Portable ECG Electrodes for Detection of Heart Rate and Arrhythmia Classification

[1] K. Jeeva, [2] Dr. D. Selvaraj, [3]Dr. S. Leones Sherwin Vimal Raj
[1]PG Student, [2, 3] Professor, Department of Electronics and Communication Engineering
Panimalar Engineering College,Chennai, India

***Abstract*— Long term continuous monitoring of electrocardiogram (ECG) in a free living environment provides valuable information for prevention on the heart attack and other high risk diseases. This paper presents the design of a real-time wearable ECG monitoring system with associated cardiac arrhythmia classification algorithms. However, these techniques are severely hampered by motion artifacts and are limited to heart rate detection. To address these shortcomings we present a new ECG wearable that is similar to the clinical approach for heart monitoring. Our device weightless and is ultra low power, extending the battery lifetime to over a month to make the device more appropriate for in-home health care applications. The device uses two electrodes activated by the user to measure the voltage across the wrists. The electrodes are made from a flexible ink and can be painted on to the device casing, making it adaptable for different shapes and users. Also show the result of heart rate of beats per minute (bpm) based on the R-R interval (peaks) calculation. That means whether the heart function is normal or abnormal (Tachycardia, Bradycardia).**

Keywords- Tachycardia; ECG; Bradycardia; butterworth;

I. INTRODUCTION

Electrocardiogram (ECG) represents electrical activity of human heart. ECG is composite from 5 waves - P, Q, R, S and T. This signal could be measured by electrodes from human body in typical engagement. Signals from these electrodes are brought to simple electrical circuits with amplifiers and analogue – digital converters. The main problem of digitalized signal is interference with other noisy signals like power supply network 50 Hz frequency and breathing muscle artefacts. These noisy elements have to be removed before the signal is used for next data processing like heart rate frequency detection. Digital filters and signal processing should be designed very effective for next real-time applications in embedded devices. Heart rate frequency is very important health status information. The frequency measurement is used in many medical or sport applications like stress tests or life treating situation prediction. One of possible ways how to get heart rate frequency is compute it from the ECG signal. Heart rate frequency can be detected d from ECG signal by many methods and algorithms. Many algorithms for heart rate detection are based on QRS complex detection and hear rate is computed like distance between QRS complexes. QRS complex can be detected using for example algorithms from the field of artificial neural networks, genetic algorithms, wavelet transforms or filterbanks. Moreover the next way how to detect QRS complex is to use adaptive threshold . The direct methods for heart rate detection are ECG signal spectral analyse and Short-Term Autocorrelation method. Disadvantage of all these methods is their complicated implementation to microprocessor unit for real time heart rate frequency detection. Real time QRS detector and heart rate computing algorithm from resting 24 hours ECG signal for 8-bit microcontroller is described in. This algorithm is not designed for physical stress test with artefacts. The designed digital filters and heart rate frequency detection algorithms are very simple but robust. They can be used for ECG signal processing during physical stress test with muscle artefacts. They are suitable for easy implementation in C language to microprocessor unit in embedded device. Design of these methods has been very easy with Matlab tools and functions.

A. Signal acquisition

ECG signal for digital signal processing and heart rate calculation was acquired by measurement card with sampling frequency fs = 500 Hz. The first ECG lead was measured. Analogue signal pre-processing was done on simple amplifier circuit designated for ECG signal measurement. The circuit with ECG amplifier is fully described in. there is shown raw ECG signal sampled by measuring card. This signal was used as input signal for the digital filters and the heart rate detection algorithms designing and testing.

B. Digital signal processing with digital filters

The main noise elements are power supply network 50 Hz frequency and breathing muscle movements. These artefacts have to be removed before the signal is used for next data processing like heart rate frequency determination. The block schema of digital signal processing with digital filters.

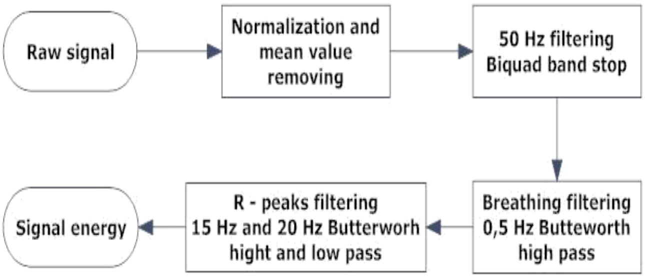

Figure 1. Digital signal processing and digital filters

At the beginning, the mean value is removed from signal. Then signal is normalized for unit maximum amplitude. Network interference at 50 Hz frequency is removed by first filter. This filter type is biquad band stop. Advantage of this filter is very narrow band stop which is created by poles and zeros location. Baseline wander was provided by means of the next filter. This filter is second order Butterworth filter set to frequency of 0.5 Hz. This filter is usually used in professional ECG filtering applications.

