Design Gas Leak Detection System in Residential Areas Using LoRa Communication

Bima Satria Adji Nugraha[1], Muhammad Syirajuddin Suja'i[2*], Dianthy Marya[3]

[1,3] Digital Telecommunication Network Study Program, Department of Electrical Engineering, State Polytechnic of Malang, 65141, Indonesia.

[2] Telecommunication Engineering Study Program, Department of Electrical Engineering, State Polytechnic of Malang, 65141, Indonesia.

[1]bimasatriaan@gmail.com, [2]syirajuddin@polinema.ac.id, [3]dianthy@polinema.ac.id

***Abstract*—This research designs and implements a gas leak detection system for residential areas utilizing Long Range (LoRa) communication to enhance safety. The proposed system consists of multiple transmitter nodes, each integrated with an MQ-6 sensor (for liquefied petroleum gas/LPG), an MQ-2 sensor (for combustible gases), a flame sensor, and a DHT11 temperature sensor. A gas solenoid valve is incorporated to automatically shut off the gas supply upon leak detection. All sensor data from the transmitter nodes are sent wirelessly via LoRa to a central receiver unit, which then relays the information to a user-accessible smartphone application for real-time monitoring. Testing results demonstrate the system's effectiveness: the MQ-6 and MQ-2 sensors successfully detected hazardous gas concentrations, reaching 230 PPM and 234 PPM respectively, which are levels indicating a significant leak risk. The flame sensor accurately identified fire presence within a 45 cm range, and the DHT11 sensor provided ambient temperature readings (e.g., 30°C). The study concludes that the integration of multi-sensor nodes with LoRa communication presents a reliable, low-power, and wide-coverage solution for early warning and prevention of gas-related accidents in residential communities.**

***Keywords*— Gas Leak Detection, LoRa, Microcontroller ESP8266, MQ-6 Sensor, Home Safety System, Early Warning System, LPG.**

I. INTRODUCTION

Liquefied Petroleum Gas (LPG), primarily composed of propane (C_3H_8) and butane (C_4H_{10}), remains a prevalent fuel source for domestic cooking globally due to its high calorific value and portability [1]. However, its inherent flammability and the high pressure of storage cylinders present significant safety hazards. Leaks, often resulting from faulty regulators, degraded hoses, or improper cylinder handling, can lead to catastrophic fires or explosions if undetected [2], [3]. Statistics from fire departments worldwide consistently attribute a substantial percentage of residential fires to LPG-related incidents [4].

Consequently, the development of reliable early warning systems is paramount. Traditional detection methods often rely on standalone semiconductor gas sensors, like the MQ series, which trigger local audible or visual alarms upon exceeding a gas concentration threshold [5], [6]. While cost-effective, these systems suffer from critical limitations: they lack proactive mitigation mechanisms (e.g., automatic gas supply shut-off) and cannot provide remote alerts, leaving properties vulnerable when unoccupied [7], [8]. The integration of Internet of Things (IoT) principles offers a solution by enabling remote monitoring and control.

Among IoT communication protocols, LoRa (Long Range) technology is particularly suited for wide-area, low-power applications. Its superior range (up to several kilometers in suburban areas) and low energy consumption outperform traditional Wi-Fi or Bluetooth for decentralized residential monitoring networks [9], [10]. Recent studies have begun exploring LoRa for safety applications, demonstrating its efficacy in environmental monitoring and alert dissemination [11], [12]. However, integrated systems combining multi-parameter sensing (gas, fire, temperature), automatic physical intervention, and LoRa-based communication for residential LPG safety represent a nascent research area requiring further practical implementation and validation.

To address the identified gaps, this research proposes and implements a comprehensive gas leak detection and mitigation system for residential areas utilizing LoRa communication. The system employs a sensor array comprising MQ-2 and MQ-6 gas sensors for redundant combustible gas detection, a flame sensor for fire identification, and a DHT11 sensor for ambient context monitoring. An ESP8266 microcontroller processes sensor data and, upon detecting a hazard, executes an automatic shutdown of the gas supply via a solenoid valve while simultaneously transmitting real-time alert data via a LoRa RA-02 module to a remote receiver. This design aims to enhance household safety through immediate local response and reliable remote notification, forming a robust layer of protection against LPG-related accidents.

II. METHOD

This study employed an experimental research methodology involving the design, construction, programming, and performance evaluation of a prototype gas leak detection system. The process was structured into four primary phases: system architecture design, hardware integration and assembly, software development for the microcontroller and receiver, and functional testing of the complete prototype.

A. System Block Diagram

The overall system architecture, depicted in Fig. 1, is divided into a transmitter (sensing) node and a receiver (monitoring)

*Corresponding author

node, communicating via LoRa. The transmitter node is installed near the LPG usage point and integrates multiple sensors with an actuation unit.

Sensing Unit: This unit includes: 1) An MQ-6 sensor, optimized for LPG detection [6]; 2) An MQ-2 sensor for broader combustible gas detection (e.g., methane, smoke) providing redundancy [13]; 3) A flame sensor (IR receiver) to detect fire presence; and 4) A DHT11 sensor to monitor ambient temperature and humidity, providing environmental context.

