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Article

Biomedical Signal Acquisition of Heart Rate and SpO2 Using Arduino-Based Platform

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Abstract: This project presents the development of a portable system for real-time monitoring of heart rate and blood oxygen saturation (SpO_2) using Arduino technology. The device utilizes a pulse sensor and integrates a MAX30100 optical sensor to collect biometric data in a non-invasive manner. Traditional methods of monitoring vital signs—such as checking the pulse manually or using standard hospital equipment—are often limited by accessibility, cost, or complexity. In contrast, this Arduino-based system provides a low-cost and user-friendly alternative that can be used in various environments including homes, schools, and clinics. The system measures heartbeat and SpO_2 levels using photoplethysmography (PPG) and displays the results on an LCD screen. This study explores the design, hardware implementation, and operational testing of the system, demonstrating its potential as an effective solution for continuous vital sign monitoring.

Keywords: Heart Rate Monitoring‹Blood Oxygen Saturation, Photoplethysmography (PPG), Arduino-Based System, Biomedical Sensors, Wearable Health Technology

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1. Introduction

The human heart Is a vital organ responsible for pumping oxygenated blood throughout the body to sustain life. Located centrally within the thoracic cavity, it operates as a dual-pump system composed of four chambers: two atria and two ventricles [1]. The right side of the heart collects deoxygenated blood and pumps it to the lungs for oxygenation, while the left side delivers oxygen-rich blood to the rest of the body. This rhythmic contraction and relaxation, known as the cardiac cycle, is crucial for maintaining consistent circulation and supporting the metabolic needs of tissues and organs. The heart's performance is often evaluated using physiological metrics such as heart rate and arterial oxygen saturation, which are key indicators of cardiovascular and respiratory function [2].

In parallel with technological and societal advancement, public awareness of health and wellness has significantly increased. As a result, individuals are now more concerned with regularly tracking vital health metrics such as heart rate and blood oxygen levels. In clinical and home environments alike, monitoring these parameters plays a crucial role in early detection of disease and general health management[3].

However, traditional diagnostic procedures can be complex, time-consuming, and costly. In some cases, patients are required to undergo invasive methods or rely on hospital visits for simple measurements. Moreover, challenges such as limited access to medical facilities, geographical distance, and procedural inefficiencies make regular monitoring impractical for many. These issues highlight the need for a portable, cost-effective, and user-friendly solution that can measure vital signs with minimal discomfort and without clinical supervision[4].

To address this gap, this project proposes the development of a compact, non-invasive health monitoring system using Arduino and optical sensor technology. The system is designed to accurately detect heart rate and blood oxygen saturation in real-time without requiring complex procedures or causing any harm to the user. Through the integration of photoplethysmographic sensors and microcontroller-based processing, this device enables continuous health monitoring and provides valuable physiological insights that can support medical decision-making and promote self-care [5].

Background

Heart rate Is one of the most fundamental physiological indicators of cardiovascular health, and its measurement has become an essential aspect of both clinical diagnosis and personal health monitoring. Traditionally, heart rate is assessed through electrocardiograms (ECG) or by manually detecting pulse signals from areas such as the wrist or neck. These measurements reflect the rhythmic contraction of the heart as it pumps blood through the circulatory system, a process that is Influenced by various factors including physical activity, emotional state, age, and overall health condition [5].

With growing interest In wearable and mobile health technologies, new methods for continuous and non-invasive heart rate monitoring have emerged. These include optical sensors and microcontroller-based systems capable of detecting pulse through changes in blood volume. These signals are captured using techniques such as photoplethysmography (PPG), which leverages light absorption patterns to estimate heart rate and oxygen saturation [6].

Despite the widespread adoption of wearable devices, challenges still persist in ensuring the accuracy and consistency of the collected data. Factors such as sensor positioning, skin pigmentation, motion artifacts, and ambient light interference can all affect signal quality. Furthermore, commercially available systems often come at a high cost and may not be suitable for educational or low-resource settings [7]

Given these limitations, this study explores the development of an affordable, Arduino-based monitoring system that integrates pulse sensors with oxygen saturation detection capabilities. By utilizing open-source platforms and accessible electronic components, the goal is to deliver a system that is both functional and practical for widespread use, especially in environments where conventional medical devices may not be readily available [8].

