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Design, Hardware Implementation of a Domestic Pulse Oximeter Using IOT for COVID – 19 Patient

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ABSTRACT

In COVID – 19 eras, research shows that many people died in coronavirus due to shortage of oxygen in the body. Another symptom of COVID is high fever. So, it is very needful to keep track of the Oxygen level and Temperature of the patient. In present market several types of pulse oximeters are present, but none of them is IoT enabled hence one must physically come close to the patient to check the health conditions, this cause infection to spread among the health staff or the family members. COVID-19 is highly infectious disease and can be treated at home, but the patient has to stay in isolation during treatment period. Hence, a simple, easy cost-effective pulse oximeter enabled with IoT based remote monitoring. is proposed, designed, and implemented. This device can measure body temperature, pulse rate and oxygen level (SpO2) of the patient and can show the data remotely. Here minimum number of sensors are used to maintain cost effectivity and operation simplicity of the device. Ability to connect to IoT platform enables this device to monitor oxygen level remotely from smart phone via Blynk IoT platform. Blynk is a hardware connected mobile IoT platform to monitor data remotely and it is free to use. An OLED display is also installed in the device. So, measured data can be visible in both the device and in IoT connected app. A 5V DC USB type micro-B power adaptor needed to power up the device. An alarm indicator is setup when heartbeat is measured by the device. LED is set up inside application page to warned on body temperature rise and fall of oxygen level., thus someone can take necessary steps to prevent casualty of that patient.

KEYWORDS

IoT; Smart Healthcare; Remote Health Monitoring; COVID-19; ESP8266; IoT; Pulse Oximeter.

1. INTRODUCTION

Present day, Coronavirus (COVID - 19) pandemic makes a huge casualty of lives around the world. Many people died in this virus because there are no specific treatment policies are present [1]. Medical research shows that mains symptoms of COVID – 19 are increasing temperature and fall of oxygen level within very short period[3],[16]. Rapid fall ofoxygen level in blood leads death of people. The safe oxygenlevel of blood is considered as 100 while anything about below 95 considered as fault situation and the patient needs to give oxygen to maintain oxygen level. In India there are about 3.3 lakh (as of May 2021) people have already died in this pandemic [2]. Many people have died because they didn't get to understand that the oxygen level is falling, as initial fall of oxygen level from 98% to 93% cause slight discomfortwhich leads to negligence. When the oxygen saturation falls below 90% and starts rapidly falling further, then that attracts symptoms like shortness of breath and coughing. In this stage quick response of treatment can save a life. Thus, a device which can measure oxygen level of the body can save life in many ways [26]. In this paper a simple, domestic use, cost effective pulse oximeter is proposed, implemented, and tested. In this device we use only pulse oximeter sensor and temperature sensor to keep device cost effective andsimple [21]. Here, ESP8266 Wi-Fi module is used as which is embedded in Node MCU microcontroller in this device, which cancollect data from the sensors and deliver to cloud to obtain remote monitoring of the patient. Blynk IoT platform is taken to monitor data of the device remotely [25]. The power circuit also consists of external power supply. The device needs a 5V dc adaptor USB micro-B type to power up the device[34][21]. Some of the hardwires run on 3.3V power supply and SMD 3.3 voltage regulator takes 5V as input and supplies power to those hardwires [21]. The flowchart of the system is described followed by experimental setup and then experimental result with data analysis followed by conclusion. The block diagram of the proposed system is shown in fig 1.

