Development of a Microcontroller Based Gas Leakage Detector with Dual SMS Alert

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ORIGINAL RESEARCH

Abstract— The prevailing treat to lives and property by the usage of gas for cooking, etc, and the rapidly increasing evolution in new technologies worldwide, a novel approach utilizing dual communication network providers is applied to alert users in the event of leakage of Liquefied Petroleum Gas (LPG). In this work, a prototype gas leakage detector, based on dedicated Peripheral Interface Controller (PIC), sensitive MQ-6 gas sensor, GSM/GPRS SIM900 and discrete components is developed and tested. Glo and MTN network service providers were selected for the design. Both indoor and laboratory tests were conducted where the results indicate gas concentration levels of 372 ppm to 255 ppm were measured to display a message on Liquid Crystal Display (LCD) and trigger audio alarm at instances of 2.42 secs and 8.35 secs in locations of 5 cm and 30 cm away from gas source respectively. Finally, the viability test proved satisfactory as it indicates that whenever a particular network fails, the second network was available to receive the SMS message adequately. This could be applied in homes, restaurants, etc where cooking gas is often used. Future enhancements should include the deployment of all available communication network service providers to augment for the limitation of the only two networks in this work.

Keywords— Dual Sims, GSM Module, Microcontroller, MQ-6 LPG gas sensor

1 Introduction

The use of firewood and charcoal in rural and urban areas of most countries is gradually being replaced by hydrocarbon fuels, due to the comparative advantage of the latter. Amongst the fossil fuels found beneath the earth's surface is natural gas, and by extension, the LPG, which is a mixture of commercial propane and butane that is characterized by saturated and unsaturated hydrocarbons. The versatility of LPG has made it a sure candidate for application in domestic, industrial heating and its environmental friendliness of producing clean energy, high calorific value, less smoke and soot.

However, the serious threat in the form of risk of fire and explosions posed in the event of leakages of gas in any area of application necessitates the development of electronic gas leakage detectors. Also because of the lack of colour of natural gas, it becomes imperative to design and implement intelligent gas detection and alarm system towards averting the ugly scenarios. The large deployments of LPG for use in domestic and commercial areas have resulted in high cases of fire and explosions due to gas leakages (Shahrulzaman,2009, Adelagun, 2021). When humans inhale leaked gases, the noticeable effects include symptoms like lack of coordination, heart disease, asthmatics, fatigue, irritability of eyes and throat, nausea, headache, dizziness and sometimes high concentrated leakages may lead to breathing stress, loss of consciousness and eventual loss of life (NGST, 2022).

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Section B- ELECTRICAL/ COMPUTER ENGINEERING & RELATED SCIENCES
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The increasing problem of gas leakages worldwide has made home security a major issue using different engineering and science-based approaches. Accidents from gas leakages are caused by external interference, corrosion, construction defects, material failure and ground movement (Baba *et al* 2018). In an effort to minimize these accidents, there is definitely the need to engage gas leakage detectors.

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2 Related Work

In recent times, automatic controls employing embedded systems and Global System for Mobile Communications (GSM) infrastructure have played vital roles in the advancement of science and engineering in such essential areas as gas flow and fluid delivery in homes and the process industries. Several studies in gas detection have been done using wireless communication protocols such as Bluetooth, Wi-Fi, IoT, GSM, ZigBee, and other emerging technologies.

A prototype GSM Based Gas Leakage Detector for Disabled and Handicapped which provides safety and security to lives was designed (Pervaiz and Waqar, 2016**)**. This system does not only alert or warn people but the accommodating factor is to issue a runtime safety by evacuating the leaked particles of combustible gas present in air on immediate basis, in case a custodian is not at home to take care of handicapped and disabled ones. Nuga, *et al* (2017) designed and developed a GSM-Based Gas Leakage Detection and Alert System. The system's performance assessment proved satisfactory.

