

DEGRADATION OF NOBLE METAL ELECTRODES IN AN ARDUINO-CONTROLLED ECG MONITORING DEVICE

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Abstract

In recent years, the development of healthcare technology has led to an influx of data for monitoring various health conditions, which alerts to guardians in emergencies. Heart disease, a growing concern globally, underscores the necessity of continuous and early monitoring. Early detection and analysis of ECG signals can be pivotal in preventing severe heart conditions. By leverage IoT technology, this system automates the monitoring process, providing doctors with constant updates over the internet. This approach enhances the efficiency of patient care, reduces the need of physical visits, and allows for timely regulation, potentially saving lives and improving overall healthcare management. This project focuses on developing an ECG monitoring system using the AD8232 ECG sensor and Arduino UNO. The AD8232 is a compact and efficient chip designed to measure the heart's electrical activity, producing an ECG or electrocardiogram. This signal is crucial for diagnosing various heart conditions, making real-time monitoring essential.

Keywords- Keywords: Internet of Things (IoT), ECG Monitoring System, Electrocardiogram (ECG), AD8232 ECG Sensor, Arduino UNO, Heart Disease Detection, Real-Time Health Monitoring, Remote Patient Monitoring.

1. Introduction

One of the largest public health issues in the world is cardiovascular disease (CVD), which has affected badly in India. According to the data from the Register General of India, the burden of CVDs has dramatically increased over time, making them a primary cause of mortality. Overall, 17% death rate is known from CVDs and 26% of adult deaths between 2001 and 2003; by 2013, the percentage had increased up to 23% of all deaths and 32% of adult deaths [2]. This pattern draws attention to the rising incidence of heart-related conditions, which is a significant obstacle for the healthcare system.

Risk factors like poor eating habits, sedentary lifestyles, stress, and rising obesity and diabetes rates

add to the burden of CVDs [3]. These risks have been further increased by India's constant development and changes in lifestyle, making cardiac ailments a

social and medical concern. Furthermore, the issue is made worse by a lack of timely and reasonably priced access to healthcare, especially in rural areas [4].

The fight against this growing illness requires multifaceted approaches. These include bolstering public health programs, enhancing early detection and treatment infrastructure, and raising awareness of healthy lifestyles. In order to lower the mortality and morbidity linked to CVDs in India, research into cutting-edge technologies and preventative strategies is also essential. It is essential that communities,

health professionals, and legislators work together effectively to address this pressing issue [5].

2. Related Work

Pandey et al. 2012 reported on design of a portable ECG device using the AD8232 microchip as the analog front-end device (AFE). Open-source hardware and software components were used in breadboard prototype, resulting in a custom printed circuit board. The device accommodates the microchip on an SMD-to-DIP adapter and uses an Arduino micro controller, data logger, and Bluetooth breakout board. The ECG signal is digitized using the 10-bit ADC of the ATmega328 micro controller, and the signal is recorded to a micro-SD card [10].

Xia et al. 2013 reported a cloud-based healthcare system designed for mobile devices or web browsers, focusing on the usefulness of ECG data collected from patients. The system includes algorithms for enhancement, quality evaluation, and parameter extraction. Demonstrated in real-time analysis, the system is functional, accurate, and efficient, demonstrating the potential of cloud-based healthcare services [11].

Garg et al. 2014 reported one cloud computing which aims to provide users with limited usage and cost-effectiveness. Mobile Cloud Computing, which allows data processing and storage from mobile devices, is expected to grow due to the increasing use of mobile devices. However, data security concerns persist, leading many IT professionals to avoid Mobile Cloud Computing. A proposed mechanism uses RSA algorithm, Hash function, and cryptography tools to ensure data integrity and confidentiality [12].

Yang et al. 2016 proposed a new method for ECG monitoring based on IoT techniques, allowing wearable monitoring nodes to collect and transmit data directly to the IoT cloud via Wi-Fi. The system uses HTTP and MQTT protocols, allowing users to access visual and timely data. Experiments on healthy volunteers confirmed the system's reliability in collecting and displaying real-time ECG data, aiding in the primary diagnosis of certain heart diseases [13].

Polk et al. introduces a robust fabrication method for Ag/Ag-cl micro electrodes tailored for microfluidic systems. By combining photolithography and electroplating, the authors achieved highly stable electrodes with improved lifespan. These electrodes

were chemically oxidized for uniform Ag-cl formation and tested for stability using electrochemical impedance spectroscopy. The results highlight their potential for seamless integration into microfluidic channels, offering enhanced performance and reliability compared to traditional micro electrodes [14].

