Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 5(3): 222-228
 (ISSN: 2141-7016)
jeteas.scholarlinkresearch.org, jeteas.scholarlinkresearch.com

Design and Development of Kitchen Gas Leakage Detection and Automatic Gas Shut off System

Apeh S.T[1], Erameh K.B[2] and Iruansi U.[3]
[1, 2]Department of Computer Engineering, University of Benin, Benin City
[3]Department of Electrical, Electronics and Computer Engineering,
University of KwaZulu-Natal, Howard College Campus, Durban, South Africa.
Corresponding Author: Apeh S.T

Abstract
Gas leakages resulting into fatal inferno has become a serious problem in household and other areas where household gas is handled and used. Gas leakage leads to various accidents resulting in financial loss as well as human injuries and/or loss. The work aims at designing a system that detects gas leakage and alerts the subscriber through alarm and status display besides turning off the gas supply valve as a primary safety measure. The shutting off of the supply valve stops further gas flow to the cooker to prevent fire outbreak arising from attempt at igniting of the cooker. The system more like a first Aid, automatically uses a normally closed solenoid valve for the shutting off of the gas valve before calling for help via visual display and audible alarm to those within the environment. The system is an intelligent system, as it does not create a noise nuisance by continuously sounding alarm but the alarm stops beeping once the concentration of the gas in the atmosphere after leakage goes below the set point and opens the valve again for normal operations. This work will minimize injuries/losses occasioned by explosions due to gas leakages and improve safety of life and property while using domestic cooking gas.

Keywords: gas sensor, gas leakage detection, buzzer, microcontroller, solenoid valve

INTRODUCTION

The use of liquefied petroleum gas (LPG) is rapidly increasing in developing countries like Nigeria as it produces low smoke and less soot. The LPG is a flammable mixture of hydrocarbon gases like propane and butane.*[**Ashish et al, 2013**]* Gas pipe lines (that feed domestic cooking systems) are safe but they are prone to gas leakage due to mishandling, accidents and over filling of the gas cylinder. ***[Massachusetts Department of Fire Services]*** Explosions resulting from domestic cooking gas leakage can be fatal causing loss of property and injuries or even deaths.

A number of research papers have been published on gas leakage security system in which gas sensors are used to detect gas leakage and a response circuit is caused to initiate an alert procedure and/or take action to avert an incident. One such method detects gas leakage and sends SMS to the householder.*[**Zhijie et al, 2011**;* **Soundarya** *et al, 2014]* This does not make provision for halting further gas leakage. Another method not only detects gas leakage but also alerts (Beep) and turns off main power and gas supplies, and send an SMS. GSM module is used which alert the user by sending an SMS *[**Ashish et al, 2013**]*. This has broader focus beyond kitchen gas leakages. Another approach uses a smart security phone attached gas leakage sensor that senses leakage and sounds an alert alarm as well as sending a SMS to the home owner and emergency services. *[Alka, 2012]* This approach also does not make provision for halting further gas leakage.

The design of a wireless LPG leakage monitoring system is proposed for home safety. This system detects the leakage of the LPG and alerts the consumer about the leak by SMS and as an emergency measure the system will turn off the power supply, while activating the alarm. The additional advantage of the system is that it continuously monitors the level of the LPG present in the cylinder using load sensor and if the gas level reaches below the threshold limit of gas around 2kg so that the user can replace the old cylinder with new in time and automatically books the cylinder using a GSM module .The device ensures safety and prevents suffocation and explosion due to gas leakage. This project is implemented using ARM 7 processor and simulated using keil software. *[**PadmaPriya** et al, 2014]* This approach does not make provision for kitchen gas that uses gas cylinders not supplied by power utility supply, which the commonest is found in developing countries like Nigeria who have not developed such infrastructure.

In yet another approach, leak detection module consists of MQ-6 gas sensor to detect amount of combustible gas present in the surrounding. As the leakage detects the ARM 7 controller sends the message to LCD which displays "Gas Leakage Detected". The ARM 7 controller checks the concentration of gas is within safe level if it beyond safe level (safety level is programmable) then ARM 7 controller not only immediately activates buzzer but also switch on the exhaust fan so that the gases are sent out and GPS receiver gives altitude location of gas leakage. *[**Shinde** et al ,2012]* This system provides for components that can be considered overkill for household kitchen gas detection and response.

