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Prototype Design of Toxic Gas (CO) Monitoring Equipment In Motorcycle Workshop

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ABSTRACT

Workshop is one of the places that contributes a significant amount of carbon monoxide gas, originating from motor vehicle exhaust. A workshop is also a place at high risk of fire. Due to the lack of awareness among visi- tors and workshop workers about the dangers of carbon monoxide gas and the potential for fires in motorcycle workshops, a tool is needed to monitor carbon monoxide levels and detect fire in the workshop. The aim of this final project is to design and develop a device, software, and demonstrate the per- formance of a system for monitoring carbon monoxide levels and detecting fire in a motorcycle workshop. This research uses the Research and Develop- ment (R&D) method. The results of the monitoring system created showed good outcomes. The sensor used was able to read carbon monoxide levels with an error rate of 5.56%, while the Flame sensor was able to detect fire at a maximum distance of up to 70 cm. The monitoring system functioned well, with carbon monoxide levels visualized using ThingSpeak. The DC fan also worked effectively, when carbon monoxide levels in the room reached 25 ppm or higher, the DC fan would turn on and help with air circulation.

Bengkel merupakan salah satu tempat yang menyumbang banyak gas karbon monoksida yang berasal dari gas buangan kendaraan bermotor. Bengkel juga merupakan suatu tempat yang berisiko terjadinya kebakaran. Kurangnya kesadaran para pengunjung dan pekerja bengkel akan bahayanya gas karbon monoksida dan rentannya terjadinya kebakaran pada bengkel motor, dibutuhkan alat yang dapat memonitoring kadar karbon monoksida dan api yang ada pada bengkel. Tujuan dari proyek akhir ini adalah untuk merancang bangun alat, software, dan melakukan unjuk kerja dari sistem monitoring kadar karbon monoksida dan api pada bengkel motor. Penelitian ini menggunakan metode Research and Development (R&D). Hasil dari pembuatan sistem monitoring yang dibuat mendapatkan hasil yang baik. Sensor yang digunakan dapat membaca kadar gas karbon monoksida dengan nilai error sebesar 5.56%, sedangkan sensor Flame dapat membaca adanya api dengan jarak maksimal sejauh 70 cm. Sistem monitoring yang dibuat dapat berjalan dengan baik, kadar karbon monoksida dapat divisualisasikan menggunakan thingspeak. Fan DC yang digunakan juga berfungsi dengan baik, ketika gas karbon monoksida yang berada di ruangan terbaca 25 ppm atau lebih maka fan DC akan menyala dan dapat membantu sirkulasi udara.

1. Introduction

Clean air is essential for the life of living things on earth, including humans [1]. Thus, the need for clean air becomes crucial for the sustainability of human life. However, along with the rapid development of technology, there are negative impacts in the form of increased human activities. Every activity conducted by humans can generate waste that leads to a decline in environmental quality [2].

Pollution arises from human activities, such as pollution from factory industries, motor vehicles, waste burning, agricultural residues, and natural events. This pollution can damage the clean air that is a crucial aspect of human survival. One example of air pollution is the exhaust gas from motor vehicles, namely carbon monoxide (CO) [3].

According to the World Health Organization (WHO), the exposure limit for CO in humans is 90-100 ppm for 15 minutes, 25-35 ppm for 1 hour, and 9-10 ppm for 8 hours. Meanwhile, the Occupational Safety and Health Administration (OSHA) recommends a maximum CO exposure limit of 35 ppm over 8 hours in a workday. Levels considered immediately dangerous to life or health are 1500 ppm [4]. According to WHO, high concentrations of CO in the blood within a few minutes can cause respiratory distress and death.

Workshop is one of the locations that significantly contributes CO emissions originating from motor vehicle exhaust gasses. This situation has become worse because exhaust gasses that should be dispersed and conditioned become stagnant, and many workshops still lack adequate systems for conditioning these exhaust gasses. CO levels in motor vehicle workshops have been found to reach as high as 600 mg/m^3, and the blood of the workshop workers can contain COHb up to five times higher than normal levels [5].

The threshold limit value for carbon monoxide, based on the Regulation of the Minister of Manpower and Transmigration on Threshold Limit Values for Physical and Chemical Factors in the Work- place, is 25 ppm. This regulation emphasizes the importance of monitoring CO levels in the work- place to ensure the safety and health of workers.

