http://dx.doi.org/10.21172/ijiet.122.04

Design Of Cost Effective Ecg Signal Acquisition System

Kiruba Nandhini[1]. K, Vidya. M[2]
[1]UG student, *Department of Instrumentation and Control Engineering*
Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India
[2]Assistant Professor, *Department of Instrumentation and Control Engineering*
Sri Krishna college of Technology, Coimbatore, Tamil Nadu, India

Abstract- Electrocardiography (ECG) is the interpretation of the electrical activity of one's heart over a period of time. Recently, it is found that many people are suffering from various heart diseases due to their lifestyle changes and food habits. So, it is important to monitor their heart rate from time to time. The ultimate aim of the project is to design a low cost circuit and to reduce the complexity. This paper aims at observing the patient's heart rate continuously so that the irregularities can be detected in the early stages. Here, the wireless transmission is implemented using the HC-05 Bluetooth module.
Keywords – Electrocardiography, Heart rate monitoring, Electrodes, Bluetooth, wireless transmission.

I. INTRODUCTION

ECG deals with the study of the electrical activity of the heart muscles. When it is normal, the heartbeat is regular and has just the right rate as shown in Fig.1. But when the heartbeat is too fast, too slow, or beats in an irregular rhythm, it is known as a cardiac arrhythmia (abnormal heart rhythm), which is among the most common of the heart disorders. Arrhythmia is caused due the abnormalities in the heart's normal electrical system which regulates the heart rate and heart rhythm.

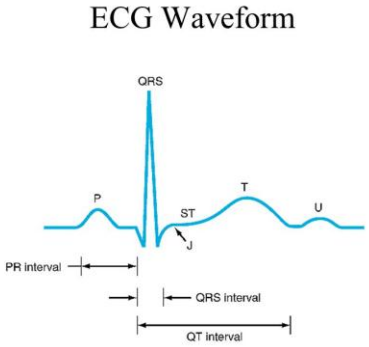

Figure 1. Normal ECG waveform

There are many kinds of cardiac arrhythmias like, Bradycardia which makes the heart rate to slow down. Sinus bradycardia is caused due the malfunctioning of the sinus node. Heart block is the most dangerous variety of bradycardia which occurs when there is some electrical impulse generated by the sinus node. Tachycardia makes the heart rate too fast. These types of disorders are more common in recent times and needs to be monitored along with proper medication.

The electrocardiogram is used to detect the arrhythmias and it is a non-invasive diagnostic test which helps in evaluating the heart's electrical system to assess the heart disease. An Einthoven's triangle is helpful in identifying the incorrect placement of leads.

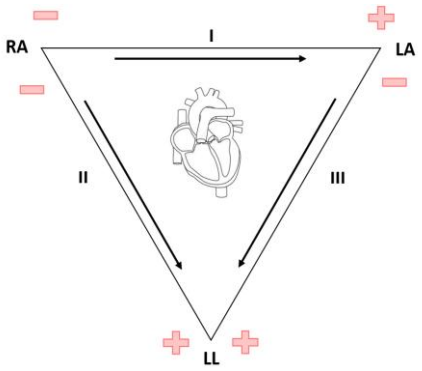

Figure 2. Einthoven's triangle

It is an imaginary formation of three limb leads in the form of a triangle as shown in Fig.2 used in electrocardiography, formed by the shoulders and the pubis. The shape forms an inverted equilateral triangle with the heart at the center that produces zero potential when the voltages are summed.

1.1 ECG signal characteristics

There are three main components in an ECG, the P wave, which represents the depolarization of the atria; the QRS complex, that represents the depolarization of the ventricles and corresponds to the contraction of the large ventricular muscles; and the T wave, which represents the repolarization of the ventricles.

1.2 ECG noise and sources

Inaccurate electrode placement and poor contact leads to misinterpretation of ECG examination. The most frequent noises that occurs during ECG signal acquisition are baseline wander, power line interference and muscle noise. Baseline wander is basically a low frequency bandwidth component. Power line interference is due to electromagnetic fields radiated from power lines. Muscle noise arises due to the muscle contractions.

1.3 Bluetooth technology

Bluetooth technology was implemented for the wireless transmission of data. It enables short-range wireless connections and transmits small packets of data at a time [1]. Bluetooth devices work using the radio waves and they are used as a replacement for RS-232 cables.

Figure 3. Block diagram of Bluetooth technology

Here, the signal from the ECG sensor is transmitted to the smartphone via the Bluetooth module as shown in Fig 3.

