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Product Development

Smart LPG Regulator

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Abstract: The Smart LPG Regulator is designed to oversee the regulation of pressurized steel gas cylinders in residential households. The primary goal of this project is to prevent the potential risks associated with LPG gas leaks, including the loss of life, injuries, and health concerns. The system is equipped to identify gas leaks and issue auditory and visual alerts through a buzzer, a display, and a servo motor, which promptly closes the gas cylinder regulator to terminate the gas supply. The LPG Gas Detector (MQ6) is a suitable sensor with high sensitivity to Liquid Petroleum Gas (LPG), including propane, proficient, isobutene, and natural gas. It is also capable of detecting easily flammable gases, mainly methane. Data collected by the MQ6 sensor is processed by the Atmega 328P microcontroller and presented through the output components. The LCD screen will display 'GAS LEAK,' the buzzer will sound an alarm, and the servo motor will continue to close the regulator valve on the gas cylinder. The MQ6 sensor can identify gas leaks from the gas cylinder, gas pipes, or kitchen stove burners. One significant advantage of this system is its ability to shut off the gas cylinder supply, indirectly preventing accidents and injuries. The system's design is tailored to accommodate the standard size of gas cylinders used in residential homes, with domestic consumers as the target user group.

Keywords: LPG Gas; Servo motor; Gas Regulator; Atmega 328P microcontroller

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1. Introduction

Made up of propane and butane, LPG (Liquefied Petroleum Gas) is a versatile fuel with a mix of saturated and unsaturated hydrocarbons. This versatility makes it popular for various applications in homes, industries, vehicles, and even for lighting and heating (Karande *et al*., 2017). The growing demand for LPG is driven by its clean-burning properties. It produces high heat (calorific value), minimal soot and smoke, and has a lower

environmental impact compared to other fuels. As a result, it is increasingly employed as a propellant in aerosols and as a refrigerant to replace chlorofluorocarbons to reduce ozone layer depletion. LPG is produced through refined petroleum or natural gas, primarily derived from fossil fuel sources or gas deposits in the ground. Burning this gas is relatively clean, leaving minimal residue and emitting very little sulphur. Its gaseous nature means it does not contaminate water or soil but can contribute to air pollution.

Jualayba (2018) stated that leaving gases like hydrogen, propane/butane, and methane unattended could be dangerous. LPG leakages can result in explosions, causing numerous fatalities (Sitan, 2018). As the domestic use of LPG increases, the number of accidents caused by LPG explosions also rises. Edward *et al*. (2024) indicate that LPG users sometimes expose cylinders to heat, increasing the risk of accidents like gas leaks and potential explosions. Common causes of gas leaks at home include poorly fitted or faulty appliances, as well as those that have not been properly maintained. These leaks result in several deaths each year and hundreds of hospitalizations. Therefore, it is crucial for every household to prioritize gas safety. Based on fire incident statistics released by the Ministry of Local Government and Housing (Statistic KPKT, 2021), there were 311 cases of fires caused by cooking gas in 2021. LPG gas ranked third out of seven known causes of fires. Indeed, this indicates that fire incidents in Malaysia caused by LPG gas leaks are both serious and prevalent.

A fire occurring in a residential area not only endangers the occupants of the house but also poses a risk to nearby neighbors. This risk underscores the need for introducing innovative safety products that can protect residents from fire hazards. Safety products like gas sensors play a crucial role in ensuring the safety of house occupants and the surrounding areas. According to Meshram (2019), the detection and alarm system for LPG gases important to prevent fire accidents and ensure the safety of the home. Likewise, Unnikrishnan, *et al*. (2017) noted that the LPG monitoring and leakage detection system primarily caters to household needs. It provides users with notifications regarding the remaining LPG quantity in the cylinder and alerts them to any gas leaks, thereby enabling them to take proactive measures to prevent potential explosions. Therefore, this study aims to develop a microcontroller-based hazardous gas detection and notification system that notifies people that a hazardous gas leak could eventually lead to an explosion. Consequently, implementing gas leak detection systems can significantly enhance public safety in Malaysia.

