



ORIGINAL RESEARCH ARTICLE

DEVELOPMENT AND DESIGN OF A MICROCONTROLLER-BASED GAS WEIGHT  
AND LEAKAGE DETECTION SYSTEM

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ABSTRACT

This paper presents the design and development of a prototype system for monitoring gas leakage and weight in residential and semi-commercial. Liquid Petroleum Gas (LPG) installations LPG is widely used as a fuel source, but its leakage can lead to devastating fires, posing a significant threat to life and properties. Traditional methods of gas management based on natural nasal detection and estimation of usage are considered unsafe. The proposed system incorporates the MQ-5 sensor for gas leakage detection and the HX711 IC device for weight sensing. It includes a user alert system with a buzzer and LED for timely notifications of gas leakage and low gas levels. The control system, driven by the ATmega328p microcontroller, receives data from the sensors and triggers alerts accordingly. The power unit utilizes a 3.7-volts amplified lithium polymer battery stepped up by the MT3608. The results show that through week-long testing, the prototype demonstrated its effectiveness in monitoring weight and gas leakage, with constant monitoring of sound, LED, and display readings. This paper offers insights for replication as students projects, and suggests the need for more testing and calibration to ensure safety and the need for IoT-enabled features for smarter deployment and management. Furthermore, the prototype had contributed to promoting safety and preventing accidents in LPG installations by addressing the critical issue of gas leakage.

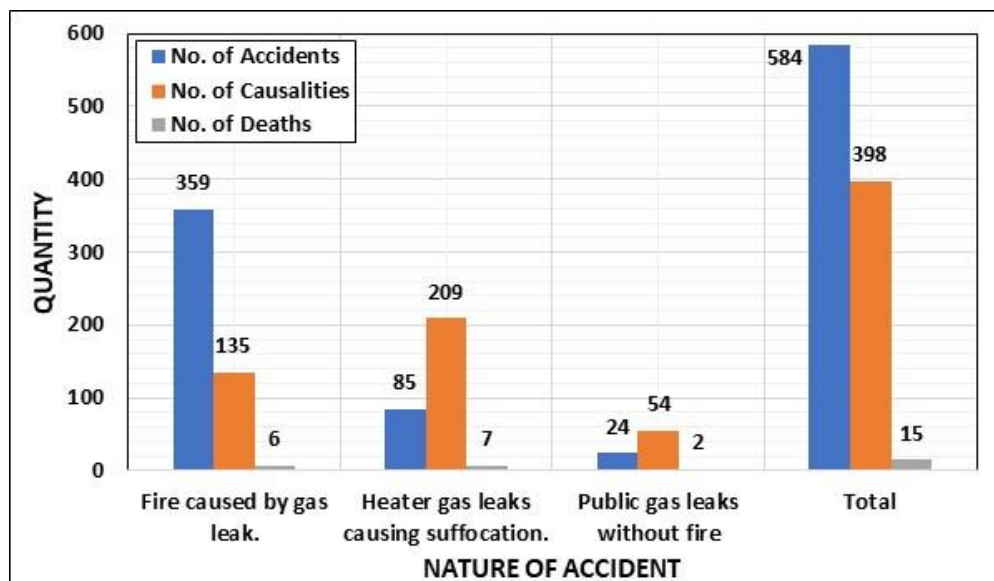
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1.0 Introduction

The use of electronic devices has become a norm in everyday life. It contributes significantly to various aspects of human activities at domestic and industrial levels, enabling greater efficiency and enhancement in these activities. Some of these devices are able to sense, monitor, and control various activities (Falohun et al., 2016). Liquefied Petroleum Gas (LPG) is a term used for a mixture of hydrocarbons that is stored in a specified cylinder for confinement purposes (Ihemtuge and Aimikhe, 2020). LPG is a clean source of fossil fuel and is used by domestic, commercial, and industrial users. It is mostly used for cooking purposes in Nigeria, accounting for major domestic use. LPG is used in households due to its relative speed of getting the cooking work done, thereby saving time during cooking activities. Moreover, it also offers a cleaner environment Olorunfemi et al. (2020), with increasing penetration across urban, suburban, and rural settlements and the potential to enhance the United Nations Sustainable Development Agenda.

