COMPARISON OF OUTPUT WAVEFORMS OF PHONOCARDIOGRAM AND SOLAR BASED PORTABLE ECG MONITORING SYSTEM

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

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ABSTRACT

The paper deals with Electrocardiogram (ECG) machines observing the electrical

activity of the guts using electrodes on the skin surface and extract vital information about its functionality. Cardiovascular diseases (CVDs) are the number one explanation for death globally, taking an estimated 17.9 million lives annually. CVDs are a gaggle of disorders of the guts and blood vessels and include coronary heart condition , cerebrovascular disease, rheumatic heart condition and other conditions. Four out of 5 CVD deaths are thanks to heart attacks and strokes. In conventional methods, the diagnosis of heart diseases were done by doctors using ECG output. The objective of this paper is to propose a system that will cross verify the doctor’s opinion about the patient's condition. The entire system is composed of an ECG module and GSM module.

An ECG module retrieves and amplifies the bioelectric signals received from the body to enable further processing. Phonocardiogram picks up the heart sounds and converts them into waves. In ECG output, lesser Q-waves, ST-T patterns, and frequent premature beats were related to almost twice greater risk. Among various methods, Artificial neural network classification, low pass filter and wavelet feature extraction have been used to differentiate the normal and abnormal ECG waves. The diseases due to variations in the PQRST waves of ECG signals are also detected with the help of the Arduino programme and displayed in a LCD. The output waves and the disease conditions from both PCG and ECG are compared and the results are obtained.

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LIST OF ABBREVIATIONS

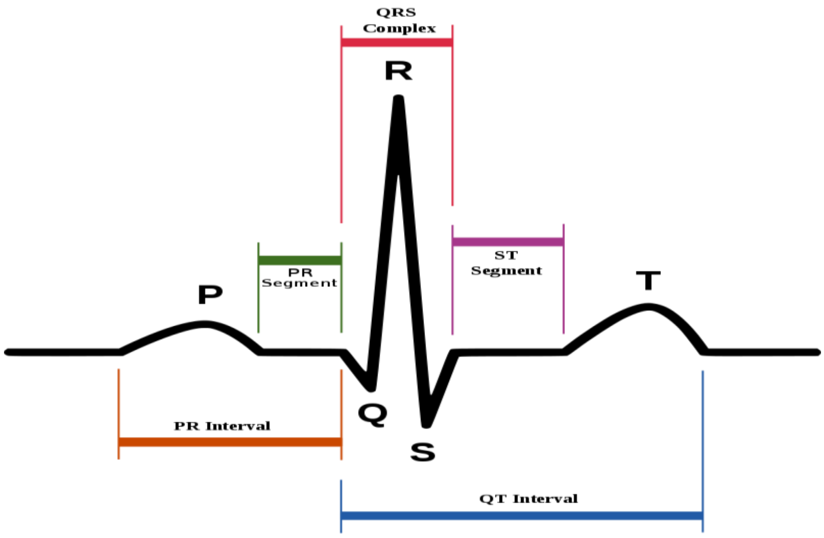
ECG	Electrocardiograph
PCG	Phonocardiograph
DWT	Discrete Wavelet Transform
LCD	Liquid Crystal Display
IOT	Internet Of Things
CWT	Continuous Wavelet Transform
CVD	Cardio Vascular Disease
CRO	Cathode Ray Oscilloscope
GUI	Graphical User Interface
BLE	Bluetooth Low Energy
FFT	Fast Fourier Transform
RA	Right Arm
LA	Left Arm
LL	Left Leg
ANN	Artificial Neural Network
SVM	Support Vector Machine
ELM	Extreme Learning Machine
LVQ	Linear Vector Quantization
SOM	Self Organizing Map
IDE	Integrated Development Environment
USB	Universal Serial Bus
LPF	Low Pass Filter
HPF	High Pass Filter

CHAPTER 1

INTRODUCTION

The electrocardiogram (ECG) has played an important role in the understanding of cardiovascular diseases. It has broad applications in the clinical diagnosis and prognosis of cardiovascular diseases, as well as in health assessment, biomedical recognition, fatigue study, and other areas. Electrocardiography is the process of producing an electrocardiogram . It is a graph of voltage versus time of the electrical activity of the heart using electrodes placed on the skin. These electrodes detect the small electrical changes that are a consequence of cardiac muscle depolarization followed by repolarization during each cardiac cycle . Changes in the normal ECG pattern occur in numerous cardiac abnormalities, including cardiac rhythm disturbances such as atrial fibrillation and ventricular tachycardia, inadequate coronary artery blood flow such as myocardial ischemia and myocardial infarction, and electrolyte disturbances such as hypokalemia and hyperkalemia.

In a conventional 12-lead ECG, ten electrodes are placed on the patient's limbs and on the surface of the chest. The overall magnitude of the heart's electrical potential is then measured from twelve different angles and is recorded over a period of time usually ten seconds. In this way, the overall magnitude and direction of the heart's electrical depolarization is captured at each moment throughout the cardiac cycle.The three main components of ECG include the P wave, which represents the depolarization of the atria; the QRS complex, which represents the depolarization of the ventricles; and the T wave, which represents the re polarization of the ventricles.



1.1 ECG WAVEFORM

The electrocardiogram (ECG) has played an important role in the understanding of cardiovascular diseases. It has broad applications in the clinical diagnosis and prognosis of cardiovascular diseases, as well as in health assessment, biomedical recognition, fatigue study, and other areas. diagnosis of LQTS. In 1959, Prinzmetal first described a variant angina pectoris condition that manifested as ST segment elevation rather than typical angina with ST segment depression. In the 1960s, the now- retired cardiologist treated the typical heart attack patient: male, about 50 years old, obese, with high blood pressure, high cholesterol and a sedentary lifestyle. The patient would stay in hospital for weeks and he might not even return to work. There was no specific treatment for heart disease at the time – no coronary care unit in the hospital, stents, angioplasty, pacemakers or drugs to correct heart arrhythmia or blood pressure. Electrocardiography, nowadays, is an essential part of the initial evaluation for patients presenting with cardiac complaints. As a first line diagnostic tool, health care providers at different levels of training and expertise frequently find it imperative to interpret electrocardiograms.

It is likely that an understanding of the electrical basis of electrocardiograms would reduce the likelihood of error. Electrocardiographs are recorded by machines that consist of a set of electrodes connected to a central unit. Early ECG machines were constructed with analog electronics where the signal drove a motor to print out the signal onto paper. Today, electrocardiographs use analog-to-digital converters to convert the electrical activity of the heart to a digital signal. Many ECG machines are now portable and commonly include a screen, keyboard, and printer on a small wheeled cart. Recent advancements in electrocardiography include developing even smaller devices for inclusion in fitness trackers and smart watches. These smaller devices often rely on only two electrodes to deliver a single lead I.Portable six-lead devices are also available. Recording an ECG is a safe and painless procedure. The machines are powered by mains power but they are designed with several safety features including an earthed lead.

1.2 POTABLE ECG MACHINE

Electrodes are the actual conductive pads attached to the body surface. Any pair of electrodes can measure the electrical potential difference between the two corresponding locations of attachment.
Such a pair forms a lead. However, leads can also be formed between a physical electrode and a virtual electrode, known as the Wilson's central

terminal, whose potential is defined as the average potential measured by three limb electrodes that are attached to the right arm, the left arm, and the left foot, respectively.Commonly, 10 electrodes attached to the body are used to form 12 ECG leads, with each lead measuring a specific electrical potential difference. An understanding of the disorders behind electrocardiographic phenomena could reduce the need for memorizing what may seem to be an endless list of patterns. Electrocardiograms provide a window to cardiac condition through electrical activity at the surface of the skin, but requiring hospital visits for routine monitoring can be expensive, time- consuming, and frustrating. Therefore, having access to intelligent hardware and software packages that are portable, cheap, and user- friendly would allow patients to monitor themselves and get access to health care when use of the device suggests a problem. Signs of abnormal cardiac behavior would prompt the user to visit the hospital for perhaps a 12-lead ECG.

A phonocardiogram or PCG is a plot of high-fidelity recording of the sounds and murmurs made by the heart with the help of the machine called the phonocardiograph; thus, phonocardiography is the recording of all the sounds made by the heart during a cardiac cycle.The sounds result from vibrations created by closure of the heart valves, there are at least two: the first when the atrioventricular valves (tricuspid and mitral) close at the beginning of systole and the second when the aortic valve and pulmonary valve (semi lunar valves) close at the end of systole. It allows the detection of sub audible sounds and murmurs, and makes a permanent record of these events.

In contrast, the stethoscope cannot always detect all such sounds or murmurs, and it provides no record of their occurrence. The ability to quantitate the sounds made by the heart provides information not readily available from more sophisticated tests, and it provides vital information about the effects of certain drugs on the heart. It is also an effective method for tracking the progress of the person's disease.

Figure 10. Power Spectrum of the heart sounds shown above.

