IOT BASED PORTABLE HEART RATE & SPO2 PULSE OXIMETER

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ABSTRACT

A pulse oximeter is a gadget that uses light sensors attached to the finger to monitor a person's heart rate and oxygen saturation level. Doctors or carers can monitor the data from an IoT-based pulse oximeter by sending it via Wi-Fi to a remote server or application. In the setting of COVID-19, where low oxygen levels can signify serious infection, this can aid in the detection and prevention of any significant health concerns. Additionally helpful to patients with long-term respiratory conditions like asthma, COPD, or lung cancer is an Internet of Things-based pulse oximeter.

In this project, we design and implement an IoT-based pulse oximeter system that can measure and transmit the oxygen saturation level and heart rate of a person to a cloud platform. We use a MAX30100 sensor, which combines a red LED and an infrared LED with a photodetector, to capture the blood volume changes in the finger. We use an ESP8266 microcontroller, which has built-in Wi-Fi capabilities, to process the sensor data and send it to a Blynk application, where it can be displayed and stored. We compare the performance of our system with a commercial pulse oximeter and evaluate its accuracy and reliability. We also discuss the potential applications and benefits of our system for healthcare and remote patient monitoring.

This project aims to create a low-cost, portable, Internet of Things (IoT) heart rate and SpO2 sensor that can be used to track real-time health during the COVID-19 pandemic. The system includes a MAX30100 pulse oximeter sensor, an embedded OLED display, and an HTML webpage with Wi-Fi capability for online data access. The device is simple to use, consumes little energy, and can perform measurements at high sample rates. The proposed system aims to give everyone an easy-to-use, Internet of Things (IoT)-based pulse oximeter/heart monitoring system.

KEYWORDS: IOT Based SpO2 Pulse Oximeter, We Mos D1 mini- ESP8266, MAX30100

I. INTRODUCTION

Pulse oximetry is a non-invasive method of measuring the oxygen saturation level and heart rate of a person by using light sensors attached to the finger. It is a vital sign that can indicate the health status of a person, especially in the context of COVID-19, where low oxygen levels can signal severe infection. However, conventional pulse oximeters are standalone devices that do not allow remote monitoring or data logging.

Therefore, there is a need for an IoT-based pulse oximeter system that can transmit the data to a cloud platform or an application, where it can be accessed by doctors or caregivers. Such a system can enable early detection and intervention of critical health conditions, as well as provide convenience and comfort for the patients. In this project, we aim to design and implement an IoT-based pulse oximeter system using a low-cost and low-power sensor module, a Wi-Fi-enabled microcontroller, and a Blynk application. We will also evaluate the performance and accuracy of our system and compare it with a commercial pulse oximeter.

The IOT project pulse oximeter is a portable, affordable medical device that measures blood oxygen levels and heart rate. The device is easy to use and convenient for real-time health monitoring because it has an integrated OLED display and can communicate acquired data online. Because the pulse oximeter is built on the MAX30100 sensor, it can host an HTML page that can be accessed remotely over a local area network. This IOT-based pulse oximeter can help ease the strain on healthcare systems by enabling remote health monitoring. It is an invaluable tool for keeping an eye on patients' vital signs, particularly during the COVID-19 pandemic.

II. LITERATURE SURVEY

Pulse oximetry is a non-invasive technique for determining heart rate and oxygen saturation level of a person by using light sensors attached to the finger. It is widely used in clinical settings and home care to monitor the health status of individuals with respiratory conditions, like COVID-19, asthma, COPD, etc. However, conventional pulse oximeters are standalone devices that require manual recording and transmission of the data, which can be inconvenient, time-consuming and imprecise. Additionally, they don't offer real-time feedback or alerts to the patients or the doctors in case of any abnormality.

