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# GSM-Based Gas Leakage Detection and Alert System

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***Abstract***: *In this communication, an efficient method of detecting the leakage of cooking gas and alerting people about its occurrence via the use of existing Global System for Mobile Communication (GSM) infrastructure was developed. The GSM-based gas leakage alert system utilizes a gas sensor to detect leakages in the event that it occurs and then send short message to a predefined telephone number. MQ2 gas sensor, PIC 16F877A microcontroller, GSM modem and a DC stepper motor are the main hardware components employed in the development the gas leakage detection and alert system. The proposed system plays two roles in the event of gas leakage: alerting people about the leakage of gas by sending short message to the predefined telephone number and by closing of the cylinder head to prevent further leakage by using the stepper motor. The developed GSM-based gas leakage detection and alert systems is suitable for deployment in homes, laboratories and restaurants to check undesirable event of gas leakages and attendant risks.*

***Keywords:*** GSM modem, Detection, Cooking Gas, DC Stepper Motor, PIC Microcontroller.

## 1. INTRODUCTION

There are disasters that are heard of and looking back at them, we realize they are actually avoidable especially domestic fire incidents. One frequent cause of domestic fire incident, which can be prevented, is the gas leakage. In modern homes, gas cookers are fast replacing electric cookers and kerosene stoves for domestic cooking. In offices and laboratories, cooking gas is employed for diverse applications. The cooking gas, otherwise known as the Liquefied Petroleum Gas (LPG), is first produced in 1910 by Walter Snelling as a mixture of commercial Propane and commercial Butane. It comprises of both saturated and unsaturated hydrocarbons. Going by increasing level of patronage of LPG for cooking and heating applications, coming up with safety measure and method of checkmating the impact of fire outbreak that may result from its leakage has attracted attentions of many researchers.

Prior to the development of household electronic gas detectors in the early 90s, chemically infused paper, that changes its colour in response to exposure of the gas, is used to detect presence of cooking gas. Since the introduction of electronic gas detectors, a number of devices have been developed to monitor and alert the people in the event of wide array of gases leakage [1,2].

Wireless sensors network were used for detection of leakage in gas tanker [3]. A multiple gas sensing was worked upon using Taguchi sensor [4]. Ramya and Palaniappan developed embedded system for system detecting hazardous gas [5]. Murugan et al. developed an embedded system using GSM for monitoring Industrial temperature [6]. GSM based energy meter was developed by Jain et al., in 2012 [7].

Likewise, various works have applied the stepper motor, which was applied in this work, for high speed control, parameter estimation and even its modeling and damping technique [8-11].

MQ2 gas sensor is a semiconductor type material basically used as a domestic gas leakage detector. The sensitive material of the gas sensor is tin oxide which has low conductivity in clean air. In the detection system the MQ2 gas sensor is used which is sensible to LPG, isobutene and propane gases [12, 13]. The sensor can detect up to 10000 parts per million concentration of gas in the air [14].

GSM infrastructures are widely available in most areas where cooking gas is heavily employed for cooking and heating purposes. When use is made of these resources, a modular gas leakage detection and alert system can be developed. This motivates this work, where GSM-based gas leakage detection and alerting system is developed using MQ2 gas sensor as a detector and GSM module as agent for alert via short message. The developed device has six major functional units: the power supply, the sensor, the microcontroller, the transmitter, alarm and the mechanical units.

## 2. DESIGN CONSIDERATIONS

The developed GSM-based gas leakage detection and alert system is illustrated in Figure 1. It works by sensing the leakage of LPG. This is indicated visually via switching ON of a Light Emitting Diode (LED) to alert surrounding people about the event LPG leakage. Simultaneously, a short message is sent to a pre-defined telephone number to alert the concern people of the occurrence of the LPG leakage.

MQ2 gas sensor used is capable of detecting wide varieties of domestic cooking gases like butane, propane and methane. The gas sensor is interfaced with the microcontroller so that if any gas leakage is detected at its input, it gives an output that is fed into the Analogue to Digital Converter (ADC) unit of the microcontroller. The microcontroller then generates short message as a response to the GSM module. Provision is made for mechanical unit in the developed system to provide a third level of control such that after visual indication of gas leakage through lighting of LED and sending of short message to a pre-defined telephone number, a DC stepper motor switches off the gas supply to prevent its further spread.