1.3 POCKET PC

Thus the aim of this paper is to propose a system that may help the doctors to cross - verify their opinion. The system will be able to diagnose the diseases from the ECG signals obtained. The diseases will be displayed in the LCD. Another goal of this paper is that the ECG signals derived through electrodes and the phonocardiogram signals derived from stethoscope are compared to ensure better results.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE SURVEY

1. Smart Detection and Transmission of Abnormalities in ECG via Bluetooth(Pavan Lakshmi Penmatsa, Dr.D.V. Rama Koti Reddy)

Technology plays the major role in healthcare not only for sensory devices but also in data transfer accordingly and displaying it. Networked sensors, either worn on the body or embedded in our living environment, makes it possible for gathering rich information indicative of our physical and mental health in a smart approach. In this paper the Arduino based microcontroller is used as a gateway to communicate to the various sensors such as temperature sensor, ECG Sensor and pulse oximeter sensor etc. The microcontroller picks up the sensor data and sends it to the network through Bluetooth using Bluetooth module interfaced to Arduino.This paper mainly explains about detection of abnormalities in heart through specially designed ECG circuit and transmission of data to smart phone via Bluetooth. Hence provides real time monitoring of the health care parameters for doctors and care takers where data can be accessed anytime. This system is efficient with low power consumption capability, easy setup, high performance and time to time response. This paper explains in brief how IoT functions and how it is used in conjunction with wireless and sensing techniques to implement the desired healthcare applications.It uses the Arduino based microcontroller as a gateway to communicate the various sensors such as temperature sensor, ECG sensor ,pulse oximeter sensor and to detect the abnormalities in heart through specially designed ECG circuit and transmission of data to smart phone via Bluetooth.The limitation of this system is short range of communication.

2.Portable ECG Measurement Device based on MSP430 MCU (Hong Ming, Zhang Yajun, Hu Xiaoping)

We design a portable measurement device which can monitor electrocardiograph (ECG) and analyze arrhythmia. It is small, light, lower power, and consists of two parts: the main system and the sub. The device gets ECG signals by the electrode sticking to the chest skin. This make the device is suitable for monitoring in long time. 16-bits MCU-MSP430 is the most important part. Besides, there are amplifier circuit, filter circuit, wireless transmitting-receive circuit, data management part, keyboard and LCD display part, etc. The device can detect QRS complex and analyze ECG signals in real-time. For the MIT-BIH database and actual persons, the accuracy of monitor reaches above 99 percent of the QRS complex of ambulatory ECG signals

Low-Power Wearable ECG Monitoring System for Multiple-Patient Remote Monitoring(Elisa Spano, Stefano Di Pascoli, Giuseppe Iannaccone)

The paper proposed an ECG remote monitoring system that is dedicated to non technical users in need of long term health monitoring in residential environments and is integrated in a broader Internet Of Things(IOT) infrastructure. The limitations associated with this system are low robustness, least reliability, correlation problem.

4.Fetal Heart Rate Monitoring System with Mobile Internet(Wendi Yang, Kai Yang, Hanjun Jiang, Zhihua Wang, Qingliang Lin, WenJia)

The fetal heart rate is vital for monitoring fetal well-being. Fetal heart rate monitoring based on acoustic techniques is passive and noninvasive. In this work, a fetal heart rate monitoring system based on phonocardiographic method is proposed. A portable low-power stethoscope is customized which meets the need for sensitivity in the monitoring. A noise cancellation method and adaptive matching method are applied to extract the fetal heart rate effectively. Clinical trials are carried out on pregnant women, and the comparison of fetal heart rates given by the proposed system with those given by the Doppler monitor is given to show the accuracy.

5.A Review On Design of Portable ECG System(Vidhyashree K N, Dr. B.S Sathyanarayana, Dr. S. C. Prasanna Kumar, Dr. B.G Sudharshan)

The electrical activity of the heart is represented by the ECG signal. A wide range of heart conditions can be detected by ECG interpretation. Hence it is increasingly being used in medical sciences and technology as a valuable diagnostic tool. The commonly used ECG-machine used for diagnosis and supervision at the present is expensive and stationary. The design of a portable , affordable, user friendly ECG monitor system that can be manageable by common man is a great research area. This paper presents review on the considerations for design of portable ECG machine, which mainly deals with the circuitry of ECG machine, such as electrodes, analog front end unit, processing and display units. By choosing the appropriate components a portable ECG machine can be constructed. This paper presents review on the considerations for design of portable ECG machine, which mainly deals with the circuitry of ECG machine, such as electrodes, analog front end unit, processing and display units.

6.An Automated Methodology for Fetal Heart Rate Extraction From Abdominal Electrocardiogram (Evaggelos, C.Karvounis Dimitrios, I.Fotiadis)

This paper introduces an automated methodology for the extraction of fetal heart rate from cutaneous potential ab- dominal electrocardiogram (abdECG) recordings. A three-stage methodology is proposed. Having the initial recording, which con- sists of a small number of abdECG leads in the first stage, the maternal R-peaks and fiducial points (QRS onset and offset) are detected using time–frequency (t–f) analysis and medical knowl- edge. Then, the maternal QRS complexes are eliminated. In the second stage, the positions of the candidate fetal R-peaks are lo- cated using complex wavelets and matching theory techniques. In the third stage, the fetal R-peaks, which overlap with the mater- nal QRS complexes (eliminated in the first stage) are found using two approaches: a heuristic algorithm technique and a histogram- based technique. The fetal R-peaks detected are used to calculate the fetal heart rate. The methodology is validated using a dataset of eight short and ten long-duration recordings, obtained between the 20th and the 41st week of gestation, and the obtained accuracy is 97.47%. The proposed methodology is advantageous, since it is based on the analysis of few abdominal leads in contrast to other proposed methods, which need a large number of leads.Also proposed a methodology for the automated extraction of fHR from the abdECG signal has been developed. The methodology is based on t–f analysis and CCWT. The major drawback of the proposed method is the difficulty to extract the fR-peaks in noisy background or in cases where the fECG is not easily distinguishable.

Solar ECG Acquisition System (Vispute Deepali Dilip, Prof. S.T. Khot)

Cardiovascular (CVD) disease causes many people dying every year and these are sudden events hence can cause immediate death if not diagnosed early. Electrocardiogram (ECG) is the best available option today for diagnosis of heart and problems related to it. But conventional methods for ECG monitoring are based on line voltage so, it can contain noise and ECG signals are very sensitive to noise. It should be accurate for the diagnosis of the problems related to heart. Hence the system proposed here is based on solar power. The line voltage noise can be removed by this and the accuracy of signal increases. Today also there are many areas present in the world where electricity is not present. Such remote areas are not accessible for the advanced equipments like ECG monitoring device. Also, the tests with these equipments are so expensive, that poor people cannot afford it. Hence the system proposed here will provide the solution for this problem, that anyone can observe their own ECG. The system mainly consists of solar cell and batteries which provides the power to the acquisition system. The system output has been checked on digital CRO. It gives the ECG signal waveform. Testing of the system is done with digital CRO later the output can be provide to the mobile phone and further study of the ECG can be done with that. The initial stages of heart attack or heart problems can be detected with this and accordingly the help can be provided.Also proposed the ECG system based on solar power ,to remove the line voltage noise and to increase the accuracy of the signal.The limitation of this system is the occurence of noisy signal when transmitted on mobile phone.

Design of an ECG system (K.Krishna Bai, SC Prasanna Kumar, BS Sathayanarayana & BG Sudharshan)

The paper proposed a system that uses compact low power embedded hardware technology and advanced signal platform that led a way to design a more efficient ECG system.

9.A wearable, Low-Power, Real-Time ECG Monitor for Smart T-Shirtand IoT Healthcare Applications(Taiyang Wu, Jean-Michel Redoute, Mehmet Yuce)

A wearable health monitoring system combined with Internet of Things (IoT) is going to be a promising alternative to the conventional healthcare systems. In this work, a small, flexible and wearable real-time electrocardiograph (ECG) moni- toring system integrated on a T-shirt is proposed. It uses an off-the-shelf biopotential analog front end (AFE) chip, AD8232, to collect subjects' ECG data with satisfactory quality. The collected ECG data are transmitted through Bluetooth low energy (BLE) to an end device for real-time display. A PC graphical user interface (GUI) and a smartphone application are designed for indoor and outdoor real-time visualisation respectively. The power consumption of the proposed wearable ECG monitoring system can be as low as 5.2 mW. Powered by a 240 mAh rechargeable battery, it can operate for more than 110 h continuously. To prolong the lifetime of the battery, a flexible solar energy harvester is also adopted within this system.And proposed a small, flexible, wearable real time ECG monitoring system integrated on T-shirt and to transmit the collected data through Bluetooth Low Energy(BLE) for real time display.The limitations of this system is to cause discomfort to patients due to the presence of wet electrodes.

10.Design of a Solar-Powered Portable ECG Device with Optimal Power Consumption and High Accuracy Measurement(Ngoc Thang Bui,Tan Hung Vo,Byung-Gak Kim, Junghwan Oh)

It use solar energy as a main power source for heart rate monitoring and to assist doctors in analyzing ECG signals with high accuracy via embedded operating software. Reduced software enhancement for detection of abnormalities includes the limitation of this system.

