iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** II **Month of publication:** February 2023

DOI: https://doi.org/10.22214/ijraset.2023.49303

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue II Feb 2023- Available at www.ijraset.com

IoT Based Smart ECG Monitoring System

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Abstract: Public healthcare has been paid increasing attention given the exponential growth human population and medical expenses. It is well known that an effective health monitoring system can detect abnormalities of health conditions in time and make diagnoses according to the gleaned data. As a vital approach to diagnosing heart diseases, ECG monitoring is widely studied and applied. However, nearly all existing portable ECG monitoring systems cannot work without a mobile application, which is responsible for data collection and display. In this project, we propose a new method for ECG monitoring based on Internet-of-Things (IoT) techniques. ECG data are gathered using a wearable monitoring node and are transmitted directly to the IoT cloud using Wi-Fi. Both the HTTP and MQTT protocols are employed in the IoT cloud in order to provide visual and timely ECG data to users. Nearly all smart terminals with a web browser can acquire ECG data conveniently, which has greatly alleviated the cross-platform issue. Experiments are carried out on healthy volunteers in order to verify the reliability of the entire system. Experimental results reveal that the proposed system is reliable in collecting and displaying real-time ECG data, which can aid in the primary diagnosis of certain heart diseases.

I. INTRODUCTION

Heart diseases are becoming a big issue for the last few decades and many people die because of certain health problems. Therefore, heart disease cannot be taken lightly. In every country, the number of deaths caused by chronic and cardiovascular diseases (CVDs) has increased over the last decade. CVDs are ailments that affect the heart and blood vessels. Vascular illnesses, such as coronary artery diseases, are CVDs that affect the blood vessels. Heart failure, cardiomyopathy, rheumatic heart disorders, stroke, heart attack, and arrhythmias are among the conditions that affect the heart. CVDs are the leading cause of death worldwide, according to the World Health Organization (WHO), with 17.9 million death per year. It is still the leading cause of mortality in the United States, killing over 8,40,000 people in 2016. Moreover, according to the 2017 edition of the European Health Network European Cardiovascular Disease Statics, CVDs cause 3.9 million fatalities in Europe and over 1.8 million people die in the European Union (EU) per year. This accounts for 45% of all deaths in Europe and 37% of all deaths in the European Union. Continues heart rate monitoring and immediate heartbeat detection are important priorities in today's healthcare. As a result, monitoring physiological signals like electrocardiogram (ECG) signals provides a new holistic paradigm for assessing CVD and aiding disease control and prevention. Sensor technology, communication infrastructure, data processing, modeling, and analytics algorithms have advanced to the point where the risk of impairments can be better addressed than ever before. As a result, a new era of smart, proactive healthcare would emerge, especially given the significant obstacle of limited medical resources. By 2020, the Internet of Things (IoT) will have grown to the point where it will be possible to converse with about a billion connected gadgets over the internet. A cloud-based mobile ECG monitoring service was demonstrated. These can detect ECG signals using a sensor and communicate them to a screen using wireless transmission systems like Bluetooth, Low - power wireless, and Wi-Fi. An ECG monitoring device that can be worn on the body and delivers data directly to the IoT cloud through Wi-Fi without the use of a mobile terminal is available. When compared to Bluetooth or Zigbee, Wi-Fi can deliver faster data speeds and wider coverage areas. A web-based graphical user interface is built to make it simple for doctors and patients to access data services supplied by the IoT cloud utilizing smartphones running on various OS systems. There are several works in electrocardiogram IoT. In The framework was created using Arduino and GSM module for a home-alone elderly patient to determine if there are any heart troubles or if the patient's condition has fallen.

The framework delivers data to the specialist by cell phone SMS, and it was created using Arduino and GSM modules. The framework sends an alert to designated expected individuals or a medical center if the Echocardiography and body vibration signals are out of the ordinary. Their method makes use of a Raspberry Pi as a microcontroller and the cloud as a medium for transferring ECG data to a viewing system. This system still has flaws, such as the requirement for a good internet connection so that doctors may access it at any time. presented a system that can send messages to users and doctors if a deformity is discovered following an ECG analysis.

