



## DESIGNING OF PORTABLE AND LOW COST ECG SIGNAL ACQUISITION SYSTEM

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### ABSTRACT

The accurate Electrocardiogram (ECG) and heart rate information is one of the vital aspects for the different kinds of heart functioning disorder identification. The work proposed a universal portable, low cost system to acquire ECGs. A very simple algorithm is developed which can compensate base line shift, high frequency noise present in the ECG, peak detection without losing any information along with removing some artifacts. The algorithm accomplished with six order polynomial fitting curve for the purpose of removing baseline shift and digital filtering techniques are applied to overcome with high frequency noise and artifacts. The value of the real time heart rate is displayed in digital format along with the ECG if the system is connected with computer.

**Key words-** ECG, portable heart rate monitor, Butterworth filter, Base line shift removal.

### INTRODUCTION

Electrocardiogram is facilitated with real time signal recording feature with all possible signal conditioning and processing techniques and resulting output is obtained as electrocardiograph. The real time heart functioning signal is recorded by this instrument is the function of time. In practical, the recorded ECG signals are very weak signals having very low frequency and high impedance, so it requires signal processing before going to display unit. The plotted signal is illustrated in Fig.1. The real time ECG signal processing and monitoring is very important for bedridden patient such as paralyzed people, aged people, patient under comma and many other patients those are under operation or being bedridden on the ventilator for long times. Different technique is available for ECG signal acquisition, some implementation used single

electrode [3], many of them focus on ECG monitoring for application purpose [4-12]. The continuous or periodically recorded signal can be store for the future application. ECG pulse indicates whether the subject is alive or dead, once the ECG pulse disappears the subject may declare dead there is no need of any other parameter measurement. The positive peak in the plot is known as the R-peak similarly the heart functioning ECG wave is divided into different interval like P-wave interval, PQR-wave interval, T-wave interval and so on. The all ECG wave interval has fixed time width, hence even a small variation in any wave interval represents a specific deficiency or disease in heart functioning. For example, R-to-R interval gives the heart rate in beats per minutes (bpm).

$$\text{Heart Rate (HR)} = \frac{60}{(\text{R-to-R})_{\text{interval}}} \text{ bpm} \quad \dots(1)$$

Equ.1 is illustrated that if there is even a much slight variation in R-to-R interval will come out with large variation in heart rate (HR) and that variation is nothing but a kind of disease or disorder. The normal heart rate of the human being is 72bpm and if the heart rate goes below the 60bpm, it will called bradycardia and if it goes above the 100bpm, it will called tachycardia.

ECG signal acquisition is very important for lethal diseases diagnosis like heart functioning, cardiac output etc. A lots of researches are going on ECG signal processing [1,2]. AC interface, muscles tremor, wandering base line are some common noises (artifacts) which are generally present in any kinds of ECG signal acquisition technique. AC interface is due to power supply frequency, wandering base line interference occurs sue to electrode loss connection and muscles tremor is highly effective because it comes due to muscles uncontrolled function. The muscles tremor cannot remove completely because it's involuntary activity.



Fig. 1. Real time heart rate functioning signal (ECG) is plotted using Cathode Ray Oscilloscope (CRO)

In this advanced research age, a lots of research is going to implement a novel kind of ECG data acquisition circuit which can reduce all possible artifacts up to the zero level. Bioelectrical impedance, strain gauge, surface electrode (Einthoven technique) and many other techniques are using for exact information enhancement. There are several techniques available for ECG signal acquisition but no one technique is completely noise free, all the techniques need signal processing before making any decision about the acquired ECG signal.

## MATERIALS AND METHOD

To create a more accuracy in acquired information we have used MATLAB® for signal processing after using hardware signal conditioning circuitry like amplifier (MCP6004, 386 audio frequency range signal amplifier), filter (RC), analog to digital convertor (Arduino Uno). Since there are lots of high frequencies signals presented in the raw ECG signal so first of all we have to go through filtering (Butterworth filter) unit of MATLAB® of specific cut off frequency then the signal base line shift, signal peak detection and many other processing techniques are applied.

A simple and efficient ECG signal acquisition circuit module is designed with very low cost. The circuit include sensor, amplifier and filtering unit as shown in Fig.2. Surface electrode with proper jelly is used at the point of sensor which is directly interact with the electrical activity of the heart resulting a very week electrical signal is appeared in that surface electrode, so an amplifier is require to amplify this signal up to the specific level before apply any signal processing technique.

