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Arduino-Based LPG Leakage Smart Detection System

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Abstract

Leaking of liquefied petroleum gas (LPG) can result in significant mishaps, even though it is a common fuel for both residential and commercial activities. In this study, a microcontroller with an MQ-2 gas sensor, a buzzer, and a GSM module is used to detect LPG leaks. Upon early detection of leakage, the wireless system can initiate automatic safety actions and send short message service (SMS) warnings and sound alarms. The design and implementation of a microcontroller-based LPG leak detection and alert system are presented in this work. An MQ-2 gas sensor is used by the suggested system to continuously check the surroundings for LPG. The system is appropriate for both home and commercial applications because it is made to be affordable, dependable, and simple to use. The suggested system improves current safety precautions and lowers the possibility of serious mishaps brought on by undetected gas leaks by providing early detection and real-time alarms. Overall, this work shows how sensor technology, embedded systems, and wireless communication may be integrated to improve LPG safety in an effective and useful way. The microcontroller instantly interprets the sensor data and turns on a buzzer to offer an auditory warning when it detects a gas concentration that is higher than a predetermined safety threshold. To ensure that users are aware of the hazard even when they are not in the monitored area, a GSM module is incorporated into the system to send SMS notifications to predetermined mobile numbers in addition to local alerts. Because this system is cost-effective and efficient, it improves safety precautions in both home and business settings.

Keywords: Gas sensor, GSM module, LPG, microcontroller, safety system

INTRODUCTION

Liquefied petroleum gas (LPG) is extensively utilized in Philippine residences; however, a leak may result in explosions and flames. Conventional gas leak detection systems are frequently ineffective and sluggish. Self-automated detection systems employing gas sensors can deliver immediate alarms, thereby enhancing response times to mitigate fatalities and injuries. The main aim of this study is to develop and implement a reliable and economical LPG leak detection system [1]. Incorporating a relay module to deactivate the primary gas supply automatically is an alternative solution. The proposed method is economical, energy-efficient, and simple to install in residential properties, dining establishments, gas storage facilities, and vehicles operating on LPG. This apparatus aids in averting hazardous incidents and provides real-time surveillance [2].

LITERATURE REVIEW

This LPG leakage detection system is employed to detect the presence of gas and is commonly utilized in various settings, such as industries where the risk of detonation poses significant threats to

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safety and personnel. In residential environments, it is particularly effective for identifying LPG leaks, which are prevalent in daily use. Additionally, it applies to vehicles that transport gas cylinders and numerous other locations [3]. Dr. Walter Snelling was an inaugural individual who introduced LPG in 1910. It is a mixture of propane and commercial propane. The area is highly volcanic, and several incidents arise because of LPG leaks. Consequently, it is imperative to address and mitigate gas leakage. Gas detectors can be categorized in several ways.

They are categorized into groups according to the type of gas detected, the automation that drives the sensor's output, and the components influencing the sensor's power (semiconductors, oxidation, catalysis, photoionization, infrared, etc.). In our daily lives, we employ a variety of devices for different functions, and these devices can release various gases or chemicals into the air during operation [4]. In any system, it is challenging for an individual to monitor the levels of gas application or ascertain the presence of a gas leak. Gas leakage in unmonitored areas poses a significant risk of detonation, even from a minor spark. In addition, the presence of hazardous gases can result in suffocation and subsequent respiratory issues. Numerous applications exist for the observation and monitoring of gas leakage; however, researchers are working towards developing an advanced application that will offer a more cost-effective solution [5].

METHODOLOGY

The proposed system was engineered to identify LPG leaks and to deliver immediate notifications to prevent accidents. The approach comprises the following steps.

1. *Gas detection:* An MQ-6 gas sensor was employed to continually monitor the concentration of LPG in the environment. The sensor produced an analog signal corresponding to the gas concentration. Figure 1 illustrates the circuit diagram of the proposed model, which comprises the following components.
2. *Data processing:* The output of the sensor was transmitted to a microcontroller (Arduino/8051). The microprocessor evaluated the gas level against a predetermined threshold value.
3. *Alert system:* When gas concentration exceeds the threshold, a buzzer is activated to provide an audible alarm.
4. *GSM module:* A GSM module transmits SMS notifications to the user.
5. *Relay:* If employed, the relay module disconnects the primary gas supply or electrical power.
6. *Continuous monitoring:* If gas levels are within normal parameters, the system persists in monitoring without triggering any alerts, as shown in Figure 1.

