International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

IOT Based Low Cost ECG Monitoring System

Jabed Rana Ridoy[1], Shanjana Shaznin[2] , Chaluvaraju P P[3]

[1]*Department of Electronics & Communication Engineering (ece), Jain Deemed to-be University, Bangalore, 562112, India*

[2]*Department of Electronics & Communication Engineering (ece), Jain Deemed to-be University, Bangalore, 562112, India*

[3]*Associate Professor, Department of Electronics & Communication Engineering (ece)*

Jain Deemed to-be-University, Bangalore,562112, India

DOI: https://doi.org/10.55248/gengpi.4.623.46717

A B S T R A C T

The development of new technologies has led to remarkable enhancements in the quality of healthcare, especially in the area of heart health. Internet of Things (IoT)-enabled electrocardiogram (ECG) and heart monitoring systems have changed the way cardiac health is tracked and managed because of their low cost. Our goal with this project is to contribute to this change by creating a low-cost electrocardiogram (ECG) and heart-monitoring device that runs entirely on an Arduino Uno microcontroller. Using Bluetooth media, the system enables monitoring from a distance of up to 100 metres without an internet connection. A notification will immediately sent to the user and doctors when a deformity is detected so they may analyze the patients' severe conditions and give emergency medical care. Our solution provides a reliable and accurate way of monitoring heart health, allowing healthcare professionals to detect and diagnose heart-related issues in real-time. In this study, we detail the planning, execution, and assessment processes that led to our system's 86% accuracy, highlighting its salient features, useful advantages, and prospective healthcare applications. We think our initiative has the potential to greatly improve healthcare outcomes, especially for the poor and those without access to costly medical equipment, by providing an inexpensive and efficient alternative for heart health monitoring.

Key word: ECG(electrocardiogram), IoT, Arduino Uno, Low-cost, Remote-Monitoring.

1. Introduction

ECG is the way to detect abnormality in the heart. It detects our heart rate in real time. It recruits an electrode to estimate and note the electrical task of the heart muscle. In the current world, ECG is present in some hospitals where it is used to detect heart abnormalities and even prevent serious illness such as a heart attack by taking medical help on time. So its very important that each one of us can check our ECG on our own and then consult a doctor. [1] 12 lead systems are also used in certain hospitals to get the ECG report of the patients. But this is an expensive process for personal use. On top of that, regular routine check up can also be difficult and expensive especially for elderly people plus it also increases hospital's workload. Moreover, elderly people are the ones who actually require regular heart checkup as they have high risks of heart diseases. [2] A system was proposed to detect ECG by taking raspberry pie as a microcontroller with the help of IOT. It had ECG data processor which transformed analog signal to digital signal and also had an ECG signal reader. It was a low cost system but at the same time had its own drawbacks such as it would require good internet connection. This was a bit difficult for remote areas. [3] Another system was also proposed for nonprofessional issues which again had a drawback that its operational range was only 10 meters as it was dependent on Bluetooth.[4] A system which was android phone based was also proposed. In this system, the data of the heart rate was stored in the memory card of the phone. But still it had limitations as it was not monitored in real time . Here in the proposed system, we use an ECG monitoring system which is cloud based for detecting the heart rate using Wi-Fi and sensor. It detects the heart rate and sends it to the IOT cloud through Wi-Fi. Wi-Fi is much faster than Bluetooth or Zig-Bee and also has more coverage area. This is a low cost system and it also connects the individuals to the health Institutions in times of need. Here we are capable of having a real time access to the patient's heartbeat anytime and anywhere.

1.1 Tables

Here is a comparison of the usual ECGsensing networs.

Table 1 - A COMPARISON OF THE USUAL ECG SENSING NETWORKS, SUCH AS BLUETOOTH , ZIGBEE AND WI-FI.

Standards	Wi-Fi ECG monitoring network	Network for ECG detection using Bluetooth	ZigBee-based ECG sensing network
Agreement	IEEE 802.11	IEEE 802.15.1	IEEE 802.15.4
Range	20-200 m	20-30 m	2-20 m

Accounting data	11-54 Mbps	3-24 Mbps	10-250 kbps
Power demanding	Medium	Low	Low
Lethal dependency	Independent data collection of smart terminals	Sensing data must be received and sent to smart terminals.	The receiving and transmitting of sensed data requires smart terminals.