LPG leakage detection system that applied *ARM 7* processor and keil software which can detect and prevent leakages in various premises was designed and implemented (Meenakshi *et al.*, 2017). During the system actuation, the user is alerted through SMS, neighbours alarmed by buzzer, power supply is cut off and the incorporated stepper motor closes the gas pipeline.

Halder and Chatterjee (2019) designed and implemented an LPG sensor and alarming system by applying Arduino UNO microcontroller. The device sensor is sensitive to toxic gases, combustibles, propane, iso-butane and Liquefied Natural Gas (LNG). A cost-effective device was developed in the work with a simple circuitry. An Internet of Things (IoT) based LPG Gas Leakage Monitoring and Alert System using Arduino Mega with MQ-6 sensor was designed and developed (Siddika and Hossain, 2020). For the reason of high risk involved in the use of LPG in homes and cars, this study focuses on an IoT based system to prevent home and vehicle accidents.

Khan (2020) proposed a Sensor-Based Gas Leakage Detector System that can detect, alert and control gas leakage**.** The semiconductor (SnO2) with gas detection range of 200–10,000 ppm (parts per million) in the work, is sensitive to Propane, Butane and LPG, and high response to Natural gas could be used to detect different combustible gases, especially Methane. Shahewaz & Prasad (2020) developed gas leakage detection and alerting system using Arduino Uno. This system is used to detect leak of gas simultaneously at three different locations, alerts people by buzzer and sends SMS by GSM to the person whose number is written in the source code.

In this work, the special characteristic is the adoption of dual GSM subscriber identity module (SIM) for two different networks, namely GLOBACOM (Glo) and Mobile Telecommunications Nigeria (MTN). This is to forestall eventuality of non-delivery of the message arising from any one network failing. Also, it is a cost-effective design, when compared with existing ones, that can be mass-produced easily and affordable in developing economies.

3 Materials and Methods

3.1 Materials Required

The software applied is the C++ Programming language. The hardware components used are:

i. Breadboard
ii. Mini Vero-board
iii. PIC18F2550 microcontroller
iv. 12 Volts dc power supply
v. 9 V Battery
vi. 5V Regulator
vii. MQ-6 LPG gas sensor
viii. GSM/GPRS SIM900 Module
ix. Dual GSM Sims [Glo & MTN]
x. 16x2 LCD Display
xi. Buzzer
xii. Mini Gas cylinder
xiii. Connecting wires

The system architecture /workflow is depicted in Fig.1.

3.2 Gas Sensor

Numerous gas sensors exist for the detection of the presence of gas namely: MQ-2, MQ-3, MQ-5, MQ-6, MQ-7, MQ-9, MQ-135, etc the MQ representing 'Message Queue'. These gas sensors are made of various sensitive materials but Tin dioxide (SnO_2) is the mostly used material (Pervaiz& Waqar, 2016). In this work, an MQ-6 semiconductor sensor is selected for application. Its advantages include: Availability, stable, long shelf life, high sensitivity, quick response time to LPG and low cost. The specifications of this gas sensor vis-à-vis Sensitivity characteristic are provided in Table1.

Table 1. Specification of MQ-6 gas sensor (Source: Hanwei Sensors, 2021)

Symbol	Parameter name	Technical condition	Remarks
Rs	Sensing Resistance	10KΩ- 60KΩ 1000ppm LPG	Detecting concentration scope : 200-10000ppm LPG, iso-butane, propane, LNG
1000ppm/ 4000ppm LPG	Concentration slope rate	≤0.6	
Standard detecting condition	Temp:20°C◎ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1		
Preheat time	Over 24 hours		