11.ECG Monitoring Using Android Mobile Phone and Bluetooth(Samuel E. de Lucena, Daniel J.B.S.Sampaio,Benjamin Mall)

This paperwork describes the development and test of circuitry and software to enable the use of Android mobile phones equipped with Bluetooth to receive the incoming electrocardiogram (ECG) signal from a user and show it in real- time on the cell phone screen. The system comprises three distinct subsystems. The first one is dedicated to condition the analog ECG signal, preparing it for conversion to the digital world. The second one consists of a microcontroller and a Bluetooth module. This unit samples the ECG, serializes the samples and transmits them via the Bluetooth module to the Android cell phone. The third subsystem is the cell phone itself. An application program written to the cell phone receives the ECG samples and suitably charts the ECG signal on the screen for analysis. The good quality of the ECG signal allows for identification of arrhythmias.It comprises the system to condition the analog signals to convert it into digital one,to use microcontroller and Bluetooth module to transmit the signal via bluetooth to the android cell phone.Reduced Transmission rate, Short range communication includes some of the limitations.

Low Powered Solar ECG with ZigBee Based Bio-Telemetry(Parin Dedhia,Harsh Doshi,Mrunal Rane)

It proposed a system to acquire the ECG for more than 30 hours and to transmit wirelessly via ZigBee. Functionality of the software is less in this system.

13. **Electronic Stethoscope With Wireless Communication to a Smart-phone, Including a Signal Filtering and Segmentation Algorithm of Digital Phonocardiography Signals (Reynolds Jorge, Forero Jose,Botero Juan)**

This paper describes the construction of an elec- tronic stethoscope prototype, able to amplify and filter several sounds in order to obtain heart sounds captured by a micro- phone attached to a conventional stethoscope chest piece, using the diaphragm; sending wirelessly, over Bluetooth, this data to an android smartphone app, capable to play and plot the sound, acting as a Phonocardiogram(PCG); and parallel, the develop- ment of a software designed to denoise sound signals through Wavelet Filters, in order to migrate this algorithm to the phone app. We obtained an acceptable sound acquisition to identify cardiac activity, however, without an optimum audio fidelity and contaminated signals due to noise addition in the wireless trans- mission to the phone. On the other hand the development of the signal processing is divided on 3 main steps: the fist one is the normalization of the signal, the second is the PCG denoising and the last one is the identification of different sounds with the en- velope. We obtain the peaks of the normal heart sounds, base for the sound segmentation. This project must continue under research in order to improve transmission quality, and adapta- tion of filtering software into the app, moreover, integrate to the developed software a comparison algorithm for the detection of pathologies and achieve an application of suggested diagnosis, as final target of this investigation on long term.It describes the construction of an electronic stethoscope prototype, able to amplify and filter several sounds in order to obtain heart sounds captured by a microphone attached to a conventional stethoscope chest piece, using the diaphragm; sending wirelessly, over Bluetooth, this data to an android smartphone app, capable to play and plot the sound, acting as a Phonocardiogram.

14.The Improvement of Phonocardiograph Signal (PCG) Representation Through the Electronic Stethoscope(Sumarna, Juli Astono,Agus Purwanto)

A conventional stethoscope (an acoustic stethoscope) is an acoustic medical device that is always used for preliminary examination of patients with any heart abnormalities. The main disadvantage of acoustic stethoscope is its dependence on how to use it and the experience of the examining physician. This paper presents a simple electronic stethoscope design in Phonocardiograph system that is free from subjectivity of doctors or other medical personnel. This electronic stethoscope is made sensitive in order to capture as many acoustic signal as possible from the activities of the human body, especially the heart and lungs. The design of this electronic stethoscope consists of chest piece, a pipe with proper acoustic impedance, mic condenser, mic preamp, and battery. The output of the mic preamp is connected to the mic channel on the laptop. The recording signal then processed separately. The repeatability of output signal was investigated in this paper. The signal was analyzed by using the Fast

Fourier Transform (FFT). The result showed that the frequency response of the output signals are consistent, hence the instrument is reliable. Furthermore, the frequency response of the system with filter that connecting chest piece and mic condensor were also investigated.It presents a simple electronic stethoscope design in Phonocardiograph system that is free from subjectivity of doctors or other medical personnel.

A Systemic Review on the Technological Development in the field of Phonocardiogram (Subhashis Maitra, Deepneha Dutta)

Medical advancement in the field of computation and technology has made the process of continuous surveillance of an individual's health much easier and pocket friendly. Three of the well approved tests by medical personnel to assess the cardiac health of an individual are the Holter Monitoring, Phonocardiogram and the 12 lead Electrocardiograph. In urban India, due to busy lifestyle, people suffer from lack of time, whereas, in rural India there is a huge lack of awareness regarding health and also there are a very few number of health centers to guide the rural people with proper medical assistance. This has lead to an unexpected rise of cardiovascular diseases, leading to death. This paper provides a comprehensive review on the various articles published, concentrating on the key factors revolving around the tele-monitoring of an individual's cardiac condition by designing a cardiac abnormality detector using the electronic stethoscope.It provides a comprehensive review on the various articles published, concentrating on the key factors revolving around the tele-monitoring of an individual's cardiac condition by designing a cardiac abnormality detector using the electronic stethoscope.

Authors	Title	Methodology	Limitation
1. Vispute Deepali Dilip 2. Prof. S.T. Khot	Solar ECG Acquisition System	Signal Acquisition	Noisy signal when transmitted on mobile phone
1. Pavan Lakshmi Penmatsa 2. Dr.D.V. Rama Koti Reddy	Smart Detection and Transmission of Abnormalities in ECG via Bluetooth	Data Acquisition, Analysis and Data transfer	Short range communication
1. Taiyang Wu 2. Jean-Michel Redoute 3. Mehmet Yuce	A wearable, Low-Power, Real-Time ECG Monitor for Smart T-Shirt and IoT Healthcare Applications	Data Acquisition, Processing, Transmission, Visualisation	Wet electrodes cause dscomfort to patients
1. Elisa Spano 2. Stefano Di Pascoli 3. Giuseppe Iannaccone	Low-Power Wearable ECG Monitoring System for Multiple-Patient Remote Monitoring	Data Acquisition, Data compression, Transmission	Less Robust, Least reliable, Correlation problems

Authors	Title	Methodology	Limitation
1. Samuel E. de Lucena 2. Daniel J.B.S.Sampaio 3. Benjamin Mall	ECG Monitoring Using Android Mobile Phone and Bluetooth	Data Acquisition, Sampling, Transmission	Reduced Transmission rate, Short range communication
1. Parin Dedhia 2. Harsh Doshi 3. Mrunal Rane	Low Powered Solar ECG with ZigBee Based Bio-Telemetry	Signal Acquisition, Conditioning, Digitizing, Transmission	Functionality of the software is less
1. Reynolds Jorge 2. Forero Jose 3. Botero Juan	Electronic Stethoscope With Wireless Communication to a Smart-phone, Including a Signal Filtering and Segmentation Algorithm of Digital Phonocardiography Signals	Pre-amplification, Filteration, Amplification, Transmission	Reduced Transmission Quality
1. Sumarna 2. Juli Astono 3. Agus Purwanto	The Improvement of Phonocardiograph Signal (PCG) Representation Through the Electronic Stethoscope	Pre-amplification, Storage, Amplification, Filteration	Accuracy is less

2.2 PROBLEM IDENTIFIED

All the existing systems have a minimum of one limitation either in accuracy, functionality, transmission bandwidth or reliability. To overcome the maximum number of limitations, we have proposed this system of cost efficient ECG.

CHAPTER 3

METHODOLOGY

3.1 ECG ACQUISITION SYSTEM

Biosignals are recorded as potentials, voltages, and electrical field strengths generated by nerves and muscles. The measurements involve voltages at very low levels, typically ranging between 1 μV and 100 mV, with high source impedances. Bio signals need to be amplified to make them compatible with devices such as displays, recorders, or A/D converters for computerized equipment. Amplifiers adequate to measure these signals have to satisfy very specific requirements. They have to provide amplification selective to the physiological signal, reject noise and interference signals.

ECG mainly uses 3 electrodes (RA, LA and LL) Monitor displays the bipolar leads (I, II and III) To get best results, electrodes are placed on the chest wall equidistant from the heart. The ECG acquisition system consisting of instrumentation amplifier amplifies the potentials and which is used to reject the common mode signals collected from electrodes with the gain of 364.

Add conductive adhesive gel to the electrodes before placing them on the patient. Then, connect the electrodes to the circuit using wires with alligator clips. Turn on the oscilloscope and acquire the ECG signal. Adjust the horizontal and vertical scales as needed. The ECG signals are acquired by the two sensing electrodes attached on the human body, then forwarded into the ECG detector.