The importance of raising awareness and safety among workers is essential and can create a work environment with minimal risks. Workshops are also places that are at risk of fire. Fires can be triggered by fuel leaks, sparks, or workshop equipment operating at high temperatures. Along with the increasing demands for the safety of workers and visitors, there is also growing awareness of the impact of exhaust gasses in motorcycle workshops.

This device uses an MQ-7 sensor that can detect exhaust gasses from motor vehicles in workshops, specifically CO gas, and a flame sensor that can detect fire in case of a fire in the workshop. The output of this device is a monitoring system that can monitor the CO level in the room and a DC fan that will turn on when the CO level in the room reaches a dangerous point. The device is expected to help and raise awareness among workers and customers to create a healthy and safe working environment.

2. The Proposed Method

2.1 Carbon Monoxide

Carbon monoxide is a colorless, tasteless, and odorless compound produced by incomplete combustion. Inhaling high concentrations of carbon monoxide gas can have negative effects and pose dangers to humans and the surrounding environment. Carbon monoxide is a dangerous gas that can cause poisoning and even death if inhaled by the human body in large amounts.

Motor vehicles are one of the contributors to carbon monoxide gas, which comes from emissions due to incomplete combustion. The human body can experience disturbances and even death if exposed to concentrations exceeding normal exposure limits. According to the Regulation of the Minister of Manpower and Transmigration on the Threshold Limit Values for Physical and Chemical Factors in the Workplace, the threshold limit for carbon monoxide is 25 ppm.

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2.2 Internet of Things

Internet of Things (IoT) is a concept where devices connected to the internet can exchange data and communicate with other devices to help simplify tasks for users. IoT devices include several components such as sensors used to read and collect data, devices like microcontrollers to process the data, and devices that can be used to store and present the received data.

The process begins with using sensors or detection devices installed on specific objects or in certain environments. The primary task of the sensor is to collect data from the object or environment being measured. Then, the data collected by the sensor is gathered and processed by a device such as a microcontroller. After the data is collected and processed, the device transmits it through a communication network. The transmitted data can then be further processed and stored in databases, computers, or other systems. Users can subsequently access the data via the internet or cloud services using devices such as computers, smartphones, laptops, or other smart devices.

2.3 NodeMCU ESP32

Espressif Systems Processor, commonly known as ESP, is an open-source microcontroller integrated with Wi-Fi and Bluetooth features. Several types of ESP microcontrollers commonly used are the ESP8266 and ESP32. The way the ESP8266 and ESP32 work is almost the same, but the ESP32 is superior with features such as dual-band Wi-Fi, Bluetooth, and higher computational capabilities compared to the ESP8266. The frequency they operate on also differs, with the ESP8266 having a frequency of 80MHz, while the ESP32 operates at 160MHz.

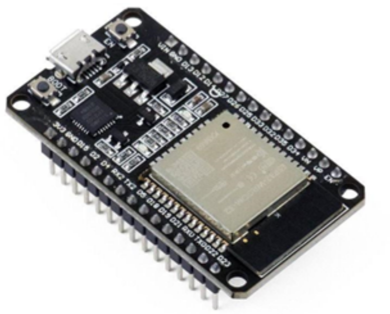

Fig. 1. NodeMCU ESP32

The NodeMCU ESP32 is a hardware development module that utilizes the ESP32 chip. This module facilitates the development of Internet of Things (IoT) projects, supported by Wi-Fi and Bluetooth features, providing robust wireless connectivity. The NodeMCU ESP32 is equipped with numerous General Purpose Input/Output (GPIO) pins that can be configured as digital inputs and outputs, analog inputs, and other functions. The availability of these pins makes it easier to manage additional circuits.

2.4 MQ-7 Sensor

MQ-7 sensor is a sensitive gas sensor capable of detecting various harmful compounds in the air, such as smoke (CO), CO2, NH3, NOx, alcohol, and other gasses. The working principle of the MQ-7 sensor involves detecting changes in resistance when exposed to gas.

The MQ-7 sensor has a relatively low dependency on temperature and humidity, making it suitable for applications in air quality monitoring and CO level detection. The resistance of the MQ-7 sensor, which varies depending on the concentration of each gas, determines how the sensor should be calibrated. To calibrate the sensor readings to ppm values, the Rs/Ro graph from the MQ-7 sensor datasheet is used. Here, Rs represents the sensor's resistance at a given gas concentration, and Ro represents the sensor's resistance in clean air. The MQ-7 sensor provides air quality detection results as changes in analog resistance values on its output pin.