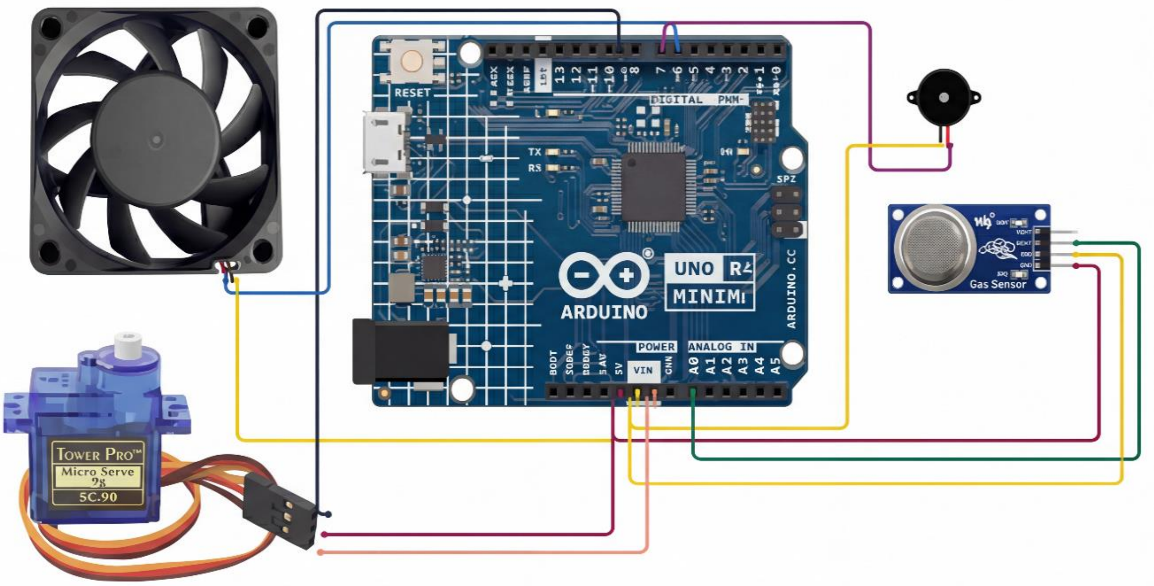

Figure 1. Prototype model circuit diagram.

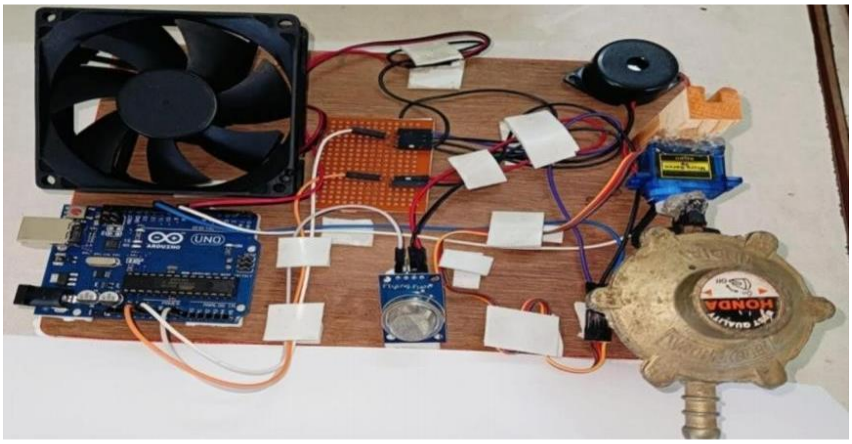

Figure 2. Hardware model.

PROPOSED SYSTEM MODEL

As illustrated in Figure 2, the sensors were powered by microcontrollers, relays, liquid crystal displays (LCDs), and a buzzer. This voltage regulation sector is responsible for converting alternating current to direct current and for attenuating the transmitted signal. These sensors were capable of detecting gas leaks. The MQ-2 sensor is operational for detecting LPG concentrations in the atmosphere. The gases within the 200–10,000 ppm concentration range could be identified, and the reaction time was exceedingly rapid. The output of the sensor was an analog power signal. A sequential communication circuit transitions from an analog resistor to a voltage. The microcontroller then reports the voltage.