3.2 ARTIFICIAL NEURAL NETWORKS

To achieve the automatic classification of ECG signals, scientists have proposed several methods to automatically classify heartbeats, including the Fourier transform, principle component analysis, wavelet transform, and the hidden Markov method. Moreover, machine learning methods, such as artificial neural networks (ANNs), support vector machines (SVMs), least squares support vector machines (LS-SVMs), particle swarm optimization support vector machines (PSO-SVMs), particle swarm optimization radial basis functions (PSO-RBFs), and extreme learning machines (ELMs), have also been developed for the accurate classification of heartbeats. Several classification techniques can be used for ECG classification including Support Vector Machines (SVM), decision tree, neural network, nearest neighbors, etc . Linear discriminant analysis is a linear classifier that minimizes the interclass variance and maximizes the mean values of the two classes to find a line in lower dimension of feature space. They do not take into account the difference between adjacent sample points. Support Vector Machines (SVM) on the other hand use the adjacent sample points to draw a discriminatory line used for classification. SVM is considered to give higher accuracies and hence is preferable. Artificial Neural Networks. ANN classifiers can be fed by various parameters three of which can be spectral entropy, Poincare plot geometry, and largest Lyapunov exponent.

The analysis of ECGs can benefit from the wide availability of computing technology. This paper presents some results achieved by carrying out the classification tasks of equipment integrating the most common features of the ECG analysis: arrhythmia, myocardial ischemia, chronic alterations. Several ANN architectures are implemented, tested, and compared with competing alternatives. The approach, structure, and learning algorithm of

ANNs are designed according to the features of each particular classification task. The trade-off between the time consuming training of ANNs and their performance is also explored. Data pre- and post-processing efforts for system performance are critically tested. The crucial role of these efforts for the reduction of input space dimensions, for a more significant description of the input features, and for improving new or ambiguous event processing is also documented. Finally, algorithm assessment is done on data coming from available ECG databases.

3.3 FEATURE EXTRACTION

The raw ECG signal is processed to filter out noise and extract the RR interval using Pan Tompkins algorithm which is further used to extract 15 features out of each signal. The extracted features are fed into 4 different neural networks for training and are then validated using various test files. The accuracy is calculated for each neural network and each disease. The same process is performed for the proposed classification technique as well and the results are compared. ECG signal includes noise as a part of the signal which needs to be removed before processing is done on it for feature extraction. Pan-Tompkins algorithm is a real-time algorithm for detection of the QRS complexes of ECG signals developed by Jiapu Pan and Willis J. Tompkins. It reliably recognizes QRS complexes on the basis of digital analysis of slope, amplitude, and width. In this algorithm, a special digital band pass filter reduces false detections which are caused by the various types of interferences present in ECG signals. This filtering allows the use of low thresholds, and hence helps in increasing the detection sensitivity.

Feature Extraction aims to reduce the number of features in a data set by creating many new features from the current ones (and then discarding the original features). The new reduced set of features should be able to summarize the information contained in the original set of features. By doing this, new version of the original features can be created from a combination of the original set.

A Mathematical morphology for ECG feature extraction to evaluate the classification performance of an automatic classifier of the electrocardiogram (ECG) for the detection abnormal beats with new concept of feature extraction stage was proposed. The obtained feature sets were based on ECG morphology and RR-intervals. Configuration adopted a well known Kohonen self-organizing maps (SOM) for examination of signal features and clustering. A classifier was developed with SOM and learning vector quantization (LVQ) algorithms using the data from the records recommended by ANSI/AAMI EC57 standard.

A feature extraction method using Discrete Wavelet Transform (DWT) to extract the relevant information from the ECG input data in order to perform the classification task. In the feature extraction module the Wavelet Transform (DWT) is designed to address the problem of non-stationary ECG signals. It was derived from a single generating function called the mother wavelet by translation and dilation operations. Using DWT in feature extraction may lead to an optimal frequency resolution in all frequency ranges as it has a varying window size, broad at lower frequencies, and narrow at higher frequencies. The DWT characterization will deliver the stable features to the morphology variations of the ECG waveforms.

3.4 FILTERING

Filtering on an ECG is done four fold: high-pass, low-pass, notch, and common mode filtering. High-pass filters remove low frequency signals (i.e. only higher frequencies may pass), and low-pass filters remove high frequency signals. The high-pass and low-pass filters together are known as a bandpass filter, literally allowing only a certain frequency band to pass through. The notch filter is used to eliminate the line frequency and is usually printed on the ECG (e.g. ~60 Hz). Common mode rejection is often done via right-leg drive, where an inverse signal of the three limb electrodes are sent back through the right leg electrode.

All filters introduce distortion in the resulting output signal. This distortion can be in amplitude or phase. Filters found in cardiac monitors need to be real time and thus cannot tolerate delays. Because of this, the filter output exhibits non-linear characteristics due to their required shorter delays. Basically, they distort different frequencies differently causing phase distortion. If the filters were applied during post-processing, where real-time output of the signal is unnecessary, the design of these filters can be linear which minimizes phase distortion.

Low-pass filters on the ECG are used to remove high frequency muscle artifact and external interference. They typically attenuate only the amplitude of higher frequency ECG components. Analog low-pass filtering has a noticeable affect on the QRS complex, epsilon, and J-waves but do not alter repolarization signals.

High-pass filters remove low-frequency components such as motion artifact, respiratory variation, and baseline wander. Unlike low-pass filters, analog high-pass filters do not attenuate much of the signal. However, analog high-pass filters suffer from phase shift affecting the first 5 to 10 harmonics of the signal. This means that a 0.5 Hz high pass filter, which is a lower frequency than the myocardium produces, still can affect frequencies up to 5 Hz!

If a linear-phase high-pass filter is used, such as on a post-processed ECG, the frequency cutoff can be as high as 0.67 Hz without affecting ventricular repolarization at normal heart rates. However, because this filter design requires delays which do not permit real time display of the ECG signal, they are not commonly used in cardiac monitors. If a non-linear high-pass filter is used, the cutoff should be set to 0.05 Hz in order to minimize distortion to the ST-segment (10 times 0.05 Hz is 0.5 Hz, which is below physiological heart rates).

3.5 ARDUINO IDE 1.8.12

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++.[2] It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. By default, avrdude is used as the uploading tool to flash the user code onto official Arduino boards.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (For prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers can be programmed using C and C++ programming languages. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

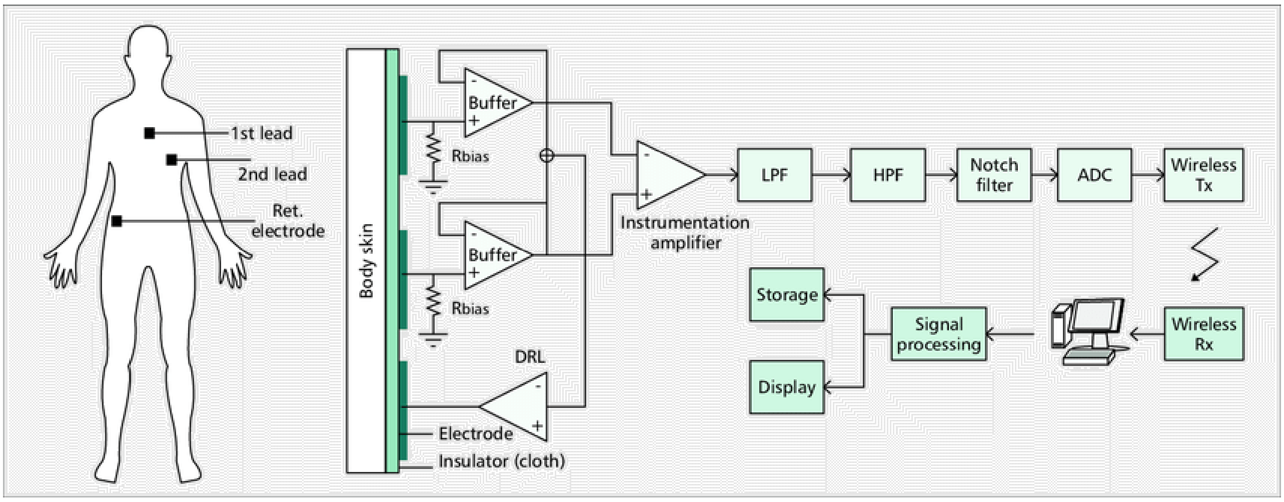
CHAPTER 4

PROPOSED SYSTEM

The aim of this paper is to propose a system that may help the doctors to cross - verify their opinion. The system will be able to diagnose the diseases from the ECG signals obtained. The diseases will be displayed in the LCD. Another goal of this paper is that the ECG signals derived through electrodes and the phonocardiogram signals derived from stethoscope are compared to ensure better results.

