

Design Of LPG Leakage Detection Device Using MQ-2 Sensor Equipped with Hazard Warning System

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ABSTRACT

The use of liquefied petroleum gas (LPG) as household fuel in Indonesia has increased because it has greater heating power and equipment efficiency than other fuels. LPG is flammable and can explode if a leakage occurs and is exposed to a fire source. Therefore, explosions can be anticipated by installing a gas leakage detector equipped with a danger warning feature called Tor-G (LPG Detector) based on the NodeMCU ESP8266 microcontroller using an MQ-2 sensor with a buzzer and LED as a danger warning feature. Tor-G can detect when a gas leakage occurs and provides a danger signal in the form of a sound from a buzzer which can be heard several meters away by the homeowner so that an explosion can be anticipated quickly. This research carried out four tests: the sensor accuracy test, the sensor responsiveness test, the distance between the sensor and the leakage source test, and the responsiveness of the buzzer and LED test. The results of the tests show that the sensor only detects the LPG. The sensor readings are accurate since the value of Rs/Ro on the Tor-G is not much different from that of Rs/Ro on the datasheet, thus producing an error value in the 0% -0.08% range. The ideal installation position of the Tor-G is 75 cm from the gas cylinder and the danger warning system from the buzzer and red LED lights up within 18.88 seconds.



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1. INTRODUCTION

In this progressive era, there is a shift from the use of conventional fuels to environmentally friendly fuels, one such environmentally friendly fuel is LPG (Liquefied Petroleum Gas) [1] [2]. LPG is a hydrocarbon gas consisting of propane and butane liquefied under pressure for easy storage [3]. Apart from being composed of these two main components, LPG gas also consists of small amounts of propylene and butylene, as well as the addition of a small amount of a pungent gas mixture such as Ethanethiol which serves to make it easier for the gas to be smelled when a gas leak occurs [4]. Several sizes of LPG circulating on the market, namely 3 kg, 5 kg and 12 kg, but 3 kg LPG is generally used in households. Based on data from the Ministry of Energy and Mineral Resources, the use of LPG as household fuel in Indonesia will reach 8.2 million tons in 2022 [5]. This is in line with the presentation by the Central Statistics Agency (BPS) regarding the comparison of household fuel use in 2021, which consists of LPG at around 82%, firewood at 11%, kerosene 2%, electric stove 0.7%, gas network/ biogas 0.5% and briquettes/charcoal 0.08% [6]. The increase in the use of LPG as a household fuel is due to

greater heating power and equipment efficiency than other fuels. Using LPG as household fuel can also support the government program switching kerosene fuel to LPG.

While LPG has many advantages as a household fuel, it has disadvantages, including being flammable and having the potential to explode if leakage occurs and exposure to a fire source [7]. Explosions due to LPG leakages can happen when the gas level is between the Lower Explosion Threshold (ALB) and the Upper Explosion Threshold (ALA). This is because, in this situation, the levels of LPG and oxygen in the air are of balanced composition (between 1.95% and 8.95% in the air), which causes an explosion. If the leakage ed gas level is below the Lower Explosion Threshold (ALB), it is still safe and will not cause an explosion because, in this condition, the oxygen level is higher than the leakage ed gas level [8]. This also happens in ALA conditions because the leaked gas levels are higher than the oxygen levels in the air, so it does not cause an explosion but can cause health problems for users exposed to the leakage. Reporting from *kompas.com*, in the 2018-2022 period, there were 3,208 cases of fires in Indonesia involving household fires and 859 cases caused by LPG leakages. Data from the Bandar Lampung Regional Disaster Management Agency (BPBD) as of 2022 recorded 60 cases of fires due to LPG leakages [9]. The cause of LPG leakages in households are caused by several problems with the main components, such as hoses, regulators, stoves and gas cylinders, that do not meet the specified safety standards [10]. Apart from that, can identify other factors that could cause an explosion, namely negligence and the presence of inappropriate gas cylinders [11].

One effort that can be made to prevent and overcome gas leakage fires is by installing an LPG leakage detection device equipped with a danger warning when a gas leakage occurs [12] [13]. Therefore, the author developed and designed an LPG leakage detection tool based on the NodeMCU ESP8266 microcontroller using an MQ-2 sensor as a gas leakage level detector, a buzzer and an LED as a danger warning feature when the owner is at home.