This analog voltage was converted to digital form using a 12-bit analog-to-digital converter, as shown in Figure 2.

This sophisticated gas detection system effectively addresses both the monitoring and identification of hazardous gases in the vicinity. An MQ-2 sensor was used for the detection of various gases. Upon detecting a gas leak, the sensor transmits a signal to the Arduino UNO for subsequent operations, where other hardware components are connected. The Arduino UNO transmits a signal to the LCD to display an alarm. The buzzer should be activated to alert the background personnel, and the main power supply will be disconnected. The 5 V relay supplies electricity to the exhaust fan to eliminate dangerous gases from the environment. The application container receives the message through the GSM module [6].

COMPONENTS USED AND THEIR DESCRIPTIONS

The following components are used in the prototype model:

- Arduino Pro Mini
- Microcontroller unit (MCU) module
- LPG sensor module
- Buzzer
- 16×2 LCD
- Cooling fan
- Relay.

The component descriptions are as follows:

Arduino Pro Mini

ATmega328P serves as the foundation for the Arduino Pro Mini (Figure 3) microcontroller board. It features a built-in resonator, six inputs, and 14 digital input/output pins. There were holes for installing pin headers and a restart button. An future technology devices international (FTDI) cable or board communication system can be linked to a six-pin header.

The Arduino ProMini was designed to be installed in items in a semi-permanent manner. Because there are no pre-mounted headers on the panel, the wires can be soldered directly or looped in different ways. The Arduino Mini was compatible with the pin layout. One version of Pro Mini operates at 3.3 V and 8 MHz, while the other type operates at 5 V and 16 MHz, as shown in Figure 3.

MCU Module

Processor unit memory modules, peripherals, and communication interfaces comprise an MCU (Figure 4) and an intelligent semiconductor integrated circuit. Numerous devices, such as robots, drones, game consoles, radios, and washing machines, use microcontroller units, as shown in Figure 4.

Lpg Sensor Module

The sensing element (Figure 5) was designed to identify six distinct types of flammable gases based on label sensitivity. The sensing element may be identified as defective in the potentiometer installed within the jailbreak board of the MQ-6 gas sensing element. The sensor element provided an analog output. MQ-6 (LPG sensor) detects gas concentrations ranging from 200 to 10,000 ppm. The sensor output was an analog resistance. The connection with the sensing element module was terminated via a 4-pin header suitable for the board, as shown in Figure 5.

Figure 3. Arduino Pro Mini.

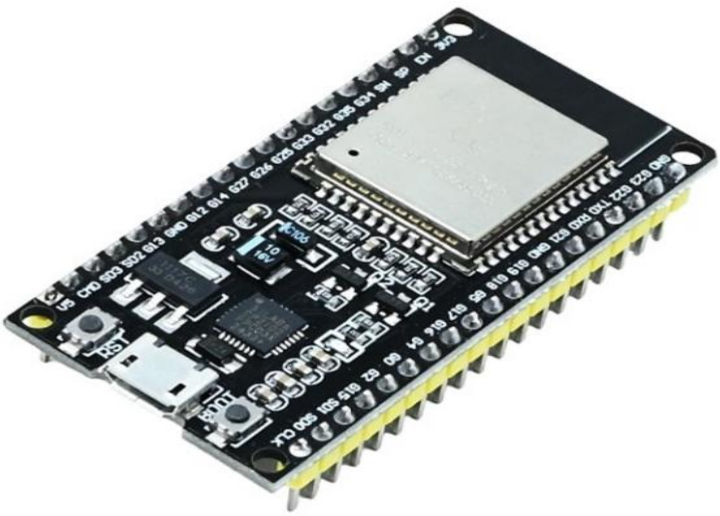

Figure 4. MCU module.

Buzzer

A buzzer or pager is an auditory signaling apparatus that may be mechanical in nature. The buzzer (Figure 6) contained two pins. The design is straightforward and inexpensive, making it suitable for various applications such as vehicle reversing indicators, computers, and notification bells. The phenomenon of generating electricity when mechanical pressure is applied to certain materials, and vice versa, is also valid, as shown in Figure 6.

16×2 LCD

It is an LCD. It employs a liquid to provide a distinct display, with each character constructed from 16 × 2-pixel elements. The 4.7–5.3 V voltage (Figure 7). The present consumption was 1 mA in the absence of a backlight, as shown in Figure 7.