II. RELATED WORK

Nowadays, people are getting more and more concern on their own fitness conditions and it has become a digital healthy lifestyle movement. A basic activity tracker has given many data on the user's movement to fulfill their daily goal of calories burned. An advance tracker can also measure heart rate with accurate activity intense level. However, consider if these fitness devices can be used for clinical diagnosis by adding an ECG, then it can be a daily health monitoring or a health assisted device by connecting it to the internet via a smartphone.

To use an ECG as a wearable device, the electrode positions has to fulfill the clinical placement[1]. A new biomedical electrodes placement is proposed in this paper to meet the practicality of a fitness lifestyle device but has a medical ECG result for continuous heart monitoring in a form of a necklace. The device has a single lead ECG analog front end that is connected to an ARM-Cortex M4 microcontroller. It uses a 4 GB memory card, rechargeable battery, and a Bluetooth Low Energy 4.0 to communicate with an Android 4.3 smart phone.

The test results were taken from a 32-year-old male subject with normal heart condition. The signal acquired from the electrode placement at the backside of the neck shows Lead I waveform with 10% from the normal position amplitude value. The R-wave of every heartbeat can be seen for heart rate calculation. Therefore, it is able to do a daily heart monitoring with a lifestyle device.Electrocardiogram (ECG) is a graphic recording of the electrical activity produced by the heart.

The accuracy of any electrocardiogram waveform extraction plays a vital role in helping a better diagnosis of any heart related illnesses[2]. We present a computer-aided application model for detection of cardiac arrhythmia in ECG signal, which consists of signal pre-processing and detection of the ECG signal components adapting Pan-Tompkins and Hamilton-Tompkins algorithms; feature extraction from the detected QRS complexes, and classification of the beats extracted from QRS complexes using Back Propagation Neural Network (BPNN). The application model was developed for ECG signal classification under 'Normal' or 'Abnormal' heartbeats to detect cardiac arrhythmia in the ECG signal[20]. The model was trained with standard arrhythmia database of Massachusetts Institute of Technology Division of Health Science and Technology/Beth Israel Hospital (MIT-BIH), and taking into account the Association for the Advance of Medical Instrumentation (AAMI) standard.

The performance of the developed application model for classification of ECG signals was investigated using the MIT-BIH database. The accuracy of detection and extraction of the signal components and features (based only on the MIT-BIH database used) shows that the developed application model can be employed for the detection of heart diseases in patients. Detection and delineation of Electrocardiogram has played a vital role in cardiovascular monitoring systems.

The enormous database of heart beats which characterize the heart disease, uncertainity, randomness in occurrence of these beats necessitate the use of Rough set theory. Over the years Rough set theory has been effectively used for removal of uncertainties and reduction of dataset .This paper discusses an optimized rough set based algorithm for detection of fiducial points for ten classes of ECG .Fiducial points help determine the peaks, valleys, onset and offset of the waves. Ten morphological features have been identified and investigation of efficiency of Rough set theory to reduce and extract the decision rules from the database has been done.

The experimental results show that the proposed method has sensitivity 48%; average specificity 96% and average detection accuracy 91%.Methods involving the use of evolutionary algorithms have also been a powerful tool for dealing with complex optimization problems[9]. Rough-fuzzy approach accompanied with Ant colony optimization ,Particle swarm optimization and Genetic algorithm as search methods has also been studied. The results obtained by integrating Multilayer Perceptron or Fuzzy-Rough neural network with fuzzy rough approach for attribute selection as well has shown the highest accuracy of around 96%.