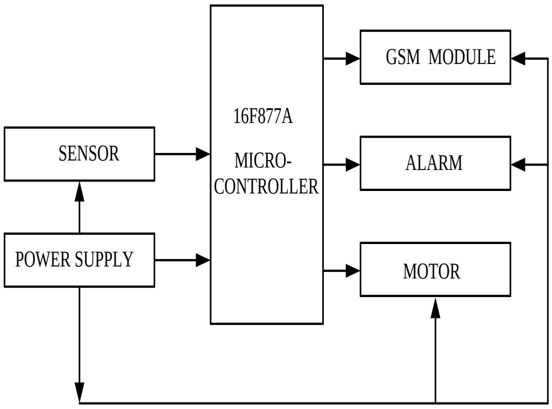


Figure 1:The Block Diagram of the GSM Based Gas Leakage Security Alert System

### 2.1 Power Supply

The power supply unit for this work was developed to factor in power requirement of various components that make up the entire device. The stepper motor used requires 24V dc supply. A 220/12V, 300mA centre tap transformer was used in the power supply unit. Half wave rectification was done to achieve charging of the battery which powered the developed gas detector and alert system. IN4007 diode was employed in this regard and a capacitor $C_O$ with value of 1000µF was used for smoothening.

### 2.2 PIC Microcontroller

The microcontroller employed in this work is the PIC 16F877A. It is a 40-pin, 8-bit, with reduced instruction set computing main architecture. The microcontroller used in this work operates at an input frequency of 20MHz [15]. Crystal oscillator was used to generate clock and to provide frequency stability to the microcontroller. What determines the choice of the crystal is the type of GSM modem employed. The baud rate of the GSM modem used is 115.2kb/s. The crystal oscillator terminals are connected to the PIN 13 and PIN 14 of the micro controller to drive the device. Two capacitors $C_1$ and $C_2$, act as the load capacitance of the crystal and for smoothening of the clock pulses. Generally, the load capacitance, stray capacitance and smoothening capacitance are related by:

$$C_L = \frac{C_1 \times C_2}{C_1 + C_2} + C_s \qquad (1)$$

$C_L$ is the optimum load capacitance for a given crystal as specified by the crystal oscillator manufacturer. $C_S$ is the stray capacitance on the printed board circuit; typically a value of 5.5pF is specified in the datasheet.
Suppose $C_1 = C_2$, equation (1) reduces to

$$C_L = \frac{C_1}{2} + C_s \qquad (2)$$

With $C_L$ = 22pF and $C_S$ = 5pF, the value of $C_1$ is determined using eqn. (2) to be 30pF.

### 2.3 Sensor

MQ2 gas sensor is employed as gas sensing device. The sensitive material of the MQ2 sensor is tin oxide, which has low conductivity in clean air. With presence of gas in its environment, MQ2 conductivity increases in proportion to gas concentration. MQ2 sensor uses a simple drive circuit to convert change in its conductivity to the corresponding output signal representing the gas concentration. The sensor has six pins. Four of the pins are used for fetching of signals while the other two pins provide enough heat to the sensing element. MQ2 sensor requires two voltages: heat voltage $V_H$ and circuit voltage $V_C$. $V_H$ is needed to ensure the sensor is maintained at certified working temperature while $V_H$ is used to detect voltage $V_{RL}$ on series load resistance with the sensor. From datasheet [16] both $V_H$ and $V_c$ should be 5V ± 0.1 each. In the event of gas detection, MQ2 sends signal in the form of current in analogue form to the analogue input pins of the microcontroller, which are pins 2 and 3. This explains the choice of pins 2 and 3 of the microcontroller for the connection of the gas sensor. The resistance of the sensing element is changed in response to gas absorption. The value of the current coming out of the sensor is thus altered from that of input. Eqns. (3) and (4) are the governing equations for the sensor resistance and power sensitivity. Figure 2 illustrates the test circuit diagram of MQ2 sensor.

$$R_s = \frac{V_c}{V_{RL} - 1} \qquad (3)$$

$$P_s = V_c^2 \times \frac{R_s}{(R_s + R_L)^2} \qquad (4)$$

where, $R_s$ = the sensing resistance of the MQ2 sensor; $V_c$= circuit voltage; $V_{RL}$ = voltage drop across load resistance;
$R_L$ =load resistance and $P_s$ = power sensitivity

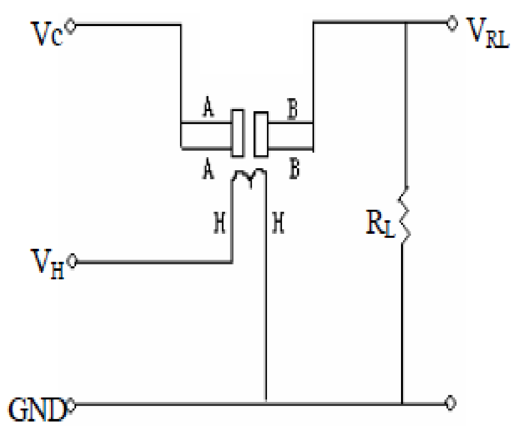


Figure 2: Test Circuit of MQ 2 Gas Sensor

Gas is traditionally kept in an airtight cylinder, the pressure of which is a function of the volume of the gas inside. The volume of the gas leak detected is a function of the condition of the space where the cylinder is located. Such factors include the size of the space, the level of ventilation and the ambient temperature of the location.

