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Research Article

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An Embedded Arduino based LPG Detection System with SMS Alert and Automatic Gas Shut Off

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Abstract The level of technological advancement which engendered enhanced transportation of Liquefied Petroleum Gas (LPG) has, to a large extent, solved the problem of energy demand. Unfortunately, in doing this, it brought about concomitant risk- damage to the pipes as a result of human errors, natural disasters, and acts of vandalism. This paper addresses the issue of gas leakage and proposes a leakage detection system using an MQ-2 gas sensor, a buzzer, and a GSM module. A response mechanism which shut off the supply of gas when the level of leakage seems not to reduce.

Keywords LPG gas, Leakage, MQ-2 Sensor, GSM, SMS

Introduction

LPG is gaining wider usage in developing countries like Nigeria because it offers higher energy density and it emits low smoke and produces lesser soot. LPG is made up of a mixture of slighter light hydrocarbons like propane and butane. Light hydrocarbons like methane and ethane used in gas cylinders are safe provided there's no leak.

However, gas leakage has been a major concern lately because its effects can be devastating. From explosion to suffocation, it can result in death or even loss of properties worth millions of dollars. Most cases of the leak are associated with human errors; forgetting to switch off gas cylinders or overfilling them at gas stations. As a result, there has been a growing desire for a remotely controlled leak-detection system for gas cylinders.

This paper aims to address this challenge by inventing a novel approach to automatically detect and control the leak. It detects leak using a sensor. Thereafter, the system is automatically shut off. GSM technology is then used to send SMS signals to a mobile device to inform the owner of a leak. An Arduino board was used (self-contained USB development board centred on an ATMeg328P microcontroller) and imitated using Proteus software.

The set-up uses an MQ- gas sensor to detect any leakage. The concentration of gas in the operational area is then reduced by using an extractor fan. However, if gas concentration increases above a threshold amount, then gas supply is shut-off, the alarm is turned on and an SMS is sent.

Related Works

Over the years, various inventions have been created to detect LPG leakage. Even before household leak detection was first used in the 1980s, a chemically infused paper that changed colour on exposure to leak was used in leak detection. In recent times, more sophisticated means have been invented to detect, monitor and control leak situations. In 2015, Didpaye [1] developed a means of continuously monitoring leakage. In 2011,

Batzias [2] proposed that gases like methane are lighter than air and the density variation causes a fluctuation that can be used to determine the possibility of a leak. In 1989, Sandberg, et al [3], used a cable sensitive to hydrocarbon to detect a leak with an accuracy within 20 meters. However, the unavailability of sensing cable brought about the decline of its adoption. Zhijie [4] in 2011 and Soundarya [5] in 2014 developed a gas detection and monitoring system but failed to cater for shutting off the leakage.

In 2013, Ashish et al [6] made use of an MQ-6 sensor, a GSM module and a Philip controller to design a GSM-based LPG detection system. The MQ-6 sensor is highly sensitive to LPG and is effective in detecting even the minutest amount of leak. In the event of a leak detected by the sensor, the microcontroller relays the information through an SMS sent to a GSM so as to notify the authority for adequate actions. Conclusively, from literature, it can be observed that there is need for designing LPG gas detection and shut off system for developing countries.

Hardware design of the System

The aim of this work is to design an effective system that will; accurately detect leakage, display leakage message and shut-off gas supply in an event of an uncontrollable leak so as to prevent wastage and eliminate the possibility of an accident.

The setup is made up of a microcontroller with an MQ-2 gas sensor that detects the smallest amount of leakage. The microcontroller is integrated with an alarm system and an LCD. When a leak is detected, the alarm goes on and a visual leak message is displayed on the LCD. Also, in the event of a leak, a GSM module automatically relays the information to the authorized person. The setup also consists of an Emergency Shutdown System (ESDS) that automatically shut off the gas supply if the leakage exceeds the specified threshold.

The overall system is made up of smaller units and the overall integration was achieved by;

1. Designing a Power Supply unit
2. Designing and construction of a Gas sensing unit
3. The programming of the Microcontroller (ARDUINO board centred on Atmega28) unit.
4. The implementation of an Extractor fan and alarming unit
5. The implementation of an SMS sending unit using a GSM module

1. Power Unit

The Power Supply Unit is made up of 220V, 50 Hz AC source. A step-down transformer is used to step down to about 9.5V. Rectification of the 9.5V AC is achieved by the use of a full wave bridge rectifier and is then smoothened by a shunt capacitor filter to 12 V DC. The 12V is then regulated to 5V before being fed to the buzzer, microcontroller and gas sensor. The Circuit diagram for this arrangement is as shown below in Figure 1;