2. RESEARCH METHODS

The components used in the LPG leakage detection device are as follows:

a. MQ-2 Sensor

The MQ-2 sensor is used to detect gases such as LPG, carbon monoxide, and hydrogen in the air. This sensor can detect within a temperature range of -20°C to 50°C and can use a current of no more than 150 mA at 5 V [14]. The specifications of the MQ-2 sensor include pins for 5 V VCC, ground, digital output, and analogue output. The output from the MQ-2 sensor is a resistance value that must be converted into parts per million (ppm) units to be used as input for the microcontroller [15]. The MQ-2 sensor can detect not only LPG but also other gases and smoke. To accurately detect LPG without interference from other gases, the sensor needs to be calibrated.

b. NodeMCU ESP8266

The NodeMCU ESP8266 is an IoT-based component that is open source. This device uses the ESP8266 system on a chip, which can perform microcontroller functions and provide internet connectivity. NodeMCU refers to the firmware that can be used on the development kit. The advancement of NodeMCU technology allows for features like microcontroller access with Wi-Fi and a Universal Serial Bus (USB) to serial communication chip, simplifying the user experience without needing wiring techniques or USB to serial modules to download a program. This feature makes it possible to program the NodeMCU ESP8266 using a USB data cable, similar to a smartphone data or charging cable.

c. Adaptor

An adapter or power supply is an important component used in electronic devices that provides DC voltage for powering the device. The main function of the adapter is to control the voltage to prevent overheating and to convert Alternating Current (AC) electricity into Direct Current (DC).

d. Buzzer

A buzzer is an electronic component that produces sound from electrical vibration changes. Its operating principle is that when a current flows, the coil acts as an electromagnet, attracting and repelling the diaphragm, causing air to vibrate and produce sound. Buzzers are often used as warning indicators when a device encounters an error.

e. LED

A light-emitting diode or LED is an electronic component that indicates the state of an electronic device through coloured light. LEDs have different characteristics based on the colour used. When a high current flows, the indicator light will shine very brightly. The current used in LEDs is around 10 mA-20 mA, and if the current exceeds this standard, the light may burn out. To prevent such issues, resistors are used to limit the current.

f. LCD

A liquid crystal display or LCD is an electronic component used to provide information or an indicator derived from a microcontroller.

The diagram block of the LPG leakage detection device using the MQ-2 sensor is shown in Figure 1. The MQ-2 sensor is used because it can detect LPG within a concentration range of 200 parts per million (ppm) to 10,000 ppm. Additionally, the microcontroller is utilized as an open-source program storage device. LPG leakage monitoring is performed by connecting the microcontroller to a Direct Current (DC) adapter powered by electricity. The data is then presented via a liquid crystal display (LCD), Light Emitting Diode (LED), and buzzer for close-range notification.

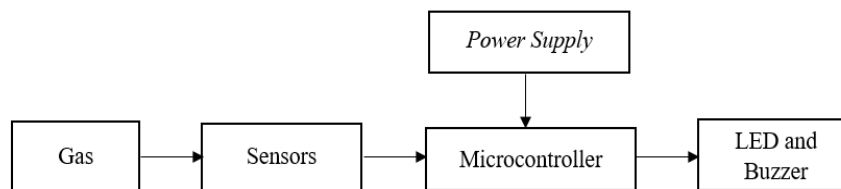


Figure 1. Diagram block of the LPG leakage detection device

The methodology for developing the LPG leakage detection device begins with the design of the electrical circuit and product layout. This initial stage involves creating a schematic diagram that includes all necessary components such as the MQ-2 sensor, NodeMCU ESP8266, buzzer, LED, LCD, and power supply. Additionally, a physical layout is planned to ensure efficient and functional placement of these components within the device.


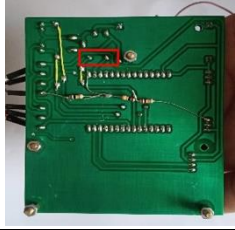


Following the layout design, the focus shifts to software development. Using the Arduino IDE, the required software is coded to meet the system's functional requirements. This code enables the system to interface with the MQ-2 sensor for gas detection, process the data received, and appropriately trigger alarms or indicators through the buzzer, LED, and LCD. The software also facilitates communication with the NodeMCU ESP8266, allowing for data transmission and remote monitoring capabilities.

The final stage is the product assembly, where the designed circuit is physically assembled on a Printed Circuit Board (PCB). This involves soldering the components securely to ensure proper electrical connections and structural stability. After assembling the hardware, the developed software is uploaded to the NodeMCU ESP8266, completing the process and ensuring that the device operates according to the intended design specifications.