### 2.4 GSM Modem

SIM900 modem, which is a complete Quad-band GSM solution that can be embedded in the consumer application, is utilized in this work. The modem requires voltage in the range of 3V-3.9V to function. The GSM modem is interfaced with AT cellular command as well as an external subscriber identity module (SIM) card at a voltage 3V/1.8V[17,18]. Each of the microcontroller pin is at voltage of 5V. Since the modem operates at 3.9V (maximum), its direct interfacing with the microcontroller is not possible to avoid damage. To interface the PIC transmitter and GSM receiver, a limiting resistor is used in series with a Zener diode. This is employed to step down 5V from the microcontroller to 3.9V (maximum) requires by the GSM modem. The value of the limiting resistor used with the Zener diode is obtained as

$$R = \frac{V_s - V_z}{I_z} = \frac{5-3}{10\times 10^{-3}} = 200\Omega$$

where $R =$ the limiting resistance; $V_S$ = microcontroller pin voltage; $V_2$ = voltage drop across Zener diode and $I_2$ = current through Zener diode, which is usually 10mA.

### 2.5 Alarm

Visual alarm is provided in this work via the use of the light emitting diodes (LEDs). Eight LEDs are utilized in this work for indications. The LEDS operation are configured such that on power on of the developed device, only the last five LEDs will lit up while the first three will not. In the event of gas leak, the first three LEDs come up to alerts people around of the occurrence of the gas leak. A voltage of 2V is required by a LED with a minimum current of 10mA. There is need for limiting resistor to interface a LED with a microcontroller pin at 5V. The value of limiting resistance employed is 1kΩ.

### 2.6 DC Stepper Motor

The stepper motor is the type where a full rotation is divided into number of smaller steps. By this, the operation of the motor can be carefully calibrated to suit applications such as turning on or off of a knob. The operation of stepper motor is very dependent on its drive circuit. In other words, the motor's position, through calibration can be commanded to move and hold at any of its steps provided the motor is carefully sized to its application. The steps per inch is the number of steps the motor shaft must turn in order for the motor to cover an inch distance. This is computed using the relation given in eqn. (5)

$$\frac{S}{I} = \frac{L_r}{L_i} \times \frac{1}{M_c} \times \frac{M_s}{M_r} \qquad (5)$$

Where $S/I$ = steps per inch; $L_r/L_i$ =lead screw revolution per inches;
$M_c$=number of micro steps the electronics are configured for;
$M_s/M_r$ = the motor steps per revolution.
The motor step per second measured in Hertz is computed using

$$S/\sec = \frac{MMS}{60} \times \frac{S}{I} \qquad (6)$$

where $MMS =$ maximum machine speed.

The motor is powered by 24V dc supply. A 1000$\mu F$ capacitor is used in the motor circuit to check the ripple that may arise from motor action. Complimentary pair configuration of transistor is utilized to ensure the required current of 100mA is available to drive the steeper motor.

## 3. SOFTWARE PHASE AND DESIGN IMPLEMENTATION

The microcontroller is the only component that requires instruction to be written and run it to perform the desire roles. Assembly language is used in the programming of the microcontroller. Figure 3 illustrates the flowchart of procedure of programming the microcontroller to achieve the desire function.

After the design exercise, various components described earlier in the design consideration section were sourced. The developed GSM-based gas leakage detection and alert system was then implemented using the obtained circuit diagram from the design.