Problem Statement

With advancements in biotechnology, the conventional heart rate monitoring systems have raised considerable attention regarding their application in hospitals and clinics. However, this concept has led to the development of portable heart rate monitors (HRMs). Conversely, there are numerous challenges in the field of biotelemetry, one of which involves the analysis of bioelectrical signals produced by the HRMs. The heart signals acquired from these portable devices may not be as precise when compared to those obtained in hospitals. Another issue that arises with optical heart monitors is the correct positioning of sensors on various body parts, specifically identifying which area yields the highest or lowest amplitude of the pulse. Additionally, interferences such as noise, skin tone, and the crossover problem can result in poor outcomes in optical HRMs. In comparison to standard heart monitors, the efficacy of wearable pulse oximeters is deficient in accurately calculating heart rates, leading to significant errors in detection [9].

Objectives

The main goal of the project is to build an Arduino based heart rate monitor

Individuals using it anywhere easily in hospitals, home, offices, schools etc. as an alert by No serious issues .The aim of the project is to study and conduct research in the department

Biometric devices, such as PPG and other principles related to cardiac monitoring systems. By and Broadly speaking, the main objectives of the project are listed below :

1. Design and development of an improved heart rate monitor using two different modules ;standard
2. Pulse sensor and infrared pulse module .
3. Analyze and study the performance of sensor placement in different locations of the body :
4. The index finger and wrist have two conditions: rest and exercise.

2. Materials and Methods

Arduino Uno

The Uno serves as an excellent choice for your first Arduino. This Arduino board is based on an ATmega328P microcontroller. In comparison to other Arduino board types, it is quite user-friendly, similar to the Arduino Mega board. It features 14 digital I/O pins, of which 6 can function as PWM (pulse width modulation) outputs, along with 6 analog inputs, a reset button, a power jack, a USB connection, and an In-Circuit Serial Programming header (ICSP), among other components. It encompasses all necessary elements to support the microcontroller; simply connect it to a PC using a USB cable and provide power through an AC-to-DC adapter or battery to begin using the Arduino Uno (R3) [10].

Figure 1. Arduino Uno

Max30100 Oxygen Sensor

The max30100 sensor is an effective and painless way to measure blood oxygen saturation (blood oxygen) in addition to heart rate .

It consists of two light transmitters (LED), one for red rays and the other for infrared rays, a photoreceptor, optical lenses, as well as an analogue signal processor [11].

Figure 2. Max30100 Oxygen Sensor

Working Principle

Before knowing the working principle of the sensor, we must understand the meaning of the oxygen ratio. As is known, the blood coming from the lungs carries oxygen and this is done using hemoglobin, and hemoglobin that is not loaded with oxygen is called (deoxy Hb) or deoxygenated blood). As for the hemoglobin loaded with oxygen, it is called (oxy Hb).

(oxygenated blood). It can be said that the oxygenation or the percentage of blood saturation with oxygen indicates the ratio of hemoglobin loaded with oxygen to the non-loaded hemoglobin. The function of the sensor is to know this ratio. [12]

