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RESEARCH ARTICLE OPEN ACCESS

A PORTABLE ECG MONITOR BASED ON ARDUINO-UNO WITH AD8232 BOARD IN MONITORING THE CARDIAC PHYSIOLOGICAL SYSTEM

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ABSTRACT

The electrocardiogram (ECG) is a record of electrical phenomena that originate during cardiac activity to the cycles of polarization and depolarization of cardiac cells pass around the heart itself and a small part of these waves of electrical tension can travel up to the body surface by capturing the signal from the electrodes on top of the skin. However, the high cost and the inaccessibility of the ECG limit the use in scientific research or hospital center in a region with little investment in medical and hospital equipment. The aim of present study was to build an ECG prototype that monitors the electrical activity signal of the heart based on the cardiac sensor AD8232 designed to extract, amplify and filter the biopotential ECG signal with three electrodes, in which it is coupled essential to operate on Arduino with the objective of digitizing the analog signal by the microprocessor from the lines of codes configured in a script enabling its use through a USB connection. Finally, to be designed in the software visualization of the ECG signals. The results obtained, using the script, showed that it is possible to perform the monitoring of electrical activity with the identification of the P wave, the QRS complex and the T wave. In conclusion, the Arduino with AD8232 board for cardiac monitoring of simple and inexpensive technology that makes it possible to develop scientific research in the field of cardiovascular health and the examination of cardiac monitoring in complete communities that have difficulty in accessing the professional ECG.

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INTRODUCTION

The Electrocardiogram (ECG) was created by Augustus Desiré Waller in 1887 as a diagnostic assessment tool of the electrical activity of the heart through electrical signals captured by electrodes attached to the skin that record on a monitor the electrical phenomena, recognizing the heart rhythm and interpreting the shapes of the heart waves and the ECG intervals (Serhani *et al.,* 2020). This exam assesses the condition of the heart, indicates abnormalities or morphological problems (Harris, 2016), arrhythmias (Singh; Peter, 2016) and also contributes to disease monitoring by analyzing the action of drugs on the cardiac system and the movement of the heart chambers (Harris, 2016). As a result, ECG monitoring systems have been developed and widely used in the healthcare sector for the past few decades (Baty, 2021) and have significantly evolved over time due to the emergence of smart enabling technologies (Langanke *et al.,* 2021; Wang *et al.,* 2014). Nowadays, ECG monitoring systems are used in hospitals (Palumbo *et al.,* 2021), homes (Wang *et al.,* 2015), outpatient ambulatory settings (Farasat *et al.,* 2021) and in remote contexts (Hermans *et al.,* 2018). ECG monitoring systems have also evolved to serve purposes and targets other than disease diagnosis and control (Nguyen; Silva, 2018), including daily activities (Kańtoch *et al.,* 2014) and sports (Benson *et al.,* 2020). The ECG representation consists of characteristic waves P, Q, R, S and T, which correspond to electrical events of cardiac muscle activities. The P wave is caused by the electrical potentials generated when the atria depolarize, prior to atrial contraction (Serhani *et al.,* 2020). The QRS complex is caused by the potentials generated when the ventricles depolarize, prior to their contraction. The T wave is caused by the potentials generated when the ventricles recover from the depolarizing state (Baty, 2021).

In this sense, the project was developed in order to simplify and cheapen the physiological cardiac electrical monitoring, especially in communities with difficult access to medical-hospital equipment, specifically in the state of Amapá, located in the northwest of the North Region of Brazil, also known as the Amazon Region. It is worth mentioning that the ECG prototype does not replace the professional ECG, which is considered the gold standard in the analysis or diagnosis of cardiovascular problems (Harris, 2016). The aim of present study was to build equipment that monitors the cardiac electrical signal in a practical and accessible way, a prototype developed in Arduino, consequently, combined with cardiac sensors of simple and cheap technology.

METHODS AND MATERIALS

The ECG prototype of the present project was assembled on the protoboard coupling the AD8232 cardiac sensor board to the Arduino Uno board to perform the digitalization of the signal by the microprocessor from the lines of codes configured through a USB connection (Figure 1) to be projected in the software and visualize the ECG signal.

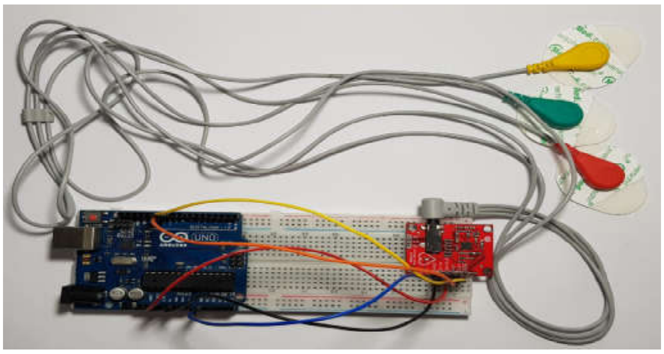

Figure 1. Circuit mounted on the protoboard coupling the AD8232 heart sensor board to the Arduino Uno board

Instrumentation: The AD8232 cardiac sensor (Sparkfun, USA) is an analog-to-digital converter with an operating voltage of 3.3 V, an operating temperature of -40°C to +85°C, and a three-way electrode 3.5 mm connector with a cable length of 50 cm, and is designed to extract, amplify, and filter ECG signal. The heart sensor has a two-pole high-pass filter and a three-pole low-pass filter to eliminate noise generated by motion and signal pickup by the sensors. In addition, to improve common-mode rejection of line frequencies in the system and other unwanted interference, the AD8232 uses a configuration known as the Driven Right Leg Circuit (DRL), feeds back a voltage at the patient that is the average of the voltage sensed at the other differential inputs (Sparkfun, 2021). The Arduino which is a free, single-board hardware electronic prototyping platform (Uno, Italy), designed with an Atmel AVR microcontroller with built-in input/output support, USB-Serial converter: Atmega 16U2, 5 V operating voltage, and a standard programming language, which originates from Wiring, and is essentially C/C++ (Mcroberts, 2018).
The Arduine Integrated Development Environment (IDE) is a multi-platform application written in Java derived from the Processing and Wiring projects, which introduces programming by including a code editor with features and automatic identification, being able to compile and load programs to the board in a very simple way.