1.2 Problem Definition

One of the main causes of death on a global and national scale is cardiovascular disease. Every year, this illness claims 18.7 million lives. Such ailments include coronary heart disease, cerebrovascular disease, and rheumatic heart diseases are among the disorders of the blood arteries and the heart that are included under the term "CVDs.”. In order to prevent this problem, continual heart monitoring and heartbeat observation are required so that precautions can be immediately taken in case of any irregularities. This will not only detect the irregularities but also safe the patient by helping him/her take the help of doctor in time.

1.3 Hardware and Software Requirements

Hardware Specifications:

- ECG Electrode as signal reader
- AD8232 as ECG Modul
- Microcontroller with ATmega328P as IC
- HC-05 as bluetooth communication
- Android 5.1 as ECG signal viewer

Software Specifications:

- Arduino IDE

2. Literature Survey

Here are some Literature surveys which we have covered for theimplementation of our project and finding the best route to deploy it.

Table 2 - Literature Survey

Year	Concepts which were researched and published
2009	The Normal ECG and its (Normal) variants. In: The ECG manual.
2015	MEG-based multimodal database for decoding affective physiological responses.
2016	Low power wearable ECG monitoring system for multiple-patient remote monitoring
2017	Real Time ECG Monitoring System Based on Internet of Things (IoT)
2019	IoT-based Portable ECG Monitoring System for Smart Healthcare
2020	Minimum System Design of The IoT-Based ECG Monitoring

2.1 Related Work

[1] “M. Chhabra and M. Kalsi, "Real Time ECG Monitoring System Based on Internet of Things (IoT)," International Journal of Scientific and Research Publications, pp. 547-550, 2017. Several initiatives are being made to monitor the Internet of Things using electrocardiograms. One of these is the ECG monitoring by Chhabra and Kalsi. Their method uses a Raspberry Pi as the microcontroller and the cloud as the transfer channel to provide ECG data to the viewer system. The sensor used to read and convert the ECG signal to an analogue signal is the AD8232. After processing the signal, the microcontroller uses the cloud to transmit the generated data to the viewer system. This technology still has drawbacks since in order for doctors to use the system at any time, they need a steady internet connection. An Internet of Things-based ECG monitoring system that can save ECG data was presented by Kamble and Birajdar.

[2] “P. Kamble and A. Birajdar, "IoT Based Portable ECG Monitoring Device for Smart Healthcare," Fifth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), pp. 471- 474, 2019. This paper proposes an Internet of Things-based sensor-based system architecture for ECG monitoring. Finally, based on the architecture, we created an ECG-based heart rate monitoring system, even though the authors [7] employed Resberi-pi 3b. The database server will get the recorded ECG data right away thanks to a Wi-Fi module. Wi-Fi was selected because it may offer broader coverage areas and quicker data transmission speeds.

