LP GAS LEAKAGE ALARM

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2 authors:

Manoj Wickramasinghe
Sabaragamuwa University of Sri Lanka

Nimsiri Abhayasinghe
Sri Lanka Institute of Information Technology

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M. G.. D. D. Wickramasinghe [1*], N. Abhayasinghe [2]

[1*] Corresponding Author, Department of Electronic and Computer Engineering, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka. Email: darshi_d@live.com
[2] Department of Electronic and Computer Engineering, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka. Email: nimsiri.a@sliit.lk

ABSTRACT

One of the most common types of energy source used in domestic is propane in which liquefied gas contains. Though the safety issues are considered by the company, leakage of gas has become very common accident which can cause damage to human lives and property. This paper presents a low cost, power efficient centralized LP gal leakage alarm system. The system has two main devices: the gas detector and the centralized alarm unit. The gas detector that is located close to the gas usage point (gas cylinder) is a battery operated device that is designed to operate up to 6 months with two AA size alkaline batteries. There can be more than one detector in the systems, which can be separately identified in the system. The centralized alarm unit detects the alerts sent by the detectors and releases the alarm. It has an indication of which detector has released the alert. The alarm unit is ac mains powered and has a battery backup to cater power failures. The components of the device have been chosen considering the power consumption and the time intervals have been calculated concerning the current consumption of each component.

***Key words*:** Liquefied Petroleum Gas (LPG), Power Management, Radio Frequency (RF), Alarm

1. INTRODUCTION

Liquefied petroleum gas is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. Varieties of LPG bought and sold include mixtures that are primarily propane (C3H8), primarily butane (C4H10) and, most commonly, includes both propane and butane, depending on the application [1].

Unlike natural gas, LPG is heavier than air, unlike natural gas, and thus will flow along floors & tend to settle in lower spots, such as basements. There are two main dangers from this [2].

- Possible explosion if mixture of LPG & air is right & if there is an ignition source.
- Suffocation due to LPG displacing air, causing a decrease in oxygen concentration.

1.1. Use of LPG

According to the 2011 Census of India, 28.5% of Indian households or 33.6 million Indian households used LPG as cooking fuel in 2011, which is supplied to their homes either in pressurized cylinders or through pipes [3].

LPG can be used as a power source for combined heat and power technologies (CHP). CHP is the process of generating both electrical power and useful heat from a single fuel source. This technology has allowed LPG to be used not just as fuel for heating and cooking, but also for de-centralized generation of electricity.

LPG can be stored in a variety of ways. LPG as with other fossil fuel can be combined with renewable power sources to provide greater reliability while still achieving some reduction in Carbon dioxide emissions.

1.2. Properties of LPG

Table 1: Properties of LPG

Gas	Formula	%LEL	%UEL	Ignition Temperature	Flash point in ℃
Propane	C_3H_8	2.2	9.5	470	97
Butane	C_4H_{10}	1.8	8.4	365	152

The properties of LP Gas is shown in Table 1. The explosion happens when the below three conditions are fulfilled,

- The concentration of gas is between LEL.
- A sufficient amount of Oxygen exists.
- There is a source of ignition [4].

2. METHODOLOGY

As mentioned, this device has two modules, the gas detector and the centralized alarm unit.

Sensing module – Battery powered for continuous 6 months small in size which is located in the kitchen near to usage unit (LPG cylinder.). All the components have been selected with a deep analysis of power consumption.

Structure: LP gas sensor (TGS 2610D00), sense every 5 minutes and if the ppm level is above 1800 the sensor module (Voltage is above 2.5V) sends address bit to alarm unit which make the buzzer on. Since the sensing module operates in 5V boosting up is essential. (Two alkaline batteries is 3V). For a high efficient booster NCP 1402 is used.
Input power = 5V*59mA
Output power = 3V*130mA
Efficiency = 75.64%

Since most of the timer module consumes high power (CMOS 555 timer). So as a solution DS1305 alarm real time clock is used since it has a very low current consumption as 200 nA.

Power consumption = 39.2 uA*3V = 117.6 uW (micro seconds)

Power consumption = 200nA*3V = 0.6 uW

Current consumption for 6 months = 0.0002*24*30*6 = 0.864 mAh

To make sure that both the modules are in alert mode, sensing module sends an address to alarm module in every 30 minutes. If the sensing module does not receive it within 40 minutes it beeps to inform that one of the modules are not in alert module.

Alarm module – This is a centralized alarm unit powered by AC mains. It has back up batteries to cater the power failures. All the LEDs are indicated in this module. This can be used as the single centralized module with multiple gas detecting devices.

Structure: If the risk level exceeds the alarm rings. Back up battery unit can continuously operate up to hours. Since the receiving unit is main AC powered a backup battery is essential. The MCP73831 is a highly advanced linear charge management controller for use in space-limited, cost sensitive applications

Receiver max current consumption=100 mA
Phone battery capacity=1500 mAh

Continuous operation of back up unit=15 hrs

To communicate between these two devices radio frequency (RF) module has been used.. To maintain 100% accuracy and security two time intervals has been taken into account, sampling time interval and handshaking time interval.