The use of LPG is on the rise throughout the world owing to the increase in the population and the adverse effects observed from the use of other fossil fuels (wood and kerosene) contributing to climate change (Ihemtuge and Aimikhe, 2020). It was also observed that alternative sources of energy have caused severe health conditions, which include low birth weight and tuberculosis (Bergvall et al., 2005). However, the use of LPG attracts a great feeling of insecurity due to the fear of explosions, according to Fraiwan et al. (2011), with some statistics in Figure 1. It is noteworthy that some of the factors responsible for gas-related explosions include the proliferation of sub-standard LPG cylinders, over-pressurized cylinders, lack of adequate inspection and maintenance, and human-related errors (Klaene and Sanders, 2007). Most people, therefore, often regard it as a highly risky energy source and therefore use it with fear.

Gas-related fire incidences often occur due to the uncontrolled combination of gas with oxygen, aided by a momentary unintended spark (Falohun et al., 2016). The level of explosion, fire, and suffocation caused by a gas leak depends on the physical properties of the gas (such as toxicity and flammability) (Das et al., 2018). LPG is used in heating appliances, cooking equipment, and automobiles. Hence, fire incidents can occur at these points of usage, sale, and transportation. While LPG is used in stove burners in most homes, offices, hotels, restaurants, and workshops, it is conveyed using tubes. Mishandling of tubes and other gadgets can result in unwanted leakage of gas into the work area. Fire incidences are always severe, claiming lives, properties, and other important items during the occurrence (Odonkor, 2020). Exposure to LPG also leads to cold burns to the skin, loss of consciousness, and subsequent anoxia (Olorunfemi et al. 2020). Hence, the need to develop a device that is able to detect the leakage of gas from cylinders at various points of usage to ensure the safety of human life and properties.



**Figure 1:** Statistics on accidents involving the use and handling of LPG and natural gas in Jordan (Fraiwan et al., 2011)

Over the years, various related designs have been developed to ensure the safety of life and properties during LPG usage. Apeh et al. (2014) and Loshali et al. (2017) developed a kitchen gas leakage system which notifies occupants via an alarm system to ensure safety. Similarly, Shinde et al. (2012) developed a leakage detection system that employs the use of artificial intelligence and machine learning. The system can also detect the level of gas and leakage in the cylinder and is also equipped with an SMS feedback system to notify occupants. Furthermore, Murugam, (2020) also conducted a study in which an intelligent gas booking and leakage system was developed, employing the use of wireless sensors to notify owners of leakage and the current weight of gas in the cylinder. Shrivastava et al. (2013) developed a GSM-based gas leakage detection system. This creates a wireless notification which is sent to occupants or users regardless of their geological location.

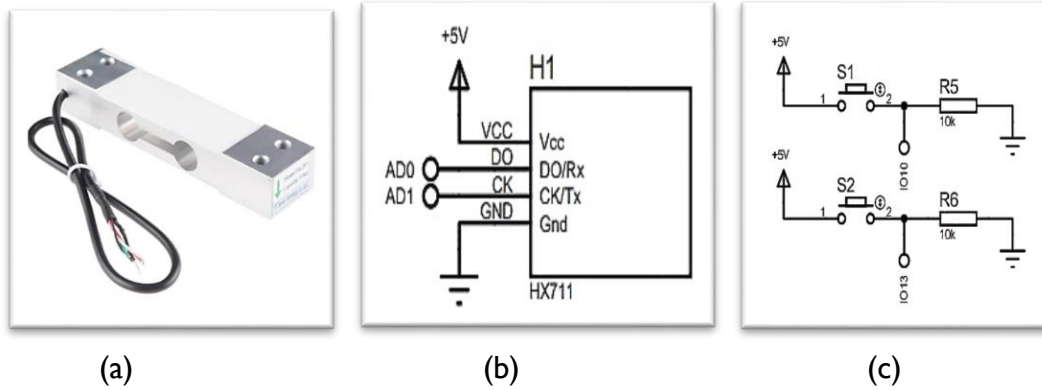
In the recent designs by Anika et al. (2021), the Arduino UNO microcontroller was used to create a smart gas detection system using a variety of sensors and actuators (MQ2, IR Fire Sensor, air fan, buzzer). When a gas leak is detected, the customer will be notified through SMS and via the Blynk application at the same time. Again, a recent study by Amadi et al. (2021) identifies a distribution mechanism for safely transporting cooking gas to homes in Rivers State. This gas distribution strategy is based on a single supplier, which could be public or private. Choba was chosen as a case study due to its strategic location. Additionally, gas properties were analyzed in conjunction with pipe properties. Although the study provides an economic analysis of how distributing cooking gas to homes can increase Nigerian gas utilization and benefits over the next decade, its feasibility remains a major concern.