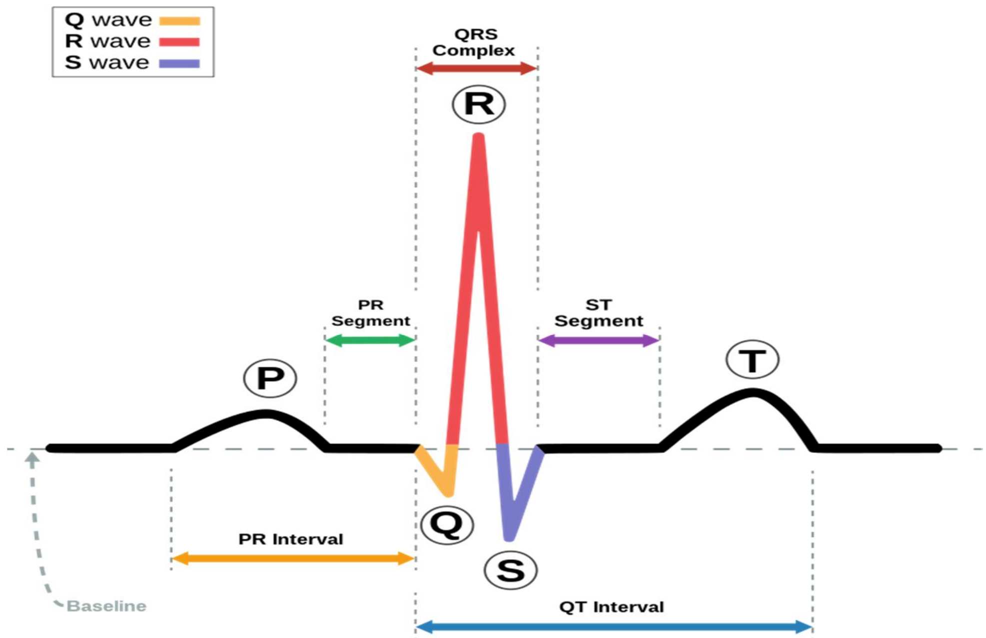

Figure-1: Physiology of ECG (Wikipedia)

II. ARCHITECTURE OF IOT-BASED ECG MONITORING SYSTEM

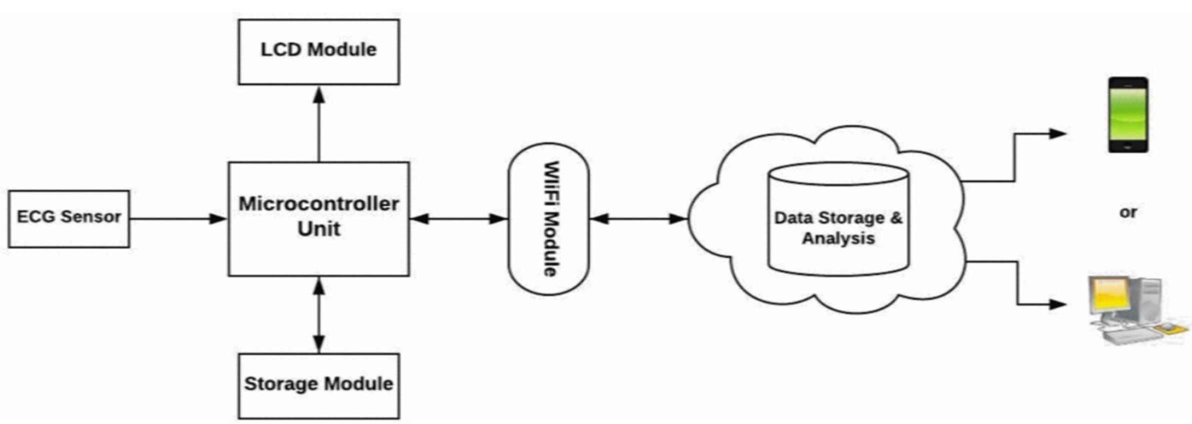

Figure-2: Architecture of ECG recording framework (ResearchGate)

Figure-2 illustrates the IoT-based ECG recording framework architecture.

