International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2216-2223

A Low-Cost Smart Microcontroller Based Hazardous Gas Detecting System Suitable for Camps

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Abstract

High concentrations of harmful gases in the surrounding air might become poisonous, lead to fires or suffocation, and most likely, if no action is taken it might lead to injury or even death. The risk become much higher in poor society (for example, refugee camps). Hence, it is crucial to have a low cost and smart system that is able to detect and to react when a threat is present. The main focus of the presented scheme is to design and implement a low cast smart hazardous gas detecting system. The proposed design is controlled through Arduino, which in turn is connected to gas and temperature sensors. Furthermore, the Arduino is connected to suitable alarm, warning devices and elements with the ability to take appropriate actions when needed, thus a complete gas detection and alarm smart system is established. The proposed implementation detects the concentration of Liquefied Petroleum Gas (LPG) in the surrounding air, and measure the temperature; based upon these factors the device will act accordingly. A sensor is incorporated to indicate the concentration of the gas via a unique relationship between the concentration of the gas and the conductivity of the sensor material. The later signal is then processed using an analog to digital converter in the Arduino. Then the concentration and the temperature will be displayed on the GUI (Graphical User Interface) that is manipulated by LabVIEW program. The device is modeled to include 6 different stages of the concentration of LPG and 1 level of temperature, each stage can be modified and has its own based upon actions. The device is tested against some threats like those resulting from LPG stoves which are widely used and successfully detects and react accordingly.

Keywords: LPG, Hazardous gas detection, Microcontroller system, Smart safety systems.

I. INTRODUCTION

The burning of LPG provides enormous amount of energy, but on the other hand it's very dangerous. In many countries around the world heating, cooking, and even sometimes water boiling depend mainly on one of petroleum derivatives, like LPG. Suffocation incidents, injuries, and even deaths caused by gas leaking (LPG leaking) or incomplete burn of LPG gases are observed clearly in our country and other 3rd world countries over the whole world, where safety is not a priority for the residents in these places. From taking a quick glance over incidents and statistics for our country we should be able to realize how much it's important to have a device that works as a first or initial alarm system, a device that should be very simple to use by ordinary people, very basic, satisfying its purpose completely, and yet affordable.

There are many relevant researches that dealt with the problem of gas leakage detection [1-18]. Here are some of these researches that are relevant to our project:

In paper [1], a detection system for gas leakage that meets health standards of UK is proposed, the objective of it is to present the design of an effective automatic warning system, which can identify petroleum gas-leak in premises. Particularly, this system designed has a significant sensitivity for primarily butane, which sometimes sold bottled as a fuel for cooking and camping. Validation results are demonstrated for an USB powered gas-leak detection system and it was able to provide early warning under less severe conditions and activates and a high pitched alarm in emergency situations protecting the users.

In [2], the paper presented a gas discharge detection kit so as to prevent accident related to the gas discharge at the vulnerable places. The aim of this project is to show such a style that may mechanically find, alert and management gas discharge. When the discharge of gas is detected, the valve is mechanically closed, thereby stopping the discharge. Then the electrical power source is additionally stop working to stop fireplace accidents. especially, gas sensing element has been used that has high sensitivity to gases like gas and fuel. Gas discharge system consists of GSM module, alerts the user by broadcasting SMS.

In [3], the proposed system integrated into an alarming system, to produce sound or to give an GUI indication of the LPG wrong concentration. A sensor with high sensitivity incorporated with a fast response time. The sensor is selected to sense isobutane, LNG, and cigarettes. In case that the sensor senses any a gas discharge or leakage from storage the outcome flow change to low one.

II. PRELIMINARIES AND DESIGN ASPECTS

The hazardous gas detector is a device that can detect poisonous gases. The device built in this project aims to work as a smart detection and alarm system for the gases produced during the leakage of LPG (Liquefied Petroleum Gas). In this proposed scheme, the consumer is alerted about the fuel or gas leakage

via many numerous moves proposed, the machine or unit in which the leakage is detected with the aid of the gas sensor and convey the consequences and responses in forms of audio and visible. it provides a design scheme on software program in addition to hardware. Onn this bendy reliable smart detection scheme, the leakage is detected and managed via an arduino. the machine has sensors are used for detecting the temperature and for monitoring the extent of gas in the surrounding air respectively.