This study was aimed at the design and development of a prototype for monitoring gas leakage and weight in residential and semi-commercial LPG installations. It is a simple electronic system capable of detecting gas shortages or leaks and alerting users to the occurrence early enough to mitigate gas-based accidents.

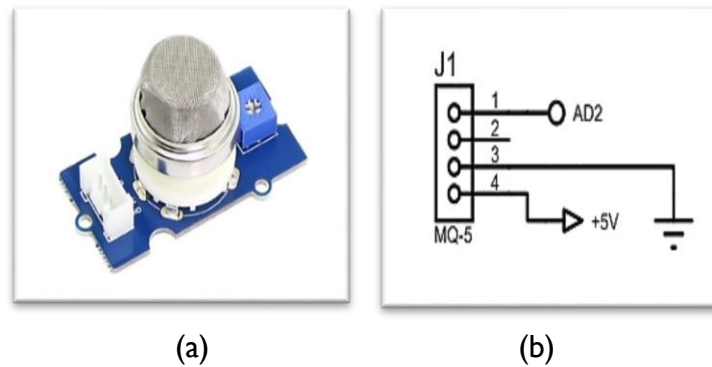
## **2. Materials and Methods**

The functionality of the designed gas leakage and level detection system is divided into the following sub-sections, which operate in concert to accomplish the prototype's objectives: sensing unit, user alert system, power/charging unit, and control unit. The sensing operation is based on the sensory circuitry, which is comprised of a gas leakage sensing circuit and an active weighing circuit.

Figures 2(a) and (b) depict the weight sensor HX711 IC and its circuit diagram, which operates within a voltage range of 2.6 to 5.5v. These diagrams provide a detailed representation of the necessary connections and components to ensure accurate weight measurements in the system. On the other hand, Figure 2(c) showcases the circuit design for the sensing knobs, essential for user interaction and control. The circuit design enables seamless integration of the sensing knobs, allowing users to interact effectively with the system. The provided circuit diagrams offer valuable insights into the connections, components, and design considerations needed for the successful implementation and functionality of the weight sensor HX711 IC and the sensing knobs within the system.



**Figure 2:** (a) 50Kg Load cell and (b) HX711 load cell amplifier circuit (c) Sensing Buttons for decision making.



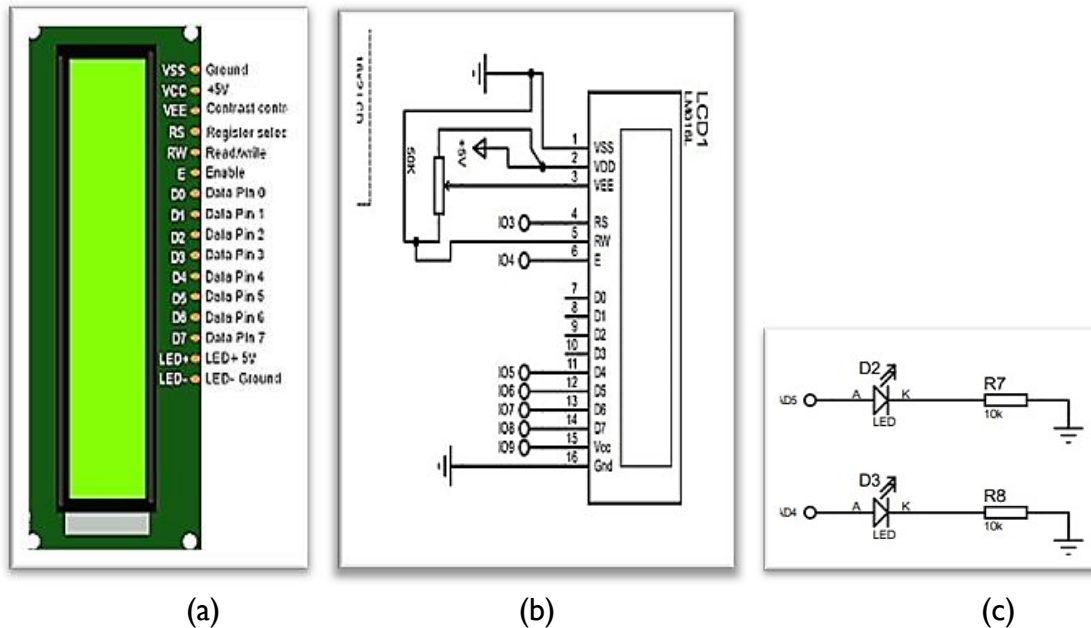
**Figure 3:** (a) The MQ-5 gas sensor (b) MQ-5 circuit diagram.