Several academics have invented the Internet of Things (IoT) to get around these restrictions-based pulse oximeter systems that can wirelessly forward the information to a smartphone or a web platform via Wi-Fi, Bluetooth, or GSM. These systems can enable remote monitoring, data analysis, and notification of the vital signs of the patients, which can improve the quality of care and reduce the risk of complications. Some of the examples of IoT based pulse oximeter systems are:

- **IoT Based Pulse Oximeter System:** This system uses Utilising an ESP8266 microcontroller and a MAX30100 sensor, the oxygen level and heart rate to a Blynk app on a smartphone or a web server
- **Smart Pulse Oximeter:** This system uses oxygen sensor and pulse rate sensor to detect the values and Arduino microcontroller to send them to a Ubisoft's app on a smartphone
- **IoT Based Pulse Oximeter:** This system uses Utilising the Neelum microcontroller and MAX30100 sensor, the oxygen level is measured and transmitted. heart rate to a Things peak platform on a web browser
- **Vital Signs Monitoring Based on Pulse Oximeter Sensor and IoT platform:** This system measures and transmits the heart rate and oxygen level to a Firebase platform on a web browser using an ESP32 microcontroller and a MAX30100 sensor.
- Sensors and the microcontrollers may vary depending on the environmental conditions, the finger placement, the skin color, the motion artifacts, etc.
- The security and privacy of the data transmission and storage may be compromised by unauthorized access, hacking, or data leakage.
- The power consumption and battery life of the devices may be affected by the frequency and duration • Additional features, such data visualisation, data analysis, data sharing, data export, etc., could enhance the user interface and experience of smartphone apps and web platforms. These include data transfer and the usage of Wi-Fi, Bluetooth, or GSM modules. Therefore, there is still room for improvement and innovation in the design and development of IoT based pulse oximeter systems that can address these issues and provide better performance, functionality, and usability.

III. BLOCK DIAGRAM AND WORKING PRINCIPLE

A pulse oximeter is a device that demonstrating the pulse oximeter and saturation of oxygen the of a person's blood. It uses two light sources (red and infrared) and a photo-detector to sense the changes in blood volume and colour due to the heartbeat. The device can be connected to the internet using an ESP32 microcontroller and a Blynk application, which allows remote monitoring of the health data.

A possible block diagram for a pulse oximeter IoT project is shown below:

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+-----------------+   +-----------------+   +-----------------+
| Pulse Oximeter |    | ESP32         |     | Blynk Server   |
| Sensor        |     | Microcontroller |   | and Application |
| (MAX30100)    |     |               |     |               |
+-----------------+   +-----------------+   +-----------------+
| Red LED       |     | OLED Display  |     | Smartphone     |
| Infrared LED  |     | WIFI Module   |     | Dashboard      |
| Photo-detector |    | ADC           |     | Notifications  |
| I2C Interface  |<--->| I2C Interface  |<--->| Internet       |
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Fig.3.1 Block representation of connections

The working principle of the pulse oximeter IoT project is as follows:

- The pulse oximeter sensor emits red and infrared light through the finger or earlobe of the person and detects the amount of light that passes through or reflects back to the photo-detector.The sensor uses the I2C protocol to send the raw data to the ESP32 microcontroller, which converts the analog signals to digital values using an ADC (analogue-to-digital converter)
- The ESP32 microcontroller processes the information and determines the pulse rate (PR) and oxygen saturation (SpO2) of the person

using an algorithm. It also displays the results on an OLED display module connected via I2C.

- • The data is sent from the ESP32 microcontroller to the Blynk server, which saves and displays it on a smartphone application, via an internet connection made possible by a Wi-Fi module.
- The Blynk application allows the user to continuously check the health data and get alerts or messages if the values are abnormal or out of range.

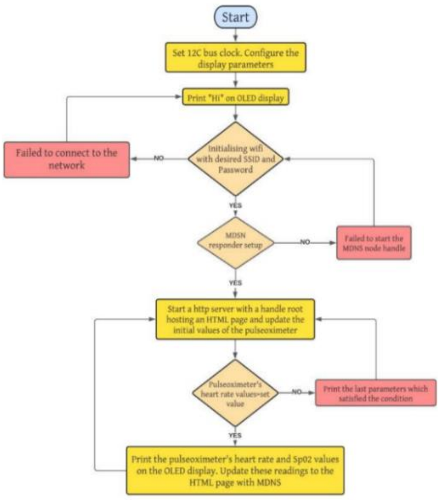

Fig.3.2: The operating instruction flowchart

IV. HARD DESCRIPTION

The Internet of Things (IoT) pulse oximeter project is the design and implementation of a monitoring system.

