Bit-Tech (Binary Digital - Technology)
Vol.6, No.2, December 2023
Available online at: http://jurnal.kdi.or.id/index.php/bt

Designing Prototype of Volume Detector for Medical Oxygen Cylinder Using NodeMCU ESP8266

Mamad Muhamad Mansur[1)], Rahmat Ismatullah Ibrahim[2)], Ade Surya Budiman[3)*]

[1)2)3)]*Program Studi Teknologi Komputer, Fakultas Teknik dan Informatika, Universitas Bina Sarana Informatika Jalan Kramat Raya No. 98, Senen, Jakarta Pusat, DKI Jakarta, Indonesia*

[1)]mamadmuhmansur134@gmail.com

[2)]ahmatismatullah@gmail.com

[3)]ade.aum@bsi.ac.id

Article history:

Received 09 Oct 2023;
Revised 14 Oct 2023;
Accepted 21 Oct 2023;
Available online 28 Dec 2023

Keywords:

Early Notification
Internet Of Things
Nodemcu Esp8266
Oxygen Cylinder
Volume Detector

Abstract

The COVID-19 pandemic posed significant challenges to the healthcare sector, particularly due to the imbalance between patient numbers and available medical staff, resulting in difficulties during emergencies. One such challenge was the prompt replacement of oxygen cylinders. Leveraging Internet of Things (IoT) technology, we developed a prototype oxygen cylinder volume detector aimed at providing early notifications to healthcare professionals. This prototype incorporates the NodeMCU ESP8266, equipped with an Infrared (IR) Obstacle Sensor. The sensor communicates with a relay to activate an MP3 module, delivering audible alerts. Furthermore, the NodeMCU ESP8266 system integrates CTBot to send text notifications through the Telegram application to the nearest healthcare personnel. Visual alerts are also provided through red LED lights attached to the cylinders, indicating which oxygen cylinder is approaching depletion. Comprehensive testing validated the proper functionality of all system components. This innovative oxygen cylinder detector prototype is designed to streamline healthcare worker and nurse workflows by offering quicker access to accurate information regarding the status of medical oxygen cylinders. Not only does this enhance patient care efficiency, but it also ensuring the availability of oxygen is crucial for critical patients.

I. Introduction

The COVID-19 pandemic has presented enormous challenges for the medical community, including in Indonesia. A high need for the availability of oxygen cylinders hit Indonesia during the pandemic. COVID-19 is a type of disease that attacks all respiratory components of the patient. Thus, it can paralyze humans' ability to breathe normally. Emergency treatment of this condition requires invasive mechanical ventilation (using an endotracheal tube / ETT and mechanical ventilator) or you can also use non-invasive ventilation methods (using a face mask model) to prevent more severe damage to the respiratory system [1], [2]. These two methods will help patients to get oxygen supply and release carbon dioxide.

Oxygen is really needed as a low-cost therapy for COVID-19 patients, and can also help increase life expectancy for these patients [3]. Oxygen therapy helps the respiratory system to enter oxygen into the lungs where it is then filtered and delivered to the organs, tissues and cells of the human body through the blood vessels [4]. The availability of oxygen supply is very important for patients who experience difficulty in respiratory circulation. Patients with respiratory difficulties must immediately and always be connected to an oxygen cylinder to assist the respiratory circulation process. In the field of severe and critical COVID-19 treatment, the world's attention is focusing on the expansion of intensive care capacity, including the use of mechanical ventilation [5].

This is a challenge in itself, to ensure the availability of oxygen volume in the oxygen cylinder connected to the patient. Difficulty in the location of the medical gas installation room, because it is far from the operator's room, is one of the factors that can cause delays in replacing exhausted medical gas cylinders [6]. Apart from problems with the volume of the oxygen cylinder, the pressure of the oxygen gas in the cylinder also needs close

[*] Corresponding author

ISSN 2622-2728 (online) 2622-271X (print)
doi: 10.32877/bt.v6i2.980

monitoring. However, in practice, to determine the pressure and volume of a gas cylinder, it is still only a rough estimate by the nurse or relevant medical officer [7].