Bravo-Zanoguera et al. 2019 studied on the design of a portable ECG device using the AD8232 microchip as the analog front-end (AFE). Open-source hardware and software components were integrated into a breadboard prototype, resulting in a custom printed circuit board. The device accommodates the microchip on an SMD-to-DIP adapter and uses an Arduino microcontroller, data logger, and Bluetooth breakout board. The ECG signal is digitized using the 10-bit ADC of the ATmega328 microcontroller, and the signal is recorded to a micro-SD card [15].

Prasad et al. 2019 reported a smart healthcare device that monitors ECG signals and heartbeat counts at a low cost, transmitting real-time signals via Bluetooth and Android software, enabling remote monitoring of patients [16].

Yasemin et al. 2019 used a Raspberry Pi 3B+ based ECG device for real-time detection of cardiac arrhythmia, utilizing the AD8232 heart rate sensor and Python-developed software. The R-peak detection algorithm determines beats per minute and arrhythmia type [17].

Rahman et al. 2021 proposed a system using an AD8232 heartbeat sensor to detect heart conditions using an electrocardiogram (ECG) and heart rate (BPM). The data is transmitted to a cloud server via an ESP32 microcontroller, enabling remote monitoring by health specialists using Ubidots and Thingspeak platforms. This system can help prevent heart disease and ensure proper monitoring of heart health [18].

Hayder Fadhil Jawad et al. 2022 combined scientific and technological advancements to create a monitoring system for blood oxygen saturation, heart rate, and body temperature. The system uses ESP32 microcontroller and LoRa wireless communication, with MLX90614 sensor for body temperature and MAX30100 sensor for blood oxygen saturation and heart rate. The tool's accuracy is 98.18% for blood oxygen saturation, 96.54% for heart rate, and 98.78% for body temperature, with a total accuracy of 97.63% [19].

3. Materials and Methods

The proposed study involves an ECG monitoring device that includes various devices and sensors.

A. Monitoring Heartbeat with AD8232

This system consists of an AD8232 ECG monitoring sensor and it is attached with Arduino Uno microcontroller for processing and analyzing the data. The AD8232 sensor detects heart beat variations and amplifies a very weak signal from the heart. Three lead electrodes are attached to the body to gather the signal it forms a closed circuit which helps analyzing voltage of each pulse. Electrical signals produced from the AD8232 is sent to arduino uno microcontroller.

Here microcontroller is used to process raw ECG signal received from Ad8232. A very important part of this process is detection of R peak from the heart beat, a algorithm used to detect peaks of an ECG signal which is also called as r peak or r wave. The system will be able to measure accurately the time interval between heartbeats and calculate the heart rate, know the data is ready for transmission after heartrate is processed and R peaks identified.



Fig1 AD8232 ECG Sensor with electrodes

B. Electrical Components Control Unit

The ECG monitoring device control unit is the Arduino uno board, along with a variety of electrical systems necessary for its proper functioning of the device. This element mainly contributes to controlling the power supply and ensures that all other components function properly. Arduino uno board is an adjustable micro controller with Wi-Fi technology which can be attached near to the chest. This device can be powered by two ways using USB link and external source. It features the automatic changing of the power source according to the best one suited for the board, allowing the system to work without glitch. The

various parts of the system like ECG sensor, and Wi-Fi module are powered using both power supply methods. Among two power source one power source will be 9V battery which provides a portable and steady power source for the device and the other power source is a 5V USB link from a laptop, serving as an alternative power source, which can be used for set-ups that don't need to be moved.

C. SYSTEM FLOW

Power Supply

It provides electric supply for every part of the device. It makes sure that every component, including the ECG amplifier, micro-controller, and Wi-Fi module, receive power for functioning.

ECG Amplifier

It is used to amplify the ECG signal generated through the heart to a stage that may be processed in addition. The ECG amplification is crucial because the signal sent by electrodes are at very less frequency for transmission, so the signals need to be amplified before transmission.

R Peak Detection

It is used for detecting the R wave inside the ECG, which represents the height of the electric pulse in a heartbeat. This is essential for figuring out coronary heart rate and detecting if any abnormalities inside the heart.

Micro- controller with analog to Digital converter

It consists of an analog Digital (A/D) converter that transforms the analog ECG signals to digital signal for transmission which then may be processed through the micro controller and dispatched over a virtual environment.

