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Design of Medical Devices to Monitor Body Temperature, Heart Rate And Oxygen Saturation Levels In Human Body Based On IoT

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ABSTRACT

Understanding body temperature and heart rate plays a crucial role in detecting disease symptoms. Heart rate serves as a vital parameter reflecting human body function, with a typical range of 60-100 beats per minute for adults. This study aims to leverage Internet of Things (IoT) technology to create a monitoring system for heart rate and body temperature.The main objective of this final project is to design a device capable of monitoring body temperature, heart rate, and oxygen saturation levels in the human body. The anticipated benefits of this research include facilitating the continuous monitoring of body temperature, heart rate, and oxygen saturation levels, thus aiding in timely health assessments. To achieve this, the study employs the MLX90614 sensor for temperature measurement and the MAX30100 sensor for heart rate and oxygen saturation level readings. These sensors are integrated with the Arduino Nano microcontroller and NodeMCU ESP8266.The study's findings demonstrate that the sensors effectively measure body temperature, heart rate, and oxygen saturation levels, as confirmed by comparison with medical-grade devices. The system developed in this research performs well and is ready for practical application, providing the desired benefits of enhanced monitoring capabilities for healthcare purposes.

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1. INTRODUCTION

Comprehending body temperature is highly crucial for identifying illness symptoms. It is essential to be aware of the typical range of body temperature and how to measure it accurately, as well as recognizing abnormal body temperature, as it can indicate potentially life-threatening conditions. The normal human body temperature generally falls within the range of 36.5-37.2 degrees Celsius.Heart rate serves as a parameter to evaluate the functioning of the human body, with a typical range of 60-100 beats per minute for adults. The average heart rate provides insights into the heart's activity and overall cardiovascular health.[1].

The aim of developing an IoT-based heart rate and body temperature monitoring system is to enable direct online monitoring through Android and desktop devices, allowing doctors and families to access heart rate and body temperature data anytime. By using an IoT-based system, geographical distance becomes inconsequential in the monitoring process [2]. The study draws on related research, such as LM35 Sensors and SIM800L Module [4], NodeMCU—an open-source IoT platform [5], real-time health condition monitoring [6], and heart rate, oxygen saturation levels, and body temperature assessment [7]. The collected data is then presented through an application [8]. The importance of maintaining good health is emphasized. Measuring body temperature, heart rate, and oxygen saturation serves as crucial parameters to identify clinical signs and enhance disease diagnosis [9]. These supporting technologies involve the use of microcontrollers and sensors, culminating in the creation of a diagnostic tool utilizing wireless or IoT-based systems [10]. Sensors can be monitored through a single microcontroller device, and the data can be sent to the cloud. The rapid advancement of microcontrollers offers an alternative for developing medical equipment and facilitates checkups at any time [11].

The Internet of Things operates by utilizing programming commands to enable automatic interactions between machines regardless of distance. It finds applications in various fields, including security, wherein internet-based controls are employed [12]. A microcontroller is a tiny controller enclosed within a chip [13]. NodeMCU, an open-source IoT platform, is composed of hardware in the form of the ESP8266 System On Chip developed by Espressif System [14]. This platform incorporates the ESP8266 wifi chip into a board with features similar to an Arduino microcontroller board [15]. An ATmega 328 microcontroller is used [16]. A sensor is a device designed to detect changes in physical quantities [17]. The MLX90614 sensor integrates a low noise amplifier signal conditioner, a 17-bit ADC, and a powerful DSP unit, achieving high accuracy and resolution in temperature measurements [18]. The sensor's photosensitive detector converts infrared energy emitted by an object into an electrical signal, directly proportional to the object's temperature. The MLX90614 Sensor data can be read using the I2C/TWI protocol [19]. The MAX30100 sensor integrates pulse oximetry to monitor heart rate signals and blood oxygen levels. This sensor contains two LEDs and a photodetector, exploiting the properties of red blood cells, such as light absorption and pulsatile blood flow in the arteries, to calculate oxygen levels in the body [20].