A. *Data Collection Network*

The Data gathering structure is the base of the total framework, that is committed for gathering the anatomical data from the surface of the body. As Wi-Fi protocol can give higher data esteems and more extensive inclusion regions, the ECG information assembled from the sensors are sent to IoT Cloud by methods of Wi-Fi convention.

B. Data Storage and Display

An SD card is used for offline storage of ECG information as it is very suitable to implement since its communication is based on an advanced nine-pin interface and its design is operated in a low voltage. A Thin film transistor (TFT) LCD is Interfaced in order to display the Real Time ECG Wave.

C. Cloud Server

The ECG information can store and inspect enough and successfully with the enhancement of the progressed Internet-of-Things systems. With the help of an Internet-of-Things Cloud, information activities and scrutinizes can be done in high-power servers, which incredibly decreases the heap on smart gadgets.

D. Graphical User Interface (GUI)

The Graphical User Interface is in charge of information perception and administration. It gives an easy comprehensibility Module; 3) Communication Module; 4) Offline Storage Module 5) Display module 6) Power Module.

The architecture of the IoT-based ECG Monitoring System is mainly consisting of three parts- AD8232 ECG Sensor, NodeMCU ESP8266, and Ubidots.

1) AD8232 ECG Sensor

Electrocardiography or ECG is a technique for gathering electrical signals which are generated from the human heart. When someone experiences physiological arousal then the ECG sensor allows us to recognize the level, however, it is also used for understanding the psychological state of humans. So an AD8232 sensor is used to calculate the electrical activity of the heart. This is a small chip and the electrical action of this can be charted like an ECG (Electrocardiogram). Electrocardiography can be used to help in diagnosing different conditions of the heart.

The AD8232 ECG sensor is a commercial board used to calculate the electrical movement of the human heart. This action can be chart like an Electrocardiogram and the output of this is an analog reading. Electrocardiograms can be very noisy, so to reduce the noise the AD8232 chip can be used. The working principle of the ECG sensor is like an operational amplifier to help in getting a clear signal from the intervals simply. The AD8232 sensor is used for signal conditioning in ECG as well as other measurement applications of biopotential. The main purpose of this chip is to amplify, extract as well as filter biopotential signals which are small in the noisy conditions like those formed through the replacement of remote electrode as well as motion.

The heart rate monitoring sensor like AD8232 includes the pins like SDN pin, LO+ pin, LO- pin, OUTPUT pin, 3.3V pin, and GND pin. So that we can connect this IC to development boards like Arduino by soldering pins. Additionally, this board includes pins like the right arm (RA), left arm (LA) & right leg (RL) pins to connect custom sensors. An LED indicator in this board is used to indicate the heartbeat rhythm of humans. The AD8232 sensor comprises a function like quick restore, used to decrease the length of long resolving tails of the HPFs. This sensor is accessible in a 4 mm × 4 mm size, and the package of this sensor is 20-lead LFCSP. It operates from −40°C -to- +85°C but the performance is specified from 0°C -to- 70°C.

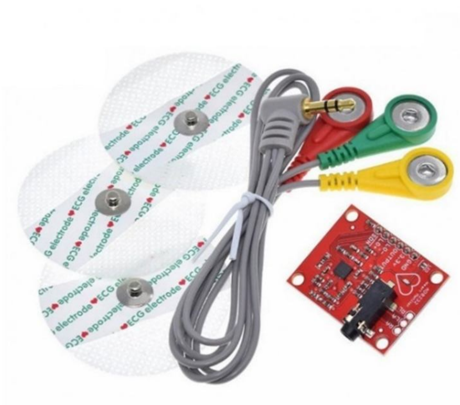

Figure-3: AD8232 ECG Sensor (ELPROCUS)

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2) Node MCU ESP8266

NodeMCU is an open-source Lua based firmware and **development board** specially targeted for IoT based Applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. This board contains a microcontroller and Wi-Fi module. The operating voltage of ESP8266 is 3.3 V. The single board microcontroller utilized in this board contains 12 GPIO and D0. It does not fortify open drain/interrupt/PWM/1-Wire and it is a 32bit microcontroller. It as a recollection of 128Bytes and its storage capacity is 4Mbytes. ESP8266 is a Wi-Fi module integrated with TENSILICA XTENSA LX106 core which is widely utilized in IoT applications. NodeMCU fortifies MQTT protocol.

