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Remote ECG Monitoring Using Arduino Application

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Annotation: This ECG project relies on a sensor for data acquisition, leveraging technology and programming for its design. It involves thorough research into modern ECG technologies and user requirements. The project encompasses designing, prototyping, and testing the system to ensure precise cardiac monitoring and user-friendly functionality. Key considerations include user comfort, portability, and compatibility with existing medical equipment. Moreover, the integration of advanced technologies and programming techniques facilitates real-time data analysis, remote monitoring capabilities, and customizable features tailored to individual patient needs. Ultimately, the project aims to advance diagnostic accuracy, treatment planning, and overall cardiac health outcomes through the seamless fusion of hardware, software, and medical expertise, while ensuring the highest standards of patient confidentiality and privacy.

Introduction

The ECG is an important screening tool that offers practitioners a wealth of information that can be used alongside the history and clinical findings. An ECG provides a measurement of the rate and rhythm of the heart. It also provides information about the health of the electrical system, the size of the heart chambers, and the supply of blood to the heart muscle [1].ECGs are pivotal in the diagnosis of cardiac ischaemia and infarction, provide the evidence for pacemaker implantation, and detect inherited abnormalities such as cardiomyopathy and long-QT syndrome. ECGs are also useful in detecting non-cardiac pathology, for example, pulmonary emboli and electrolyte disorders. From many practitioners‟‟ perspective, ECGs are perceived as complex and difficult to understand-a„black art‟‟ understood by the few. However, the premise of this series is that this doesn‟‟t have to be the case. We will put forward the argument that ECGs can be understood by anyone with the time and patience to build the necessary knowledge [2].

1.1. Project Objectives

1. Design and implement an ECG system that is small and powered by a battery.

2. Transmit an ECG signal using Arduino (or other microcontrollers) over the Internet or local network to monitor the ECG signal using a mobile app or web browser or with the signal displayed on the screen.

1.2. Why might I need an electrocardiogram?

Some reasons your healthcare provider may request an ECG include:

1. To look for the cause of chest pain.

2. To evaluate problems that may be heart-related, such as severe tiredness (fatigue), shortness of breath, dizziness, or fainting.

3. To identify irregular heartbeats.

4. To help assess the overall health of the heart before procedures, such as surgery; after treatment for a heart attack (myocardial infarction), endocarditis (inflammation or infection of one or more of the heart valves), or other condition; or after heart surgery or cardiac catheterization.

5. To see how an implanted pacemaker is working.

1.3. How the device works?

ECG (Electrocardiography) works by measuring the electrical activity of the heart. It involves placing electrodes on the skin, which detect the electrical signals generated by the heart as it beats. These signals are then amplified and recorded as a graph, showing the rhythm and strength of the heart's electrical impulses.

The basic principles behind ECG include:

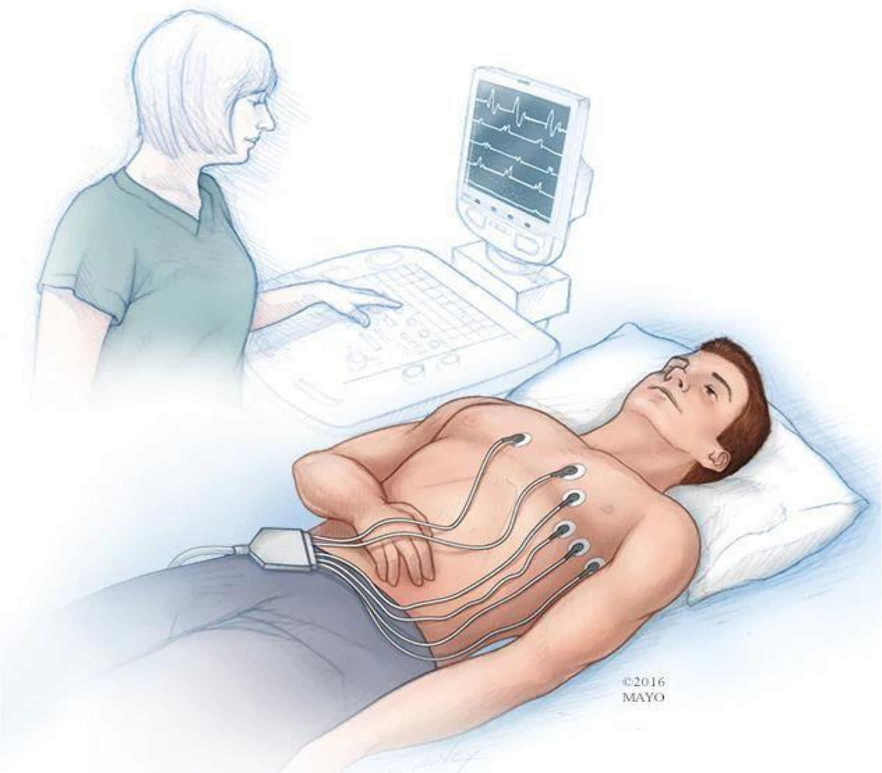
1. Electrodes Placement: Electrodes are placed on specific areas of the body, typically on the limbs and chest, to detect electrical signals.

2. Signal Detection: The electrodes detect the electrical impulses generated by the heart muscle during each heartbeat.

3. Amplification: The detected signals are amplified to make them easier to analyze.

4. Recording: The amplified signals are recorded on graph paper or digitally, showing the characteristic waveforms associated with different phases of the cardiac cycle.

5. Interpretation: Healthcare professionals interpret the ECG patterns to diagnose various heart conditions such as arrhythmias, myocardial infarction (heart attack), and abnormalities in heart structure.

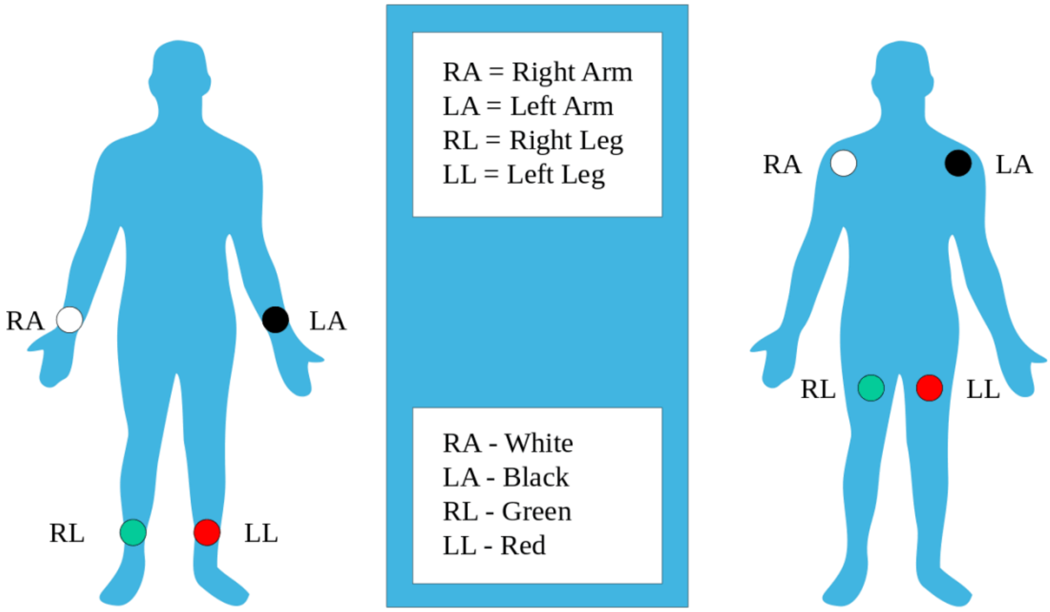


1.4. How to measure heart activity?

Heart activity can be recorded in two ways:

1. Electrocardiography (ECG, EKG)

ECG records the electrical activity generated by heart muscle depolarizations (a negative change in the electric charge), which propagates as pulsating electrical waves towards the skin . Although the amount of electricity is in fact very small, it can be picked up reliably with ECG electrodes attached to the skin (in microvolts, or uV).The full ECG setup comprises at least four electrodes which are placed on the chest or at the four extremities (the right arm, left arm, right leg, and left leg). Variations of this setup also exist in order to allow more flexible and less intrusive recordings. For example, it's possible to attach the electrodes to just the forearms and legs. ECG electrodes are typically wet sensors, meaning that they require the use of a conductive gel to increase conductivity between skin and electrodes.]3[



2. Photo-Plethysmography (PPG).

Throughout the cardiac cycle, blood pressure throughout the body increases and decreases – even in the outer layers and small vessels of the skin. This peripheral blood flow can then be measured using optical sensors attached to the fingertip, the ear lobe or other capillary tissue. The device has an LED that sends light into the tissue and records how much light is either absorbed or reflected to the photodiode (a light-sensitive sensor). As the blood pulses into the tissue, more light is absorbed – as the blood flows away from the tissue, more light is reflected. PPG clips use dry sensors and can be attached much quicker compared to ECG setups, making the device relatively easy to use, and a little bit less bothersome for participants.

1.5. What happens during an electrocardiogram?

An ECG may be done on an outpatient basis or as part of a hospital stay. Steps may vary depending on your condition and your provider‟s practices. Generally, an ECG follows this process:

1. You'll be asked to remove any jewelry or other objects that may interfere with the test.

2. You'll be asked to remove clothing from the waist up. You will be given a sheet or gown to wear so that only the necessary skin is exposed during the test.

3. You'll lie flat on a table or bed for the test. It's important for you to lie still and not talk during the ECG, so that you don‟t change the results.

4. If your chest, arms, or legs are very hairy, the technician may shave or clip small patches of hair so that the electrodes will stick to your skin.

5. Electrodes will be attached to your chest, arms, and legs.

6. The lead wires will be attached to the electrodes.

2.1. Once the leads are attached, the technician may enter identifying information about you into the machine's computer.

2.2. Design and development of a ECG

The addition of the screen provides a visual interface that clearly and directly displays vital signals, facilitating healthcare professionals in promptly interpreting data and making informed decisions. Thanks to this screen, users can effortlessly monitor various parameters and promptly track the patient's progress. As for the oxygen sensor, it's meticulously designed to accurately measure blood oxygen levels. This enhances the precision of provided data, contributing to the improvement of diagnostic processes and treatment procedures. Directly linked to the electrocardiogram device, it offers comprehensive and integrated readings, simplifying the understanding of the patient's condition and expediting the therapeutic process.

ILI9341 TFT display

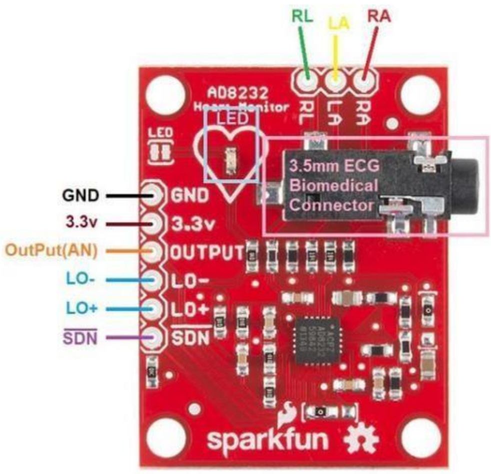
Pulse Oximeter Heart Rate Sensor

3.1. Arduino

It is an open source electronic platform based on easy-to-use hardware and software. Arduino boards are inefficient at reading inputs - a light on a sensor, or a finger on a button - turning them into outputs - powering a motor, turning on an LED, or posting something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do this, you can use the Arduino programming language (Wiring-based), and the Arduino software (IDE), which is built on the computer. Arduino software (IDE) was used for us to emulate and program the sensors and display with Esp32

3.2. AD8232 ECG Sensor Electrodes Placement (3 Lead Sensor)

The AD8232 ECG sensor is the most commonly used and available ECG sensor that is affordable and can be used for hobby purposes. It is a 3 lead or single-channel ECG module. Other ECG sensor types available are 5 lead and 10 lead.