2. RESEARCH METHOD

This study is carried out in the implementation stages: Literature Study Method, Observartion Method, Cyber Method and Interview Method. The research framework in Figure 1 below:

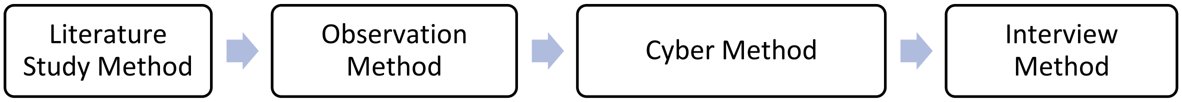

Figure 1. Research Outline

1) **Literature Study Method:** Specifically, a way of gathering data about the tool monitoring system's health from books, the internet, papers, and other sources.
2) **Observation Method:** Specifically, a way of gathering data about the tool monitoring system's health from books, the internet, papers, and other sources.
3) **Cyber Method:** This strategy involves browsing the internet for information and data relating to the subject being discussed as reference material for the report.
4) **Interview Method:** Specifically, a technique including interviews and conferences with the necessary supervisor over the Author's Final Assignment.

2.1. Hardware Design

In Hardware Design, a component is needed to make a device, and below are the components used in the health monitoring device.

2.1.1. Microcontroller NodeMCU ESP8266

NodeMCU is an open-source IoT platform comprising hardware based on the System On Chip ESP8266, developed by Espressif System. It operates on the Lua scripting programming language. It is important to note that the term "NodeMCU" primarily refers to the firmware utilized rather than the hardware development kit itself. In essence, NodeMCU can be likened to the foundation firmware for the ESP8266 board [14].

2.1.2. Microcontroller Arduino Nano

The Arduino Nano utilizes the Atmega 328 microcontroller for Arduino Nano 3.x and Atmega168 for Arduino Nano 2.x. For the implementation of this final project, the author has opted for the ATmega 328 microcontroller. The Arduino Nano offers 14 digital pins that can serve as either inputs or outputs, with their functionalities controlled through the pinMode(), digitalWrite(), and digitalRead() functions. Additionally, the Arduino Nano provides 8 analog input pins, labeled A0 through A7, each offering 10 bits of resolution, equating to 1024 different values. By default, these pins can measure and set values ranging from Ground to 5 Volts [16].

2.1.3. Sensor MLX90614

The MLX90614 is a non-contact infrared thermometer designed for temperature measurement. It incorporates an IR-sensitive thermopile detector chip and a signal conditioning ASIC, effectively integrated within the sensor packaging of the O-39 model. The MLX90614 further integrates a low noise signal conditioner amplifier, a 17-bit ADC, and a powerful DSP unit, enabling the thermometer to achieve high accuracy and resolution in temperature readings [18].

2.1.4. Sensor MLX90614

The MAX30100 sensor is a combination of pulse oximetry capabilities, enabling it to monitor both heart rate signals and blood oxygen levels. This sensor is equipped with two LEDs and a photodetector. It operates based on the unique properties of red blood cells, which absorb light as well as the pulsating blood flow in arteries. By leveraging these characteristics, the sensor can accurately calculate oxygen levels in the body. The device includes a probe with a light source, light detector, and microprocessor, facilitating comparisons and measurements of oxygen-rich and oxygen-deficient blood cells. Additionally, the sensor can measure heart rate by analyzing the variations in blood flow [20].

2.1.5. Assembling Tools

At this stage, after the components needed by the device have been collected, then here the components are assembled into a health monitoring device.

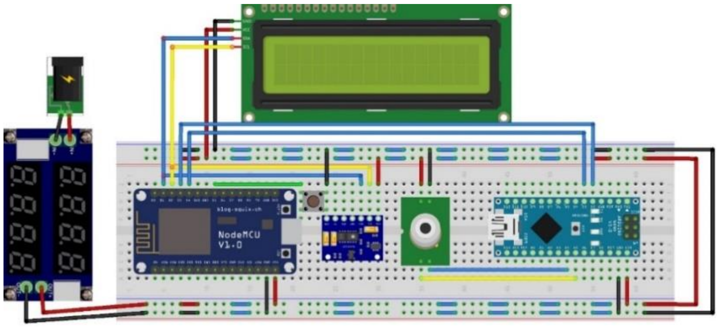

Figure 2. Circuit Schematic Device

Figure 2 represents the comprehensive circuit design plan created using hardware components. The circuit design utilizes a 12V adapter as the power source, which is then connected to the LM2596 stepdown module. The LM2596 stepdown module reduces the voltage from the adapter to 5V. The ATMega 328P microcontroller, ESP8266 NodeMCU, MLX90614 sensor, MAX30100 sensor, and 16 x 2 I2C LCD all directly receive the 5V voltage from the stepdown controller.

