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A Real Time Portable Wireless ECG Device for Detecting Cardiac Abnormalities

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Abstract
This paper presents light weight, wireless, ambulatory system that is used to monitor cardiovascular disease, which is one of the most prevalent and costly health problem in the world. This system consists of ECG device which acquires the ECG signals which are then transmitted to the microcontroller and processed by expert system to detect the abnormalities. The alert signal is then sent to the caretaker. The circuit is simulated using Multisim and implemented using microcontroller.

Keywords: Portable ECG device, Wireless system, cardiovascular disease, Sinus Tachycardia, Sinus Bradycardia, Atrial Fibrillation, Wide QRS Complex

1. Introduction
[1] Cardiac diseases are one of the most prevalent diseases in today's life. About 50% of the people lose their lives because of these diseases. More than 70% people suffer from the same. Most of the people are affected because of the untimely treatment provided to them. The first hour of cardiac arrest is the most important time during which the treatment has to be provided. Here we develop an algorithm to monitor and pre-determine the cardiac abnormalities beforehand, so that doctor can take the initiative as soon as possible. The reason for the cardiac problems can be 1. Poor lifestyle and lack of physical activities. 2. Demand for increased accessibility to hospitals. 3. Financial constraints. Here we have designed an ECG device which is used to monitor the abnormalities and report the same. The project also provides a wireless interface for doctors/caretakers to keep a track of the patient's heart condition from a distantly located nursing station. The system is portable so that patients suffering from cardiac disorders can monitor themselves whenever and wherever required. This is a lightweight, portable device which is used to monitor the ECG signals. [2] 12 lead electrode is reduced to 3 lead electrodes which is connected in any one of the lead configurations. These signals are then passed to the instrumentation amplifier. The signal obtained is then amplified and passed to the microcontroller and then based on the status, the message or the alert signal is sent to the caretaker through the wireless network. [3] The basic types of abnormalities that are detected are–1) Sinus Bradycardia. 2) Sinus Tachycardia. 3) Wide QRS Complex. 4) Atrial Fibrillation. The increased death rates due to Cardio Vascular Diseases (CVD's) has called for the requirement of a device that can detect it in a real time manner and which can help the patient suffering from CVD to get the treatment in a timely manner. The main objective of the project is to design such a system which is handy and can be carried with the patient and helps him to monitor the status of his heart in a real time manner. The system also automatically notifies the care taker or the doctor if any abnormalities are found in the heart.

2. Working of a Human Heart
The human heart is also called as "MYOCARDIUM" meaning that it can operate on its own. The heart serves as a four chambered pump for the body's blood circulatory system. The four chambers are Left Atrium, Right Atrium, Left Ventricle and Right Ventricle. The following figure shows the path of the blood flow.

