Research Article / Review Article FUPRE JOURNAL 7(3): 79-92 (2023)

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Development of an IoT-based Wireless Remote Health Monitoring Device

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ARTICLE INFO

Received: 18/04/2023
Accepted: 24/05/2023

Keywords

Blood oxygen saturation, Heart rate, IoT, patient health, Node MCU

ABSTRACT

The design and deployment of an internet of things-based wireless remote health monitoring device for continuous monitoring of patients' vitals are presented in this paper. The device makes use of a MAX30102 pulse oximeter sensor which measures the temperature, heart rate, and blood oxygen saturation of an individual, transforms these measured physical quantities into electrical signals, and transmits them to the NodeMCU for processing. Using Google Firebase cloud technology, the data is uploaded to the cloud. The results are displayed on a TFT LCD, and before the vitals get to the preset thresholds, a mobile app notification is received at intervals by the doctor and caregiver's mobile devices via the built-in Wi-Fi module. Thus, the individual can be given prompt medical attention. The results obtained from the developed IoT-based health monitoring device are compared with the results obtained from the standard measuring devices used in two different medical centers and the values were found to be very close, showing that the developed IoT-based device closely match the standard.

1. INTRODUCTION

Improving human health and providing access to affordable, quality health care is a key concern for all countries. An important element of public health is the availability of adequate and timely medical care to facilitate the tracking, monitoring, and eventual control of disease outbreaks. The Nigerian health care system has suffered several infectious disease outbreaks year after year (Osain, 2011). There is therefore a need to tackle this problem because healthy workers are more productive and healthy students learn better.

Information and communication technology (ICT) has the potential to address some of the challenges faced by both developed and developing countries by providing accessible, cost-effective, and quality health care services. Medical IoT in particular facilitates the monitoring of a patient's health state and the tracking of medical staff through a network of smart devices and sensors connected to the cloud. Through the incorporation of IoT in medicine, patients'

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outcome can be improved through real-time patient monitoring and advanced diagnostics. Monitoring one's body's temperature, even when healthy, can help in the early detection and diagnosis of diseases and even aid in the determination of the efficacy of a treatment method. A typical adult's body temperature should be between 36 ºC – 37 ºC, while that of babies and children range between 36 ºC - 38º C (Felson, 2017).

The blood oxygen level, which is the amount of oxygen circulating in the blood, is an indication of how well the body distributes oxygen from the lungs to the cells. A healthy blood oxygen level varies between 95% and 100% (Silva, 2022). It is closely monitored by the body to keep them within a specific range so that there is sufficient oxygen to meet every cell's need.

According to World Health Organization (2020), one of the leading causes of death and disability worldwide between 2000 and 2019 was heart disease. It has remained the leading cause of death at the global level for the last 20 years, and the number of deaths from heart disease has increased by more than 2 million since 2000, reaching nearly 9 million in 2019, thereby making heart disease responsible for about 16% of total deaths from all causes.

Kumar (2021) designed and implemented a portable health monitoring system using a PSoC mixed-signal array chip. The system is used to remotely monitor a patient's temperature, heart rate, and blood oxygen saturation using pulse oximetry, blood pH, and an electrocardiogram. This system allows the physician to understand the patient's scenario on the computer screen via a wireless module. The shortcomings of using the Zigbee module for the implementation includes low data speed, high maintenance costs, and low network stability. However, our designed IoT-based device had greater processing speed, and low maintenance cost.

Khan et al (2019) designed and constructed a healthcare monitoring system that transformed the monitored data into real-time clinical feedback based on IoT using the Raspberry Pi. This approach used an IoT-based, intelligent Health Monitoring System (HMS), which continuously monitors patients' health parameters like blood pressure, heart rate, and ECG. The size of this system makes it not so mobile, and the use of the Raspberry Pi affects the overall speed of the system.