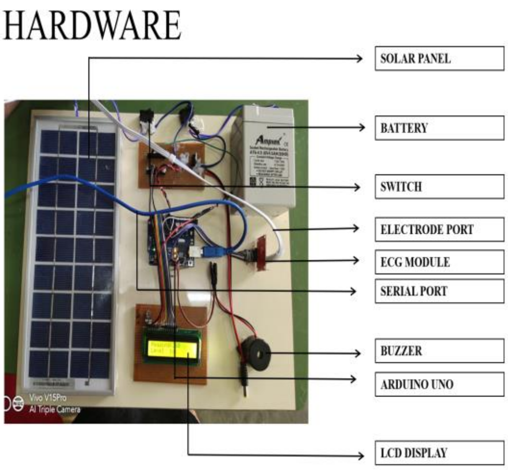
4.1 BLOCK DIAGRAM

PORTABLE ECG MODULE



4.1.1 BLOCK DIAGRAM OF ECG MODULE

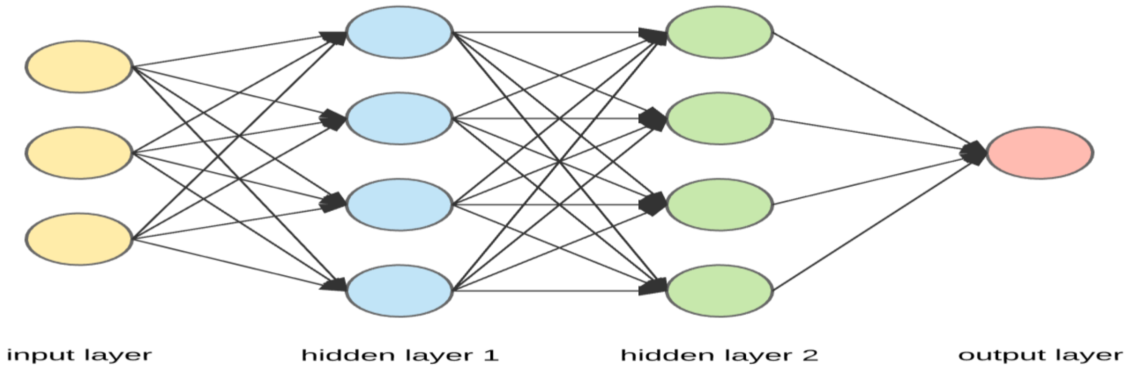
HARDWARE



4.1.2 HARDWARE SYSTEM

4.2 ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANN) are multi layer fully-connected neural nets that look like the figure below. They consist of an input layer, multiple hidden layers, and an output layer. Every node in one layer is connected to every other node in the next layer. We make the network deeper by increasing the number of hidden layers.



4.2.1 Nodes of ANN

An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal to other neurons. An artificial neuron that receives a signal then processes it and can signal neurons connected to it.

The weighted sum of its inputs passed through a non-linear activation function. It can be represented as a vector dot product, where *n* is the number of inputs for the node.

$$z = f(x \cdot w) = f\left(\sum_{i=1}^{n} x_i w_i\right)$$

$$x \in d_{1\times n},\ w \in d_{n\times 1},\ z \in d_{1\times 1}$$

The above equation looks as follows with the bias included.

$$z = f(b + x \cdot w) = f\left(b + \sum_{i=1}^{n} x_i w_i\right)$$

$$x \in d_{1\times n},\ w \in d_{n\times 1},\ b \in d_{1\times 1},\ z \in d_{1\times 1}$$

COMPONENTS OF ANNS

Neurons

ANNs are composed of artificial neurons which retain the biological concept of neurons, which receive input, combine the input with their internal state (activation) and an optional threshold using an activation function, and produce output using an output function.

Connections and weights

The network consists of connections, each connection providing the output of one neuron as an input to another neuron. Each connection is assigned a weight that represents its relative importance.

Propagation function

The propagation function computes the input to a neuron from the outputs of its predecessor neurons and their connections as a weighted sum.

4.3 FEATURE EXTRACTION

Feature Extraction aims to reduce the number of features in a data set by creating many new features from the current ones (and then discarding the original features). The new reduced set of features should be able to summarize the information contained in the original set of features. By doing this, new version of the original features can be created from a combination of the original set.

Various diseases can be identified using several variations in the ECG wave. Some of them are,

MYOCARDIAL INFARCTION which is caused due to the sudden death of cardiac muscle is caused due to the abnormalities in the ST wave elevation. A blood levelthat is below normal in potassium an important body chemical.

HYPOKALEMIA can result in fatigue , muscle cramps and abnormal heart rhythms is caused due to the abnormalities in,

T wave inversion

ST wave depression

QT prolongation

U wave visible

VENTRICULAR TACHYCARDIA is the condition in which the lower chambers of the heart ventricles beat very quickly. It occurs due to the electrical impulse problem.And that is caused as the QRS wave widens.

ATRIAL FIBRILLATION is an irregular often rapid heart rate that commonly causes poor blood flow . The heart's upper chambers beat out of coordination with lower chambers and is caused due to the absence of P wave.

CARDIOMEGALY, an enlarged heart which is usually a sign of another condition (heart valve problem or heart disease). That causes an increase duration of P wave and QRS complex.

CONSTRICTIVE PERICARDITIS is the inflammation of the pericardium and is chronic case and is denoted by T wave flattening.

ANGINA the heart failure is denoted by the ST wave depression and the T wave inversion.

MITRAL VALVE PROLAPSE,(barlow syndrome) Improper closure of the valve betweenthe heart's upper and lower left chambers.It is also a genetic disorder denoted by QT prolongation and T wave inversion.

ARRHYTHMIA

In BRADYARRHYTHMIA,

Sino arterial disease : Dysfunction or sinus node disease is due to irregular heart rhythms.

Sinus bradycardia – P wave follewde by QRS wave heart rate is greater than 60.

Sinus arrest which is denoted by the absence of P wave.

Atrioventricular node disease: Due to the impairment of electrical continuity between atria and ventricles. It occurs when the atrial depolarization failed to reach the ventricles or is conducted with an abnormally a long delay.

Primary atrio ventricular block which is denoted by PR interval prolongation.

Secondary atrio ventricular block : P wave that is not followed by QRS wave but whenever QRS waveis there it will be preceeded by P wave

Tertiary AV block : which is denoted by QRS wave widening, T wave and QRS wave will be in oppoisite direction whereas QRS wave is independent of P wave.

In TACHYARRYTHMIA,

A rapids heart beat that may be regular or irregular, but is ourt of proportion to age and level of age and level of excursion or activity and aren’t dure to underlying disease.

Depending on the origin:

Sino atrial node (sinus tachycardia) in which HR greater than 100, P wave is followed by QRS wave.

Atrial (atrial tachycardia) which is denoted by abnormal P wave, HR will be 100-250 per min.

Atrial flutter : which is denoted by sawtooth P wave . in which P wave will not be followed bvy QRS wave and also T wave is hidden by P wave.

Atrial dfibrillation : In which P wave is absent “F”(fibrillatory) wave is seen and heart rate will bre irregular.

Atrio ventricular node (P aroxysmal supraventricular tachycardia) in which the P wave is absent.

In VENTRICULAR TACHYARRYTHMIA,

A condition in which the lower chambers of heart beat very quickly.

Ventricular tachyarrythmia which is denoted by widening of the QRS wave, T wave and QRS wave will be in opposite direction.

Ventricular flutter-wide QRS , HR greater than 250.

Ventricular fibrillation-asynchronised waves and no definite QRS.

CONGESTIVE HEART FAILURE

RT ventricular hypertrophy is identified by larger R waves

LT ventricular hypertrophy is identified by smaller S wave

The Wavelet Transform (WT) is designed to address the problem of non-stationary ECG signals. It derived from a single generating function called the mother wavelet by translation and dilation operations. The feature vectors were then extracted from these decomposed signals as normalised energy and entropy. To improve the classification of the feature vectors of normal and abnormal beats, the normal beats which occur before and after the abnormal beats were eliminated from the group of normal beats.

The ECG signals which consisting of many data points, can be compressed into a few features by performing spectral analysis of the signals with the WT.The ECG signals were decomposed into time-frequency representations using Discrete Wavelet Transform (DWT).

The DWT represents a 1-Decompodition signal s(t) in terms of shifted versions of a low pass scaling function φ(t) and shifted and dilated versions of a prototype bandpass wavelet function ψ(t).

$$\Psi_{j,k}(t) = 2^{(-j/2)} \psi (2^{-j} t - k) \quad (1)$$

$$\varphi_{j,k} (t) = 2^{-j} \varphi (2^{-j} t - k) \quad (2)$$

where: j controls the dilation or translation

k denotes the position of the wavelet function

4.4 FILTERING

A low-pass filter (LPF) is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The exact frequency response of the filter depends on the filter design. The filter is sometimes called a high-cut filter, or treble-cut filter in audio applications. A low-pass filter is the complement of a high-pass filter.Filter designers will often use the low-pass form as a prototype filter. That is, a filter with unity bandwidth and impedance. The desired filter is obtained from the prototype by scaling for the desired bandwidth and impedance and transforming into the desired band form (that is low-pass, high-pass, band-pass or band-stop).An ideal low-pass filter completely eliminates all frequencies above the cutoff frequency while passing those below unchanged; its frequency response is a rectangular function and is a brick-wall filter. The transition region present in practical filters does not exist in an ideal filter. An ideal low-pass filter can be realized mathematically (theoretically) by multiplying a signal by the rectangular function in the frequency domain or, equivalently, convolution with its impulse response, a sinc function, in the time domain.