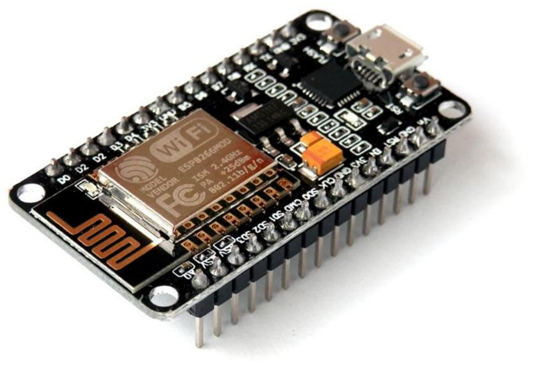

Figure-4: NodeMCU ESP8266 (COMPONENTS101)

3) Ubidots

Ubidots is an IoT Application Enablement Platform (AEP) enabling System Integrators (SIs) and SMBs to rapidly assemble and launch IoT applications. Ubidots building blocks including drag-and-drop dashboards, device friendly APIs, analytics, reports, and alerts.

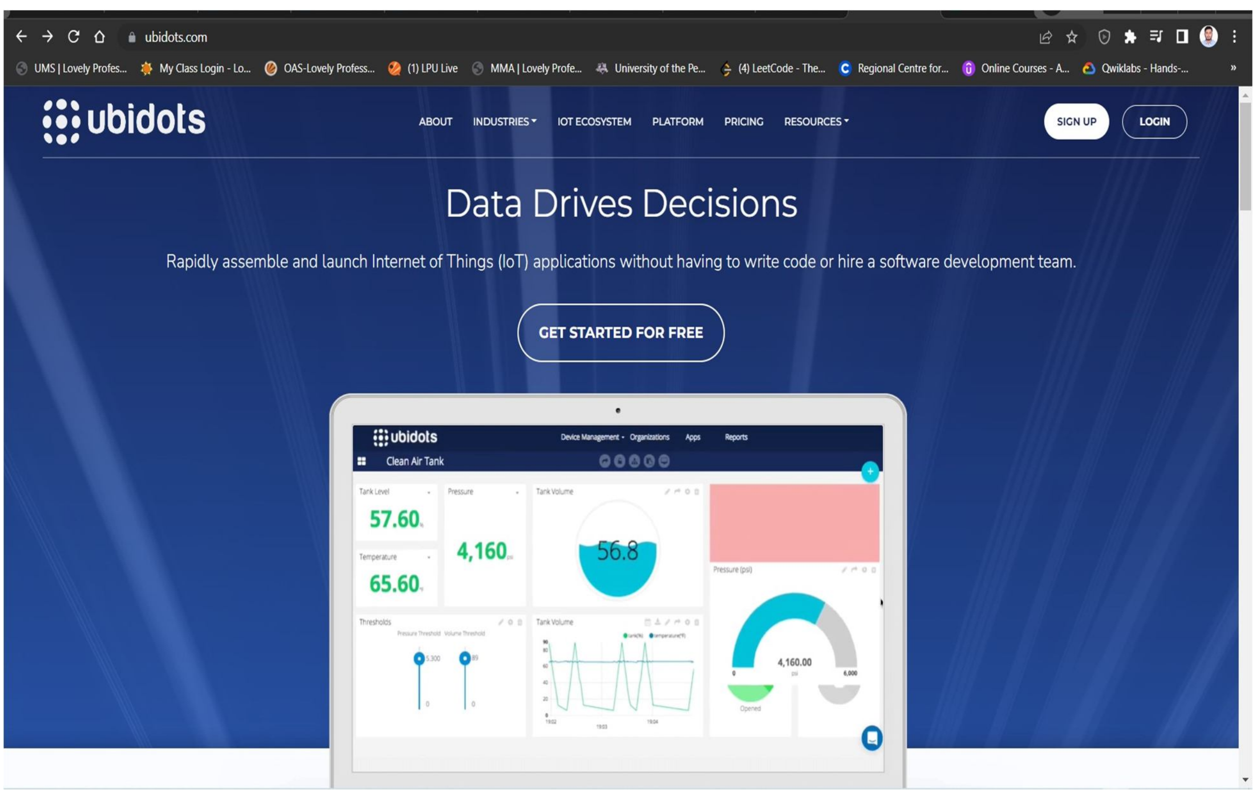

Figure-5: Ubidots GUI

Table I: According to [7], comparison among typical ECG Sensing Networks such as Wi-Fi, Bluetooth, and ZigBee.

Standards	Wi-Fi based sensing network	Bluetooth based ECG sensing Network	ZigBee-based ECG sensing network
Protocol	IEEE 802.11	IEEE 802.15.1	IEEE 802.15.4
Coverage	100 m	10 m	10-100 m
Data Rates	54 Mbps	1 Mbps	250 Kbps
Power Consumption	Medium	Low	Low
Terminal Dependency	Data collection in dependent of smart terminals	Smart terminals are needed for receiving and forwarding sensed data	Smart terminals needed for receiving and forwarding sensed data

III. MATERIAL & METHOD

A. *Proposed System*

Table-II: The following components are used to run the project:

S. No	Components Name	Description
1	NodeMCU	Wi-Fi module ESP8266 A1 Cloud Inside
2	ECG Sensor	AD8232 ECG Sensor Kit
3	Jumper Wire	-
4	Breadboard	-
5	Laptop/Mobile	-

B. *Circuit Diagram: Interfacing AD8232 ECG Sensor with NodeMCU ESP8266*

Here is a circuit diagram for Interfacing AD8232 ECG Sensor with NodeMCU ESP8266**.** There are 6 pins in AD8232 Breakout Board. SDN is not connected.

