Research Paper

International Journal of Research and Review
Vol. 10; Issue: 12; December 2023
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Design of a Covid-19 Patient Respiration Monitoring System Using an ESP 32 Microcontroller and an MPU 6050 Sensor for the Internet of Medical Things (IoMT) System

Ahmad Ridlo Hanifudin Tahier[1], Muchammad Azam[2], Ngurah Ayu Ketut Umiati[2], Isnain Gunadi[2], Wahyu Aji Nugroho[1]

[1]Department of Automation Engineering, Vocation school
[2] Department of Physics, Faculty of Science and Mathematics,
Diponegoro University, Semarang, 50275, Indonesia

Corresponding Author: Muchammad Azam

DOI: https://doi.org/10.52403/ijrr.20231224

ABSTRACT

The main manifestation of COVID-19 disease infection is caused by respiratory system disorders. Periodic monitoring is needed to support good care and prevent complications caused by the slow response of nurses to the decline of the patient's clinical condition based on several physiological parameters in the National Early Warning Score COVID-19. This aim of this research is to build, design, and implement data acquisition systems on respiration sensors in a monitoring system or monitoring periodically based on the Internet of Medical Things (IoMT). The sensor that used to calculate the respiration cycle is the MPU6050 sensor by measuring the magnitude of the vibration. Sensor-scalable data will be acquired by the ESP32 microcontroller and sent to data storage on a computer over a W-Fi network in real time using the MQTT (Message Queuing Telemetry Transport) communication protocol and displayed in a web-based interface. The system that has been built runs well that can calculate the value of the respiration cycle per minute from patients with a small average deviation value of 1.26 % from manual calculations using stopwatches. Periodic monitoring can also be done with an average response time of 03.48 seconds.

Keywords: ESP32 microcontroller, respiration cycle, COVID-19, MQTT

INTRODUCTION

The 2019 coronavirus disease, or COVID-19, is brought on by severe acute respiratory distress. SARS-CoV-2, also known as the coronavirus, is a disease that spreads quickly and can lead to pandemic circumstances. Infection with SARS-CoV-2 primarily manifests as respiratory system diseases [1]. Gas exchange during respiration includes the exchange of carbon dioxide (CO2) and oxygen (O2), which the body needs for cellular metabolism [2]. In order to reduce the danger of COVID-19 viral transmission and facilitate the monitoring of patients' conditions by nurses, a gadget or healthcare facility is required [4]. However, nurses should avoid direct contact with patients who have the COVID-19 virus indirectly. In order to conduct a research, a method for tracking COVID-19-infected individuals was developed [3][4].

One tool for determining urgency in the ward is the Early Warning Score (EWS) [16]. Additionally, EWS aids in the early detection and prevention of clinical and physiological symptoms [5] [17]. The ESP32 microcontroller is the ESP8266 microcontroller's upgrade and has more complete feature. Because this microcontroller already has a Wi-Fi module built in, building an Internet of Things application system is made very easy [6].

Table 1. Comparison Table between Arduino Uno, ESP8266, and ESP32

	Arduino Uno	**Node MCU (ESP8266)**	**ESP32**
CPU	ATmega328 - 16MHz	Xtensa single core L106 – 60 MHz	Xtensa dual coreLX6 - 160 MHz
Bluetooth	-	-	√
Wi-fi	-	√	√
Arsitektur	8 Bit	32 Bit	32 Bit
Voltage operation	5 Volt	3,3 Volt	3,3 Volt
SPI/I2C/UART	1/1/1	2/1/2	4/2/2
GPIO Pin (ADC/DAC)	14 (6/-)	17(1/-)	36(18/2)
Flash Memory	32kB	16MB	16MB
SRAM	2kB	160kB	512kB

Webserver XAMPP

PHP programming is supported by the Apache web server software known as XAMPP, which also comes with a MySQL database server. XAMPP is free, simple to use, and compatible with both Windows and Linux installations. An additional benefit is that many modules, including MySQL Database Server, PHP Support (PHP 4 and PHP 5), Apache Web Server, and numerous more [7].