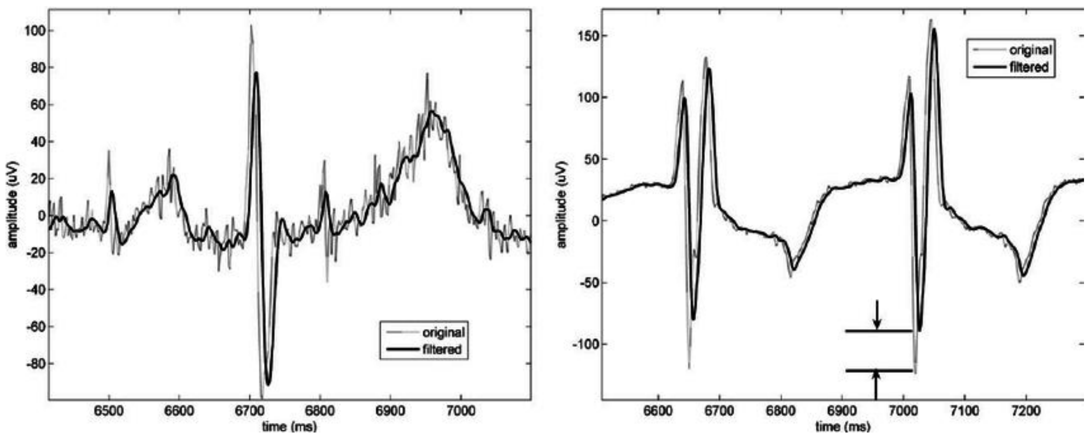


Fig 4.4.1 Filtered ECG signal

Low-pass filters on the ECG are used to remove high frequency muscle artifact and external interference. They typically attenuate only the amplitude of higher frequency ECG components. Analog low-pass filtering has a noticeable affect on the QRS complex, epsilon, and J-waves but do not alter re-polarization signals.

4.5 ARDUINO IDE 1.8.12

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (For prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers can be programmed using C and C++ programming languages. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

IDE

The Arduino integrated development environment (IDE) is a cross-platform application for Windows that is written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The source code for the IDE is released under the GNU General Public License, version 2.

The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub *main()* into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program *avrdude* to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

Pro IDE

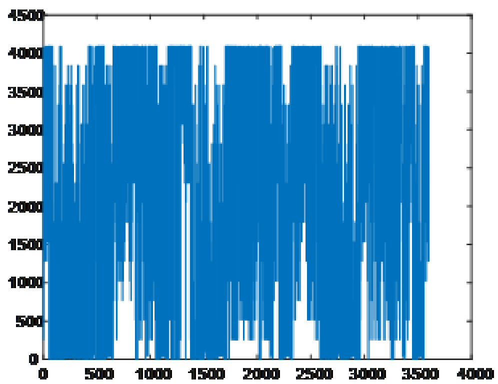
On October 18th, 2019, Arduino Pro IDE (alpha preview) was released. The system still uses Arduino CLI (Command Line Interface), but improvements include a more professional development environment, autocompletion support, and Git integration. The application front end is based on the Eclipse Theia Open Source IDE.

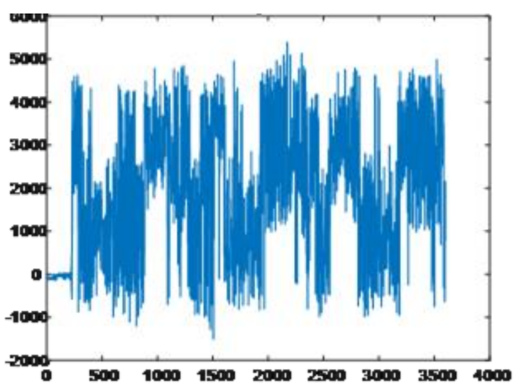
CHAPTER 5
RESULT AND DISCUSSION

5.1 ECG OUTPUT

The ECG signals were obtained from different patients under various health conditions such as normal and diseased conditions which include arrhythmia, Mitral valve prolapse and congenital heart failure.

Input 1
Condition : Normal





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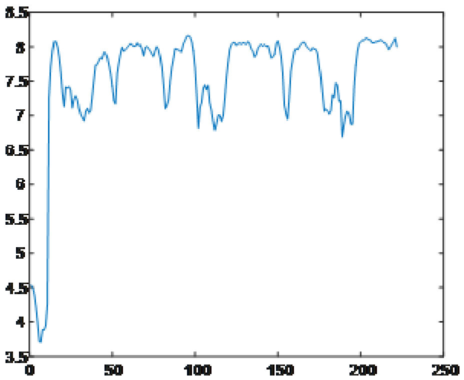
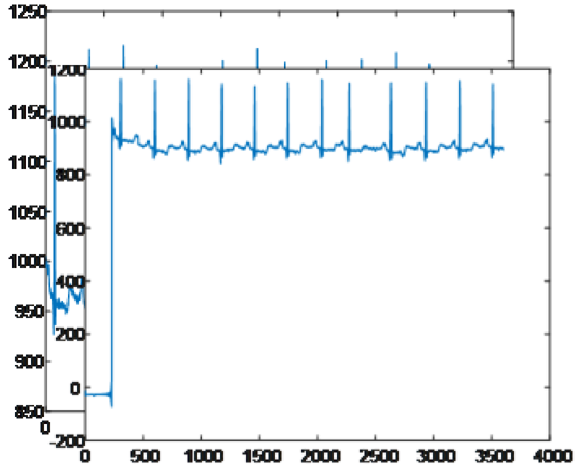


(c)

5.1.1 ECG obtained from normal person

Input 2
Condition : Arrhythmia



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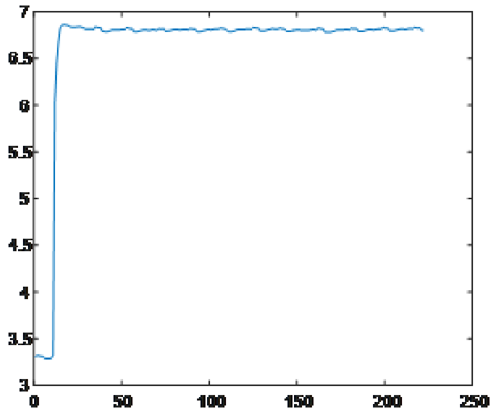
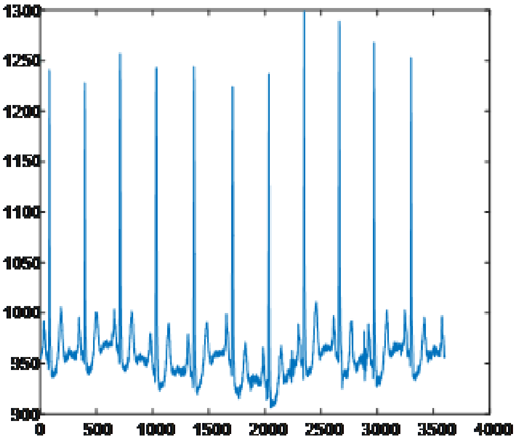


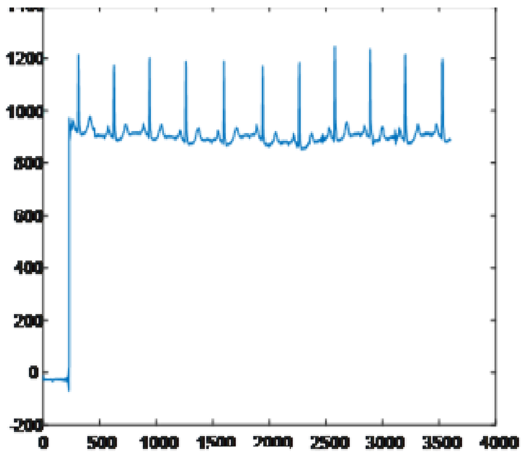
(c)

5.1.2 ECG obtained from patient 1 with arrhythmia

Input 3
Condition : Arrhythmia



(a)



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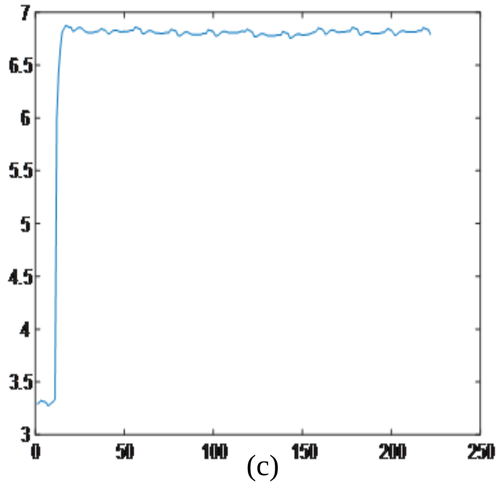
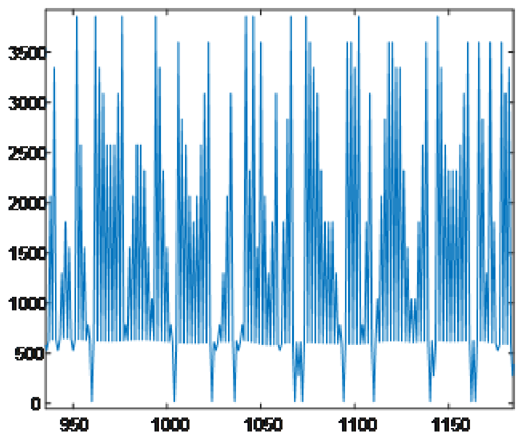