The device uses Bluetooth to transfer the data it collects from a patient's body temperature, heart rate, and blood oxygen saturation level (SpO2) to a mobile

The project's main goal is to make greater affordability and accessibility of healthcare services for the general public. The system's goal is to make it easier for patients to use a medical gadget that would otherwise be complicated while at home for the least amount of money. The system applies a maximum relative error of 5% to all measures pertaining to the patient's health metrics, hence providing a 95% confidence interval. The general public's adoption of these gadgets as assistance aids in particular circumstances may have a big influence on their own life.

Individuals with long-term conditions that require ongoing observation, such as COVID-19, high blood pressure, diabetes, and other ailments, will find the system very helpful. Real-time monitoring of the patient's health parameters by the system makes it possible to identify any irregularities early on and take appropriate action. Additionally, the system can give medical personnel access to the patient's health information, empowering them to decide on the patient's care with knowledge..

A temperature sensor, a microprocessor, a Bluetooth module, a mobile application, and a pulse oximeter sensor make up the system. The patient's body temperature is measured by the temperature sensor, while their heart rate and SpO2 level are determined by the pulse oximeter sensor. After processing the data gathered by the sensors, the microcontroller uses Bluetooth to transmit it to the mobile application. The patient and healthcare providers can keep an eye on each other's health thanks to the user-friendly format in which the results are shown on the smartphone application.

The system was tested on three different human participants and the findings demonstrated that the system could measure the patient's health data accurately. The study of temperature measurement data revealed that, despite small variances brought on by the various body types of test subjects, the temperature values were quite near for each measurement setting. The examination of the pulse rate measurement revealed that the heart rates of the three subjects were similar, and the suggested method displayed standard heart rate values. The examination of the SpO2 measurement revealed that the three individuals' SpO2 levels were quite similar, and the suggested method displayed standard SpO2 values.

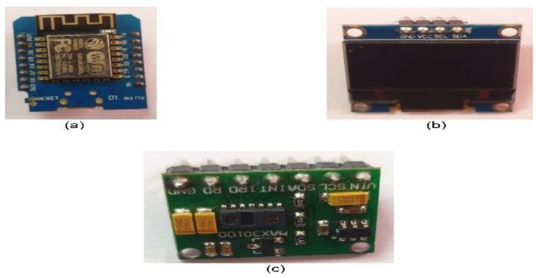

Fig.4.1. The Key Electronic Modules Of The System A)D1 Mini Wemos Microcontroller, B)128*64 Oled Display, C)Max30100 Pulse Oximeter Module.

A PCB with the entire hardware circuitry completed and soldered to it is housed in a PLA case that was 3D printed.

This device's salient features comprise:

- An Internet of Things-based health monitoring system
- Easy to put up and operate.

- Economical

V BUILD INSTRUCTION

To build an IoT pulse oximeter, you will need the following components:

- ESP32: A microcontroller board that can connect to Wi-Fi and communicate with the pulse oximeter sensor and the OLED display.
- MAX30100: A pulse oximeter sensor that can measure the SpO2 and BPM of a person using red and infrared LEDs and photodetectors.
- OLED Display: A 0.96 inch blue OLED display module that can show the SpO2 and BPM values on the screen.
- 3D Printed Enclosure: A case that can hold the ESP32, the MAX30100, and the OLED display together and provide a slot for the finger to insert.
- Blynk Application: A smartphone app that may build a dashboard to show the BPM and SpO2 readings online.
- The basic steps for building an IoT pulse oximeter are as follows:
- Connect the I2C pins (SCL and SDA) of the ESP32, the MAX30100, and the OLED display together. Also, connect the VCC and GND pins of the ESP32 to the VCC and GND pins of the MAX30100 and the OLED display.
- Download and install the Arduino IDE and the ESP32 board support package. Also, download and install the libraries for the MAX30100 and the OLED display.
- Create a Blynk account and a new project. Choose ESP32 as the device and get the auth token. Also, add a gauge widget and a super chart widget to the dashboard and set the virtual pins to V5 and V6 respectively.
- Write the code for the ESP32 to read the SpO2 and BPM values from the MAX30100 sensor, display them on the OLED screen, and send them to the Blynk server as a template and modify it according to your needs.
- Upload the code to the ESP32 and test the device. Insert your finger into the slot of the MAX30100 sensor and see if the OLED display shows the correct values. Also, check if the Blynk app shows the same values on the dashboard.
- Interfacing between Adafruit OLED module and D1 mini microcontroller: OLED module The SSD1306 model of organic light-emitting diode (OLED) display, which has monochromatic colour and resolution, was utilized in this project.