3. RESULTS AND DISCUSSION

In its implementation, all components, including the MQ-2 sensor, buzzer, and LED, are connected to the microcontroller. The MQ-2 sensor is the component that interacts directly with the gas and serves as the input for the ESP8266. The input data is processed and then sent to the buzzer and LED, which act as the final outputs in this subsystem according to the conditions set on the ESP8266. The pin configuration for each component with the NodeMCU ESP8266 is provided in Table 1, and the implementation of these components is shown in Figure 2.

Table 1. Configuration of components pin with NodeMCU ESP8266 pin

Component	Pin on component	Pin on NodeMCU ESP8266	Implementation
MQ-2 Sensor	VCC Pin	15 (VCC) Pin	
	GND Pin	14 (GND) Pin	
	AO Pin	1 (AO) Pin	
Buzzer	VCC Pin	22 (D6) Pin	
	GND Pin	2 (GND) Pin	
Red LED	VCC Pin	21 (D7) Pin	
	GND Pin	14 (GND) Pin	
Green LED	VCC Pin	20 (D8) Pin	
	GND Pin	14 (GND) Pin	

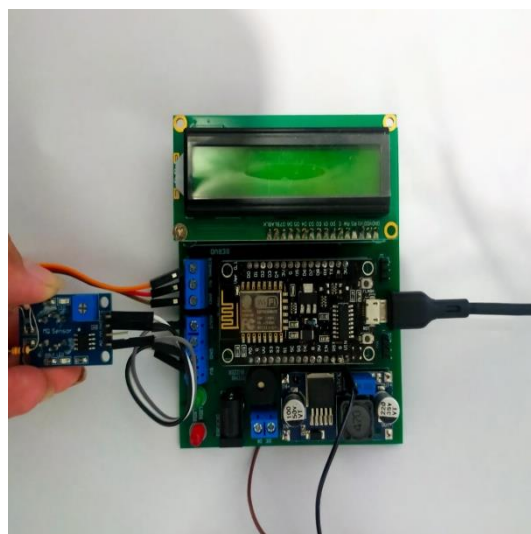


Figure 2. Implementation of components in the LPG leakage detection device

There are 4 tests in this project, namely sensor accuracy testing, testing the sensor's responsiveness, testing the sensor's distance to the source of the LPG leakage and testing the responsiveness of the buzzer and LED. Testing is carried out on the sensor to determine that the sensor, buzzer and LED are working

according to the expected device design. Each test on the Tor-G sensing subsystem is explained in detail in the following sub-section.

3.1. Sensor Accuracy Testing

Sensor accuracy testing is carried out to determine the accuracy of sensor readings. To obtain accurate data from sensor readings regarding LPG levels, data on the ratio of the resistance of LPG levels to the reference resistance in the form of air (R_s/R_o) from the value on the sensor datasheet with sensor test data is carried out. This test was carried out in a room measuring 4 m × 4.5 m at room temperature. A comparison graph of the datasheet ratio with the test ratio can be seen in Figure 3.

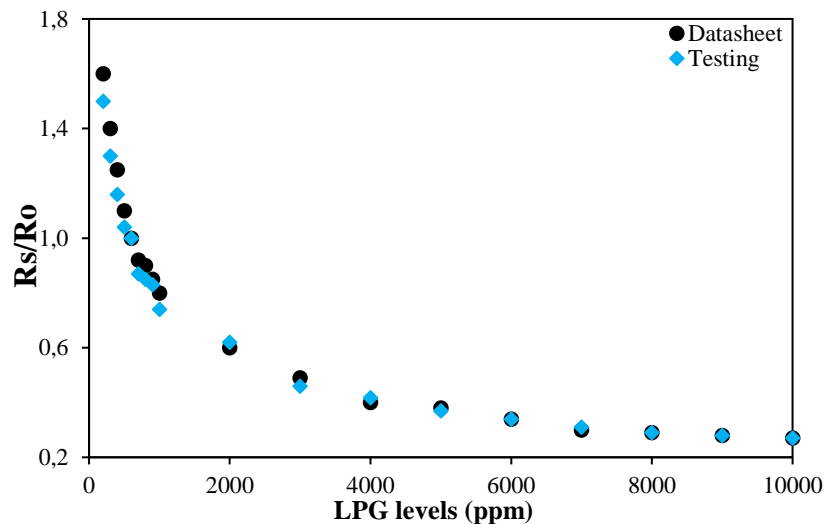


Figure 3. Graph Of Sensor Accuracy Testing Results

From testing the accuracy of the MQ-2 sensor which was carried out by comparing the ratio values from the tool readings with the ratio values on the sensor datasheet, data was obtained in the form of datasheet ratio values, test ratios and error values. The error value aims to see that the data read is accurate. The ratio value comparison is taken from 200 ppm to 10,000 ppm according to the detection range of the MQ-2 sensor for LPG. From the data that has been presented, it can be seen that the ratio value from the tool reading results is not much different from the ratio value on the sensor datasheet, resulting in an error value in the range of 0% -0.08%. The resulting error value shows that the tool reading for LPG is accurate because the resulting error value does not exceed the error tolerance value of 10%.