Having considered the relevance of the above parameters and the shortcomings of similar devices, the objective of this paper is to design and implement an IoT-based wireless remote health monitoring device that will continuously track the patients' vitals, such as temperature, blood oxygen saturation, and heart rate, through the sensor, while displaying the real-time values obtained on the TFT-LCD screen. It will also transmit the information obtained to the Android application on the doctor's mobile device for prompt medical care or diagnosis. Mobility issues are taken care of in the developed IoT-based wireless remote health monitoring device as it is compact in size.

2. METHODOLOGY

The implemented IoT-based wireless remote health monitoring system consists of a Node microcontroller unit programmed to process the vitals measured by the MAX30102 sensor and a mobile application that reflects the status of a patient in real-time. The block diagram of the IoT-based wireless remote health monitoring device in Figure 1 shows the components that make up the system.

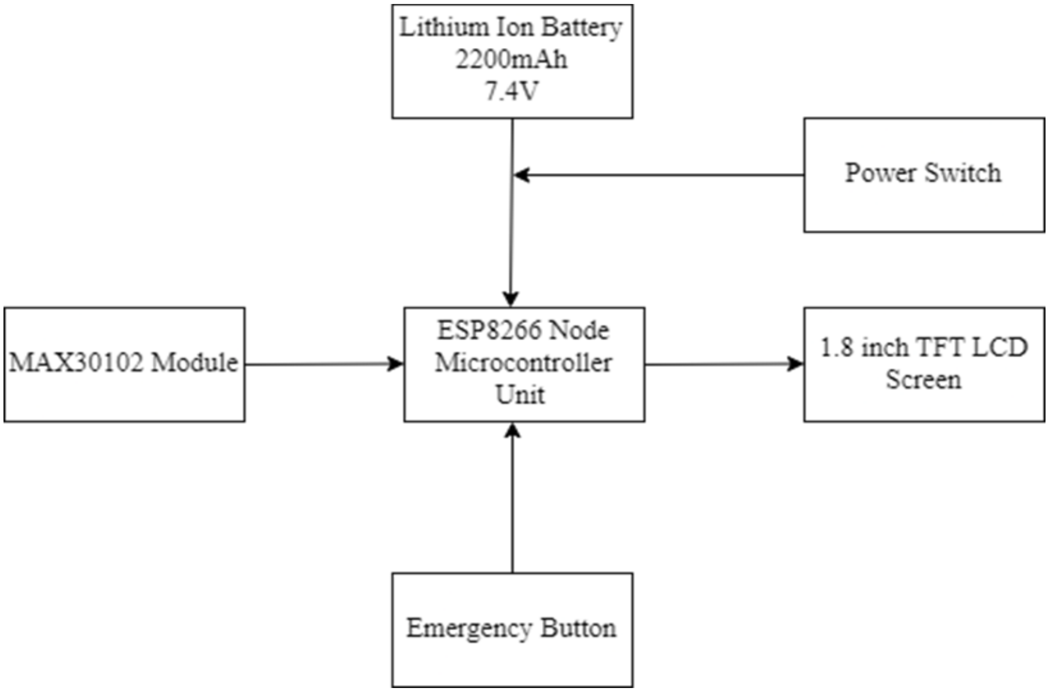

Figure 1: Block diagram of the IoT-based wireless remote health monitoring device
(Source: Author)

2.1 Hardware Requirements

2.1.1 Node MCU: The NodeMCU shown in Figure 2 is a user-friendly and low-cost open-source Lua-based firmware that provides internet connectivity to IoT-based applications. It fetches data from the internet using APIs and serves as both an access point (it can create a hotspot) and a station (it can connect to Wi-Fi), making the process of fetching and uploading data to the cloud seamless. This module has an in-built voltage regulator that steps down the input voltage received from the source to the operating voltage of 3.3 V.