For this reason, technology is needed that can assist medical personnel in monitoring the pressure and volume in the medical oxygen cylinder. For example, in order to facilitate patient monitoring and diagnosis, a parameter monitoring tool based on the Internet of Things is triggered by telegram notifications to allow patients to be treated quickly [8]. The existence of a backup cylinder (secondary cylinder) also needs to be used as a substitute for oxygen supply to the patient if the main cylinder has run out. However, a gas pressure detection mechanism is needed in the main tube, in the form of a manifold system found in the oxygen cylinder [9].

The application of the Internet of Things (IoT) in the detection and notification process to nearby medical personnel can also be a consideration to prevent oxygen supply from being cut off. As IoT has been tried to be applied in monitoring infusion flow, with the help of Telegram message notifications to nurses [10], or in real-time monitoring of patient health where IoT integrates this monitoring with clinical practice [11].

The internet network is a very effective link for modern technologies. One of its uses is the Internet of Things (IoT), as a form of technological revolution in the modern era and also a milestone in technological achievement in the field of artificial intelligence [12]. Great enthusiasm for using IoT has also spread to the medical sector. The use of IoT is a way for various new technologies in the medical sector to further develop, through the presence of contemporary medical devices and sensors that can be connected via the internet network [13]. Important information is delivered via the internet network, making it easier to monitor patient conditions remotely, predict types of disease, and make it easier for medical personnel such as doctors to understand disease symptoms and diagnose patient conditions. Technology such as IoT, Energy Internet, artificial intelligence, and human-environment sensors are used to optimize community infrastructure, services, and strategic planning [14].

Thus, the integration of internet-based applications with healthcare devices will certainly really help medical officers in carrying out their duties, including monitoring medical equipment such as medical oxygen cylinders. For this reason, considering the use of internet-based applications such as Telegram is expected to help medical officers monitor the volume and pressure of oxygen cylinders. This real-time monitoring is intended to avoid the possibility of fatalities in patients due to reduced pressure or lack of oxygen volume in the tube. This is, for example, in conditions when a patient using an oxygen cylinder is being carried in an ambulance. Nearest medical personnel, such as ambulance drivers and accompanying nurses, can immediately find out the remaining oxygen volume in real-time. In this research, we utilized the NodeMCU ESP8266 which was integrated with an oxygen cylinder device to detect the volume and pressure of oxygen in the cylinder, and provide notification of cylinder replacement to officers via voice messages from the speaker and text messages on the Telegram application.

NodeMCU (Micro Controller Unit) is an open-source hardware and software development environment [15]. This NodeMCU is integrated with the ESP8266 chip, which is a type of System-on-a-Chip (SoC). As an integrated system, the ESP8266 consists of a Central Processing Unit (CPU), Random Access Memory (RAM), access to the internet network via Wifi, and can be equipped with an operating system and Software Development Kit (SDK). In the research, compatibility between NodeMCU and Arduino Integrated Development Environment (IDE) was used as an add-on in making this oxygen cylinder detector prototype. To be able to send notifications via Telegram to the nearest medical staff or oxygen cylinder operators, this system must be added with an Arduino Library called CTBot which is compatible for use with the ESP8266/ESP32 chip architecture. Furthermore, in order to be used, the CTBot Library requires the ArduinoJson Library to be installed first. This is because ArduinoJson is a library that is included in the data processing type, while CTBot is a library for communication.

II. METHODS

To obtain research results in accordance with the research objectives, this research was carried out in a number of stages. This research, which aims to create a design, is described in the research cycle as shown in Figure 1. The research method we use refers to The Basic Steps Of The Engineering Design Process, which consists of seven steps, namely: Ask, Research, Imagine, Plan, Create, Test and Improve [16].

The prototype development starts from the first step, namely ASK, to identify and analyze user needs, system requirements and limitations. User needs are the main background underlying the creation of the prototype in this research. From the second stage, namely RESEARCH, searching for problem points, we concluded that users need a system that can provide early warnings and notifications regarding the volume of oxygen cylinders, especially when patients with oxygen cylinders are transported by ambulance between medical installations. So, the possible solution (step 3: IMAGINE) is that the system is expected to be able to warn ambulance drivers and accompanying medical personnel regarding the availability of oxygen gas in the cylinder, and prevent patients from running out of oxygen before arriving at the intended medical installation location. The system created is mobile and must be able to work with an independent power supply, without requiring a power supply from fixed electricity infrastructure (for example from the National Electric Company/PLN installation).