Fig. 2. MQ-7 Sensor

3. Method

In the research conducted, the Research and Development (R&D) method was used. The Research and Development method is a research approach aimed at developing a product through several stages. After completing each stage, the effectiveness of the product is then tested. The Research and Development method involves several steps. Product development begins with gathering information and conducting a literature review on the existing problems. This is followed by the design of a validated product. Once the design process is complete, the next stage is product creation, which is then followed by various tests until the product is ready for implementation.

3.1 Units

In this research process, it is necessary to identify the requirements needed for creating the device. This identification includes aspects of Hardware, Software, and tools that meet the project's needs. The purpose of this identification is to ensure that the selection of Hardware, Software, and tools aligns with the requirements of the project to be developed. Below is the identification of the needs required for the final project.

- **ESP32**, It is used as a microcontroller that functions to process data and control other devices, such as sensors that can connect to a Wi-Fi network to support Internet of Things (IoT)-based systems.
- **MQ-7 Sensor**, MQ-7 sensor is a sensor that will be used to measure the concentration of CO gas in the workshop area. This sensor is sensitive to toxic gasses such as CO, CO2, NH3, CH4, and other hazardous gasses.
- **Flame Sensor KY-026**, The KY-026 Flame Sensor is a sensor used to detect the presence of flames in the workshop.
- **Arduino IDE**, Arduino IDE is the software used to program the ESP32 microcontroller.
- **Thingspeak**, hingSpeak is used for testing the monitoring system website.

3.2 Design

The hardware needed to make this final project is adjusted to the needs of the tools to be made. The component used is ESP32 which is connected to a Wi-Fi network to support the interests of Internet of Things-based circuits. MQ-7 sensor to measure CO gas concentration in workshop rooms. Flame Sensor KY-026 to detect fire in the workshop room. Buzzer is an alarm or warning that can emit a sound when the surrounding gas reaches a danger value. DC Power Adapter 12V as a power source in microcontrollers, sensors, actuators. L298N Motor Driver for controlling DC motors or fans. Mini fan DC as an actuator.

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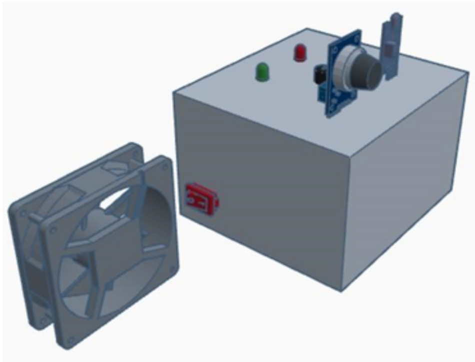

Fig. 3. Device design

3.3 Testing Methods

The testing method is carried out to obtain research data from the problem statements that will be used for analysis. The testing is done by evaluating the design of each component and the entire system that has been created. This testing is conducted to ensure that the entire system functions and operates according to its intended purpose.

- **Sensor Testing**: Sensor testing is conducted to determine the accuracy and performance of the sensor in measuring how accurately it can operate. This testing is done by comparing the results from the MQ-7 sensor with a standard carbon monoxide gas detector. The testing process for the MQ-7 sensor involves connecting the sensor to a microcontroller to measure the carbon monoxide levels in the room. The testing of the KY-026 Flame Sensor is conducted to determine if the sensor can detect the presence of a flame when it is ignited.
- **Motor Driver L298N**: This testing is conducted to determine whether the motor driver can operate correctly. The testing involves evaluating the direction of rotation and the speed of the DC fan according to the commands given by the microcontroller. This testing is performed to ensure that the motor driver functions as intended.
- **Buzzer**: Buzzer testing is conducted to determine whether the buzzer can function properly. The testing is performed by connecting the buzzer to the microcontroller to produce an output according to the given commands.
- **Performance Testing**: This testing is conducted to assess the functionality of the assembled components, with the aim of determining whether each component used is working properly and to evaluate the overall operation and functionality of the device as expected.