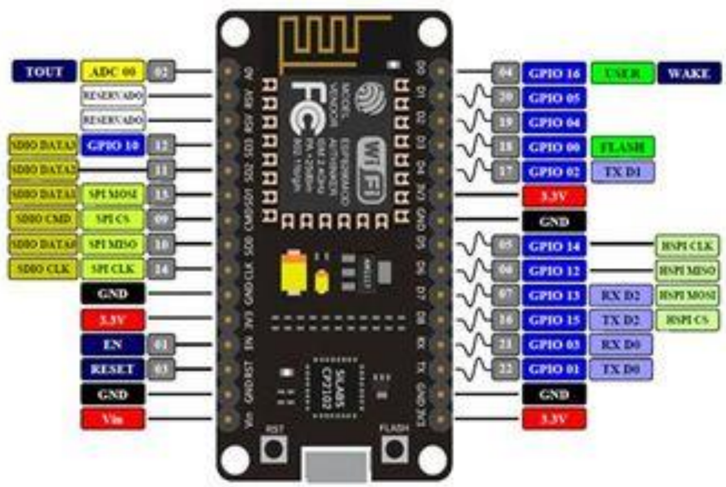

Figure 2: Node Microcontroller Unit (Aziz, 2018)

2.1.2 Pulse Oximeter Sensor: The MAX30102 module shown in Figure 3 is very versatile and can be used to measure the body temperature, heart rate, and blood oxygen saturation level. It consists of two LEDs (one for infrared light and one for red), a photo-detector, optics, and a low-noise signal processing unit for detecting pulse oximetry (SpO2) and heart rate (HR) signals. The red LED has a wavelength of 660 nm, while the wavelength of the infrared ray LED is 880 nm. Photoplethysmogram is the name of this method of light-based pulse detection. The operating voltage of the module is between 3.3 V - 5 V, and its low power consumption makes it suitable for battery-powered devices.

2.1.3 TFT-LCD Screen: It is composed of two layers of the glass substrate which sandwich the liquid crystal to form a parallel plate capacitor. Both the capacitor and the built-in storage capacitor are charged through the TFT embedded on the lower glass substrate to maintain each TFT-LCD. The TFT-LCD shown in Figure 4 does not emit light by itself, so its backlight requires a backlight panel to provide a light source with high brightness and uniform brightness distribution. It has a relatively fast response time and a large viewing angle.

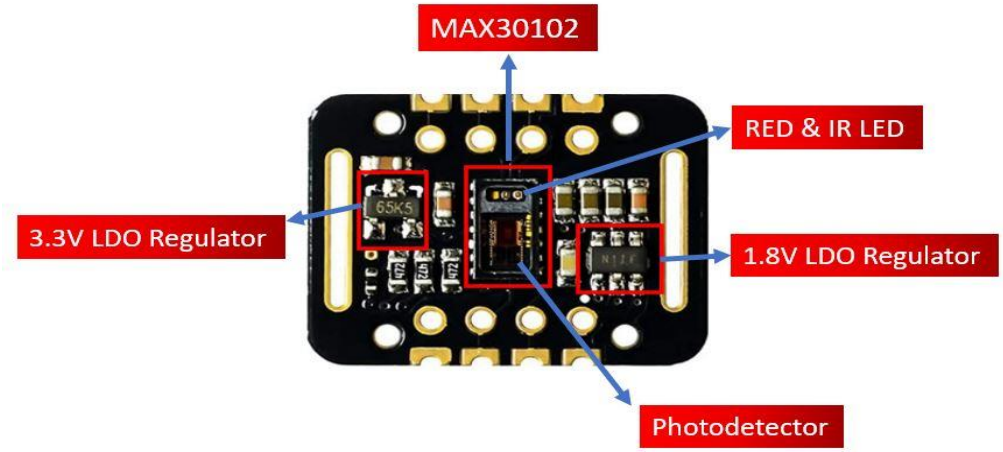

Figure 3: The Pulse Oximeter Module (Seidle, 2022)