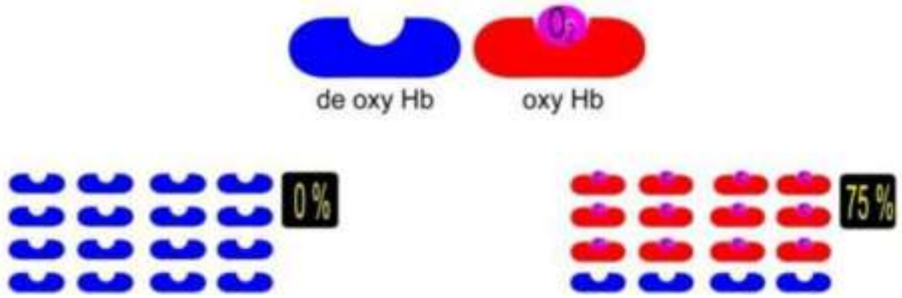

Figure 3. De Oxy Hb and Oxy Hb

The oxygen sensor is available in various forms. It can be designed as a forceps that is placed on the finger, or it may utilize reflection technology similar to the sensor discussed in our article. However, the fundamental working principle remains consistent across all types, as the sensor emits beams of red and infrared light. These light packets must traverse the finger to reach the receiver. During this process, a portion of the light will be absorbed by the blood, while the non-absorbed part continues on to the photoreceptor [13].

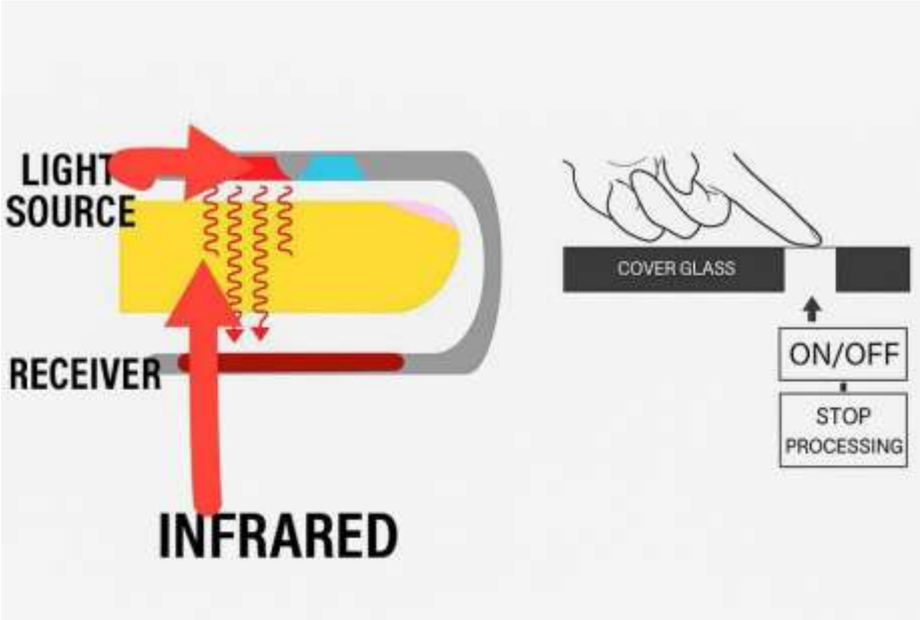

Figure 4. Working Principle Max Sensor30100

LCD 20*412C

An LCD screen is a flat panel electronic display device that operates on the principle of light modulation properties. It functions by applying different electrical voltages to a layer of liquid crystals, resulting in alterations to its light characteristics. The screen comprises a matrix of pixels that present graphical characters and numbers.

The 16x2 Arduino LCD Screen utilizes an I2C communication interface. It is capable of displaying 16x2 characters across two lines, featuring white characters against a blue background. This display addresses the limitation of the LCD 1602 Parallel LCD Display, which necessitates approximately 8 pins on your microcontroller for operation. [14]

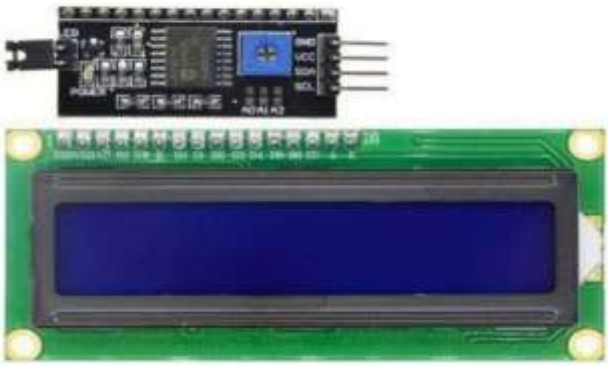

Figure 5. 20*412C

Jumper Wires

Breadboard Jumper Wire Pack (200mm&100mm)

Breadboard one pin dual-male jumper wire 75pcs pack. The pack comes with two different lengths: 200mm (25pcs) and 100mm (50pcs). Perfect design and adequate quality for breadboard and Arduino connection, you can use it repeatedly [15].