Block Diagram of AD8232

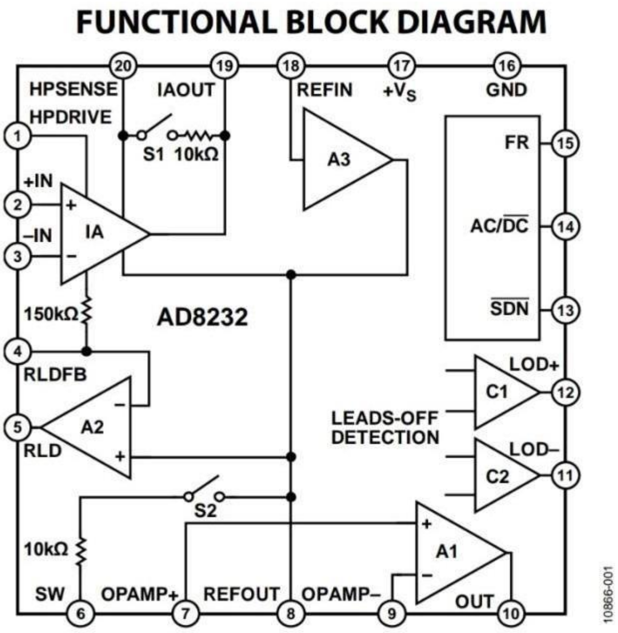


Figure 1.

3.4. pulse oximeter Heart rate sensor

The GY MAX30100 sensor is an integrated pulse oximetry and heart-rate monitor module. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to accurately measure the heart rate and oxygen saturation levels in the blood.

]6[

SDA (Serial Data Line) is the line used for bidirectional data transfer between the device and the microcontroller. Data is directed through this line in both directions.

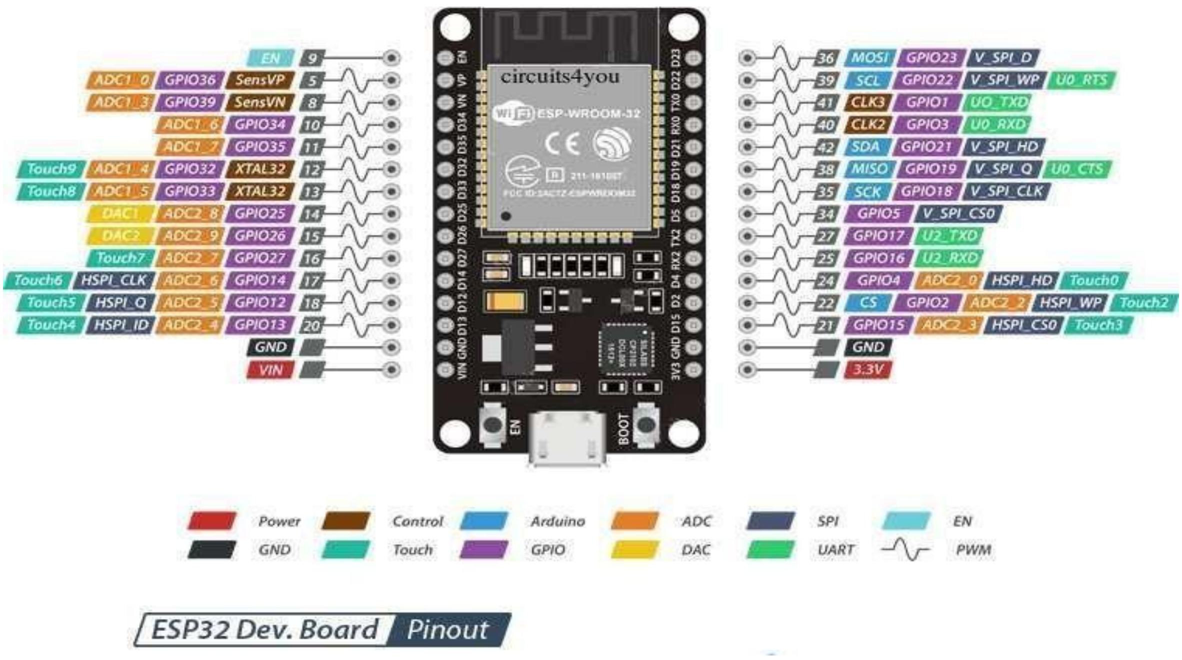
SCL (Serial Clock Line) is the line used for synchronizing data transfer between the device and the microcontroller. This line is used to determine the data transfer rate.