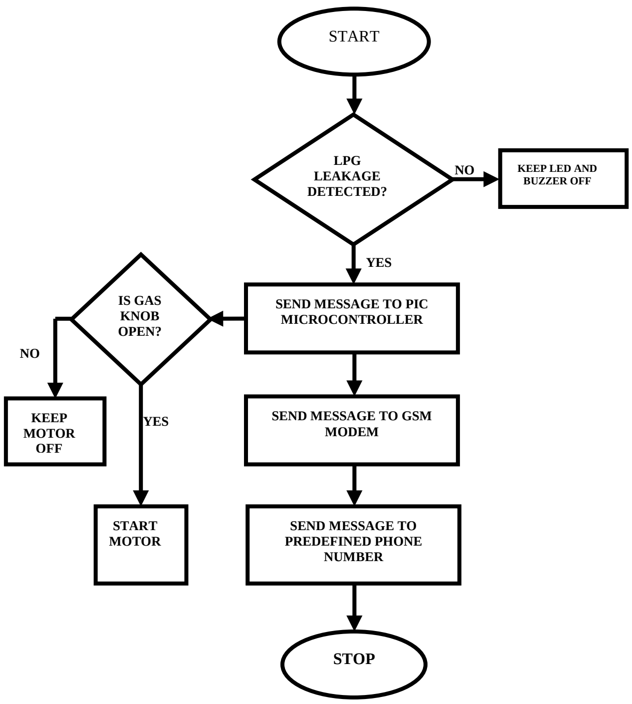


Figure 3: Flowchart of GSM-based Gas Leakage Detection and Alert System

## 4. RESULTS AND DISCUSSION

Upon execution of this work, a GSM based gas leakage detection and alert system was obtained. The testing of the device was done from the initial stage of the circuit to the final stage where all sections of the device had been coupled.

### 4.1 Sensor Unit

The MQ2 sensor is the concern component for test here. Although the gas sensor is used to detect mainly LPG, it can detect other substances like kerosene, petrol, and cigarette smoke. Hence, the testing of the GSM-based gas leakage detection and alert system was carried out using LPG and premium motor spirit (petrol).Different quantities of these substances were measured and used to test the operation of the gas sensor by observing the response time of the sensor to detect the presence or otherwise of the substance. Obtained results are presented in Tables 1 and 2, respectively, for petrol and LPG. The quantity of petrol was measured in terms of volume while the quantity of the LPG was measured in terms of concentration (small, medium and large concentration). The quantity of LPG was measured in concentration because volume of the gas that leaked could not be easily measured. Hence the measurement was defined in concentration.

Table 1: Time response of sensor to varying quantities of petrol

| Volume of Petrol (ml) | Time taken by the sensor for detection (sec) | | | |
|---|---|---|---|---|
| | First | Second | Third | Average |
| 19 | 2.00 | 2.00 | 2.00 | 2.00 |
| 38 | 1.00 | 1.00 | 0.80 | 0.93 |
| 57 | 0.60 | 0.70 | 0.70 | 0.67 |
| 76 | 0.60 | 0.50 | 0.50 | 0.53 |
| 95 | 0.50 | 0.50 | 0.50 | 0.50 |

Table 2: Time response of sensor to varying quantities of LPG

| Concentration | Time taken by the sensor for detection (sec) | | | |
|---|---|---|---|---|
| | First | Second | Third | Average |
| Small | 2.00 | 2.00 | 2.00 | 2.00 |
| Medium | 1.00 | 1.00 | 2.00 | 1.33 |
| Large | 0.80 | 0.70 | 0.80 | 0.73 |

### 4.2 GSM Module

It is necessary to ascertain which of the operator offers better services in the area where the developed gas leakage detection and alert system is to be deployed. The ability of the GSM module to send short message to a predefined phone number is tested. The test was conducted at the Electronics Laboratory of the Federal University of Agriculture, Abeokuta (FUNAAB). The module was found to communicate effectively well with the pre-defined phone number i.e. relay the information from the signal processing module of the gas leakage detection and alert system to the pre-defined user phone number. The time taken by different communication networks to deliver the sent message was also recorded. The SIM card in the GSM modem was changed in turn while carrying out this test. The readings obtained for four different mobile networks available currently in Nigeria are presented in Table 3.

It can be inferred from Table 3 that, as at the time of conducting the message delivery time test on the developed GSM-based gas leakage detection and alert system, the communication network A perform better than the other three. The implication of this result is that periodically, the user should check and ascertain the average message delivery time in order to decide the preferred SIM card to insert in the GSM module. This is in order to ensure reduced time of getting the message and faster response time in case of emergencies.