This work develops a gas detection and response system that detects gas leakage and automatically shuts off supply through the gas valve and sounds an alarm. It is focused on managing cylinder gas supply used in domestic household cooking in the kitchen to minimize accidents due to gas leakages. It does not however protect against explosions resulting from expired gas cylinder use.

DESIGN METHODOLOGY

In this work a sensor capable of detecting the presence of gas in the air around the household gas cooking system is required. To avoid increasing the gas concentration which will hasten fire incidents, supply of gas to the burner must be halted, if it is already been supplied, or must not be allowed in the event that the burner is turned on. Also to alert the owner of the status of the gas cooking system, an alarm and display were added.

THE DESIGN OF THE POWER SUPPLY UNIT (PSU)

The PSU converts the 220V available mains voltage to approximate 12V and 5V d.c which is used to power the circuit. Fig. 1 shows the circuit diagram of the power supply unit.

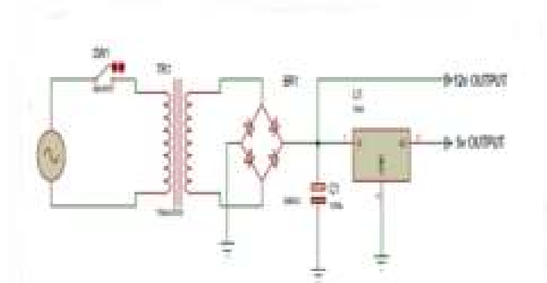

Fig. 1: Power supply unit circuit diagram

DESIGN OF THE FILTER CAPACITOR

From the circuit diagram, transformer, TRI steps down the main voltage from 220V to approximately 15V A.C. Bridge rectifier BR1, rectifies the 12V A.C from the transformer to pulsating D.C voltage; the pulsating D.C voltage from the bridge rectifier is filtered by the electrolytic capacitor C1. I.C voltage regulator U1 regulates the pure D.C voltage from the capacitor to approximately 5V D.C. The filter capacitor is used to filter out all the ripples in the dc output of the bridge, so as to have a smooth and pure d.c voltage. The value of this capacitor was calculated to be approximately 1000µf as shown in Eqn.1: *[**Apeh** et al, 2010; **Theraja and Theraja, 2002**]*

$$C = \frac{I_{dc}}{2 \times V_{ripple} \times F} \dots\dots\dots\dots\dots\dots\dots (1)$$

Where I_{dc} = current drawn from the circuit in mA ≈ 500mA, F = mains frequency ≈ 50HZ and V_{ripple} = 0.007

$$C = \frac{500}{2 \times 0.007 \times 50} = 714\mu f$$

. A standard 1000µf capacitor was used.

DESIGN OF THE GAS SENSOR UNIT

The gas detector circuit is implemented with the MQ-6 LPG gas detector module. This is a simple-to-use liquefied petroleum gas (LPG) sensor, suitable for sensing LPG (composed of mostly propane and butane) concentrations in the air. The MQ-6 can detect gas concentrations anywhere from 200 to 10000ppm. This sensor has a high sensitivity and fast response time. The sensor's output is an analog resistance. *[Alka, 2012]* The Sensitive material of the MQ-6 gas sensor is SnO_2 which lower conductivity in clean air. The sensor’s conductivity is higher with the gas concentration rising.

The resistance of the sensor (RS) is given by Eqn.2: *[**PadmaPriya** et al, 2014]*

$$RS = \left(\frac{VC}{VRL} - 1\right) \times RL \dots\dots\dots\dots\dots (2)$$

Where VH is heater voltage = 12V, RS is sensor resistance = 10kΩ, VC is the supply voltage to load = 12V, VRL is the voltage across load resistance, and RL is the load resistance = 10kΩ

Substituting the given values in Eqn. 2:

$$10k = (12/VRL - 1) \times 10k \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Solving Eqn. 3 gives

VRL = 13V

Power consumed

$P_s = (VC2 * Rs)/(Rs + RL)^2$ ……….(4)

Substituting the given values in Eqn. 3 gives:

Power consumed P_s = 3.6 mW

Shown in Fig.2 is the gas detector circuit diagram.