Benefits and Features:

1. Integrated Red and Infrared LEDs: The sensor includes both red and infrared LEDs, allowing it to measure changes in blood volume and oxygen saturation based on the absorption of these wavelengths.
2. High Signal-to-Noise Ratio (SNR): The GY MAX30100 sensor offers a high SNR
3. Low Power Consumption: With its low power consumption design
4. Compact and Integrated Design: The module's compact size and integrated design simplify the integration process into various.
5. I2C Communication Interface: The sensor communicates with microcontrollers or other host devices via the I2C interface, providing easy integration and control.
6. Wide Dynamic Range: It offers a wide dynamic range for pulse oximetry measurements

3.5. ESP-32

The ESP32 is a powerful and versatile microcontroller developed by Espressif Systems. It is part of the ESP32 series of low-cost, low-power system-on-chip (SoC) microcontrollers designed for Internet of Things (IoT) applications. Launched as the successor to the ESP8266, the ESP32 offers enhanced features and capabilities, making it a popular choice among developers for a wide range of projects]7[



Key Technical Features:

1. Dual-Core Processor: One of the standout features of the ESP32 is its dual-core Xtensa LX6 microprocessor, which operates at up to 240 MHz.
2. Wireless Connectivity: The ESP32 offers built-in Wi-Fi and Bluetooth connectivity, allowing devices to connect to local networks and communicate with other devices wirelessly.
3. Ultra-Low Power Consumption: Despite its powerful features, the ESP32 is designed for ultra-low power consumption,.

3.6. ILI9341 TFT Display

The ILI9341 TFT LCD SPI screen is a popular choice for display solutions in various electronic projects. It features a thin-film transistor (TFT) liquid crystal display (LCD) with a Serial Peripheral Interface (SPI) communication protocol, making it easy to interface with microcontrollers and other devices. Developed by ILI Technology Corp, the ILI9341 screen offers several technical features and benefits for a wide range of applications.]8[

