

LPG Gas Leakage Detection and Control System Using ESP32 with Automated Solenoid Valve and Telegram Integration

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ABSTRACT

A gas leak is hazardous since it may cause fires, lead to explosions and result in people dying. This is the reason why it is important to have procedures for detecting a gas leak and for stopping it quickly. A smart gas leak system built on the Internet of Things is described in this study. This system is able to detect a gas leak promptly, gives the user an immediate alarm and automatically switches off the gas. It uses an ESP32 microcontroller as its main element. An MQ-2 gas sensor is employed to detect a leak of LPG gas. A relay-controlled solenoid valve is used to stop the gas flow. A buzzer and an I2C LCD display are used to give alarms. A Telegram bot sends messages quickly and enables people to check from a distance. Tests have proved that the system detects gas leaks accurately and reacts swiftly when the gas level goes above the limit. As soon as a gas leak is detected, the system sounds the alarm, closes the valve to stop the further flow of gas and sends a Telegram message. The system offers a real solution for improving gas leak safety by combining instant communication with automatic action. It works well in houses and small factories and can act as a basis for more intelligent gas safety systems in the future.

Keywords: *Internet of Things; Gas Leak Monitoring; ESP32; MQ-2 Gas Sensor; Telegram Notification; Solenoid Valve Control*

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1. INTRODUCTION

Catastrophic occurrences including explosions, fires, poisoning, and asphyxiation are a significant risk connected to gas leaks. These incidents happen in both residential and commercial settings when methane and liquefied petroleum gas (LPG) are utilized. When property is lost and human lives are at risk due to delayed notice and response, the risk becomes much more severe. Thus, a major endeavor to increase public safety and reduce environmental harm is the creation of an accurate, quick, and dependable gas leak detecting system.

Over the past ten years, sensor networks and the Internet of Things (IoT) have rapidly advanced and altered safety and monitoring systems. Local alarm systems like buzzers or indication lights that only provided warnings in the nearby area were the only options available in early gas detection designs. In order to improve accessibility and response time, remote monitoring solutions utilizing cloud platforms and SMS-based notifications have been developed as a result of the development of IoT technology. An ESP32 microcontroller integrated with the ThingSpeak cloud platform was used to create an Internet of Things (IoT) gas leak and fire detection system. This system successfully monitored environmental conditions and sent data to the cloud, but it lacked an automatic mitigation mechanism like a solenoid valve to stop gas flow [1]. Another study employed a MQ-6 sensor to identify gas leaks and a solenoid valve for automatic gas closure. Even though the system was successful in providing local security, it did not permit remote alerts or user interaction capabilities for more comprehensive real-time control [2].

The IoT idea has also been adopted by other sectors, such as smart agriculture and environmental automation. An instrumentation system for hydroponic farming data collection and monitoring that employed an ESP32 microcontroller connected to Google Firebase demonstrated real-time data transfer, monitoring, and cloud-based integration [3]. This implies that when it comes to providing automation and remote control, IoT-based systems are highly flexible. Although these systems increase connectivity and monitoring efficiency, they do not yet meet the urgent need for real-time automatic mitigation in hazardous environments, such as gas leak incidents [4].

Numerous studies have looked on IoT-based gas sensing and monitoring systems. Buzzers and LCDs are used in a gas fire detection system that uses an ATmega8535 microprocessor and MQ-2 sensor to provide instant alerts [5]. A later invention connected an Arduino Nano to the ThingSpeak platform to display the gas level remotely, however the communication was one-way only [6]. An additional research integrated a SIM800L GSM module with an SMS alert system so that users could receive SMS notifications of site modifications even when they were not present [7]. The Telegram bot and an ESP8266 NodeMCU module were recently used in a project that enabled SMS alerts via a mobile device [8]. Although these efforts have improved notification methods, the great majority of systems are still unable to integrate intelligent communication with automatic scenario mitigation in a single system.

The Internet of Things (IoT) is a technology that uses the internet to link various physical things, enabling them to automatically exchange and analyze data with the goal of making daily chores less labor-intensive and more efficient [9]. In terms of gas safety, the Internet of Things (IoT) is a platform that collaborates by combining detection, communication, and reaction capabilities simultaneously to improve surveillance accuracy and enable quick emergency response [10]. The primary brain of this system, the ESP32 microcontroller, performs both control and calculation and includes integrated Wi-Fi networking. It instantly transmits data to every component of the system [3]. The MQ-2 gas sensor is the part that determines whether combustible gas is present. Because that gas sensor is sensitive to a variety of gasses, including propane and LPG, it helps avoid hazardous circumstances that could result in poisonous or explosive effects by detecting extremely low concentrations of these gasses [11]. The system uses a Telegram bot to facilitate two-way real-time communication, which allows users to interact with the device, receive instant updates on its status, and make quick decisions in dire circumstances [12]. Last but not least, a solenoid valve functions as a reaction mechanism by cutting off the gas supply as soon as a leak is discovered, lowering the risk of an explosion and removing the need for human intervention in the manual handling of situations [13].