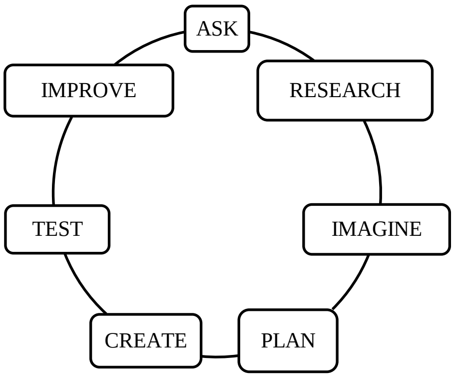

Fig 1. Research Method Refers to The Engineering Design Process

Then we planned (step 4: PLAN) to make this prototype in the form of the right design and layout to be installed side by side with the oxygen cylinder. The oxygen cylinder used to design this prototype is a small oxygen cylinder. Thus, the detection equipment is also designed with a small size. Next, all electronic components are assembled and installed on the circuit board used.

The 5th stage is CREATE, where we initialize the system and inject commands through programming on the NodeMCU ESP8266 module. To run the Arduino circuit board used, a program called Sketch is used. The coding construction carried out consists of program initialization, reading input, process commands, and output control. Step 6 is in the form of testing (TEST) on the prototype that is built. After the program is injected into the detection system, a series of tests are then carried out on the components and the tool as a whole. Testing to ensure all components can work properly and the product can function as planned. The 7th step is IMPROVE, which in this research consists of outlining the shortcomings and limitations of the prototype we created and recommending improvements or redesign if necessary, as suggestions for subsequent research.

III. RESULTS

A. *Specific Overview of Research Objects*

As explained in the introduction, this research aims to create a detection and notification system regarding the volume of oxygen gas contained in medical oxygen cylinders. This Internet of Things (IoT) based system consists of NodeMCU ESP8266 as the main processing center, Passive Infra Red sensor, MP3 module and is connected to the Telegram CTBot library and ArduinoJson library. With these hardware and software components, the system will detect the volume of gas remaining in the cylinder. When the volume of gas in the cylinder runs out, the speaker will provide a sound notification which is expected to be heard by nearby medical personnel. Apart from sound notifications, text notifications or messages will also go to the Telegram application on the smartphone of the nearest medical officer. Although it can be applied to various conditions and placements of oxygen cylinders, this detection system is specifically applied to conditions where patients using oxygen cylinders are being carried in an ambulance. Medical officers who will receive notification include ambulance drivers and/or accompanying nurses.

B. *Circuit Blocks and Schematics*

In general, the circuit block in this research is divided into three parts, namely input components, process components and output components. In Figure 2, the block diagram of the prototype oxygen cylinder detector equipment that was made is shown.

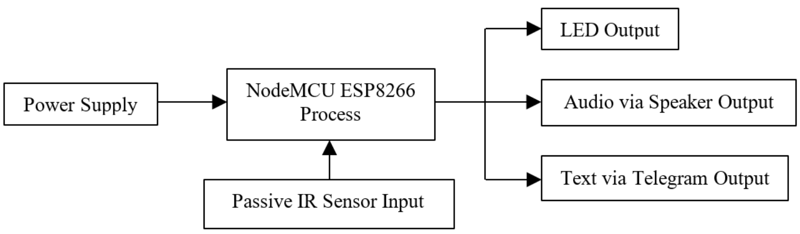

Fig. 2. Block Diagram

The input component consists of:

1. The power supply that provides 5 Volt input voltage is used as input power to the NodeMCU ESP8266, namely the VIN and GND pins, relays, and DFPlayer Mini.

2. Passive Infra Red sensor which functions to detect the movement of the needle on the oxygen cylinder measuring instrument which is received and processed by the NodeMCU ESP8266 and forwarded to the output.
3. MP3 module which functions to obtain sound that we save on the microSD to be transmitted to the speaker output.
4. Relay which functions to control the DFPlayer Mini power input on the NO and NC contacts.