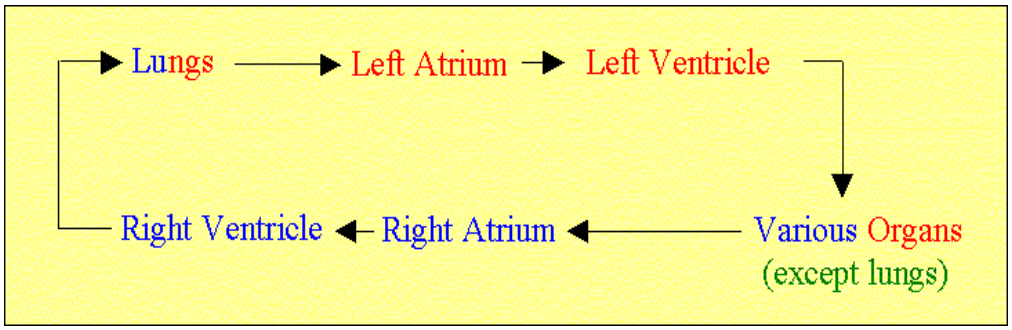

Fig 1: Path for Blood Flow in the human body

In the above figure the red color indicates the oxygen rich arterial blood while the blue color indicates the oxygen-poor venous blood. The blood enters the heart from the Left Atrium and moves down to Left Ventricle. Then the blood is supplied from the left ventricle to all parts of the body except the lungs. The oxygen deficient blood from various parts of the body enters the heart again through the left atrium and moves down to right Ventricle and then finally pumped to the lungs where the blood is oxygenated and sent back to the heart. This is a continuous process. The complete cycle of the heart is divided in to two phases. They are the SYSTOLE and DIASTOLE. Systole refers to the contractile or the pumping phase and Diastole refers to the resting of filling phase. The rhythmic contraction of the atria and ventricles has an underlying electrical precursor in the form of a well-coordinated series of electrical events that takes place within the heart. This series of electrical events originates in the Sino-Atrial (SA) node which is located at the junction of the superior vena cava and the right atrium. The SA node acts as a pulse generator. Each impulse generated by the SA node leads to a heartbeat. Therefore, in a normal heart, the heart rate (beats per minute) is determined by the period of the pulses generated by the SA node. The impulse generated by the SA node first spreads all over the muscles of the two atria, causing the contraction of the atria. After a short delay, the impulse spreads over the muscles of the two ventricles and causes their contraction. The ECG waveform recorded on the body surface is produced by the electrical activities associated with the muscles contraction and relaxation of the atria and ventricles. The heart is designed in such a beautiful manner that there are two other alternatives that can source the electrical pulses. They are the Atrio-Ventricular node or AV node and the other is called the "Bundle of His". If the SA node fails then the action is taken over by the AV node and if AV node fails the action of generating the pulse is taken over by the "Bundle of His".

3. Normal Ecg Waveform

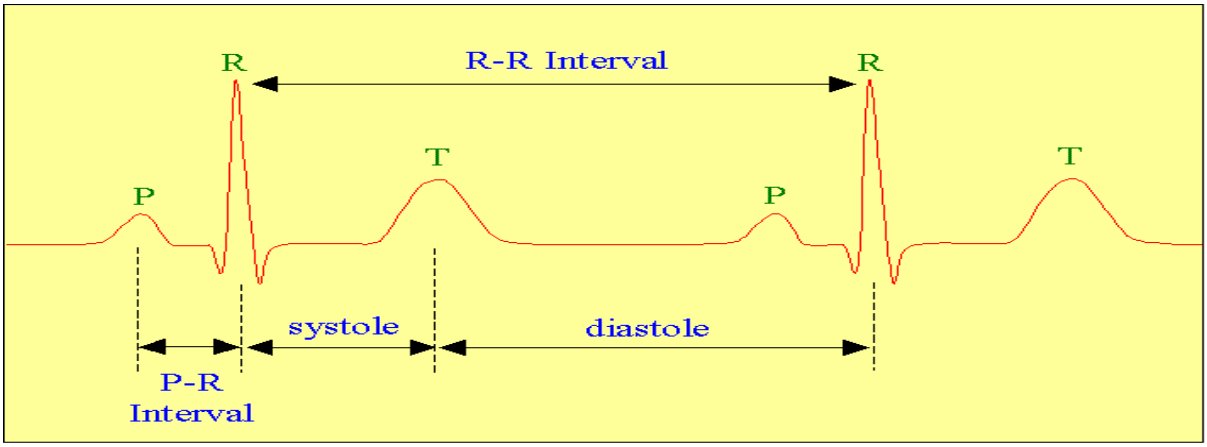

Fig 2: Normal ECG waveform

The ECG waveforms can be divided in to different waveforms as shown in Fig 2.2. The peaks of different waves are labeled as P, Q, R, S and T. P-wave is produced by muscle contraction of atria. Normal Q waves, when present, represent depolarization of the inter-ventricular septum. For this reason, they are referred to as septal Q waves. R-wave marks the ending of atrial contraction and the beginning of ventricular contraction. Finally, T-wave marks the ending of ventricular contraction. The magnitude of the R-wave normally ranges from 0.1 mV to 1.5 mV. A narrow and high R-wave indicates a physically strong heart. The heart rate is defined as the number of beats that are produced by the heart in one minute. Typically it is measured in beats per minute. The heart beat rate can be calculated using the formula,

Heart Rate = 60000/(ΔR-R… Eq. (1)

Where 60000 denote the number of milliseconds in a minute and ΔR-R represents the time interval (in milliseconds) between two R-Peaks in an ECG.