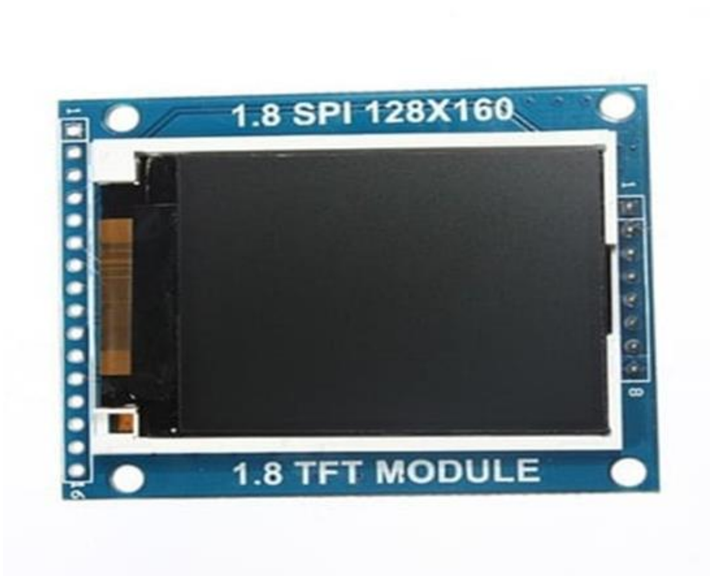

Figure 4: Thin Film Transistor LCD (Damirchi, 2021)

2.1.4 Push Button: A push button is a switch with a sealed mechanism (button) that is used in electrical automatic control circuits to manually send control signals that control contactors, relays, and electromagnetic starters when pressed. The working principle of the push button switch shown in Figure 5, is based on the principle of electromagnetism. An electromagnet adsorption device is contained inside the button. By pushing the button down, the electromagnet is energized to generate magnetism, and the circuit is connected or disconnected by the adsorption device to accommodate functions such as the remote-control circuit.

2.2 Software Requirements

2.2.1 Program Development: The IoT-based wireless remote health monitoring device was programmed using C language and the Arduino IDE. The flow charts for the program are shown in Figures 6 and 7. Figure 6 shows the operation of the IoT-based wireless health monitoring device while Figure 7 shows the communication between the IoT-based device and the Mobile App.

Figure 5: Push button (Arefín & Mondal, 2014)