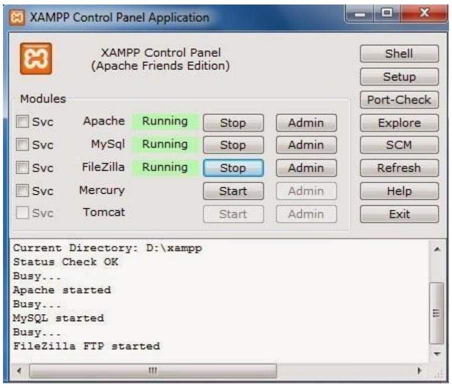


Figure 1: Panel Control of XAMPP

The TCP/IP stack is used by the MQTT (Message Queuing Telemetry Transport) protocol, which has a minimum data packet size of 2 bytes and a minor overhead. This protocol is a form of data-agnostic protocol, meaning that any sort of data, including text, binary data, XML, and JSON, may be sent [8] [9]. Instead of using a client-server architecture, this protocol employs a publish/subscribe approach. A software framework called Node.JS is intended for web application development. Another name for Node.JS is a runtime environment. It features event driven programming and asynchronous input/output. It is developed in a combination of C++ and JavaScript [10]. Message Queuing Telemetry Transport (MQTT) is a client server publish/subscribe transport protocol. A lightweight, open and simple protocol, designed to be easy to implement. These characteristics make MQTT usable in many situations, including its use in machine-to-machine (M2M) communications and the Internet of Things (IoT), this protocol runs on TCP/IP. The MQTT protocol requires a transport that carries out MQTT commands, a byte stream from client to server or server to client. The transport protocol used is TCP/IP. TCP/IP can be used for MQTT, besides TLS and WebSocket can also use TCP/IP.

Internet of Medical Things (IoMT)

Internet of Medical Things (IoMT) is a novel approach to integrate medical devices and their applications with healthcare IT systems [13]. It has proven possible to stop the COVID-19 virus from spreading, enhance safety, boost efficacy, and lower fatality rates by utilising the Internet of Medical Things (IoMT). The COVID-19 patient condition monitoring system may make use of the Internet of Medical Things (IoMT), particularly when it comes to respiratory system diseases [12]. By monitoring the length of each breathing cycle, MPU 6050 sensors may be used to track the vital signs of COVID-19 patients. Internet of Things (IoT) technology may be used to show the collected data on the nurse's monitor by use of an ESP32 [14].

Respiratory System using MPU6050

The respiratory system for COVID-19 patients and the database system for tracking COVID-19 patient respiration readings are the two types of systems that have been built. Designing the COVID-19 patient respiratory reading system using the MPU6050 sensor is the initial step [13] [24]. Then, creation of the COVID-19 patient data collection system using MySQL is the second step, where the database is automatically entered into MySQL to apply the system to the created programme. A wireless router is included with this system as a communication tool [15] [18]. System testing is the third step. Analysis is carried out after testing. After every device is linked to the same network, the system performance analysis in this research may begin. From accelerometer and gyroscope sensors datasheet, the MPU6050 vibration sensor can determine an object's angular tilt. In addition, this sensor has a temperature sensor that allows it to be used to determine the ambient temperature [19].

MATERIALS & METHODS

The MPU6050 sensor counts breaths by sensing vibrations, the AD8232 ECG sensor counts heartbeats in COVID-19 patients, and the MAX30102 sensor measures body temperature and oxygen saturation [20]. The local database receives the data that has been collected from many sensors over Wi-Fi. The monitoring web interface will show the local database so that users may simply save and search for data from COVID-19 patients.