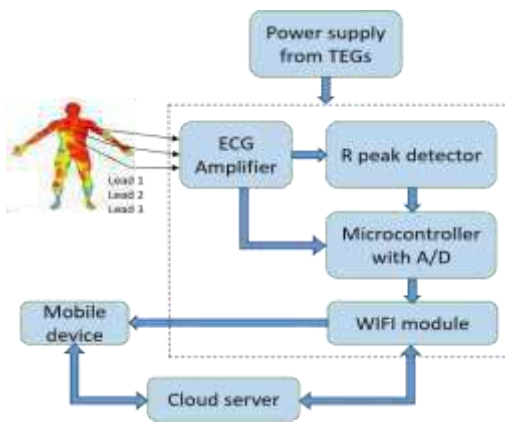


Fig 3 -ECG Device system

4. Results and Discussion

The recorded data is periodic signal and a representation of physical events, like heartbeats. It records the oscillations which occurs between positive and negative amplitudes are regular in nature. Significantly peaks occurring with a time interval approximately about 1 second can indeed represent common features of physiologic rhythms like a cardiac cycle. These are common peaks, with amplitudes ranging from 0.68 to 0.85, at times during the points of time; for example, 0.4s, 1.4s, and 2.4s. Such large peaks can be associated with the R-peaks in the ECG, indicating that perhaps this is the depolarization of the ventricles; this is an important event within the cardiac cycle. There are some major peaks along with these and a few minor ones appearing at intermediately after the intervals; for instance, 2.2s, 3.15s, and 8.15s have the amplitude of about 0.2. These lesser peaks might signify noise or be smaller physiological events.

The valleys in the signal, which fall to negative amplitude values, are interspersed between the peaks and are most pronounced at certain points, such as at 0.3s (-0.08) and 1.45s (-0.05). These dips probably corresponded to phases of cardiac relaxation, such as the T-wave in an ECG, indicating the re-polarization of the ventricles. The periodicity in the signal implies that the cycles repeat approximately at every 1 second, which corresponds to about 60 to 70 beats per minute, a resting rate for a healthy adult.

Some minor fluctuations exist between peaks in amplitude, although most of the variations appear

over the cycles. For instance, the peak at 1.4s has a value of 0.7, while 4.4s is recorded at 0.73. Such differences may be due to physiological changes due to respiration, which may affect the heart rate and intensity of the signal. Also, the depth of the valleys is different, and some of them are deeper than others, which may indicate some minor noise in the signal; for filtering we employ DSP techniques, namely, Butterworth filters, as they have a smooth frequency response and low signal distortion. The use of Python (scipy signal) applies high-pass, notch, and low-pass filters sequentially to remove all unwanted components.

On the contrary, Fig 6 gives average R-peak values for the reuse of Ag/AgCl electrode multiple (10) time used to detect ECG over the course of time. This figure indicates the degradation rate of the wet electrodes made from metal noble utilized in cardiac-based sensing electrodes. According to the study on these electrodes, Ag/AgCl electrodes have low skin electrode contact impedance and high noise factor since they can be used only once. The results obtained show that for the use of an ECG detecting IoT device, the R-peak voltage is dramatically reduced from 0.8 mV to 0.2 mV for 10 consecutive uses.

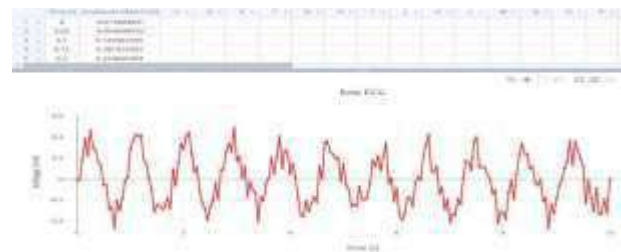


Fig 4 -Unfiltered ECG plotting from received data

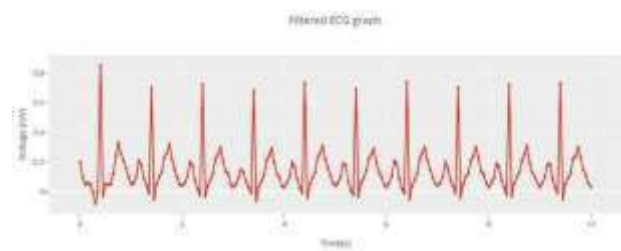


Fig 5- Filtered ECG plotting from received data



Fig 6 - Average R-peak values for multiple reuse (10) of Ag/AgCl electrode for ECG detection.

5. Conclusion

This paper experiments the research on the rate of Ag/AgCl electrode over multiple uses with an innovative system that represents the functions of ECG device for real-time monitoring of heart with the help of sensors like the AD8232 ECG sensor, Arduino UNO. The system offers a complete solution for non-invasive health monitoring. It automatically collects data and analyze ECG enhancing patient care by enabling timely monitoring. The system represents high accuracy in obtaining heart signals representing potential for adopting it into wearable health devices. Future research could explore advancements in sensor technology, implementing non-invasive glucose monitoring device and transmission to medical professionals via Wi-Fi, AI-based predictive analysis, and improvements in system power efficiency and security by developing continuously wearable and efficient electrodes. Overall, this work contributes to the growing field of remote health monitoring and holds promise for broader clinical applications in managing cardiovascular diseases and diabetes.

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