2.2. Design of Devices

The complete design of the Internet of Things-based health monitoring device is visible in the illustration. Positioned at the top front of the device is an LCD display, which serves to present the readings from the various sensors. Directly below the display is the MAX30100 sensor. Slightly to the right, there is a button, and at the bottom center, the MLX90614 sensor is placed.

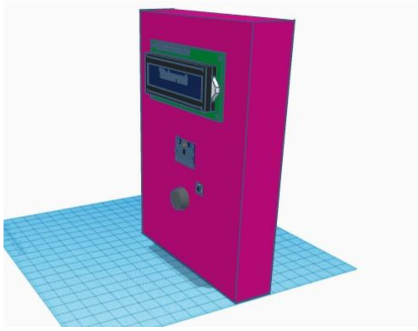

Figure 3. Tools Design

Figure 3 depicts a design for a tool in which all sensors are set in one location and connected to the NODEMCU ESP8266 microcontroller that serves as the device's microcontroller. Figure 4 depicts the arrangement of all used components:

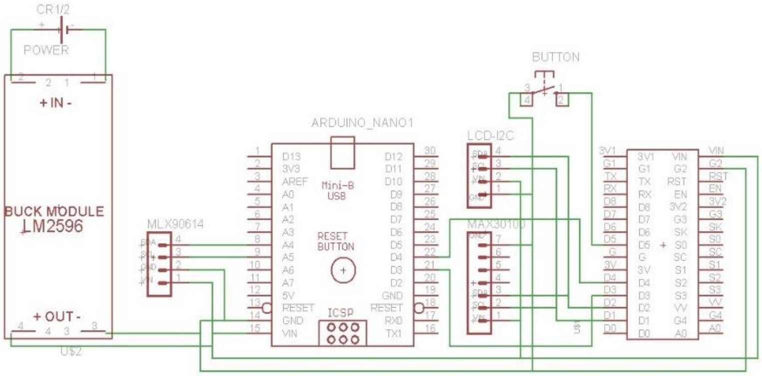

Figure 4. Component Layout

There are components in the overall circuit picture that perform the following functions:

1. The ESP8266 and ATMega328P microcontrollers, which are used to control electronic circuits.
2. LCD 16x2 I2C that functions to display data by connecting to a microcontroller via pin SDA and SCL on the I2C module and pin D2 and D1 on the ESP8266.
3. MLX90614 sensor, which measures temperature by connecting the sensor's SDA and SCL pins to ATMega328P pins A5 and A4.
4. MAX30100 sensor, which measures heart rate and oxygen saturation by connecting the SDA and SCL pins to ESP8266 pins D2 and D1.
5. The button functions as input to start reading on the sensor by connecting the pin on one leg of the button to pin D5 on ESP8266 and the other leg to GND.

2.3. Device Set

The next stage, following the creation of the device design and component layout, is to assemble the actual device using the sensors and components that were previously chosen. The device is depicted in Figure 5 below.

(a) (b) (c)

Figure 5. Device Set (a) display image of start testing tool button (b) image reveals LCD output of pulse testing (c) display image reveals temperature testing output

3. RESULTS AND DISCUSSION

3.1. Testing of Body Temperature Readings using MLX90614 Sensor

The MLX90614 temperature sensor undergoes testing, taking into account variations in measuring distance and ambient temperature. The sensor is subjected to 10 test runs, with data collected at 5 cm intervals, ranging from 15 cm to 60 cm in measuring distance. These tests are conducted at different times of the day, including morning, afternoon, and evening, with three different ambient temperatures. The outcomes of the sensor testing are presented in Table 1 below.