4. Abnormalities Targeted in the Project

There are a number of cardiac abnormalities that can be found out based on the ECG waveform. Among them the most important ones are the SINUS TACHYCARDIA, SINUS BRADYCARDIA, ATRIAL FIBRILLATION, WIDE QRS COMPLEX and CARDIAC ASYSTOLE.

A. Sinus Tachycardia

Tachycardia is a heart rate that exceeds the normal range. A heart rate over 100 beats per minute is generally accepted as tachycardia. Tachycardia can be caused by various factors which often are benign. However, tachycardia can be dangerous depending on the speed and type of rhythm. When the heart beats excessively rapidly, the heart pumps less efficiently and provides less blood flow to the rest of the body, including the heart itself. The increased heart rate also leads to increased work and oxygen demand by the heart, which can lead to rate related ischemia.

B. Sinus Bradycardia

Sinus bradycardia is a heart rhythm that originates from the sinus node and has a rate of fewer than 60 beats per minute. The decreased heart rate can cause a decreased cardiac output resulting in symptoms such as lightheadedness, dizziness, hypotension, vertigo, and syncope. The slow heart rate may also lead to atrial, junctional, or ventricular ectopic rhythms. Bradycardia is not necessarily problematic. People who regularly practice sports may have sinus bradycardia, because their trained hearts can pump enough blood in each contraction to allow a low resting heart rate.

C. Atrial Fibrillation

Atrial fibrillation is the most common cardiac arrhythmia (irregular heart beat). It may cause no symptoms, but it is often associated with palpitations, fainting, chest pain, or congestive heart failure. However, in some people atrial fibrillation is caused by otherwise idiopathic or benign conditions. AF increases the risk of stroke; the degree of stroke risk can be up to seven times that of the average population, depending on the presence of additional risk factors (such as high blood pressure). It may be identified clinically when taking a pulse, and the presence of AF can be confirmed with an electrocardiogram (ECG or EKG) which demonstrates the absence of P waves together with an irregular ventricular rate. In AF, the normal regular electrical impulses generated by the sinoatrial node are overwhelmed by disorganized electrical impulses usually originating in the roots of the pulmonary veins, leading to irregular conduction of impulses to the ventricles which generate the heartbeat. AF may occur in episodes lasting from minutes to days ("paroxysmal"), or be permanent in nature. A number of medical conditions increase the risk of AF, particularly mitral stenosis (narrowing of the mitral valve of the heart). Atrial fibrillation may be treated with medications to either slow the heart rate to a normal range ("rate control") or revert the heart rhythm back to normal ("rhythm control"). Synchronized electrical cardioversion can be used to convert AF to a normal heart rhythm. Surgical and catheter-based therapies may be used to prevent recurrence of AF in certain individuals. People with AF often take anticoagulants such as warfarin to protect them from stroke, depending on the calculated risk. The prevalence of AF in a population increases with age, with 8% of people over 80 having AF. Chronic AF leads to a small increase in the risk of death. A third of all strokes are caused by AF.

D. Wide Qrs Complex

The QRS complex is a name for the combination of three of the graphical deflections seen on a typical electrocardiogram (ECG). It is usually the central and most visually obvious part of the tracing. It corresponds to the depolarization of the right and left ventricles of the human heart. In adults, it normally lasts 0.06 - 0.10 s; in children and during physical activity, it may be shorter. The WIDE QRS complex abnormality occurs when the width of the QRS complex exceeds 120ms. This is the condition used to determine the first degree heart block.