1.4 Related works

S.NO	Paper details	Contribution
1.	Low-cost Prototype Design of a Portable ECG Signal Recorder [2]	Design integrated with the Arduino Nano platform.
2.	Design of a Simple 3-Lead ECG Acquisition System Based on MSP430F149 [3]	ECG signal is monitored in real time through mobile phone.
3.	Design of ECG signal acquisition and processing system [4]	The transmitted signal is processed in LabVIEW.
4.	Design of an ECG sensor circuitry for cardiovascular disease diagnosis [5]	ECG signal is obtained using different filters for accuracy.
5.	Design of a Three Lead ECG Amplifier System [6]	The system is designed with a preamplifier and ECG amplifier to protect the circuit from the major noise interference.

Table 1. Different ECG monitoring techniques

ECG monitoring systems and techniques are compared in Table 1. The systems presented in the literature survey produce results at the cost of more complexity of hardware and software [2]-[6]. This paper focuses on producing a portable and less complex circuitry that consumes less power.

II. SYSTEM ARCHITECTURE

In this paper, the circuit developed is a right-leg drive circuit. Here, the ECG is monitored through a portable device built using an ECG sensor. The signal obtained from the ECG sensor is given to the Arduino and then it is transmitted using the Bluetooth module as shown in Fig.4. The results can be observed on a laptop, PC or a smartphone. This device consumes less power and it is cost effective. The implementation of the system is discussed alongside its working principle with the results.

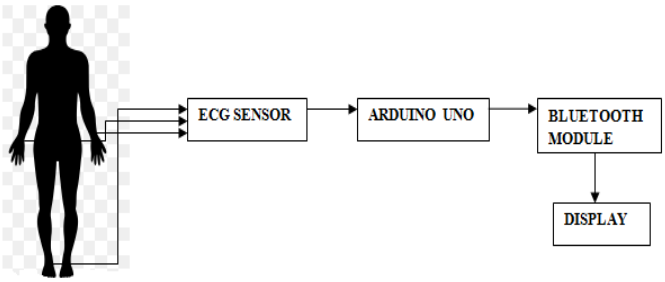

Figure 4. Architectural block diagram

This device consists of an ECG sensor AD8232, Arduino UNO, a Bluetooth module HC-05 and a power source [7]. The working and the functionality are described below.

2.1 ECG sensor AD8232

The electrical activity of the heart is measured using the ECG sensor [8]. This sensor acts as an operational amplifier which helps in obtaining a clear signal from the PR and QT Intervals. It can operate in two or three lead configurations. The inputs are taken from the electrodes placed at different locations in our body. The output obtained is an analog signal and this can be used to plot the waveform.

2.2 Arduino UNO

The Arduino UNO board is a microcontroller based on the ATmega328 [9]. It is an open source electronic prototyping platform which consists of digital and analog input/output pins along with a USB connection, a power jack and a reset button. There are 14 digital pins out of which 6 pins provide PWM output, 6 analog pins. And it is programmable with the Arduino IDE. It can be powered with the help of an adapter, USB cable or battery. The operating voltage is 5 volts.

2.3 Bluetooth module HC-05

HC-05 module is a Bluetooth SPP (Serial Port Protocol) module, designed for wireless serial connection [10]. It provides a UART interface with programmable baud rate. This Bluetooth module has the ability to auto connect to the last device on power and it is used for simple and fast transmission of data.

2.4 3-lead electrode system

A 3-lead ECG machine uses 3 electrodes. It can be used in pre-hospital care, for continuous monitoring of a patient's heart rate. 3-lead is simple to use and requires a much less sensitive machine, and it is capable of picking up the specific electrical rhythm of the heart.

2.5 Electrodes

The electrical activity of the heart can be measured using different types of electrodes. Here, surface electrodes are used. The disposable foam pad electrode has a conductive gel for forming an electrical contact and these are often used in electrocardiography. The surface electrode has an adhesive on the back, which helps the electrode to stick firmly to the patient's skin. It used to measure the biopotential signals from the surface of the skin.

2.6 Right leg drive circuit

The right leg drive circuit as shown in Fig.5 is often used with differential amplifiers to reduce common mode interference. It used to eliminate noise by cancelling the interference. The ground electrode is connected to the right leg of the patient [7].