Despite these advancements in technology, there is still a field of study for which there is no known cure. The majority of research on Internet of Things-based gas detection systems focused on either local automatic control [2] or distant notification [1]. Few have combined these two capabilities into a unitary interactive system that can detect, alert, and mitigate a gas leak in real time. Previous studies revealed encouraging advancements in IoT-based surveillance, but none of them could be used as a one-stop shop that combined gas valve shutdown with Telegram instant messaging [1][2][14].

To address this issue, the current study focuses on developing and implementing an intelligent gas leak detection approach that uses IoT technology, real-time warnings via Telegram bots, and a valve to lessen the gas leak. This project uses a modular ESP32 board as the microcontroller, a MQ-2 sensor for gas detection, and other essential parts like a relay, buzzer, and I2C display for user feedback. The main objectives of this work are to: (1) develop a fully internet-connected gas detection and leak mitigation system; (2) build functions for real-time gas level monitoring and alerts via a chat application with bots; and (3) assess the accuracy, response time, and dependability of the system's gas leak response [3], [7], [10], [11], and [13].

In this study, a platform that integrates automated hazard prevention with AI-assisted gas leak detection alerts is presented. This strategy offers a multifaceted, time-and space-efficient, and highly adaptable protection mechanism for gas leak prevention. This paper's primary contribution is a completely new method that integrates an interactive Telegram alert system with a control solenoid valve, which was not sufficiently covered in previous research [8], [9], and [13]. This innovative concept opens the door for Internet of Things-based safety systems that combine autonomous control and real-time communication to improve accident prevention. Modern IoT-based gas leak detection applications have made extensive use of MQ-series autonomous monitoring sensors to enhance user safety and early leak detection [1], [2], [4], and [5].

Continuous sensing and real-time data access are essential for handling hazardous situations like gas leaks, such as those involving liquefied petroleum gas (LPG) [3], [9], [10], and [11]. IOT monitoring platforms provide these

capabilities. The benefits of Telegram bots, which enable quick and dependable communication between sensing equipment and end users, have been demonstrated by certain researchers using Telegram to alert consumers in the event of a gas leak and for user interaction [8], [12], and [17]. As a result, users can receive immediate notifications through Telegram and take the appropriate steps to lessen the impact of such incidents.

Despite these advancements, previous studies have not adequately connected Telegram's features to the direct action of effectors like the solenoid valve mechanism, which is a crucial component of the autonomous hazard containment system. Solenoid valves have been shown to be effective in regulating fluid and gas flow in Internet of Things-based automation [19]. The tight linkage of live Telegram alerts with trigger signals to open solenoid valves from a distance is therefore the centerpiece of our research, merging many components into a fully automated safety system that can actively monitor and respond to a hazard.

2. RELATED WORK

2.1 Sensor-Based Gas Detection Systems

The use of MQ-series sensors in conjunction with microcontrollers for the early identification of hazardous gas accumulation has been the main focus of research on gas leak detection. In contemporary IoT-based gas leak detection systems, MQ-series sensors are extensively employed in automated monitoring to improve early detection accuracy and user safety [1], [2], [4], [5]. Using an ESP32 microcontroller interfaced with the ThingSpeak cloud platform, Ibrahim [1] created an Internet of Things (IoT) gas leak and fire detection system that successfully monitors environmental conditions and transmits data to the cloud. However, it lacks an automated mitigation mechanism, such as a solenoid valve to stop the gas flow. Tommy [2] has created a gas leak detection system that uses a solenoid valve for automatic gas closing and a MQ-6 sensor. Although the system offered good local protection, it was unable to deliver distant alerts or the user interaction features required for more extensive real-time control.

With an emphasis on quick development and iterative testing, Hasan et al. [4] created an

automatic LPG gas leak detector utilizing an Arduino Uno and the prototype method. Hutagalung [5] created a device that uses an ATmega8535 microprocessor and a MQ-2 sensor to detect gas and fire. Buzzers and an LCD are used in the system's local warning system. The foundation for sensor-based detection is strengthened by these efforts, which also confirm the efficacy of MQ-series sensors in identifying different flammable gasses. However, they lack automatic mitigation capabilities and remote accessibility, and thus are restricted to local alarms or simple notification systems.