Hence, the Smart LPG Regulator was developed to address the issues of LPG gas-related fires and detect gas leaks in the rubber hoses of gas stoves commonly used in households. This device is highly suitable for use by every homeowner because it will automatically shut off the LPG cylinder valve when a gas leak is detected. The absence of residents in the house can lead to an increased fire risk due to undetected gas leaks. With this device, the absence of residents no longer becomes a factor in the occurrence of fires.

2. Literature Review

Many innovative products have been developed to prevent fires caused by gas cylinder explosions due to leaks. The Malaysian Fire and Rescue Department has also recognized the need for LPG gas leak detection products and has developed related innovative products. For instance, the 'White Sand Warriors' team from the Pasir Puteh Fire and Rescue Station has introduced an innovation to prevent fires and explosions in the kitchen due to leaks in liquefied petroleum gas (LPG) cylinders during cooking (Kamarudin, 2021). Another innovative project known as Smart LPG Gas Level Detection and Safety System using IoT tackles gas level monitoring and leak detection (Naidu *et al*., 2020). The system tracks the gas remaining in the cylinder and automatically sends a refill request to your phone when it falls below a set level. Moreover, it is also detects gas leaks. If a leak is identified, the gas valve automatically shuts off to prevent accidents. Additionally, an alert is sent to user phone along with an audible buzzer notification. Suma (2019) developed an IoT-based gas leak detection system to detect gas leaks using the MQ-5 gas sensor. In this IoT gas leak detection system, the device is connected to Wi-Fi, and users can set the minimum and maximum parameters as needed. This IoT-based gas leak detection system is built on Arduino Uno and can be installed in domestic residential areas.

Figure 1 illustrates the block diagram of the LPG gas detection system. This system utilizes the input, and the MQ-5 gas sensor is employed to detect LPG gas levels in the air continuously. During monitoring, if the LPG gas levels in the air fall within the predefined limits, the RGB LED on the circuit will illuminate in green, indicating safety. However, if the gas levels exceed the set limits, the RGB LED will turn red, and simultaneously, the solenoid valve will shut off and send an alert through IoT. This Arduino Uno and IoT project detects gas leaks in the environment.

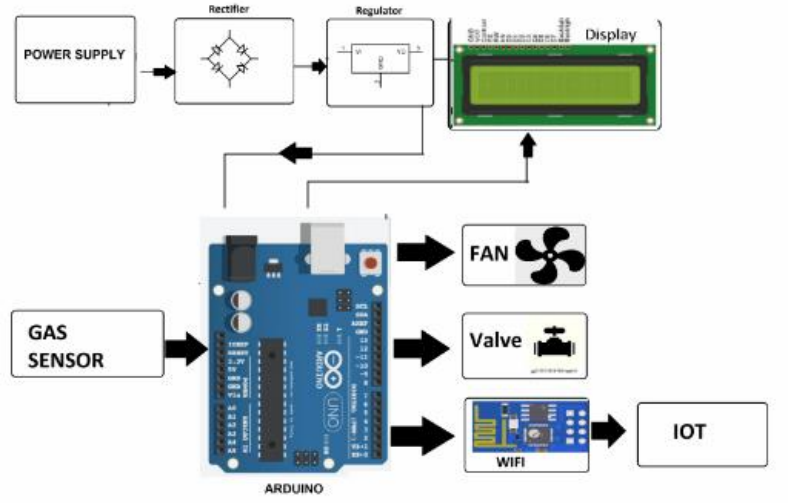

Figure 1. Block Diagram of An IOT Gas Leakage Detector Using Arduino Uno

Figure 2 illustrates the block diagram of this system. Electroduino (2021) developed an LPG gas detector using a 555 Timer. The LPG gas leak detection project is based on a straightforward concept and is easy to construct. When this system detects LPG gas, it warns by activating an LED and a buzzer. Meshram (2019) used a gas sensor with a high sensitivity to gases such as propane and butane and LPG. An alarm is triggered once the LPG has been detected. The main components used are the MQ2 gas sensor module, BC557 transistor, 555 Timer IC, LED, and buzzer.

The MQ2 gas sensor module can detect LPG, alcohol, propane, hydrogen, CO, and methane. In this project, it is used specifically to detect LPG. The BC557 transistor acts as a switching device and is activated by the sensor output. Here, it is used to drive the 555 Timer IC. The 555 Timer IC is the core component, generating an output to control the LED and buzzer. The LED and buzzer serve as indicators in the system.