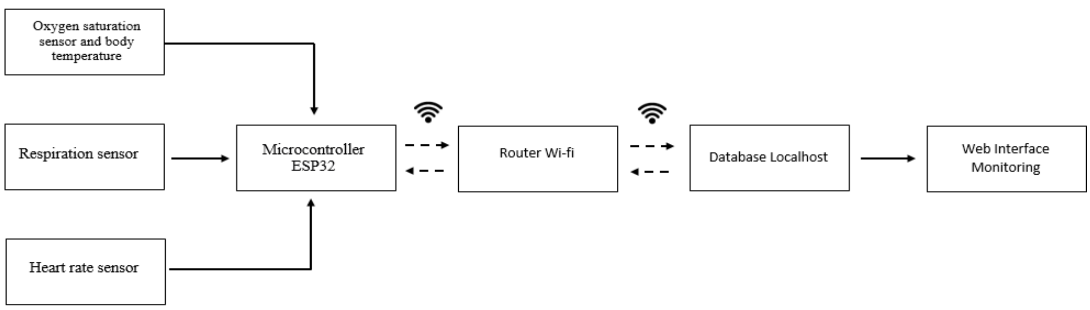


Figure 2: Monitoring system Design

The MPU6050 sensor counts breaths by sensing vibrations, the AD8232 ECG sensor counts heartbeats in COVID-19 patients, and the MAX30102 sensor measures body temperature and oxygen saturation. The local database receives the data that has been collected from many sensors over Wi-Fi [17]. The monitoring web interface will show the local database so that users may simply save and search for data from COVID-19 patients.

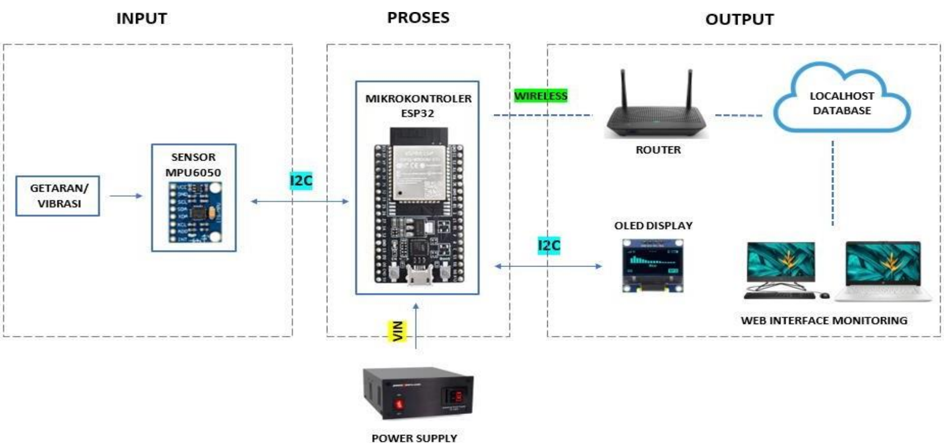


Figure 3: Block Diagram of Respiration Reading System Design for COVID-19 Patients

The OLED Display will show the quantity of breaths generated, allowing patients to view and track how many breaths they take individually [21]. Additionally, the COVID-19 patient monitoring web interface will save and show the number of breaths that are transmitted via Wi-Fi to the local monitoring database [21] [22]. In order to publish and subscribe for each piece of data, the MQTT Broker acts as a communication channel between the device and the database system. Following connection, the system will determine if the client.id is linked or not; the client.id is used to publish topic-specific data. The topic will then receive data from the respiration sensor when the client.id is connected, and the client.id will then publish the data it has received from the topic to the server and the accessible interface. To allow us to keep an eye on the patient's status in real time, the system will keep repeating itself until it loses connection.

RESULT

Sensor Test

By comparing the results of angular movement on the MPU6050 sensor—whether it is an angle of 30^o, 45^o, 60^o, or 90^o when moved 20 times—angle testing is used to determine the angle that is used to calculate the respiration cycle of COVID-19 patients. The value of the movement detected at each angle tested for the MPU6050 sensor can be seen on the OLED Display attached to the circuit as well as on the serial monitor in the Arduino software. In this investigation, the angle with the lowest deviation value will be chosen. Following the completion of the angle testing procedure, the MPU6050 sensor displays comparison findings for each angle. Angle testing results for the MPU6050 sensor are displayed in Table 1.