The input component will then be processed by the process block. The process block is the main component that functions to manage data received by input which will then produce output. In this process we use NodeMCU ESP8266 with Sensor. As already mentioned, the processing results from the process block are channeled to the output block of the circuit.
The resulting output is as follows:

1. The LED functions as an indicator to find out whether the device is working or not, as well as an indication of whether the device is connected to WiFi or not.
2. The speaker functions to produce sound from the mp3 module.
3. The Telegram application functions to provide information or notifications in the form of incoming messages or texts related to the status of the oxygen volume in the cylinder

C. Working Mechanism of Electronic Components

The electronic circuit that works in this prototype consists of:

1. The power supply uses a 5 Volt DC adapter.
2. 1 x NodeMCU ESP8266
3. 1 x Passive Infrared Sensor
4. 2 x LEDs to which 2 1K ohm resistors are added
5. 1 x mp3 module
6. 1 x Relay 1 channel 5v
7. 1 x Speakers

Figure 3 shows the electrical schematic of the equipment designed in this research.

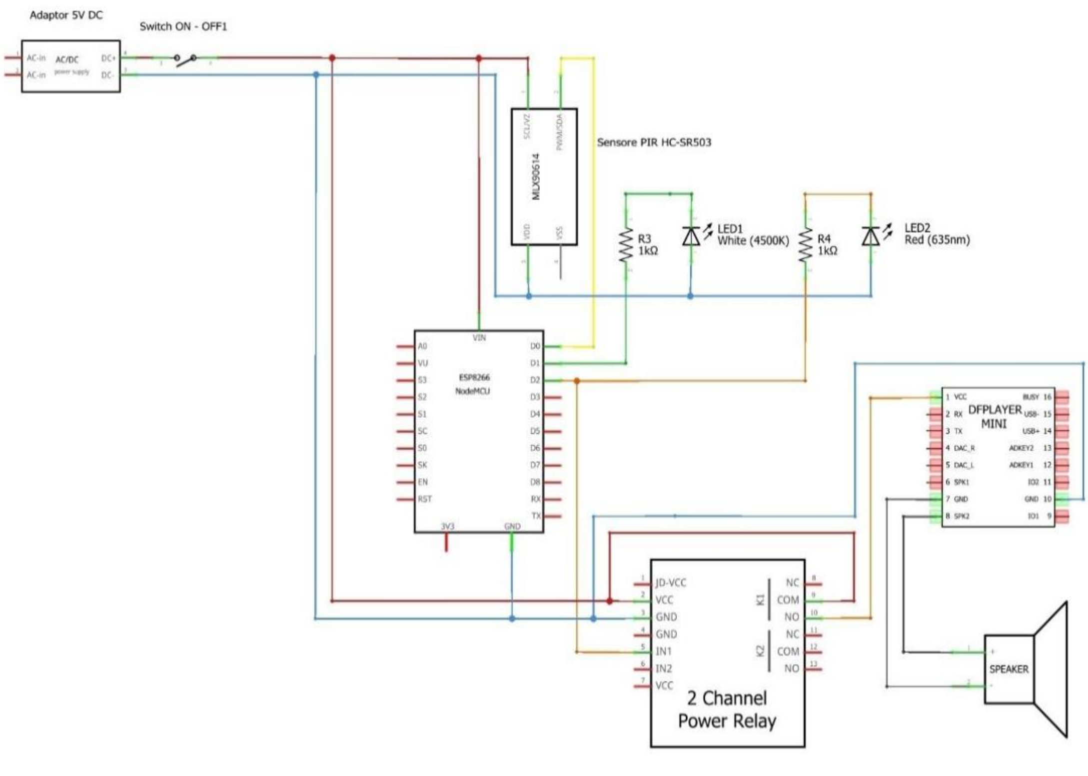

Fig 3. Electrical Schematic Circuit Using in the Prototype

A 5 Volt DC voltage source is used to supply the components in this circuit. As an IoT device, this oxygen cylinder detector must be connected to the internet network. This requires a wifi connection, which if the NodeMCU ESP8266 is connected via a wifi network, the D1 pin will be HIGH so the white LED will light up. Passive Infra Red sensor as a reader of the movement of the oxygen cylinder detector which is connected to the