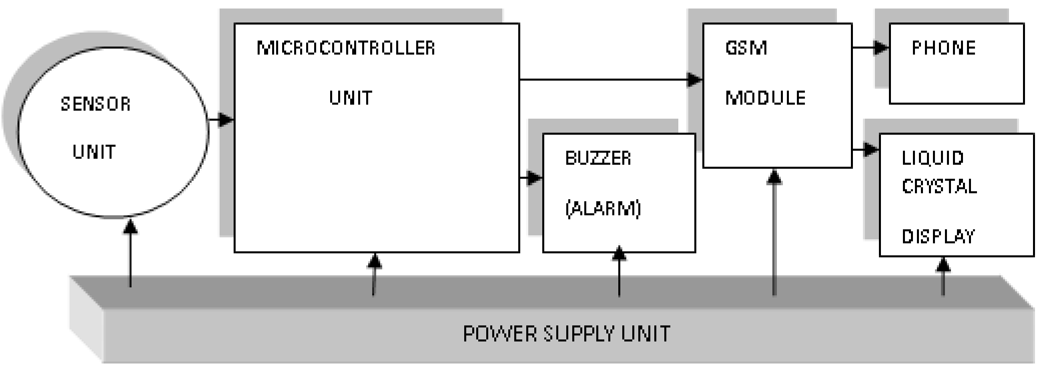

Fig. 1: Microcontroller Based Gas leakage detector with dual SMS alert

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The basic schematic diagram for MQ-6 semiconductor gas sensor is shown in Fig.2.

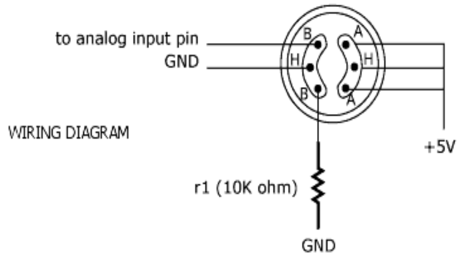

Fig. 2: Schematic diagram for MQ-6 sensor (Source: Hanwei Sensors, 2021)

3.3 Microcontroller Unit

Microcontrollers are compact, very large scale integrated (VLSI) circuits designed to control a specific operation in an embedded system. The microcontroller applied in this work is PIC 18F2550 which is a High-Performance, Enhanced flash, USB Microcontroller with Nano-Watt-Technology. For the dynamic operation of microcontrollers, crystal oscillator produces the required oscillation frequency. The choice of standard value of *20 MHz* crystal oscillator is made for the following reasons: highly stable oscillation frequency, incredibly high quality (Q) and very small frequency drifts due to temperature changes, ageing and other causes.

3.4 GSM/GPRS SIM 900 Module

This is a complete Quad-band GSM/GPRS (General Packet Radio Service) module that offers means for communication with the users of a mobile sim. The image of GSM SIM900 Module is depicted in Fig.3.

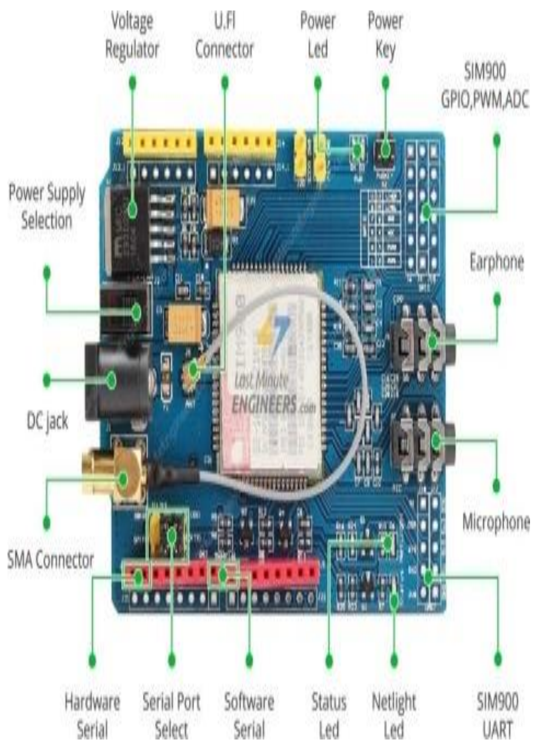

Fig. 3: A typical GSM SIM900 module

3.5 System Flow Chart

The system flow chart is shown in Fig.4. At the start of the flow process, the input/output pins of the microcontroller are configured, registers declared and analog to digital converter set up. Then the liquid crystal display and GSM modem are initialized in a short duration time. At the decision box, if gas leak is detected, SMS alert and buzzer alarm (beep sound) are actuated. The constructed working model of the LPG gas leakage detector (GLD) is shown in Plate 1.