III. PROPOSED MODEL

Heart Rate is the number of times that our heart contracts or beats in a minute. Main function of the heart is to maintain adequate blood supply [Heart sends oxygenated blood to the body so that tissues could extract the oxygen for their use]. Therefore the heart rate varies according to demands of body. The normal heart rate at rest for healthy adults, including older-aged adults and kids >10 years is between 60 and 100 heartbeats a minute. Resting heart is the heart rate is the rate at which our heart beats when we are resting or relaxed. When we say normal heart rate, we mostly refer to resting heart rate. With exertion, our heart rate goes up as the demand for oxygen increases and heart, by upping the rate of beating [and pumping blood] tries to meet the demand. Another thing that happens is increased breath rate because lungs function to extract more oxygen from the inhaled air. Anxiety, fear, surprise also lead to increase in the heart rate. This is caused by release of adrenaline or epinephrine in the body, preparing us for fight or flight. The normal heart rate undergoes healthy variation, going up in response to some conditions, including exercise, body temperature, body position (such as for a short while after standing up quickly), and emotion (such as anxiety and arousal).

A. Heart rate and Pulse

Pulse is defined as the number of times arteries expand and contract in response to the heartbeat. This rate is exactly equal to the heartbeat, the rate of heart contractions, because these heart contractions cause the increases in blood pressure and the pulse in the arteries. Pulse, therefore, is a direct measure of heart rate.

The pulse volume may be affected by changes in the arteries. Absence of pulse may indicate a problem in the vessel.

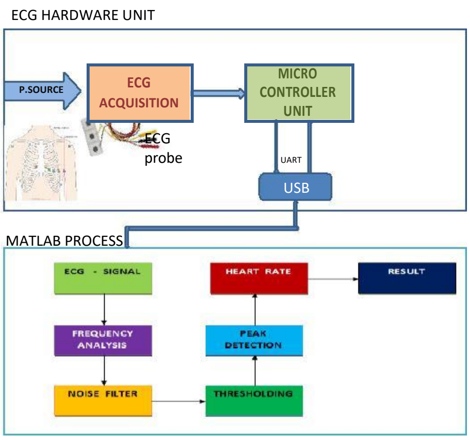

Figure 2. Block diagram for heart rate

Hardware Description

ECG probe

The ECG electrode is fixed on the module, that electrode will continuously monitor the Heart rate.

The ECG(electrocardiogram) Records the heart's electrical activity: Heart beat rate, Heart beat rhythm, Heart strength and timing.

The ECG Electrode is Lead and the signal recorded as the difference between two potentials on the body surface is called an "ECG lead". Each lead is said to look at the heart from a different angle.

The ecg signals from the electrodes are fed into microcontroller and pass the information to mat lab processing.

Data Acquisition

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by system.

Data acquisition system typically convert analog waveform into digital form for easy processing.

Data acquisition systems is advantage as we can store a lots of physical condition data in digital form.

Microcontroller

The electrode is interfaced with microcontroller. The signals from the body is taken by the electrodes, the signals are very weak hence it is given to the amplifier.

The front-end for the signal acquisition system is an instrumentation amplifier. It has a very high common mode rejection ratio (CMRR) and high input impedance which is required for capturing ECG signals.

Along with the signal noise also gets amplified, this noise is removed by band pass filter. Since the acquired signals are weak it is given to the buffer amplifier. The signals are digitized using Analog to Digital Converter(ADC).

Then it is given to USB for mat lab processing.

IV. SIMULATION RESULTS

This example shows how to detect the QRS complex of electrocardiogram (ECG) signal in real-time. Model based design is used to assist in the development, testing and deployment of the algorithm.

The electrocardiogram (ECG) is a recording of body surface potentials generated by the electrical activity of the heart. Clinicians can evaluate an individual's cardiac condition and overall health from the ECG recording and perform further diagnosis.

A normal ECG waveform is illustrated in the following . Because of the physiological variability of the QRS complex and various types of noise present in the real ECG signal, it is challenging to accurately detect the QRS complex.

The Noise sources that corrupt the raw ECG signals include:

Baseline wander

Power line interference (50 Hz or 60 Hz)
Electro myographic (EMG) or muscle
noise Artifacts due to electrode motion
Electrode Contact Noise

The simulation results are in the heart rate calculator in matlab algorithm. In this project matlab 2013a is used. In this we get the result are using butterworth filter for removing the noise.

A. ECG Waveform and ECG FFT Waveform

The figure 3 shows ECG waveform and ECG FFT waveform for heart rate calculation and peak detection.

