DESIGN AND IMPLEMENTATION OF AN ELECTRONIC GAS LEAKAGE SENSOR SYSTEM

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Abstract: Over the years incidences of fire outbreaks in both industrial environments and homes that resulted from gas leakages have been reported and documented. The inferno that resulted from some of the leakages were so enormous that colossal damages were recorded. These damages included loss of human lives, serious fire injury resulting in permanent disability, loss of properties, loss of relevant documents and other precious belongings that run into billions of naira to mention but a few. This paper shows the design and implementation of an electronic gas leakage sensor system which senses gas leakage(s) and promptly alerts the user through both an incorporated alarm system via the buzzer, and a status display on the liquid crystal display. The overall design aim was achieved using a microcontroller and an MQ-2 gas sensor which sends signal to the microcontroller whenever the concentration of the gas in the system's environment is above 400 ppm (0.04%).The microcontroller in turn sends signals to the LCD which displays the statement 'Gas detected' and the Buzzer which sounds to alert the user of gas leak/presence of gas in the environment continuously until the system is reset.

Keywords: Microcontroller, MQ-2 gas sensor, Buzzer, LCD, LPG

Introduction

Liquefied petroleum gas (LPG) has over the years been used for central heating, cooking, and in mobile heaters for leisure activities such as boats, caravans, and barbecues. This energy source is primarily composed of propane and butane which are highly flammable chemical compounds. Liquefied petroleum gas (LPG) leaks can happen, though rarely, inside a home, commercial premises or in gas powered vehicles. Leakages from Liquefied petroleum gas may be fatal as they amplify the risk of causing fire that may result in colossal damages.

Since Liquefied petroleum gas (LPG) is odourless, gas companies/refineries add an odorant such as ethanethiol, thiophene or a mercaptan so that leaks can be detected easily by most people, National Institute of Health,(2004). But some people whose sense of smell is reduced cannot rely on this safety mechanism. In such cases, an electronic gas leakage sensor system becomes vital and helps to protect people from the dangers of gas leakage. Many works have been published on gas leakage detection techniques. A wireless home safety electronic gas leakage sensor system was proposed in Fraiwan *et al*,(2011), where the alarm device is portable and hence movable within the building/premises.

Detecting gas leakages and identifying their exact location is one of the most significant tasks of pipeline operators in the gas industry. Flow monitoring and linear parameter varying (LPV) model based methods are widely used in the gas industry to detect gas leakage. These two approaches continuously measure the pressure at various segments of the pipeline, usually at ends as seen in Johansson (1998). But the setback of these methods is that they strongly rely on the noise of pressure/temperature measurement. Reliability issues of gas leakage detectors were addressed in Nasaruddin *et al*. (2009). The sound of gas that emanates from the leaks in the pipelines were analysed in Nakano *et al*. (2005) to locate the leakage. (Ashish *et al*., 2013) designed a GSM based liquefied petroleum gas detection system which consisted of a Phillip's microcontroller, MQ-6 sensor and a GSM module. The MQ-6 sensor is very sensitive to liquefied petroleum gas and Propane and hence its capability of detecting the smallest leakage of the gas. The microcontroller responds to the leakage(s) detected by the sensor by sending an SMS through the GSM module to the authority for appropriate response.

A similar project by Sunithaa and Sushmitha (2012) was designed to detect the leakage of liquefied petroleum gas and promptly informs the user alerts of the leakage, and as an emergency measure, the system switches on an exhaust fan to circulate the gas. An additional feature of the system is that the amount of gas consumed is shown in terms of the in terms of the total weight of gas. The system alerts the user about gas leakage via SMS through an incorporated GSM module. Whenever the system detects the increase in the concentration of the liquefied petroleum gas, it immediately alerts users by activating an alarm and simultaneously sending message to the specified mobile phones, then the exhaust fan is switched on.