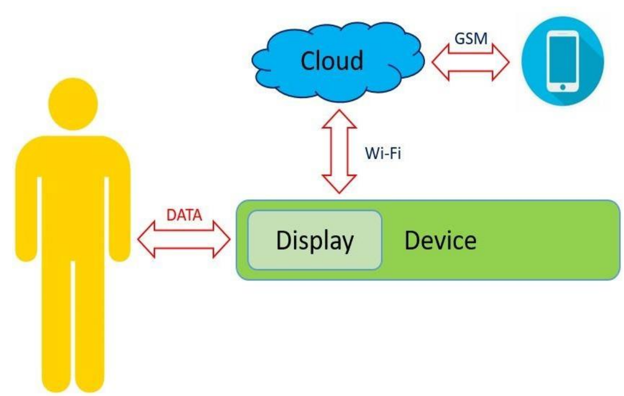

Fig. 1 Simple diagram of pulse oximeter

2. PROPOSED SYSTEM

The core objective of this device is to measure and monitor blood oxygen level and pulse rate and temperature of the human body. This system consists of three modules, hardware system,server, and android application. Pulse oximeter sensor and temperature sensor collect data from human body which are connects into the microcontroller, then the measured data is shown in OLED display and in the connected smart phone via Blynk app [4]. Communication has been done between sensors, controller, and other peripherals of the device. MAX30100 sensor module and OLED display is embedded with Node MCU controller via Inter Integrated Circuits (I2C) communication [34]. DS18B20 sensor is connected using one wire communication. Data is sent to the cloud from controller via Wi-Fi and furthermore smart phone is connected via Wi-Fi protocol to receive data. The hardware architecture of the proposed system along with the flowchart is given below.

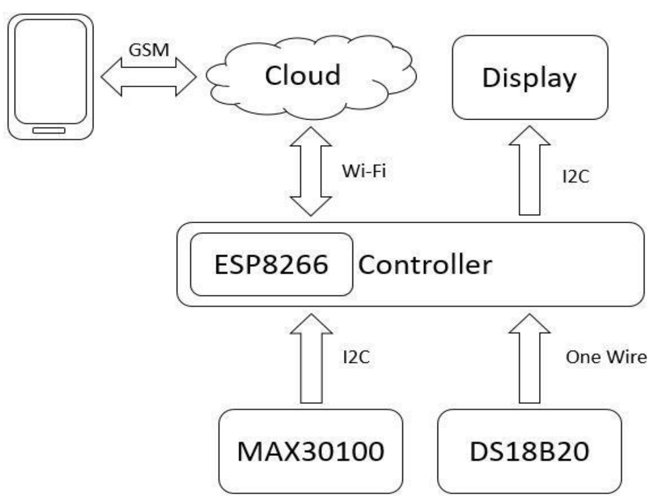

Fig. 2 Proposed Hardware Architecture of the Pulse Oximeter

First the display is initiated when the power is plugged in the device and communion started between the sensors i.e., DS10B20, MAX30100 and microcontroller Node MCU. If successful initialization fails, the reinitialization process repeats automatically. After successful initialization the measurement of body temperature, pulse beat and SpO2 level is done by the sensors. Then all the analog signal is passed to analog to digital converter (ADC) situated inside the sensor module. Which is then transmitted to the main controller board (ESP8266). Followed by checking is done if button widget is pressed or not. Temperature check is only done if it is requested by pressing a push button widget through the app. If pressed, then analog signal collected and processed by DS18B20 is sent to the main controller board (ESP8266). Once all the data is received it is sent to the OLED display moduleto be displayed. Followed by sent to cloud for storage and remote monitoring through the Blynk app. If the push button widget in the app is not pressed only the oxygen level and heartrate is displayed and sent to the cloud for remote monitoring [35]. Fig. 3. is the flowchart of proposed implemented device.