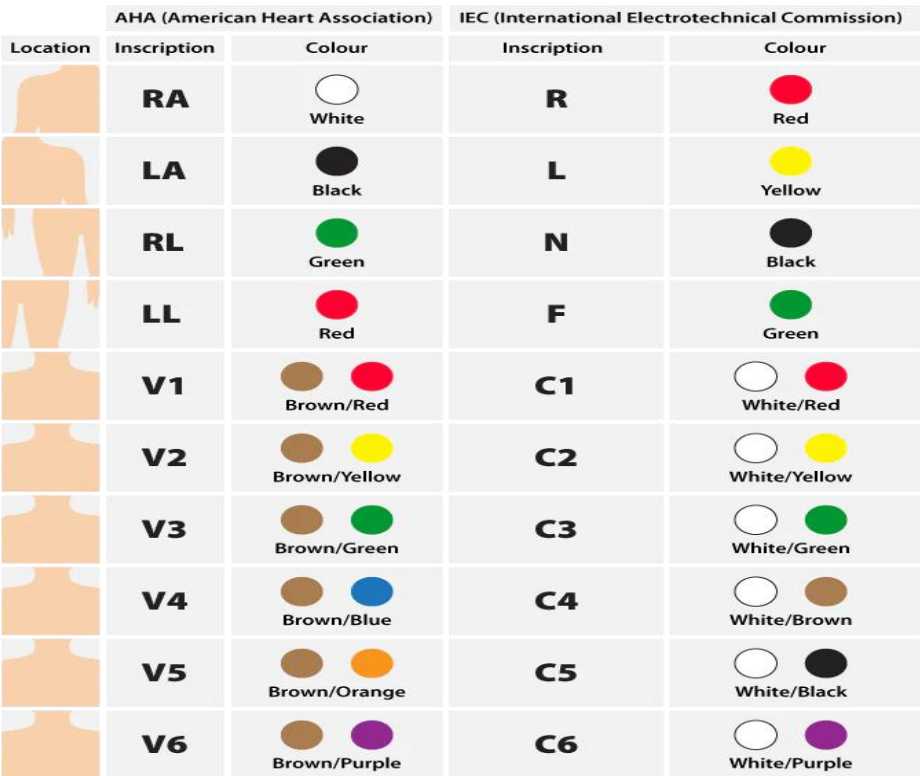
[3] “A. F. Ghifari and R. S. Perdana, "Minimum System Design of The IoT-Based ECG Monitoring," 2020 International Conference on ICT for Smart Society (ICISS), Bandung, Indonesia, 2020, pp. 1-6. This paper introduces the ECG monitoring architecture, describes the monitoring value chain and the main processes involved. It also describes the experts’ taxonomy of ECG monitoring systems. It details, compares, and analyzes each cluster of studies, as well as highlights the key features and reviews some research challenges. It emphasizes the key challenges related to ECG monitoring systems. Finally, the last section summarizes and discusses our findings and points to future research directions for ECG monitoring systems.

[4] Tseng, K., Lin, B., Liao, L., and et al., “Development of a wearable mobile electrocardiogram monitoring system by using novel dry foam electrodes”. *IEEE Syst. J.* 8:900–906, 2014. Systems have been proposed using an ECG sensor in [2], [3], [5], [6], [7]. They have attached the ECG sensors onto the patient's body, which they use to record continuous ECG data of the given patients, which is then saved onto their databases or is sent to the cloud server for later processing and analysis. Some of the approaches have used Heart Rate monitoring in their system, the sensor used, calculates the BPM of the patient continuously. Temperature sensors have been quite a common approach for the studies done in this particular topic, researchers have proposed a system that takes in temperature reading of the patients at all time, and saves it for future references.

[5] Shneiderman, B., and Plaisant, C., “Sharpening analytic focus to cope with big data volume and variety”. *IEEE Comput. Graph. Appl.* 35:10–14, 2015. Holter-based ECG monitoring is another type of system proposed. It is connected to the patient’s body through electrodes. A small and smart ECG Holter monitoring system integrated smartphones to retrieve ECGs from sensors, classify and detect abnormal signs.

2.2 Existing Work

Traditional 12 leads systems are utilised in medical facilities or hospitals to gather the body of the patient's ECG signals. You cannot move about with this equipment.



	AHA (American Heart Association)		IEC (International Electrotechnical Commission)	
Location	Inscription	Colour	Inscription	Colour
	RA	White	R	Red
	LA	Black	L	Yellow
	RL	Green	N	Black
	LL	Red	F	Green
	V1	Brown/Red	C1	White/Red
	V2	Brown/Yellow	C2	White/Yellow
	V3	Brown/Green	C3	White/Green
	V4	Brown/Blue	C4	White/Brown
	V5	Brown/Orange	C5	White/Black
	V6	Brown/Purple	C6	White/Purple

Figure 1 : 12 Leads System

2.3 Problems in Existing Work

Here is some problem in the existing system which should be highly considered for present day.