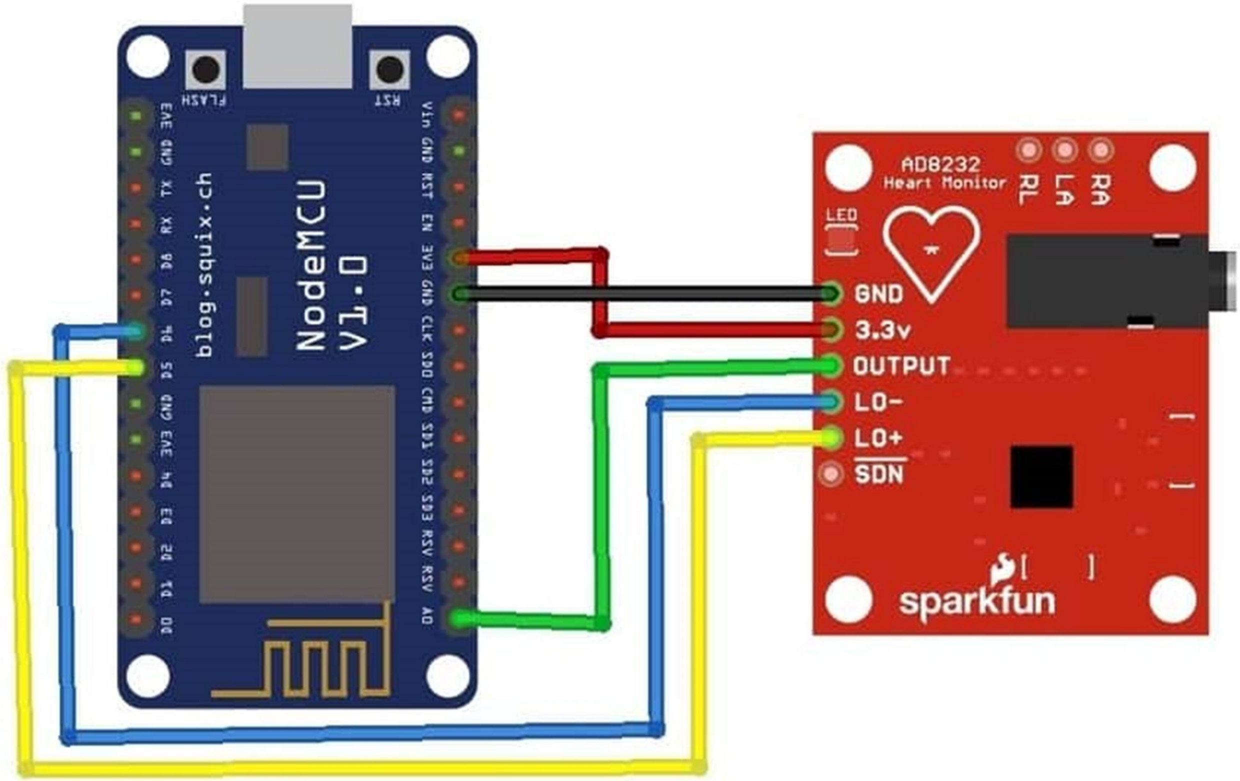

Figure-6: Circuit Diagram (How2Electronics)

Connect the output to analog A0 of NodeMCU. Connect the LO+ & LO- to D5 & D6 of NodeMCU respectively. Supply the AD8232 kit with 3.3V VCC and connect its GND to GND.

C. ECG Leads/Electrodes Placement

It is recommended to snap the sensor pads on the leads before application to the body. The closer to the heart the pads are, the better measurement. The cables are color-coded to help identify proper placement.

Red: RA (Right ARM)

Yellow: LA (Left ARM)

Green: RL (Right Leg)