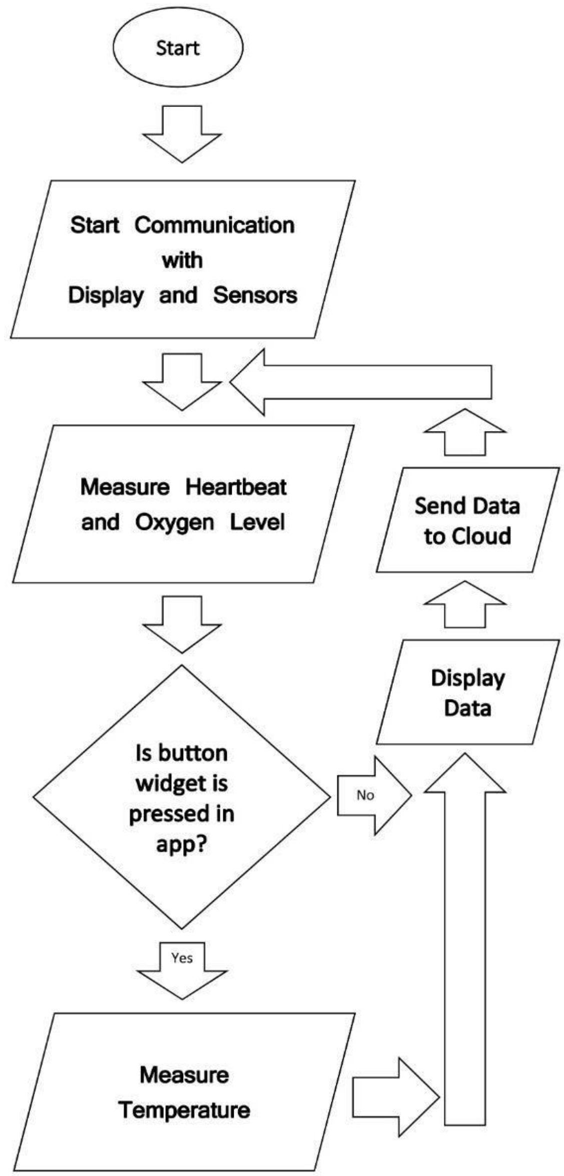

Fig. 3 Flowchart of the proposed system

3. COMPONENT USED

In this device two sensors are used, which will connect to a microcontroller to collect and pass data into the server. An OLEDdisplay is used to display the measured data and Blynk app is used to show measured data remotely.

3.1 Microcontroller Module (ESP8266):

ESP 8266 Module has been used for sending Data to Cloud [21]. The ESP8266 microcontroller embeds a Ten silica L106 32-bit RISC processor, which consumes extra-low power and achieve a maximum clock speed of 160 MHz The Real- Time Operating System (RTOS) and Wi-Fi stack allow about 85% of the processing power to be available for user application programming and development [41][5].

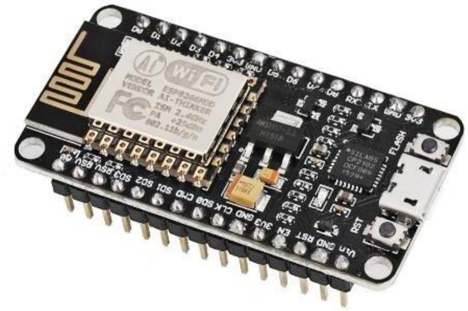

Fig. 4 ESP8266 WI-FI microcontroller.

3.2 Temperature Sensor (DS18B20):

The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points. The DS18B20 communicates over a 1-Wire bus that requires only one data line (and ground) for communication with a central microprocessor [14]. In addition,the DS18B20 can derive power directly from the data line ("parasite power"), eliminating the need for an external power supply. Each DS18B20 has a unique 64-bit serial code, whichallows multiple DS18B20s to function on the same 1-Wire bus. Thus, it is simple to use one microprocessor to control many DS18B20s distributed over a large area [7]. Applications that can benefit from this feature include HVAC environmental controls, temperature monitoring systems inside buildings,equipment, or machinery, and process monitoring and controlsystems [40].

Fig. 5 DS180B20 Temperature Sensor.

3.3 Heart Rate Sensor (MAX30100):

The MAX30100 is an integrated pulse oximetry and heart rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals. The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to always remain connected [36][9].