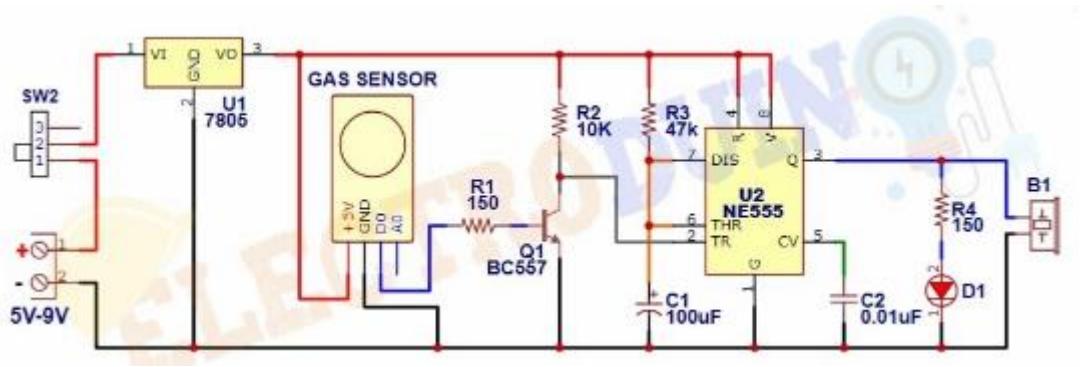

Figure 2. Block Diagram of An LPG Gas Detector Using A 555 Timer

Table 1 compares the Smart LPG Regulator and two alternative projects, considering the microcontroller employed and the input and output components utilized. After conducting this comparison, it is evident that the Smart LPG Regulator offers distinct advantages over the other systems.

Table 1. Comparison Between Project

	IOT Gas Leakage	**LPG Gas Detector Using A 555 Timer**	**Smart LPG Regulator**
Input Component	Gas Sensor MQ-5	Gas Sensor MQ-2 Gas sensor MQ-6	Gas Sensor MQ-6 Push Button
Output	Fan LCD Display	Buzzer LED	Buzzer LCD Display Servo Motor
Material	Plastic	Prospect	Metal, Plastic
Microcontroller	Arduino Uno	555 Timer IC	Arduino ATmega

The MQ-6 gas sensor is a potentially good option for your project, especially if you want good sensitivity and low cost. MQ-6 is a type of gas sensor that can be used to detect various gases such as methane (CH4), propane (C3H8), isobutane (C4H10), and smoke.

Additionally, it can be used to detect natural gas and household waste gases. The sensitive material in the MQ-6 gas sensor is SnO2, which has low conductivity in clean air and becomes more sensitive as the gas concentration increases (Raj, 2015). Additionally, it is designed to ignore gases like cooking fumes.

Here are some key features and considerations for using MQ-6 in this project. Due to its sensitivity, the MQ-6 has good sensitivity to certain gases, making it suitable for detecting the presence of specific gases in the air. One of the main advantages of MQ-6 is its low cost, making it an economical choice for various projects. MQ-6 can detect several types of gases, allowing it to be used for various applications where multiple gases may be present. MQ-6 typically has an analog interface that is easy to connect to a microcontroller or monitoring system to monitor gas readings, and it can also be influenced by factors such as temperature and humidity. Therefore, it is essential to consider these factors when using the sensor.

Khan (2020) stated that an MQ6 semiconductor sensor is used. The sensitive material of the MQ-6 gas sensor is SnO2, which has lower conductivity in clean air. When the target combustible gas exists, the sensor conductivity and the rising gas concentration increase. The MQ6 gas sensor has a high sensitivity to Propane, Butane and LPG and response to Natural gas. Referring to Leavline (2017), MQ6 has demonstrates remarkable sensitivity and swift response. The MQ-6 gas sensor is highly sensitive to propane, butane, and LPG, can also detect natural gas (T Soundarya, 2014). It is particularly effective at sensing methane, making it an affordable and adaptable choice for various applications.