Gas Leakage Parameters:

Propane vapors are heavier than air. For this reason, they may accumulate in low-lying areas such as basements, crawl spaces, and ditches, or along the floor level. However, air currents can sometimes carry propane vapors elsewhere within a building.

At the beginning, before the measuring to proceed, the sensor needs to be put in the related environment for a while.

Monitoring the environment for long enough period of time by this sensor and one with already calibrated output will show the presence of other gases that can be considered as a constant part of the signal.

In order to associate the risk of fire/explosion and toxicity with the use of flammable gas cylinders, several scenarios were constructed. It is assumed that the gas being used is a mixture of propane and butane.

Example: A small flammable gas cylinder ruptures in a small space ($1m^3$). There is no ventilation. This would be similar to a release into a small storage cupboard [5].

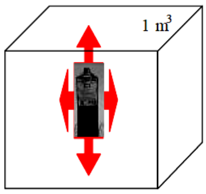

Figure 1: Small spaced cylinder without ventilation

Table 2: Effect of leakage for various sizes of cylinder

Cylinder Size (g)	Concentration of gas (mg/m³)	ppm	% in air	Effect
190	190 000	105 600	10	Above UEL
250	250 000	138 900	13	Above UEL
500	500 000	277 800	26	Above UEL
900	900 000	500 100	47	Above UEL
1250	1 250 00	694 600	66	Above UEL

Table 2 expresses the Effect of leakage for various sizes of cylinder. By considering above examples it is clear that the small dispersion into air exceed the risk limit depending on the size of the cylinder [6].

It is assumed that the gas leakage is maximum and the small dispersion into air. Summary of all risk levels shown Table 3.

Table 3: Risk Levels of Safety

Workplace size	Ventilation	Release rate	Probability of occurrence	Risk to safety	
				Cylinder Size	Risk
1 m^3	Dispersion	Over 30min	Low	Up to 900g 1.25kg	Low High
4.5m^3	Dispersion	Over 10 min	Medium	Upto 500g 900g 1.25kg	Low Medium High
4.5 m^3	0.25ms^{-1}	Over 10 min	Medium	Any	Low

After about 5 minutes the concentration has approximated equilibrium. Over the first 10 minutes the cylinder is leaking. After 10 minutes, dilution ventilation / extraction allow the concentration to decay to safe levels [7].

In domestic leakages the time duration of leakage which make hazarded zone is minimum 10 minutes. Sometimes it may enhance to 30 minutes depending on the speed of leakage. Therefore, the sampling period should be lower than 10 minutes to meet the safe levels.

2.1. Sampling Rate Vs. Handshaking Rate

To satisfy risk level of safety and the battery power, sampling period is chosen a value below to 10 minutes.

Power consumption of the device for 6 months is given in Equation 1.

$$\left\{(a*1)+\frac{(b-a)*1*\frac{60}{x}}{3600}+\frac{c*1*\frac{60}{y}}{3600}\right\}*24*30*6 \qquad (1)$$

Where,

a = sleep mode current consumption
b = sensing mode current consumption
c = handshaking current consumption
x = sampling rate in minutes
y = handshaking rate in minutes

The Sensing algorithm is shown in Figure 2.

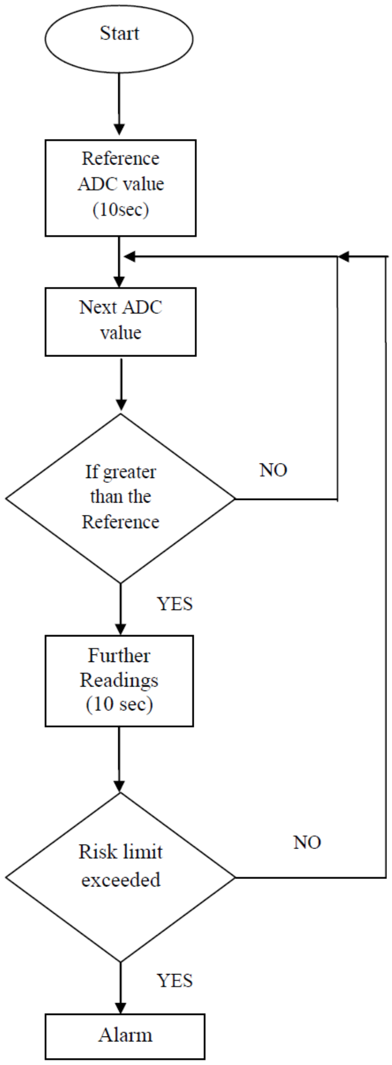

Figure 2: Sensing Algorithm

Capacity of the batteries is shown in Figure 4.

