used as a prototype. As an example, the proposed *Q*-varying digital IIR notch filter was used to remove the 15-Hz interference from the simulated and real ECG signals. The results of simulations confirmed that, using the proposed *Q*-varying notch IIR filter, both the transient duration and the selectivity of the filter are at an acceptable level. An Adaptive Kalman Filter for ECG Signal Enhancement is presented by Rik Vullings, Bert de Vries, and Jan W. M. Bergmans. in this paper[5], a sequential averaging filter is developed that, in essence, adaptively varies the number of complexes included in the averaging based on the characteristics of the ECG signal. The filter has the form of an adaptive Kalman filter. The adaptive estimation of the process and measurement noise covariances is performed by maximizing the Bayesian evidence function of the sequential ECG estimation and by exploiting the spatial correlation between several simultaneously recorded ECG signals, respectively. The noise covariance estimates thus obtained render the filter capable of ascribing more weight to newly arriving data when these data contain morphological variability, and of reducing this weight in cases of no morphological variability. The filter is evaluated by applying it to a variety of ECG signals. To gauge the relevance of the adaptive noise-covariance estimation, the performance of the filter is compared to that of a Kalman filter with fixed, (*a posteriori*) optimized noise covariance. This comparison demonstrates that, without using *a priori* knowledge on signal characteristics, the filter with adaptive noise estimation performs similar to the filter with optimized fixed noise covariance, favouring the adaptive filter in caseswhere no *a priori* information is available or where signal characteristics are expected to fluctuate. The filter is derived using a Bayesian framework and constitutes a Kalman filter in which the dynamic variations in the ECG are modeled by a covariance matrix that is adaptively estimated every time new data arrive. In this paper, a Kalman filter with adaptive noise-covariance estimation has been developed and evaluated on a variety of ECG signals to assess whether the filter is capable of enhancing the SNR of these signals, while at the same time preserving clinically relevant morphological variations in the ECG. The filter operates by sequentially estimating the measurement and process noise covariances and uses these covariances to estimate the Kalman gain and update the estimated ECG complexes. In cases where the variations between consecutive ECG complexes can no longer be explained as measurement noise, the variations are taken to be morphological variations and the process noise covariance is increased. This, in turn, leads to an increase of the Kalman gain, and consequently, more weight is ascribed to the newly arriving ECG complex. The performance of the filter is compared with the performance of a similar Kalman filter with fixed process noise covariance. For this fixed Kalman filter, the process noise covariance needs to be *a priori* estimated, and hence, to ensure adequate performance of the filter, requires rather detailed information on the ECG signal dynamics. The comparison between the fixed and adaptive Kalman filters demonstrates that the adaptive filter performs almost as a fixed Kalman filter with optimally chosen process.

OBJECTIVE:

Removing noise from ECG is a critical task. By studying literature it is observed that appropriate filter is required in order to get noise free and interference free signal. The analysis is need to be perform on the basis of parameters like MSE, RMSE and SNR.

To design filters such as conventional, IIR notch filter, Kalman Filter, Adaptive Kalman filter.

Verifying the results.

Comparison of results on factor such as mean square error (MSE), root mean square error(RMSE), signal to noise ratio(SNR). Suggesting the best result from above four designed filters.

PROPOSED METHODOLOGY:

Implementation of conventional filter that is band stop filter.

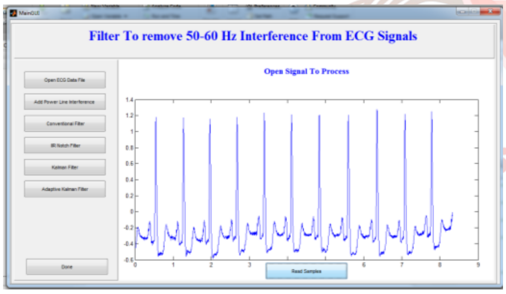
Implementation of IIR notch filter.

Implementation of Kalman filter.

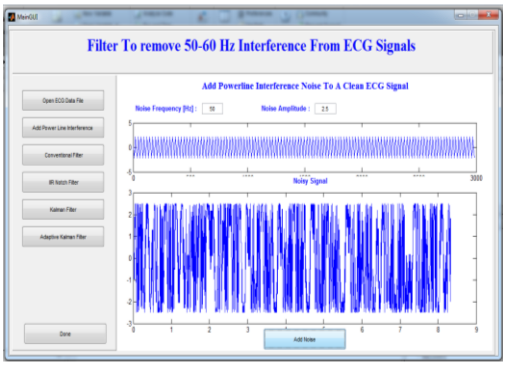
Study and design of Adaptive kalman filter and its implementation .The method is to obtain data that is ECG signal from MIT-BIH and adding noise that is interference.The noisy signal is pass through conventional filter, IIR notch filter , kalman filter and adaptive kalman filter.