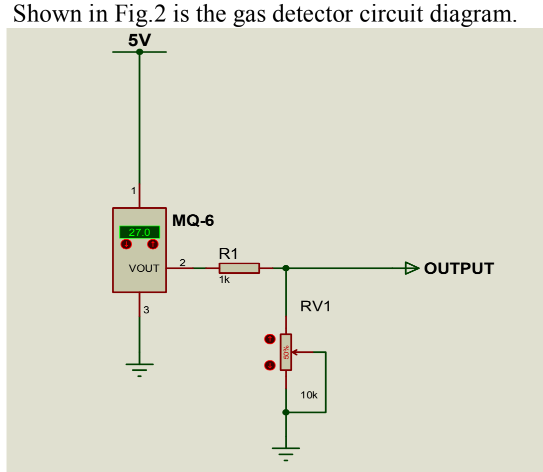

Fig.2: the gas detector circuit diagram.

THE DESIGN OF THE CONTROL UNIT

The control unit receives signal from the gas detector sensor and then sends signal to the solenoid valve drive unit and then activate an alarm. It also displays the status of the gas concentration on a 16x2 LCD screen. Shown in Fig.3 is the control unit circuit diagram.

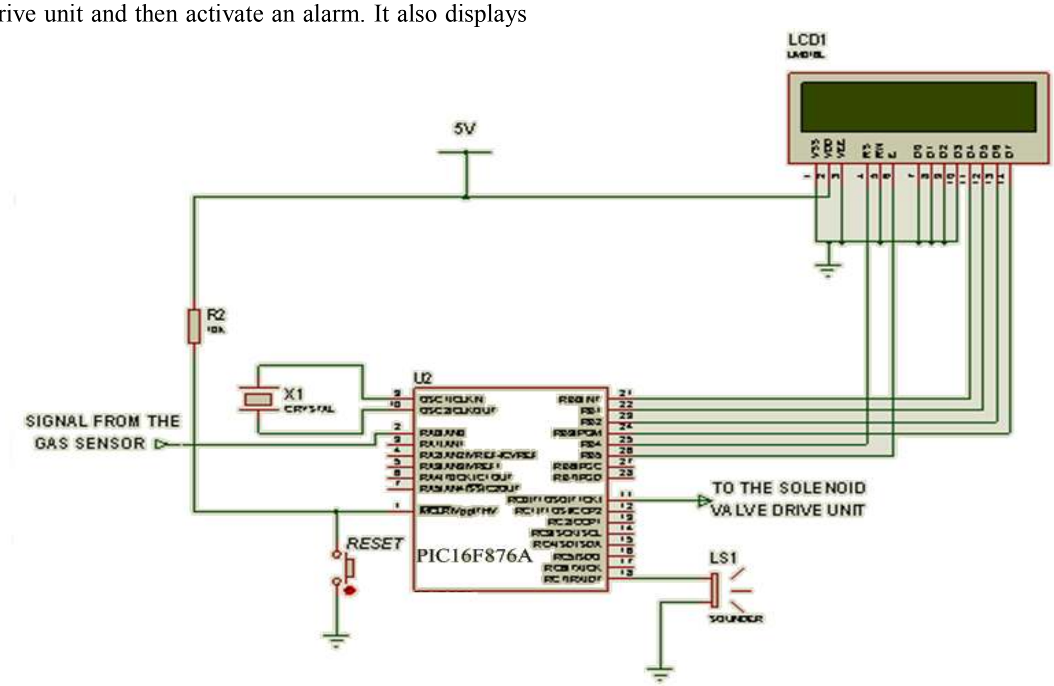

Fig.3: the control unit circuit diagram.

From the circuit diagram, the control circuit is implemented with a PIC16F876A microcontroller. The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the Synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART).*[Vipin et al, 2014]* The PIC16F876A microcontroller has three input/output ports (i.e. Port A, Port B, and Port C). The signals from the MQ-6 gas sensors is used as signal input at Port A, Port A is configured as an input port. Receives signal from the gas sensor. Port B is configured as an output port. Port B is used to drive the 16x2 LCD. Port C is configured as an output port. Port C is used to drive the buzzer alarm and the solenoid valve drive control signal. The microcontroller unit is operated with 4MHz crystal oscillator. The LCD is operated in 4-bits mode. The analog to digital converter of the PIC16F876A microcontroller is implemented at portA of the microcontroller. The analog signal from the MQ-6 gas detector is converted to 10-bits digital signal. When the concentration of gas rises above that of set point in the microcontroller, the microcontroller sends a signal to the solenoid valve drive unit to close the solenoid valve so as to shut off gas supply and also activate an alarm to alert that there is gas leakage.

The flowchart for the control algorithm is shown in Fig. 4.