This work provides a very cheap solution which is audio-visual in nature for the detection of LPG leakages in both homes and commercial environments and audibly alerts the users of a hazardous situation and provides warning signals (beeps) that there is a risk of gas flames resulting from the leakage. Several regulations have been put in place for the design of a gas leakage detection system such as IEEE, BS 5730, and IEC. For this work, the recommended UK safety standards, British Standards Institution (1999), British Standards Institution (2000) have been adopted. The proposed alarm system is aimed at detecting gas leakage, which is most commonly used in both homes and commercial environments. The device which senses Liquefied petroleum gas (LPG) leakage, such as propane and butane detects the presence of gas (gasl-eak), and raises an appropriate audio-visual alarm. The designed system ensures a continuous monitoring of the gas' concentration in its vicinity. If the gas' concentration in its vicinity increases beyond the reference / safe threshold of 400 ppm butane (LPG), the device activates high severity audio alarms at one second (1s) intervals warning the occupants to run to safety and possibly find solution to or prevent a possible fire outbreak. To ensure the users' safety, the alarm will continue to beep until the concentration of gas in the surrounding drops to the normal value as seen UK occupational safety standards Energy Institute London (2004).

System Design/Methodology

The methodology employed in this work takes into account both the hardware section which consists essentially of all the component units such as the display unit (LCD), oscillator-control, microcontroller, actuator section, gas sensor, reset unit and power supply units, and the software section which contains an embedded 'C' language program made up of instructions that were transferred to a microcontroller. The

AT89C52 controller is the heart of the entire circuit; it functions to ensure that different actions are carried out accordingly. The Fig. 1 is the functional block diagram of the designed the electronic gas leakage sensor system. It shows the interconnection between each section of the designed system as well.

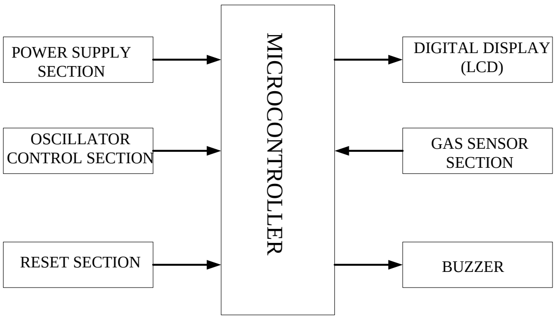

Fig. 1: Generalized block diagram of the electronic gas leakage sensor system

Gas sensor unit

The sensor used in this work is the Ionization gas detector. It detector contains two electrodes and an ionization chamber filled with ions such that when there is no gas, the ions move freely and the electrodes conduct normally. In the presence of gas, the chamber is filled with gas and interrupts the movement of ions, thus the electrodes do not conduct anymore.

The sensor used in this project is MQ-2 Gas/Smoke sensor. It is sensitive to LPG, hydrogen, smoke, methane, propane, alcohol, butane and other industrial combustible gases. It has two electrodes made of Aluminium Oxide (Al_2O_3) and a heating element made of Tin dioxide (SnO_2) which acts as the main sensing layer. The circuit diagram of the MQ-2 gas sensor is shown in Fig. 2.

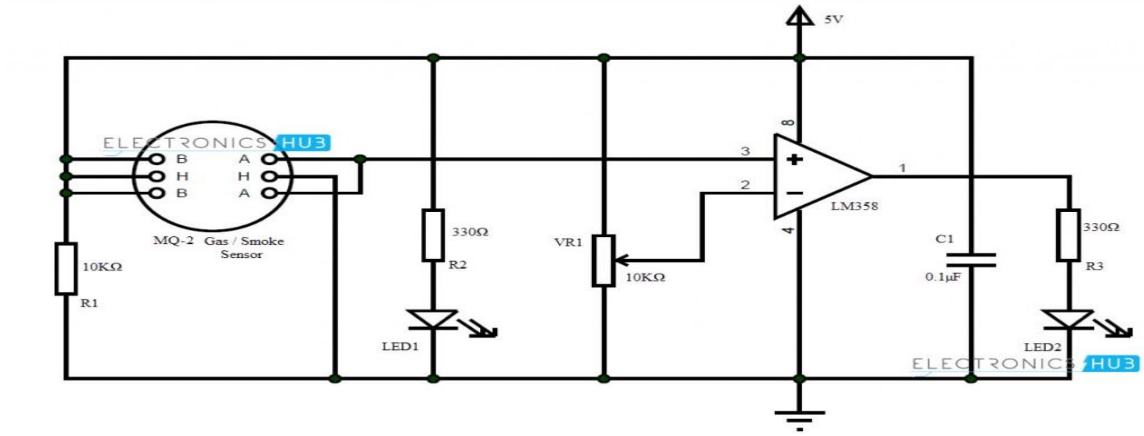

Fig. 2: Circuit diagram of the MQ-2 gas sensor (Source: Electronic hub)