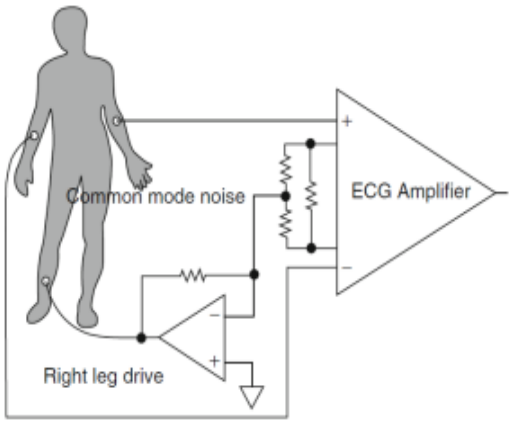

Figure 5. Right leg drive circuit

III. METHODOLOGY

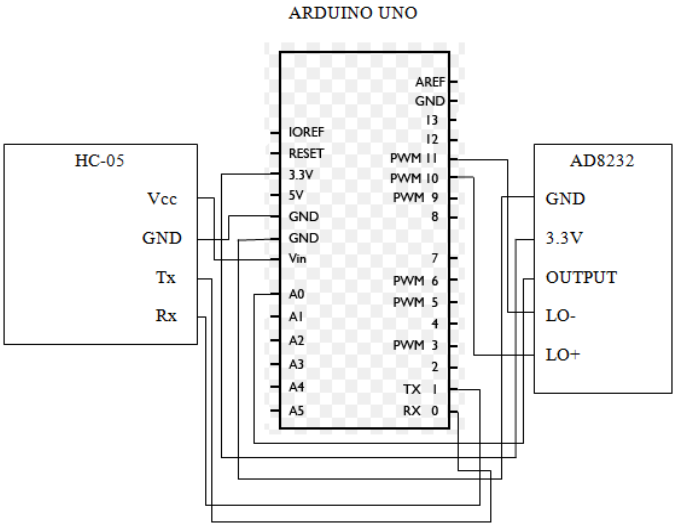

Figure 6. Circuit diagram for ECG signal acquisition system

The working of the components is checked and then the measuring of ECG is done by placing the electrodes on the right arm, left arm and right leg. Here, the AC adapter is used to provide power to the circuit. The biopotential signal obtained from the patient is sent to the ECG sensor AD8232 by the surface electrodes. The ECG sensor collects, amplifies and filters the small signal by eliminating the noise. The output obtained is in the analog form. The main feature of this sensor is that, it can be easily interfaced with any microcontroller to acquire the output signal. So, the Arduino is used to convert the signal into digital form. The digital data obtained from the microcontroller are then transmitted to the Bluetooth module as shown in Fig.6 the output can be monitored through smartphones, which enables the mobility of the doctor and the patient. The waveform can be monitored through laptops or Pc's. The circuit is powered using an adapter. It is a type of external power supply. Adapters are used to reduce the complexity of the circuit. In this circuit AC adapter is used as they can power small and portable devices.

3.1 Overall process flow

The signal acquired is conditioned to produce efficient results. The conditioned signal is digitized and then transmitted via Bluetooth [9]. The process flow is shown in Fig.7.

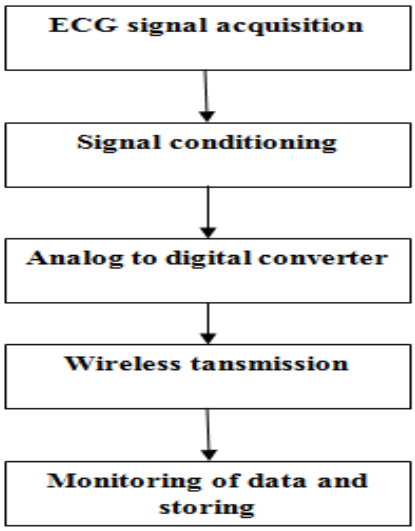

Figure 7. Acquisition of ECG using hardware component.

3.2 Conversion of analog signal to digital signal

The ECG signal obtained from the sensor is in analog form. Since the inputs to the Arduino is only in digital form, the conditioned ECG signal has to be converted to digital before transmitting it via the Arduino. Hence, the signal is sampled and quantized. The quantized data is in eight bits [10]. The digital signal is transmitted through Bluetooth and then it is received by the mobile phone. The signal can be monitored through different applications. Here, the serial Bluetooth terminal is used.

