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Developing a Smart Bracelet to Measure Blood Oxygen (SpO2) and Heart Rate Using MAX30102 Sensor and Arduino Board

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Abstract: With the increasing interest in wearable healthcare technologies, the development of smart devices to monitor vital signs has become essential to enhance the quality of medical care and improve patients' response to critical health conditions. This research aims to design and develop a smart bracelet capable of measuring blood oxygen (SpO2) and heart rate based on the MAX30102 sensor, which is characterized by high accuracy in measuring these values through optical absorption technology. The system includes an Arduino or ESP32 processing unit, along with a wireless communication unit (Bluetooth/Wi-Fi) to transfer data to a smartphone application or an OLED display screen. The device was tested on a group of users, where the results showed high accuracy compared to traditional medical devices. This research reflects the importance of integrating smart technology into personalized medicine, while providing proposed improvements to increase the efficiency and accuracy of the system.

In addition, the system relies on signal processing algorithms to accurately extract vital values and reduce noise resulting from movement. The bracelet is also designed to be comfortable for daily use, with a low-consumption battery that ensures continuous operation for long periods. The evaluations included comparison of measurements with reference medical devices, which showed a low error rate within clinically acceptable limits. This research contributes to the development of wearable medical technologies, allowing individuals to proactively monitor their health and reduce the need for routine check-ups in medical facilities.

Keywords: Smart Bracelet. Heart Rate. Esp32 Module. Smart Health Monitoring. Wearable Devices. Blood Oxygen Sensor.

1. Introduction:

With the rapid development of medical technology, wearable devices have become an integral part of modern health monitoring systems. These devices provide non-invasive solutions for monitoring vital signs in real time, which contributes to improving medical care and reducing the need for traditional examinations in hospitals.

Blood oxygen saturation (SpO2) and heart rate are among the most important vital signs that can be used to detect many health problems, such as heart disease, respiratory disorders, and hypoxia. With the increasing need to monitor these values continuously, the need to develop low-cost, easy-to-use, and accurate devices has emerged.

In this research, we present the design and development of a smart bracelet based on the MAX30102 sensor to measure SpO2 and heart rate, where the data is transmitted to a smartphone or a small display screen, making it easier to monitor the health status of users at any time. This bracelet features the MAX30102 sensor, which uses optical absorption technology to measure blood oxygen and heart rate with high accuracy. The data is sent to a central processing unit (Arduino or ESP32) that processes the biometric signals and filters out motion-induced interference, enhancing the reliability of the results. The wireless communication system (Bluetooth/Wi-Fi) also allows the data to be transferred to a smartphone application, where the user can track their health status throughout the day. This device is an effective alternative to traditional medical devices, as it offers a compact design, low power consumption, and ease of use, making it ideal for individuals who need continuous monitoring of their health status, whether they are chronic patients, athletes, or ordinary people concerned about their health.

2. Project Objectives:

1. Develop a wearable smart bracelet to measure blood oxygen (SpO2) and heart rate using the MAX30102 sensor, enabling continuous health monitoring without the need for large medical devices.
2. Improve the accuracy of measuring vital signs by using digital signal processing techniques to filter out noise caused by movement and ensure the reliability of readings.
3. Design an effective wireless communication system using Bluetooth/Wi-Fi to transfer data to a smartphone application, facilitating the user's monitoring of their health status in real time.
4. Provide an interactive user interface through a built-in OLED screen or a smart application that displays readings in a clear and easy-to-understand manner, with the ability to store data for later reference
5. Analyze the device's performance and compare it with traditional medical devices to evaluate the accuracy of measurements and the possibility of using it as a supportive medical tool in clinical practice.
6. Achieve low power consumption to ensure that the bracelet operates for long periods, making it suitable for daily use without the need for frequent recharging.
7. Suggest future improvements such as integrating additional sensors (such as ECG to measure electrocardiogram) or using artificial intelligence to analyze health data and predict potential health risks.

3. Project Components:

The smart bracelet system for measuring blood oxygen (SpO2) and heart rate using the MAX30102 sensor consists of several main components, including:

1-Arduino nano:

Arduino Nano is one of the most popular microcontrollers used in embedded systems projects, characterized by its small size, low power consumption, and ease of programming. It is based on the ATmega328P processor, which is the same processor used in the Arduino Uno, but it comes with a compact design that makes it suitable for applications that require a small size without sacrificing performance. It is small in size, strong in performance, and easy to connect as it contains several pins. It supports 5-volt operation from a USB port or 12-volt operation from an external battery port. The Arduino is programmed using a programming code to implement several projects with a set of sensors and others.