The value of vibration or movement with the least deviation value is the MPU6050 sensor at an angle of 0^o with the direction of movement in the direction of the Z-axis; the average deviation value produced is 8%. These results are based on Table 1. which shows the average deviation value obtained at each different angle with the sensor position in the Z-axis direction. The MPU6050 sensor can function rather effectively at that 0^o angle since the resultant deviation is quite modest in comparison to other angles. Following the COVID-19 patient's respiration measurement procedure, the patient's breathing cycle was manually computed using a stopwatch, and the results were compared on Table 2.

Table 1. Test of Angle MPU6050 Sensor

Sensor position	Angle sensor	Number of vibrations	System result using MPU6050
Z-Axis	0^o	20	22
			18
			19
			19
			18
	Average deviation (%)		8 %
	30^o	20	2
			2
			2
			3
			1
	Average deviation (%)		90 %
	45^o	20	5
			4
			1
			3
			3
	Average deviation (%)		84 %
	60^o	20	2
			2
			2
			2
			2
	Average deviation (%)		90 %

	90º	20	12
			12
			11
			15
			13
	Average deviation (%)		**37 %**

Table 2 Respiration Sensor Test

No	Number normal respiration cycle (per minute)	Number respiration cycle in system (per minute)	Deviation (%)
1	13	14	1
2	14	16	2
3	14	13	1
4	14	13	1
5	15	17	2
6	14	15	1
7	14	16	2
8	14	14	0
9	14	16	2
10	13	13	0
11	13	12	1
12	14	12	2
13	13	15	2
14	14	16	2
15	16	16	0
Number of average deviation (%)			1,26 %

The respiration sensor manufactured by the system yields an average deviation value of 1.26%. The respiration sensor manufactured in this system has an average deviation value that is relatively minimal, meaning that it is near to the value of the respiration cycle that is manually determined using a stopwatch. A number of reasons contribute to the discrepancy in value: either human mistake when using a stopwatch to monitor respiration, or an error in the respiration sensor inside the system that misreads the breathing cycle. The data collection procedure from the sensor to the MySQL database, which serves as a central repository for data received by the sensor, is tested, as is the web interface that uses XAMPP software to show measurement results in order to evaluate the COVID-19 patient respiration monitoring system.

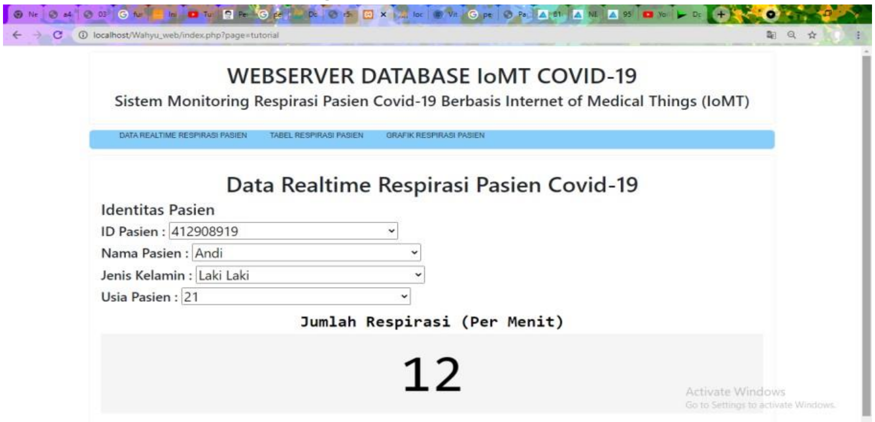
DISCUSSION

This research began by identifying what problems were being experienced at the research location. Problem identification aims to find out existing problems so that the problem can then be formulated clearly. The problem that is known from observations in several hospitals is that a tool is needed to monitor COVID-19 patients but does not have direct contact between patients and nurses in hospitals to reduce the transmission of COVID-19 from infected patients. Next, a literature study is carried out to obtain theories related to the research being carried out in order to facilitate or help the author in processing the data. The research continues by analyzing what requirements are needed to create a system to be studied, both hardware and software requirements.