Table 1. MLX90614 Sensor Testing Results Body Temperature Measurement Test Results (To = 36.3) with Variation in Measuring Distance and Ambient Temperature (Ta)

Measuring Distance	**To Ta=28ºC (morning)**	***Error* (%)**	**To Ta=32.3ºC (afternoon)**	***Error* (%)**	**To Ta=29ºC (night)**	***Error* (%)**
15 cm	36.4 ºC	-0.3%	36.8 ºC	-1.4%	35.5 ºC	2.2%
20 cm	36.4 ºC	-0.3%	36.8 ºC	-1.4%	35.8 ºC	1.4%
25 cm	36.3 ºC	0.0%	36.7 ºC	-1.1%	35.8 ºC	1.4%
30 cm	36.1 ºC	0.6%	36.4 ºC	-0.3%	36.1 ºC	0.6%
35 cm	36.2 ºC	0.3%	36.5 ºC	-0.6%	36.0 ºC	0.8%
40 cm	35.7 ºC	1.7%	35.4 ºC	2.5%	35.9 ºC	1.1%
45 cm	35.1 ºC	3.3%	35.1 ºC	3.3%	34.7 ºC	4.4%
50 cm	34.8 ºC	4.1%	34.8 ºC	4.1%	34.1 ºC	6.1%
55 cm	32.6 ºC	10.2%	34.4 ºC	5.2%	33.4 ºC	8.0%
60 cm	30.4 ºC	16.3%	33.9 ºC	6.6%	31.2 ºC	14.0%

After conducting the testing, error values were obtained as shown in the table above. The results of the above testing can be visualized in the form of a graph as depicted in Figure 6 below.

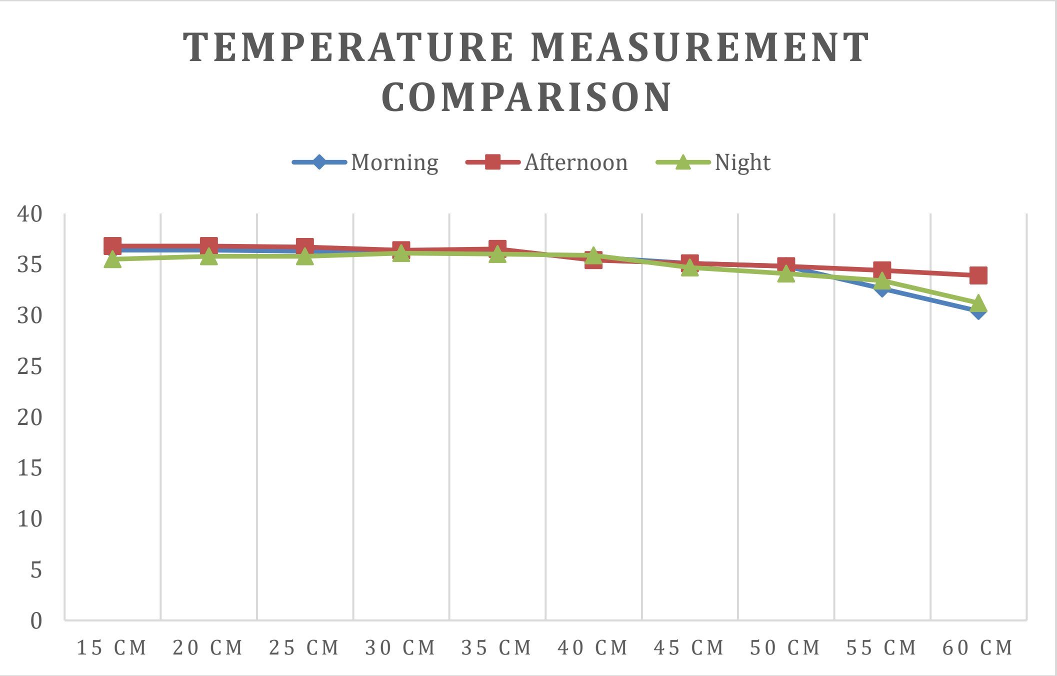

Figure 6. is a graph displaying the results of temperature measurements over distance.

3.2. Testing of SpO_2 Readings using MAX30100 Sensor

The testing of blood oxygen level readings using MAX30100 was conducted through a direct measurement procedure on the fingertip of the same individual at their body temperature. The results of the sensor testing can be observed in Table 2 below.

Table 2. MAX30100 Sensor Testing Results for SpO2 Parameter

Pulse Oxymetry	MAX30100	*Error*(%)
96 %	94 %	2.1%
96 %	98 %	-2.1%
98 %	97 %	1.0%
98 %	98 %	0.0%
99 %	97 %	2.0%
99 %	98 %	1.0%
97 %	96 %	1.0%
97 %	95 %	2.1%
96 %	98 %	-2.1%
98%	97 %	1.0%

After conducting the testing, very small error values were obtained as shown in the table above. The results of the above testing can be visualized in the form of a graph as depicted in Figure 7 below.