Fig. 6 Fig. 6. MAX300100 Heart rate sensor

3.4 OLED Display:

Tiny 128×64 is an OLED Display 4 Pin based on SSD1306 Display controller chip. The display is mounted on an easy to solder PCB. The SSD1306 Display interfaces to microcontrollers through an I2C serial bus interface. This OLED Technology has Self-luminous, need no backlight (consumes less energy) [15]. It has high resolution of 128 * 64 pixels. It has a viewing angle greater than 160 degrees. It consumes low power, full screen lit 0.08W. Operating Voltage 3.3V Nominal (1.65V to 3.3V) [42][6].

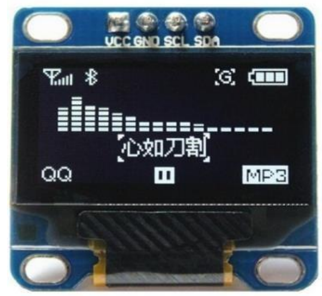

Fig. 7 OLED Display

3.5 Blynk Application:

IoT based remote monitoring to a cloud server Blynk IoT platform offers a full suite of software allowing to prototype, deploy, and remotely manage connected electronic devices at any scale: from small IoT projects to millions of commercial connected products [34]. Blynk has pioneered the no-code approach to IoT app building and gained global popularity for its best-in-class mobile app editor [13]. Over 500,000 developers and business clients in 136 countries use Blynk spanning industries from Smart Home and Agriculture to HVAC and Asset Tracking. Platform is offered branded or white-labeled. With Blynk, you can connect hardware to the cloud and use pre-made app modules to build iOS, Android, and web applications ready for the end-users,[8] all without hiring a design or engineering team. Blynk offering includes secure private cloud infrastructure, sensor data visualization, device management, environmental monitoring, remote control of equipment, firmware over-the-air updates, digital twinning, rule and notification controls, multi-tenancy with role and permission settings, aggregated data analytics, machine learning and more. Blynk supports over 400 hardware models [37].

4. DESIGN METHODOLOGY

Sensor included in the experimental method to monitor the detection of COVID- 19 decease. Block diagram as seen in fig. 5 to use wireless contract to calculate several body parameters which must measure. Continuous online patient condition monitoring is the main idea of the proposed device. Therefore, the pulse oximeter utilizes the three-stage architectural features, namely (1) Sensor Module (2) Data Processing Module (3) Web User Interface [12]. The sensors are wired which are used to collect data from the patient's body by gathering physiological touches in the sensors. The collected data are then processed via a Node MCU module and send to the gateway server. For the android app user interface, Blynk is used for graphical interpretation, and display of collected results. Blynk shows the status and process of transactions [10]. The overall system architecture of the developed system is illustrated in Fig. 8.

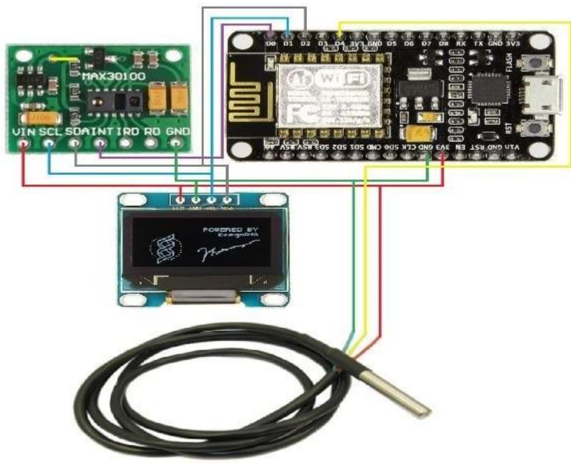

Fig. 8 Connection diagram of the device

From Fig. 8, all the sensors are used to collect data from the patient's body. DS180B20 sensor and OLED display connected in one wire communication method, whereas MAX30100 connected in I2C communication with a processing unit called ESP8266. Upon attaching these (temperature, heartbeat, SpO_2) sensors, Node MCU works as a heart of the system. ESP8266 collectssensor data and then wirelessly transfers it to IoT websites. The board uses its Wi-Fi and its own processing unit. The sensor output is then linked to the website of IoT. The data is accessed through any network supported device.There, the data are shown, and it is a channel-based system, and every time while accessing it needs password.