AT89C52 Microcontroller

The AT89C52 is a low-power, high-performance CMOS 8-bit microcomputer with 8K bytes of Flash programmable and erasable read only memory (PEROM). The device which was manufactured using Atmel's high-density non-volatile memory technology and is compatible with the industry-standard 80C51 and 80C52 instruction set of 255 operation codes (opcodes), 32 input/output line (that is port 1, port 2, port 3, and port 4), three user-controllable timers, an integrated and automatic serial port, and 256 bytes of chip RAM.

The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C52 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89C52 was designed such that control of the microcontroller and all input/output between the microcontroller and external device is accomplished via Special Function Registers (SFR). Writing a value of 1 to a bit of these SFR will send a high signal on the corresponding input/output pin whereas a value of 0 will bring it to low level The AT89C52 microcontroller structure is shown in Fig. 3.

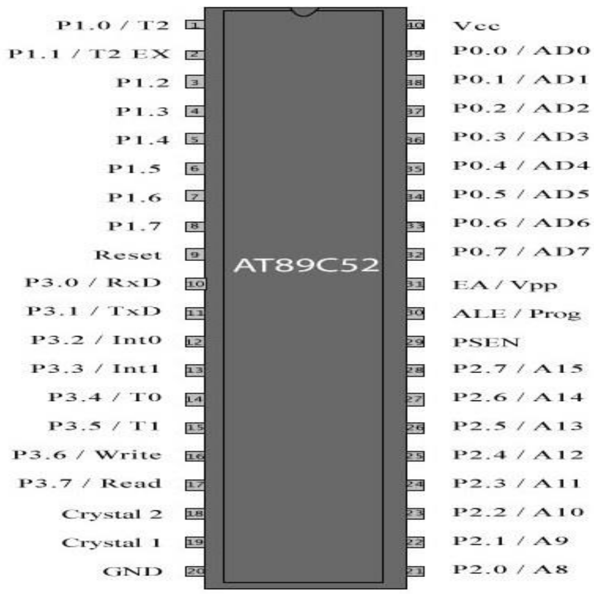

Fig. 3: AT89C52 pin diagram (Source: Engineers Garage)

Crystal oscillator circuit

This unit controls the speed of the microcontroller. It is shown in Fig. 4.

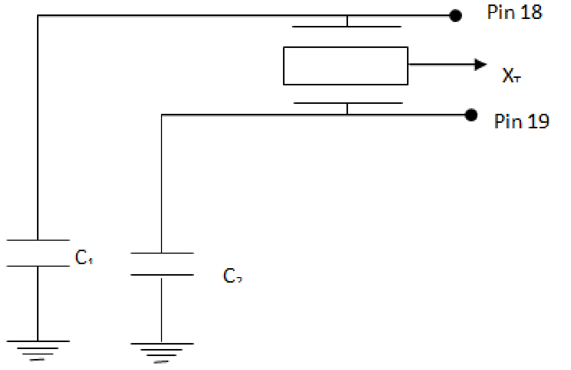

Fig. 4: Crystal oscillator circuit

Selection of the resonator circuit

C_1, C_2 and X_T forms the resonator circuit C_1, C_2 is a capacitor and X_T is a crystal oscillator. The values of C_1, C_2 and X_T are default value given by the manufacturer of AT89C52. Their values are in different ranges from whence users can make their choices.

$C_1 = C_2$ and ranges from 18pf – 33pf

X_T ranges from 4 MHz – 40 MHz

The higher the frequency, the faster the speed of instruction execution; but the higher the frequency, the more current drawn by the microcontroller.

Value of 30pf was used for C_1 and C_2 and 12 MHz used for X_T.

