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Abstract

Purpose: Gas leakages have posed a major safety threat in the society especially in homes. Devices for early detection of Liquefied Petroleum Gas (LPG) popularly used in many developing countries are not so common and costly when available. This paper proposes a low-cost alarm-based LPG leakage monitoring system for home safety.

Materials and Methods: It uses MQ-6 gas sensor with PIC16F877A microcontroller circuit powered by a 9VDC battery to sustain the system even when the main power is out. The microcontroller is connected to an LCD screen and a buzzer to show the alerting part. An exhaust fan is connected at the output in order to disperse the gas away from the ignition source. Different quantities of the gas and perfume (for comparison) were measured and used for the test and the response time was observed. The system was designed and first simulated successfully using Proteus 8 before hardware implementation.

Findings: The results show that for high, medium and low concentration of LPG, the average response times obtained are 0.78s, 1.05s and 1.95s respectively. Similarly, for the perfume tested at different volumes ranging from 11ml to 29ml, the corresponding average response times range from 1.95s to 0.61s. The results show that for both tests, the average response time reduces with concentration. The higher the concentration, the shorter the time to raise the alarm. The cost analysis of the system shows that it is affordable for domestic use. **Implications to Theory, Practice and Policy:** Further work can involve control actuator such as solenoid to cut off the gas supply.

Keywords: *LPG (Liquefied Petroleum Gas, Gas Sensor MQ-6, Microcontroller (PIC16F877A), Liquid-Crystal Display (LCD), Piezo Buzzer.*

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1.0 INTRODUCTION

Safety plays a vital role in the world and thus good safety systems are needed at homes, schools and Industries. Liquefied Petroleum Gas (LPG) is one of the fuels used for cooking in many developing countries like Nigeria, India, South Africa etc. It is also used as an alternate fuel for automobiles due to the high price of diesel and petrol. It consists of mixture of propane and butane which are highly flammable chemicals [1]. In a case of gas leakage, it might be difficult to be able to sense the leakage because of poor sense of smell when the concentration is low. Thus, a gas leakage system detector system is often proposed as solution [2]. The MQ-6 gas sensor with a range of 200-10000 ppm[3] is required in this design, which will be connected with an alarm and display system. The 1984 San Juanico tragedy in Mexico City, one of the most severe LPG disasters in history was caused by undetected LPG leakage[4]. This makes gas detection very important for safety of life and properties as gas leakage poses a great treat to both industrial, commercial and domestic users[5].

In Nigeria, there have been fire incidents and explosions in industries and environment where LPG is used[6]. Although, there are few records of LPG related accident in Nigeria, one of the few recorded case includes an accident that occurred in august 2015, in which a Family in Azia community of Anambra State Nigeria took delivery of nine bodies of their children who were involved in a fire accident caused by undetected gas leakage in Lagos Nigeria[7]. The major problem is that in most homes, gas leakage detection systems are not installed. In such a situation, there will be no system to alarm the occupants or to automatically shut the gas supply[8]. This causes a fire safety gap that can lead to a greater disaster when an ignitions source is present. Thus, the gas detection system is very important to prevent fire accidents from taking place. Devices for early detection of Liquefied Petroleum Gas (LPG) popularly used in many developing countries are not so common and costly when available.

The objective of this work is to design a micro controller based detecting and alerting system. The paper aims at developing a low cost prototype of a working gas leakage detector system capable of detecting LPG gas leakage using an MQ-6 sensor which raises an alarm to alert the consumer and also capable of shutting the gas supply through a solenoid valve when connected to the port provided.

A number of papers have been published on LPG leak detection system where the gas sensor detects the gas and communicates with a circuit that will initiate an alarm that can alert the user to take precautionary measures [9, 10, 11]. There is a need to look into existing safety model used at home with the aim of modifying it[12]. Various research groups are working to develop similar detectors due to its safety importance. LPG, first produced in 1910 by Dr. Walter Snelling is a mixture of commercial propane and commercial butane having saturated and unsaturated hydrocarbons [1]. Gas presence was detected using chemically infused paper that changes its colour in response to exposure of the gas before the development of electronic based gas detectors [13]. In gas tankers, wireless sensors were used for detection of leakage[14]. Ramya and Palaniappan also developed an embedded system for system detecting hazardous gas[15]. There are varieties of sensors that can be used for sensing LPG amongst which are MQ-2, MQ-6, and MQ- 312 etc.