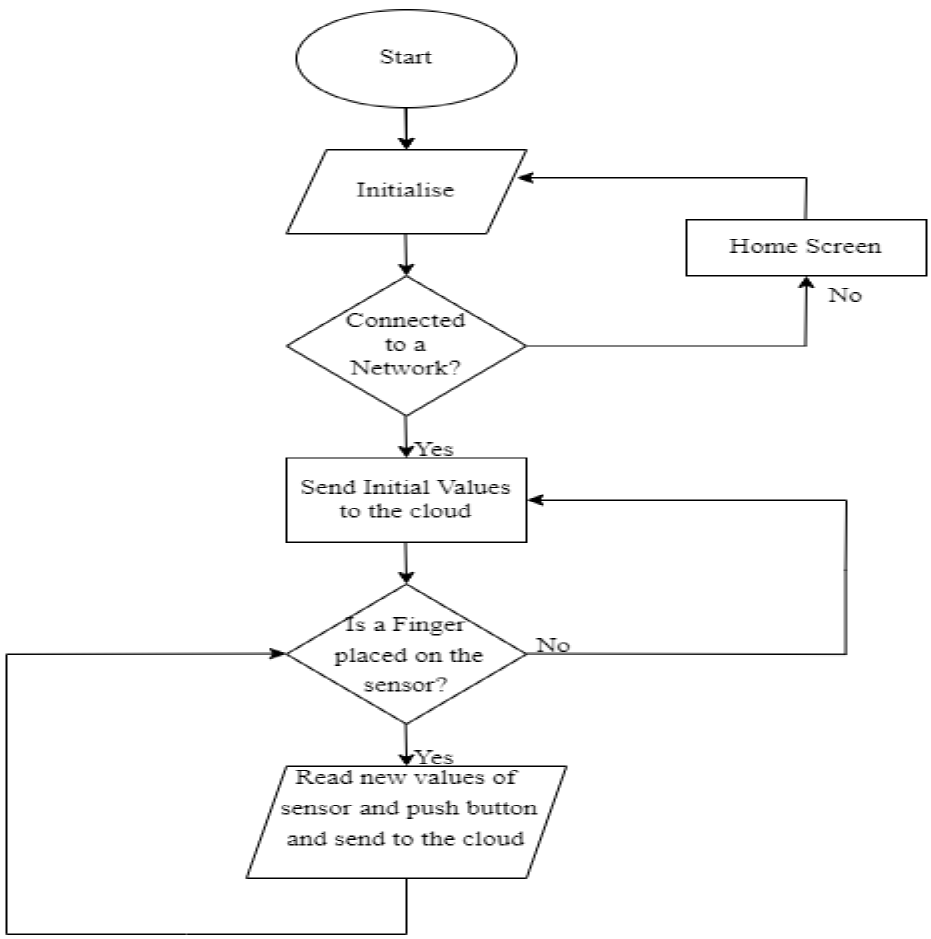

Figure 6: Flow chart showing the operation of the IoT-based wireless health monitoring device (Source: Author)

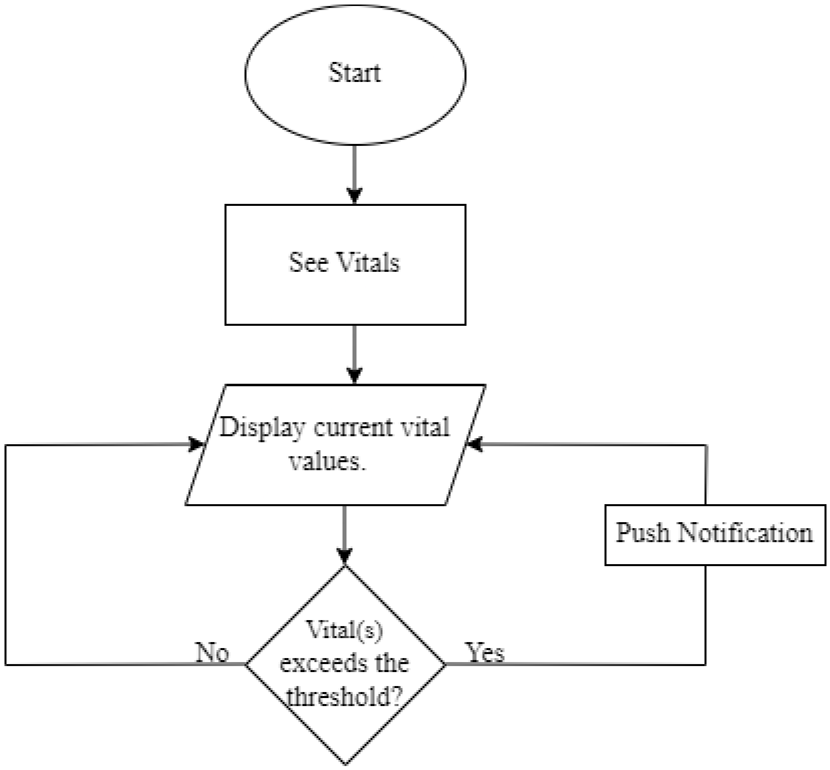

Figure 7: Flow chart showing the communication between the Mobile App and IoT device (Source: Author)