Speed of instruction execution $= \frac{Clock\ cycle}{Frequency}$

For AT89C52, clock cycle per instruction = 12

Therefore, speed of instruction execution

$$= \frac{12}{12MHz} = \frac{12}{12 \times 10^6} = 1 \times 10^{-6} \text{ secs}$$

= ~ 1 µsecs per instruction

Reset circuit

The microcontroller is fabricated in such a way that a HIGH at the reset input pin (Pin 9 of the microcontroller) will cause the AT89C52 controller to reset. Also, a HIGH on this pin for two machine cycles while the oscillator is running resets the device and causes program counter to jump to origin of the program. The reset circuit for this work is shown in the Fig. 5.

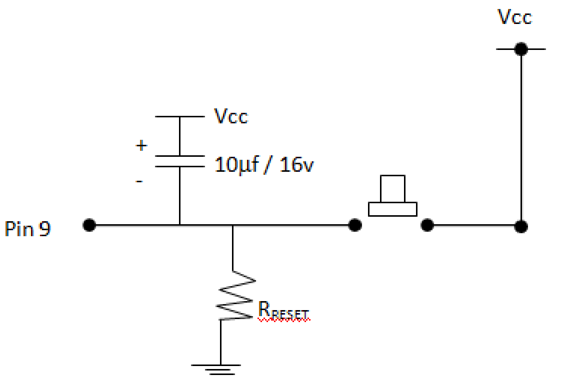

Fig 5: Reset circuit

Selection of the pull down resistor (R_{RESET})

This capacitor and resistors are connected such that when the button is depressed, a high comes to pin 9 of the microcontroller and when the button is released, the capacitor discharges through the resistor (R_{RESET}). According to data sheet specification of the AT89C52 microcontroller, the capacitor value of the reset pin must be 10µF,thus, the resistor value (R_{RESET}) must be determined. This can be done using the formula below:

$$Vc = Ve^{-t}/Rc \qquad (1)$$

But Vc = 4.5v

V = 5v

t = 10ms

C = 10µF

The above values were gotten from data book

$Vc = Ve^{-t}/ R_{RESET}$

$e^{-t} / R_{RESET} = Vc/v$

$-T/C\ R_{RESET} = \text{In}(Vc/v)$

$(- 10 \times 0.001)/(10 \times 0.000001 \times R_{RESET}) = \text{In}(4.5/5)$

$-1000/ R_{RESET} = \text{In } 0.9$

$-1000 = -0.1054\ R_{RESET}$

$R_{RESET} = -1000/-0.1054$

$R_{RESET} = 948.7 = 1000$

$R_{RESET} = 1K$

Therefore for this design 1K will be used since it is readily available in local electronic market.

Display uint

The display unit used in this work, shown in Fig. 6, is a 16x2 LCD (Liquid Crystal Display) screen. It is an electronic display module which is used in many applications.

16x2 means it can display 16 characters per line and there are 2 such lines. LCDs have two registers, namely, Command, and Data.

The instructions given to the LCD are stored in the command register, while the data to be displayed on the LCD are stored in the data rgister.What is displayed on the LCD is the ASCII value of the character which represents the data.

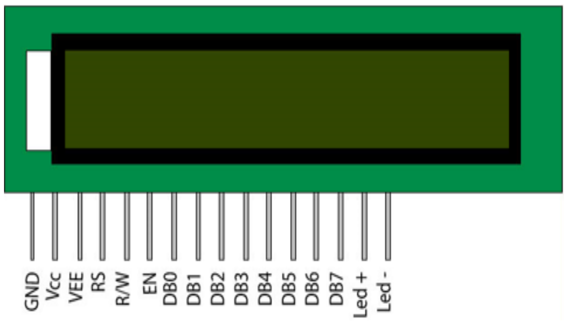

Fig. 6: LCD Pin diagram(Source: Engineer Garage)

Buzzer

A buzzer is an audio signalling device which may be used in alarm devices, timers and other forms of alerts. They are usually mechanical, electromechanical, or piezoelectric. Piezoelectric elements are driven by an oscillating electronic circuit or other audio signal source, driven with a piezoelectric audio amplifier. A piezoelectric buzzer was selected for this work.

Fig. 7: Buzzer

While the signal from Port 2.1 of the AT89C52 controller is applied to the base of the transistor Q1, a limiting resistor, 10K, was used to bias the base current of transistor Q1.