Figure 6. Jumper Wires

LED

A light-emitting diode (LED) is a type of PN junction diode that emits visible light when activated. When voltage is applied across its components, electrons combine with holes within the LED, releasing energy in the form of photons, which produces visible light. LEDs can have both dimming and full brightness capabilities [15].

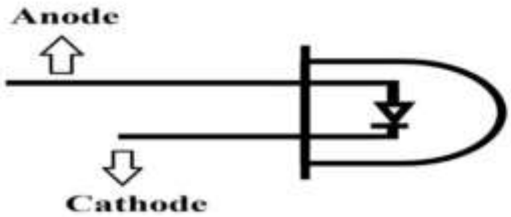

Figure 7. LED

Breadboard

A breadboard is a reusable platform used for building and testing electronic circuits without soldering. It allows components to be easily inserted and removed, making it ideal for prototyping and experimentation [16].

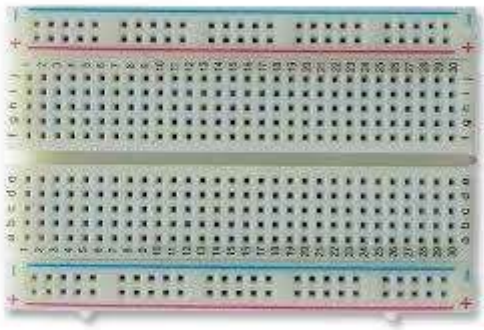

Figure 8. Breadboard

Dual lithium battery holder

A dual lithium battery holder is a device designed to securely house and connect two lithium batteries in a circuit. It simplifies battery installation and replacement while providing reliable electrical connections for powering electronic projects [17].

Figure 9. Dual lithium battery holder

Buzzer

A buzzer is an audio signaling device that produces sound through mechanical, electromechanical, or piezoelectric methods. It is commonly used in alarms, timers, and user input feedback systems. Buzzers are compact, easy to integrate, and emit a distinct tone when activated by an electrical signal [18].

Figure 10. Buzzer

Batteries

Batteries are energy storage devices that convert chemical energy into electrical energy to power electronic circuits. They come in various types and sizes, providing portable and consistent power sources [17].

Figure 11. Batteries

Plastic box

A plastic box is a protective enclosure used to house electronic components like the Arduino. It shields the board from dust, moisture, and physical damage during operation or transport. These boxes often come with cutouts or mounting options for easy access to ports and wiring.

Figure 12. Plastic box

Methodology

This section outlines the procedural steps taken to design, assemble, and program the heart rate and oxygen saturation monitoring system using Arduino and biomedical sensors. The methodology includes both hardware integration and software implementation to ensure accurate and real-time physiological measurements [19].

First step, we fed the board experiments with Arduino, by connecting a wire from Arduino from Ben five volts, the board experiments on the positive line, and that is by connecting a wire from Arduino from Ben Soldier, the board experiments on the negative line

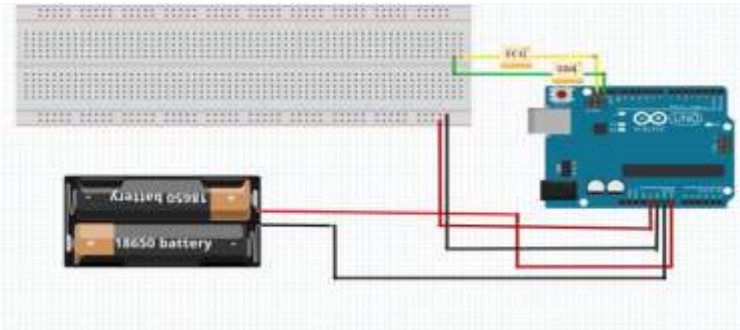

Figure 13. How to power the board experiments with the Arduino

We connect the SCL from the Arduino to the negative board We connect the SDA from the Arduino to the negative board