Table 4: Battery Capacity

Battery	Capacity (mAh)	Energy (mWh)	Life		
			Hours	Days	Months
Alkaline AAA	1250	1875	2293	95	3
Alkaline AA	2890	4335	6921	288	9

By analyzing the battery capacity and the power consumption of the sensing module, sampling rate is chosen as 5 minutes and the handshaking time is chosen as 30 minutes as in the Table 5.

Table 5: Selection of sampling and handshaking intervals

Sampling Rate - X (Minutes) \ Handshaking Rate - Y (Minutes)	5	10	15	20	25	30
1	4238.6	4179.2	4159.4	4149.5	4143.6	4139.6
2	2204.6	2145.2	2125.4	2115.5	2109.6	2105.6
3	1526.6	1467.2	1447.4	1437.5	1431.6	1427.6
4	1187.6	1128.2	1108.4	1098.5	1092.6	1088.6
5	984.2	924.8	905	895.1	889.2	885.2
6	848.6	789.2	769.4	759.5	753.6	749.6
7	751.8	692.4	672.6	662.7	656.7	652.8
8	679.1	619.7	599.9	590	584.1	580.1
9	622.6	563.2	543.4	533.5	527.6	523.6
10	577.4	518	498.2	488.3	482.4	478.4
11	540.5	481.1	461.3	451.4	445.4	441.5
12	509.6	450.2	430.4	420.5	414.6	410.6
13	483.6	424.2	404.4	394.5	388.5	384.6

3. RESULTS

Surface mount level PCB was designed as the final product without modules and kits as shown in the Figure 3 and 4 with a twenty pence coin.

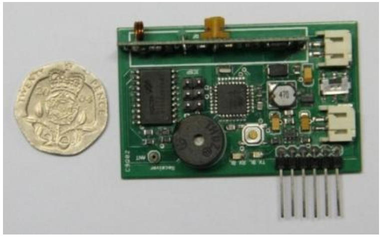

Figure 3: Alarm Device

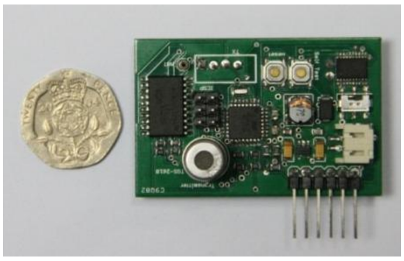

Figure 4: Sensing Device

Two modules were designed and implemented in printed circuit board. Power consumption for each module was calculated and compared with the estimated values as in Table 6.

Table 6: Comparison of Estimated and Real Time Values

Modes	Estimated Current Consumption	Real time Current Consumption
Sleep	12uA	70uA
LPG sensing	56.5mA	59mA
RF Handshaking	8.25mA	15mA

3.1. Power Calculation of Sensing Module

Referring to Equation 1,
Power consumption for 6 months,

a = sleep mode current consumption =70 uA
b = sensing mode current consumption = 59 mA
c = handshaking current consumption = 15 mA
x = sampling rate in minutes = 5 min
y = handshaking rate in minutes = 30 min

Power consumption for 6 months = 1,188 mAh

Power boosting efficiency is 75.64% practically. Input voltage is 3 V (Two AA Alkaline batteries)

$$\text{Battery capacity} = \frac{1188 \times 5}{3 \times 0.7564} = 2620\,mAh$$

Battery capacity of AA Alkaline battery is 2,890 mAh. This proves that this device is capable of continues operation more than 6 months.

3.2. Power Calculation of Alarm Module

Power consumption of alarm unit = 16.67mA x 5 = 83.35 mW per hour

Table 7: Power Consumption of Alarm Module

Mode	Current consumption
Ideal	16.67mA
Buzzer (Alert or Communication error)	18.74mA

In kWh = 83.35mWh x 60 = 0.005 kWh

Final product includes;

- Reset button and self test button is allocated in the sensing module.
- Battery status LED of the sensing module is allocated in the alarm module as an indicator.
- Indicators such as power LED, Back up battery operating LED are allocated.

4. CONCLUSION

The paper presented the design, development and implementation of low power, accurate LP gas detector. The 6 month duration of gas detector is proved theoretically and practically. This product features can be extended with the wider range of requirement.

When dealing with more than one unit handshaking is really important. It assures that two devices are in alert mode. Since these devices are dealing with hazardous gas, safety becomes the major requirement. So handshaking in every 30 minutes assures the two devices are in alert mode.

As derived above power consumption of sensing unit for 6 months is 1,188 mAh where the battery capacity of 2 alkaline batteries is 2,620 mAh. This means this device had achieved the target and it can be even in operation for more than 6 months.

Final device is less than 2 inches^2, surface mount boards which can be straight away deliver to the customer with proper enclose.

This project can be advanced due to requirement of the consumer. Though this device targets domestic need, it is possible to make it advanced by using more sensors according to the industrial needs.

As an advance modification this device may include several gas sensors such as carbon monoxide nitrogen dioxide etc. since those sensors do not consume much current comparing to LPG sensor.

Furthermore gas level can be detected according to hazards ppm level and can be transmit for further processing according to industrial need.

5. REFERENCES

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