For intelligent gas leakage detection, the MQ-5 gas sensor was employed due to its exceptional capabilities. The sensor offers several advantages, including high sensitivity, quick response time, and the ability to detect a wide range of gases such as ethane and methane. To ensure proper functionality, the MQ-5 sensor requires a 5v direct current (DC) power source. Therefore, a 5v supply voltage was employed to power this specific component in the prototype design. The circuit diagram for the MQ-5 gas sensor is illustrated in Figure 3(a) and (b), providing a visual representation of the connections and components involved in incorporating the sensor into the system. By utilizing the MQ-5 gas sensor and adhering to its voltage requirements, the prototype design achieves efficient and accurate gas leakage detection.

The prototype incorporates a liquid crystal display (LCD) measuring [80.0 × 36.0 × 13.5] mm as shown in Figure 4(a), providing users with timely information. The LCD utilizes the advanced capabilities of the ATmega328p microcontroller for seamless communication and displaying the LPG's weight and leakage status. The circuit diagram for the LCD display is depicted in Figure 4(b). Additionally, the device features a light-emitting diode (LED) as an extra user indicator, indicating various levels and conditions such as "LOW GAS," "GAS LEAKAGE," and "POWER ON or OFF." The circuit diagram for the LED indicator unit is shown in Figure 4(c). To regulate the LED current, a 10 kΩ resistor is employed, adhering to Ohm's law (Equation 1) (Theraja, 2006).

$$V = I \times R \quad (v) \quad (1)$$

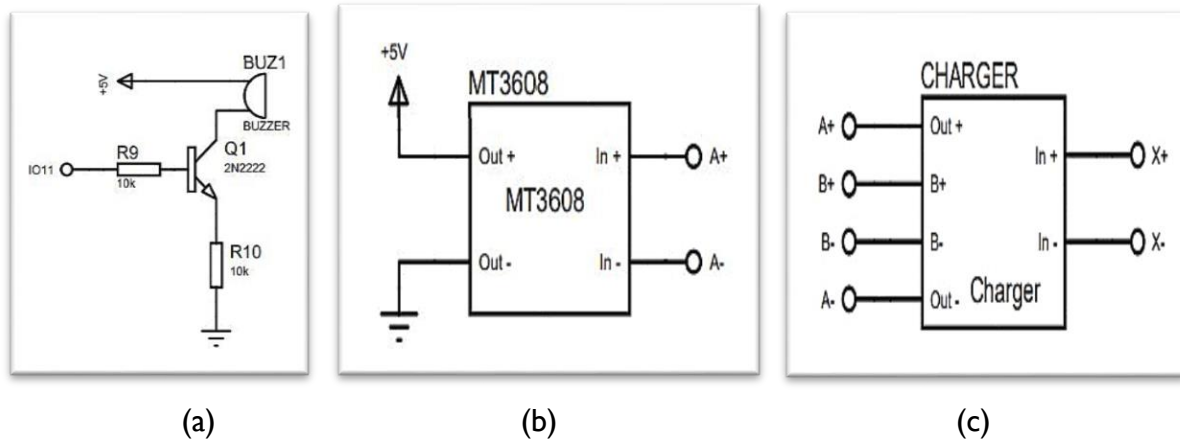
where  $V$  is the voltage in volts (v),  $I$  is the current in Amperes (A), while  $R$  is the resistance in Ohms ( $\Omega$ ).