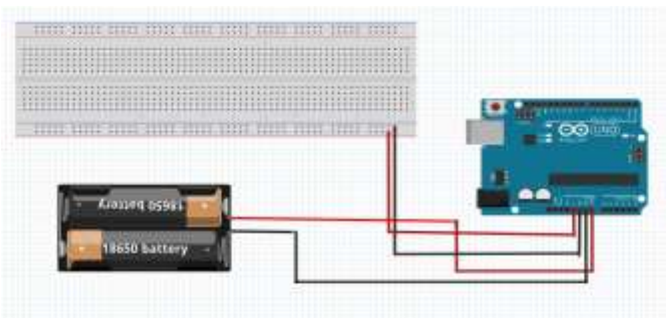

Figure 14. Delivery SCL AND SDA

We connect the monitor We connect the UIN from the monitor to the positive line of the board

We connect GND from the monitor to the test board

We connect the SCL from the monitor to the testing board We connect the SDA from the monitor to the testing board.

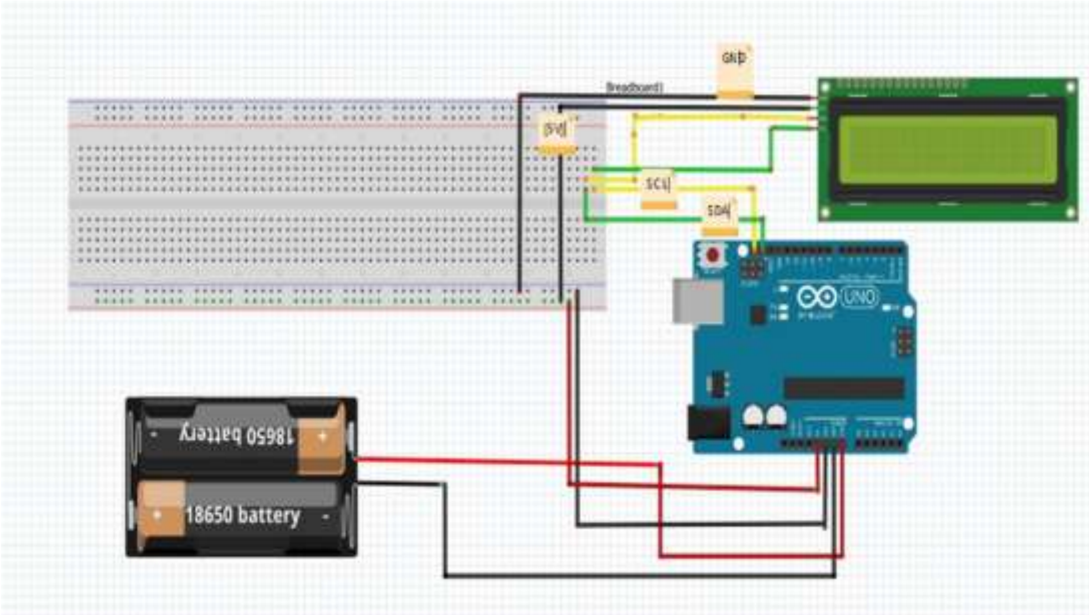

Figure 15. Connect a screen

We connect the heart rate and oxygen sensor. We connect the UIN from the sensor to the positive line of the board.

We connect the GND of the heart rate sensor to the breadboard We connect the SCL of the heart rate sensor to the breadboard We connect the SDA from the heart rate sensor to the breadboard [20].