Here are the main objectives of this work:

- Design a Gas detecting device that can detect the concentration of the LPG in the surrounding area.
- This device is a smart and reliable safety solution, detect the LPG and temperature degree then act accordingly to this reading.
- The device is simple, portable, and easy to use by ordinary people.

Recall that the main focus on detecting the concentration of the LPG during the leakage, 6 levels of the gas readings are considered in addition to temperature measuring. Those levels can be modified to satisfy the user demands. In each level the device will act accordingly, so reduce the danger which could happens if the room reaches high level of concentrations.

A. Design Process

The proposed unit is designed to detect the attention of LPG within the air, and measure the temperature; primarily based upon these elements the tool will act thus. The sensor will indicate the attention or concentration of the gasoline through a unique courting among the attention of the gas and the inner sensor conductivity. LPG (liquid petroleum fuel) is used to define gases, which in general comprise 3 and four carbons (C3 and C4) hydrocarbons and may liquefy underneath low stress. In its herbal form, LPG is a drab and scentless substance. it's far denser than air and is saved in liquid form under pressure. Aromatizes are delivered for smooth notice in case of leakage. LPG vapor is heavier than air. it can circulate faraway from its supply with density distinction and air movement, and acquire in low regions in outside, and lower floors in homes [19-20].

Figure 1. LPG Cylinder

This signal will be processed using an analog to digital converter controlled by an Arduino. It then will be displayed on a screen, it can detect different 6 stages of the concentration of LPG and 1 level of temperature, each stage shows different degree of seriousness of the situation, and it has its own based upon actions. So, to achieve of covering all related applications, the requirements and objectives of our project are determined and the best hardware and software implementations are then selected.

The set of actions related to each level are given as follows:

- Level 1: Green light is ON.
- Level 2: Green and Orange lights are ON.
- Level 3: Green, Orange, and Red lights are ON.
- Level 4: Buzzer is ON, and "Gas Leakage Detected" SMS message will be sent to the user number.
- Level 5: Fan is ON.
- Level 6: Window is open.

In addition to gas concentration levels, the user can modify the temperature degree which considered as dangerous case, so the device will call the user number through the GSM and turn on the FAN. Moreover, in order to have a suitable design that matches the entire requirement we used the following hardware:

1. **Arduino Uno:** Arduino is known due to its biggest advantage 'Ready to use'. It is an open-source platform based on simplified form of hardware/software features.
2. **PIC Microcontroller 16F877A:** The name PIC initially referred to "Peripheral Interface Controller", used to control the servo motor which connected to the Automated Window.
3. **MQ-2:** It is a simplified LPG based sensor, used to sense the gas concentrations or attention in the surrounding air.
4. **LM35:** The LM35 is a sensor of temperature, use an output voltage which is linearly proportional to temperature in Centigrade.
5. **GSM Modem (SIM900):** GSM known as the Global System for Mobile Communication is the most successful mobile communications system worldwide.
6. **DC Fan:** A DC fan is used in this project to allow the fresh air from the inner environment to be exchanged with the air in the outer environment when the poisonous gases ratios are high**.**
7. **Servo Motor for Automated Window:** MG995 servo motor is used in this project to open and close the window.

B. Problem Models

LPG may be an extremely flammable substance and quickly forms explosive air - organic compound mixture once subjected to part conditions [19-20]. It contains a combination of fuel (C3H8) and fuel (C4H10) gases. once oil merchandise containing carbon and H molecules are burned and full combustion' doesn't happen, gases like monoxide, that is

extremely harmful and even deadly for human health, is created.