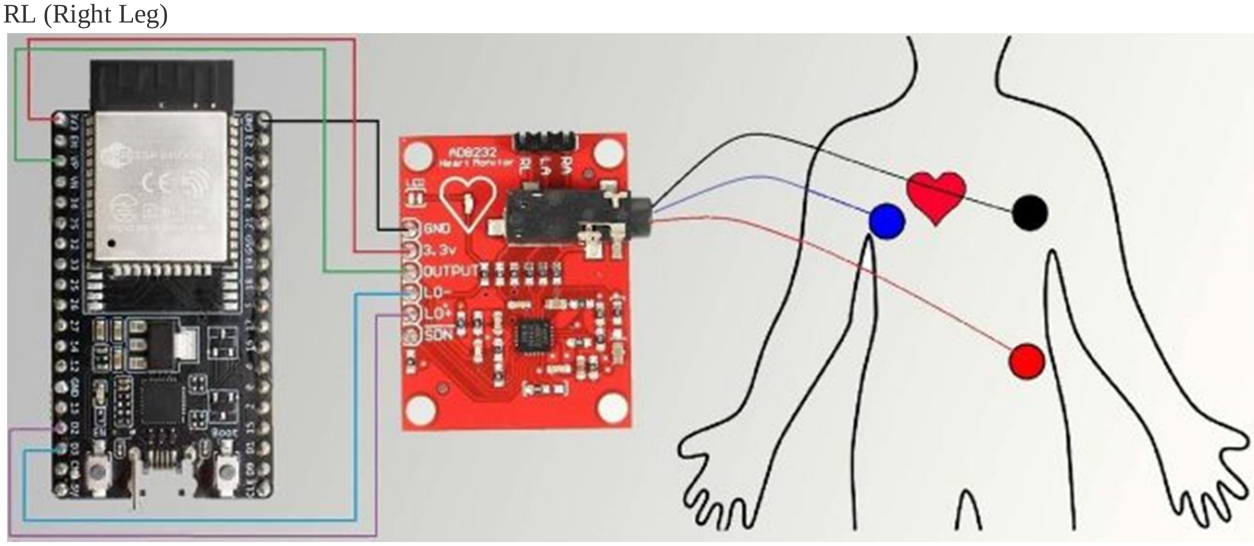

Figure-7: ECG Leads/Electrodes Placement (How2Electronics)

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IV. EXPERIMENTAL RESULT AND ANALYSIS

A 3-lead placement is adequate to analyze the primary features of ECG signal compared to conventional 12-lead ECG monitoring device used in hospitals. In order to best sample the ECG signal, the electrodes need to be placed around the heart and form a triangle. In order to justify the performance of our system we have conducted several tests on some patients.