5. The Overall System

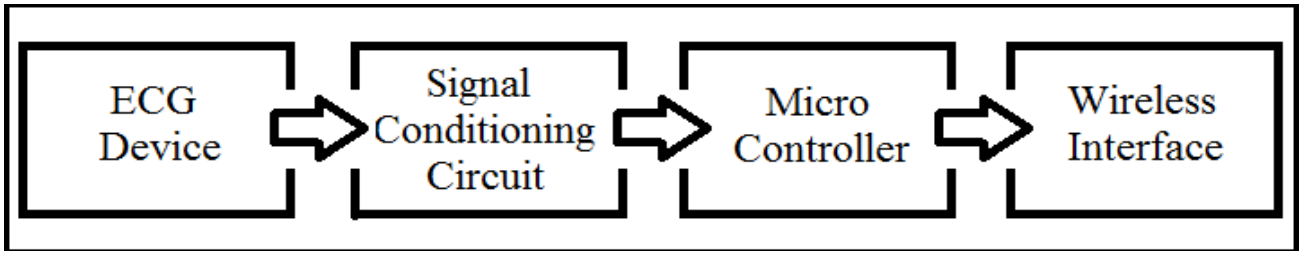

Fig 3: Block diagram of the system

The system consists of 3 lead wireless ECG device, a microcontroller expert system to meet the objectives. A small 3 lead ECG device is set up using electrodes which is fixed on the human body. The temperature sensor is also fixed which senses the temperature of human body and delivers the same to the microcontroller. This ECG device is connected to the nursing station using GSM module. When the abnormal signal is detected, the system automatically transmits the data to the caretaker or the nursing station for further examination. For some patients admitted to a cardiovascular ward or intensive care unit(ICU), the proposed cardio-healthcare system provides greater freedom of movement for the doctors. Paring lightweight wireless ECG devices with mobile phones offers continuous and reliable patient monitoring. The alert system is activated when an abnormal ECG wave appears. GSM targets the application domain of low power, low duty cycle and low data rate requirement devices. In the abnormal heart condition, the heart beat increases for an average of 7-8 beats for every single degree increase in temperature. The hardware circuit consists of ECG device, signal conditioning circuit, microcontroller and GSM. The nodes are connected together to share the power, reference voltage and clocks. The GSM is used to send the data pertaining to the acquired ECG signal. The algorithm which is used to find the abnormalities is done by detecting the R waves and calculating the duration between adjacent R peaks or by counting the number of peaks to calculate the number of beats in each minute.

6. Results and Conclusions

The ECG waveform as acquired from the designed device is as shown in the figure below.