The outcome of complete combustion of methane in a gas heater is as follows [19]:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

As seen from the equation, complete combustion of methane produces Carbon Dioxide and water molecules. However, incomplete combustion of methane will produce Carbon monoxide in addition to carbon dioxide, the equation is as follows:

$$CH_4 + 2O_2 \rightarrow \beta H_2O + \gamma CO + CH_4 + \delta O_2$$

Further, carbon monoxide gas (CO) poisoning thanks to intentional or accidental exposure continues to be one in every of the foremost common poisoning-related death causes in developed/developing countries. CO poisoning will increase and reaches its peak in winter significantly annually in several countries. worth counseled for CO by the Environmental Protection Agency (EPA= and also the World Health Organization (WHO) is set as follows: nine ppm for eight hours, and most twenty-five to be taken in one hour. the rationale for poisoning from geyser or gas isn't providing recent air entry into the toilet whereas the gas is burnt or victimisation the whole current gas in bathroom since geyser is not connected to flue. toxic CO gas starts forming if the gas in lavatory is reduced and continues to burn. If there's no/poor flue affiliation, CO gas forming as a results of combustion spreads to the atmosphere and causes poisoning.

Carbon monoxide is cyanogenetic thanks to its explicit interest in haemoprotein. It connects to haemoprotein 250 times over gas and forms carboxy hemoglobin. Low levels of carboxy haemoprotein may be detected in anyone. CO has insidious cyanogenetic effects. cerise color is determined on the skin and lips thanks to red color of carboxy haemoprotein [19-20]. Table 1 provides some symptoms of carbon monoxide inhaling.

Hence, two sensors are used here, MQ-2 and LM35 for sensing the concentration of the gas and the temperature degree of the air respectively. LM35 heat sensor Rated from −55° to +150°C range and it has a Linear scale factor + 10.0 mV/°C, which means that every 10 mV the reading of the temperature will increase 1 °C, in order to have an accurate reading suitable for the design we multiply the reading of the sensor by 100. Also the MQ-2 has a range from 300-10000 ppm and its need a preheat time Over 48 hours, in order to have the specified levels readings without the need for this long time we multiply the reading by 700. The design is connected to 12V-1A power supply. The Power consumption of the proposed design almost equal to 5.5W as shown in Table 2.

Table 1. Carbon monoxide concentrations and associated symptoms [20]

Carbon monoxide concentration	Signs and symptoms
35 ppm	Headache and dizziness within 6 to 8 h of constant exposure.
100 ppm	Slight headache in 2 to 3 h.
200 ppm	Slight headache within 2 to 3 h; loss of judgment.
400 ppm	Frontal headache within 1 to 2 h.
800 ppm	Dizziness, nausea, and convulsions within 45 min; insensible within 2 h.
1600 ppm	Headache, tachycardia, dizziness, and nausea within 20 min; death in less than 2 h.
3200 ppm	Headache, dizziness, and nausea in 5 to 10 min; death within 30 min.
6400 ppm	Headache and dizziness in 1 to 2 min; convulsions, respiratory arrest, and death in less than 20 min.
12800 ppm	Death in less than 3 min.

Table 2. Power consumption calculation.

Item	Voltage	Current	Power consumed
ARDUINO	5V	40mA	0.2 W
PIC	5V	15 mA	0.075 W
SERVO MOTOR	5V	250 mA	1.25 W
FAN	12V	53 mA	0.636 W
LCD	5V	120 Ma	0.6 W
LEDS *3	5V	30 mA	0.15W
MQ2	5V	160 mA	0.8 W
LM35	5V	60 mA	0.3 W
GSM	5V	250 mA	1.25 W
		TOTAL =	5.261 W

III. DETAILED DESIGN OF THE PROTOTYPE

The design is clear and deterministic; a hazardous gas detecting device will act accordingly to the LPG concentration and temperature readings. This section has the description for the whole project including the flow chart and I/O module. GUI (Graphical User Interface), which is an interface that provide the users with a way to deal and interact with the source code, and in turn allowing to convert the values passed to the given source code, and monitor the information that the code manipulate. Furthermore, in LabVIEW tool, the interface which is important to detect and clarify the I/O of a software development problem at the design step of development phases (see Fig 2).