3.2 Sensor Responsiveness Testing

Sensor responsiveness testing is carried out to determine the relationship between the level of leakage gas and the sensor readings. Apart from that, this test also determines how quickly the sensor responds in detecting LPG leakages. The test was carried out using LPG installed with a high-pressure regulator as a source of gas leakages. There are 3 variations of lever rotation data as the leakage level used in this test, namely at rotation positions 1, 2 and 4. The distance between the leakage source and the tool is 30 cm, and it is carried out in a room measuring 4 m × 4.5 m at room temperature. This test was carried out 5 times each at each rotation point. The following data from the MQ-2 sensor responsiveness testing results can be seen in Figure 3.

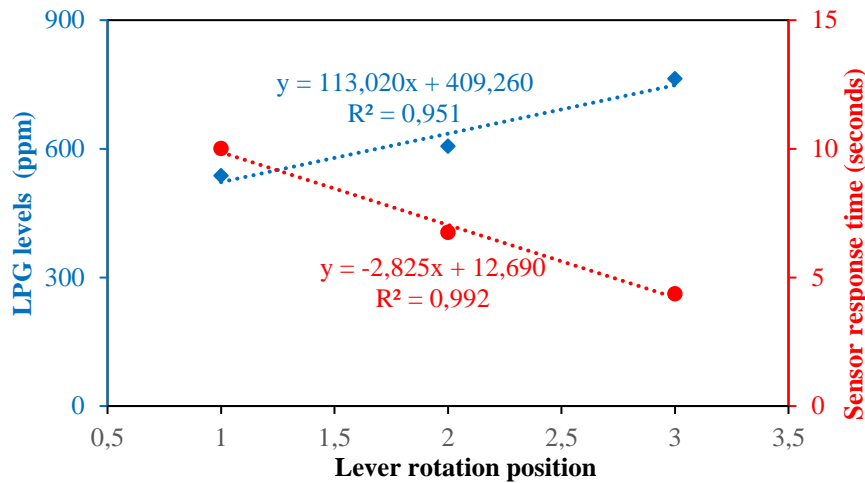


Figure 4. Graph Of Sensor Responsiveness Testing Results

From the graphic analysis, it can be concluded that the amount of gas detected by the sensor is directly proportional to the amount of rotation of the head on the regulator. This can happen because the more significant the rotation of the regulator on the gas cylinder, the greater the pressure received by the gas cylinder so the greater the level of gas that comes out. The greater the level of gas that comes out, the faster the sensor can detect a leakage. This can be seen in Figure 3, there is a relationship between the rotation of the regulator head and the detected gas level and the time measured is directly proportional. Apart from that, in this test, it can be seen that the test result data for gas levels is linear for each rotation of the regulator head.

3.3 Testing Sensor Distance from LPG Leakage Source

Testing the distance of the sensor from the source of the LPG leakage is a test carried out to determine the proportional position of the device. Apart from that, this test also determines how far the sensor can detect LPG leakages. The test was carried out using LPG installed with a high-pressure regulator as a source of gas leakages. There are 4 distances used in this test, namely at 25 cm, 50 cm, 75 cm and 100 cm. This test was carried out and carried out in a room measuring 4 meters by 4.5 meters at room temperature. This test was carried out 5 times each at each distance variation. The following graph shows the relationship between changes in the rotation of the regulator lever with rate and time, which can be seen in Figure 4.