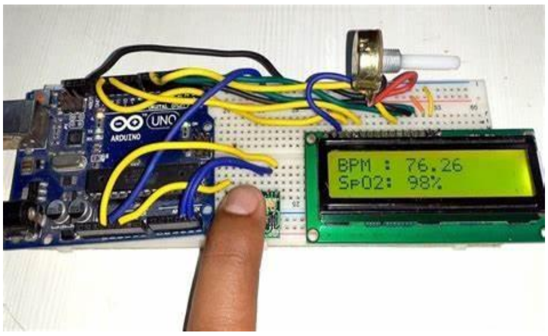

Fig. (A)

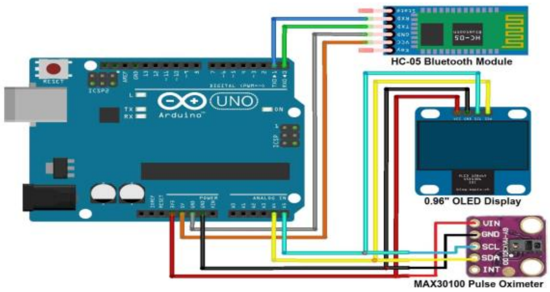

Fig.5.1: A) Schematic Diagram Of Jioning Circuit B). Connection Of Oled Display126*64, Max8266mod, Aurdino Uno, Hc-05 Blutooth Module

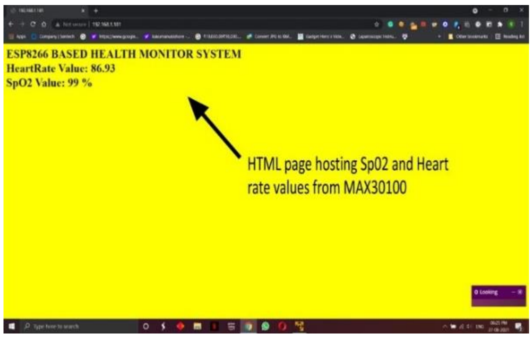

Fig.5.2. Esp8266 Based D1 Mini Hosting A Html Page.

of 128 x 64 pixels and a 0.96-inch display size. When compared to LCD displays, OLED displays have the advantage of not requiring a backlight, which enhances the contrast of the image when seen in low light.When compared to other displays, these OLED screens have a relatively low power consumption. This OLED is interfaced with D1 small, via I2C protocol. Of the seven pins on the chip, only four (VCC,GND,SDA, and SCL) are used for communication. Unlike conventional LCDs, which require interfaces with 12 pin connections, OLEDs only require 4 pins.

Fig.5.3: A Model Commercially Available Pulse Oximeter

VI OPERATION INSTRUCTION

- A pulse oximeter is a tool used to evaluate blood oxygen saturation. You must do the following actions in order to utilise a pulse oximeter:

Install:

- Two AAA batteries according to the battery installation instructions.
- Open the oximeter and insert one of your fingers into the rubber hole. Make sure your nail surface is facing upward.
- Press the function button once on the front panel. The oximeter will turn on and display your oxygen saturation and pulse rate.
- Keep your finger still and do not shake it during the measurement. The reading may take a few seconds to stabilize.
- Read the corresponding data on the display screen. The normal range of oxygen saturation is 95% to 100%. If your reading is lower than 90%, you may have hypoxemia and should consult a doctor.
- To turn off the oximeter, press the function button again or remove your finger from the device.

