Design and Implementation of an Economic Gas Leakage Detector

Conference Paper · March 2012

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Design and Implementation of an Economic Gas Leakage Detector

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Abstract: - Gas leakage is a major concern with residential, commercial premises and gas powered transportation vehicles. One of the preventive measures to avoid the danger associated with gas leakage is to install a gas leakage detector at vulnerable locations. The objective of this work is to present the design of a cost effective automatic alarming system, which can detect liquefied petroleum gas leakage in various premises. In particular, the alarming system designed has a high sensitivity for primarily butane, which is also individually sold bottled as a fuel for cooking and camping. The proposed system is designed to meet UK occupational health and safety standards. Test results are demonstrated for an USB powered gas leakage detection system and it gives early warning signals under less severe conditions and activates a high pitched alarm in case of emergency situations to safeguard the users.

Key-Words: - LPG, Gas leakage detection, Leakage exposure limits, Audio-visual alarm, Safety system.

1 Introduction

Liquid petroleum gas (LPG) is commonly used in homes for central heating, hot-water, gas-fires, 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. LPG leaks can happen, though rarely, inside a home, commercial premises or in gas powered vehicles. Leakage of this gas can be dangerous as it raises the risk of building fire or an explosion. The casualties caused by this hazard are still common news in the media. Since the LPG as such does not have any odour, gas companies/refineries add an odorant such as ethanethiol, thiophene or a mercaptan so that leaks can be detected easily by most people [1]. However, some people who have a reduced sense of smell may not be able to rely upon this inherent safety mechanism. In such cases, a gas leakage detector becomes vital and helps to protect people from the dangers of gas leakage. A number of research papers have been published on gas leakage detection techniques [2-11]. A wireless home safety gas leakage system has been proposed in [2] where the alarm device provides mobility within the house premises.

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Leakage detection and identifying its location is the most important task 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. Both these methods continuously measure the pressure at different sections of the pipeline, usually at extreme ends [3-8]. However, the drawback of these techniques is that they are strongly dependent on the noise of pressure/temperature measurements. Reliability issues of gas leakage detectors were addressed in [9]. Gas leakage sounds generated from the cracks in the pipelines were analysed in [10] to locate the leakage.

This paper provides a cost effective audio-visual solution for LPG leakage detection in homes and commercial premises and audibly alert the users of those premises in case of a hazardous situation and provide warning signals (beeps) in case of low risk scenarios – in particular, when the appliances may be left unattended in a premises or there is a risk of gas flames blowing out or being forgotten to be lit.

2 Problem Formulation

Several standards have been formulated for the design of a gas leakage detection system such as IEEE, BS 5730, and IEC. For this work, the recommended UK safety standards [12] [13] have been adopted. The proposed alarm system is mainly meant to detect LPG leakage, which is most commonly used in residential and commercial premises. The system detects not only the presence of gas (gas leak), but also the amount of leakage in the air, and accordingly raises an appropriate audio-visual alarm. The objective of the system is to detect LPG gases such as propane and butane. The allowed UK level for butane is 600ppm above which it is considered to be of high level and poses a danger.

The proposed system ensures a continuous monitoring of the gas levels. If the gas level increases above the normal threshold level of 400ppm butane (LPG), the system starts to issue early warning alarms at 100ms interval, which implies low level gas leakage. If the leakage level increases to 575ppm of butane (LPG), the system activates high severity audio alarms at 50ms intervals warning the occupants to run to safety. To ensure the user's/occupier's safety, the alarm will not switch off until the level of gas reaches the normal value of 400ppm. These gas leakage levels correspond to the UK occupational safety standards [14] [15].

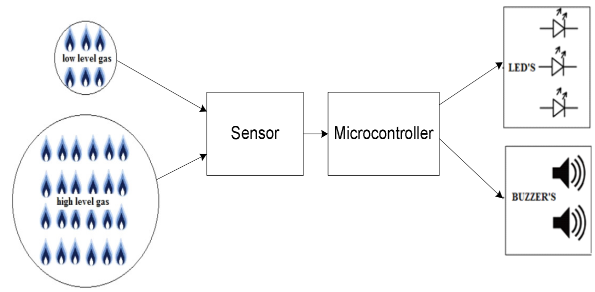


Fig. 1 Block diagram of the proposed gas leakage detection system

The basic block diagram of the proposed system is shown in Figure 1. Any gas leak is detected by the sensor and the voltage output from the sensor is fed to the microcontroller for processing to produce an appropriate audio-visual alarm. The microcontroller receives a voltage signal proportionate to the extent of gas leak detected (low or high) and drives the alarming system connected with LEDs and buzzers. Bearing in mind the user accessibility and convenience, the system is made to produce both audio and visual alarms. LEDS represent the visual alarms, while the buzzers represent the audible alarms meant to draw the immediate attention of users.