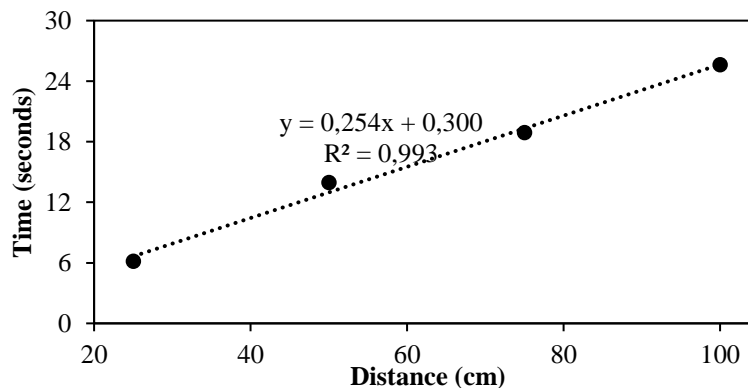


Figure 5. Graph Of Sensor Distance from LPG Leakage Source Testing Result

Test data on the distance between the sensor and the source of the LPG leakage can be seen in Figure 4. The test was carried out at four different distances (25 cm, 50 cm, 75 cm and 100 cm), each with five tests. The graph shows that the relationship between sensor distance and gas levels and response time decreases the detected gas levels as the distance increases. In addition, the sensor response time also increases with distance. This shows that distance dramatically influences the performance of the MQ-2 sensor in detecting gas levels, where the sensor is more responsive at closer distances.

Distance has a significant influence on the performance of the MQ-2 sensor. The sensor detects higher gas levels at closer distances and responds more quickly. Conversely, the detected gas levels are lower at longer distances, and the response time is longer. This must be considered when setting the sensor distance, which requires accurate and fast gas detection.

3.4 Buzzer and LED Responsiveness Testing

Testing the responsiveness of the buzzer and LED is carried out by bringing the gas cylinder with the high-pressure regulator installed close to the rotation position at point 1 at a distance of 75 cm. Distance selection in this test is done by finding the median value of the time data obtained in the previous distance test. This is done after knowing the proportional distance from the installation of the tool to the source of the leakage. The following data from the buzzer and LED responsiveness testing results can be seen in Table 1.

Table 1. Data From Buzzer and LED Responsiveness Testing Results

Testing To-	Distance (cm)	Rate (ppm)	LED response	Buzzer Response	Time (seconds)
1	75	593,10	The red LED is on	On	18,47
2		555,40	The red LED is on	On	19,50
3		585,30	The red LED is on	On	18,52
4		548,00	The red LED is on	On	18,67
5		570,10	The red LED is on	On	18,98
Average		570,38	The red LED is on	On	18,88

Testing the responsiveness of the buzzer and LED is carried out by providing a gas leakage with a high-pressure regulator installed in the rotation position at point 1 at a distance of 75 cm. The selection of this distance is based on the value of the time data obtained in the previous distance test, which aims to determine the proportional distance from the installation of the device to the source of the gas leakage. An average gas content value of 570.38 ppm indicates that the MQ-2 sensor is quite sensitive in detecting gas levels at this distance. The red LED and buzzer that light up on each trial suggest that the sensor can detect gas levels in the alert condition to trigger an alarm, and consistency in this response indicates that the warning system is working correctly. The average response time of 18.88 seconds means the sensor takes approximately 19 seconds to detect gas levels and activate the warning device. From the results of the data analysis in Table 4.1, it can be concluded that the MQ-2 sensor at a distance of 75 cm has good capabilities in detecting gas levels and providing a warning response via a red LED and buzzer. The detected gas levels were pretty consistent, and the warning device functioned well whenever the alert condition was reached.

4. CONCLUSION

LPG leakage detection device using the MQ-2 sensor equipped with a danger warning system or Tor-G can detect LPG leakages in 3 levels of conditions, namely safe conditions for leakage levels of 200 ppm-500 ppm, alert conditions at levels above 500 ppm - 1000 ppm and dangerous conditions for levels above 1000 ppm. From the tests related to sensor accuracy that have been carried out, data for safe conditions was obtained, and the error value from the comparison of the ratio values on the datasheet with the test data was 0.26%. In alert conditions, the error value is 0.21%; in dangerous conditions, the error value is 0.02%. From the three errors data, it can be concluded that the sensor readings in detecting LPG are accurate because the error value does not exceed the error tolerance limit. These three conditions have preventive measures to prevent explosions due to LPG leakages. Tor-G is equipped with an early warning system in the form of a sound from a buzzer and a red LED, which will be active when the system detects leakageing gas levels above 500 ppm-1000 ppm or in standby condition. From tests carried out on the buzzer and LED responses, which were carried out 5 times, it was found that both warning systems succeeded in providing information in the form of sound and visual signals within 18.88 seconds so that users at home could take preventive action in the form of opening windows as air ventilation. Even though an LPG leakage detection device using the MQ-2 sensor shows accurate results, ensuring reliable detection at lower concentrations of LPG could involve integrating additional sensors

or developing advanced algorithms for data processing. Additionally, investigating the use of alternative power sources, such as solar power, could enhance the device's sustainability and make it more versatile and valuable for broader applications in residential, industrial, or commercial settings.

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