**Figure 4:** (a): Liquid Crystal Display (b) LCD display circuit diagram (c) Indicator light circuit diagram

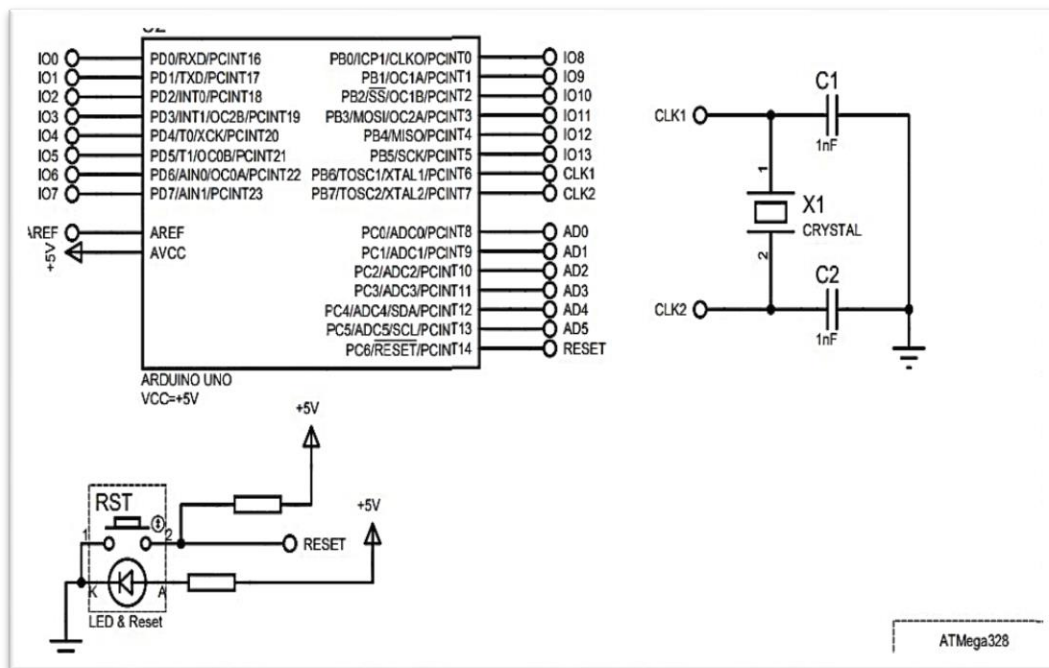
An effective buzzing system is integrated into the prototype to promptly notify and warn users. The circuit diagram for this buzzing system can be seen in Figure 5(a), illustrating the connections and components involved in generating the audible alerts. The buzzing system plays a crucial role in enhancing user awareness and ensuring timely response to gas leakage or low gas level, thereby enhancing user safety and attentiveness to critical situations.

The device relies on a 3.7v (nominal) lithium polymer battery with a 2A current rating to power its operations. To regulate the battery's charge and discharge rate, the TP4056 integrated circuit (IC) is utilized. This IC ensures the optimal management of the battery's performance and longevity. The TP4056 IC outputs a voltage of 4.2v, which is then directed to the MT3608 bulk converter (Figure 5(b)). The MT3608 converter steps up the voltage as required, allowing the device to operate at higher voltage levels necessary for specific components or subsystems. Through the combined use of these components, the device effectively utilizes the power supply from the lithium polymer battery, with controlled charging and discharging (Figure 5(c)), and the ability to handle higher voltage requirements when needed.



**Figure 5:** (a) Output buzzer circuit diagram, (b) MT3608 circuit diagram, (c) TP4056 circuit diagram

To power the ATmega328P microcontroller and other sensors and units, a voltage boost is employed to increase the voltage to 5v. This step is necessary to ensure proper operation and functionality. Additionally, the control unit becomes essential in situations where the power supply operates in multiple phases, providing synchronized and regulated electrical current. By employing these measures, the prototype achieves optimal power supply management and ensures the reliable operation of the system components. The pin mapping for the Microcontroller is as shown in Figure 6 with a section of the circuit diagram of the gas leakage detecting system.



**Figure 6:** Microcontroller pin mapping with a section of the circuit diagram for the system

The gas leakage detection system's circuit diagram is visually represented in Figure 6, providing an overview of the interconnected components and their relationships. The foundation of the system design primarily relies on the utilization of the ATmega328P microcontroller, which serves as the central processing unit. Alongside the microcontroller, various input devices play crucial roles in the system's functionality. These input devices consist of the MQ5 gas sensor, responsible for detecting gas leakage, the weight measuring sensor for monitoring weight-related parameters, and the control knobs enabling user interaction and adjustments.

Additionally, the system incorporates several output devices that provide relevant information and alerts. These output devices include a liquid crystal display (LCD) for presenting relevant data and messages to the user, a buzzer to generate audible alarms or notifications, and LED indicators to visually convey specific system states or conditions. By integrating these components into the circuit design, the gas leakage detection system becomes a comprehensive solution capable of accurately sensing gas leakage, monitoring weight measurements, facilitating user control, and conveying vital information through the LCD, buzzer, and LEDs.

$$F_S = 1/(2\pi \sqrt{L_S C_S}) \quad (2)$$

where  $F_S$  is the oscillating frequency of the crystal oscillator,  $L_S$  is the inductance which is given as  $4.5 \times 10^{-6}H$ , while  $C_S$  is the value of the capacitor (Theraja, 2006).