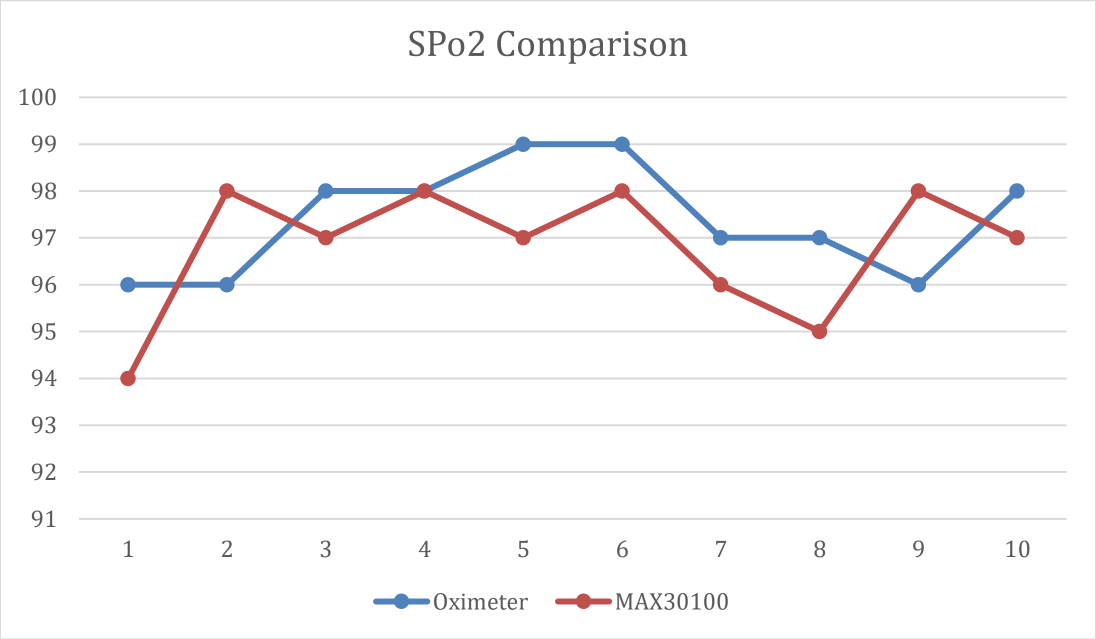

Figure 7. Is a Graph Comparing SpO2 Readings With Readings From A Conventional Oximeter

3.3. Verifying Heart Rate Sensor Readings for the MAX30100

The testing of heart rate readings using MAX30100 was conducted through a direct measurement procedure on the fingertip of the same individual at their body temperature. The results of the sensor testing can be observed in Table 3 below.

Table 3. MAX30100 Sensor Testing Results for SpO2 Parameter

Conventional Heart Beat Mete	**MAX30100**	*Error*(%)
78 BPM	78 BPM	0.0%
77 BPM	80 BPM	-3.9%
78 BPM	77 BPM	1.3%
80 BPM	78 BPM	2.5%
79 BPM	78 BPM	1.3%
78 BPM	77 BPM	1.3%
78 BPM	78 BPM	0.0%
79 BPM	78 BPM	1.3%
78 BPM	79 BPM	-1.3%
77 BPM	78 BPM	-1.3%

After conducting the testing, very small error values were obtained, as shown in the table above. The results of the above testing can be visualized in the form of a graph, as depicted in Figure 8 below.