4. Result and Discussion

4.1 Implementation

Fig. 4. Implementation of device design

In this process, several main hardware components are involved, including electronic components, the PCB, and the device casing. Once these components are ready, the assembly of each component is carried out step by step. The optimization of this device involves several key components, including the device casing and a NodeMCU ESP32 as the microcontroller, which is mounted on the PCB along with components such as sensors, LEDs, a buzzer, the L298N motor driver, and a 12V DC fan pin.

The Internet of Things platform results using ThingSpeak can be accessed through http://thingspeak. com by first logging in with an account that has been created. The monitoring system dashboard using ThingSpeak can be viewed in the Fig. 5.

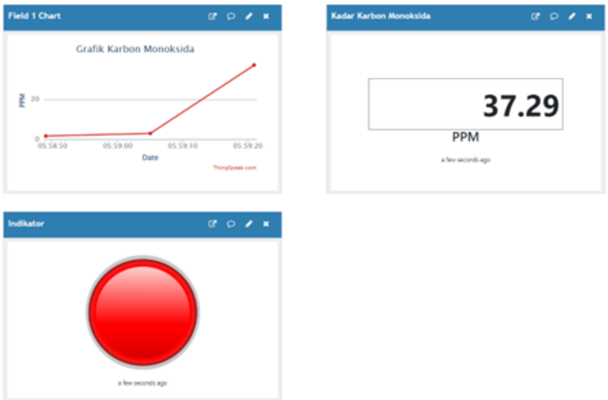

Fig. 5. Thingspeak dashboard

4.2 Microcontroller Testing

Testing of the ESP32 microcontroller is conducted to determine whether the input and output voltage values meet the specified standards. This testing is performed because the microcontroller is a core component of the system that has been developed. The test involves measuring the Vin and Vout of the microcontroller using a multimeter to identify any error in the voltage currents entering and exiting the ESP32 microcontroller. To calculate the error value, the formula used is:

$$\%errorr = \frac{x - x_i}{x_i} \tag{1}$$

The test results show that after conducting the test three times, there was a 3% error observed when measuring Vout, both with and without a load. Meanwhile, for the Vin measurement, the results matched the specified value of 5V.

Table 1. ESP32 Testing

No	Aspect	Specification		Result		Error	
		Vin	Vout	Vin	Vout	Vin	Vout
1	Without voltage load	5V	3.3V	5V	3.2V	0%	3%
	Using voltage load	5V	3.3V	5V	3.2V	0%	3%
2	Without voltage load	5V	3.3V	5V	3.2V	0%	3%
	Using voltage load	5V	3.3V	5V	3.2V	0%	3%
3	Without voltage load	5V	3.3V	5V	3.2V	0%	3%
	Using voltage load	5V	3.3V	5V	3.2V	0%	3%

4.3 MQ-7 Sensor Testing

The purpose of testing the MQ-7 sensor is to determine its accuracy and the error by comparing it with a reference device, specifically a carbon monoxide detector available on the market. The testing is conducted by comparing the custom-built device with the monitoring system display.

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Table 2. MQ-7 Sensor Testing

Sensor MQ-7 (ppm)	Carbon Monoxide Detector (ppm)	Difference
999.99	990	9
365.29	350	15.29
338.07	330	8.07
168.90	160	8.90

The testing was conducted by placing the sensor and the comparison tool close to the motorcycle's exhaust. There were two values recorded: the highest and the lowest. At the highest value, the sensor and the comparison tool reached the maximum reading limits of 999 and 990, with a difference of 9. Meanwhile, the lowest value was obtained when the sensor and the comparison tool were placed 1 meter away from the motorcycle's exhaust. The results for the lowest reading were 168.90 and 160, with a difference of 8.90. The %error was calculated to be 0.9% for the highest value and 5.56% for the lowest.

4.4 Flame Sensor Testing

The Flame Sensor testing was conducted to determine the accuracy of the sensor's readings. The testing process involved burning paper at a predetermined distance. This test was carried out four times, each at different burning angle. The purpose of this testing was to assess the Flame Sensor's ability to detect environmental conditions when a fire is ignited.