Once the signal is amplified, a filter of center frequency 50Hz that is notch filter is used to remove AC artifacts from the raw ECG signal. The breadboard circuit implementation of ECG signal acquisition is illustrated in Fig.2. While the simulated circuit diagram of the implemented ECG circuitry is illustrated in Fig.3 with the all electronics components used.

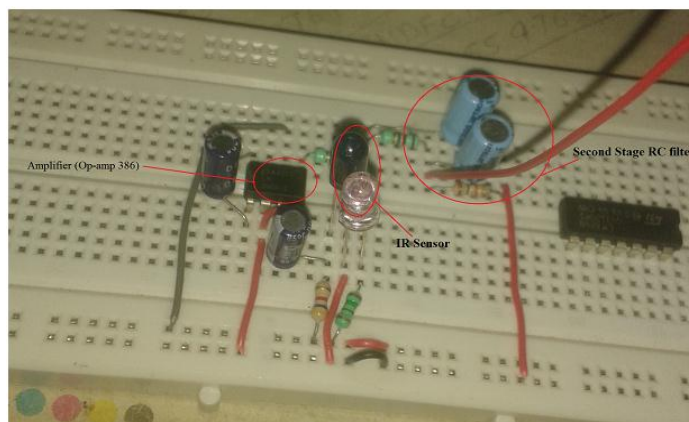


Fig. 2. ECG signal acquisition circuit on breadboard with (I) IR-sensor, (II) amplifier (Op-amp 386), (III) filter (RC-passive). The final output generated across the load is being applying to the input of Arduino Uno for analog to digital conversion and then finally the digital signal is now going to collect in PC.

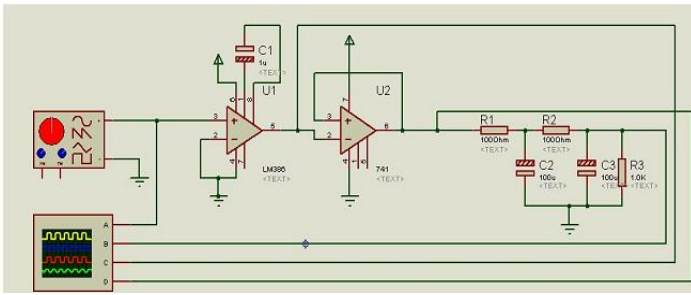


Fig. 3. Simulation of ECG hardware using PROTEOUS

For the testing of the circuit, signal generator is used as the input while the amplified signal is being displayed on the cathode ray oscilloscope (CRO). Since the response of the simulated ECG circuitry is shown in Fig.4. It is well defined itself that the weak input signal is amplified with excellent gain constant and the gain constant can't be changed by changing the feedback resistance or input resistance of the op-amplifier.

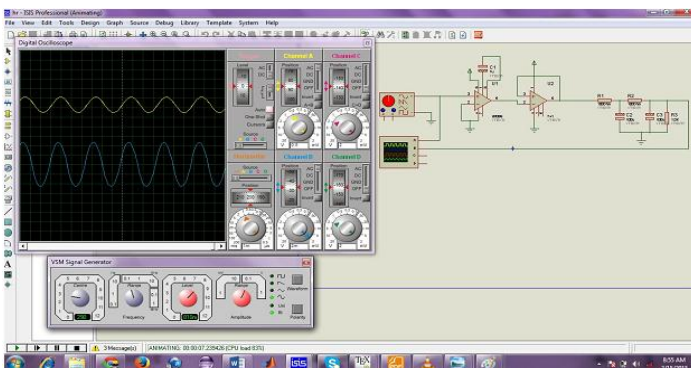


Fig. 4. Simulated response of the ECG circuitry with a very weak sinusoidal signal. (I) The first yellow color signal is input (II) second one blue signal which is strong in nature is output signal

### High frequency noise cancellation

AC or power line artifacts removing technique includes Fast Fourier Transform (FFT) along with the Butterworth filter. Fast Fourier Transform gives the information about the frequencies associated with ECG raw signal. Once the associated frequencies are identified, a suitable band pass Butterworth filter is applied to eliminate the DC range of noise as well as of high frequency noise. The transfer function of the  $N^{\text{th}}$  order Butterworth filter is given in Equ.2. It is well known from the Equ.2 that the  $N^{\text{th}}$  order Butterworth filter will return  $(N+1)$  numerator and denominator coefficient.

$$H(Z) = \frac{b(1)+b(2)z^{-1}+b(3)z^{-2}+\dots+b(n+1)z^{-n}}{1+a(2)z^{-1}+a(3)z^{-2}+\dots+a(n+1)z^{-n}} \dots\dots(2)$$

The recorded ECG raw data is shown in Fig.5 and its fast Fourier transform is also shown. The FFT of the original ECG signal is calculated to finding the frequency components associated with the signal, in doing so the appropriate filter can be apply for noise cancellation. As the Fig.6 itself illustrated that the required information is associated with the high peaks of very low frequency while the rest of the signal are consider as noise. To come out with better efficiency during noise reduction a band pass Butterworth filter of high order is applied, resulting the high frequency as well as the DC noise get eliminated. The filtered signal is shown in the Fig.7 with high precision and accuracy.