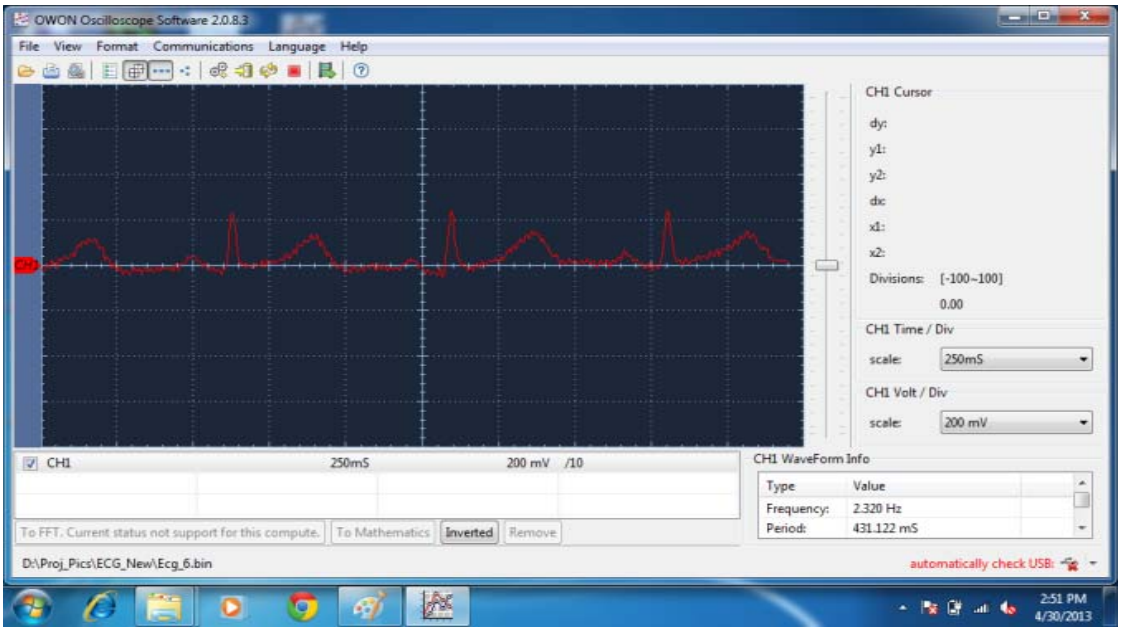

Fig 4: ECG waveform acquired from the device.

The above device was tested on 12 people and the corresponding accuracies was calculated. Five ECG samples of 12 people were recorded and the heart rate was calculated as well as recorded from the ECG device. The subjects as well as the average accuracy of five readings as as given in Table 1.

Subject	Average Accuracy
A	98.114
B	97.554
C	99.292
D	98.766
E	98.992
F	97.462
G	99.756
H	97.114
I	98.042
J	98.324
K	99.020
L	98.510

The total average accuracy of the system is found to be 98.41 %. The plot of each subject versus the accuracy is as depicted in Fig.5

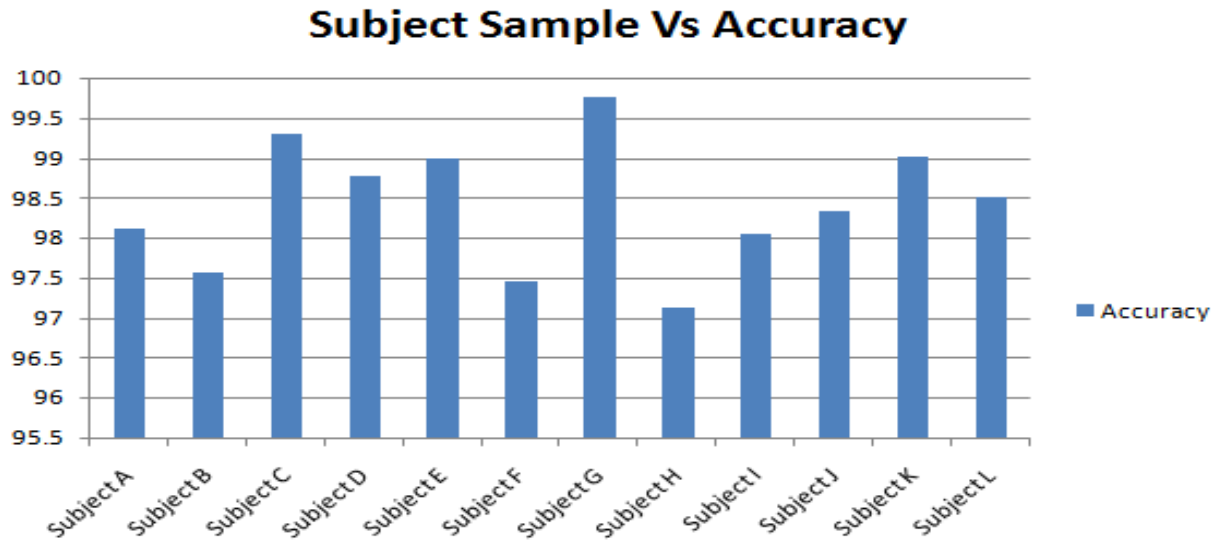

Fig 5: Graph of subjects versus the accuracy

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