2.2 IoT-Based Monitoring and Connectivity

IoT-based monitoring solutions have improved detection capabilities by enabling continuous sensing, instantaneous data collection, and networked monitoring—all essential for handling hazardous circumstances such as LPG leaks [3], [9], [10], and [11]. Megantoro et al. [3] demonstrated the possibility of real-time data transfer, supervision, and cloud-based integration by establishing an instrumentation system for data collection and monitoring hydroponic agriculture using an ESP32 microcontroller connected to Google Firebase. This implies that IoT-driven frameworks are highly flexible for facilitating automation and remote management in a variety of applications.

A gas leak monitoring system that connects an Arduino Nano to the ThingSpeak platform for remote gas level display was developed by Roihan et al. [6]. However, the communication was one-way and lacked any user interaction capabilities. Using MQ-2 and SIM800L, Mulyati and Sumardi [7] created an IoT prototype for gas leak detection that included a GSM module for SMS notifications, allowing users to get alerts from a distance. The IoT approach for gas safety systems has been further validated by an international study. An intelligent LPG gas leak detection system using IoT with cloud connectivity and mobile app interfaces was presented by Y. B. R. K. et al. [10]. In order to provide fixed detection systems with more mobility, Trisnawan et al. [11] used the MQ-2 sensor for gas leak detection on autonomous mobile devices.

The term "Internet of Things" (IoT) is a technology that uses the internet to connect

many physical items, enabling them to automatically share and analyze data to improve the effectiveness and intelligence of routine actions [9]. IoT serves as a unified framework in gas safety that combines response, communication, and detection components into a single system to increase monitoring accuracy and enhance emergency response. Although these methods increase accessibility and enable real-time environmental monitoring, most systems focus more on data transmission and sensing than on automatic mitigation or user-interactive management.

2.3 Telegram Bot Integration in IoT safety Applications

Telegram-based notification systems for gas leak warnings and user interaction have been deployed by several research projects to enhance system responsiveness, demonstrating that Telegram bots enable rapid and reliable communication between sensing equipment and end users [8], [12], [17]. Users can receive alerts promptly and react appropriately in an emergency by using this method. Using the two-way communication capabilities of NodeMCU, Sulistyorini et al. [8] recently combined an ESP8266 NodeMCU with a Telegram bot to deliver instant message notifications on mobile devices, utilizing Telegram for gas leak monitoring.

In a sense, worldwide academics like A. M. Rahman and associates [12] developed an Internet of Things-based gas leak detection system that uses the Telegram app to send out alerts. The gas leak detection system demonstrates that real-time, minimally delayed alarms are sent. Additionally, the system provides interactive gas leak detection functionality by allowing users to inquire about sensor status using text commands. With an emphasis on home safety and convenient access via mobile messaging platforms, Stefanie [17] developed an LPG gas leak monitoring system that uses a MQ 2 sensor and provides Telegram bot warnings for houses. In order to further investigate IoT-enabled gas leak detection and safety automation systems, Sarumathi [13] added relay control that turns on when the sensor hits a threshold.

The way individuals connect is still limited to giving and receiving information, even though these platforms do a good job of providing communication features and allowing

users to receive organized alerts with support for photographs and videos. Real-world devices are not really controlled by it. The majority of systems still do not combine communication and automated solutions in one location, despite the fact that this research improved the way warnings are sent. Messages can be received by people. See how the system is operating, but they are unable to use the Telegram app to manage devices like shut-off mechanisms or valves.

2.4 Integration of Notification and Automated Mitigation in IoT-Based Gas Safety Systems

Three areas have seen significant advancements in recent studies on gas leak detection using the Internet of Things: (1) using sensors to detect gas, such as MQ-series sensors; (2) connecting devices via the Internet of Things to monitor from a distance; and (3) sending alerts via messages, such as Telegram or SMS. However, these components are typically handled independently by current systems. Solenoid valves are used to stop gas leaks in control systems that do not connect to communication platforms [2] [19], whereas research utilizing MQ-2 or MQ-6 sensors frequently focuses on cloud monitoring [1] [6] or local alarms [2] or message alerts [7] [8] [12] [17].

IoT systems with Telegram capabilities offer two-way communication. Prior research utilizing Telegram bots primarily concentrated on responding to user inquiries or sending alerts. Physical safety measures, such as shutting off a valve, were not connected to these systems. Solenoid valves are effective for quick automatic control of fluids or gasses, according to on-the-ground study. Remote user access and messaging services are not included in these research [19]. Sensor detection, Telegram-based warnings, and automatic solenoid valve control have not yet been combined into a single, comprehensive system.

Table 1 contrasts pertinent studies in terms of sensors, platforms, communication techniques, actuator control, and user interaction in order to draw attention to this gap.