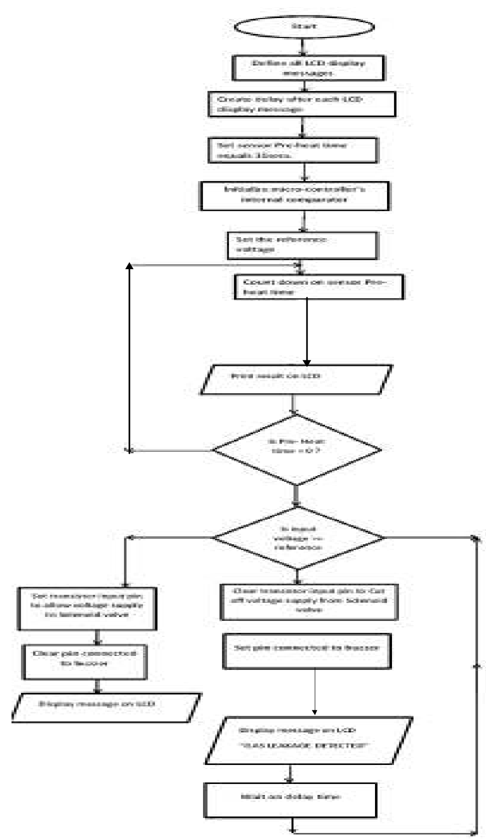

Fig. 4: Flowchart for the control algorithm.

THE DESIGN OF THE SOLENOID VALVE DRIVE UNIT

The solenoid valve drive unit controls the opening and closing of the solenoid valve which controls the flow of gas from the supply to the point where the gas is being used. The solenoid valve drive receives signal from the control unit and the carries out the appropriate action. Fig.5 is solenoid valve drive unit circuit diagram.

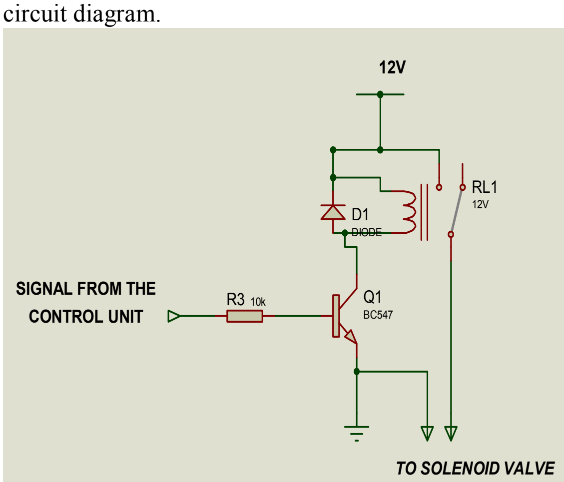

Fig. 5: The solenoid valve drive unit circuit diagram.

The signal from PortC.0 is applied to the base of BJT transistors Q1. Resistor R3 is the current limiting resistor which is used to bias the base current of transistor Q1.

At maximum rating of the BC547 (from datasheet), Ic = 100mA, h_{fe} = 700, V_{BE} max = 0.9) R_4=R_5 is determined according to equations (6) and (7) as: *[**Apeh** et al, 2010; **Theraja and Theraja, 2002**]*

$$R_4 = \frac{V - V_{BE}}{I_B} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$I_B = \frac{I_C}{h_{fe}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$I_B = \frac{I_C}{h_{fe}} = \frac{100 \times 10^{-3}}{700} = 1.42857 \times 10^{-4} A$$

$$= 142.857\ \mu A$$

For safe operation of the transistor, 4 times the operating current value for biasing. Thus,

$$R_4 = \frac{5 - 0.9}{4 \times 1.42857 \times 10^{-4}} = 0.7175 \times 10^4\ \Omega = 7.2\ K\Omega$$

10KΩ was chosen.

COMPLETE SCHEMATIC DIAGRAM OF THE CIRCUIT

Shown in Fig.6 is the complete circuit diagram of the gas detector.