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

| Network Provider | At New female hostel FUNAAB | | At Camp, Abeokuta | |
|---|---|---|---|---|
| | Delivery Time (s) | Average delivery time (s) | Delivery Time (s) | Average delivery time (s) |
| A | 7 | 7 | 5 | 5 |
| | 7 | | 6 | |
| | 7 | | 4 | |
| B | 5 | 4 | 27 | 27 |
| | 3 | | 25 | |
| | 4 | | 29 | |
| C | 8 | 9 | 12 | 9 |
| | 6 | | 7 | |
| | 13 | | 7 | |
| D | 7 | 6 | 46 | 48 |
| | 6 | | 51 | |
| | 5 | | 45 | |

## 5. CONCLUSIONS

A gas leakage detection and alert system has been developed in this work. The developed system will not only detect LPG leakage but go further to prevent further leakage if the cause of the leakage is due to accidental or deliberate opening of the head. Simultaneously, a short SMS is sent to a pre-defined phone number using GSM infrastructures to alert the concern people of the incident of gas leakage. Going by the results of the tests carried out after implementation of the design of this work, it is concluded that the developed system is suitable for use in homes and restaurants to forestall and check incidence of LPG leakage and disaster that may follow such leakage. All that is required is to place the developed device on or beside the LPG cylinder head.

## REFERENCES

[1] Sood, A., Sonkar, B., Ranjan, A., Faisal, A. (2015). Microcontroller Based LPG Gas Leakage Detector Using GSM Module. International Journal of Electrical and Electronics Research vol. 3 no2, pp 264-269

[2] Nuga, O.O., Amusa, K. A., Olanipekun, A. J., Odedina, O.T.. (2016). GSM Based Gas Leakage Security Alert System. Proceedings of the 2016 International Conference on SET: A driving force for sustainable development tagged COLENG 2016, Federal University of Agriculture, Abeokuta, March 7-11, 2016.pp 46-53.

[3] Shinde, S., Patil, S. B. and Patil, A. J. (2012), “Development of movable gas tanker leakage detection using wireless sensor network based on embedded system,” *International Journal of Engineering Research and Application(IJTERA)*, vol. 2, pp. 1180-1183,

[4] Solis, J. L., Li, Y. and KishsL,. B., (2005) “Fluctuation-Enhanced Multiple-gas sensing by Commercial Taguchi Sensor,”*IEEE Sensor Journal*, vol. 5, no. 6, pp 1-15,

[5] Ramya, V. and Palaniappan, B.,(2012) “Embedded system for hazardous gas detection and Alerting,” in *Proc. OfInternational Journal of Distributed and parallelsystem(IJDPS)*, vol. 3, no. 3, pp 287-300.

[6] Murugan, T., Periasamy, A. and Muruganand, S.,(2012).“Embedded Based Industrial temperature monitoringsystem using GSM,”*International Journal of computer application*, vol. 58, no. 19, pp 6-11.

[7] Jain, A., Kumar, D. and Kedia, J. (2012), “Design and development of GSM based energy Meter,” *International Journal of Computer Application*, vol. 47, no. 12, pp 41-45.

[8] Gajipara, J. G. and Sanagara, K. A. (2012). “Stepper motor driver for high speed control by high voltage and constant current,” in *Proc. of IEEE International Journal of advanced engineering and studies*, vol. 1, pp. 178-180

[9] Blauch A. J., Marc. Bodson and J. Chiasson (1993). “ High-Speed Parameter Estimation of stepper motors,” *IEEEtrans. of on control system Tech.*, vol.1, no. 4, pp. 270-279

[10] Stoianovici, D., Patriciu, A., Petriso,r D., Mazilu, D. and Kavoussi, L.,(2007). “A new type of motor: Pneumatic step Motor,”*IEEE/ASME Trans. of Mechatronic*, vol. 12, no. 1,.pp 98-106.

[11] Tsui, K. W. H., Cheung, N. C. and Yuen, K. C. W. (2009) “Novel Modeling and damping technique for Hybrid Stepper Motor,” *IEEE Trans. on Ind. Electrons*, vol. 56, no. 1, pp. 202-211.

[12] Fraiwan, L., Lweesy, K., Bani-Salma, A and Mani, N, (2011). A wireless homesafety gas leakage detection system”, Proc. of 1st Middle East, Conference on Biomedical Engineering, pp.11-14

[13] Soundarya, T. and Anchitaalagammai, J.V. (2014). Control and Monitoring System for Liquefied Petroleum Gas (LPG) Detection and Prevention. International Journal of Innovative Research in Science, Engineering and Technology, vol. 3, no 3, pp 696-700.

[14] Polulu. (2013). MQ-2 semiconductor sensor for combustible gas. Available: www.polulu.com

[15] Kim, C. (2006). Embedded Computing with PIC 16877- Assembly Language Approach. Available: www.mwftr.com

[16] Hanwei Eletronics (2016). MQ2 Gas Sensor. Technical Data. Available: www.hwsensor.com

[17] Probots. (2012). SIM 900 GSM Modem Starter Guide. Available: www.probots.co.in

[18] Propox. (2012). SIM 900-The GSM/GPRS Module for M2M Applications. Available: www.propox.com,