RESULT ANALYSIS:

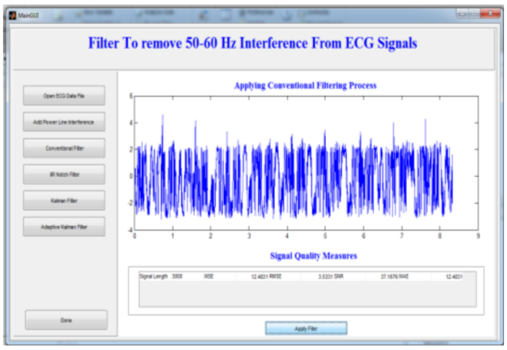
Reading samples of ECG from MIT-BIH data base for data 101.dat



Adding Power Line Noise interference

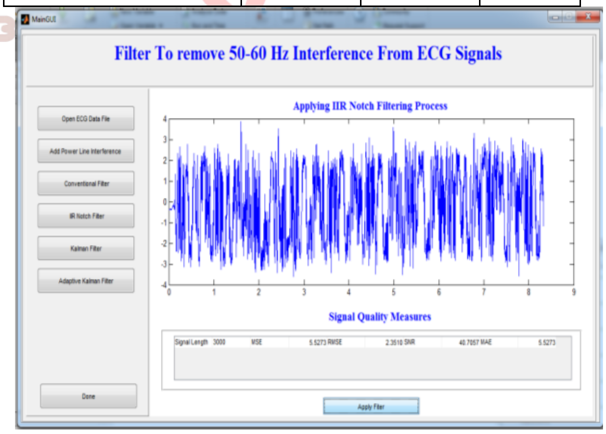


Denoising corrupted ECG signal Using CONVENTIONAL FILTER

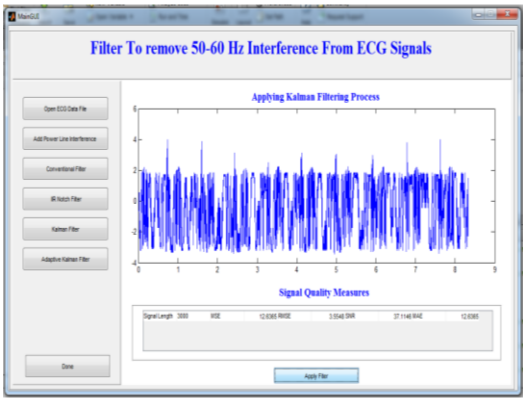


Denoising corrupted ECG signal Using IIR NOTCH FILTER

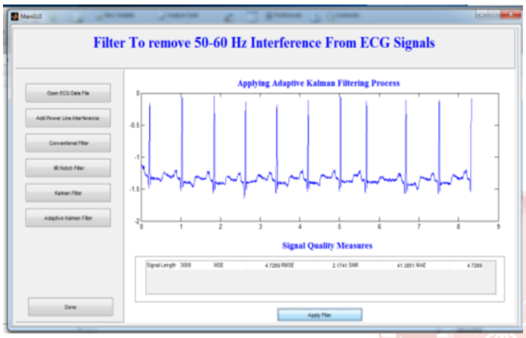
FILTER	MSE	RMSE	SNR(db)
Conventional Filter	2.1885	1.4794	44.7293
IIR notch Filter	1.2555	1.12	47.1425
Kalman Filter	2.2157	1.4885	44.6757
adptv. Kalman Filter	2.3074	1.579	44.4995



Denoising corrupted ECG signal Using KALMAN Filter



Denoising corrupted ECG signal Using ADAPTIVE KALMAN Filter



MSE, RMSE and SNR for varying amplitude and frequency range is compared and conclusion is drawn.

a.Frequency: 50Hz, Amplitude: 1mV

b. Frequency: 50Hz, Amplitude: 0.5mV

CONCLUSION AND ANALYSIS OF RESULT:

After implementation of conventional filter, IIR notch filter, Kalman filter and Adaptive kalman filter following results are observed.

For 50-60Hz PLI with amplitude 2.5mV

Adaptive Kalman filter is better than IIR notch filter by 3.727%

Adaptive Kalman filter is better than Kalman Filter by 11.22%

Adaptive Kalman filter is better than Conventional Filter by 11.01%

FILTER	MSE	RMSE	SNR(db)
Conventional Filter	0.662	0.8136	49.9224
IIR notch Filter	0.426	0.6527	51.8368
Kalman Filter	0.6686	0.8177	49.8794
adptv. Kalman Filter	1.9142	1.3836	45.3109