Cooling Fan

If an excessive gas release increases the likelihood of missing, an exhaust fan is employed for evacuation (Figure 8). Cripple fans typically facilitate the removal of hot or humid air from a confined area, allowing the influx of fresh air from an alternate source, such as a door or ventilation system, to replace it. The hot air removed by the electric fan is conveyed through a heat exchanger and expelled outdoors, as shown in Figure 8.

Figure 5. LPG sensor module.

Figure 6. Buzzer.

Figure 7. LCD.

Figure 8. Cooling fan.

Figure 9. Relay.

Relay

A relay with both 220 V and 5 V inputs was utilized in the circuit to disconnect the electricity when necessary. The relay contains five pins (Figure 9). Digital pins on the Arduino board were connected to a single pin. One was connected to the switch for the 220 V power source. This power is shifted to the devices between the alternate pins. The other two were beaches as the primary energy source, and the other for the Arduino board, as shown in Figure 9.

PROPOSED SYSTEM WORKING PRINCIPLE

The LPG leakage detection system operates by continually monitoring the concentration of LPG in ambient air using an MQ-6 gas sensor. This sensor produces an analog voltage signal that fluctuates with the gas concentration. The signal is relayed to a microcontroller such as an Arduino, which juxtaposes it against a predetermined threshold value. If the observed gas concentration is above this threshold, the microcontroller activates safety protocols. It operates a buzzer to generate an immediate audible alarm and, if connected, engages a relay module to sever the gas supply or power to mitigate future risk. A GSM module can be utilized to provide SMS notifications to the user, thereby guaranteeing timely notification [7]. The device incorporated an exhaust fan activated through the relay to remove any lost gas. If the gas levels remain within a safe range, the system continues to monitor them discreetly. This automated system guarantees real-time, dependable, and economical gas leak detection using the following steps:

Gas Detection

The MQ-6 gas sensor detects whether LPG is present in the surroundings.

The resistance of the sensor varied with the LPG concentration, resulting in an analog voltage output that was proportional to the gas level.

Processing Signals

A microcontroller (such as an Arduino or 8051) received the analog signal of the sensor. The observed gas concentration was compared to a predetermined threshold value by using a microcontroller.

Activation of the Alert

The system monitors whether the gas concentration falls below the cutoff value. When the gas concentration exceeded the cutoff, the microcontroller enabled an audible alert by turning on a buzzer. If fitted, it activates a relay module that cuts off power or gas supply to prevent mishaps.

Constant Function

Following an alert, the system continues to track the gas concentration and silences the alarm when the levels stabilize.

CONFIGURATION FOR TESTING

The system was set up using a controlled LPG supply in a contained space.

To detect LPG concentrations above permissible limits (approximately 200 ppm), the MQ-6 gas sensor threshold was chosen.

OBSERVATIONS

1. The accurate detection of LPG concentrations over a predetermined threshold was achieved using the MQ-6 gas sensor.
2. After the cutoff point was reached, the buzzer alert was activated. The gas supply was successfully turned off by the relay module when it was attached.
3. The warning was automatically switched off after the LPG content stabilized.

ANALYSIS OF PERFORMANCE

The performance, dependability, and response time of the prototype LPG leakage detection system were assessed under various testing scenarios.

- *Response time:* Quick action was possible because the average detection-to-alert time was less than 6 s. Accuracy: With few false alarms, the system could identify LPG leaks in extremely low quantities.
- *Reliability:* After 24 h of continuous operation, there were no malfunctions, and the performance was steady.
- *Cost-effectiveness:* Because the system's components are inexpensive, both small businesses and households can afford them.

GRAPHICAL ANALYSIS

To illustrate the sensor sensitivity, a graph was created by plotting the LPG concentration (ppm) against the sensor output voltage (V), as shown in Figure 10.

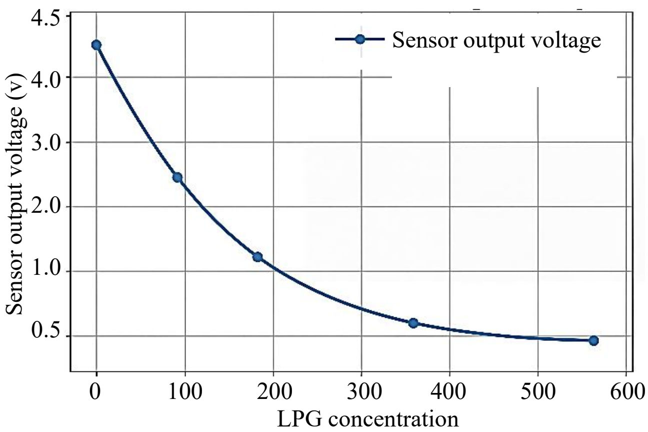

Figure 10. LPG concentration versus output voltage.