ISSN: 2278-0181

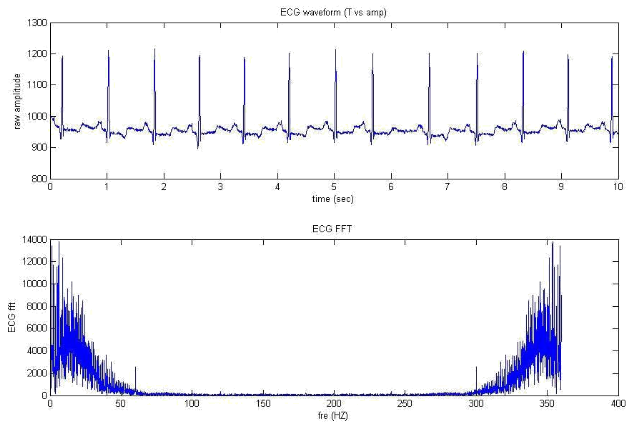

Figure 3. ECG waveform and ECG FFT waveform

B. .Total Filtered Signal

The figure 4 shows total filtered signal waveform for heart rate calculation and peak detection.

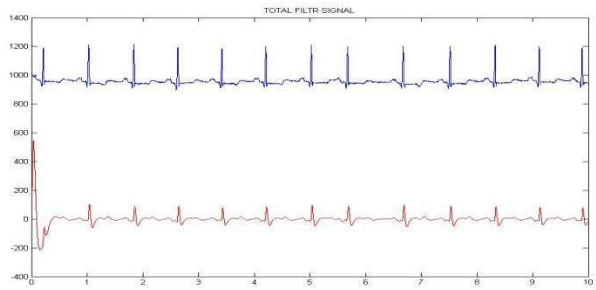

Figure 4. Total Filtered Signal

C. ECG Conditioned Result

The figure 5 shows ECG conditioned result waveform for heart rate calculation and peak detection.

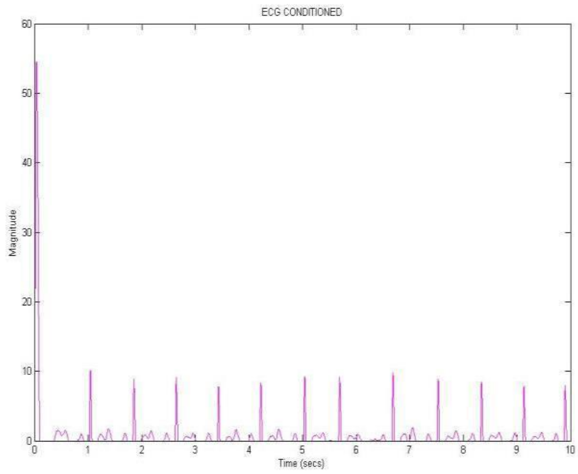

Figure 5. ECG Conditioned Result

D. Peak Detector

The figure 6 shows peak detector waveform for heart rate calculation and peak detection.

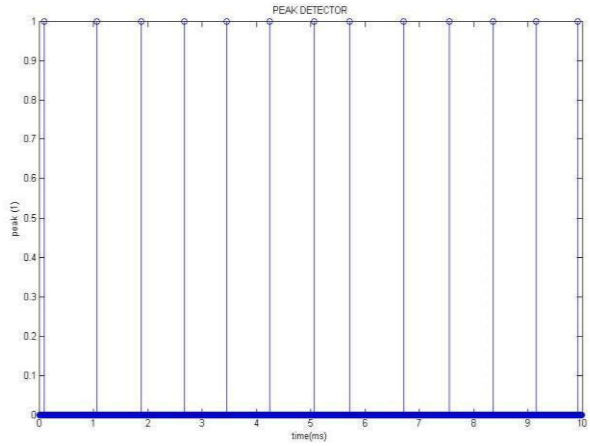

Figure 6. Peak Detector

These are the simulation results of peak detector and heart rate calculator by using the butterworth filter for removing the noise.

V. CONCLUSION

Combined use of MATLAB and Simulink is very useful in ECG signal analysis. Different digital filters are used in simulink to remove noise from raw ECG signal. The noise free ECG signal obtained from filter circuit is used as input for ECG analysis to find various intervals and peaks in MATLAB environment. Many works are done in the field of ECG analysis and they involve complicated calculations and hence difficult to design.

The algorithm used in this work is very efficient and simple, so it can be easily implemented on ECG signal. In this case the waveform is divided into positive and negative parts and each section is analyzed separately. Various peaks are detected by finding local maxima and minima of the signal and then setting minimum threshold limit for them according to the standard values.

The results obtained can be used for clinical diagnosis by the physician and will be very helpful in finding various abnormalities in the heart.