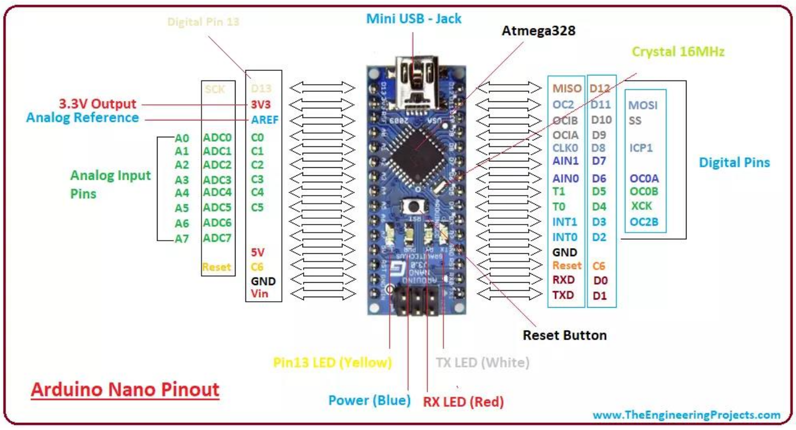

Fig (1): Arduino Nano.

2. MAX30102 Sensor:

Uses optical absorption technology to measure blood oxygen saturation (SpO2) and heart rate through infrared and infrared light. It is highly efficient in detecting changes in blood flow through tissues, allowing for accurate measurements.

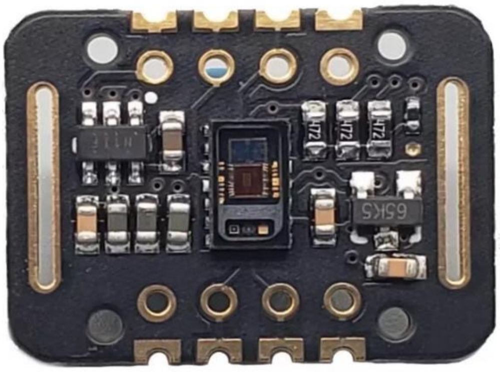

Fig (2): MAX30102 Sensor.

3. ESP32:

It is one of the most popular microcontrollers in Internet of Things (IoT) applications and embedded systems, as it is characterized by its high processing capacity, support for wireless communication via Wi-Fi and Bluetooth, in addition to its low power consumption. This controller is used in artificial intelligence projects, smart automation, and wireless monitoring systems thanks to its advanced capabilities. The number of digital inputs and outputs is: more than 30 pins, a low-power operating system, and a random-access memory of 520 KB.and a frequency of up to 240 MHz.

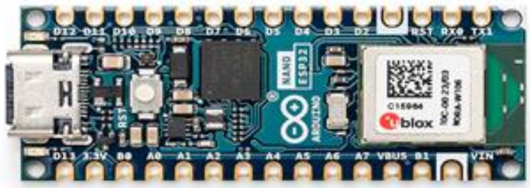

Fig (3): Esp32.

4. Display Interface:

A small OLED screen (0.96 inches or larger) to display values directly on the bracelet. A Smartphone app to receive and display data in a more detailed way, with the ability to store and analyze readings over time.

Fig (4): small OLED.

5. Wireless Communication Module:

Bluetooth or Wi-Fi module (found in ESP32 or separate for Arduino) to transfer data to the application on the smartphone. This module allows monitoring the user's health data in real time.

6. Power Supply Unit:

Li-Po battery with 3.7V voltage and 500mAh or more capacity to ensure long-term operation of the device.

TP4056 charging unit with protection circuit to recharge the battery safely.

Fig (5): Power Supply.

7. Software and Algorithms:

Programming Arduino IDE / Micro Python (ESP32) to process the bio-signals coming from the sensor.

Using signal filtering algorithms (such as Kalman Filter or Moving Average Filter) to improve the accuracy of the readings and eliminate the noise caused by hand movement.

Developing an Android/iOS application using Flutter or MIT App Inventor to display the data in a visual and user-friendly way.

4. Working principle:

4.1. Working Principle of Heart rate and Oxygen Sensor (Max30102):

MAX30102 is an advanced sensor for measuring oxygen and heart rate, using red and infrared light technology to measure light absorption in tissues, allowing for accurate calculation of blood oxygen levels. This sensor has many advantages, including:

1. Low power consumption, making it ideal for wearable devices.

2. Small size and easy integration with controllers such as Arduino and ESP32.

3. High accuracy compared to traditional sensors.

The MAX30102 heart rate and oxygen sensor functions on the principle of light absorption by blood within tissues and blood vessels. It employs infrared (IR) and red-light reflection technology to assess the user's oxygen saturation (SpO2) and heart rate (HR).

This sensor features infrared and red LEDs, along with a photonic filter, to produce suitable light that penetrates the skin and red-hued tissues. The infrared LED is capable of penetrating deeper into the skin, whereas the red LED has a shallower penetration depth. As the light passes through the skin, it reflects off the flowing blood in the underlying blood vessels.