Processing and Control Unit: A NodeMCU ESP8266 microcontroller serves as the central processor. It reads analog/digital signals from all sensors, executes the detection algorithm, and controls output devices.

Actuation Unit: Upon hazard confirmation, the ESP8266 triggers a 5V relay module, which cuts power to a normally-open 12V DC solenoid valve installed on the gas line, halting the fuel supply. A local buzzer is also activated for in-situ auditory warning.

Communication Unit: A LoRa RA-02 (SX1278) module connected to the ESP8260 transmits sensor readings, system status, and alert messages. The receiver node, comprising another LoRa module connected to an Arduino or similar microcontroller, captures this data for display on an LCD and can forward it to a cloud server or smartphone application for user alerts [14], [15].

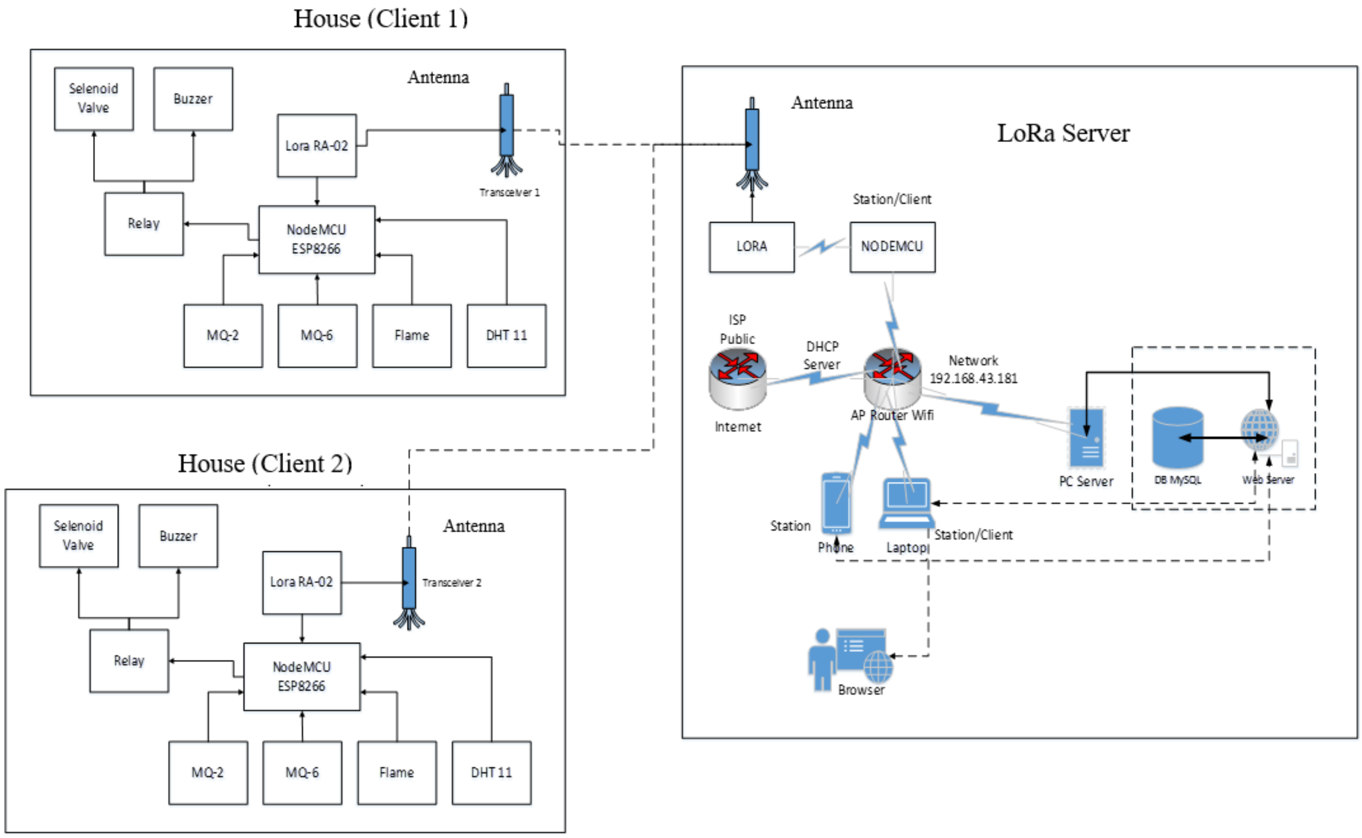

Figure 1. System block diagram

B. System Flowchart

The software flowchart governing the transmitter node's operation is shown in Fig. 2. After initializing all peripherals, the system enters a continuous loop:

- Data Acquisition: The ESP8266 sequentially reads data from the MQ-6, MQ-2, flame, and DHT11 sensors.
- Hazard Assessment: The readings are compared against predefined safety thresholds (e.g., 200 ppm for MQ-6, a digital high for flame sensor).
- Automatic Response: If any sensor indicates a hazard (gas leak or fire), the system immediately: i) Activates the buzzer, ii) Energizes the relay to close the solenoid valve, and iii) Formats and transmits a high-priority alert packet via LoRa.
- Regular Communication: Under normal conditions, the system packages sensor data into a periodic status packet (e.g., every 3 seconds) and transmits it via LoRa to the receiver for monitoring.
- Manual Override: The system can also accept manual "close valve" or "reset" commands sent from the receiver node via LoRa, ensuring remote operator control.