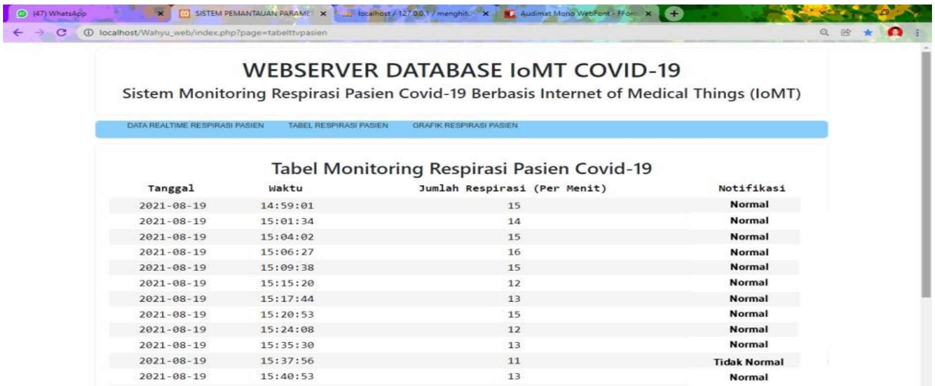
The data acquisition circuit consists of a main circuit containing an MPU6050 vibration sensor and an ESP32 microcontroller. In the main circuit, the computer can communicate with the ESP32 microcontroller, both sending data and receiving data between the computer and the microcontroller. When the host server is activated via the XAMPP Control Panel and the ESP32 microcontroller is turned on, the microcontroller sends data to a database which is stored and displayed on the computer, the data acquisition system circuit is shown in Figure 3.5. In this research, reading the MPU6050 vibration sensor requires microcontroller programming. The process of data acquisition and creating an interface on a computer uses Arduino IDE software and the PHP programming language. The process of data acquisition and interface creation begins with programming to read data from sensors, then the data is saved into a database. After that, the respiration of COVID-19 patients was calculated and the data was displayed on the website using the PHP programming language.

Using the PHP (Hypertext Preprocessor) programming language, the local Web interface may be tested by displaying it. Figure 5. shows the primary display on the web interface of this monitoring system, which shows real-time data measured by the sensor.

Figure 5. Main Interface view



This main display shows the individual patient data of the patient to be watched. Among the menu items available for selection are patient respiration tables, charts, and real-time patient respiration data. All of these help nurses monitor patients on a regular basis. The respiration table, which displays all of the measured and system-stored data, is the second display. The menu for the respiratory table is displayed in Figure 6.



Tanggal	Waktu	Jumlah Respirasi (Per Menit)	Notifikasi
2021-08-19	14:59:01	15	Normal
2021-08-19	15:01:34	14	Normal
2021-08-19	15:04:02	15	Normal
2021-08-19	15:06:27	16	Normal
2021-08-19	15:09:38	15	Normal
2021-08-19	15:15:20	12	Normal
2021-08-19	15:17:44	13	Normal
2021-08-19	15:20:53	15	Normal
2021-08-19	15:24:08	12	Normal
2021-08-19	15:35:30	13	Normal
2021-08-19	15:37:56	11	Tidak Normal
2021-08-19	15:40:53	13	Normal

Figure 6. Respiratory table on IoMT

Respiration sensor testing is carried out by comparing the value of the respiration cycle per minute read by the sensor on the computer to the respiration cycle per minute read using a stopwatch. Respiration testing is carried out on patients with several test equipment components, including a respiration sensor as a measuring medium, a stopwatch as a comparison medium, a power supply as a voltage supply, a computer as a place for data display and database collection, and a Wi-Fi router as a communication medium between the systems. with a database or computer. This test is carried out with the sensor position facing the Z-axis with movement in the direction of the Z-axis and at an angle of 0o, or in other words, the COVID-19 patient whose respiration will be counted must be in a supine sleeping position.