- But this is an expensive process for personal use
- Our system cannot be remotely controlled moved from one location to another.
- Inaccurate electrode placement and differences in inter-individual human anatomies can lead to misinterpretation of ECG examination

2.4 Proposed System

As opposed to the standard 12-lead ECG monitoring equipment used in hospitals, a 3-lead placement is sufficient for analyzing the critical ECG signal features [9]. The electrodes must be arranged around the heart in a triangular shape for the best ECG data collecting. The P wave, T wave, Q wave, R wave, and S wave are the five main wave types that make up a typical ECG signal, as seen in "Fig. 5". These waves' intervals are utilized to identify a number of cardiac conditions. The database server will get the recorded ECG data right away thanks to a Wi-Fi module. Wi-Fi was selected because it may offer broader coverage areas and quicker data transmission speeds. Wi-Fi is utilized to send emails to the patient's physicians or family in the case of a medical emergency. This smart device may be used to monitor a user's health condition so that physicians can take the appropriate precautions to prevent sudden cardiac death. It is also cheaply priced.

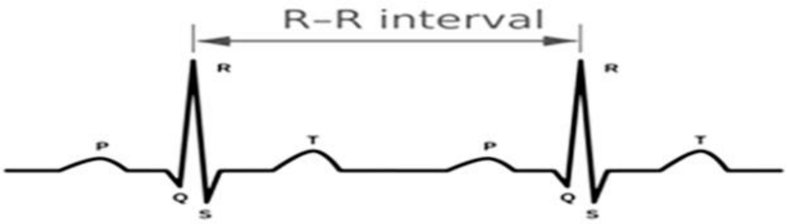


Figure 2: Standard ECG Signal

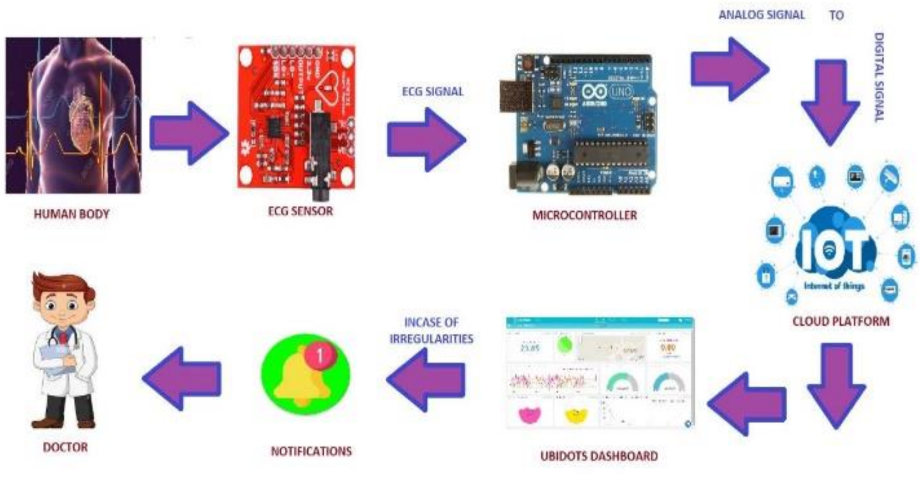


Figure 3: Proposed system Block diagram

3. System Design

3.1 Flowchart diagram

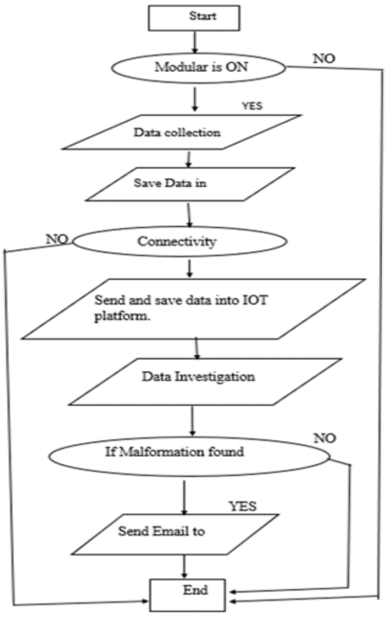


Figure 4: Proposed working model flowchart

As per the Fig.3 - Proposed Flowchart which shows how the proposed system will work accordingly.