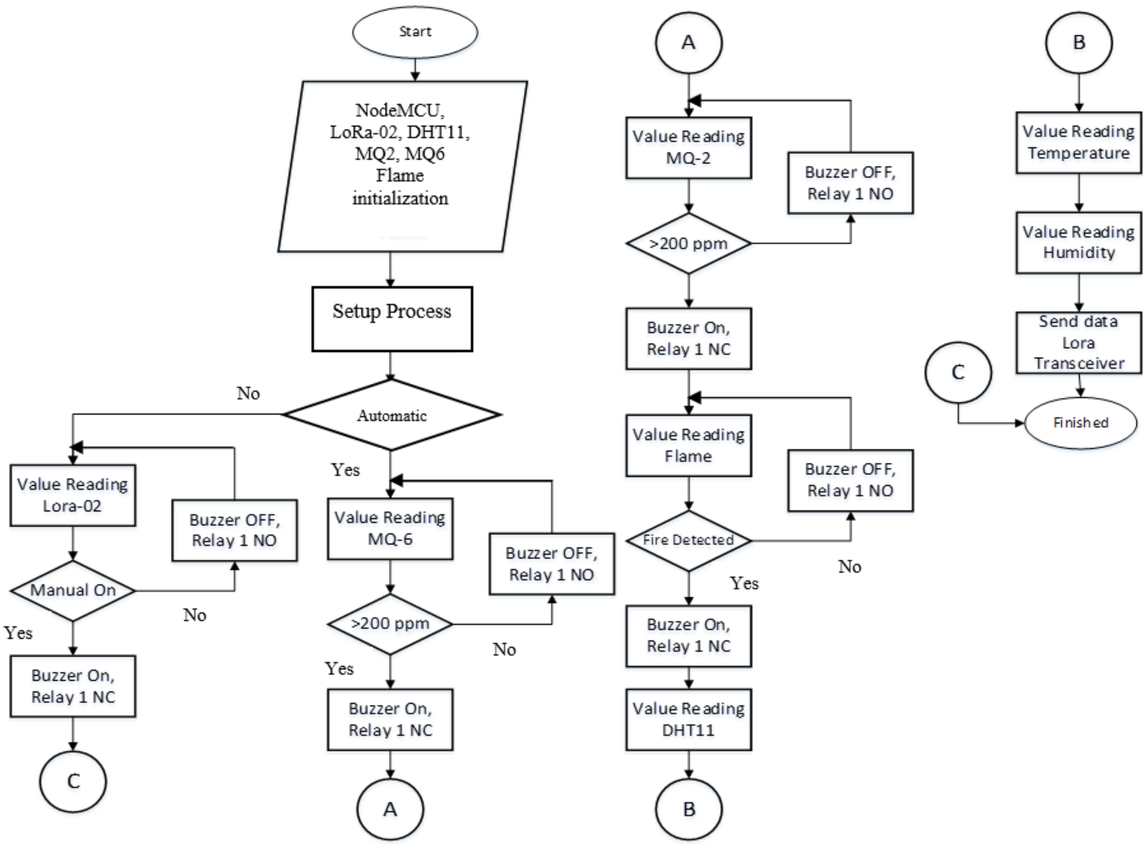

Figure 2. Flowchart system

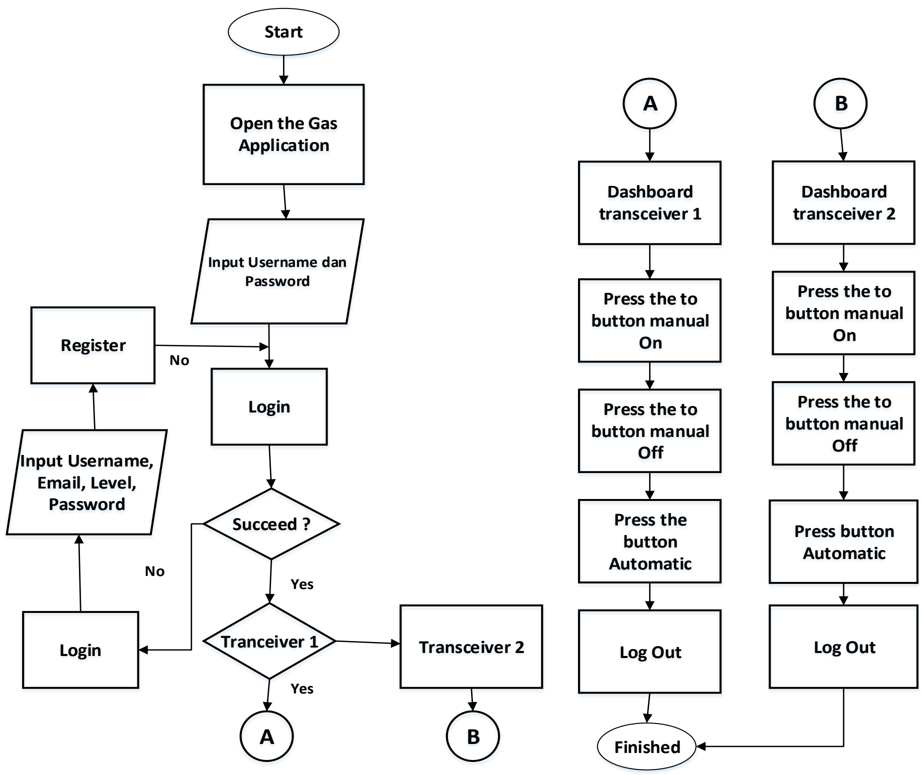

Figure 3. Tool operating procedures

C. Testing and Evaluation Protocol

The prototype underwent rigorous functional testing. This included: 1) Sensor Calibration: Exposing gas sensors to known concentrations of LPG to validate accuracy; 2) Threshold Testing: Triggering the buzzer and valve actuation at set points; 3) Range Testing: Evaluating the reliability and packet loss of the LoRa link at varying distances (50m to 1km) in an urban residential environment; and 4) Integrated Scenario Testing: Simulating gas leaks and flame events to assess the end-to-end response time and reliability of the complete system [16].

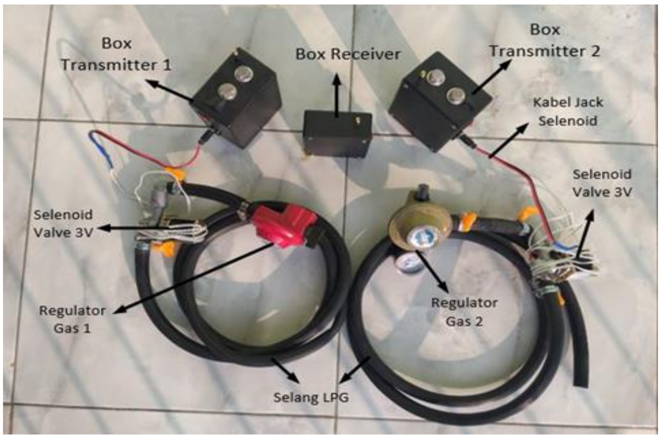

Figure 4. Tool design results

Figure 5. The results of the tool design into LPG

Figure 6. Transmitter hardware design results 1

Figure 7. Transmitter hardware design results 2