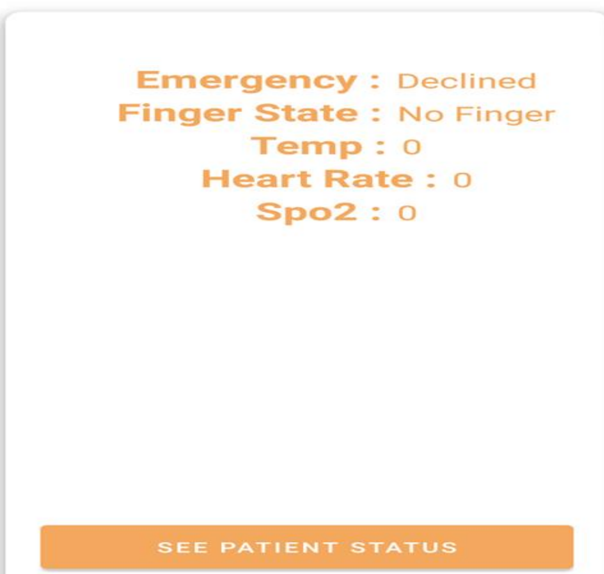

Figure 8: Health Monitoring Application (Source: Author)

2.2.2 Mobile Application Design: The mobile application shown in Figure 8, was designed using JavaScript while Google firebase was used for the Application Programming Interface (API) and database. JavaScript is a scripting language that allows the implementation of complex features on web pages. It is suitable for developing interactive webpages that display timely information updates such as interactive maps, animated 2D/3D graphics, scrolling video jukeboxes, etc. The stored information in the database is fetched by the mobile application using cloud technology. This application is only compatible with android mobile devices i.e., APK.

2.3. Mode of Operation

The circuit diagram of the IoT-based remote health monitoring system is shown in Figure 9. A pair of 7.4 V batteries is used to supply power to the microcontroller and sensor. The NodeMCU has an in-built voltage regulator that steps down the input voltage to an operating voltage of 3.3 V.

In this system, different vital signs are scanned and processed using the MAX30102 sensor in combination with the Node microcontroller unit. The NodeMCU supports Bluetooth Low Energy, making the transmitting device run on an integrated battery for a longer time. The heart rate, temperature, and oxygen saturation of the patient are measured by the MAX30102 sensor. All vitals obtained from the sensor are sent to the NodeMCU for processing. It then uploads the information to the cloud. The display used is a TFT LCD, which offers a wider viewing angle, has a faster response time, is more flexible, is thinner, and consumes less electricity. Once the vitals exceed their set points, an app notification is sent to the doctor and caregiver's mobile device through the in-built Wi-Fi module of the microcontroller. Before the vitals reach or exceed the preset thresholds, an app notification is received at intervals by the doctor and caregiver's mobile devices. When patients require the attention of the doctor or caregiver, they press the push button that will send electrical signals to the microcontroller for processing and output a sound notification on the receiver side (mobile app).

3. TESTS AND RESULTS

Figures 10 and 11 show the Pictorial views of the developed IoT-based device connected to the internet with no finger placed on the sensor and with a finger placed on the sensor respectively. When the NodeMCU module of the device receives power from the battery, the Wi-Fi chip automatically connects to the hotspot of a mobile device. The device displays the measured parameters, reading zero values for all when no finger is placed on the MAX30102 pulse oximeter sensor, as shown in Figure 10. When a finger is placed on the sensor, the device displays the values for all the vitals of the patient as seen in Figure 11.