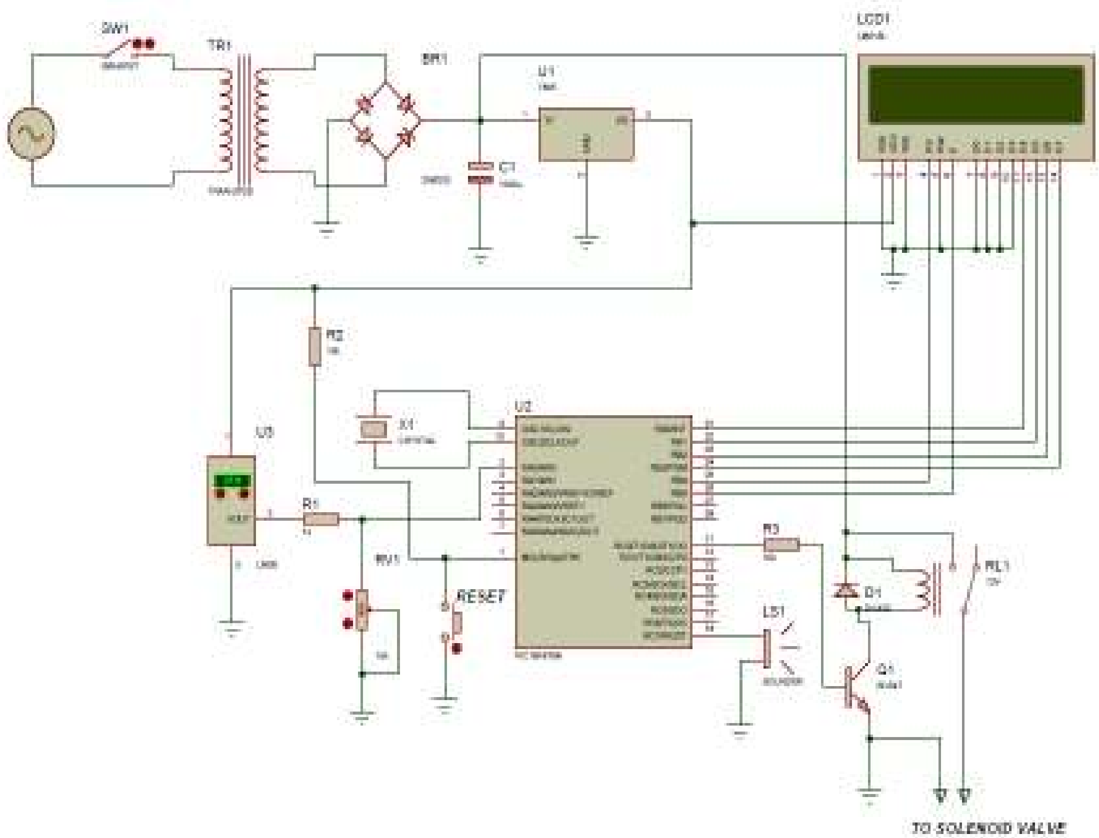

Fig.6: Complete circuit diagram of the gas detector.

TESTS, RESULTS AND DISCUSSION

Test

Testing was carried out by releasing LPG into the atmosphere around the sensor. Figs.7(a) and 7(b) show the gas detector and response unit with gas cylinder used for the test and test setup respectively. Fig. 8 shows the device's display status at startup.

Fig.7(a): LPG detector lower than gas source

Fig.7(b): LPG detector higher than gas source
Fig.7: LPG detector system testing set up

Fig. 8: Welcome messages on power-up/reset

The gas sensor used requires a Pre-heat time of over 48hours. So at startup or reset, Fig. 9 shows the display status of the device.

Fig.9: Sensor pre-heat count down on reset/power-up

After the count down, the sensor keeps checking in the atmosphere for possible LPG availability and displaying the status.

Fig.10: LPG detector system with gas concentration less than set reference.

The alarm comes on, and the gas valve is shut off once the sensor point exceeds or equals the set point, and the message, "Gas leakage detected" is displayed, Fig.11.

Fig.11: LPG detector system with gas concentration greater than set reference.

Fig.12 is a prolonged case of of high gas concentration.

Fig.12: A case of prolonged high gas concentration.

RESULTS

The results of test carried out on the device at different times and days for concentration of gas in the air around the sensor is shown in Table 1. The last four values is the case of an endless loop due to high gas concentration and was carried out on 24/02/2014. The device was tested placing the LPG device at different distances from the gas source.