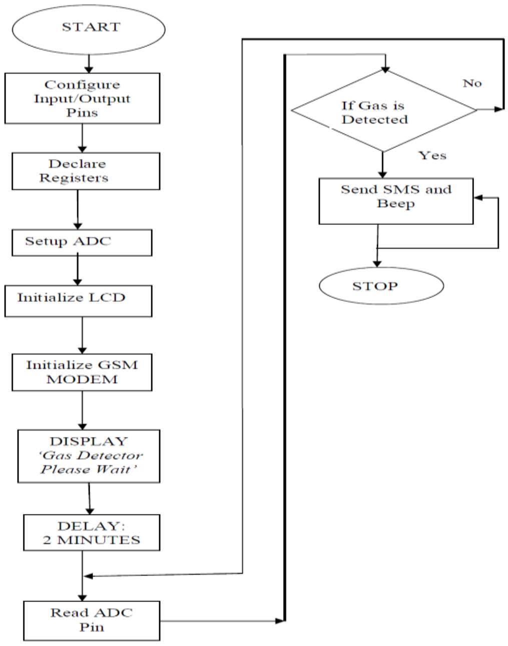

Fig. 4: System Flow chart

Plate 1: Constructed working model of GLD

4 Tests

The model shown in Fig. 5 is used for the following gas measurement scheme:

- Measurement of level of gas concentration at different distances away from the gas leakage point, and the corresponding time of buzzer audio alarm,

-Time of delivery of SMS sent at three different locations on typical days in Nigeria and Viability test for SMS delivery time by GSM module.

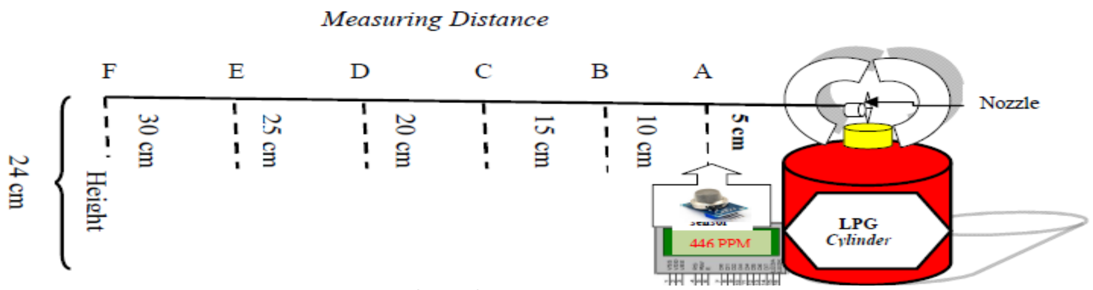

Fig. 5: Setup for gas measurement scheme

5 Results

Table 2 shows the results of various measurements of gas sensing distance versus corresponding gas amount (concentration) and buzzer alarm time. The graphical representations of the readings in Table 2 are shown in Figs. 6 and 7 respectively.