IV. EXPERIMENTAL SETUP

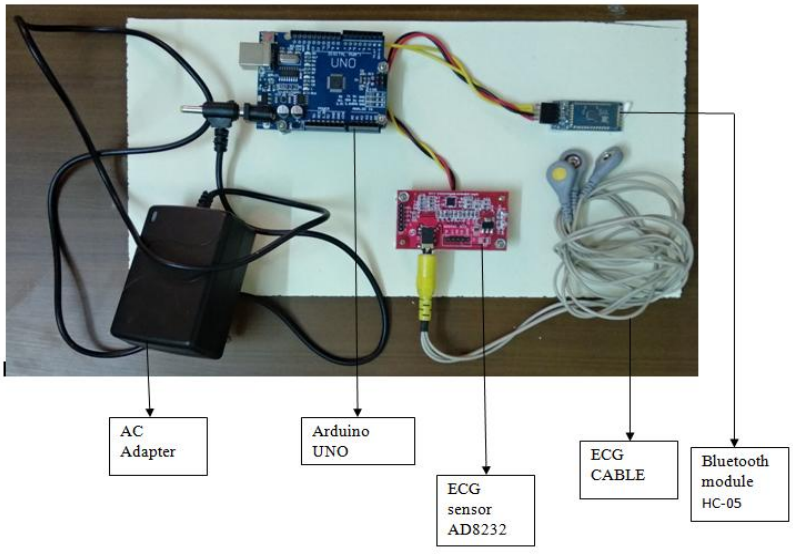

Figure.8 ECG monitoring system

In this ECG monitoring system, the code is developed in the Arduino IDE platform and uploaded to the Arduino UNO. To collect the biopotential signal from the patient's skin the electrodes placed on the surface of the skin and it is connected to ECG sensor via the ECG cables as shown in Fig.8.

Figure 9. Electrode placement

The biopotential signals are obtained from the surface electrodes as shown in Fig.9 and then the heart rate is monitored in the smartphone.

V. RESULT AND DISCUSSION

The results can be monitored in both digital and analog form. For the digital output, Serial Bluetooth Terminal is used shown in Fig.10, which gives the heart rate of the patient in beats/minute as shown in Fig.11. For the analog output, the waveform is obtained using the serial plotter which is available in the Arduino software as shown in Fig.12.

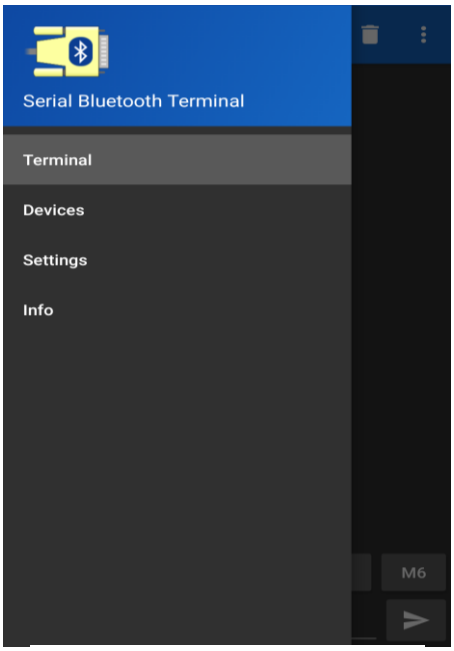

Figure 10. Serial Bluetooth Terminal

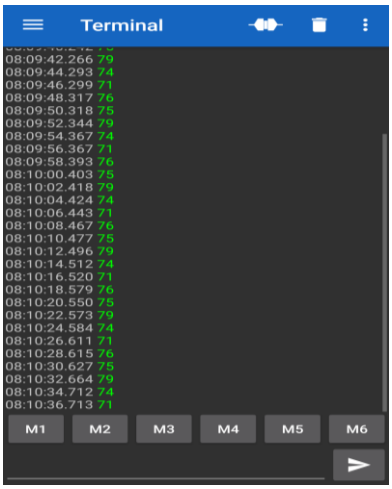

Figure 11. Digital output

The Bluetooth device has to be paired to view the results. Once the device is paired the heart rate is displayed along with the time. The main feature of this app is that the data can be saved for reference and it can be shared via e-mail, Whatsapp, etc.

5.1 Monitoring of Heart rate using Serial Bluetooth Terminal

The data collected from the app can be tabulated and it can be used for future references.

S.NO	PATIENT	HEART RATE	TIME (in hrs:mins:secs)
1.	Preethi	79	08:09:42
		74	08:09:44
		71	08:09:46
		76	08:09:48

Table 2. Heart rate of a patient.

