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Arduino-Based Real-Time ECG Monitoring System for Heart Signal Visualization

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Abstract: Electrocardiogram (ECG) monitoring is an essential tool in healthcare for diagnosing and tracking heart conditions. However, existing ECG devices are often expensive, limiting accessibility for personal or educational use. This project aims to develop a low-cost ECG monitoring system using an Arduino UNO, AD8232 sensor, and TFT SPI display. The system collects ECG signals via electrodes and displays the real-time PQRST waveform on the TFT screen and the Arduino IDE serial monitor. Resistors are utilized to ensure signal clarity by reducing electrical noise. The project successfully demonstrated the ability to visualize clear ECG signals in real time, offering a practical and cost-effective solution for continuous cardiac monitoring.
Keywords: Electrocardiogram (ECG), Arduino UNO, AD8232, Real-time monitoring

I. INTRODUCTION

Electrocardiograms (ECGs) are widely recognized as essential tools in medical diagnostics for monitoring and assessing heart function [1]. They capture the electrical activity of the heart through non-invasive electrodes, providing critical insights into heart rate, rhythm, and conditions such as arrhythmias and myocardial infarction [2]. ECG monitoring is vital for both acute and long-term management of cardiovascular health [3].

However, the accessibility of ECG technology is limited due to the high cost and complexity of conventional devices, often restricting their use to hospitals and specialized clinics [2]. This presents a barrier for individuals and communities with limited resources, particularly in educational and personal use scenarios, where real-time cardiac monitoring could be beneficial.

The increasing prevalence of cardiovascular diseases (CVDs) worldwide further emphasizes the need for affordable and reliable ECG solutions [4]. With over 17 million global deaths attributed to heart disease annually, improving access to heart monitoring systems is crucial for early diagnosis and prevention [5].

To address this gap, there is a need for low-cost, portable ECG devices that can offer real-time monitoring without sacrificing signal quality. Such devices would make cardiac monitoring more accessible, particularly in low-resource settings and for individuals interested in health education [6].

This project proposes the development of a low-cost, Arduino-based ECG monitoring system. Using the AD8232 sensor for heart signal acquisition, the system captures and displays real-time ECG data on a TFT SPI screen, ensuring signal clarity through the use of resistors to reduce electrical noise. The simplicity and affordability of the system make it ideal for educational purposes and potential home healthcare applications.

By offering an accessible and reliable alternative to expensive medical equipment, this solution provides an opportunity for broader implementation of ECG monitoring. It empowers students and enthusiasts to gain hands-on experience with medical devices, while also addressing the growing need for affordable healthcare technology.

II. SYSTEM DESIGN AND COMPONENTS

This project employs a combination of Arduino UNO and the AD8232 ECG sensor to develop a low-cost, real-time ECG monitoring system. The components used in this project are simple, readily available, and can be easily assembled to ensure a practical, hands-on solution for students and individuals seeking low-cost healthcare monitoring.

A. Arduino UNO

The Arduino UNO serves as the main microcontroller for this project, responsible for processing all incoming data from the AD8232 ECG sensor. It reads the Analog signals from the sensor, converts them into digital data, and sends them to the display unit [7]. In this setup, it ensures the continuous and real-time processing of the heart's electrical activity.

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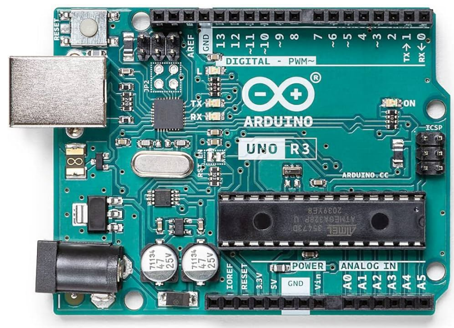

Fig. 1 Arduino Uno

B. AD8232 ECG Sensor

The AD8232 sensor is a specialized bio-potential sensor used for detecting the heart's electrical signals. It functions by extracting weak bio-signals from the body, amplifying them to a readable level, and filtering out unwanted noise to focus on the heart's activity [8]. This sensor is particularly effective in distinguishing the small electrical signals associated with the PQRST waveform of the heart, making it suitable for ECG monitoring.

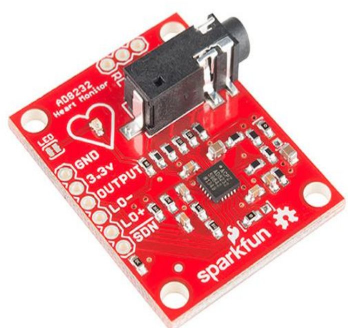

Fig. 2 AD8232 Sensor

C. TFT SPI Display

The TFT SPI display is used to visualize the ECG data in real-time, providing a graphical representation of the heart’s electrical signals [9]. It displays the PQRST waveform, which is crucial for understanding the different phases of a cardiac cycle. The display is connected to the Arduino via the SPI interface, allowing for fast and efficient data transfer. Its high resolution ensures that even small fluctuations in the ECG signal are captured clearly, offering a detailed view for analysis.