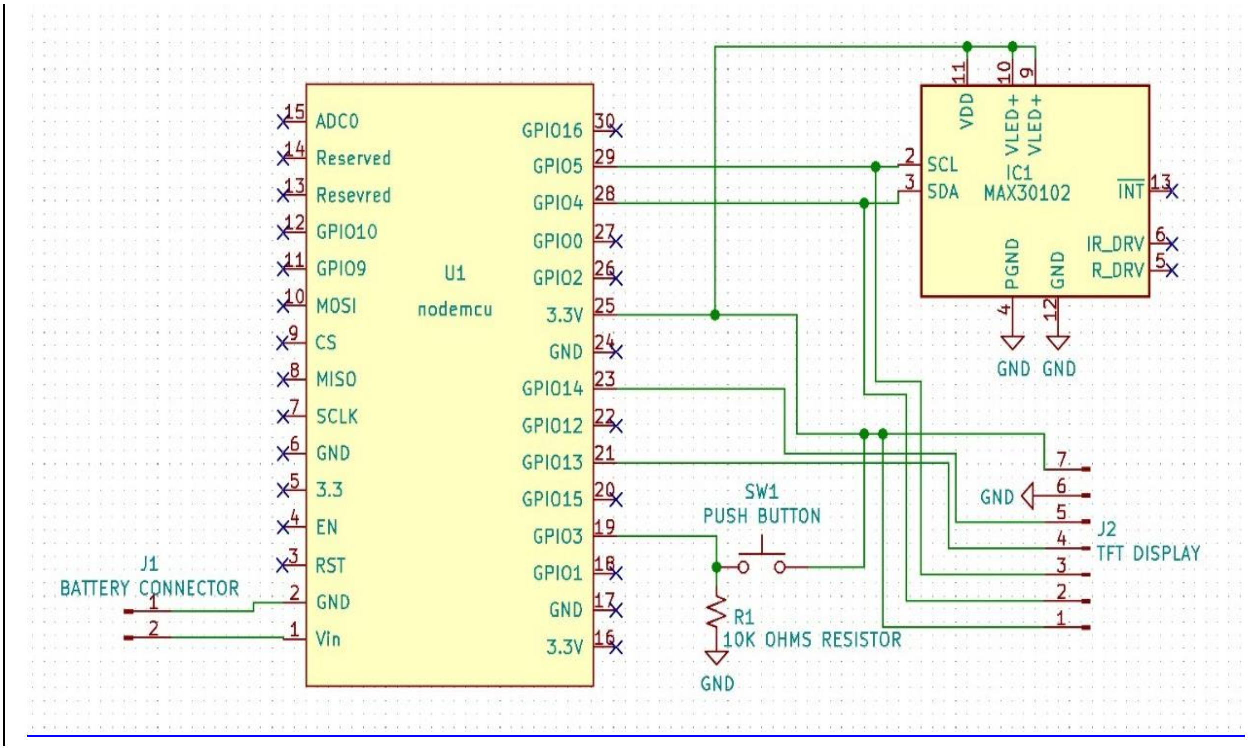

Figure 9**:** Circuit diagram of the IoT-based wireless remote health monitoring device (Source: Author)

Figure 10: Pictorial view of the IoT-based device connected to the internet with no finger placed on the sensor (Source: Author)

Figure 11: Pictorial view of the IoT-based device connected to the internet with a finger placed on the sensor (Source: Author)

The developed IoT-based device was used to take the readings of the different vitals (temperature, heart rate/pulse and blood oxygen saturation) of three different patients, and the results were compared with the values obtained using existing measuring devices in two medical centers (FUPRE Health Center, Ugbomro, Delta State, and Abieyuwa Specialist Clinic, Masoje Street, Effurun, Delta State). The results obtained are presented in tables 1 and 2. As seen in the tables, the results obtained at the FUPRE Health Center and Abieyuwa Specialist Clinic were compared with the developed IoT-based device for three different patients.

Table 1: Results obtained from the FUPRE Health Center and the IoT-based device

PATIENTS	PARAMETERS	IDEAL RANGE	FUPRE HEALTH CENTER UGBOMRO	IOT BASED DEVICE
1	HEART RATE	60 – 100	79	60
	SPO2	95 – 100 %	95	101
	TEMPERATURE	36 – 38 ºC	36.5	36.7
2	HEART RATE	60 – 100	81	66
	SPO2	95 – 100 %	95	100
	TEMPERATURE	36 – 38 ºC	36.9	35.9
3	HEART RATE	60 – 100	59	56
	SPO2	95 – 100 %	97	102
	TEMPERATURE	36 – 38 ºC	36.7	36.7

Figure 12: Pictures of Patient 3 readings obtained from FUPRE health center (Source: Author)