$$16 \text{ MHz} = 1/(2\pi \sqrt{4.5 \times 10^{-6} \times C_S}) \quad (3)$$

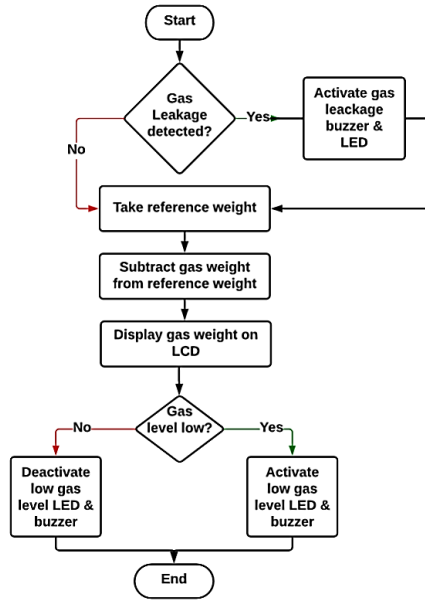
where

$$C_S = 11/(16 \text{ M} \times 2\pi \times 4.5^2 \times 10^{-12}) \quad (4)$$

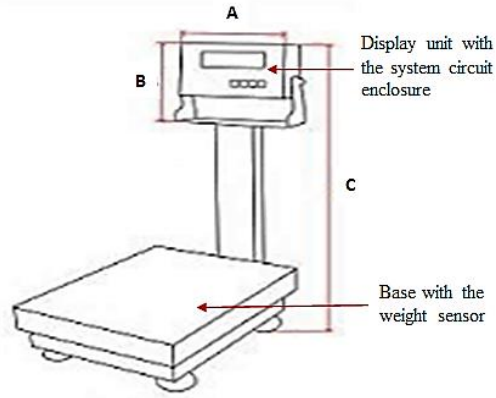
Therefore,

$$C_S = 22 \text{ pF}$$

The operational flow chart of the system prototype is depicted in Figure 7(a), providing a visual representation of the sequence of operations, while Figure 8 presents the comprehensive circuit diagram for the system. The proposed design includes a comprehensive conceptual diagram that illustrates the foundation of the system. This diagram is presented in Figure 7(b) and demonstrates the designated location for the gas cylinder, which will facilitate accurate measurement of the gas quantity and effective detection of any potential leaks. Table I shows the circuit connection pinouts. During the circuit design phase, the sizing of the capacitor was determined using Equations (2) to (4). These equations served as guidelines for establishing the appropriate capacitor size, taking into consideration the frequency of the crystal oscillator, which operates at a frequency of 16 MHz. By employing these equations, the accurate selection and integration of the capacitor to optimize the functionality and performance of the system was ensured.