(c)

5.1.3 ECG obtained from patient 2 with Arrythmia

Input 4
Condition : Mitral Valve Prolapse



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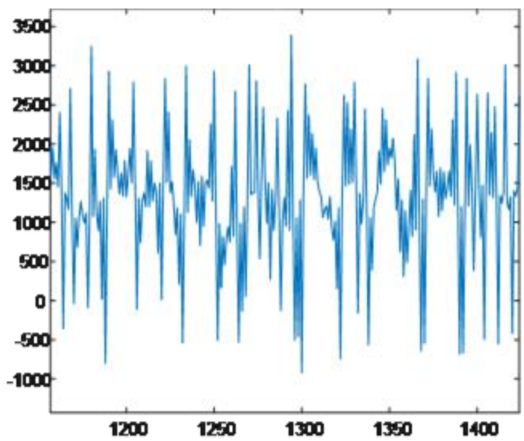

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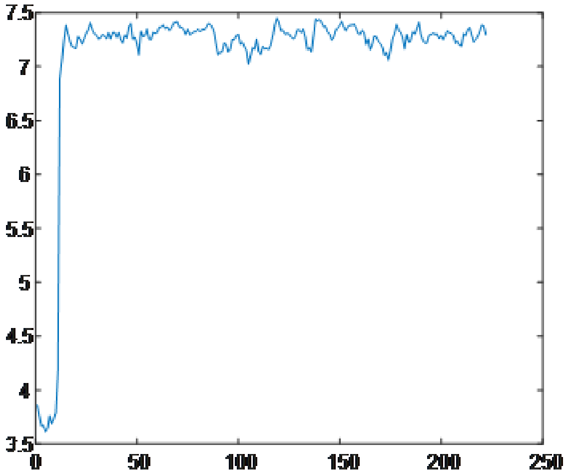
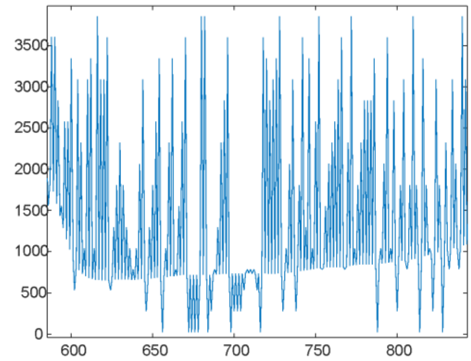
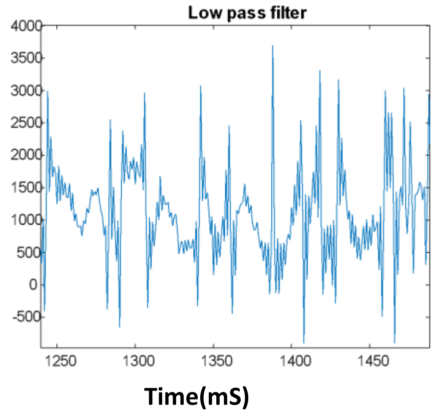


(c)

5.1.4 ECG obtained from patient 4 with mitral valve prolapse

Input : 5
Condition : Mitral Valve Prolapse





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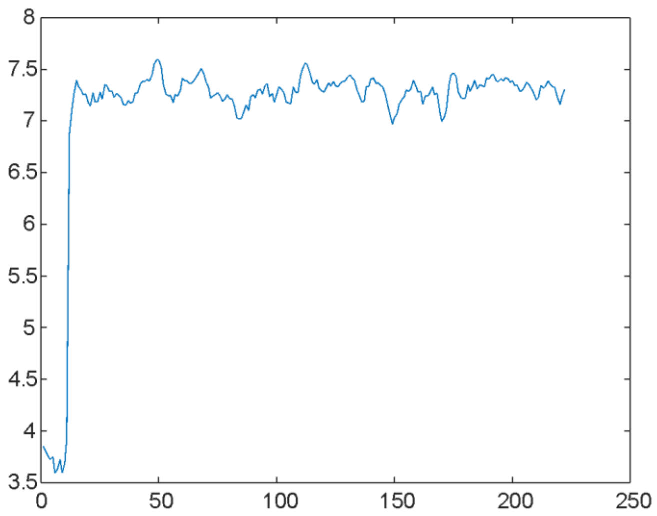
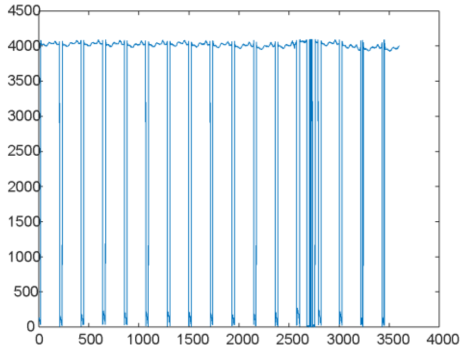
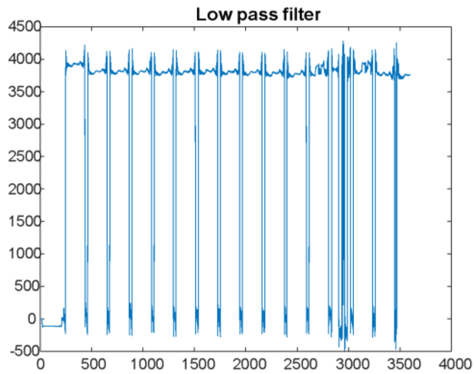


(c)

5.1.5 ECG obtained from patient 5 with mitral valve prolapse

Input : 6
Condition : Congestive Heart Failure





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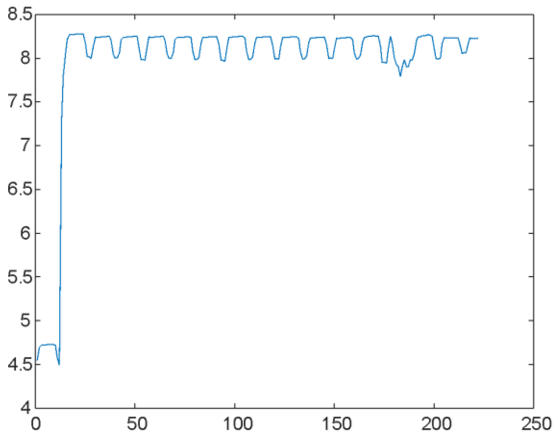


(c)

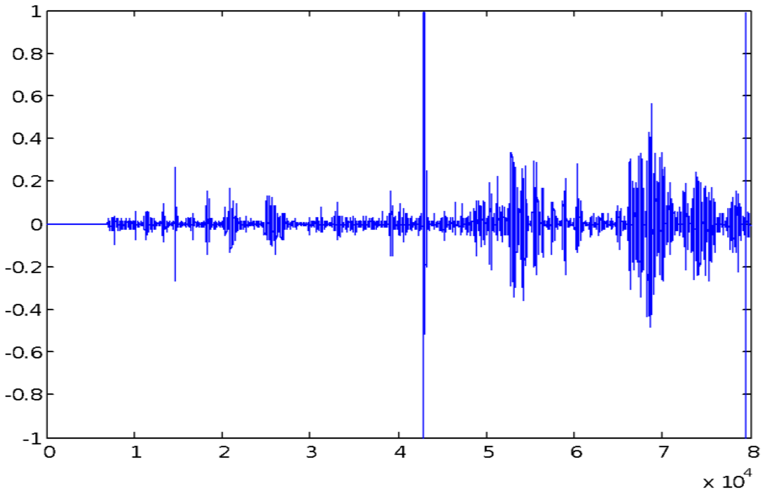
5.1.6 ECG obtained from patient 6 with Congestive Heart Failure

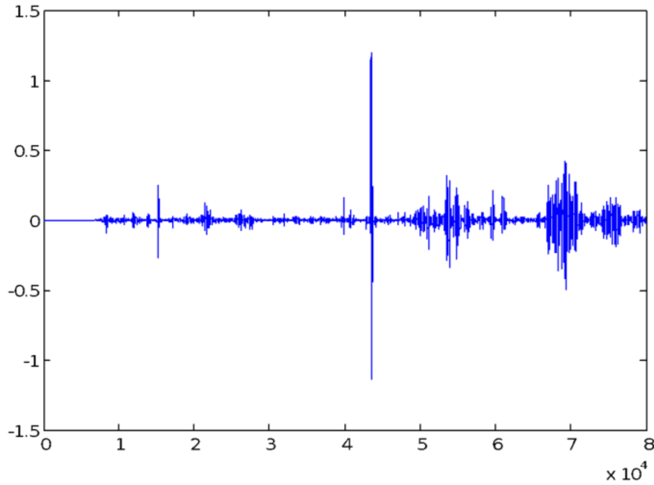
5.2 PCG OUTPUT

The PCG signals were obtained from different patients under various health conditions such as normal and Mitral valve prolapse.