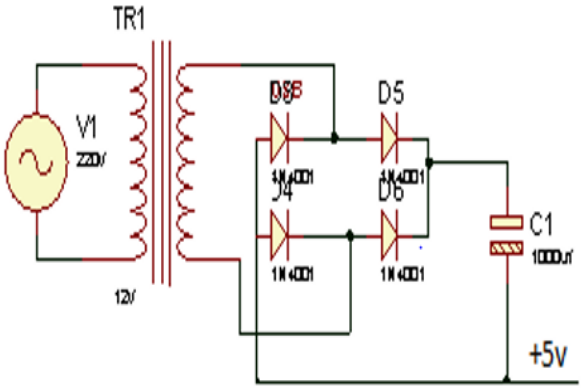

Figure 1: Circuit Diagram of Power Supply Unit

2. Gas Sensing Unit

An MQ-2 LPG detector module is the component responsible for sensing leakage. This LPG sensor is very easy to make use of and it is perfectly suited for sensing LPG (consisting of majorly propane and butane) present in the air. It is most effective when used to detect leak concentration between 200 to 10000ppm.

The resistance of the sensor (Rs) is given by the expression;

$$Rs = \left(\frac{V_c}{V_{rl}} - 1\right) \times Rl$$

Where VH is heater voltage = 12V, RS is sensor resistance = 10kN, VC is the supply voltage to load =12V, VRL is the voltage across load resistance, and RL is the load resistance = 10kN. The circuit diagram of the unit is as presented in Fig 2.

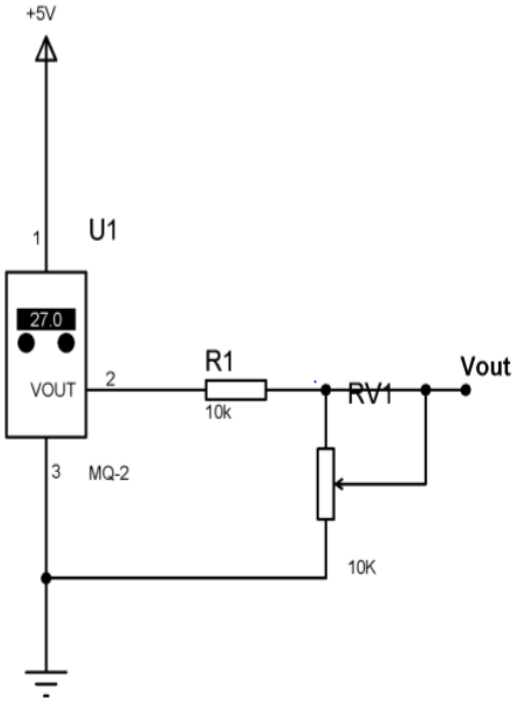

Figure 2: Gas detector unit

3. Programming the Microcontroller Unit

C programming language is used to program the microcontroller. It then translates it to produce a hexadecimal code file (machine code). The process used for developing the C language by the Code block Arduino compiler and the debugging of the code into machine language is as follows;

1. Creating the Project File and adding of source files

In the menu bar, click project→ Project Wizard. Thereafter, click 'Next' that is displayed on the project wizard dialogue box. The 'Next' window then opens. Then click on 'device', a drop-down menu comes up of which you are to select ARDUINO. Click 'Next' and select 'COM' suite from the drop-down list. Thereafter, click 'Next'. Then, fill in the project name as 'Gas detector' and specify its directory. The file is then saved and you can click on 'Finish'. Now you have successfully created a project and added the source files.

2. Compiling the Project

To compile the program, select the 'Project menu and 'click on the 'Build' option. The software is automatically compiled and a 'Build successful' message is displayed on the window screen. After the successful compilation of the program, the file 'gas detector.hex' is automatically generated.

4. Extractor fan and alarming unit.

The extractor unit controls the extractor fan that is used for extracting gas in the surrounding. Its circuit diagram is as shown in Figure 3.

The alarming unit consists of an electric buzzer that is constructed with a pin-type terminal to allow for direct mounting on the printed circuit board. Its operating voltage is between 3V – 6V. The sound wave generated by the alarm is about 85 decibels.