5. DATA ANALYSIS

In this device's body temperature, pulse rate is determined as unit Fahrenheit and Beats Per Minute (BPM) respectively. Temperature sensor connected to the analog pin of the ESP8266 controller is converted into digital value with the help of ADC. Using this digital data, the controller converts it into the actual temperature value in degree Celsius using the equation:

$$Temperature\ (°C) = [\frac{ADC\ Value * 5}{4095} - \frac{400}{1000}] * \frac{19.5}{1000}$$

For temperature sensor the range is defined below.

Table. 1 Body Temperature Chart

Body Temperature	State
96.5°F – 100.4°F	Normal
<96.5°F	Low
>100.4°F	High

The pulse oximeter sensor is based on the principle of photo plethysmography. It measures the change in volume of blood through any organ of the body, which causes a change in the light intensity through that organ (a vascular region). The digital pulses are given to a microcontroller for calculating the heat beat rate, given by the formula:

$$BPM\ (Beats\ per\ minute) = 60 * f$$

f = Pulse Frequency

Table. 2 Pulse Rate Chart

Body Temperature	State
60 BPM – 100 BPM	Normal
<60 BPM	Low
>100 BPM	High

For measuring oxygen level of the blood, a high frequency infrared light is passed through our fingertip. If blood color is much blue, then oxygen level is lesser. If blood color is much reddish then oxygen level is good enough.

Table. 3 Oxygen Level Chart

SpO2	State
94- 100	Normal
<94	Low saturation
<90	Critical emergency

These tables are for general measurement values according to WHO. Several LEDs are given in the blynk app interface if the measured data exceeds the measured value. OLED display displays the measured data which is collected from the sensors.

6. HARDWARE AND APPLICATION SETUP

This device consists of various types of sensors like pulse oximeter and heart rate sensor (MAX30100), temperature sensor (DS18B20). This device also has IoT (Internet of Thing) application based remote monitoring. The sensors are placed in a dot Veroboard through which all the sensors and microcontroller are embedded. Connection is done according to Fig. 8. A buzzer is placed in the board for heartbeat detection alert. The main circuit is kept inside a PVC box which is to prevent any kind of damage from outside. A wire gland PG7 is also set in the wall of the box to fit up the temperature sensor. A Wi-Fi module known as the Node MCU module, which acts as a controller with Wi-Fi interface. The project also contains an Android Application; this application will be connected through the server through Wi-Fi module and can receive all the data which is stored on the server. 4 different colored LEDs are set up in the Blynk app.

Table. 4 LED Status

Name	Color	Remarks
Low saturation	Yellow	SpO2 level < 94
Clinical Emergency	Red	SpO2 level <90
High temperature	Red	Body temp. >100.4°F
Checking temperature	Blue	Measurement of body temp.

Complete image of hardware setup of pulse oximeter device is given below.

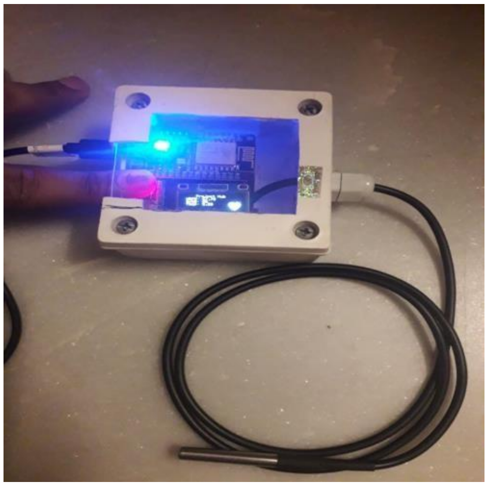

Fig. 9 Hardware setup

7. RESULTS

Starting with the initial step, the patient who is supposed to calculate or check all the reports need to touch his/her figure onto pulse oximeter sensor and hold the tip of temperature sensor, switch on the KIT, which consist of Node MCU and all the sensors. The sensors will calculate the pulse rate, oxygen level, and temperature of the body. This data from the sensors and the Node MCU will be compared with the valid data set of values. The ESP8266 will transmit the data to the server. To help the patients, a user-friendly graphical user interface is created. This application will be provided to support the user with the results gathered from the sensors. This application will display the valid sample data set of valuesthat is the result for a particular body as well as the values shown in the OLED display which is embedded in the device. 4 LEDs are set up in the Blynk app which will glow if Body temperate exhales over 100.4°F, SpO2 limit decrease below 94and further a LED is set to glow when SpO2 limit falls under 90.