Fig. 3a Front side TFT SPI display

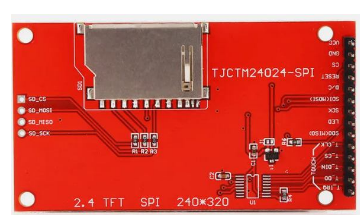

Fig. 3b Back side TFT SPI display

D. Electrodes

In this system, three electrodes are used to detect the heart’s electrical signals, placed on the left chest, right chest, and right belly. These positions are chosen to capture the bio-potential of the heart more effectively, especially for clear visualization of the PQRST waveform [10]. The electrodes transmit the signals to the AD8232 sensor for processing.

Fig. 4 Electrodes

E. Resistors

Resistors are essential for ensuring smooth communication and signal clarity in the system. They help match the impedance of the SPI communication lines, reducing signal reflections and degradation. Additionally, resistors filter out high-frequency noise and limit crosstalk between signals, which is particularly important in sensitive ECG signal acquisition.

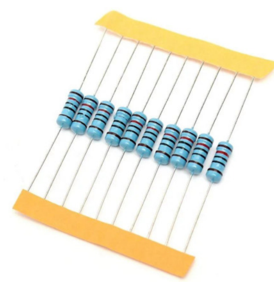

Fig. 5 Resistors

F. Circuit

The circuit integrates all components—sensor, resistor, Arduino, and screen—working together to capture, process, and display ECG data. The AD8232 sensor collects heart signals, which are then filtered and amplified, while resistors minimize noise. These signals are transmitted to the Arduino UNO for processing, and the resulting PQRST waveform is displayed on the TFT SPI screen in real-time, providing a clear output for continuous monitoring.

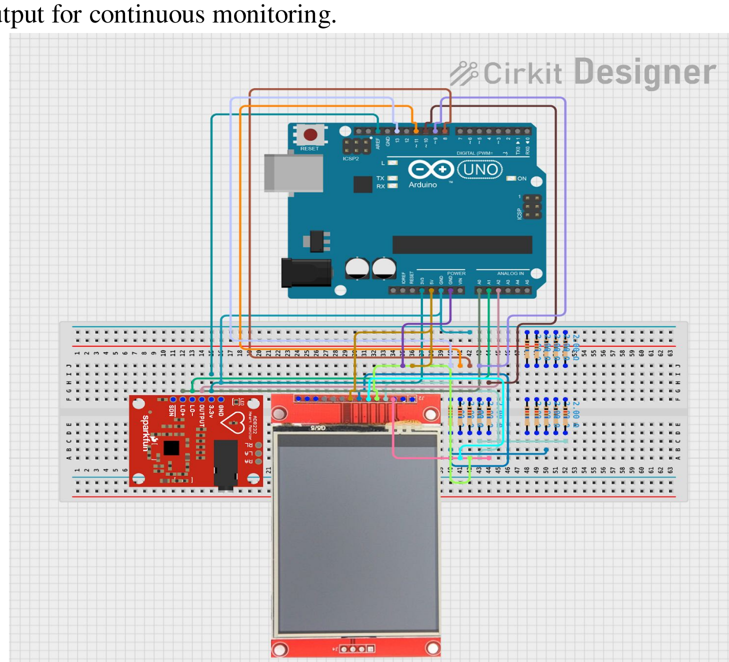

Fig. 6 Circuit Diagram of the System

III.METHODOLOGY

A. Hardware Setup

The hardware configuration begins by connecting the AD8232 sensor to the Arduino UNO. The three electrodes are placed on the body in the left chest, right chest, and right belly positions. These electrodes capture the heart's electrical signals more effectively from these positions, which are then processed by the AD8232 sensor and transmitted to the Arduino for further processing and display [11].

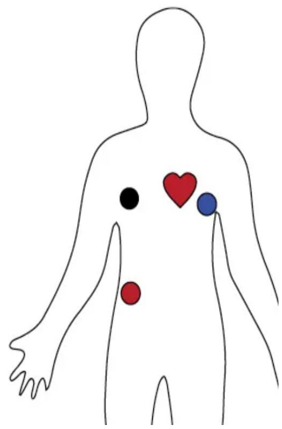

Fig. 7 Electrodes position

B. Signal Acquisition

Once the electrodes are attached, the AD8232 sensor captures the biopotential signals and filters out any muscle or environmental noise. The sensor's output is an amplified ECG signal, which is then sent to the Arduino for further processing.

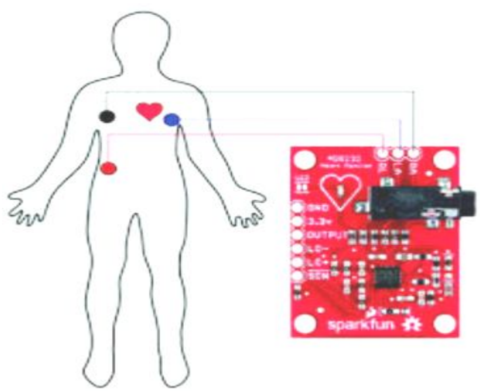

Fig. 8 Electrodes connection

C. Data Processing

The Arduino converts the analog signals from the sensor into digital data that can be displayed on the TFT SPI display. The Arduino IDE's serial monitor also captures these signals, allowing for dual visualization of the ECG waveform..