The value obtained from the respiration sensor will be transformed into a graph in the third menu that will be continuously checked to determine the patient's state. This graph displays all of the data that has been saved against time. Figure 7. shows the presentation of the respiration graph. After the process of measuring respiration in COVID-19 patients, comparison results were obtained between the patient's respiration cycle which was calculated manually using a stopwatch and the patient's respiration cycle which was calculated using sensors in the system created in this study. The average deviation value produced by the respiration sensor created in the system is 1.26%. The average deviation value of the respiration sensor in this system is quite small or it could be said that the respiration sensor made in this system is close to the respiration cycle value calculated manually using a stopwatch, but the respiration cycle read by the system is still less accurate.

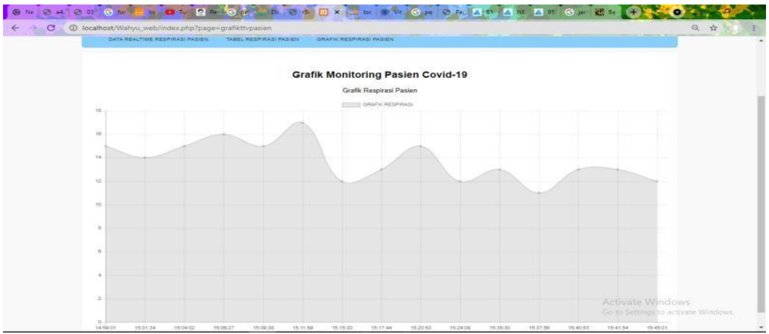


Figure 7. Respiration Graph View

CONCLUSION

Using the MPU6050 sensor, the respiration monitoring system for COVID-19 patients has been successfully constructed. It has been put into use to monitor the respiration cycle in real time and wirelessly via a Wi-Fi network using the MQTT communication protocol, making data acquisition faster and easier even at a great distance. This allows for the unhindered performance of medical monitoring from a distance. The MPU6050 sensor was successfully used in the construction of the respiration monitoring system for COVID-19 patients. This system allows for real-time monitoring of the respiration cycle and wireless data acquisition over a Wi-Fi network using the MQTT communication protocol, even at great distances. This facilitates the unhindered provision of medical monitoring services. The average deviation value of the test data collected from the COVID-19 patients' respiration sensors is 1.26%; this value is in close proximity to the respiration value manually determined using a stopwatch. A number of reasons contribute to the discrepancy in value: either human mistake when using a stopwatch to monitor respiration, or an error in the respiration sensor inside the system that misreads the breathing cycle.

Declaration by Authors
Acknowledgement: None
Source of Funding: None
Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Vania, Yuliani D, and Sumada IK, “Manifestasi Klinis Neurologis pada Covid-19,” Callosum Neurol., 2020, doi: 10.29342/cnj.v3i3.118.
2. Jamaluddin M, Yunani, and Widiyaningsih, “Latihan Peregangan Otot Pernafasan Untuk Meningkatkan Status Respirasi Pasien Asma,” Pros. Semin. Nas. Unimus, 2018.
3. Ilpaj S M. and Nurwati N, “Analisis Pengaruh Tingkat Kematian akibat Covid-19 terhadap Kesehatan Mental Masyarakat di Indonesia,” Focus J. Pekerj. Sos., 2020, doi: 10.24198/focus.v3i1.28123.
4. Yuan J, et al, “Monitoring transmissibility and mortality of COVID- 19 in Europe,” Int. J. Infect. Dis., 2020, doi: 10.1016/j.ijid.2020.03.050.