NodeMCU ESP8266 pin D0, when the needle on the oxygen cylinder detector is in the exhausted position, then pin D0 which is connected to a voltage of 3.7 Volts is in active condition 1. This will affect pin D2 in the HIGH condition which emits a voltage of 3.7 Volts to trigger the Relay on the IN pin. This trigger will make the NC relay connect to a 5 Volt voltage source on the mp3 module and produce sound emitted by the speaker, as well as turning on the red LED which is used to indicate critical conditions in the volume of the oxygen cylinder. In general, the workings of the circuit and program embedded in this prototype are shown in the flowchart in Figure 4.

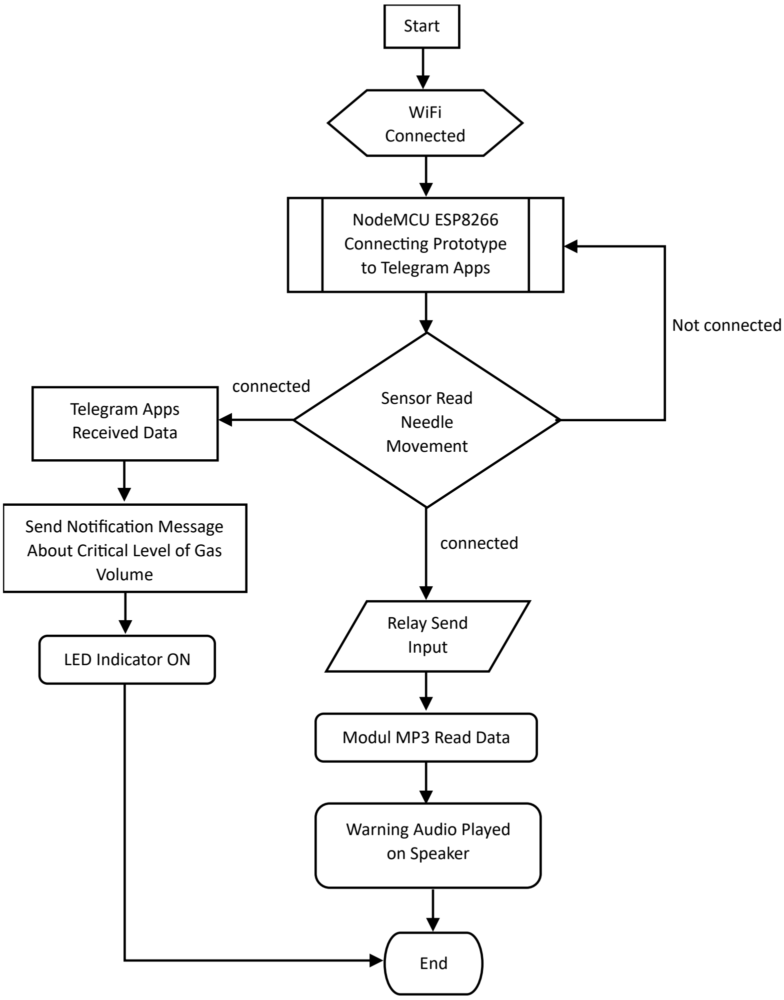

Fig 4. Prototype Flowchart

Next, the NodeMCU ESP8266 will send a message in the form of text (for example in this research a warning was created: “Awas Tabung Oksigen Habis” ("Beware the Oxygen Cylinder is Out"), which is sent via the Telegram application as a notification of the state of the volume in the oxygen cylinder. To make things easier for users, Telegram can also provide text messages (in the form of ON or OFF) to activate or deactivate the working system or detector on this tool.

IV. Discussion

A. *Initial Testing*

Initial testing was carried out to test the connectivity of the NodeMCU ESP8266 with the internet network. Followed by testing the functionality of the type and condition of the sensor, which is expected to produce an active condition that can be read by the NodeMCU ESP8266.

Testing network connectivity via wireless media from WiFi access points and hotspots from smartphones. Meanwhile, sensor testing was carried out for two conditions, namely when the passive infra red sensor was read by the detector needle, and conditions when the passive infrared sensor was not read by the detector needle.