1. The gadget checks to verify if all of the modular components are on or off when it is turned on for the first time by the user.
2. The module must be "off" in order for to keep the system turned off.
3. If the module is turned on, the system will start up and start collecting data from the human body. Following that, this data will be automatically updated in a local database.
4. A cloud database will be used to evaluate the data and search for any abnormalities. once an internet connection is found, and the results will be relayed to the consumers through Wi-Fi.
5. The technique recommended and put into practice in this study involves collecting ECG data from patients' bodies and emailing doctors in the event of any anomalies so they may take the necessary steps to reduce the harm caused by cardiovascular disorders.

3.2 Circuit Diagram

Circuit Diagram:

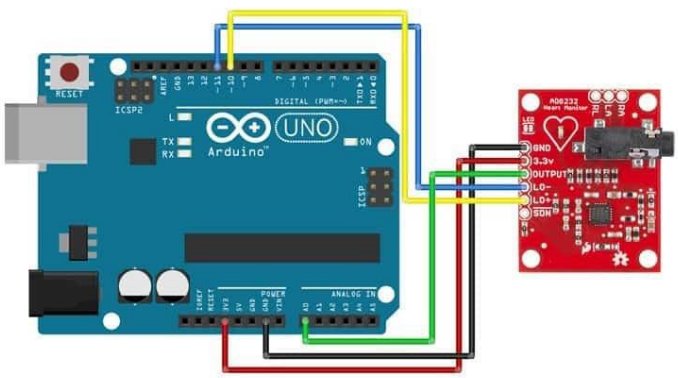


Figure 5: circuit diagram

4. Tool Description

4.1 Hardware Requirements:

ESP 32 module:

The ESP32 is a powerful and cost-effective Wi-Fi and Bluetooth module has been used in IoT-based low-cost ECG and heart rate monitoring systems. When combined with an analog front-end circuit, the ESP32 can acquire ECG and heart rate data from sensors, process it using its internal ADC and dual-core processor, and transmit it wirelessly to the cloud using its built-in Wi-Fi and Bluetooth connectivity. The Ubidots platform is used for data visualization, storage, and analysis, making it an ideal choice for IoT-based ECG and heart rate monitoring systems that use the ESP32. With its low power consumption and real-time monitoring capabilities, the ESP32 is a popular choice for developers looking to build low-cost, reliable, and accurate ECG and heart rate monitoring systems.

Figure 6: Esp32 Module

ECG Module AD8232:

Figure 7: ECG Module AD8232

Arduino UNO: Arduino is the eco-friendly board to the projects of the IOT students orelectronic department. Widely, it is used for big and small project like car robot, gas detection system, irrigation monitoring system, Bluetooth controlling device and so on. Itconsists of main pins like I/O pins, 5v power pins, GND pins, Analog and Digital pins, serialpins and so on.[1]\

Figure 8: Arduino Uno

IoT Cloud:

In this project we used Ubidots as a IoT platform to collect, store, and analyze the data generated by the monitoring devices. This data can then be used to gain insights into the patient's health status, detect any abnormalities or irregularities in their heart rate or ECG, and trigger alerts or notifications if necessary. Ubidots provides various tools and features that can be used to create custom dashboards and visualizations to monitor the ECG and heart rate data in real-time. Additionally, Ubidots also provides integrations with other third-party services, such as Google Sheets, Zapier, and Slack, which can be used to automate workflows or trigger alerts based on certain conditions or events.Overall, Ubidots can be a useful platform for low-cost ECG and heart rate monitoring, providing a user-friendly interface, data storage, and analysis tools, and integrations with other services to enhance the monitoring capabilities.

GUI:

The administration of data imagination using a graphical user interface (GUI). The procedure of putting data into the IoT cloud is made simpler. Users may sign up for the cloud to access real-time visual ECG data. Mobile applications and websites are frequently the two primary GUI kinds that clients have access to for displaying ECG data. Despite the speedy reaction times of mobile apps, websites offer the best protection and updating options.