Table 1. *Comparative Analysis of Related Work*

Study	Sensor	Platform	Telegram Alert	Buzzer/ Alarm	Actuator Control
Ibrahim [1]	MQ-2	ESP32 + ThingSpeak	No	No	No
Tommy [2]	MQ-6	Arduino	No	Buzzer	Solenoid Valve
Roihan et al. [6]	MQ-2	Arduino + ThingSpeak	No	No	No
Mulyati & Sumardi [7]	MQ-2	SIM800L	No	No	No
Sulistiyori ni et al. [8]	MQ-2	NodeMCU	Yes	Buzzer	No
Rahman et al. [12]	MQ-2	ESP32	Yes	No	No
Tambunan & Stefanie [17]	MQ-2	Arduino	Yes	Buzzer	No
Nainggolan & Caniago [19]	Water Sensor	Arduino	No	No	Solenoid Valve
Monisha & Sarumathi [13]	MQ-6	IoT App	No	Buzzer/ Relay	Relay
This Study	MQ-2	ESP32	Yes	Buzzer + Automated Telegram Notification	Relay-controlled Solenoid Valve

3. METHOD

3.1 Research Framework

The Prototyping Development Model, which emphasizes constructing systems step-by-step and continuously testing them through prototype testing, is used in this study [15]. Prototyping, in my opinion, is effective for Internet of Things (IoT)-based systems since it allows us to jointly modify software and hardware while doing real-world testing.

The IoT-based gas leak detection and prevention system prototype used in this work performs three functions: detection, notification, and mitigation. The prototype reads data from a MQ-2 sensor using an ESP32 microcontroller. The prototype uses Telegram to instantly transmit alerts. When a leak is discovered, the prototype activates a valve to halt gas flow. Over time, the iterative prototype cycle increases the prototype's speed and dependability.

3.2 System Design and Implementation

Block diagrams illustrate a system's process and the connections between its components. During the design process, block diagrams assist designers in seeing the system architecture. The block diagram in Figure 1 shows how the proposed gas leak detecting system operates. At the input, LPG gas is detected by the MQ 2 sensor. The ESP32 microcontroller gets an analog signal that is converted from the gas level by the MQ 2 sensor.

The central processing unit is the ESP32 microcontroller. The data is read by the ESP32 microcontroller. controls the system for detecting gas leaks. For the gas leak detection system, real-time response and communication are managed by the ESP32 microcontroller.

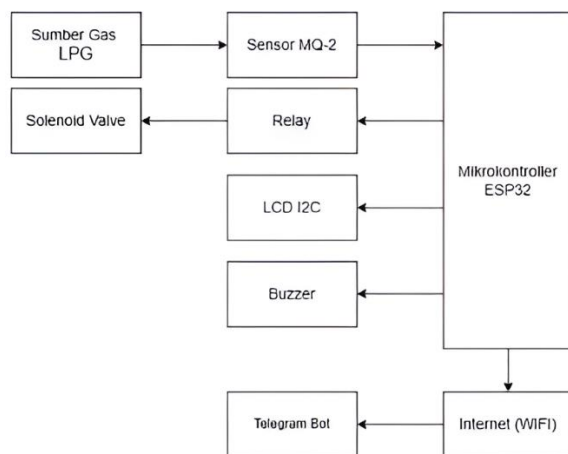


Figure 1. Block Diagram of The LPG Gas Leak Detection System

The circuit diagram, shown in Figure 2, gives an idea of how the electrical parts are connected and how they relate to each other in the system [17]. An understanding of the connections and relationships between the electrical components in the system is provided by the circuit diagram, which is displayed in Figure 2 [17]. The MQ-2 sensor, relay, I2C LCD, buzzer, and ESP32 microcontroller are among the components of the design that cooperate to ensure precise detection and prompt response. In this configuration, a 12V adaptor is used to power the solenoid valve independently of the ESP32. A DC step-down converter reduces the voltage to 5V in order to accommodate the ESP32's limitations. This division aids in maintaining power stability.

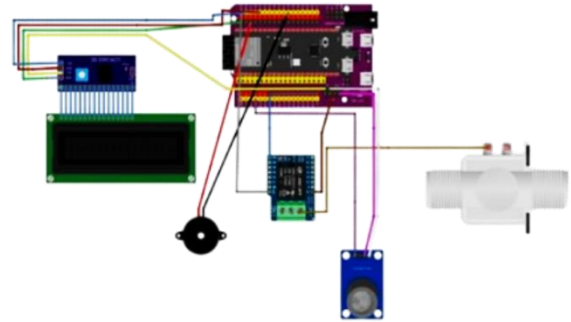


Figure 2. Circuit Schematic of The Gas Leak Detection System

The system flowchart, shown in Figure 3, explains the step-by-step process starting from gas detection all the way to notification and control. When the MQ-2 sensor finds a gas level above the predefined limit, the microcontroller starts a series of actions. It turns on the bell to give a local alarm. The LCD screen displays the current gas reading at that moment. Additionally, the system notifies the user via Telegram. Furthermore, the relay is turned on, opening the valve to halt the gas flow. To guarantee reaction and safety, all of these actions take place simultaneously.