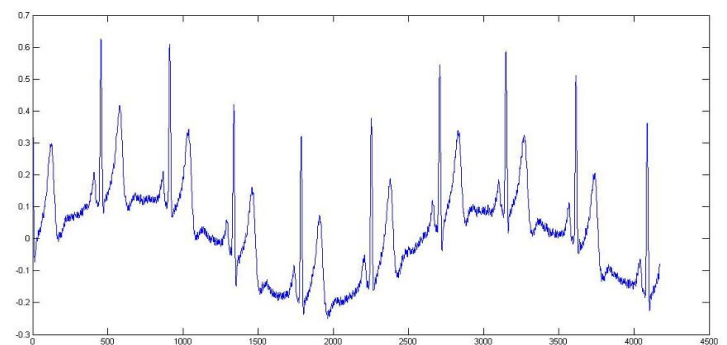


Fig. 5. Recorded ECG raw data, it includes different artifacts like DC, high frequency and muscles tremor etc.

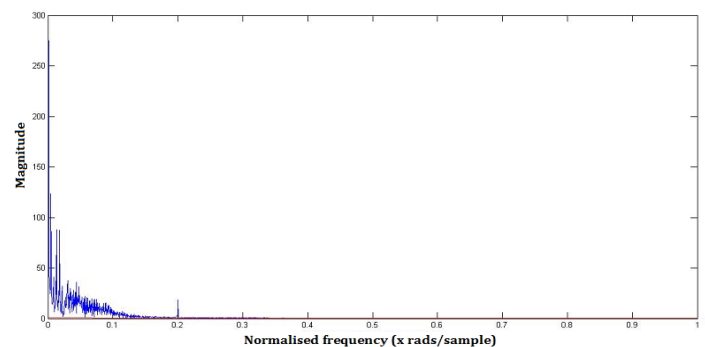


Fig. 6. FFT of the raw ECG data, it gives the information about the associated frequency component in the original ECG signal.

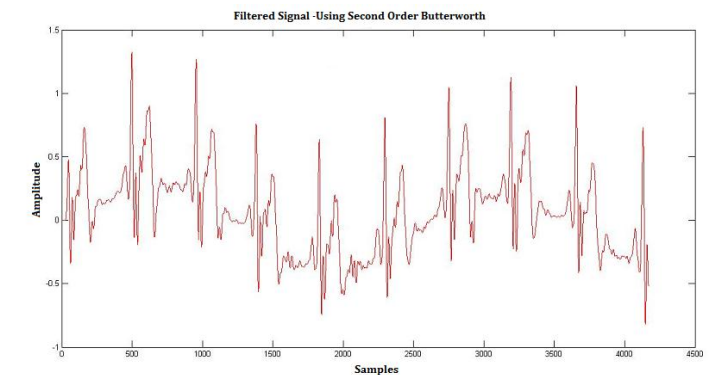


Fig. 7. ECG signal after applying High order Band Pass Butterworth Filter, the DC as well as the high frequency noises are canceled.



## Base Line Shift Estimation

It is also known as the baseline drift. It is a kind of artifact which may appear due to motion of patient or wire. Deep breathing, dirty tips of the electrode and metal dust on the subject skin may also produce baseline drift. Baseline drift only change the level of reference either by plus value or by negative value but it does not make any change in the shape of the signal. As shown in Fig.8, the base line is shifted by negative value so the drifted signal has reference line below zero level still this new reference line is not fixed for each cycle of ECG signal.

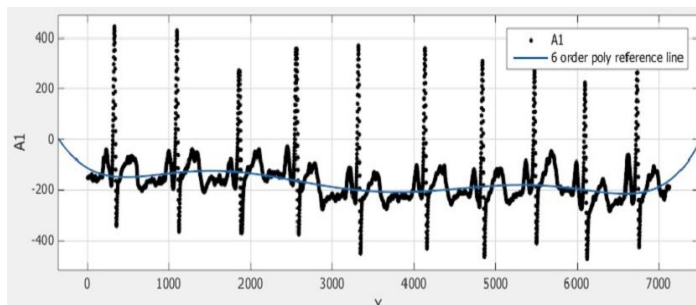


Fig. 8. The plotted ECG raw data signal obtained from subject ECG. 6-order polynomial reference line is nothing but it is the required reference line for baseline estimation.