MQ Series Gas Sensors are highly sensitive devices that are used for detecting the presence of a variety of gases in an area. MQ sensors are made of a heating element, named *heater*, and of an electrochemical sensor; the *heater* is needed in order to bring the sensor to the proper operational conditions, since only at certain temperatures the sensor‘s sensitive surface (typically, a metal oxide) will react, and will let the gases and the particles (the ones we wish to detect) penetrate it[16]. In recent times, the use of kerosene, coal and firewood for cooking in Nigeria has gradually shifted to the use of LPG due to the fact that it burns faster and doesn‘t leave stains or carbon deposits on the cooking utensils after burning. These has led to increase production of LPG and reduced flaring in the country. Companies like Nigeria LNG, Total

Gas, and Greenville LNG etc. has increased domestic distribution of LPG within Nigeria. Figure 1 shows chart comparing the gas production, utilization profile in Nigeria.

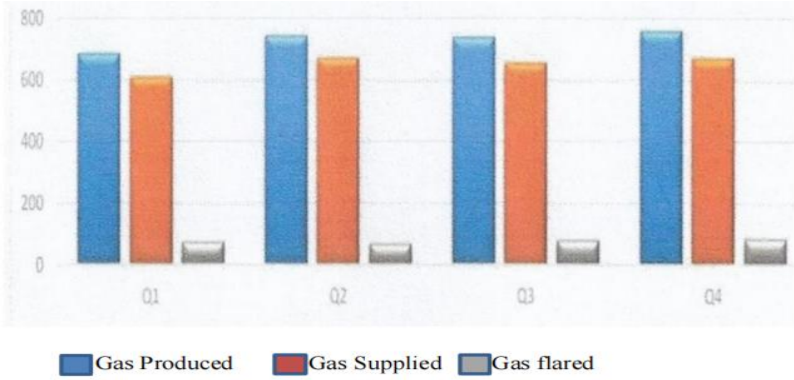

Figure 1: Gas Utilization/Production Chart [17].

MQ-6 is a semiconductor type gas sensor capable of detecting gas leakage. Tin dioxide (SnO_2) is the sensitive material of MQ-6. It has very low conductivity in clean air. MQ-6 Gas sensor is sensitive to propane, butane and other natural gases; it has a low sensitivity to cigarette smoke and alcohol[18]. The MQ-6 sensor module comes with a digital pin which makes this sensor to operate even without a microcontroller and that comes in handy when only trying to detect one particular gas [19]. MQ-6 gas sensor has a concentration range of 300-1000 ppm. This sensor is available in 6 pins package, out of which 4 pins are used for fetching the signals and other 2 pins are used for providing heating current. This sensor has fast response time. The voltage required by the sensor is 5 V. Measuring the PPM of an MQ-6 gas sensor is the best way to achieve some accuracy. This can also be used to distinguish one gas from another. Thus, PPM can be measured directly using a module. A basic wiring for the sensor from datasheet is shown in Figure 2.

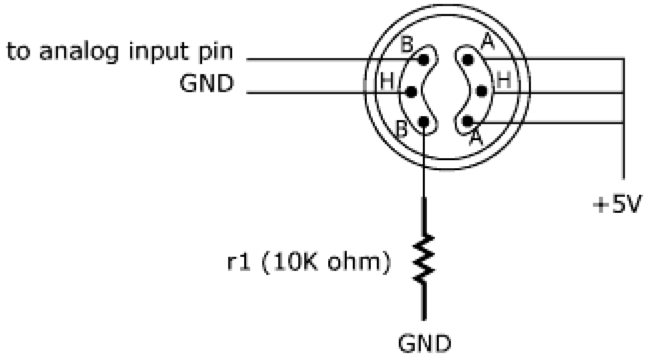

Figure 2: Wiring Diagram For MQ-6 Gas Sensor [20]

The procedure to measure PPM using MQ sensor is the same but few constant values will vary based on the type of MQ sensor used. Basically, we need to look into the (Rs/Ro) VS PPM graph given in the MQ-6 datasheet, and also shown in Figure 3.