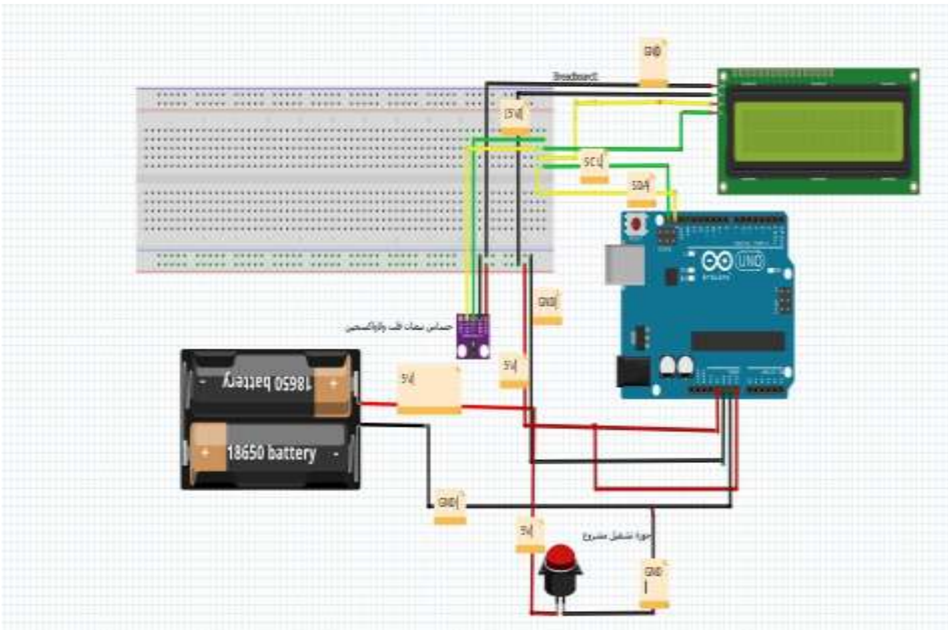

Figure 16. Connecting a heart rate and oxygen sensor

*Software code (Arduino Code)

Figure 17. Arduino code

3. Results

The designed heart rate and oxygen monitoring system was successfully implemented using the Arduino Uno and MAX30100 sensor. The device provided real-time readings of BPM (beats per minute) and SpO2 levels when tested on both the index finger and wrist. The system showed higher accuracy with finger placement using a green LED (520–560 nm) and better signal amplitude on the wrist with infrared LED (910–940 nm). Wireless data transmission was achieved using the HC-05 Bluetooth module with a 10-meter range. Comparative analysis indicated a final system accuracy of 91.9% with an 8.1% error margin. Software simulation was completed in Proteus before hardware testing. The system proved effective for low-cost, portable heart monitoring. Results confirm feasibility for home and clinical applications.

4. Discussion

To enhance the performance and usability of the heart rate monitoring system, several improvements can be implemented in future versions. Firstly, incorporating an acceleration sensor would help reduce motion artifacts and improve signal accuracy during user movement. Secondly, the system should be miniaturized onto a custom PCB board to make it lighter and more suitable for wearable applications. Additionally, integrating more physiological parameters—such as blood pressure, respiratory rate, and body temperature—would significantly expand its diagnostic capability [13].

To ensure reliability, the system should undergo clinical testing on subjects of various ages and health conditions. Moreover, upgrading the communication module to include advanced wireless technologies such as Wi-Fi, ZigBee, or RF communication would improve data transmission range and reliability. These future enhancements aim to improve the accuracy, portability, and versatility of the monitoring system for both personal and clinical use [21].

5. Conclusion

This project successfully achieved its main goal of developing a wearable heart rate monitoring system using Arduino and biometric sensors. By integrating both the MAX30100 pulse sensor and a signal conditioning circuit with infrared LED and photodiode, the system accurately measured heart rate and blood oxygen saturation (SpO_2). The Arduino Uno microcontroller provided stable control over the hardware components, while the implementation of a wireless communication system via the HC-05 Bluetooth module enabled real-time data transmission to Android devices.

Experimental tests confirmed that using a green LED on the index finger produced the most accurate heart rate readings, while infrared LEDs were better suited for wrist placement. The system demonstrated a high level of accuracy, with an error rate of only 8.1%. These results indicate that the device can serve as a low-cost, portable, and efficient solution for continuous heart monitoring in both clinical and home environments. Further development could lead to a more compact and multi-functional health monitoring tool.

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