Figure 13: Picture of Patient 3 readings gotten from the IoT-based device (Source: Author)

Table 2: Results obtained from Abieyuwa Specialist Clinic and the IoT-based device

PATIENTS	PARAMETERS	IDEAL RANGE	ABIEYUWA SPECIALIST CLINIC	IOT-BASED DEVICE
1	HEART RATE	60 – 100	62	63
	SPO2	95 – 100 %	99	100
	TEMPERATURE	36 – 38 ℃	37	37
2	HEART RATE	60 – 100	52	60
	SPO2	95 – 100 %	98	101
	TEMPERATURE	36 – 38 ℃	35.6	35.8
3	HEART RATE	60 – 100	82	80
	SPO2	95 – 100 %	92	97
	TEMPERATURE	36 – 38 ℃	35.5	36.3

Figure 14: Pictures of Patient 1 readings obtained at Abieyuwa Specialist Clinic (Source: Author)

Figure 15: Picture of Patient 1 readings gotten from the IoT-based device (Source: Author)

From the results obtained in tables 1 and 2, it can be seen that the readings from the IoT-based device closely matched the readings gotten from the standard devices at the different health centers. This indicates the reliability of the developed IoT-based device.

4. CONCLUSION

The developed IoT-based wireless remote health monitoring device proved successful in reaching its objectives: a compact embedded system that would provide real-time data of patients' vitals through the display screen and a mobile app. This device will also be advantageous in hospitals since the readings can be accessed on a doctor's or caregiver's mobile device. In densely populated countries like Nigeria where accessing a doctor might be difficult at times, this device has the potential to improve the medical sector. The use of this system, as opposed to the traditional patient monitoring setup, can reduce complications and simplify the care of patients.

References

Arefín, U., and Mondal, M. (2014). Construction of a 27 W mini-instant power supply. ResearchGate. https://www.researchgate.net/publication/271647487_Construction_of_a_27W_Mini_Instant_Power_Supply

Aziz, D. (2018, August). *Design of Smart House System based on Webserver Architecture Control*. ResearchGate. https://www.researchgate.net/figure/ESP8266-Node-MCU-Module_fig2_327070645

Damirchi, M. (2021, February 16). Interfacing 1.8-inch ST7735 TFT display with Arduino. Electropeak. https://electropeak.com/learn/interfacing-1-8-inch-st7735r-spi-tft-lcd-display-module-with-arduino/

Felson, S. (2017, March 22). What is normal body temperature? WebMD. https://www.webmd.com/first-aid/normal-body-temperature

Khan, I., Zeb, K., Mahmood, A., Uddin, W., Saif-Ul I., Pakistan, M., and Kim, H. J. (2019). Healthcare monitoring system and transforming monitored data into real time clinical feedback based on IoT using Raspberry Pi. *ResearchGate*. https://www.researchgate.net/publication/332422799_Healthcare_Monitoring_System_and_transforming_Monitored_data_into_Real_time_Clinical_Feedback_based_on_IoT_using_Raspberry_Pi

Kumar, A. (2021, February 25). What is NodeMCU development board? How to program NodeMCU using Arduino IDE? Circuits Today. https://www.circuitstoday.com/nodemcu

Osain, M. (2011). The Nigerian health care system: Need for integrating adequate medical intelligence and surveillance systems. Journal of Pharmacy and Bio allied Sciences, 3(4): 470. https://doi.org/10.4103/0975-7406.

Seidle, N. (2022, May 12). MAX30102 Pulse Oximeter and Heart Rate Sensor with ESP32. Microcontrollers

Lab. https://microcontrollerslab.com/esp32-heart-rate-pulse-oximeter-max30102

Silva, J. (2022, September 19). Normal blood oxygen levels: What is safe and what is low? Medical News Today. https://www.medicalnewstoday.com/articles/321044

World Health Organization (2020, December 9). *The top 10 causes of death*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death