Table 2. Gas sensing distance versus gas amount & buzzer time

Location	A	B	C	D	E	F
Distance(cm)	5	10	15	20	25	30
Amount of Gas (*ppm*)	372	349	337	312	278	255
Buzzer Alarm Time (sec)	2.42	2.58	3.26	4.16	6.10	8.35

Table 3. Delivery time of short messages sent by GSM module

Network Provider	Expt No.	Location/Date		
		Ajaokuta, Nigeria (Indoor) 20/10/2021	Idah, Nigeria (Laboratory) 06/11/2021	Ado Ekiti, Nigeria (Indoor) 27/11/2021
		Delivery time of SMS Alert (sec)		
GLO	1	5.5	4.5	4.3
	2	6.0	5.0	4.0
	3	5.5	4.3	3.3
	4	5.0	4.0	3.5
MTN	1	4.0	3.5	6.0
	2	3.4	3.4	5.5
	3	4.0	3.3	6.4
	4	4.4	3.5	5.4

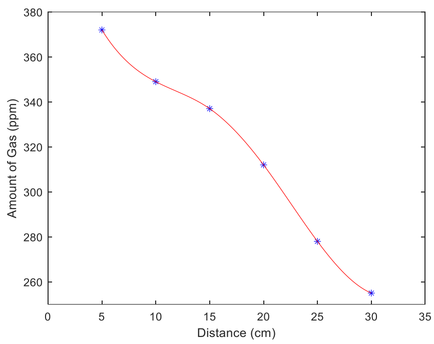

Fig. 6: Distance against Amount of gas

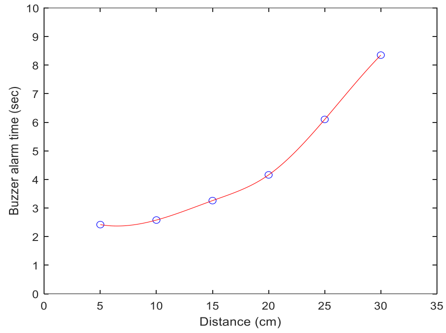

Fig.7: Distance against Buzzer time

6 Discussion

During the testing/experimentation, the observation made was that gas sensing distance versus corresponding gas amount gave a reading of 372 ppm and 255 ppm for distances of 5 cm and 30 cm respectively. This indicates that gas concentration at a point varies with the distance away from the spot of leakage. In the second test conducted, the buzzer audio alarm was at instance of 2.42 secs for the closest proximity of 5 cm and 8.35 secs for the farthest distance of 30 cm in this experimental set- up. This indicates that the sensor was more sensitive to gas at closer range than at farther range, therefore a careful choice of positioning the gas sensor should be made for its optimal performance during installation.

In the tests carried out at three locations in Nigeria, the MTN network is adjudged to perform better in delivery time of SMS message than Glo network at Ajaokuta and Idah, whereas Glo network performed better than MTN network at the indoor test location at Ado Ekiti. Although, the time of SMS messages differed due to the prevailing condition of the particular network at that instant of time of the conduct of test. However, the dual SIM design provides for safeguard against complete failure of any of the networks.

7 Conclusion

The analysis, design and construction of an LPG leakage detector with dual SMS alert capability have been carried out. The device simply detects the concentration of leaking LPG and triggers alarm, displays message on an LCD and sends distress messages to two pre-defined mobile phone numbers. This was realized by the appropriate data sheets to select desired component values. This device is useful for application in hostels, cafeteria, hotels, industries and a protection device for homes. The versatility of this device makes it deployable to any cooking environment to avert scenarios of fatal infernos in such areas in case of gas leakages. Based on the results of tests carried out, the following conclusions are drawn:

- The device can detect leaked LPG within the detection radius of the sensor attached and buzzes to alert anyone in the vicinity of the leakages.
- Information to the owner's or stakeholder's telephone is sent via SMS when gas concentration minimum level of 200 ppm is reached. The message would read "LPG Leakage Detected".

In future designs, all the communication network service providers available in a particular area of a country should be deployed for SMS alert without restricting it to only GLO and MTN services as the case here e.g., Airtel, 9-Mobile, etc. Due to variations in environmental conditions like temperature, humidity, haze, etc that may impede quick gas detection time, the sensitivity of MQ-6 sensor should be increased by the manufacturers.

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