Figure 8. Receiver box design results

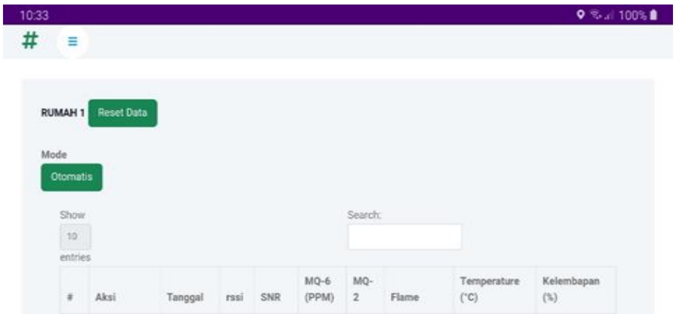

Figure 9. Software design results

III. RESULTS AND DISCUSSION

A. Testing the Gas Sensor MQ-6 and MQ-2 in 4 Conditions Transmitter 1

The gas sensor measurement testing is conducted to detect four conditions with the aim of assessing the performance, precision, and accuracy of the gas sensor.

The measurement results show that when the regulator is not installed, the MQ-6 sensor records a gas concentration of 87 PPM, while the MQ-2 sensor records 85 PPM. This indicates that both sensors have comparable sensitivity under low-leak conditions, with MQ-2 showing a slightly lower detection value; however, the difference is relatively small and does not significantly affect leak identification.

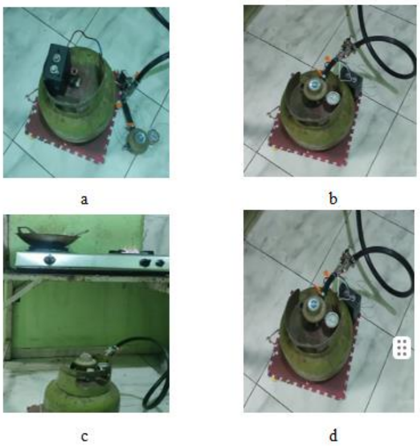

Figure 10. a) Regulator disconnected, b) built-in regulator, c) the stove is on, d) gas leak.