This paper using the Butterworth filter. This Butterworth filter used to remove the noise like interferences and while using electrode that paste also a one type of noise ,so avoid this type of noise this project using the Butterworth filter. In future using the electrodes we get real time ecg signal after that calculate the heart rate.

REFERENCES

[1] Office for National Statistics, “National population projections, 2008-based projections,” Office for National Statistics Statistical Bulletin, Tech. Rep., 2009.

[2] E. Khan et al., “A robust heart rate monitoring scheme using photoplethysmographic signals corrupted by intense motion

artifacts," IEEE Trans. Biomed. Eng., vol. 63, no. 3, pp. 550–562, 2016.

[3] Z. Zhang, Z. Pi, and B. Liu, "TROIKA: A general framework for heart rate monitoring using wrist-type photoplethysmographic signals during intensive physical exercise," IEEE Trans. Biomed. Eng., vol. 62, no. 2, pp. 522–531, 2015.

[4] R. Wang et al., "Accuracy of wrist-worn heart rate monitors," JAMA Cardiology, vol. 2, no. 1, pp. 104–106, 2017.

[5] H. Ra et al., "I am a "smart" watch, smart enough to know the accuracy of my own heart rate sensor," in HotMobile, Sonoma, February 2017.

[6] E. Aguilar-Pelaez and E. Rodriguez-Villegas, "LED power reduction trade-offs for ambulatory pulse oximetry," in IEEE EMBC, Lyon, August 2007.

[7] P. K. Baheti and H. Garudadri, "An ultra low power pulse oximeter sensor based on compressed sensing," in Sixth int. workshop wearable and implantable body sensor networks, June 2009, pp. 144– 148.

[8] J.-C. Hong, P.-H. Lin, and P.-C. Hsieh, "The effect of consumer innovativeness on perceived value and continuance intention to use smartwatch," Comput. Hum. Behav., vol. 67, no. 2, pp. 264–272, 2017.

[9] C. J. Harland, T. D. Clark, and R. J. Prance, "High resolution ambulatory electrocardiographic monitoring using wrist-mounted electric potentialsensors," Meas. Sci. Technol., vol. 14, no. 7, pp. 923–928, 2003.

[10] N. Thakor and J. G. Webster, "Ground-free ECG recording with two electrodes," IEEE Trans. Biomed. Eng., vol. 27, no. 12, pp. 699–704, 1980.

[11] E. Richard and A. D. C. Chan, "Design of a gel-less two-electrode ECG monitor," in IEEE MeMeA, Ottawa, April 2010.

[12] N. J. Fauzani et al., "Two electrodes system: Performance on ECG, FECG and EMG detection," in IEEE SCOReD, Putrajaya, December 2013.

[13] G. Gargiulo et al., "An ultra-high input impedance ECG amplifier for long-term monitoring of athletes," Med. Devices, vol. 3, no. 1, pp. 1– 9, 2010.

[14] C. D. M. Pereira and P. M. Mendes, "Development of a two-electrode ECG acquisition system with dynamic interference rejection," in IEEE ENBENG, Lisbon, March 2011.

[15] B. B. Winter and J. G. Webster, "Driven-right-leg circuit design," IEEE Trans. Biomed. Eng., vol. 30, no. 1, pp. 62–66, 1983.

[16] X. Fafoutis et al., "SPW-1: A low-maintenance wearable activity tracker for residential monitoring and healthcare applications," in Proc. Int. summit on eHealth, 2016, pp. 294–305.

[17] P. Woznowski et al., "SPHERE: A sensor platform for healthcare in a residential environment," in Designing, Developing, and Facilitating Smart Cities: Urban Design to IoT Solutions. Springer International Publishing, 2017, pp. 315–333.

[18] J. Pan and W. J. Tompkins, "A real-time QRS detection algorithm," IEEE Trans. Biomed. Eng., vol. 32, no. 3, pp. 230–236, 1985.

[19] X. Fafoutis, E. Tsimbalo, and R. Piechocki, "Timing channels in bluetooth low energy," IEEE Commun. Lett., vol. 20, no. 8, pp. 1587–1590, 2016.

[20] OKW enclosures. (2017) Home page. [Online]. Available: https: //www.okw.co.uk/en

[21] S. Krachunov and A. J. Casson, "3D printed dry EEG electrodes," Sensors, vol. 16, no. 1635, p. 18, 2016.

[22] Creative materials. (2017) Home page. [Online]. Available: http: //www.creativematerials.com