To quantify the amount of light reflected by the blood, the sensor utilizes photodiodes. These photodiodes capture the light signals and transform them into analog data. Subsequently, this data is amplified and converted into digital format by an analog-to-digital converter (ADC).

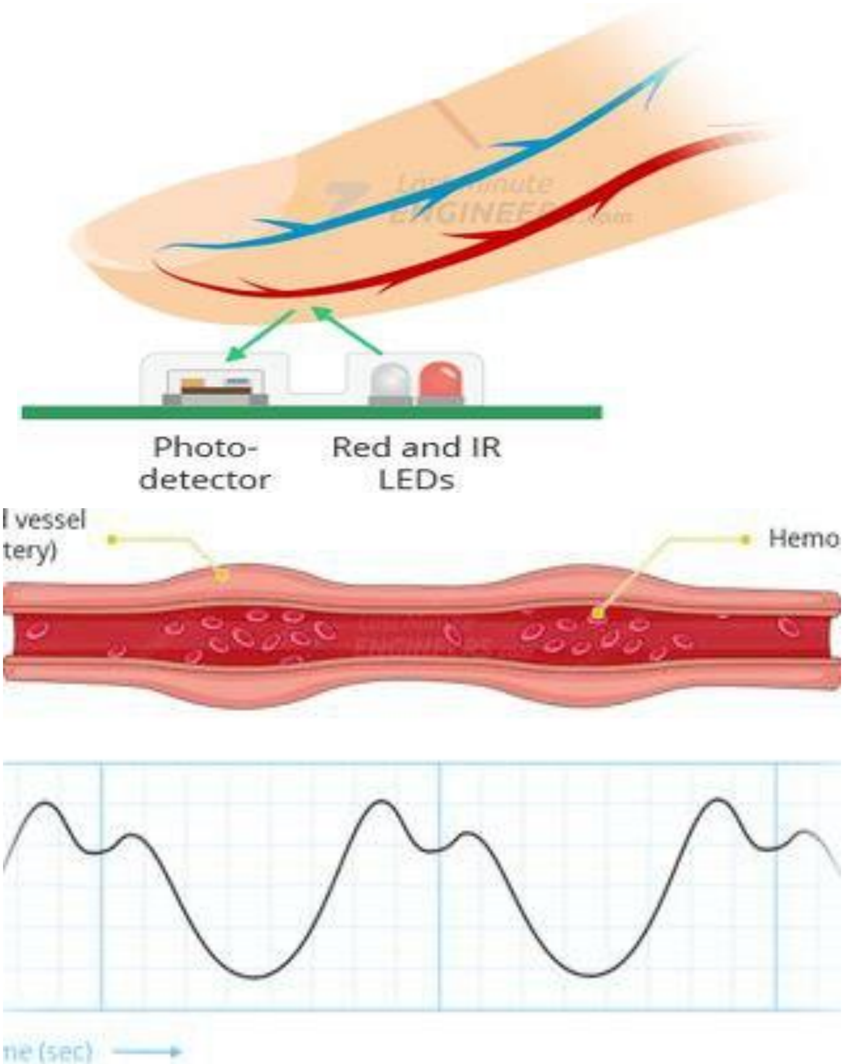

Fig (6): Max3302 Working Principle.

4.2. Working Principle of ESP32:

When the ESP32 is powered on, the processor executes the code stored in memory, interacting with communication modules, sensors, and actuators according to the pre-programmed programming. Data is exchanged via Wi-Fi or Bluetooth to enable remote control or sending data to cloud servers in IoT applications

4.3. Working Principle of Project:

The smart bracelet developed in this research is based on the MAX30102 sensor, an advanced optical sensor that uses optical reflection technology to measure blood oxygen (SpO_2) and heart rate. The sensor is connected to an Arduino board to process the data, and the ESP32 module is used to provide wireless communication and data storage.

✓ Measurement mechanism:

1. Measurement of blood oxygen (SpO_2)

The MAX30102 sensor is based on the principle of measuring optical absorption, where a dual-color light source (LEDs) emits red light (660 nm) and infrared light (880 nm)

These rays are directed to the skin, where they are absorbed and reflected by hemoglobin in the blood.

Based on the absorption ratio of both red and infrared light, the oxygen saturation rate in the blood can be calculated using mathematical equations built into the sensor.

2. Measurement of heart rate:

Heart rate is determined by measuring the periodic changes in light absorption resulting from blood flow in the blood vessels.

When the heart beats, the volume of blood in the vessels increases, which increases the absorption of light, and when it relaxes, the absorption decreases.

These temporal changes are analyzed to extract the heart rate in beats per minute (BPM).

✓ Data processing and transmission

The MAX30102 sensor is connected to an Arduino board that receives the light signals and converts them into digital data.