Table 3. Flame Sensor Testing

No	Angle	Range	Condition	Result
1	0	10 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
2	0	20 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
3	0	30 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
4	0	40 cm	Flame on	Sensor active
	30			Sensor active
	60			Sensor active
	90			Sensor off
5	0	75 cm	Flame on	Sensor off
	30			Sensor off
	60			Sensor off
	90			Sensor off

The table above shows the results of the Flame Sensor testing. The Flame Sensor was able to detect the presence of fire at a distance of 70 cm at angles of 0, 30, and 60 degrees. However, at an angle of 90 degrees, the sensor was unable to detect the presence of fire.

4.5 Buzzer Testing

The results of the buzzer testing indicate that the buzzer performed effectively and correctly in all aspects of the testing conducted. The ESP32 successfully connected to, controlled, and utilized the buzzer according to the testing requirements. These results demonstrate that the buzzer can be reliably used in applications using ESP32 microcontrollers.

Table 4. Buzzer Testing

Aspect	Result
Turning on buzzer	Success
Set buzzer sound	Success
Set buzzer sound pattern	Success
Use the buzzer as an indicator tool	Success
Connect buzzer with ESP32	Success

4.6 Motor Driver L298N Testing

The Motor Driver L298N was tested to determine whether it could receive commands from the ESP32 microcontroller through the available inputs on the motor driver. The testing also aimed to assess whether the motor driver could control the output, specifically the DC Fan being used. The results showed that the Motor Driver L298N successfully received commands from the ESP32 microcontroller to turn on, operate, and turn off the fan as instructed. These findings indicate that the motor driver can be effectively used for the intended application.

4.7 System Performance

The overall testing of the device was successful, with all components connecting and functioning as intended. As shown below, the device operates according to the assigned tasks. The MQ-7 and Flame sensors effectively detected CO levels and fire, and the microcontroller processed the data and sent the readings to a database, which were then visualized on a website. The output components responded correctly across the board: the DC Fan activated when fire was detected or when the carbon monoxide levels exceeded 25 ppm, and both the buzzer and LED functioned properly, lighting up according to the given conditions.

Table 5. System Testing

MQ-7 Sensor (ppm)	Flame Sensor	Fan DC	LED Indicator	Buzzer	Result
15.30	0	Off	Off	Off	Accurate
10.21	0	Off	Off	Off	Accurate
12.67	0	Off	Off	Off	Accurate
13.58	0	Off	Off	Off	Accurate
9.70	1	On	On	On	Accurate
18.10	1	On	On	On	Accurate
23.25	1	On	On	On	Accurate
24.60	0	Off	Off	Off	Accurate
25.17	0	On	On	On	Accurate
45.83	0	On	On	On	Accurate
56.34	0	On	On	On	Accurate
70.22	0	On	On	On	Accurate
120.19	0	On	On	On	Accurate
90.54	0	On	On	On	Accurate

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40.78	0	On	On	On	Accurate
26.14	0	On	On	On	Accurate
20.80	0	Off	Off	Off	Accurate
13.68	0	Off	Off	Off	Accurate
8.82	1	On	On	On	Accurate
9.55	1	On	On	On	Accurate

5. Conclusion

This research successfully realized the design of hardware for a device that monitors carbon monoxide levels and detects fire. The device effectively detects carbon monoxide levels and the presence of fire using the MQ-7 and Flame sensors. It also includes an LED, Buzzer, and DC Fan that activate when the sensors detect fire or when the carbon monoxide levels exceed 25 ppm. Addition- ally, the device features a monitoring system using localhost, which can be used to monitor carbon monoxide levels in a room.

This research can realize the design of software for a carbon monoxide monitoring and fire detection device. The Arduino IDE is used to create the code for the ESP32 microcontroller, utilizing several available libraries. Thingspeak can implement the monitoring design using a website that displays the readings from the MQ-7 sensor.

The performance of the carbon monoxide monitoring and fire detection device operates as expected. The components used function properly. The Flame Sensor can detect fire at distances and angles that align with its specifications. Meanwhile, the MQ-7 sensor is effective in measuring carbon monoxide levels in a room, although there is a discrepancy compared to a reference device used for measuring carbon monoxide in a motorcycle exhaust, with a difference of 8.90 ppm or a 5.56% error at the lowest value when measuring carbon monoxide at a distance of 1 meter from the motorcycle exhaust. The sensor readings are successfully visualized on a website, which can be used to monitor room conditions. The outputs, including the Buzzer, LED, and DC Fan, work effectively in response to the sensor readings regarding the room conditions.

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