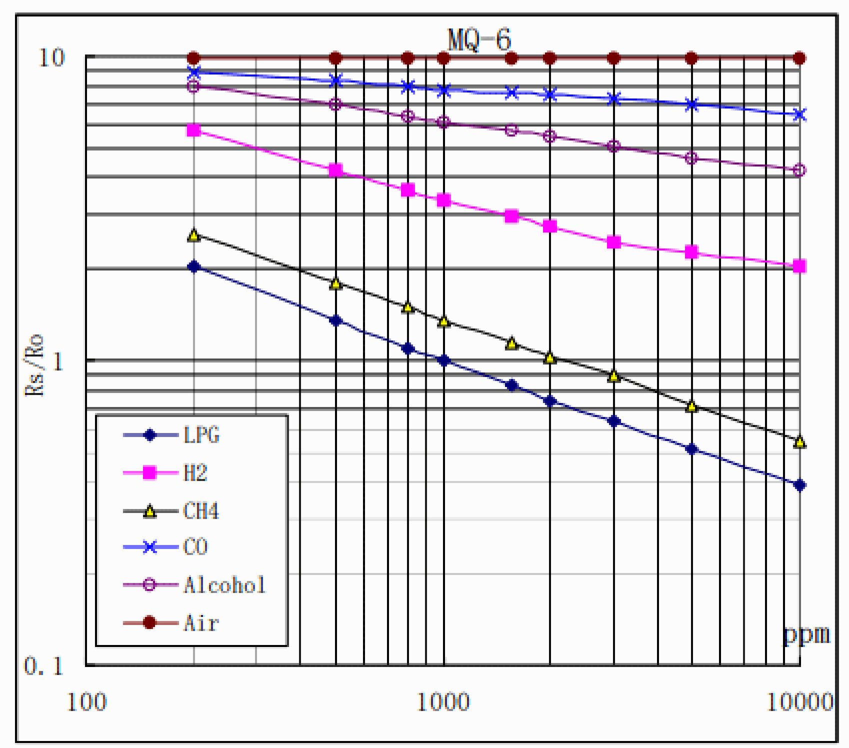

Fig. 3 MQ-6 Sensitivity Chart [19]

Ro = Value of resistance in fresh air; Rs = Value of resistance in Gas concentration.

First step is to calibrate the sensor to finding the values of Ro in fresh air and then use that value to find Resistance of sensor (Rs) using the formulae:

$$Rs = \left(\frac{v_c}{v_{RL}} - 1\right) R_L \tag{1}$$

Once Rs and Ro are calculated, the ratio can be found and then using the graph shown above

to calculate the equivalent value of PPM for that particular gas.

The PIC microcontroller PIC16f877a is one of the most used microcontrollers in the industry. It has a 200 nanosecond instruction speed. The microcontroller is very easy to use; the programming of PIC16f877a is also easier. It uses flash memory technology which gives it the advantage of being able to write-erase as many times as possible. It has a total number of 40 pins and there are 33 pins for input and output. The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART)[19]. The cost of this controller is low and its handling is also easy. It is flexible and can be used in areas where microcontrollers have never been used before as in microprocessor applications and timer functions etc.

From the analysis made so far, it is obvious that the the existing system focuses majorly on communicating with the users. However, the problem with this type of system is that there is no provision to stop the supply of gas from the source if the consumer is away. Also, they are not readily affordable.

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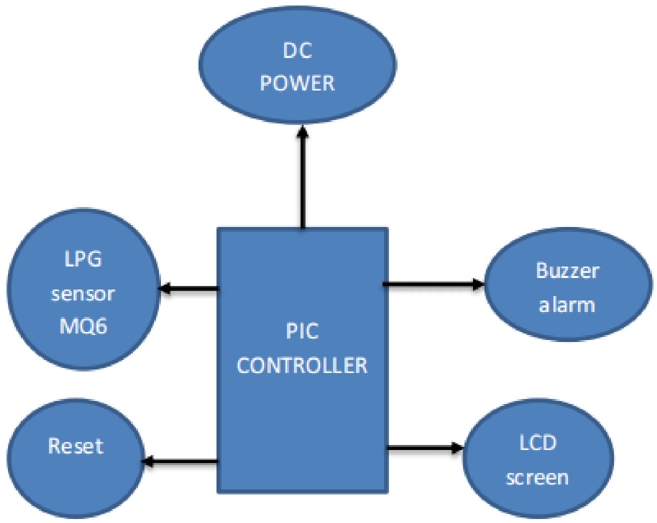
This paper design aims at bridging the gap by providing low cost system with a path to connect a solenoid operated valve that can handle that purpose.