The measurement condition on Fig. 10 and the results show on Table I. When the regulator is not installed, the results show the MQ-6 sensor records a gas concentration of 87 PPM, while the MQ-2 sensor records 85 PPM. This indicates that both sensors have comparable sensitivity under low-leak conditions, with MQ-2 showing a slightly lower detection value; however, the difference is relatively small and does not significantly affect leak identification.

When the regulator is installed and a gas leak occurs, the performance difference between the two sensors becomes more apparent. The MQ-2 sensor records 107 PPM under normal regulator conditions and increases to 494 PPM during a gas leak, indicating good responsiveness to changes in gas concentration. In contrast, the MQ-6 sensor records 88 PPM under normal conditions but rises sharply to 739 PPM during a leak, suggesting higher sensitivity to LPG gas at higher concentration levels.

Furthermore, when the stove is ignited, the MQ-2 sensor detects a higher leakage value of 150 PPM compared to 87 PPM from the MQ-6 sensor. This indicates that MQ-2 is more responsive to combustion-related gas emissions, while MQ-6 remains more stable under normal combustion conditions. Overall, these results demonstrate that MQ-2 is more sensitive to general combustible gases, whereas MQ-6 is more selective and responsive to high-concentration LPG leaks, making the combination of both sensors effective for comprehensive gas leak detection.

TABLE I
TESTING PPM GAS SENSOR MQ-2 AND MQ-6 TRANSMITTER 1

Condition	MQ-6	MQ-2
Regulator not installed on LPG	87 PPM	85 PPM
Regulator installed on LPG	88 PPM	107 PPM
When the stove is turned on	87 PPM	150 PPM
Gas Leak	739 PPM	494 PPM

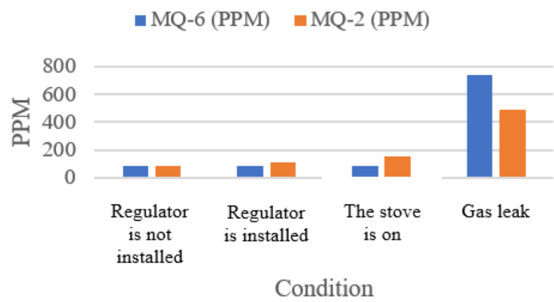

Figure 11. Comparative chart of MQ-6 and MQ-2 transmitter 1

B. Testing the Gas Sensor MQ-6 and MQ-2 in 4 Conditions Transmitter 2

The gas sensor measurement testing is conducted to detect four conditions with the aim of assessing the performance, precision, and accuracy of the gas sensor.

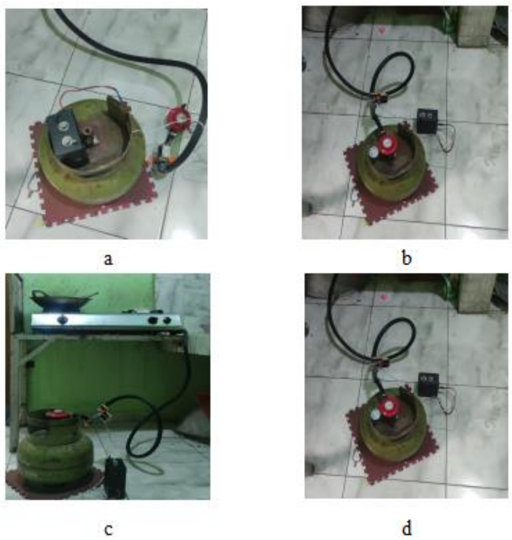

Figure 12. a) Regulator disconnected, b) built-in regulator, c) the stove is on, d) gas leak.

The measurement condition on Fig. 12 and the results show on Table II. The test results show that when the regulator is not installed, the MQ-6 sensor records a gas concentration of 60 PPM, while the MQ-2 sensor records 99 PPM. This indicates that MQ-6 detects lower background gas levels compared to MQ-2, suggesting better stability and lower sensitivity to minor or residual gas presence. This characteristic makes MQ-6 more effective in minimizing false leak indications under normal conditions.

When the regulator is installed, the MQ-6 sensor still records a stable value of 60 PPM, whereas the MQ-2 sensor increases significantly to 152 PPM. This result demonstrates that MQ-2 is more sensitive to gas exposure in the presence of the regulator, while MQ-6 maintains consistent readings, indicating higher stability in normal operating conditions.

The difference between the two sensors becomes more pronounced when the stove is turned on. The MQ-2 sensor records 157 PPM, showing a strong response to combustion-related gases, whereas the MQ-6 sensor records only 62 PPM, indicating that MQ-6 is less affected by normal stove operation. This suggests that MQ-2 is more responsive to general combustible gases, while MQ-6 is more selective toward LPG leakage.