In detail, the input test results can be seen in Table 1.

TABLE 1
INITIAL TESTING ON CONNECTIVITY AND SENSOR CONDITION

No.	Testing Items	Result
1	Access Through WiFi Access Point	Network Connected
2	*Hotspot* from Smartphone	Network Connected
3	TV Antenna	Not Connected / Not Activated
4	Radio Antenna	Not Connected / Not Activated
5	Passive Infra Red Sensor Read Detector's Needle	Active 1
6	Passive Infra Red Sensor Does Not Read Detector's Needle	Active 0
7	Light Sensor	Not Activated
8	Temperature Sensor	Not Activated

Some inputs are not activated, as shown in Table 1, because they are not needed or are not used for the detectors made in this research.

B. Prototype Testing

To test the performance of the prototype created, testing was carried out on all components contained in the medical oxygen cylinder detector. Details of the test results can be seen in Table 2. Based on the tests carried out, it is shown that the program and hardware design is in accordance with the initial target for making the tool. The experimental results show that when the input component is connected to the internet, via a message from Telegram, the condition of the oxygen cylinder detector will be obtained. Next, it will provide input to the ESP8266 NodeMCU which is processed to give commands to the output components, namely the red LED, white LED, mp3 module, speaker and relay. Overall, NodeMCU ESP will provide warning information in the form of messages (text) on the Telegram application, LED notifications and sound notifications.

TABLE 2
PROTOTYPE FUNCTIONAL TESTING

No.	Testing Items	Result						
		Telegram	White LED	Red LED	Speaker	Sensor Barrier	Relay	DF MP3
1	Sent Message ON to Telegram	Incoming Message	Active	Inactive	Inactive	Inactive	Inactive	Inactive
2	Sent Message OFF to Telegram	Incoming Message	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
3	Connected to Smartphone Hotspot	No Incoming Message	Active	Inactive	Inactive	Inactive	Inactive	Inactive
4	Connected to WiFi Access Point	No Incoming Message	Active	Inactive	Inactive	Inactive	Inactive	Inactive
5	Cylinder Regulator Needle under 500	Incoming Message	Inactive	Inactive	Active	Active	Active	Active
6	Cylinder Regulator Needle above 500	No Incoming Message	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive

In accordance with the test results shown in Table 2, it can be proven that the detector successfully sent ON/OFF messages to Telegram, in the form of text messages that came through the application. The establishment of a network connection using a hotspot on a smartphone and a WiFi network has also been successful, as indicated by the white LED lighting up on the detector. In accordance with its main function as a detector, when the regulator needle is below 500, all the main indicators, Telegram (text messages), red LED (visual), and speaker (audio) will be active to provide notifications or warnings. On the other hand, when the regulator needle is above 500 (the gas volume and pressure in the tube are in a safe condition), then all indicators do not provide any messages, notifications or warnings (in an inactive condition).

V. CONCLUSIONS

The existence of an oxygen volume detector can help medical personnel, especially in mobile conditions such as in ambulances, to avoid patients who are being transferred or evacuated from running out of oxygen supply for a long period of time. With this oxygen cylinder detector prototype, medical personnel can monitor the status of the oxygen volume in the cylinder without having to check it all the time. Apart from that, with notifications and early detection of the volume of oxygen in the cylinder, officers on the journey will be able to predict when the oxygen cylinder will run out as well as predict how far the patient can travel before it is necessary to replace the oxygen cylinder. Based on the test results, the oxygen cylinder detector prototype created in this research was able to accurately predict the oxygen volume. Output devices such as LEDs, speakers and Telegram modules can provide precise and real-time warnings and notifications to officers both audio, visual and text messages on Telegram.

Apart from the features that this prototype already has, for further research and development, communication channels with officers can be added, for example via the WhatsApp application. Apart from that, connectivity to a database system can also be developed with the aim of analyzing the need and use of gas in oxygen cylinders, for the oxygen cylinder supply chain needs for each medical installation.

REFERENCES

[1] J. M. Walter, T. C. Corbridge, and B. D. Singer, "Invasive Mechanical Ventilation," *South Med J*, vol. 111, no. 12, pp. 746–753, Dec. 2018, doi: 10.14423/SMJ.0000000000000905.