Fig. 10 Hardware Under Testing

Fig. 10. Is taken without a cover box for clear visibility of OLED display screen. Where measurement data are shown, and a heart rate symbol is blink with detection of heartbeat. A buzzer is also set in the device to provide a sound alert of heartbeat. detection. The Blynk user interface is shown here.

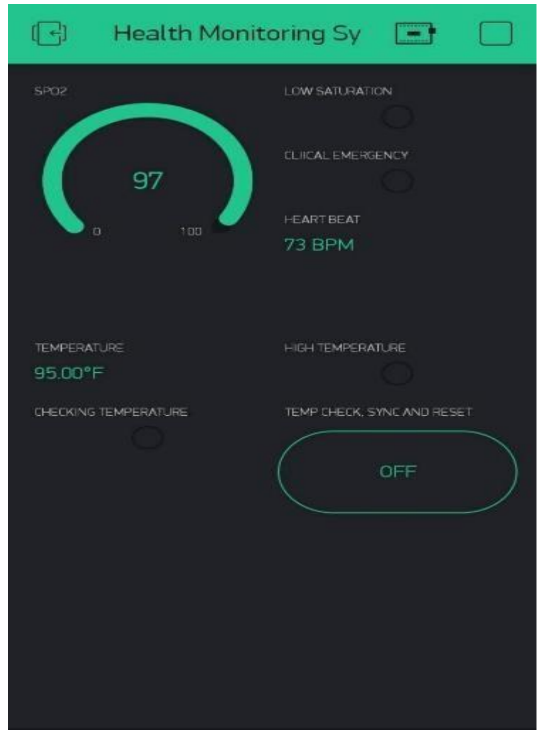

Fig. 11 Blynk User Interface

The above figure is the screenshot of the android application. There are 4 warning LED and 3 displays present. Warning LEDs are for low saturation, critical emergency, high temperature and temperature check. If any of the measured data crossed exceeds normal value, the respective LED will blink. There is also a temperature check, sync and reset button is present to check temperature and synchronize the data with cloud. The device put into a test of any random human to measure body temperature, pulse rate and SpO2 level. Hence, we can see from the screenshot that temperature is 95°F, SpO2 levelis 97 and heartbeat is 73BPM. From the measured value, wecan conclude that the patient is safe and there are no symptoms of COVID – 19 deceases.

8. CONCLUSION

This work intends to provide cost efficient and faster diagnosis to the patients since high-cost equipment are not affordable to mostly rural areas in India. This system is useful for people in areas that lack availability of hospitals and equipment and get preventive measures against COVID – 19 diseases. A device is specially made for household use; thus, the device is made in a very simple way. That everyone can use it. The development of this project is an effective tool for patients to understand the use of IoT in their daily life. By using this device, anyone can monitor a patient's health condition from a safe distance only by logging in to its respective user Id and password in Blynk app. This device is very user friendly, and it costs only INR Rs. 1000. Which makes the device very affordable. It has a very good accuracy rate compared to other pulse oximeters available in the market.

The future scope of this device comprises of areas in which introducing GSM Technology can be modified to sendinstant notification about a patient's health to respective doctors, patient family members or health centers. By implementing centralized monitoring portal health condition of multiple patients can be monitored from one single screen. By implementing Machine Learning and AI with sufficient training of the system it would be possible to predict patients' condition before it gets critical, which will result in advance precautionary measure for the patient.

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