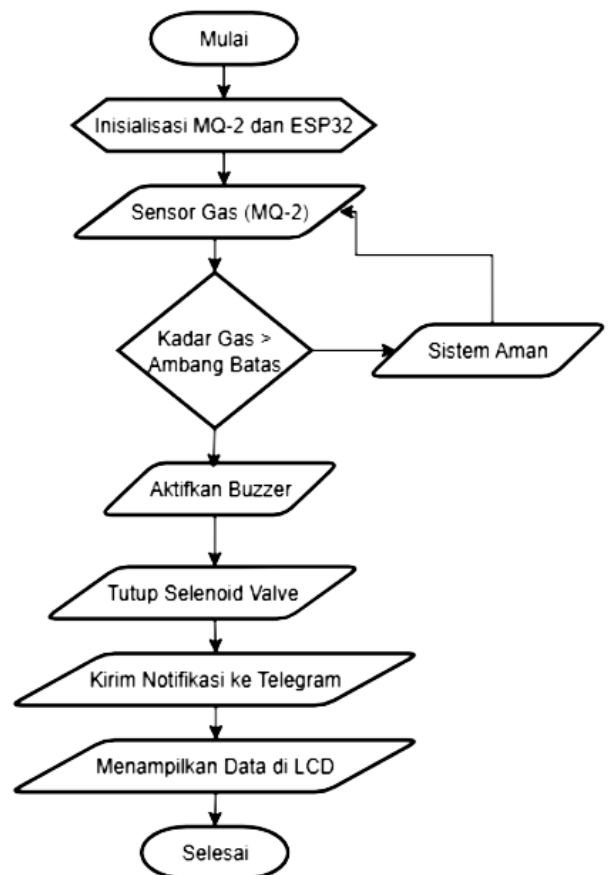


Figure 3. Flowchart of the gas leak detection system workflow

3.3 Sensor Data Processing

An analog voltage proportional to the observed gas concentration is produced by the MQ-2 sensor. The ESP32 microcontroller processes this signal by converting it into a digital value between 0 and 4095 using a 12-bit Analog-to-Digital Converter (ADC). Equation (1) expresses the conversion from ADC reading to output voltage:

$$V_{out} = \frac{ADC_{value}}{ADC_{max}} \times V_{ref} \quad (1)$$

Where V_{ref} is the ESP32 reference voltage (3.3V), ADC_{max} is the maximum ADC range (4095), ADC_{value} is the sensor's digital reading, and V_{out} is the output voltage. Certain gas concentration levels are correlated with the resulting voltage. The system automatically initiates both local and remote notifications when readings surpass a predetermined threshold.

The primary microcontroller that provides the system's central control is the ESP32. The ESP32's Wi-Fi connectivity enables the system to establish a connection to the internet network and transmit data or notifications instantly. Furthermore, the ESP32's computing power is sufficient to manage both sensor inputs and device outputs at the same time.

3.4 Tools and Component

The hardware and software components used in the system are as follows:

1. ESP32 Microcontroller: The ESP32 functions as the system's central controller. The ESP32's Wi-Fi connectivity enables the system to establish a connection to the internet network and promptly deliver data or notifications. Additionally, the ESP32 has sufficient computational power to manage both sensor inputs and device outputs simultaneously [3] [6] [13].
2. Solenoid Valve: This type of valve works by passing an electric current, either AC or DC, through a solenoid coil [19]. This part's primary function is to manage and regulate the system's gas flow. The Solenoid Valve immediately shuts off the gas line to stop leaks. A relay module linked to the ESP32 microprocessor controls the valve's actuation, guaranteeing a dependable reaction in an emergency.
3. MQ-2 Sensor: LPG (liquefied petroleum gas), butane, propane, methane, alcohol, hydrogen, and smoke are just a few of the combustible gasses that the MQ-2 Sensor can detect [14]. When gas molecules enter its sensing chamber, the sensor detects them and converts the concentration levels into an analog voltage signal. The microcontroller then analyzes this output to see if the gas concentration exceeds the safety limit. This aids in initiating mitigation measures and notifications.
4. Relay Module: This switch allows the ESP32 microcontroller to use low-power signals to control high-current devices. It serves as a link between the solenoid valve and other external devices and the microcontroller. When a gas leak is detected, it permits automatic operation while maintaining the system's separation for safety.
5. I2C LCD Display: This module uses the I2C communication protocol and is a liquid crystal display. It displays text or numbers that the microcontroller has coded. The I2C LCD in this system shows data on the gas levels that the sensor has identified in real time. The gas concentration and ambient conditions are plainly visible to users.
6. Buzzer: A buzzer converts signals into sound. It functions as an alert in this system. The buzzer alerts adjacent people when the gas level exceeds the limit. This makes it easier for people to respond fast and be safe.
7. Telegram Bot: The Telegram messaging app and the gas detection system are connected via the Telegram Bot, an API. Every time a gas leak is discovered, it notifies users. Additionally, users can use their phones to check system status and gas measurements. Monitoring and quicker emergency reaction are made possible by this.
8. Step-Down Module: Also known as a DC-DC converter, this module reduces voltage from an input, like 12V, to a