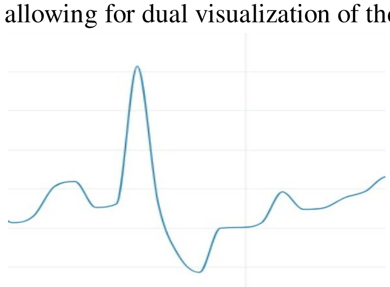

Fig. 9 Graph Serial Monitor

D. Ensuring Signal Clarity

The resistors in the circuit play a crucial role in reducing electrical noise, ensuring that the ECG signals captured from the heart are clear and undistorted. By controlling the flow of current, the resistors prevent interference and noise from affecting the signals, allowing the PQRST waveform to appear clearly on the display.

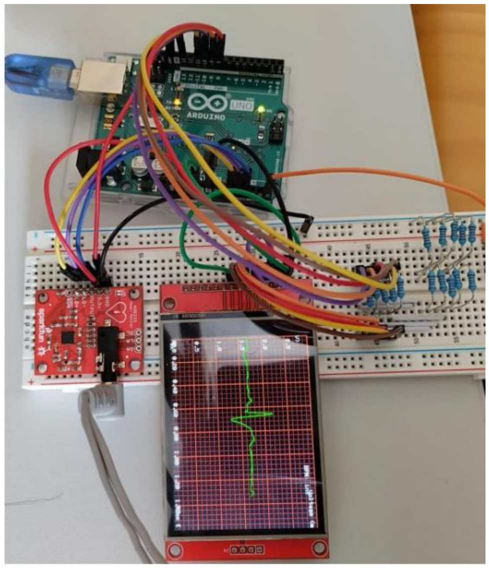

Fig. 10 Clear waveform in the setup

IV. RESULTS AND OBSERVATIONS

The system successfully displayed real-time ECG signals on both the TFT SPI screen and the Arduino IDE serial monitor, with the PQRST waveform clearly visible and the signal clarity maintained throughout the monitoring process. Thanks to the resistors used for noise reduction, the system proved capable of continuous and stable monitoring. This makes it suitable for educational and personal healthcare applications. The real-time ECG signals demonstrated clear PQRST waveforms, indicating that the system could accurately capture and display heart signals.

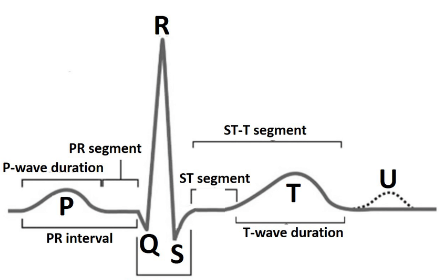

Fig. 11a PQRST waveform

Fig. 11b PQRST Waveform Captured During Testing

V. DISCUSSION

This project demonstrates the viability of creating a functional and low-cost ECG monitoring system using readily available components. The straightforward design, coupled with the use of common hardware such as Arduino and AD8232, makes the system an accessible tool for both personal and professional healthcare applications. The capability to display real-time ECG signals highlights its potential for use in various healthcare settings, particularly where resources are limited. By focusing on cost-efficiency and ease of assembly, the project lays a solid foundation for further advancements in real-time cardiac monitoring systems. This approach not only provides a practical solution for continuous heart signal monitoring but also sets the stage for future innovations aimed at enhancing cardiac care in resource-constrained environments.

VI. CONCLUSIONS

This project has successfully developed a cost-effective ECG monitoring system by utilizing Arduino, an AD8232 sensor, and a TFT SPI display. The system effectively captured and displayed real-time ECG signals with remarkable clarity, providing a practical and affordable solution for individuals in need of accessible healthcare tools. The incorporation of resistors ensured optimal signal quality, making the system reliable for continuous monitoring. Beyond its immediate application, this solution not only offers valuable insights into the fundamentals of ECG monitoring and electronics but also serves as a robust foundation for future innovations in home-based healthcare technology. Its affordability and reliability position it as a promising tool for enhancing personal health monitoring and advancing the development of accessible cardiac care solutions.

VII. FUTURE WORKS

Looking ahead, the next steps for this project involve incorporating an ESP32 to enable seamless wireless connectivity. This will simplify the user interface on a mobile application, allowing for easy display and storage of ECG data, along with real-time BPM readings. Additionally, the system will be enhanced to facilitate direct transmission of ECG data to healthcare professionals, improving the efficiency of remote consultations and patient monitoring. These advancements will make the ECG monitoring system more versatile, user-friendly, and capable of providing more comprehensive healthcare support.

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