ECG Electrodes:

Figure 9: ECG Electrode

4.2 Software Requirements:

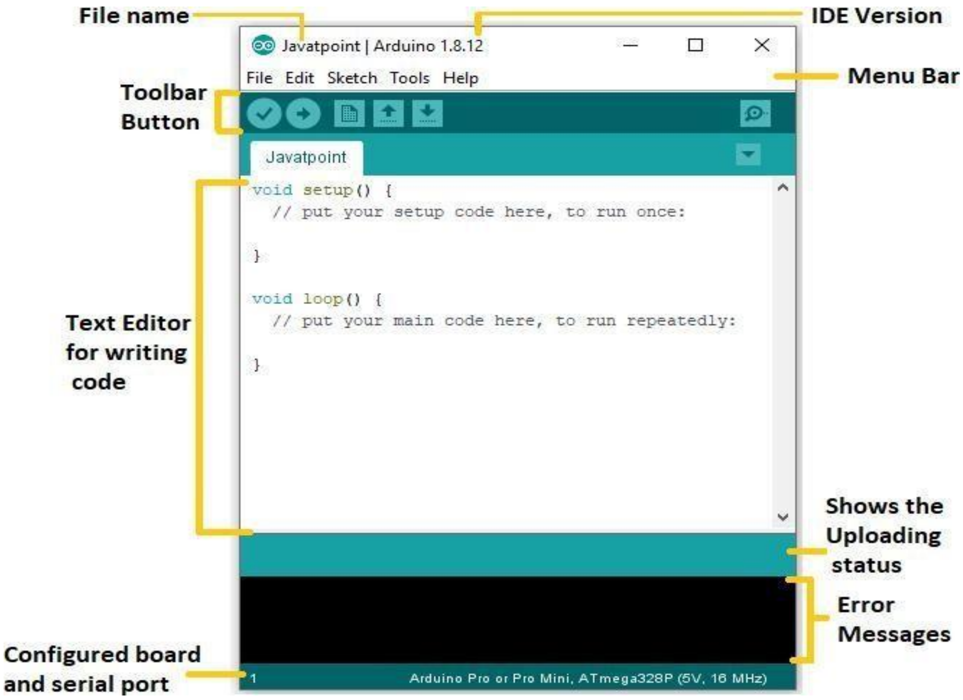


Figure 10: Arduino IDE

Due to its simplicity and inexpensive price, Arduino Uno is a well-known microcontroller board that is frequently utilized in IoT-based applications. The creation of inexpensive ECG and heart rate monitors is one of the Arduino Uno board's potential applications. An Arduino Uno board may be readily designed to gather and interpret ECG data and determine heart rate with the aid of the proper sensors and modules. A central server may then receive the wirelessly sent data from the device for remote monitoring and analysis. The possibility to deliver inexpensive ECG and heart rate monitoring to impoverished regions and contribute to raising the standard of healthcare services is presented by this cost-effective option.

5. Implementation

5.1 Implementation:

Here, we have done the implementation of the project by collecting all the required hardware and software essential tools. By combining all, we embed our system.

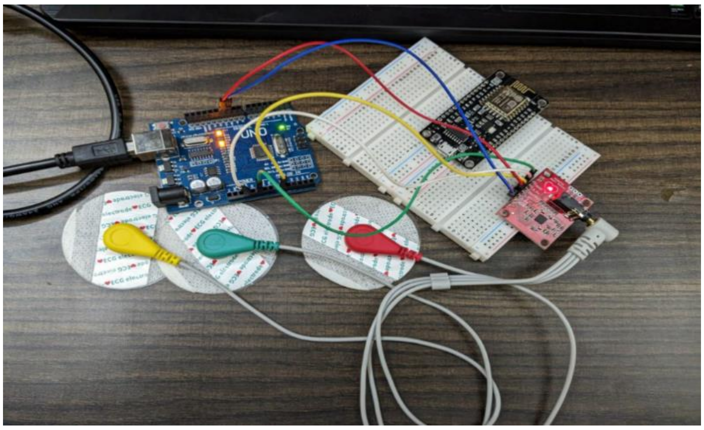


Figure11: implementation of the system

Programming with the Arduino IDE:

In order to run our car, first of all we need to setup Arduino IDE accordingly.