During a significant gas leak, the MQ-6 sensor exhibits a sharp increase to 1024 PPM, exceeding the MQ-2 sensor value of 771 PPM. This confirms that MQ-6 has higher sensitivity at high LPG concentrations, making it more effective for detecting severe leakage conditions. Overall, these results indicate that MQ-2 performs well in detecting low to moderate gas presence, while MQ-6 excels in detecting high-concentration LPG leaks, supporting the use of both sensors for reliable and comprehensive gas leak detection.

TABLE II
TESTING PPM GAS SENSOR MQ-2 AND MQ-6 TRANSMITTER 2

Condition	MQ-6	MQ-2
Regulator not installed on LPG	60 PPM	99 PPM
Regulator installed on LPG	60 PPM	152 PPM
When the stove is turned on	62 PPM	157 PPM
Gas Leak	1024 PPM	771 PPM

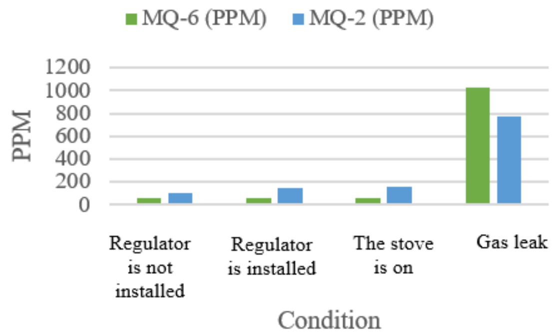

Figure 13. Comparative chart of MQ-6 and MQ-2 transmitter 2

C. LoRa Module Testing to Find Out RSSI Transmitter 1

LoRa module testing set for transmitter 1 show on Fig. 14. Distance measurement testing is conducted to determine the Received Signal Strength Indication (RSSI) in dBm, which represents the strength of the data transmission signal from the transmitter to the LoRa receiver. The RSSI values are used to evaluate communication quality and signal attenuation as the transmission distance increases, providing an indication of the reliability and performance of the LoRa communication system.

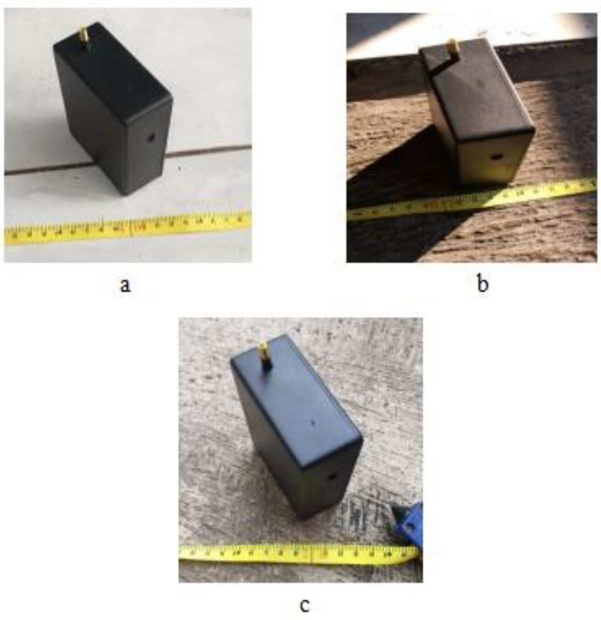

Figure 14. a) 4 meters; b) 8 meters; c) 12 meters

The data transmission distance from transmitter to receiver provides valuable insight into signal quality and effective distance in wireless communications. The test result show on Table III. In this test, the three distance points tested, namely 4 meters, 8 meters and 12 meters, showed RSSI values that decreased as the distance increased. At a distance of 4 meters, the RSSI value reaches -69, which indicates a signal with good and stable strength.

However, when the distance is expanded to 8 meters, the RSSI value drops to -75, indicating a decrease in signal strength that may be caused by the longer distance and possible obstacles. At a distance of 12 meters, the RSSI value further drops to -80, which is an indication that the signal is experiencing significant degradation and may not be strong enough to ensure good data transmission.

TABLE III
TESTING TRANSMITTER 1 DATA SENDING DISTANCE TO LORA RECEIVER TO FIND OUT RSSI

Distance	RSSI (dBm)
4 meters	-69 dBm
8 meters	-75 dBm
12 meters	-80 dBm

D. LoRa Module Testing to Find Out RSSI Transmitter 2

LoRa module testing set for transmitter 2 show on Fig. 15. Distance measurement testing was conducted to evaluate the Received Signal Strength Indication (RSSI) of the LoRa communication used in Transmitter 2. RSSI values, expressed in dBm, are used to represent the strength of the received signal from the transmitter to the LoRa receiver.

This parameter is important for assessing communication reliability, signal quality, and the effective transmission range of the LoRa module. By analyzing RSSI variations at different distances, the performance of the wireless link and its suitability for residential gas monitoring applications can be evaluated.