2.0 METHODOLOGY



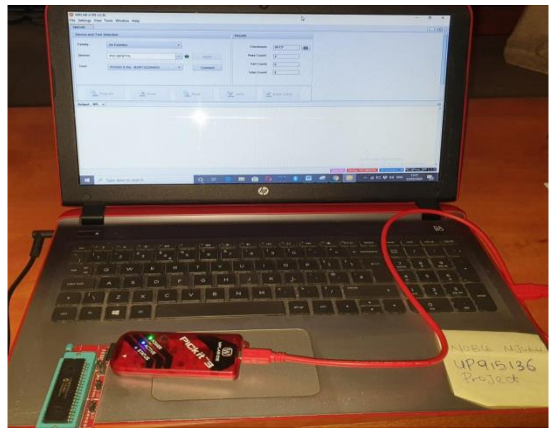


Figure 4: Block Diagram *Figure5: Pickit 3 And MPLAP X IPE Interface*

The block diagram for the system is shown in Figure 4. The program source code for this paper was written in C language compiled using a MikroC Pro for PIC as it contains the necessary LCD library for the program code written and MPLAB X IPE V.5.3 software was used for loading the HEX file into the microcontroller. The source code is first converted to a HEX file after it has been built and debugged for errors in MikroC Pro for PIC; the PIC16F877A is then attached to the PICKit 3 and connected to the computer (Figure 5), on the MPLAB X IPE Integrated programming environment software, the PIC is also selected and synchronized. Then the HEX file is selected and loaded into the chip.

The hardware adapter used was PIC Kit 3 where the microcontroller chip was attached and connected to the computer with a USB 3.0 port. The programmed microcontroller is then connected to the circuit built. The sequence of program is represented in the flow chart in Figure 6.

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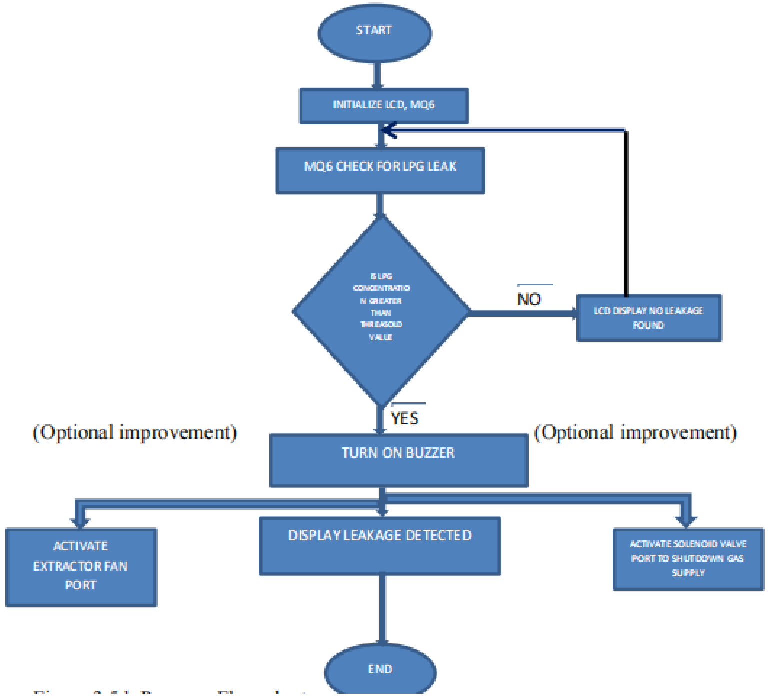

Figure 6: Program Flow Chart

The Solenoid Valve and the exhaust fan can also be connected through the same port as the buzzer using a relay supplied by a 12 Volt source.

Implementation/Modelling/Simulation

Simulation

The design software used for simulating the performance of the proposed design is Proteus 8.0 simulator. The software gives us the ability to simulate a real-life situation and also provides the possibility of generating Schematic layout, thus, making it easier to construct the prototype. The gas sensor library was first downloaded as it was not initially included in the component library when purchased. Figure 7 shows the display on Proteus simulator screen