Typical ECG signals mainly consist of five type of waves such as the P wave, T wave, Q wave, R wave, and S wave, as shown in "Figure-7". The intervals of these waves are used to diagnose several of heart diseases.

1) *RR Interval:* As one of the most conspicuous characteristics, the R wave is often used to identify the period of an ECG signal. RR interval indicates the time interval between two adjacent R waves, which may become irregular in the event of some heart diseases, for example, the arrhythmia.
2) *PR Interval:* The PR interval measures the time between the beginning of the P wave and that of the QRS complex. It indicates the time the impulse takes to reach the ventricles from the sinus node.
3) *QT Interval:* QT interval represents the time between the start of the Q wave and the end of the T wave, which is related to the ventricular depolarization and repolarization. There is an increased risk of ventricular fibrillation or even sudden cardiac death if the QT interval exceeds the normal value.
4) *QRS Complex:* QRS complex is mainly associated with the Ventricular depolarization, which consists of three important waves, i.e., Q wave, R wave and S wave. By analyzing the QRS complex, certain diseases are likely to be detected such as drug toxicity and electrolyte imbalance.

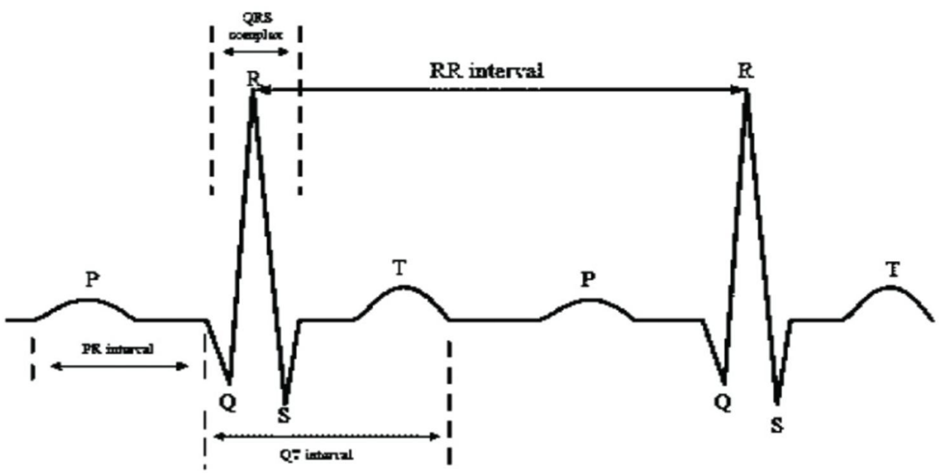

Figure-8: Standard ECG Signal

According to [9] [10], the normal values of ECG parameters are listed in Table-III.

Table-III: Normal values of key ECG Parameters

Features	Characteristics
PR Interval	0.12-0.20 sec
QRS Interval	0.06-0.10 sec
QT Interval	Less than half of the R-R interval
ST Segment	0.08 sec

Abnormalities are found when the two conditions are not valid. Finally, if any disorders are found then an emergency email has been sent to the users or doctors so that, they can take emergency steps to prevent severe damage oo the patients. This can reduce the mortality rate and any kind of damage that causes due to heart failure.

V. CONCLUSION

Integration of healthcare with IoT has opened up a vast arena of development. It will not only facilitate healthcare but will also find out new measures to prevent diseases by processing data and by analyzing global trends. Moreover, a vast future lies entirely in the automation of hospitals and treatment mechanisms that can help doctors understand diseases through artificial intelligence and IoT. However, we should take a step at a time and not rush in into this field, since it deals with human health and safety and security needs to be the top agenda. On a large scale, this can also lead to cheaper treatments and cheaper nursing costs for patients. If technology and health go hand in hand, we can reach the goal of cheap, safe, and efficient disease prevention and treatment.

VI. FURTHER SCOPE

The project can be further modified by 9 or 12 ECG leads for more accuracy. Various conditions can be analyzed and based on that prediction patient will get the alert message.