Power supply unit

The needed current and voltage of the system is supplied by the power supply. In this design a 5 V regulators was used to supply 5 V to the circuit.

The main voltage regulator functions to keep the terminal voltage of the d.c supply constant not minding variations in the input or the load voltage. Zener diodes and transistor are used for this purpose but for this project 7805 regulator was used in other to achieve a conservative design. It has an unregulated dc input voltage applied to the input terminal, a regulated output terminal of 5V from the output terminal, and with the centre terminal connected to ground. The unregulated input voltage is connected to the 7805 input terminal. The regulated voltage powers the various circuit elements that make up this design.

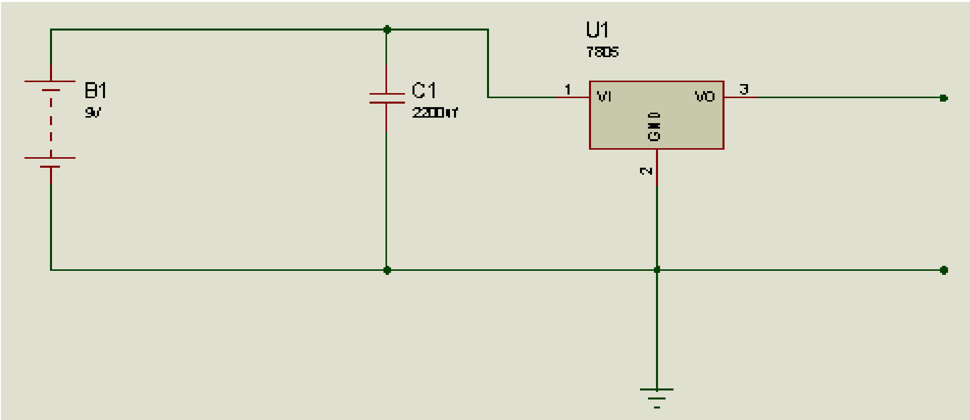

Fig. 8: Circuit diagram of a 5V$_{DC}$ supply

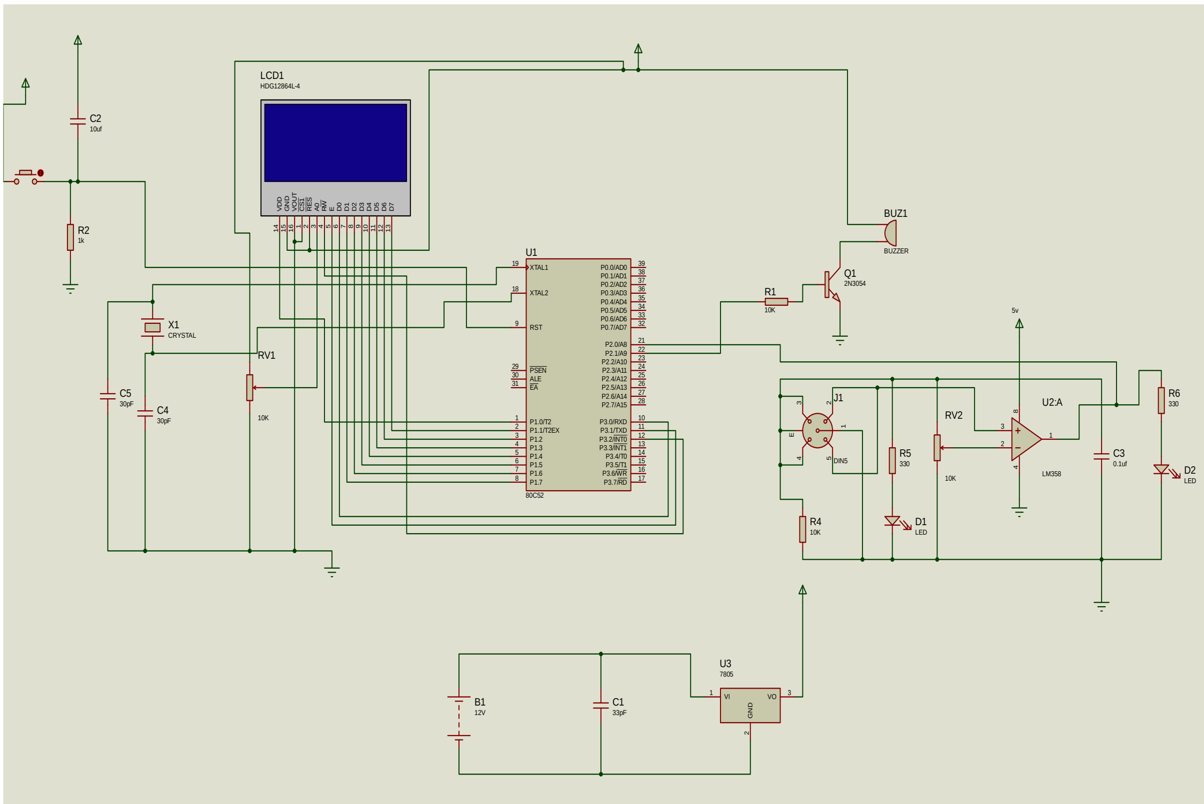

Fig. 9: Complete circuit diagram of the electronic gas leakage sensor system

Software implementation

A source code was developed and transferred to the microcontroller to enable it receive analogue input from the sensor. The microcontroller sends output signal to the buzzer and the display unit based on the analogue input received from the sensor; this triggers the buzzer as well as displays the system's status on the LCD. Embedded "C" programming language was used in this work. The written codes enable communication between the microcontroller, sensor, and LCD.

Complete circuit diagram of the system

Interconnection of the various section designed and discussed above gave rise to the complete circuit diagram of the electronic gas-leakage sensor system shown in Fig. 9.

Test and Result