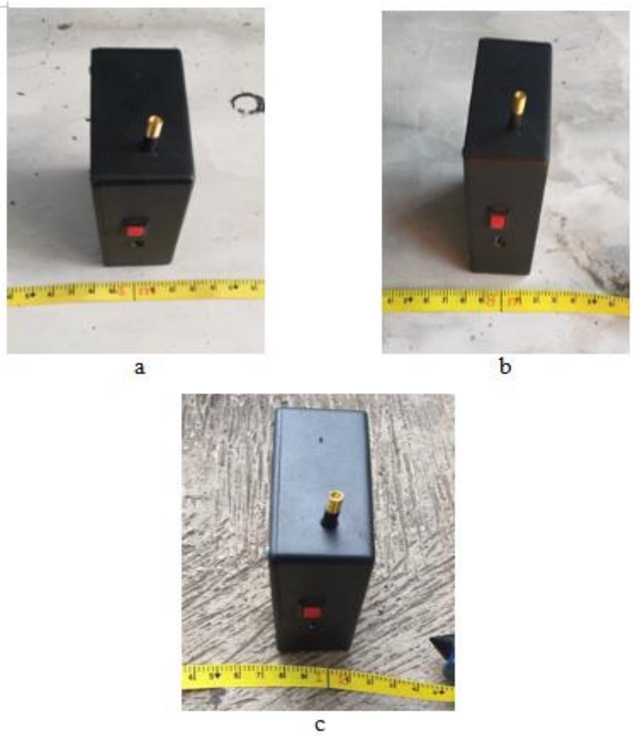

Figure 15. a) 4 meters, b) 8 meters, c) 12 meters

The data transmission range from the transmitter to the receiver provides a fairly clear understanding of how far the signal can reach the receiver with sufficient quality. The test result show on Table IV. In this test, three distance points were examined: 4 meters, 8 meters, and 12 meters, each with different RSSI values. At a distance of 4 meters, the RSSI value is -69, indicating a strong and good signal strength. However, as the distance expands to 8 meters, the RSSI value drops to -75, indicating a decrease in signal strength, possibly due to the increased distance and potential obstacles. At a distance of 12 meters, the RSSI value further decreases to -81, indicating a significant signal drop.

TABLE IV
TESTING TRANSMITTER 2 DATA SENDING DISTANCE TO LORA RECEIVER TO FIND OUT RSSI

Distance	RSSI (dBm)
4 meters	-69 dBm
8 meters	-75 dBm
12 meters	-81 dBm

E. Flame Sensor Distance Testing Transmitter 1

Flame sensor distance testing transmitter for transmitter 1 show on Fig. 16. Testing distance measurements are necessary to detect the presence of fire around LPG gas cylinders.

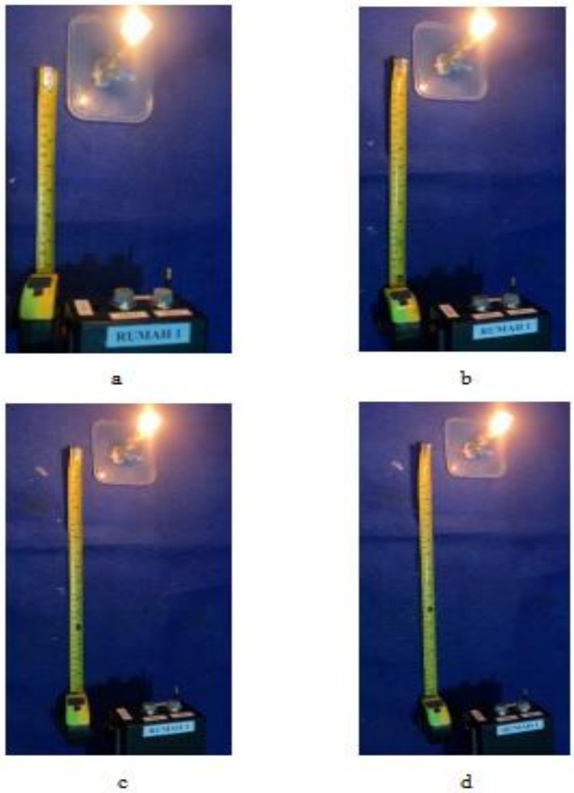

Figure 16. a) 20 cm, b) 30 cm, c) 40 cm, d) 45 cm

The test result show on Table V. The flame sensor has a light wavelength range of up to 760nm - 1100nm. The purpose of testing the range of this flame sensor is to determine the maximum distance at which the flame sensor can detect fire. The test results indicate that the maximum distance at which the flame sensor can detect fire is 40 cm. Based on these test results, it can be concluded that the flame sensor is in good condition.

TABLE V
FLAME SENSOR DISTANCE TESTING TRANSMITTER 1

Distance	Condition
20 cm	Fire Detected
30 cm	Fire Detected
40 cm	Fire Detected
45 cm	Fire Not Detected

F. Flame Sensor Distance Testing Transmitter 2

Flame sensor distance testing transmitter for transmitter 2 show on Fig. 17. Testing distance measurements are necessary to detect the presence of fire around LPG gas cylinders.