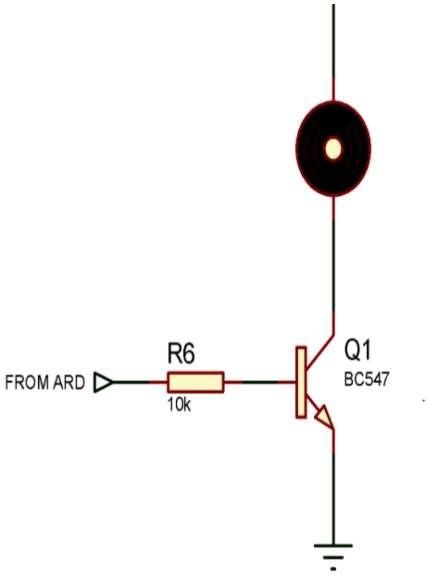

Figure 3: Extractor control circuit

5. SMS sending unit using GSM module

The SMS sending unit uses a GSM module. The SIM800 GSM module is integrated with the Arduino as shown in Figure 4. GSM (Global System for Mobile)/ GPRS (General Packet Radio Service) TTL-modem is a SIM800 Quad-band GSM/GPRS device that works on frequencies 850MHz, 900 MHz, 1800MHz, and 1900 MHz. Its small size makes it easy to connect it as a plug to the GSM Modem. The Modem possesses a 3.3 and 5 V DC TTL interfacing circuitry. This makes it possible for users to directly interface with 3.3 V microcontrollers like ARM and ARM Cortex XX or 5 V microcontrollers like PIC, Arduino, AVR, 8051, etc.

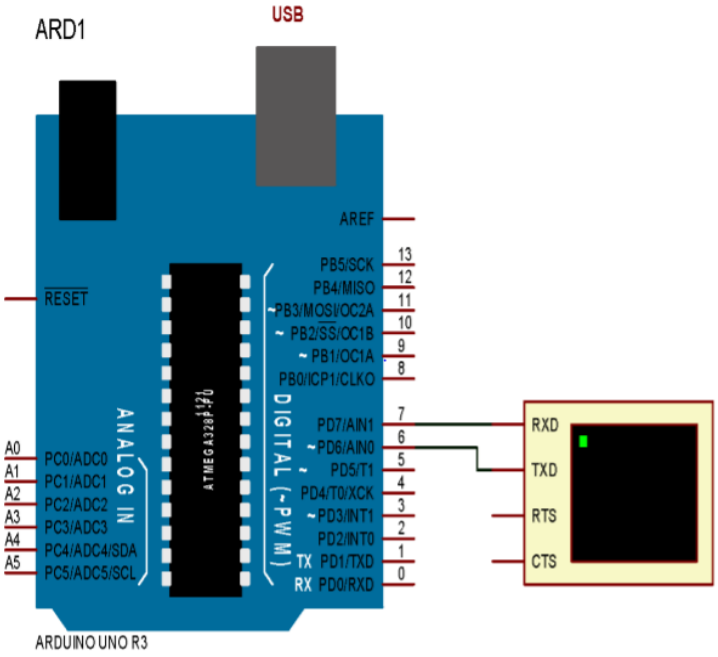

Figure 4: SIM800L GSM Module interfaced with Arduino

The Circuit diagram and the flowchart of the system is as presented in figure 5 and 6 respectively, the system circuit shows how all the units are integrated together and the flowchart shows the flow of activity of the system.