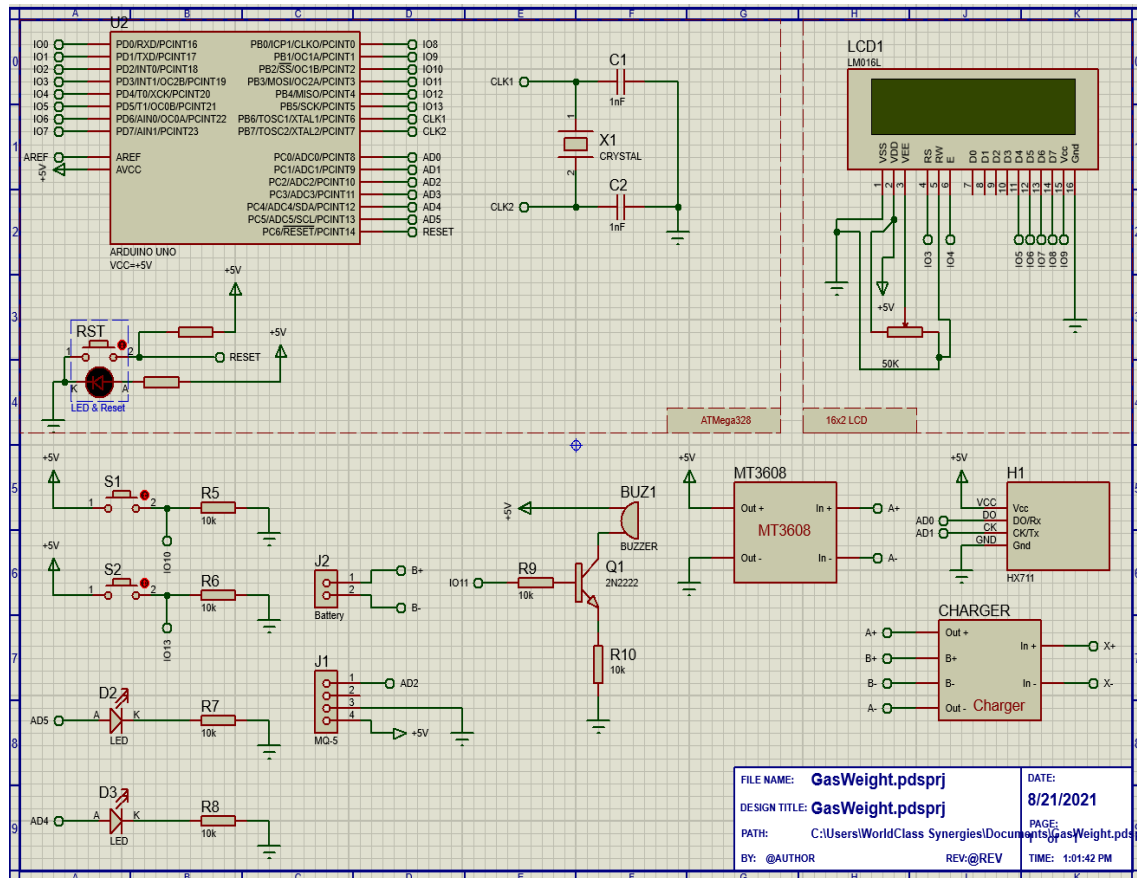


(a)



(b)

**Figure 7:** (a) Operational flow chart of the working prototype, (b) The comprehensive conceptual diagram for the system



**Figure 8:** The comprehensive circuit diagram for the system



The prototype incorporates two essential software components: a basic programming language Compiler adhering to the AVR microcontroller programming language standard and the Arduino Development Environment. The Compiler facilitates programming and interfacing with the AVR microcontroller, ensuring compatibility and smooth functionality. It provides a comprehensive set of tools for code writing, compiling, and uploading to the microcontroller. On the other hand, the Arduino Development Environment offers a user-friendly platform for coding, compiling, and uploading programs. It simplifies the development process with its extensive library of pre-written functions and examples. By utilizing these software tools, efficient code development was achieved and the capabilities of the AVR microcontroller to achieve the desired functionalities effectively was harnessed.

**Table I:** Circuit Connection and Pinouts

| S/N | FUNCTION           | CONNECTOR | INDICATION ON THE MICROCONTROLLER |
|-----|--------------------|-----------|-----------------------------------|
| 1   | POWER              | +5 v      | POWER (+5 v)                      |
|     |                    | GND       | GND                               |
| 2   | WEIGHT SENSOR      | DO        | Analog Pin 0                      |
|     |                    | CK        | Analog Pin 1                      |
| 3   | GAS SENSOR         | AD2       | Analog Pin 2                      |
| 4   | BUZZER             | IO11      | Digital Pin 11                    |
| 5   | LED                | D1        | Analog Pin 4                      |
|     |                    | D2        | Analog Pin 5                      |
| 6   | PUSH BUTTON        | RST       | Reset                             |
|     |                    | S1        | Digital Pin 10 (PWM)              |
|     |                    | S2        | Digital Pin 13                    |
| 7   | CRYSTAL OSCILLATOR | CLK1      | Crystal                           |
|     |                    | CLK2      | Crystal                           |
| 8   | LCD                | IO3       | Digital Pin 3                     |
|     |                    | IO4       | Digital Pin 4                     |
|     |                    | IO5       | Digital Pin 5                     |
|     |                    | IO6       | Digital Pin 6                     |
|     |                    | IO7       | Digital Pin 7                     |
|     |                    | IO8       | Digital Pin 8                     |
|     |                    | IO9       | Digital Pin 9                     |