Input 1

Condition : Normal



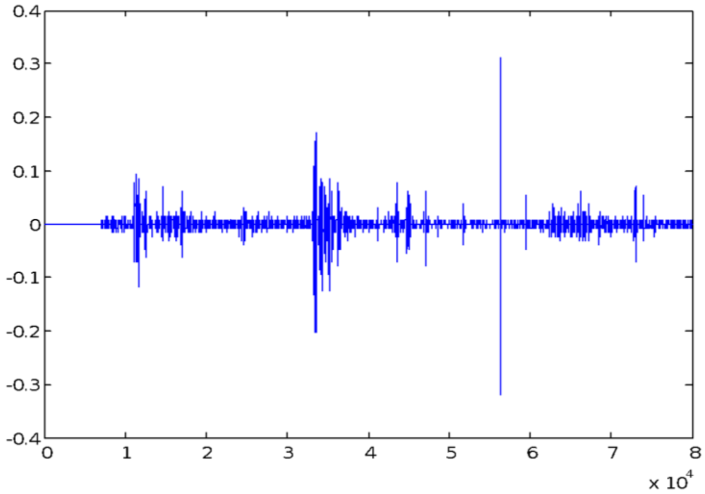


(b)

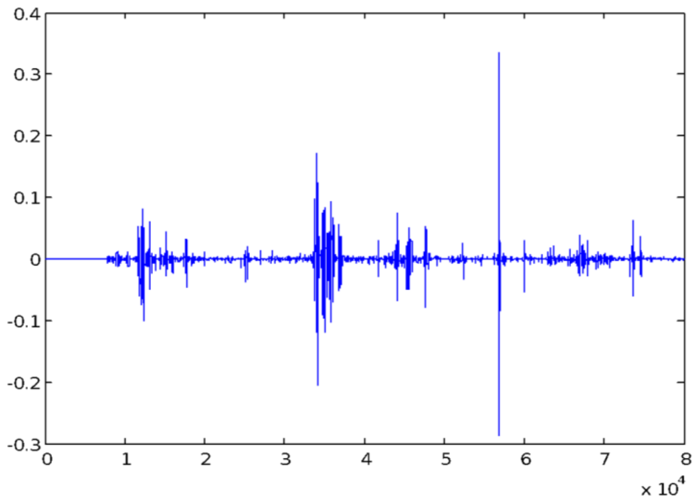
5.2.1 PCG obtained from normal person

Input 2

Condition : Normal



(a)

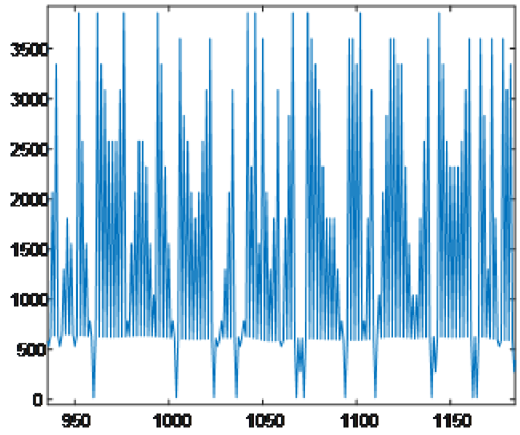


(b)

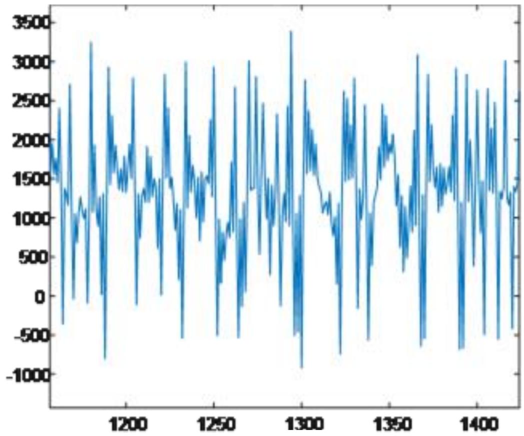
5.2.2 PCG obtained from normal person

Input 3

Condition : Mitral Valve Prolapse



(a)

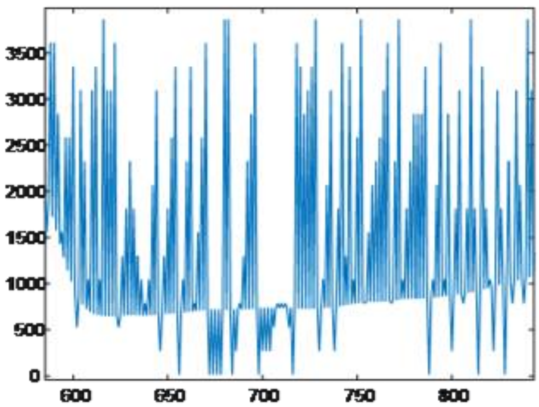


(b)

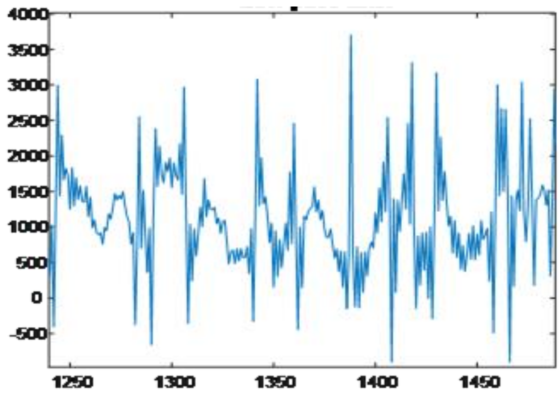
5.2.3 PCG obtained from patient 3 with mitral valve prolapse

Input 4

Condition : Mitral Valve Prolapse



(a)

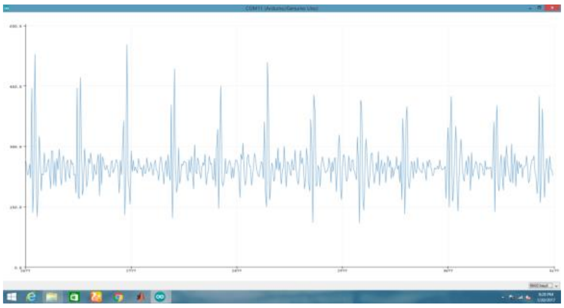


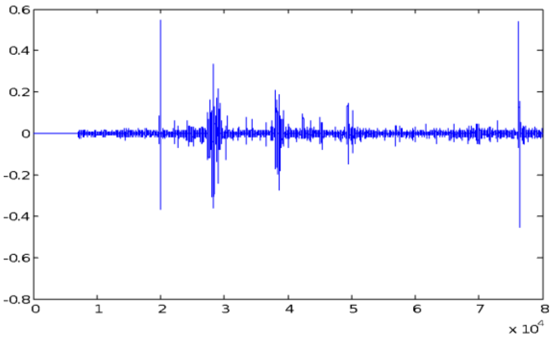
(b)

5.2.4 PCG obtained from patient 4 with mitral valve prolapse

5.3 SYSTEM EFFICIENCY

The system efficiency can be said by comparing the sound waves obtained by the Doppler effect method and by using digital stethoscopes.





5.3.1 heart sound extracted from the maternal's abdomen

CHAPTER 6

CONCLUSION AND FUTURE WORK

A completely efficient method for identifying the heart diseases with the help of the heart waveform and suggesting the doctor for improved analysis and treatment has been proposed. It is concluded from the experiment that the results of both Electrocardiogram and phonocardiogram are the same for all patients with heart related disorders. This paper deals with Matlab software for classifying the diseases. In the future work, the codes can be written in Arduino for cost efficiency and reducing the complexity of equipment. Also three diseases have been analyzed here due to lack of training signals, in future this may also be expanded to various number of diseases.

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Solar ECG Acquisition System (Vispute Deepali Dilip, Prof. S.T. Khot)

Smart Detection and Transmission of Abnormalities in ECG via Bluetooth(Pavan Lakshmi Penmatsa, Dr.D.V. Rama Koti Reddy)

A wearable, Low-Power, Real-Time ECG Monitor for Smart T-Shirt and IoT Healthcare Applications(Taiyang Wu, Jean-Michel Redoute, Mehmet Yuce)

Design of a Solar-Powered Portable ECG Device with Optimal Power Consumption and High Accuracy Measurement(Ngoc Thang Bui,Tan Hung Vo,Byung-Gak Kim, Junghwan Oh)

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Electronic Stethoscope With Wireless Communication to a Smart-phone, Including a Signal Filtering and Segmentation Algorithm of Digital Phonocardiography Signals (Reynolds Jorge,Forero Jose,Botero Juan)

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