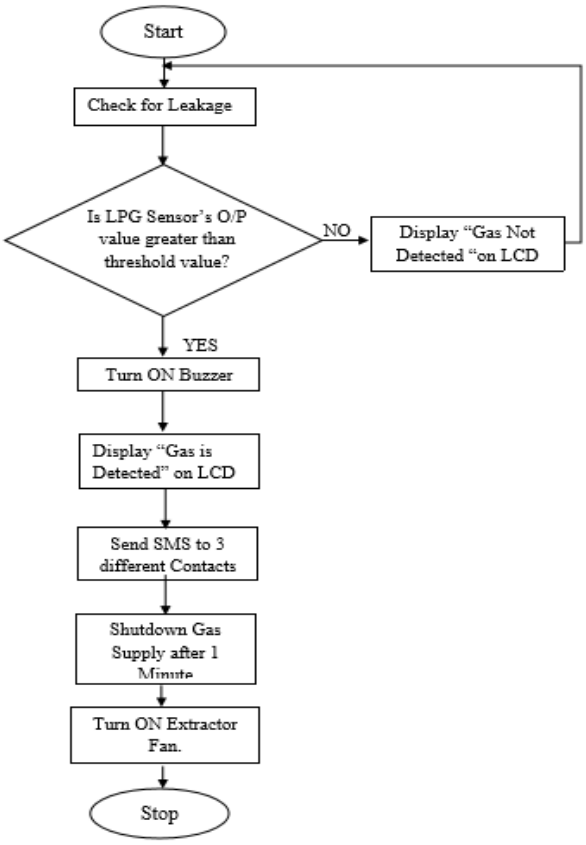

Figure 5: The flowchart of the System

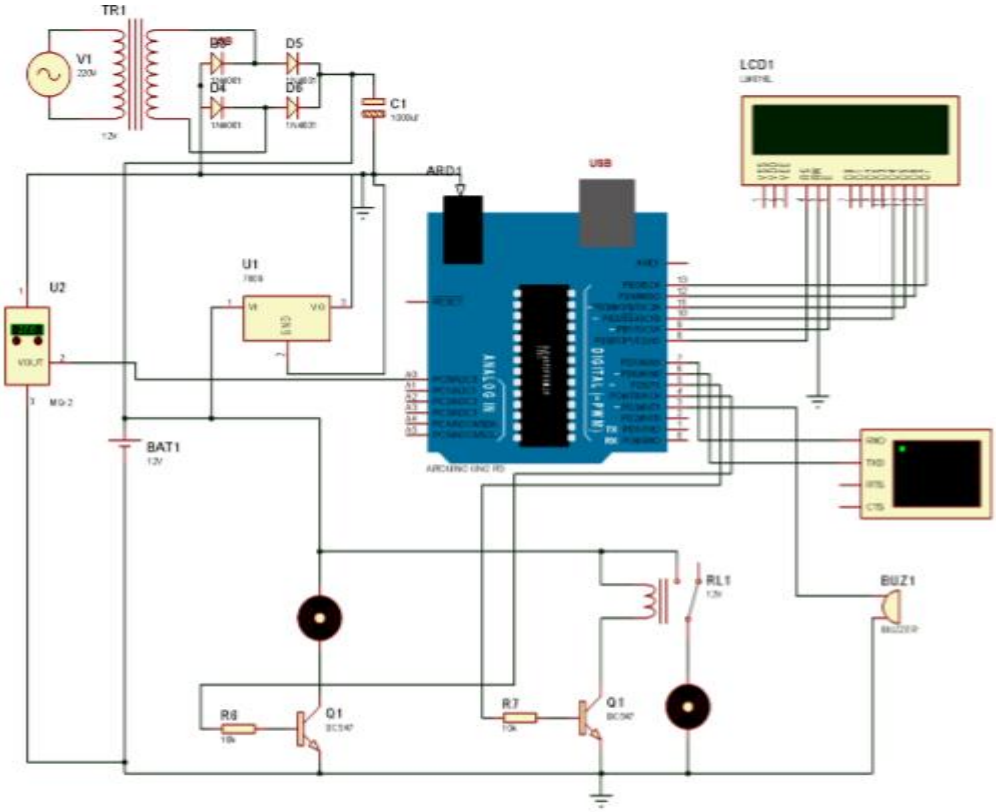

Figure 6: Circuit Diagram of the System

System Testing

The system testing was carried out by using a stage-to-stage testing approach. At different implementation stages of the projects, the following equipment was used;

A) Bench Power Supply: During the breadboard test, the bench power supply was used to feed voltage to the different stages of the circuit. Thereafter, the power supply in the project was soldered. During the soldering of the project, various stages were tested using the power supply before soldering was completed.

B) Oscilloscope: This was used to closely monitor the wave function of the power waveform. It ensures that all waveforms are at the accurate frequencies. In this system, the desired frequency was 4MHz and the waveform generated by the crystal oscillator was used to ensure that this frequency was maintained.

C. Digital Multi-meter: This is used to measure resistance, voltage, current, continuity, temperature, frequency and transistor. The implementation of the proposed design required the measurement of variables like voltage, current, continuity, and resistance of components. In some cases, the frequency was even measured. Also, the output voltage of the regulators used was regularly checked by the digital multimeter.

Figure 7 and 8 show the operation of the project under normal condition while figure 9 and 10 show the operation of the project when LPG is detected by MQ-2 gas sensor. During normal operation the microcontroller makes the LCD to display the title of the project "GAS LEACKAGE DET." Which then disappears after 5seconds and display "GAS NOT DETECTED"? Under normal condition the solenoid valve is activated thus allowing the flow of gas supply to the gas cooker.

When leakage is detected, a signal is sent to the buzzer from the microcontroller to blow an alarm, the electromagnetic solenoid is deactivated to automatically halt the flow of gas supply to the cooker. The extractor fan is activated to reduce the gas concentration from the environment. A message which reads "GAS IS LEAKING IN YOUR KITCHEN" is sent to the user's mobile phone. At same instant, the LCD shows a message notifying the gas leakage as well as the amount of its concentration in the surrounding.

Figure 7: Normal condition of the project displaying the project's title

Figure 8: Normal Condition of the Project

Figure 9: Gas leakage Condition of the Project when sending the message

Figure 10: Gas leakage Condition of the Project after the message is sent

Conclusion

This paper has investigated a novel way of managing LPG leakages which is a major challenge in today's world. The designed device is able to accurately detect a leak and even shut-off further flow when a leak occurs. This setup was simulated using Proteus.

An MQ-2 gas sensor is used to detect the smallest amount of leak. In the case of a leakage, the microcontrollers stimulate the buzzer which informs anyone close by of the leakage. In addition, with the aid of a SIM800L GSM Module, an SMS showing "GAS IS LEAKING IN YOUR KITCHEN" is sent to the mobile device of the property owner. If leakage amplifies above the threshold, the solenoid is automatically closed to prevent further wastage and even possible explosion.

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