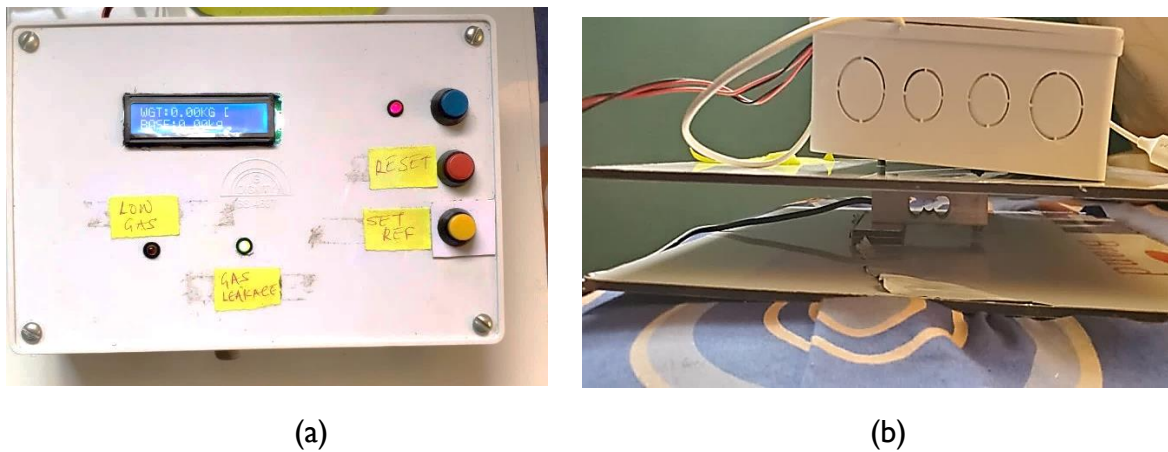
### 3. System Assembly and Testing

The proposed device incorporates various components and electronic parts enclosed within a plastic-based casing measuring (400 x 300 x 100) mm. Before attaching the indicators and knobs, precise perforations were made in the casing to accommodate these elements. The choice of this casing material stemmed from the desire for aesthetic appeal and insulation, ensuring safety during Liquid Gas System (LGS) installation.

Figure 9(a) displays the system prototype, highlighting the enclosure for the circuitry and the display unit. Figure 9(b) presents a side view of the base on which the cylinder is positioned. The prototype features an LED display indicating sample weight and detected leakage as "WGT:

0.00KG" and "BASE: 0.00KG," respectively. The gas sensor operates within an analog value range of 0 to 1023. When gas leaks, sensor readings above 300 indicate higher gas concentration and turn on the LED and Buzzer to alert of gas presence in the environment. Readings below 300 indicate no leaks. These design considerations and features significantly contribute to the overall functionality and effectiveness of the gas detection system.

Over a week, the weight and gas leakage detector were tested under typical operating settings without gas leaks. Throughout this period, the system was continuously monitored, including the buzzer, observation of LED indicators, and tracking of display readings. The device was subjected to further testing, which included the random release of gas into the environment to assess its responsiveness under different unquantified concentration levels.



**Figure 9:** (a) Gas leakage sensor in the prototype enclosure showing the display unit (b) Side view showing the gap between the weight sensor and the top plate for the base of the system.

#### 4. Results and Discussion

This section presents the results of our preliminary assessment of the gas leakage and weight detection system. Based on the observations derived from the initial evaluation, it can be concluded that the prototype demonstrates satisfactory performance. This is evident from the consistent readings obtained from the MQ-5 sensor, which consistently fell within the predetermined thresholds for both safe and unsafe conditions. Notably, the activation of the buzzer and LED indication was observed exclusively when the readings indicated an unsafe range, i.e., for readings exceeding 300. In addition, the weight sensor successfully recorded a progressive decline in gas volume over the duration of the observation time.

Nevertheless, it is important to recognize that additional extensive standardized testing may be necessary to evaluate the effectiveness of the gas sensor. This testing could encompass several aspects such as sensitivity, as well as tests examining its performance under different temperature and humidity conditions.

## 5. Conclusion

This paper presents the successful design and implementation of a gas leakage and weight sensing system prototype. The system offers a straightforward yet effective solution by promptly alerting users in the event of a gas leak and providing gas cylinder level indications, thereby mitigating potential explosions in residential and industrial environments. This documentation serves as a valuable guide for replication and adaptation by electrical and electronic engineering students working on mini projects within higher education institutions (HEIs), as well as for entrepreneurs with a solid electronics background seeking to pursue personal projects. The components utilised in the prototype are easily accessible and economically viable, resulting in a total expenditure of ₦30,000. This stands in contrast to the comparatively greater expenses associated with pre-existing commercial products or devices. Furthermore, future enhancements such as integrating IoT-enabled capabilities can be explored to enhance usability and functionality. Despite the device's functionality and gas leak response, more testing and calibration are needed to further guarantee increased safety and notify consumers. This prototype represents an important contribution to gas safety measures and offers potential avenues for further advancements in the field.

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