- Go to board manager and upload json file as according to your board.

- Go to sketch and download the library Arduino uno.
- Then go to tools, select the board Arduino uno.
- Select the baud rate, frequency.
- Paste the code to the Arduino IDE and compile the code.

Working Principle:

Table 3 - ECG KEY PARAMETER & NORMAL VALUES.

Characteristics	**Standard Range (Second)**
PR Interval	0.12-0.20
RR Interval	0.6-1
QRS Complex	<0.12
QT Intervel	0.32-0.44

- When any of the two requirements is false, anomalies are discovered**.**
- Lastly, if any abnormalities are discovered, an urgent email has been issued to users or physicians so they may act quickly to protect patients from suffering serious harm.
- This can lower heart failure-related death rates and harm of any sort.
- For quick study of the patient's condition and to obtain the most accurate data, a triangle-shaped arrangement of 3 lead electrodes is used around the heart.

6. Results

- **PR** interval: The period between the commencement of the P wave and the beginning of the QRS complex is measured by the PR interval. It displays the amount of time the impulse needs to travel from the sinus node to the ventricles.
- **RR** interval: The R wave is frequently used to determine an ECG signal's period since it is one of its most obvious features. The RR interval, which denotes the space of time between two consecutive R waves, may become irregular in the case of certain cardiac conditions, such as an arrhythmia.
- **QT** interval: The QT interval, which is connected to ventricular depolarization and repolarization, is the span of time between the beginning of the Q wave and the conclusion of the T wave. If the QT interval is longer than the usual range, there is an increased risk of ventricular fibrillation or potentially sudden cardiac death.
- **QRS** complex: The Q wave, R wave, and S wave are the three significant waves that make up the ventricular depolarization, which is primarily related to the QRS complex. Some disorders, including as medication toxicity and electrolyte imbalance, are likely to be found by studying the QRS complex.

The ECG information obtained from a healthy 23-year-old is displayed in "Fig.6". There is no indication of a danger of developing arrhythmias since the RR interval—the distance between successive R waves—is almost identical.

Fig. 12. ECG signal of a healthy volunteer in real time.

Table 4 – COMPARISON OF THE TWO SYSTEMS

Existing System		Proposed System	
Component	Price (USD)	Component	Price (USD)
Raspberry-pi 3b	$120	Arduino Uno	$10
Arduino Uno	$10	ECG AD8232sensor	$5.27
ECG sensor	$6	ECG Electrode Connector - 3.5 mm	$5.66
PCB	$1	ECG Electrodes - 3 pieces	$0.05
Other Components	$2	ESP 32	$7.46
Total Cost	$139	Total Cost	$28.44

As demonstrated in "Fig. 12," the QRS complex is also regular, proving that the ventricular depolarization and repolarization processes are normal. The QT interval is normal as well. The fact that the PR interval is within the typical range of values shows that the atria's depolarization process is also normal. Thus, there are no heart issues present in this person. The trial outcome demonstrates the dependability of our system. We came up with a high-fieldity prototype system and compared it with a 12-lead ECG machine.

Table 4 – TEST RESULTS

Test	**Test on 3-lead ECG Device**	**Test on 12-lead ECG Device**
1	Standard Sinus Rhythm	Standard Sinus Rhythm
2	Standard Sinus Rhythm	Standard Sinus Rhythm
3	Standard Sinus Rhythm	Standard Sinus Rhythm
4	Standard Sinus Rhythm	Sinus Bradycardia
5	Standard Sinus Rhythm	Standard Sinus Rhythm
6	Standard Sinus Rhythm	Standard Sinus Rhythm
7	Standard Sinus Rhythm	Standard Sinus Rhythm
8	Standard Sinus Rhythm	Sinus Bradycardia
9	Sinus Bradycardia	Standard Sinus Rhythm
10	Standard Sinus Rhythm	Sinus Tachycardia
11	Sinus Bradycardia	Sinus Bradycardia
12	Sinus Bradycardia	Standard Sinus Rhythm

We built a prototype system and used a 12-lead ECG equipment to test our invention. The test results show that our approach is trustworthy.

in "Equation (1)" is utilized to evaluate the relative between Percent Difference a 12-lead portable ECG system and a 3-lead portable ECG system.