3. Methodology

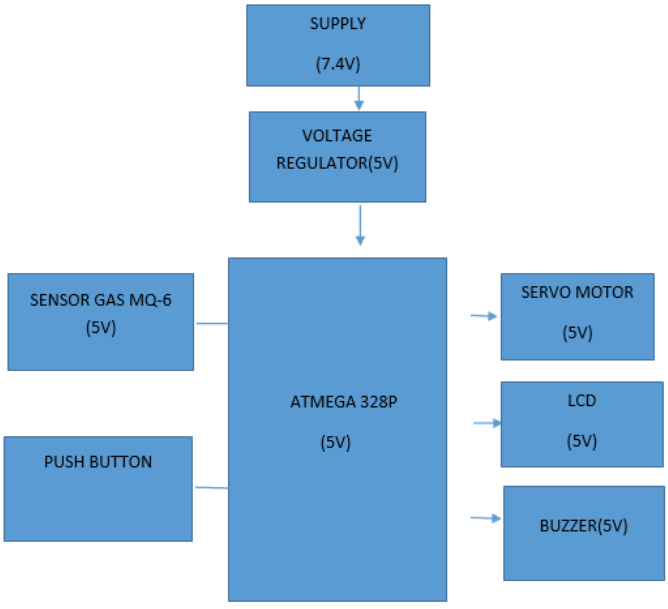

Figure 3. Block diagram of Smart LPG Regulator

Figure 3 illustrates the block diagram of the Smart LPG Regulator. This system utilizes two inputs: the MQ-6 gas sensor and a push button. It incorporates a Liquid Crystal Display (LCD), a servo motor, and the gas cylinder valve as outputs, with the Atmega 328P microcontroller serving as the system's central component.

The Smart LPG regulator is developed to shut off the gas supply to ensure there is no gas source, preventing a more significant fire hazard. Such a project is not yet available in the market, and the potential for commercialization is very high. This project is built with a power supply input of 7.4V regulated to 5V for electronic circuitry usage and an AT mega microprocessor.

The MQ-6 gas sensor is connected to the input section to detect leaks along the gas pipeline to the kitchen and the gas cylinder regulator. There are 5 MQ-6 sensors installed along a 1.5-meter gas pipe and one in the gas cylinder regulator. If any of these MQ-6 sensors detect the presence of LPG gas, the buzzer will sound, and simultaneously, the LCD will show "GAS LEAKAGE." The servo motor will rotate 180 degrees to close the gas cylinder regulator valve.

The siren will activate for 2 minutes and then remain silent for the next two minutes, repeating this cycle five times. In cases where the user is not at home, they can check for gas leaks on the LCD. This ensures the user is informed that the gas regulator valve has been closed, avoiding any misconception about gas depletion.

A push button is also placed in the input section for manual control of this project's motor movement in case of a system failure. Additionally, a push button is a manual control for the servo motor in case of automatic system malfunctions.

Figure 4 indicates the placement of this project on the gas cylinder. On the other hand, Figure 5 demonstrates the installation of the project on the gas cylinder, making it suitable for all domestic users utilizing the standard gas cylinders in Malaysia. The installation process for this project is user-friendly, requiring users to clamp it onto the top of the gas cylinder simply. Consequently, concerns about difficulties for users employing this project are alleviated.

Figure 4. Circuit Connection on The Project

Figure 5. Installation of The Project

Figure 6 below depicts the LCD response when the sensor detects the presence of LPG gas. At the same time, the buzzer activates, and the servo motor rotates 180 degrees to shut the regulator on the gas cylinder.

Figure 6. LCD

Figure 7 displays the connection between the servo motor and the gas valve head or regulator. When the MQ6 sensor detects the presence of gas, the servo motor shifts in a counter-clockwise direction to close the regulator. Additionally, pressing the reset button causes the servo motor to rotate clockwise by 180 degrees, reinstating the gas supply and resetting the entire project system to its original or normal state.

Servo motor MG995 known for its precise rotation spanning a 180º range, is widely applied in various fields, notably in robotics, aviation, and toy industries (Servo motor MG995, 2020). Specifically, it is well-suited for designing robotic arms, which endure substantial wear and tear. With its durable metal gearing, this servo motor boasts an extended lifespan, rendering it an optimal choice for robust systems such as robotic arms, where motors are subjected to high workloads.