The MQ-5 gas sensor has been selected as a candidate device which has the ability to sense multiple gases [16]. The sensitive material used in MQ-5 gas sensor is tin/stannic oxide (SnO_2), which has lower conductivity in a clean air medium. When the target LPG leak is detected, the sensor's conductivity rises and increases proportionately as the extent of gas leakage increases.

Using a PPM meter, the voltage ranges for butane gas concentration corresponding to various levels were measured and these are given in the following table.

Table 1. Butane gas concentration and voltage levels according to UK safety standards

Gas concentration	Voltage range
≤ 400ppm	≤ 1.2V
400ppm – 600ppm (Lower exposure limit)	≥ 1.2V to ≤ 4.0V (Low level early warning)
≥ 600ppm (Upper exposure limit)	≥ 4.0V (High level dangerous warning)

ISBN: 978-1-61804-074-9

3 Problem Solution

The PIC18F1320 microcontroller has been chosen to perform the desired task of gas leakage detection and activate the alarms when the exposure limit exceeds the acceptable values as per UK safety standards. The flowchart for the microcontroller program is shown in Figure 2.

When the sensor senses no gas in the air, it produces a voltage below 1.2V on the output pins which are connected to port RA0 of the microcontroller. When the sensor senses the presence of gas in the air due to a leak, the voltage rises above 1.2V. The voltage varies between 1.2V and 5V depending on the level of gas concentration detected. If the voltage is between 1.2V and 4V, the microcontroller activates a low level early warning by sending signals to ports RB1, RB2 and RB3 to turn-on the LEDs (LED_YELLOW, LED_GREEN) and the buzzer (BUZ1) respectively. The low level warning signal is supplied for 100ms (slow mode) and then stopped. This step is constantly repeated until the voltage drops to 1.2V or below or until it rises above 4V.

If the voltage increases above 4V, then the high level dangerous warning sign is activated by sending signals to ports RB0, RB3 and RB4 to turn-on the LED (LED_RED) and the buzzers (BUZ1, BUZ2) respectively. These signals are supplied for 50ms (fast mode) and then stopped. This step gets repeated until the voltage drops below 4.0V. The system remains active until the gas level is reduced below the acceptable limit of less than 400ppm.

The software package PROTEUS has been used for testing the microcontroller program and its functionality virtually through a simulation environment. Figure 3 highlights the condition when the voltage applied was above 4V (this value can be seen in the Voltmeter), and the red LED and the two buzzers being activated indicating a dangerous gas level scenario. In order to simulate the program using PROTEUS, the hex file produced by building the program in MPLAB IDE was used.

Figure 4 illustrates the situation when the voltage obtained from the gas sensor was between 1.2V to 4V, and the green and yellow LEDs and the buzzer 1 being activated for a low level gas leakage producing early warning signals. Once the program has been tested successfully via the PROTEUS simulator, it is subsequently embedded into the microcontroller.