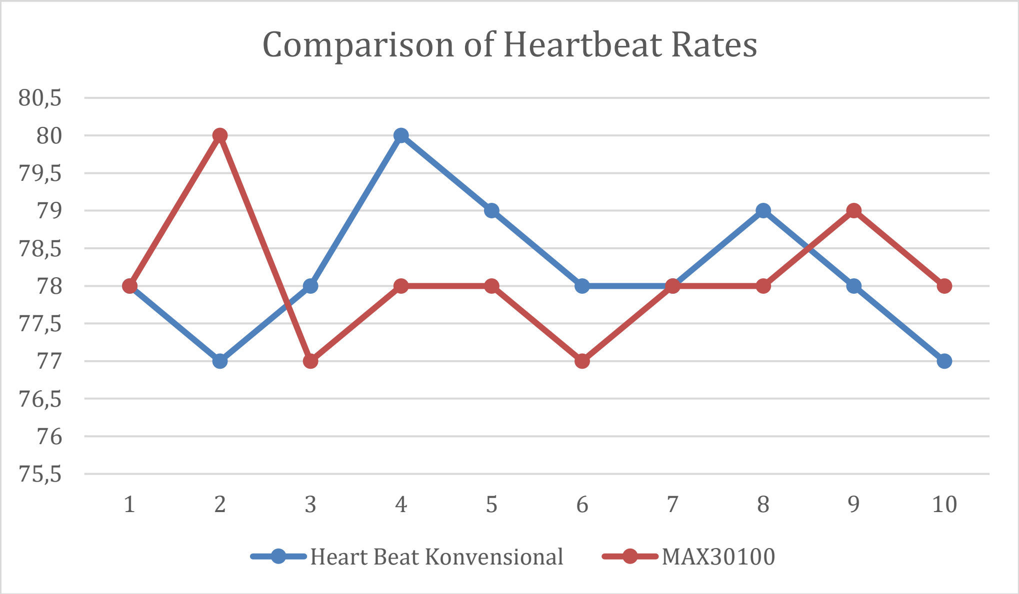

Figure 8. Is a Graph Comparing Heartbeats Recorded By MAX30100 And Conventional Heartbeat Measurements

4. CONCLUSION

The conclusion drawn from the research results is as follows. The Health Monitoring Tool successfully measures and monitors body temperature, heart rate, and oxygen saturation levels of patients. The closer the measuring distance to the MLX90614 sensor, the smaller the resulting error rate. After conducting tests on the device's sensors, it was found that the MAX30100 heart rate sensor has a high level of accuracy, with an average error rate of 1.4% at a stable voltage of 5V. Likewise, after testing the sensors used in the device, it was found that the MAX30100 oxygen saturation sensor also exhibits a high level of accuracy, with an average error rate of 1.4% at a stable voltage of 5V. The observations from the conducted tests reveal that there is a slight difference in accuracy between the readings obtained from conventional sensors and the results from the created device.

REFERENCES

[1] Y. Hendrian, R. Ali, and A. Rais, “Perancangan Alat Ukur Suhu Tubuh dan Hand Sanitizer Otomatis Berbasis IOT,” vol. 3, no. 1, 2021.
[2] I. Prayogo, R. Alfita, and K. A. Wibisono, “Monitoring System for Heart Rate and Body Temperature as an IOT (Internet Of Thing)-Based Patient Health Level Indicator Using the Fuzzy Logic Method Using Android,” J. Electr. Comput. Eng. TRIAC, vol. 4, no. 2, 2017.
[3] I. K. A. S. Sawita, I. W. Supardi, and I. G. A. Putra Adnyana, “Alat Monitoring Suhu Melalui Aplikasi Android Menggunakan Sensor LM35 dan Modul SIM800L Berbasis Mikrokontroler ATMega16,” Bul. Fis., vol. 18, no. 2, p. 58, 2017, doi: 10.24843/bf.2017.v18.i02.p03.
[4] A. Auliani, A. G. Putrada, and N. A. Suwastika, “Perancangan dan Implementasi Sistem Monitoring Suhu Pemantau Dehidrasi Berbasis Fuzzy Logic dan IOT,” e-Proceeding Eng., vol. 6, no. 1, pp. 2257–2267, 2019, [Online]. Available: https://openlibrary.telkomuniversity.ac.id
[5] A. Satriadi, Wahyudi, and Y. Christiyono, “Perangcangan Home Automation Berbasis NodeMcu,” Transient, vol. 8, no. 1, pp. 2685–0206, 2019, [Online]. Available: https://ejournal3.undip.ac.id/index.php/transient
[6] M. R. Ariwibowo1 and Inayatul Ummah2, “Systematic Literature Review: Mikrokontroler Sebagai Pengukur Suhu Tubuh Berbasis IoT Terhadap Covid-19,” Sci. TECH J. Ilmu Pengetah. dan Teknol., vol. 8, no. 1, pp. 29–41, 2021.
[7] G. H. Santoso, I. H. Santoso, A. I. Irawan, U. Telkom, and S. Oksigen, “Perancangan Dan Implementasi Alat Monitoring Detak Jantung , Saturasi Oksigen Dan Suhu Tubuh Iot Berbasis Cloud Design And Implementation Of Cloud-Based Iot Heart Rate , OXYGEN,” vol. 8, no. 6, pp. 11711–11718, 2021.
[8] M. A. Saputro, E. R. Widasari, and H. Fitriyah, “Implementasi Sistem Monitoring Detak Jantung dan Suhu Tubuh Manusia Secara Wireless,” Pengemb. Teknol. Inf. Dan Ilmu Komput., vol. 1, no. 2, pp. 148–156, 2017, [Online]. Available: http://j-ptiik.ub.ac.id/index.php/j-ptiik/article/view/53