$\underline{Expected-Actual}$

$Expected+Actual$ 2

6.1 Conclusion

The generated ECG monitoring system has been developed in compliance with the specified goals. The goal of this project is to develop a minimal IoT-based ECG monitoring system that is less expensive than a similar system created with Raspberry Pi. To create a minimal system for reading and transmitting EKG signals, Arduino Uno can be used as the IC and AD8232 as the ECG signal reader. We have collected data from patients of various ages utilising three electrode placements and have reached an 86% accuracy rate with our technique. General users, as well as patients and physicians, may use IoT-based ECG signal readings shown on the ubidot platform viewer to determine the patient's heart state without visiting the hospital. In this study, the construction of a minimal ECG monitoring system lowered manufacturing costs from USD 59.84 and 17$ (the system created by Chhabra and Kalsi (2017) Ahmad Farhan Ghifari, Riza Satria Perdana(2022) to just 15$. Compared to the prior pricing, this represents a cost reduction of 25.41%. Frequent usage of the device is highly advantageous for detecting heart disease early and reducing the risk of serious injury and death brought on by cardiovascular disease.

6.2. Future Scope

In near future, the demands of this technique will increase and will valuable for everyone. Enabling technologies provide huge opportunities for the advancement of ECG monitoring systems. IoT brings in remote, unconstrained connectivity and services that leverage data and facilitate timely, meaningful, and critical decisions for a better lifestyle. Furthermore, Fog processing and cloud processing contribute to an increased opportunity to improve efficiency and fulfill numerous in-demand scalable application services. As a future direction, exploring the field of robotics and healthcare automation has the potential to transform the next generation of ECG monitoring systems and to simplify robotic-assisted surgery procedures, elderly care, and remote and in-hospital continuous patient monitoring.

7. References:

1. Abadi, M., Subramanian, R., Kia, S., and et al., DECAF: MEG-based multimodal database for decoding affective physiological responses. IEEE Trans. Affect. Comput. 6:209–222, 2015.
2. M. Chhabra and M. Kalsi, "Real Time ECG Monitoring System Based on Internet of Things (IoT)," International Journal of Scientific and Research Publications, pp. 547-550, 2017.
3. Spanò, Elisa, Stefano Di Pascoli, and Giuseppe Iannaccone. "Lowpower wearable ECG monitoring system for multiple-patient remote monitoring." IEEESensors Journal 16, no. 13 (2016): 5452-5462.R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press
4. Yakut, Onder, Serdar Solak, and Emine Dogru Bolat. "Implementation of a Web-Based Wireless ECG Measuring and Recording System." In 17th International Conference on Medical Physics and Medical Sciences, Istanbul, vol. 9, no. 10, pp. 815-818. 2015Kim H, Kim S, Van Helleputte N et al. (2014) A configurable and low power mixed signal SoC for portable ECG monitoring applications. IEEE Transactions on Biomedical Circuits and Systems 8:257-267.
5. M. Chhabra and M. Kalsi, "Real Time ECG Monitoring System Based on Internet of Things (IoT)," International Journal of Scientific and Research Publications, pp. 547-550, 2017.
6. P. Kamble and A. Birajdar, "IoT Based Portable ECG Monitoring Device for Smart Healthcare," Fifth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), pp. 471- 474, 2019.
7. T. Shaown, I. Hasan, M. M. R. Mim and M. S. Hossain, "IoT-based Portable ECG Monitoring System for Smart Healthcare," 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), Dhaka, Bangladesh, 2019, pp. 1-5.
8. Gertsch M The Normal ECG and its (Normal) variants. In: The ECG manual. Springer, London, pp. 17-36,2009.
9. A.F. Ghifari and R. S. Perdana, "Minimum System Design of The IoT-Based ECG Monitoring," 2020 International Conference on ICT for Smart Society (ICISS), Bandung, Indonesia, 2020, pp. 1-6