5. Widiastuti L, et al, "Efektifitas Early Warning Score Dalam Deteksi Kegawatdaruratan Di Trauma Center RUMKITAL Dr. Midiyato S Tanjungpinang," J. Keperawatan, 2017.
6. Ratna S, "Sistem Monitoring Kesehatan berbasis Internet of Things (IoT)," Al Ulum J. Sains Dan Teknologi, 2020, doi: 10.31602/ajst.v5i2.2913.
7. Pratap Singh R, et al, "Internet of Medical Things (IoMT) for orthopaedic in COVID-19 pandemic: Roles, challenges, and applications," Journal of Clinical Orthopaedics and Trauma. 2020, doi: 10.1016/j.jcot.2020.05.011.
8. Mohd Aman AH, et al, "IoMT amid COVID-19 pandemic: Application, architecture, technology, and security," Journal of Network and Computer Applications. 2021, doi: 10.1016/j.jnca.2020.102886.
9. Zhu N et al., "A Novel Coronavirus from Patients with Pneumonia in China, 2019," N. Engl. J. Med., 2020, doi: 10.1056/nejmoa2001017.
10. Irgo MJ and Tjiptanata RA, "Prototype Aplikasi Pelacak ODP/PDP Berbasis Android," J. Gunadarma, 2020.
11. Firdayanti F, et al, "Jurnal Abdimas Kesehatan Perintis Pencegahan Covid-19 Melalui Pembagian Masker Di Kelurahan Romang Polong Kabupaten Gowa," J. Abdimas Kesehat. Perintis, 2020.
12. Lubis HF and Selvarajoo N, "Perbedaan Inklinasi Insisivus pada Pasien Maloklusi Klas I dan Klas II Skeletal dengan Pola Pernafasan Normal dan Pernafasan Melalui Mulut," Dentika Dent. J., 2016, doi: 10.32734/dentika. v19i1.140.
13. Sarotama A and Melyana, "Implementasi Peringatan Abnormalitas Tanda-Tanda Vital pada Telemedicine Workstation," J. Nas. Sains dan Teknol., vol. 21, no. 1, pp. 1–9, 2019: https://jurnal.umj.ac.id/index.php/semnastek/article/view/5236.
14. Swastika W, Nur AW and Kelana OH, "Monitoring Ruangan untuk Deteksi Manusia berbasis CNN dengan Fitur Push Notification," Teknika, 2019, doi: 10.34148/teknika.v8i2.166.
15. Kartika SL, "Implementasi Early Warning System berdasarkan Karakteristik, Tingkat Pengetahuan dan Motivasi Perawat," Nurs. Curr., 2013.
16. Martín-Rodríguez F et al., "Early warning scores in patients with suspected covid-19 infection in emergency departments," J. Pers. Med., 2021, doi: 10.3390/jpm11030170.
17. Myrstad M et al., "National Early Warning Score 2 (NEWS2) on Admission Predicts Severe Disease and In-Hospital Mortality from Covid-19 - A Prospective Cohort Study," Scand. J. Trauma. Resusc. Emerg. Med., 2020, doi: 10.1186/s13049-020-00764-3.
18. Dai HN, Imran M, and Haider N, "Blockchain-enabled Internet of Medical Things to Combat COVID-19," arXiv. 2020, doi: 10.1109/iotm.0001.2000087.
19. Kharisma OB, et al., "Implementasi Sensor MPU 6050 untuk Mengukur Kesetimbangan Self Balancing Robot Menggunakan Kontrol PID," Semin. Nas. Teknol. Informasi, Komun. dan Ind., 2018.
20. Ave B, D. Number D, and Date R, "MPU-6000 and MPU-6050 Product Specification," vol. 1, no. 408, 2013.
21. Setyawan LB, "Prinsip Kerja dan Teknologi OLED," Techné J. Ilm. Elektrotek., vol. 16, no. 02, pp. 121–132, 2017, doi: 10.31358/techne.v16i02.165.
22. Fajrin R, "Pengembangan Sistem Informasi Geografis berbasis Node.JS untuk Pemetaan Mesin dan Tracking Engineer dengan Pemanfaatan Geolocation pada PT IBM Indonesia," J. Inform., vol. 11, no. 2, pp. 40–47, 2017, doi: 10.26555/jifo. v11i2.a6090.

How to cite this article: Ahmad Ridlo Hanifudin Tahier, Muchammad Azam, Ngurah Ayu Ketut Umiati, Isnain Gunadi, Wahyu Aji Nugroho. Design of a Covid-19 patient respiration monitoring system using an ESP 32 microcontroller and an MPU 6050 sensor for the internet of medical things (IoMT) system. *International Journal of Research and Review*. 2023; 10(12): 188-195.
DOI: *https://doi.org/10.52403/ijrr.20231224*

******