VII VALIDATION AND CHARACTERIZATION

Validation and characterization are important steps for ensuring the accuracy and reliability of pulse oximeters. Validation is the process of testing the performance of a pulse oximeter against a reference standard, such as an arterial blood gas analysers or a pulse oximeter simulator. ***Characterization is the process of analysing the factors that affect the pulse oximeter's accuracy, such as perfusion, motion, skin pigmentation, ambient light, and temperature .***

Depending on the device's intended usage and application, there are many protocols and methods for characterising and verifying pulse oximeters. For instance, a standard (ISO 80601-2-61:2017) produced by the International Organisation for Standardisation (ISO) outlines the minimal specifications and testing procedures for pulse oximeters meant to be used in medical electrical equipment. Guidelines for the characterization and validation of pulse oximeters intended for over-the-counter and prescription usage are also offered by the FDA.

Some of the common parameters that are measured during validation and characterization of pulse oximeters are:

- Accuracy: the degree of agreement between the pulse oximeter's measurement and the reference value.
- Precision: the degree of repeatability or consistency of the pulse oximeter's measurement.
- Linearity: the degree to which the pulse oximeter's measurement changes proportionally to the reference value.
- Sensitivity: the ability of the pulse oximeter to detect changes in the reference value.
- Specificity: the ability of the pulse oximeter to distinguish between different types of haemoglobin, such as oxyhaemoglobin, carboxyhaemoglobin, and methaemoglobin.
- Response time: the time required for the pulse oximeter to display a stable measurement after a change in the reference value.
- Stability: the ability of the pulse oximeter to maintain a consistent measurement over time and under different conditions.
- Range: the minimum and maximum values that the pulse oximeter can measure.
- The following are some typical techniques and resources for characterising and validating pulse oximeters:

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Arterial blood gas analysis: a laboratory test that gauges the arterial blood's pH, partial pressure of carbon dioxide, oxygen saturation, and other characteristics. Although this is the gold standard for determining oxygen saturation, it is costly, time-consuming, and invasive.

- Pulse oximeter simulator: a device that simulates the optical properties of human tissue and blood, and generates a PPG signal with known oxygen saturation and pulse rate values. This is a convenient and non-invasive method for testing the accuracy precision of pulse oximeters, but it might not take into consideration every physiological and environmental element that influences how well a pulse oximeter works in practical settings.

- Multi-analyte calibration: a method that uses a mixture of different types of haemoglobin, such as oxyhaemoglobin, carboxyhaemoglobin, and methaemoglobin, to test the specificity and linearity of pulse oximeters. This method can also be used to generate a calibration curve for the pulse oximeter, which can improve its accuracy and reduce its bias.

- Clinical trials: a method that involves testing the pulse oximeter on human subjects under controlled or natural conditions, and comparing the results with a reference method. This is the most realistic and reliable method for validating and characterizing pulse oximeters, but it is also the most complex, costly, and ethical. Clinical studies need a sizable sample size, a strict design, and a thorough data analysis.

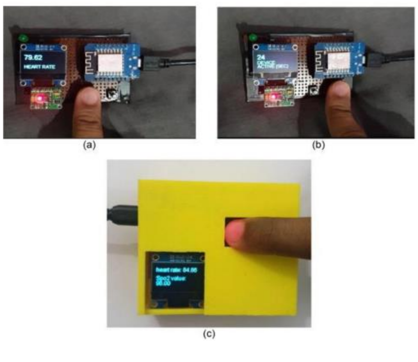

Fig.7.1: (a) Maximised heart rate reading view (b) device active time display (c)proposed system's operational condition

VIII. A DISCLOSURE OF COMPETING INTERESTS

The authors state that none of their known financial conflicts or interpersonal connections might have had an impact on the work presented in this paper.

VIII CONCLUSION

An IoT-based pulse oximeter for PCs ensures convenient health monitoring. With real-time data transmission, it facilitates remote tracking and timely interventions. This technology enhances accessibility, enabling users to monitor their health effortlessly. The integration of IoT in pulse oximetry brings about a paradigm shift in healthcare, making it more proactive and personalized. The convenience of PC connectivity further expands its usability, providing users with comprehensive health insights. Overall, this innovation signifies a significant step towards advancing digital health and empowering individuals to take charge of their well-being.

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