There are different technique available for curve fitting like Gaussian, polynomial, smoothing spinal etc. among these all technologies the polynomial methods determines the real baseline (i.e. baseline drift) directly on the ECG signal plot of each analyzed signal, so reducing instrumental noise and then improve analytical accuracy. Shown signal in Fig.8 is made estimated by using sixth order polynomial technique. The equation for the sixth order polynomial equation shown in the Equ.3.

$$f(x) = p^1x(X^6) + p^2x(X^5) + p^3x(X^4) + p^4x(X^3) + p^5x(X^2) + p^6x(X^1) + p^7 \quad (3)$$

After applying the sixth order polynomial technique the baseline drift get estimated as shown in the Fig.9.

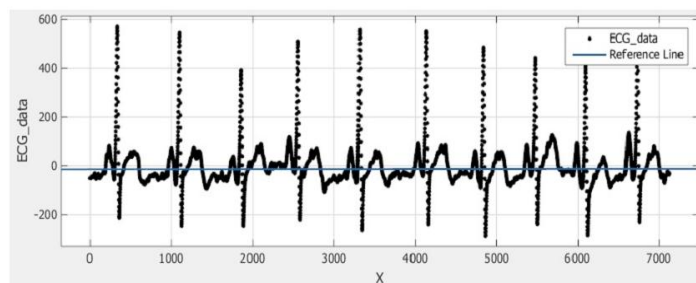


Fig. 9. The plotted ECG with estimated base line shift noise

## ECG peak detection

The heart rate of the patient is calculated just by calculating the R-to-R interval as defined in the Equ.1. R wave is nothing but it is the positive pulse of one millivolt generated in each heart beat due to atrium repolarization and ventricular depolarization of the heart simultaneously. A simple algorithm is used i.e. FOR loop, using the FOR loop the all recorded samples are checked and the value of the counter updated whenever a peak is founded. This process is repeated for certain period of interval. Once the number of peak is detected further the length of the signal is divided by the number of positive peak detected for R-to-R inter calculation. The red dots in the Fig 10 illustrate the detected peaks in the recorded ECG signal.

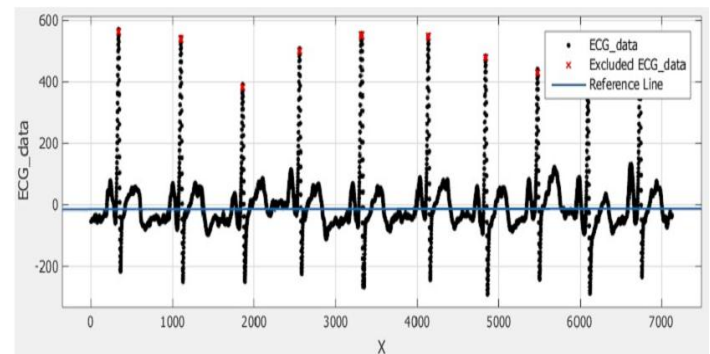


Fig. 10. Detected peaks in the processed ECG signal reveal the R-to-R interval. The each red dots in the figure represents the R ware.

## RESULTS AND DISCUSSIONS

The designed hardware for the ECG signal acquisition is quite simple and cheap with very low cost. It produces very efficient and continuous ECG signal that can be record for further disease diagnosis purpose and real time heart rate monitoring. There have applied sever MATLAB® techniques for processing the ECG signals. The applied processing algorithm is came out with very good and reliable results. The hardware of ECG data acquisition is successfully simulated in the PROTEOUS and the printed circuit board (PCB) is developed ARES Software integrated with PROTEOUS which is illustrated in the Fig.11. The acquired ECG signal from the developed system is illustrated wave form in Fig. 5 having high frequency noise that was removed using properly



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Mr. Uma Shanker Yadav obtained his Bachelor Degree in Electronics and Instrumentation Engineering from Uttar Pradesh Technical University in 2013. Subsequently he was awarded for obtaining 5<sup>th</sup> Rank in the University. He has qualified GATE (Instrumentation and Control) in 2013 and joined Indian Institute of Technology (Banaras Hindu University), Varanasi, Uttar Pradesh as Teaching Assistantship (M.Tech) in Biomedical Engineering. He has developed a completely advanced “Multi-function Hospital/Home Caregiver Bed based on Android Application”. He has presented several paper in several National and International Conferences of repute. Presently he is working on Non-invasive Bioinstrumentation for diagnosis of different lethal diseases.