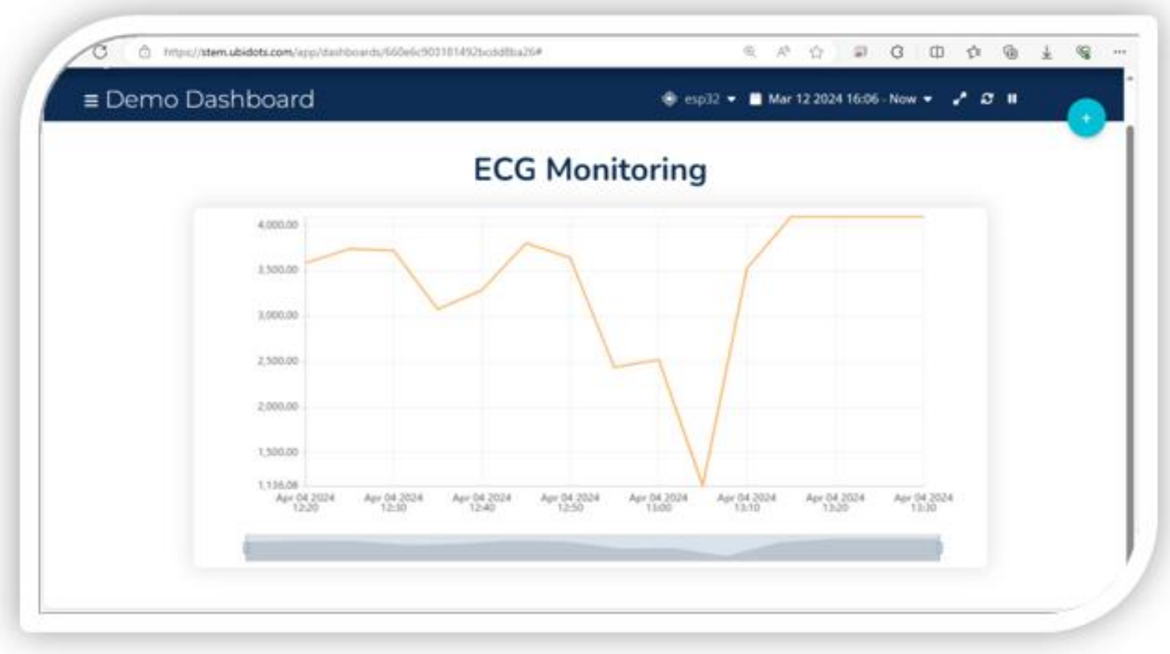
Benefits for in Project:

1. High-Quality Display: The ILI9341 screen offers a high-quality display solution in project, allowing to create visually appealing user interfaces and display relevant information to users.
2. Easy Integration: With its SPI interface and comprehensive documentation, the ILI9341 screen is easy to integrate into in project, saving time and effort in the development process.
3. Versatility: Whether you're building a smart device, a wearable gadget, or an interactive display, the ILI9341 screen offers the versatility and functionality to meet your project requirements.

3.7. Ubidots

Ubidots is a cloud platform used for collecting, storing, and visualizing data in a direct and easy way. Ubidots enables users to create Internet of Things (IoT) applications, web applications, and mobile applications that rely on account-based data.

Ubidots is a trusted source for many developers and engineers in the Internet of Things and smart applications field. [9].



4.1. Malfunctions and maintenance Maintenance

1. Regular Inspection: Periodically check wiring connections and components for any signs of damage or loosening to ensure proper functionality.

2. Calibration: Perform calibration procedures as recommended by the manufacturer to maintain accurate sensor readings and system performance.

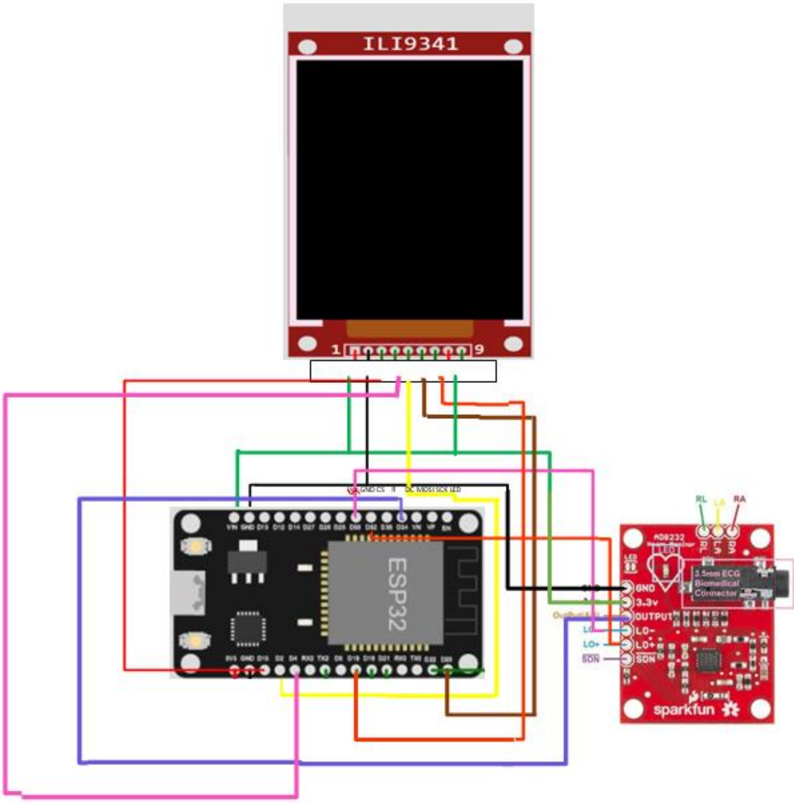
3. Cleaning and Care: Keep the components and sensors clean and free from dust or debris, especially the electrodes of the AD8232 sensor, to ensure reliable signal acquisition.