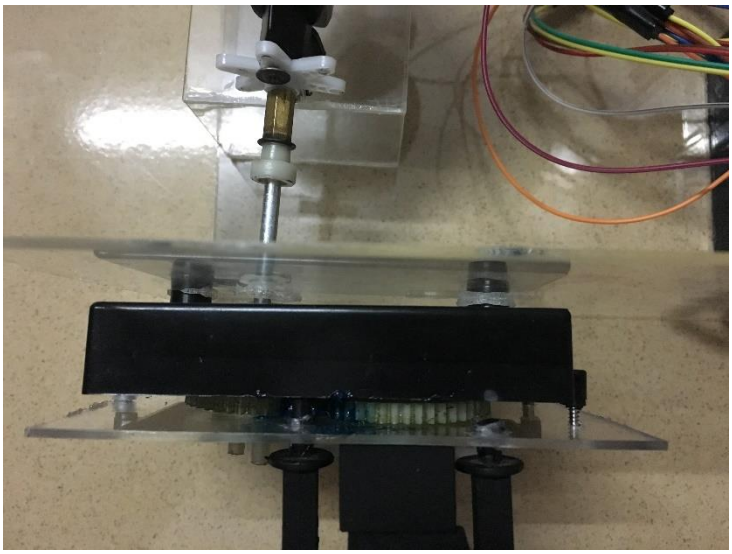

Figure 7. Connection Of Servo Motor and Gas Regulator

4. Data Analysis and Findings

This section explains the outcomes obtained from testing each circuit individually before integration. The results of the circuits employed in this project will be theoretically examined in terms of their functions and how they are incorporated into the project's operation. This section will also outline the findings and conclusions derived from testing each circuit, determining whether the circuits intended for use in the project operate effectively. Table 2 presents the analysis of voltage readings at each output of this project circuit, with voltage drops ranging from 0.1 to 0.4 volts. The highest voltage drop occurs at the Buzzer, amounting to 0.6 volts.

Table 2. Analysis of the Voltage Drop Across Each Component

Component	Experimental	Theory
Voltage Regulator	4.9v	5v
Sensor Gas MQ-6	4.8v	5v
Buzzer	4.6v	5v
LCD	4.8v	5v
MG995 Servo Motor	4.8v	5v

Table 3 displays the analysis of the MQ-6 gas sensor, specifically testing its response time and detection range for gas leaks. The information displayed in the table represents a recorded reading of 400 ppm for detected LPG gas. Sensitivity testing for the MQ6 sensor entails utilizing gas from a lighter and refilling a gas cylinder for the same lighter. The assessments were performed in an open area for a different distance.

Table 3. Analysis of MQ-6 Gas Sensor

MQ-6 Gas Sensor	Distance	Time	Detect/Not-Detect
1	60cm	2.20s	Detect
	30cm	1.96s	
2	60cm	2.30s	Detect
	30cm	2.05s	
3	60cm	3.00s	Detect
	30cm	2.12s	

Table 4 analyses the sensor's output, assessing its operational accuracy. Upon detecting LPG gas, the buzzer and LCD display emit continuous signals in the programmed sequence, with a delay time of 2.56 seconds. Furthermore, the servo motor requires 7.38 seconds to complete a full rotation to close the gas valve effectively.

Table 4. Analysis of Output Component

Component	On/Off	Time
LCD Display	On	2.56s
Buzzer	On	2.56s
Servo Motor MG995	On	7.38s

5. Discussion and Conclusion

This project's successful operation is achieved by utilising a pre-programmed Arduino ATmega328p circuit. This circuit plays a pivotal role in the project by overseeing the operation of various components, including the MQ-6 gas sensor, push button, LCD, buzzer, and MG995 servo motor. Moreover, numerous recommendations are aimed at further enhancing and optimizing this project: Upgrading the project by incorporating IoT capabilities, enabling it to send alert notifications through applications like Telegram, WhatsApp, and others and creating a more compact control circuit that can fit inside a smaller junction box, making it look neater and more organized. Enhancing the MQ-6 gas sensor component or modifying the program in the Arduino IDE to enable gas leak detection across a broader area. The suggested improvements mentioned above will enhance the project's future capabilities.

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