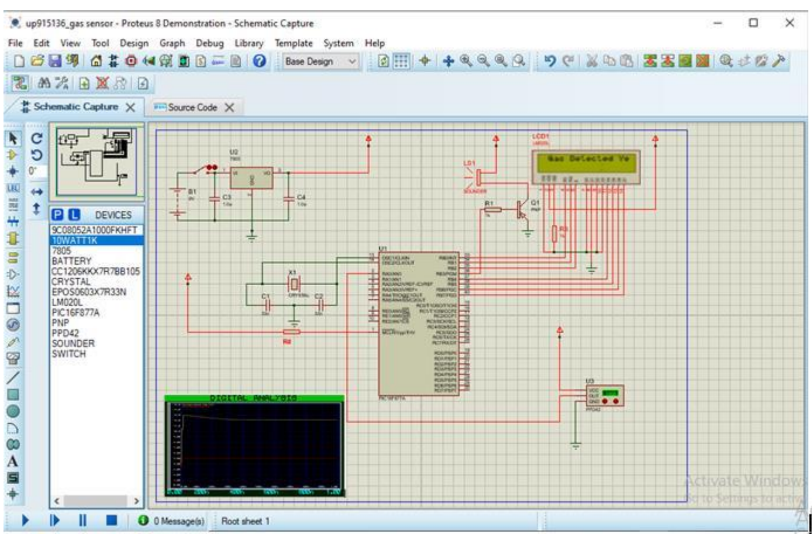

Figure 7: Proteus Simulator Screen

Analysis of Simulation

Figure 4 shows the operation of the proposed design when leakage is detected by the MQ-6 sensor respectively. When a gas leakage is detected, signal is sent to the buzzer through the microcontroller to blow an alarm. A message which reads ―Gas Detected‖ is displaced on the LCD.

Implementation

The circuit was built using a vero-board, soldering lead, components and jumper wires coupled together with a soldering iron. The completed circuit was parked into a cuboid shaped PVC box with the appropriate positions for the switch, LCD, Buzzer and Gas sensor cut open. Figure 8 shows the implementation of the circuit.

Figure 8: Implementation Set-Up

Test and Discussion

Test Analysis

Table 1: MQ-6 Time Response Test Results for LPG

LPG concentration	Time A [s]	Time B [s]	Average time [s]
High	0.75	0.80	0.78
Medium	1.10	1.00	1.05
Low	1.90	2.00	1.95

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Table 2: MQ-6 Time Response Test Results for Perfume Liquid

Perfume volume (ml)	Time A [s]	Time B [s]	Average time [s]
11	1.80	2.10	1.95
21	1.00	1.16	1.08
26	0.70	0.69	0.69
29	0.62	0.60	0.61

The MQ-6 sensor is the main focus for the test, although the gas sensor can be used to detect mainly LPG, for safety purpose, we will be using a cigarette lighter as the LPG source comparing it with a perfume liquid for this paper as it is also one of the listed substance that can be detected by the sensor. Different quantities of the gas and perfume liquid were measured and used for the test and the response time was observed. The perfume liquid was measure in terms of volume (ml) while the LPG was measured in terms of concentration (this is because it is not easy to measure the quantity of liquid that has diffused out into the air). The tables 1 and 2 show the result of the test which proves the efficiency of the MQ-6 during an actual gas leak as it reacts in almost less than a second. The results show that for for both LPG and the perfume tests, the average response time reduces with concentration. The higher the concentration, the shorter the time to raise the alarm thus confirming the validity of the system.

Cost Analysis

From the cost analysis of the Microcontroller Based LPG leakage detection system, show that the total cost was about forty six thousand naira (#46,000) as at that time with the exchange rate being 1GBP = #500). The components were sourced from locally while considering reducing the cost and keeping the good quality in mind. This makes the system affordable for domestic use.

3.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

LPG leakages have led to numerous accidents resulting to fatal casualties as well as damages to properties worth a fortune. As such a device that is capable of detecting such leakages and shutting off the gas supply was designed and first simulated successfully using Proteus 8.

The device senses the leakage of LPG through a highly sensitive MQ-6 gas sensor and with the aid of a PIC16F877A microcontroller activate a buzzer which buzzes to alert anyone nearby of leakage and also displays the ppm of the gas detected. Also, capable of supply is shut down by the solenoid value unit under minute to limit the fuel source when incorporated. The cost analysis of the proposed micro-controller based LPG leakage detection System shows that the system is viable. The components were sourced from locally while considering reducing the cost and keeping the good quality in mind. This makes the system affordable for domestic use.

Recommendations

Though this system has provision (port) to connect a solenoid valve to cut off the gas, the practical implementation of this aspect could not be actually carried out for economic reason. Therefore, to improve the work, the design should be implemented using solenoid valve for safety cut offs and exhaust fan to disperse gas build ups.

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