steady 5V output. The ESP32 and other low-power components can use this output. It guarantees that each component receives the voltage, guards against damage, and maintains steady performance over time.

3.5 Alarm and Notification Subsystem

When the MQ-2 sensor detects gas levels above the safety limit, alarms are sent via the alarm subsystem. It operates remotely as well as locally. This solution consists of two components: the Telegram Bot API for sending notifications to a user's phone and a buzzer for instantaneous sound warnings.

The buzzer is a gadget that produces loud noises using electrical signals. The buzzer emits a high-decibel tone after receiving a signal from the ESP32 when it senses a gas leak. Anyone in the vicinity is alerted by this tone, indicates that the system is now in hazard mode instead of safe mode. To control current and maintain a steady voltage, the buzzer is connected to a pin on the ESP32 via a resistor.

At that moment, a user's smartphone receives real-time alerts from the Telegram Bot API. For those who live far away, this is crucial. The ESP32 uses HTTPS to send a message when the gas concentration exceeds the threshold, specifically when the voltage increases above 0.81 V. It makes use of a chat ID and a security token that are created during system configuration. In this manner, even when they are not there, users receive a message instantly on their phone.

The system is more dependable when both the buzzer and the Telegram alert are operational. The local sound alert facilitates prompt action. The remote message ensures that the alert is received even if the person is not there or does not hear the buzzer. With the use of this dual system, users can take precautions to lessen the likelihood of a gas leak. These elements work together to create a layer of defense against gas dangers.

3.6 Telegram Bot Configuration and Operation

The Telegram Bot API is used by the system to facilitate command execution and monitoring. The user and the ESP32 microcontroller are connected by this API. The bot authentication is required before any

notifications or control actions can take effect. The Telegram conversation ID needs to be properly configured.

Making a bot with the BotFather service is the first step. Sending the /newbot command is the first step. Next, you give the bot a name and a username. BotFather then provides you with an authentication token. Because it enables the ESP32 to safely connect to the Telegram server, this token is crucial. Figure 4 illustrates how to obtain this token.

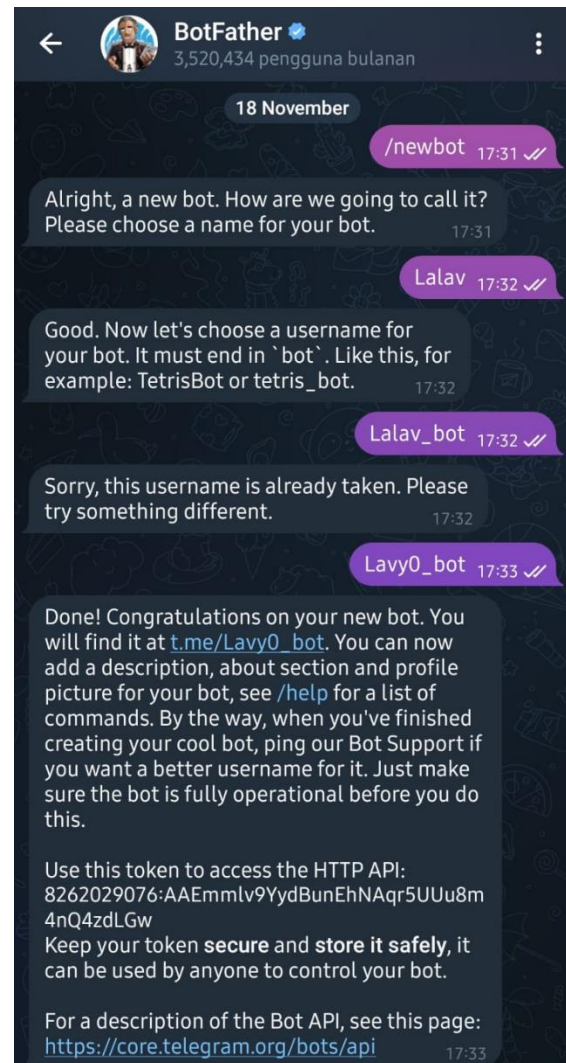


Figure 4. Procedure for Creating A Telegram Bot and Retrieving the Authentication Token