For 2mV

Adaptive Kalman filter is better than IIR notch filter by 1.7%

Adaptive Kalman filter is better than Kalman Filter by 8.6%

Adaptive Kalman filter is better than Conventional Filter by 8.29%

For 1.5 mV

IIR notch filter is better than Adaptive Kalman filter by 1.15%

Adaptive Kalman filter is better than Kalman Filter by 5.07%

Adaptive Kalman filter is better than Conventional Filter by 4.9%

For 1mV

IIR notch filter is better than Adaptive Kalman filter by 5.93%

Conventional filter is better than Adaptive Kalman filter by 0.5%

Kalman filter is better than Adaptive Kalman filter by 0.39%

For 0.5mV

IIR notch filter is better than Adaptive Kalman filter by 14.402%

Conventional filter is better than Adaptive Kalman filter by 10.177%

Kalman filter is better than Adaptive Kalman filter by 10.08%

The paper presents the study and implementation of Conventional filter, IIR notch filter, Kalman filter. The filter used are non adaptive in nature, so the adaptive filter is studied and in order to eliminate 50-60 Hz interference an adaptive kalman filter is designed. The working of Adaptive Kalman Filter is based on auto-regression algorithm.The performance of the filter is compared with Conventional filter, IIR notch filter and Kalman Filter using parameters like mean square error (MSE), root mean square error(RMSE), signal to noise ratio(SNR). This results are compared for varying amplitude and frequency ranges. From the result it is concluded that for standard range of amplitude i.e. 2 mV- 2.5 mV Adaptive Kalman denoises signal more effeciently. But its effeciency decline as the range of amplitude decrease.

REFERENCES

Ioan Tudosa, Narcis Iulian Adochiei, And Razvan Ciobotariu"Research On Possible Abnormalities Of The ECG Signal Shape " In The 7th International Symposium On ADVANCED TOPICS IN ELECTRICAL ENGINEERING The Faculty Of Electrical Engineering U.P.B., Bucharest , May 12-14, 2011

Mbachu C.B 1, Onoh G. N 2, Idigo V.E 3, Ezeagwu C.O4, Ezechukwu O.A5 "SUPPRESSION OF POWERLINE INTERFERENCE IN ECG USING ADAPTIVE DIGITAL FILTER" International Journal Of Engineering Science And Technology (IJEST)Vol. 3 No. 8 August 2011

Alireza K. Ziarani And Adalbert Konrad "A Nonlinear Adaptive Method Of Elimination Of Power Line Interference In ECG Signals".

Jacek Piskorowski "Digital Q-Varying Notch IIR Filter With Transient Suppression" IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 59, NO. 4, APRIL 2010

Maryam Butt, Nauman Razzaq, Ismail Sadiq, Muhammad Salman, Tahir Zaidi "Power Line Interference Removal From ECG Signal Using SSSRLS Algorithm" 9th International Colloquinium On Signal Processing-8-10 Mac, 2013, Kuala Lumpur Malaysia. 2013 IEEE.

Aarti J. Patel, Vandana Patel "Nyquist Filter Design To Remove Power Line Interference From Bioelectric Signals" International Journal Of Engineering Trends And Technology- Volume3Issue2-2012

Mohammad Zia Ur Rahman, Rafi Ahmad Shaikh, D V Rama Koti Reddy "Baseline Wander And Power Line Interference Elimination From Cardiac Signals Using Error Nonlinearity LMS Algorithm" Proceedings Of 2010 International Conference On System In Medicine And Biology 16-18 December 2010, IIT Kharagpur, India.

J. C. Huhta And J. G. Webster, "60-Hz Interference In Electrocardiography," IEEE Trans. Biomed. Eng., Vol. BME-20, No. 2, Pp. 91–101, Mar. 1973.

P. S. Hamilton, M. G. Curley, R. M. Aimi, And C. Sae-Hau, "Comparison Of Methods For Adaptive Removal Of Motion Artifact," In Proc. Comput. Cardiol., 2000, Pp. 383–386.

Adli And Y. Yamamoto, "Impedance Balancing Analysis For Power-Line Interference Elimination In

ECG Signal," In Proc. IEEE Instrum. Meas.Technol. Conf., May 1998, Pp. 235–238.

Y. Z. Ider, M. C. Saki, And H. Alper Guçer, "Removal Of Power Line Interference In Signal-Averaged Electrocardiography Systems," IEEE Trans. Biomed. Eng., Vol. 42, No. 7, Pp. 731–735, Jul. 1995.

Y. Z. Ider And M. C. Saki, "Line Interference Subtraction Filter For Signal Averaged Electrocardiography," In Proc. Comput. Cardiol., 1993, Pp. 799–802.

Iaon Tudosa Narcis Iulian Adochiei And Razian Ciobotarius "Research On Possible Abnormalities Of The ECG Signal Shape" The 7th International Symposium On ADVANCED TOPICS IN ELECTRICAL ENGINERING Upb, Bucharest, May 12-14 2011.

Mohammad Bilal Malik"State Space, Recursive Least Square: Parti", Signal Processing Vol84/9, Pp.1709-1728,2004