[9] H. Isyanto, A. S. Wahid, and W. Ibrahim, "Desain Alat Monitoring Real Time Suhu Tubuh, Detak Jantung dan Tekanan Darah secara Jarak Jauh melalui Smartphone berbasis Internet of Things Smart Healthcare," Resist. (Elektronika Kendali Telekomun. Tenaga List. Komputer), vol. 5, no. 1, pp. 39–48, 2022.

[10] M. A. Adrian, M. R. Widiarto, and R. S. Kusumadiarti, "Health Monitoring System dengan Indikator Suhu Tubuh, Detak Jantung dan Saturasi Oksigen Berbasis Internet of Things (IoT)," J. Petik, vol. 7, no. 2, pp. 108–118, 2021, doi: 10.31980/jpetik.v7i2.1230.

[11] A. Christopher and Y. M. Dinata, "Rancang Bangun Sistem Pemantauan Jarak Jauh Denyut Nadi, Saturasi Oksigen, dan Suhu Tubuh pada Orang Sakit di Rumah," Juisi, vol. 08, no. 01, pp. 1–11, 2022.

[12] Y. Efendi, "Internet Of Things (Iot) Sistem Pengendalian Lampu Menggunakan Raspberry Pi Berbasis Mobile," J. Ilm. Ilmu Komput., vol. 4, no. 2, pp. 21–27, 2018, doi: 10.35329/jiik.v4i2.41.

[13] B. Sitorus and A. Tahyudin, "Rancang Bangun Alat Memberi Pakan Ikan Lele Otomatis Berbasis Arduino UNO," J. Ilm. Fak. Tek., vol. 14, no. 1, pp. 1–12, 2018.

[14] M. F. Wicaksono, "Implementasi Modul Wifi Nodemcu Esp8266 Untuk Smart Home," Komputika J. Sist. Komput., vol. 6, no. 1, 2017.

[15] M. Lanthaler and C. Gütl, "Towards a RESTful service ecosystem," in 4th IEEE International Conference on Digital Ecosystems and Technologies, 2010, pp. 209–214.

[16] Y. Triawan and J. Sardi, "Perancangan Sistem Otomatisasi Pada Aquascape Berbasis Mikrokontroller Arduino Nano," JTEIN J. Tek. Elektro Indones., vol. 1, no. 2, pp. 76–83, 2020, doi: 10.24036/jtein.v1i2.30.

[17] Kho Dickson, "Pengertian Sensor dan Jenis-jenis Sensor," 2019. https://teknikelektronika.com/pengertian-sensor-jenis-jenis-sensor (accessed Jan. 25, 2023).

[18] I. Banani, "Perancangan Sistem Monitoring Suhu dan Irama Jantung Sebagai Kasus Penyerta Pada Pasien Covid-19 Berbasis IoT," 2021, [Online]. Available: http://repository.untag-sby.ac.id/9575/

[19] T. T. Saputro, "Prinsip kerja sensor MLX90614," 2018.

[20] C. Pratiwi, "Prototipe Monitoring Kesehatan Pasien Covid-19 Pada Masa Karantina Menggunakan Heartrate Dan Oximeter Sensor Berbasis Internet of Things (Iot)," Electro Natl. Conf. Politek. Negeri Sriwij., vol. 1, no. 1 Juni, pp. 264–271, 2021.