Obtaining the chat ID comes next after obtaining the bot token. The user or group that will receive messages from the system is identified by their chat ID. This ID ensures that the Telegram account receives real-time alerts from the ESP32-based monitoring system, such as gas leak warnings, status updates, or buzzer activation messages. The bot cannot send messages to the individual if the chat ID is

missing. Figure 5 illustrates how to obtain the chat ID via the Telegram API.



Figure 5. Procedure for retrieving the Telegram chat ID using the Telegram API

After the bot is configured correctly, users can use Telegram commands to communicate with the gas detection system. The system is turned on via the /start command. begins a real-time gas check. This enables the ESP32 to continue collecting data from the MQ-2 sensor and provide the user with system updates via Telegram. The technology immediately sends out an alarm if the amount of gas detected exceeds the limit.

Additionally, in an emergency, users can turn off the solenoid valve by using the /tutup command. Without having to approach the machine, this instruction allows users to stop the gas flow. Figure 6 illustrates how

commands are used by users, the Telegram bot, and the gas detection system.

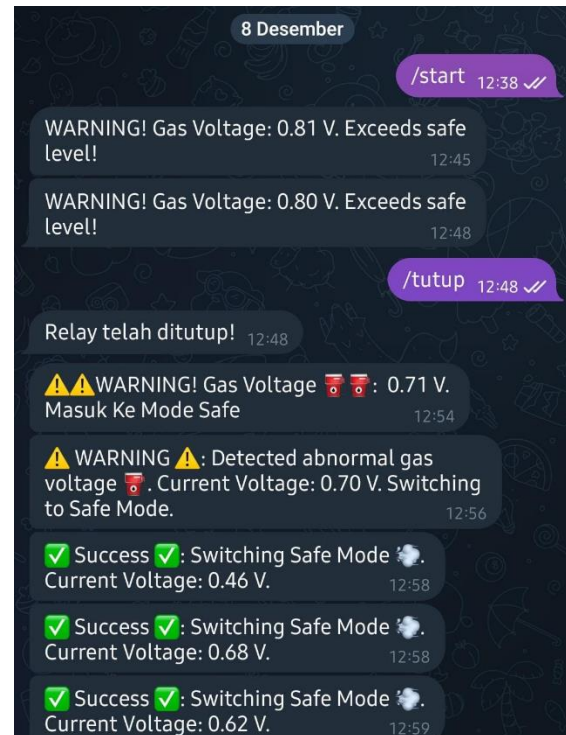


Figure 6. Telegram Bot Command Interaction For System Activation and Remote Emergency Control

4. RESULT AND DISCUSSION

4.1 System Assembly

The ESP32 microcontroller is now assembled with several components, including the MQ-2 gas sensor, solenoid valve, relay module, I2C LCD, and buzzer. A functional prototype that is prepared for laboratory testing is made by carefully placing each component inside a plastic casing. Figure 7 shows the completed physical prototype of the gas leak detection and prevention system.

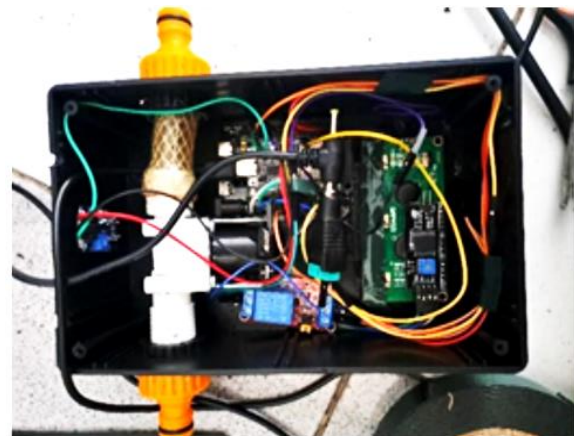


Figure 7. Assembled gas leak detection system prototype

By protecting components from dust, unintentional contact, and minor impacts, the compact enclosure design enhances system mobility and safety. In addition to keeping connections neat and parts organized, the small enclosure design lowers signal noise and short circuits. This configuration guarantees that each sensor, actuator, and output unit is correctly connected to the ESP32, allowing data to be collected consistently, control logic to operate dependably, and the entire system to remain synchronized throughout testing.