[2] S. B. Brosnahan, A. H. Jonkman, M. C. Kugler, J. S. Munger, and D. A. Kaufman, "COVID-19 and Respiratory System Disorders," *Arterioscler Thromb Vasc Biol*, vol. 40, no. 11, pp. 2586–2597, Nov. 2020, doi: 10.1161/ATVBAHA.120.314515.

[3] A. Hvarfner *et al.*, "Oxygen provision to severely ill COVID-19 patients at the peak of the 2020 pandemic in a Swedish district hospital," *PLoS One*, vol. 17, no. 1, p. e0249984, Jan. 2022, doi: 10.1371/journal.pone.0249984.

[4] Clevelend Clinic, "Oxygen Therapy," https://my.clevelandclinic.org/health/treatments/23194-oxygen-therapy.

[5] B. H. Katira, "Ventilator-Induced Lung Injury: Classic and Novel Concepts," *Respir Care*, vol. 64, no. 6, pp. 629–637, Jun. 2019, doi: 10.4187/respcare.07055.

[6] B. Rahmat, "Telemonitoring Gas Medis," in *Seminar Nasional Widya Husada 1*, Semarang: Stikes Widya Husada, 2019, pp. 32–34.

[7] N. H. Wijaya, B. Untara, and I. Khoirunnisa, "Monitoring Tekanan Gas Medis Pada Instalasi Gas Medis Rumah Sakit," *Medika Teknika : Jurnal Teknik Elektromedik Indonesia*, vol. 1, no. 1, 2019, doi: 10.18196/mt.010104.

[8] R. I. Puspitasari, D. Titisari, and L. Lamidi, "Development of Monitoring Parameters of Oxygen Concentration, Oxygen Flow Rate, Temperature and Humidity in IoT-Based CPAP Bubble (Oxygen and Humidity Concentration)," *Jurnal Teknokes*, vol. 16, no. 2, 2023.

[9] A. Hendryani, V. Nurdinawati, and N. Dharma, "Desain Manifold dengan Monitoring Tekanan untuk Pertukaran Otomatis Tabung Gas Oksigen Medis di Rumah Sakit," *Teknik*, vol. 42, no. 1, pp. 45–51, 2021.

[10] H. S. Azhari Lubis, I. R. Munthe, and R. Pane, "Infus Desain Notifikasi Dengan Aplikasi Media Sosial Berbasis Internet of Things (IOT)," *Jurnal Teknik Informatika UNIKA Santo Thomas*, pp. 117–125, Jul. 2021, doi: 10.54367/jtiust.v6i1.1286.

[11] A. H. Abdulwahid, "Modern Application of Internet of Things in Healthcare System," *International Journal of Engineering Research and Technology*, vol. 12, no. 4, pp. 464–499, 2019.

[12] T. R. Wanasinghe, R. G. Gosine, L. A. James, G. K. I. Mann, O. de Silva, and P. J. Warrian, "The Internet of Things in the Oil and Gas Industry: A Systematic Review," *IEEE Internet Things J*, vol. 7, no. 9, pp. 8654–8673, Sep. 2020, doi: 10.1109/JIOT.2020.2995617.

[13] Make-It.ca, "NodeMCU ESP8266 Detailed Review," https://www.make-it.ca/nodemcu-details-specifications.

[14] Á. Verdejo Espinosa, J. L. Lopez Ruiz, F. Mata Mata, and M. E. Estevez, "Application of IoT in Healthcare: Keys to Implementation of the Sustainable Development Goals," *Sensors*, vol. 21, no. 7, p. 2330, Mar. 2021, doi: 10.3390/s21072330.

[15] W. Wijayanto, A. P. Nevita, and H. A. Munawi, "Perancangan Sistem Otomatisasi Hand Sanitizer Berbasis Sensor Infrared Barrier Module," *Nusantara of Engineering (NOE)*, vol. 4, no. 1, 2021.

[16] TeachEngineering.org, "Design Step 1: Identify the Need (Hands-On Activity)," https://www.teachengineering.org/activities/view/cub_creative_activity1.