The signal analysis algorithms built into the program are based on signal filtering technology to remove noise and improve measurement accuracy.

The results are displayed on a small screen mounted on the bracelet, and the data is sent to a mobile phone or cloud storage using the ESP32 module via Wi-Fi or Bluetooth.

✓ Power management and practical use:

The system is designed to operate with high energy efficiency, as a rechargeable battery is used that lasts up to 72 hours

The user's comfort has been taken into account, as the sensor is mounted on the wrist to provide continuous and accurate readings without discomfort.

This bracelet can be used in medical applications to monitor patients remotely, as well as in sports applications to monitor physical performance and analyze the user's health.

Fig (7): Smart bracelet to read and measure heart rate and oxygen.

5. Connecting components:

5.1. Circuit Connections:

Max30102 Sensor to Arduino Nano:

Max30102 Pin	Arduino Nano Pin
Vcc	3.3V
GND	GND
SCL	A5 (12C Clock)
SDA	A4 (12C Data)

5.2. OLED Display to Arduino Nano:

OLED Pin	Arduino Nano Pin
Vcc	3.3v
GND	GND
SCL	A5
SDA	A4

5.3. ESP32 to Arduino Nano:

ESP32 Pin	Arduino Nano Pin
RX (GPIO16)	TX (Pin 1)
TX (GPIO170)	RX (Pin 0)
GND	GND

6. Software Program:

Arduino Code:

```
#include <Wire.h>
#include "MAX30102.h"
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#define SCREEN_WIDTH 128
#define SCREEN_HEIGHT 64
#define OLED_RESET -1
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);
```

```
MAX30102 sensor;
void setup() {
Serial.begin(115200);
Wire.begin();
// Initialize OLED Display
if (!display.begin(SSD1306_I2C_ADDRESS, 0x3C)) {
Serial.println("OLED display not found!");
while (1);
}
display.clearDisplay();
display.setTextSize(1);
display.setTextColor(WHITE);
display.setCursor(0, 10);
display.println("Initializing...");
display.display();
delay(2000);
// Initialize MAX30102 Sensor
if (!sensor.begin()) {
Serial.println("MAX30102 sensor not found!");
while (1);
}
Serial.println("MAX30102 Sensor Initialized.");
}
void loop() {
int heartRate = sensor.getHeartRate();
float spo2 = sensor.getSpO2();
// Display values on OLED
display.clearDisplay();
display.setCursor(0, 10);
display.print("Heart Rate: ");
display.print(heartRate);
display.println(" BPM");
display.print("SpO2: ");
display.print(spo2);
display.println(" %");
display.display();
// Send values to Serial Monitor
```

```
Serial.print("Heart Rate: ");
Serial.print(heartRate);
Serial.print(" BPM, SpO2: ");
Serial.print(spo2);
Serial.println(" %");
delay(1000); // Update every second
}
```

7. Results:

In this research, a smart bracelet was developed to measure blood oxygen (SpO_2) and heart rate using a MAX30102 sensor, an Arduino board, and an ESP32 to improve performance and add wireless connectivity features. After testing and analysis, we reached the following conclusions:

1. Measurement accuracy: Test results showed that the bracelet provides accurate readings of heart rate and blood oxygen compared to standard medical devices, with an error rate of ±2% for SpO_2 and ±3 beats per minute for heart rate.
2. Improved connectivity using ESP32: Using the ESP32 module improved wireless connectivity via Wi-Fi and Bluetooth, allowing data to be transferred to mobile applications or cloud servers for remote monitoring of vital signs.
3. Fast response time: Thanks to the powerful ESP32 processor, data was processed quickly and readings were displayed in real time within a few seconds of wearing the bracelet.
4. Low power consumption: The device showed good power efficiency, as it can operate for up to 72 hours on a single charge thanks to the power management improvements in the ESP32.
5. Possibility of integration with health monitoring systems: Data can be sent to smartphone applications or electronic health record systems via the Internet, allowing for remote monitoring of chronic medical conditions.
6. Scalability: Thanks to the capabilities of the ESP32, additional sensors such as temperature or ECG can be integrated, making the bracelet an integrated tool for health monitoring.

8. Conclusion:

This study represents a significant development in the design of wearable devices for monitoring vital signs. By integrating the MAX30102 with Arduino and using the ESP32, we succeeded in developing a smart bracelet that is characterized by accuracy, fast response, low power consumption, and effective wireless communication.

Despite these positive results, there are some challenges that can be worked on in the future, such as improving the accuracy of readings in different lighting conditions, developing a more user-friendly user interface, and increasing the integration of the device with smart healthcare systems.

In general, this project opens the door to multiple applications in the medical and sports fields, as this bracelet can be used to monitor patients remotely, analyze the physical performance of athletes, and even in critical environments such as intensive care units.

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