4. Firmware Updates: Stay updated with the latest firmware releases and software updates to address any bugs or compatibility issues and maintain optimal system performance.

Malfunctions

1. Low Power Supply: Insufficient power supply to the components can cause unstable operation or complete failure of the system.
2. Difficulty in Measuring ECG Signal (AD8232) : Difficulty in obtaining accurate ECG signals due to improper electrode placement or poor skin contact can result in unreliable readings.

4.2. Signal Interference: Interference from external sources, such as electromagnetic fields, can disrupt the sensor readings, leading to inaccuracies in the data.Block diagram of ECG system

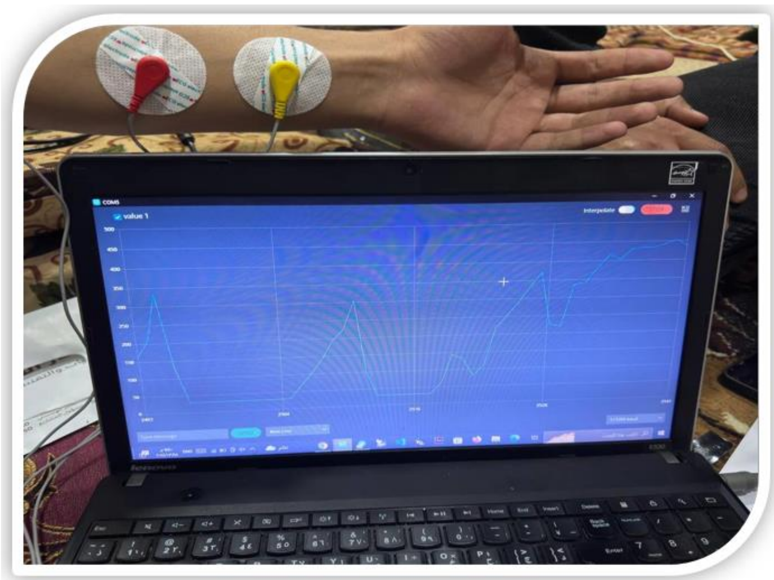


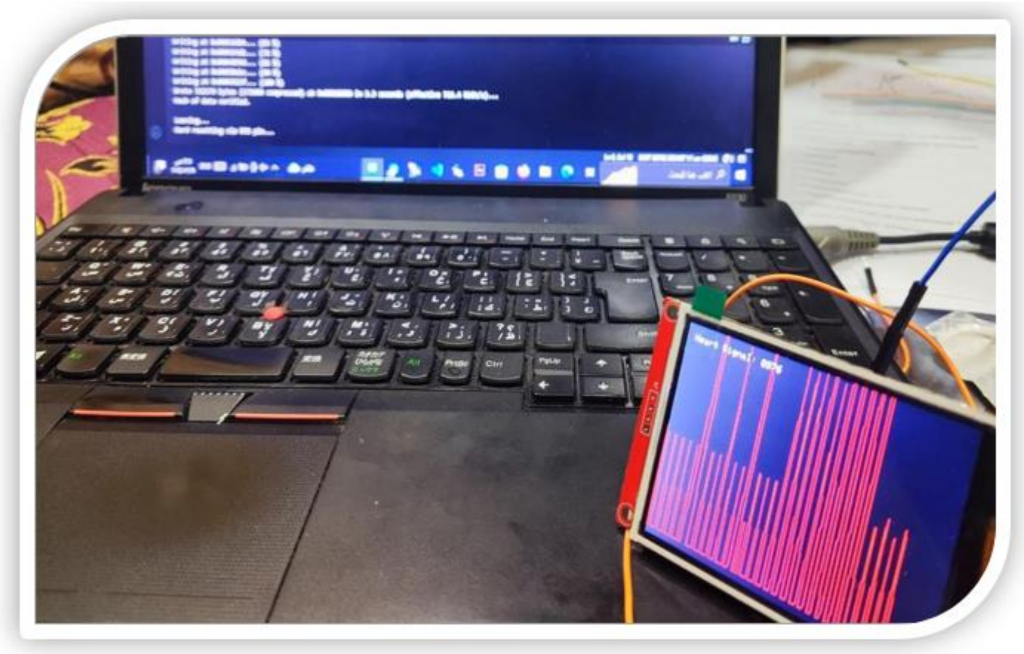
4.3. Results and discussion

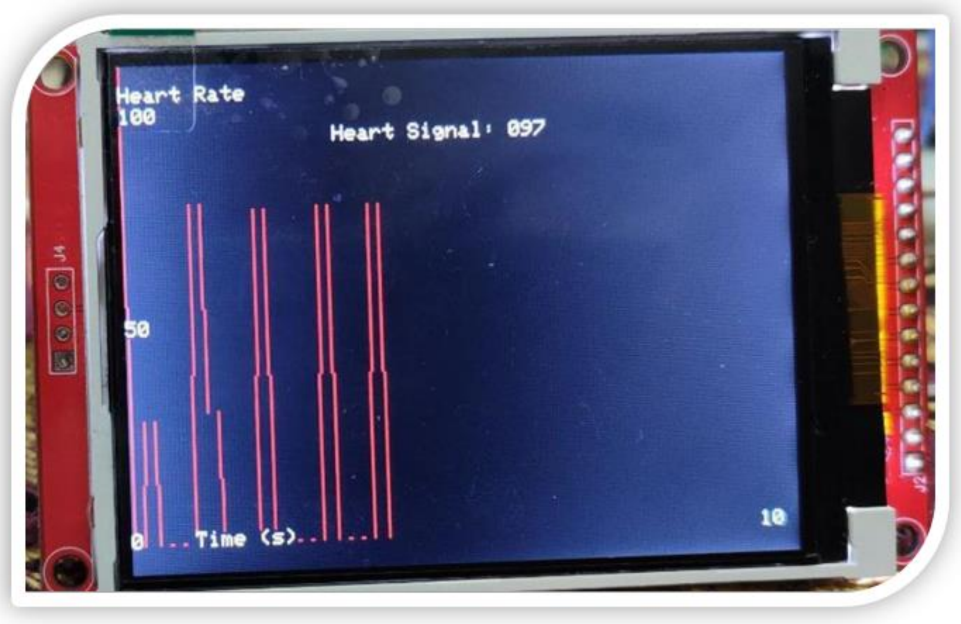
Results : I successfully designed and connected the AD8232 and GY MAX 30100 sensors with the ESP32.The ESP32 was programmed correctly to read data from the sensors and display it on the Ili9341 screen.ECG data and heart rate were displayed successfully on the screen.

Discussion :A good response was observed from the sensors with accuracy in measuring the ECG signal and heart rate.There were challenges in designing and programming the user interface, especially in displaying the data in an organized and readable manner.The project could be improved by adding more features such as data storage or remote control capability.

4.4. Readings







4.5. Conclusion and future works

The most prominent problem faced by the researcher is the inability to apply this process to the person standing and moving, but the person must be relaxed. For future proposals, this device can be developed and 10 poles can be added for a better signal, as well as the addition of sensors with a more accurate reading

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