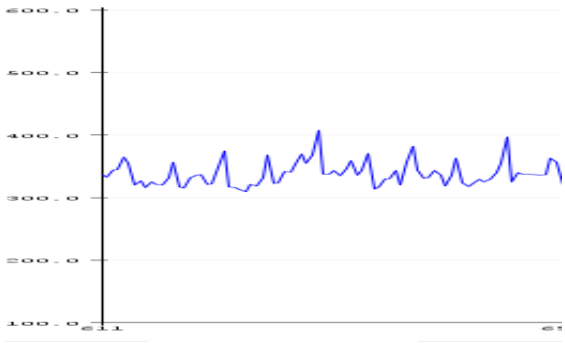

Figure 12. Analog output

VI. SPECIFICATION TABLE

S.NO	REQUIREMENTS	QUANTITY
1.	Disposable foam pad electrodes	3
2.	ECG cable	3
3.	ECG sensor AD8232	1
4.	Arduino UNO	1
5.	Bluetooth module HC-05	1
6.	AC adapter	1
7.	Serial Bluetooth terminal Application	1

Table 3. Components used in the circuit.

VII. CONCLUSION AND FUTURE WORK

In this paper, design of portable ECG signal acquisition system was proposed and implemented. This project focuses on producing low cost, simple circuitry. This device consumes less power compared to other traditional devices. Here, 3-lead electrode system is used to reduce interference. The right leg drive circuit is implemented in order to reduce the common mode noise and it also provides a reference point on the patient, generally at ground potential. The wireless transmission improves the flexibility and usability of the ECG monitoring system. In the future, with the advancement in technology, there will be more accurate devices that can produce quick results. Along with the heart rate monitor, the temperature monitoring can also be implemented.

VIII. REFERENCES

[1] Bin Yu and Lisheng Xu, Yongxu Li, "Bluetooth Low Energy (BLE) Based Mobile Electrocardiogram Monitoring System", IEEE International Conference on Information and Automation Shenyang, China, June 2012.
[2] Shin-Chi Lai, Te-Hsuan Hung, Wen-Chih Li, Yu-Syuan Jhang, Kuan-Ying Chang, Wen-Ho Juang, and Ching-Hsing Luo, "Low-Cost Prototype Design of a Portable ECG Signal Recorder", IEEE-2016.
[3] Peng Wang and Zhigang Lv, "Design of a Simple 3-Lead ECG Acquisition System Based on MSP430F149", International Conference on Computer and Automation Engineering (ICCAE 2011).
[4] Zeli Gao, Jie Wu, Jianli Zhou, Wei Jiang, Lihui Feng, "Design of ECG signal acquisition and processing system", 2012 International Conference on Biomedical Engineering and Biotechnology.
[5] Winncy Y DU, Winston JOSE, "Design of an ECG sensor circuitry for cardiovascular disease diagnosis", 2017 International Journal of Biosensors & Bioelectronics.
[6] Uma Ullas Pradhan, Naveen Kumar S K, "Design of a Three Lead ECG Amplifier System", 2015 International Journal of Advanced Research in Computer Science and Software Engineering.
[7] Apsara B, Bashyam S and Ramachandran B, "Development of Low Power Wearable Physiological Signal Monitoring System", 2017 IEEE.
[8] https://www.analog.com/media/en/technical-documentation/data-sheets/AD8232.pdf
[9] https://www.terraelectronica.ru/pdf/show?pdf_file=%2Fz%2FDatasheet%2FU%2FUNO_R3%28CH340G%29.pdf
[10] http://www.electronicaestudio.com/docs/istd016A.pdf
[11] Yishan Wang, Ralf Wunderlich and Stefan Heinen, "Design and Evaluation of a Novel Wireless Reconstructed 3-Lead ECG Monitoring System", 2013 IEEE.
[12] Sayed Tanvir Alam, Md. Moin Hossain, Md. Kafiul Islam, Mohammad Dehan Rahman, "Development of a Low Cost and Portable ECG Monitoring System for Rural/Remote Areas of Bangladesh", I.J. Image, Graphics and Signal Processing, 2018 MECS.
[13] Aparna S, Balaji Yashwanth S, Pranav V Nair, Ganesan M, Akshay K, "DESIGN OF WI-FI BASED ECG SYSTEM", International Conference on Signal Processing and Communication (ICSPC'17).