Experimental Procedure: For placement of electrocardiographic leads, the recommendations of SENIAM (Chowdhury *et al.,* 2013) were followed. The area was cleaned with alcohol, followed by trichotomy when there was excessive hair, in order to reduce the imbalance between the electrodes and the electrical impedance, thus minimizing the movement artifacts and electrical interference. We used disposable surface electrodes (Solidor, model MSGST-06, Brazil), a hydrogel to provide an appropriate interface for capturing biological signals. For the acquisition of the ECG signal we used a model with three electrodes with custom sensors RA (red), LA (yellow) and RL (green) for capturing the ECG signal that were attached to the volunteer's body, looking for the points of best result (Figure 2).

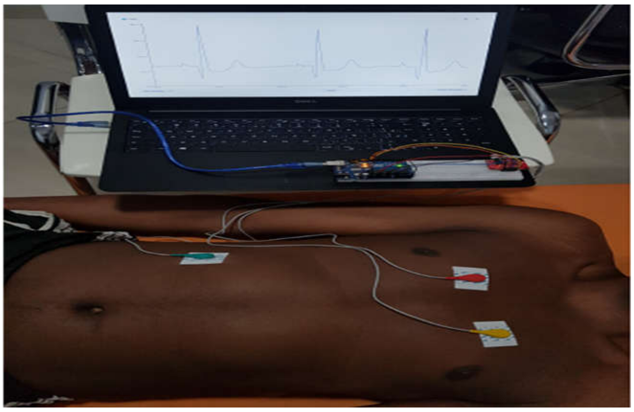

Figure 2. Sensor attachment points capturing the heart signal

RESULTS AND DISCUSSION

After assembling and programming the circuit, the signal captured by the sensors is visualized in the Arduino serial plotter window, illustrating the real-time result of the electrical activity of the volunteer's heart, in which the evaluator can perform the reading and analyze the ECG tracing (Figure 3), in which he can observe small noise in the signal and identify all stages of the cardiac cycle, mainly, the P wave, the QRS complex and the T wave.

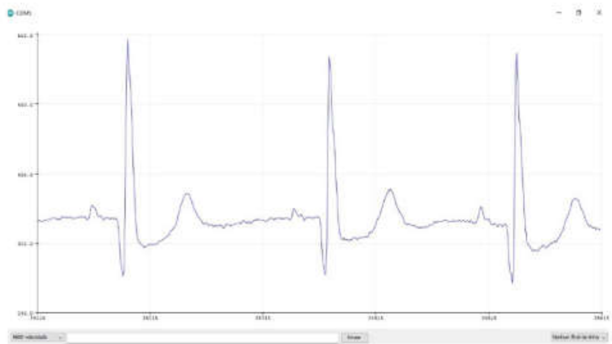

Figure 3. Resting ECG signal collected from the volunteer

In this regard, the Arduino with AD8232 module can be a good ECG in reading practical, low-cost cardiac recordings and thus reducing treatment costs (Bravo-Zanoguera *et al.,* 2020; Iskandar *et al.,* 2019; Lu *et al.,* 2014), in agreement with the result of the present study. Other advantages of the ECG prototype are the low power consumption and small size, which makes it easy to transport (Simanjuntak *et al.,* 2020) and a low-cost, high-quality portable ECG for long-term monitoring prototype that reasonably complies with electrical safety regulations and medical equipment design (Bravo-Zanoguera *et al.,* 2020). Gifari and co-authors (2015) showed that the single channel ECG module was validated with the 12-lead ECG acquisition technique, the ECG prototype can be used as an ECG home care device, making ECG diagnosis much more accessible. In accordance, design and implementation of the wireless ECG monitor based on AD8232 and CC2530, in this study can successfully obtain favorable ECG data and real-time heart rate data and display it (Wang *et al.,* 2018). As well as, the Arduino AD8232 module can be a good ECG in reading low-cost but high-accuracy heart records and it has great potential in application of wireless ECG monitoring (Simanjuntak *et al.,* 2020). Future prospect are necessary based on Arduino-Uno with AD8232 board a low-cost device that integrates sensors for reading and recording the ECG signals with heart rate counting (Iskandar *et al.,* 2019), arrhythmia detection (Kanani; Padole, 2018), atrial fibrillation detection (Simanjuntak *et al.,* 2020) and in the study of heart rate variability (Ji *et al.,* 2017) and which subsequently communicates via Wi-Fi to a cloud-based environment is proposed in order to carry out online data processing.

CONCLUSION

The ECG prototype signal based on Arduino-Uno with AD8232 board obtained in the project resulted to be reliable, being possible to identify all the stages of the cardiovascular cycle. Furthermore, it can be designed in a simple and inexpensive technology that enables the development of scientific research in the area of cardiovascular health and the cardiac monitoring in isolated communities that have difficulty in access to professional ECG.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relations hips that could be construed as a potential conflict of interest.

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