This work is made up of both software and hardware sections. The software section is essentially a program written in C language and transferred into the microcontroller. The hardware section is made up of the microcontroller which controls the various aspects of the designed system, the input unit, the power supply unit and the display unit. The input unit has a gas sensor for detecting the presence gas and it is interfaced with the microcontroller via port one (P1) of the microcontroller. The display unit, an LCD is interfaced with the microcontroller via port zero (P0) of the microcontroller (Fig. 10).

The overall circuit was broken into units and each unit was first tested on a breadboard before they were transferred to a Vero board and electrically linked by soldering and the use of jumper wires. After this several tests were carried out on the designed device to ascertain its level performance/efficiency. After which it was confirmed that the system was functioning well and in line with overall design goal.

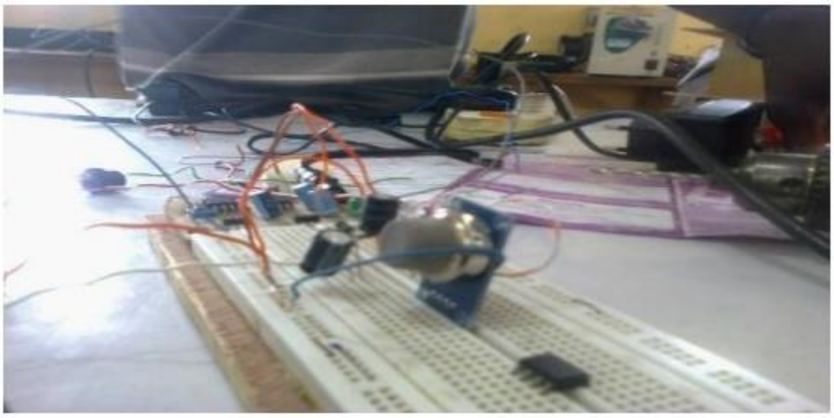

Fig. 10: Testing the various components/units on a bread board

Conclusion
A cost-effective gas leakage detection system was proposed, designed and successfully implemented as presented in this paper. The confirmation of the functionality/reliability the system was carried out employing a butane based gas-lighter, which an ingredient of LPG. The series of confirmatory/reliability tests carried out on the device satisfactorily confirmed the performance and reliability of the designed device by sensing different concentrations of leaked gas and alerting the users via the buzzer and the LCD respectively whenever the concentration of gas(LPG) within its vicinity is above the reference /safe threshold,400ppm.

Conflict of Interest
Authors declare no conflict of interest

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