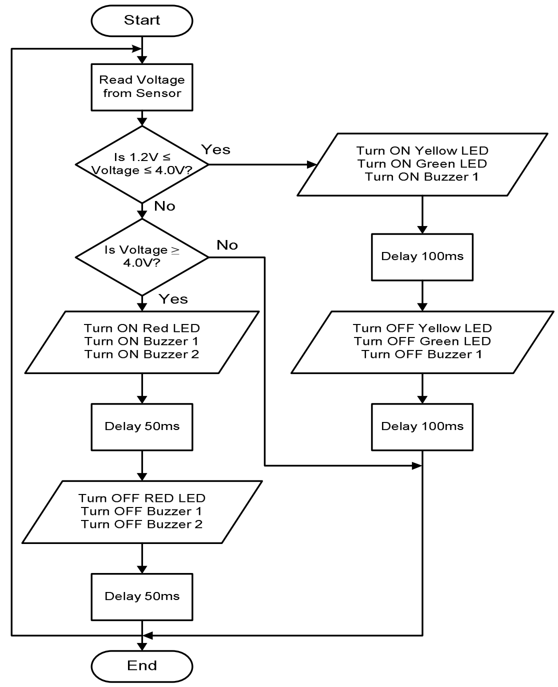


Fig. 2 Flowchart of the microcontroller function

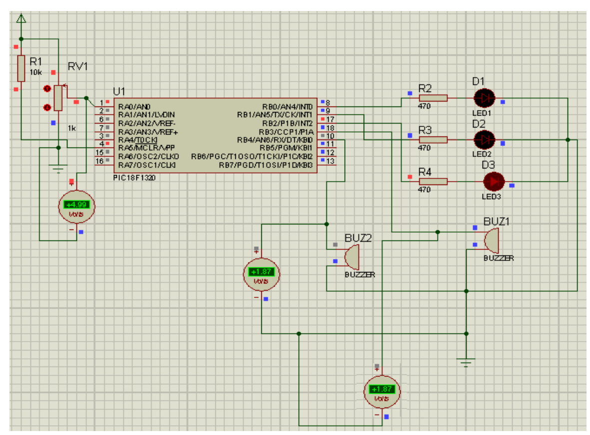


Fig. 3 Simulation result for 'high level' gas leakage

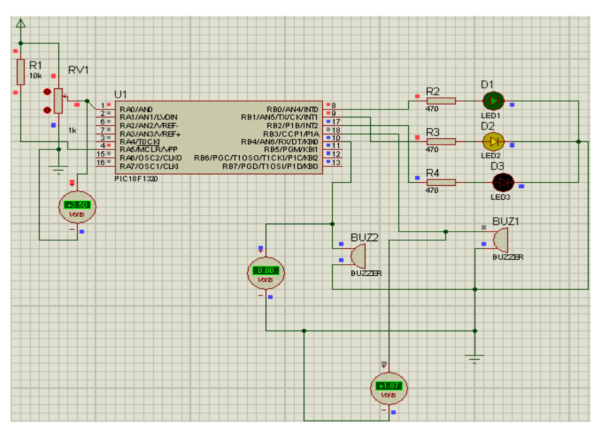
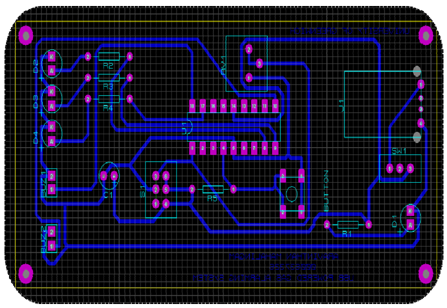


Fig. 4 Simulation result for 'low level' gas leakage

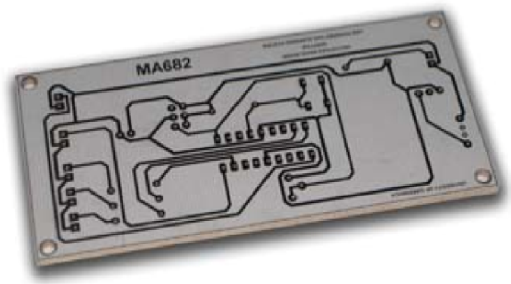
ISBN: 978-1-61804-074-9

3.1 Hardware implementation

The complete system is designed using ISIS and ARES PCB design software packages. The PCB layout and the implemented PCB are shown in Figure 5.



(a)



(b)

Fig. 5 (a) PCB design layout and (b) constructed PCB

Figure 6 depicts the prototype design of the proposed gas leakage detection system which consists of a MQ-5 gas sensor, a standalone PIC18F1320 microcontroller, buzzers, LEDs, and accessory circuitry for sensor sensitivity adjustment. The proposed system works well with power drawn from a USB connector. It can also operate based on a constant DC power source. Moreover, it can be configured to operate from a typical AC power source.

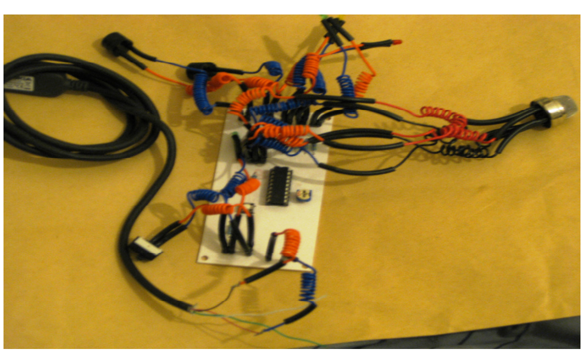


Fig. 6 Photograph of the hardware prototype

During testing, a lighter was used to replicate the LPG gas source. It was held open at a long distance to mimic low level gas concentration and was gradually brought closer to the sensor to mimic high level gas concentration. The proposed system exhibited an excellent performance with regard to detecting the gas leakage during practical testing. The cost of the entire system is only £21, which is much less than the cost of a commercially available gas leakage detector [17]. However, the cost may increase for higher sensitivity, and enhancement of sophistication of the alarming system. The following table summarizes the results obtained under different practical test scenarios.

Table 2. Summary of test conditions and results

Test condition	Green LED	Yellow LED	Red LED	Buzzer 1	Buzzer 2
No gas leakage	Off	Off	Off	Off	Off
Low level gas leak	On	On	Off	On	Off
High level gas leak	Off	Off	On	On	On

4 Conclusion

A cost-effective gas leakage detection system was proposed, designed and successfully implemented as a laboratory prototype, which was presented in this paper. The practical testing of the system was done using butane based lighter, which forms an ingredient of LPG. The test results confirm the efficient operation of the prototype by detecting low and high gas leakage levels and alerts the users by issuing appropriate audio-visual warning signals. The proposed system is designed to meet UK occupational health and safety standards with respect to gas leakage detection in residential and commercial premises. The cost involved in developing the system is significantly low and is much less than the cost of gas detectors commercially available in the market.

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ISBN: 978-1-61804-074-9