This flame sensor has a light wavelength of up to 760nm - 1100nm (nanometers). This fire sensor range test aims to determine the maximum distance of fire that can be detected by the flame sensor. The test results show on Table VI, that the maximum distance of fire detected by the flame sensor is 40 cm. Based on the test results, it can be concluded that the flame sensor is in good condition.

TABLE VI
FLAME SENSOR DISTANCE TESTING TRANSMITTER 2

Distance	Condition
20 cm	Fire Detected
30 cm	Fire Detected
40 cm	Fire Detected
45 cm	Fire Not Detected

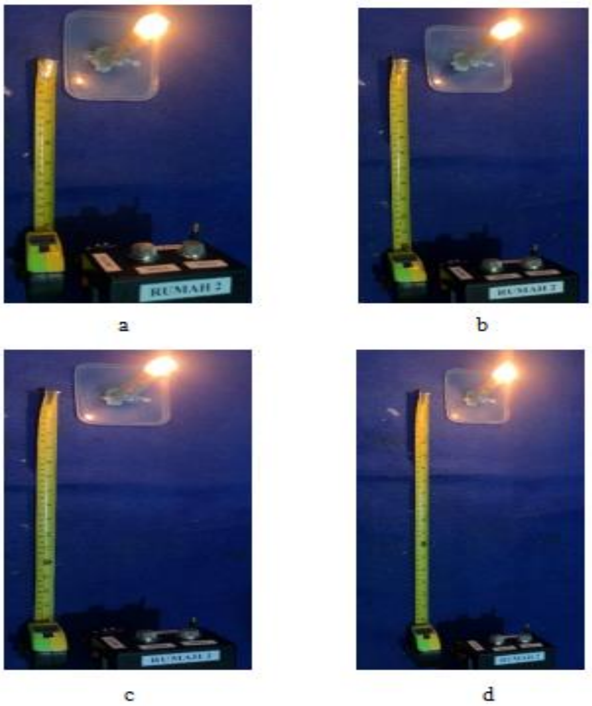

Figure 17. a) 20 cm, b) 30 cm, c) 40 cm, d) 45 cm

G. DHT 11 Sensor Testing

Testing the DHT11 sensor measurements is employed to detect three conditions based on temperature and humidity levels in the kitchen environment. The test result show on Table VII for transmitter 1 and Table VII for transmitter 2.

TABLE VII
TESTING OF THE DHT 11 TEMPERATURE SENSOR AND THERMOMETER TRANSMITTER 1

Space Conditions	DHT 11	Thermometer
Normal	27 °C	28 °C
Currently	30 °C	31 °C
Hot	34 °C	33 °C

There are three conditions: In normal room conditions, the DHT11 temperature is around 27°C, and the thermometer reads approximately 27°C, which is considered comforTable. In moderate room conditions, the DHT11 temperature is slightly higher, around 30°C, and the thermometer reads 31°C, which is still relatively comforTable but may start to feel a bit warmer. However, in hot room conditions, the DHT11 temperature jumps to 34°C, while the thermometer reads 27°C, creating a hot environment.

TABLE VIII
TESTING OF THE DHT 11 TEMPERATURE SENSOR AND THERMOMETER TRANSMITTER 2

Space Conditions	DHT 11	Thermometer
Normal	27 °C	28 °C
Currently	30 °C	31 °C
Hot	34 °C	33 °C

There are three conditions: In normal room conditions, the DHT11 temperature is around 27°C, and the thermometer reads approximately 28°C, which is considered comforTable. In moderate room conditions, the DHT11 temperature is slightly higher, around 30°C, and the thermometer reads 31°C, which is still relatively comforTable but may start to feel a bit warmer. However, in hot room conditions, the DHT11 temperature jumps to 33°C, while the thermometer reads 32°C, creating a hot environment.

IV. CONCLUSION

Based on the results of the research and discussion, the following conclusions can be drawn: In this design, two transmitters equipped with gas sensors MQ-6, MQ-2, flame sensor, and temperature sensor DHT11 have been developed to detect any possible gas leaks. This system also involves a gas solenoid valve as a cutoff for the gas flow to the stove. Data from all sensors on the transmitters are transmitted through LoRa communication to the receiver and can be accessed through a smartphone. The MQ-6 sensor recorded a value of 230 PPM during testing, while the MQ-2 sensor reached 234 PPM, with an average gas leakage result 200 PPM, indicating a significant gas leak. The flame sensor effectively detects the presence of fire at a distance of less than 45 cm, and the temperature sensor shows a room temperature of 30°C. Thus, the entire sensor system can effectively read, identify, and respond to the potential dangers of gas leaks, significantly enhancing the safety and security levels in the use of installed LPG gas. This application enables users to receive real-time data and notifications from various sensors, including the MQ-6, MQ-2 gas sensors, flame sensor, temperature sensor, and DHT11 humidity sensor. The application is also equipped with automatic and manual control features to activate or deactivate the gas solenoid valve, allowing for a swift response to potential gas leakage hazards with notifications received on the smartphone. Users can monitor gas concentrations, temperature, and detect the presence of fire, providing convenience in maintaining safety and security.

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