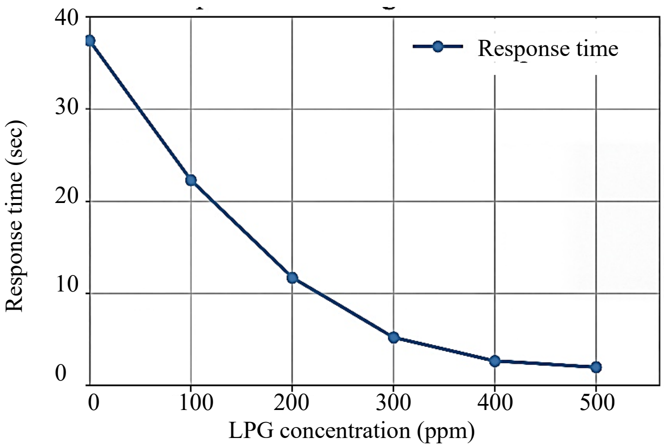

Figure 11. Response time versus gas concentration.

Figure 11 shows a graph of the relationship between the sensor output voltage (V) and the LPG concentration (ppm). As the gas concentration increased, the voltage decreased sharply and nonlinearly, respectively. Clean air was indicated by the MQ-2 sensor's high voltage (~4.3 V) at low concentrations. Below 200 ppm, the voltage rapidly decreases as LPG levels rise [8], demonstrating the sensor's remarkable sensitivity [9] to even tiny leaks.

The Arduino-based LPG detection setup is dependable and effective for safety applications because of its responsiveness, which also supports the system's capacity to detect gas early, set off alarms, and transmit GSM notifications [10]. To validate the prompt detection at greater levels, another graph that plots the response time vs. gas concentration can be used. Additionally, Figure 11 shows the inverse relationship between the sensor response time and the concentration of the LPG [11].

The X-axis denotes gas concentration in parts per million (ppm), spanning from 0 to 500 ppm, and the Y-axis illustrates the response time in seconds, ranging from 0 to 40 s. The graph labeled "Response Time" indicates that at lower concentrations (approximately 50–100 ppm), the sensor demonstrated a notably prolonged response time of approximately 35 to 25 s.

Nevertheless, as the gas concentration increased, the response time decreased significantly, falling below 10 s at 500 ppm. This pattern indicates that the sensor responded markedly more rapidly at elevated gas concentrations. The curve's general pattern indicates a nonlinear, perhaps exponential, inverse relationship between gas concentration and reaction time, underscoring the sensor's efficacy in swiftly detecting elevated amounts of LPG.

CONCLUSION

The proposed LPG leakage detection system is intended to promptly detect gas leaks and notify consumers immediately. By employing a microcontroller, GSM module, relay, and MQ-6 gas sensor, the system guarantees continuous monitoring and prompt response in the event of hazardous LPG levels. It immediately notifies the users by activating an alarm and sending SMS alerts. The system is distinguished by its cost-effectiveness, which is achieved by the use of readily available components. Additionally, it is reliable with minimal false triggers and accurate leak detection. Their user-friendly design facilitates effortless installation in industries, offices, and residences. This guarantees improved safety by delivering a response time of less than six seconds.

Future Scope

Several cutting-edge features can be added to an LPG leakage detection system to increase its efficacy.

Real-time data access and monitoring through cloud platforms via mobile or web applications will be made possible through internet of things (IoT) integration. Alerts, the health system, and real-time gas level changes can all be obtained through a tailored mobile application, including automatic shut-off valves reduces danger by promptly stopping the gas flow in the event of a leak. Solar charging and battery backup alternatives can be included to guarantee dependability during power shortages. Overall safety will be enhanced by extending the detection capabilities to include gases such as methane and carbon monoxide. AI integration can also be used to forecast possible leaks by analyzing the trends in sensor data. With these improvements, the system can be implemented in centralized, large-scale industrial settings.

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