Table 1: Test result

Set Point voltage	Sensed Voltage	Gas Leakage Detected?	Time	Date
111	97	No	4.19p.m	16/02/2014
111	111	Yes	4.20p.m	19/02/2014
110	78	No	11.41.29a.m	19/02/2014
110	78	No	11.41.35a.m	19/02/2014
110	78	No	5.53p.m	24/02/2014
110	78	No	5.53.37p.m	24/02/2014
110	79	No	5.54.03p.m	24/02/2014
110	90	No	5.54.48 p.m	24/02/2014
110	84	No	5.55.02 p.m	24/02/2014
111	82	No	5.55.59 p.m	24/02/2014
110	81	No	5.56.18 p.m	24/02/2014
110	81	No	5.56.26 p.m	24/02/2014
110	100	No	5.57.52 p.m	24/02/2014
110	102	No	5.58.48 p.m	24/02/2014
110	450	Yes	6.00.23p.m	24/02/2014
110	179	Yes	6.00.55p.m	24/02/2014
110	164	Yes	6.01.28 p.m	24/02/2014
110	155	Yes	6.02.17p.m	24/02/2014

DISCUSSION

It was observed that when the LPG device was tested by placing it at different distances from the gas source, the response time of the LPG system decreased as the distance from the gas source increased and vice versa. Also it was observed that the sensitivity of the gas sensor was very high in clean air. The gas sensor' sensitivity varied with temperature/Humidity while the reference voltage remained constant over time with error of$\pm 1\,V$. At constant gas concentration, the sensed voltage will always be constant. The gas sensor has a very fast response to gas since the time difference between test results with same concentration is very small while the difference between the sensed voltages is very high.

CONCLUSION

This work set out the problem of cooking gas leakages that has injured at other times and killed at some other times people cooking in the kitchen where it occurred. A device that can detect such leakages and shuts off the gas supply to the burner from the cylinder was designed and developed.

It was observed that when the LPG device was tested by placing it at different distances from the gas source, the response time of the LPG system decreased as the distance from the gas source increased and vice versa. The gas sensor's sensitivity varied with temperature/Humidity while the reference voltage remained constant over time with error of$\pm 1\,V$. At constant gas concentration, the sensed voltage will always be constant. The gas sensor has a very fast response to gas since the time difference between test results with same concentration is very small. This device can be deployed anywhere cooking using kitchen gas is used and will ensure that explosions resulting from leakages of cooking gas from the cylinders are averted.

REFERENCES

Alka D "Design and development of ARM7TDMI-S based GSM Mobile for home automation and security". E-Journal of Science and Technology. (4), 7, PP. 67 – 74(2012). Accessible at http://e-jst.teiath.gr

Apeh S.T., Ike S.A. and Ogbeide K.O. "Dual-Mode PC-Security Surveillance System". Journal of Civil and Environmental Systems Engineering, Vol.11, No.1, pp104-115(2010).

Ashish S., Ratnesh P., Rajeev K. and Rahul V. "GSM Based Gas Leakage Detection System". International Journal of Technical Research and Applications e-ISSN: 2320-8163, Volume 1, Issue 2, PP. 42-45(2013) . Accessible at www.ijtra.com

Massachusetts Department of Fire Services "Liquefied Petroleum Gas (LPG) Awareness.pdf", Massachusetts Department of Fire Services, Massachusetts Firefighting Academy, PP. 1-35

PadmaPriya K, Surekha M,.Preethi R. "Automatic Refill Booking Using Embedded System". International Journal of Key Scientific Research for Industrial Engineering & Technology. Vol.1, Issue 1. PP. 01-05(2014)

Shinde S.,Patil S.B, Patil A.J." Development of Movable Gas Tanker Leakage Detection Using Wireless Sensor Network Based on Embedded System". International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 6, pp.1180-1183(2012). Accessible at www.ijera.com.

Soundarya T., Anchitaalagammai J.V., Deepa P. G., Sheela K. S. "Efficient Energy (LPG) Gas Leakage Detection and Prevention System for Home Safety". Artificial intelligence systems and machine learning. Vol 6, No 1. (2014) Accessible at http://ciitresearch.org

Theraja B.L. and Theraja A.K.. "A textbook of Electrical Technology". S.Chand & Co. ltd, 23rd Edition, pp 1029-1118(2002).

Vipin J. V., Paul A., Nisha S. & Kevin J. "Experimental Investigation To Control Alcoholic Driving". International Journal of Research in Engineering & Technology. Impact Journals. ISSN(E): 2321-8843; ISSN(P): 2347-4599. Vol. 2, Issue 4, Pp. 123-128 (2014)

Zhijie T.,Wang S.,Luojun A "Remote Alarm Monitor System Based On GSM and ARM". Advances in Control Engineering and Information Science. Elsevier Ltd. Procedia Engineering 15, PP. 65 - 69(2011). Available online at www.sciencedirect.com.