4.2 System Testing

After successful programming, the system underwent a battery of performance tests to assess its response behavior, sensitivity, and reliability in simulated gas-leak scenarios. The MQ-2 sensor was tested by exposing it to different concentrations of LPG gas emitted from a home stove, simulating a typical leakage situation in domestic settings. Figure 8 depicts the experimental testing setup.



Figure 8. Gas Leak Detection System Testing Setup

During testing, the MQ-2 sensor's output voltage rose as the gas concentration levels did. The I2C LCD displayed the voltage readings in real time so users could see how the sensor responded. The system operated normally while the voltage was below the 0.81 V safety limit. To allow the gas to flow, the solenoid valve remained open.

The system immediately entered an emergency mode if the voltage reached or exceeded 0.81 V. The relay module then switched on, stopped the gas flow by closing the

solenoid valve. The bell sounded to alert people at that moment. The Telegram Bot was used to send the user a message regarding the warning. This prompt response helps avoid explosions or fires that could occur if someone didn't take action right away. Table 2 presents the primary findings from the system testing.

Table 2. Gas Leak Detection System Testing Results

No.	Sensor Voltage (V)	Telegram Notification	Buzzer	Solenoid Condition	Information
1.	0.45	No	No	Open	Safe
2.	0.52	No	No	Open	Safe
3.	0.60	No	No	Open	Safe
4.	0.67	No	No	Open	Safe
5.	0.71	No	No	Open	Safe
6.	0.75	No	No	Open	Safe
7.	0.81	Yes	Yes	Closed	Danger

Based on the testing results presented in Table 2 the performance analysis of the LPG gas leak detection system shows the following:

1. Normal Operation Condition: The LPG gas leak detection system remains in mode when the MQ-2 sensor finds gas concentration levels that are below the predetermined safety threshold of 0.81 V. In this mode, the solenoid valve remains open, allowing gas to easily enter home appliances. Neither a Telegram notification nor an audible alarm are. The LCD displays sensor information in real time constantly. This demonstrates that the LPG gas leak detection system can accurately distinguish between hazardous and safe gas levels, preventing false alarms.
2. Emergency Response Condition: The LPG gas leak detection system immediately initiates a safety sequence when the MQ-2 sensor detects gas levels that exceed the threshold of 0.81 V. The I2C LCD displays an alarm, the Telegram Bot sends a real-time message to the user's mobile device, the solenoid valve closes to stop the gas flow, and a buzzer sounds to provide an auditory warning. This coordinated reaction aids the LPG gas leak detection system in lowering the risk of an explosion or fire brought on by an LPG gas leak.

CONCLUSION

To overcome the drawbacks of conventional passive safety techniques, this

study successfully developed an Internet of Things (IoT) gas leak detection and prevention system. The system integrates these elements to provide a clever, adaptable solution. It detects the presence of gas using an MQ-2 gas sensor. When needed, the ESP32 microcontroller processes the data and initiates operations. When a leak is found, a relay-controlled solenoid valve automatically cuts off the gas supply. Local real-time data is shown on an I2C LCD. A buzzer alerts those in the vicinity. The system also sends warnings to users' phones via the Telegram Bot API. As of result, customers can receive notifications even when they are not at home.

Tests demonstrate that the system accurately detects LPG gas leaks and reacts promptly when gas levels exceed a threshold. The solenoid valve effectively stops the gas flow, preventing accumulation. Local alerts are displayed on the LCD and buzzer so that people may respond quickly. Monitoring is provided by the Telegram alerts. Messages regarding the leak can be sent to users. From anyplace, take precautions for your protection. This is particularly helpful when the user is not on the site.

The system integrates automatic reaction, communication, and sensing into a single arrangement. Reliability is increased by this cohesive design. ensures the safety of operations. Temperature and humidity detectors are examples of environmental sensors that could be added to the system in the future. To extend the system's battery life, energy efficiency could be improved. Additionally, predictive algorithms may be used to enhance alerts and adjust to various circumstances. These enhancements could lead to smarter and more reliable gas leak detection.

DECLARATIONS

Author Contributions: The first author contributed to conceptualization, research supervision, and review of the manuscript. The second author contributed to methodology, system design and implementation, investigation, data analysis, visualization, and writing the original draft. The third, fourth, and fifth authors contributed to system development, experimentation, data collection, and manuscript review. All authors reviewed and approved the final version of the manuscript.

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Ethics Approval and Informed Consent: This study focused on the development and laboratory testing of an IoT-based LPG gas leak detection and prevention prototype. It did not involve human participants or the collection of personal data; therefore, ethics approval and informed consent were not required.

Data Availability: The data, source code, and other materials supporting the findings of this study are available from the corresponding author upon reasonable request.

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