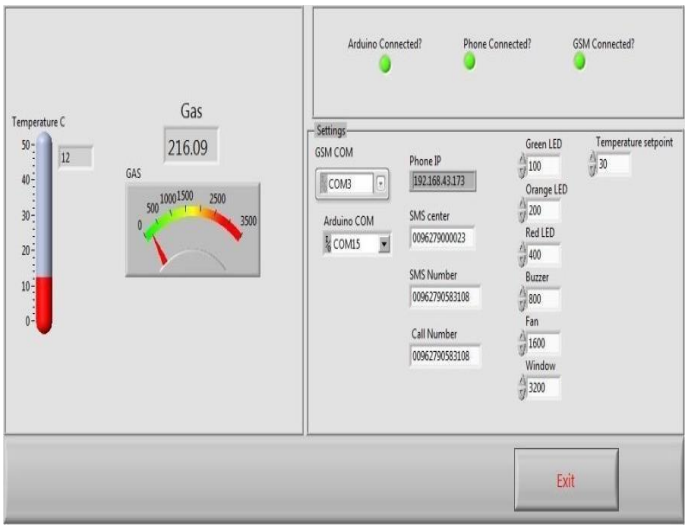

Figure 2. Design Graphical User Interface

All the details of the design interface components will be discussed later and here are the operations involved:

- Level 1: at 100 PPM concentration, green light is ON.
- Level 2 : at 200 PPM concentration, green and orange light are ON
- Level 3: at 400 PPM concentration , all lights ON (red)
- Level 4: at 800 PPM concentration, buzzer is ON, and the SMS message will be sent to the user number.
- Level5: at 1600 PPM concentration, fan is ON.
- Level6: at 3200 PPM concentration, open Window.

Operation for temperature as following:

- At 50 Celsius FAN is ON, and the GSM will call the user.

The following describes every component used in the propose smart system:

1. Arduino Uno: The Arduino shown in Fig 3 is an open-source hardware/software platform. Arduino can read inputs(i.e., light on a sensor, a finger on a button), and then turn it into an output: it can activate a motor, turn on a LED, and some more features.

Figure 3: Arduino UNO

2. MQ-2 Sensor: MQ-2 shown in Fig 4 is a semiconductor sensor used for detecting the smoke and combustible gases , the range of concentration that can be detect is 300-10000ppm. In the proposed methods, this sensor is used to detect the LPG gas concentration, it's also can detect the another gas like CO, methane and hydrogen. It is to be noted that the sensitive material of MQ-2 sensor is SnO2, which with lower conductivity in natural air. Given the target combustible gas, the sensor's conductivity becomes higher with rising gas concentration as well.

Figure 4: MQ-2 sensor

3. LM35 sensor: The LM35 shown in Fig 5 is an IC-based temperature sensor, in which the out-voltage is proportional to the Celsius temperature (linearly). According to its sheet, it runs from 4 V to 30 V, Rated for Full −55°C to 150°C Range.

Figure 5: LM35 Sensor

4. LED's (Light-Emitting Diode): LED's similar to ones shown in figure 6 are used as first indicator lamps in this device, 3 lamps are used, each one indicates different

level of gas concentration; the GREEN indicates 100 ppm, the ORANGE indicates 200 ppm and the RED 400 ppm of gas reading.

Figure 6: LEDs

5. BUZZER: A buzzer shown in Fig 7 is an Audio producing device and introduces a noisy irrespective of the the variation of the applied voltage to it and gives a sound in the range of 2 to 4 kHz. The buzzer here works like indicator that the gas concentration has reach 800 ppm.

Figure 7: buzzer

6. DC FAN: DC Fan shown in Fig 8 can operate directly from rechargeable batteries, in this project the fan is used to allow the fresh air from the inner environment to be exchanged with the air in the outer environment when the poisonous gases ratios reach 1600 ppm.

Figure 8: DC Fan

7. MG995 Servo motor for Automated Window: A servo motor shown in Fig 9 is a rotary actuator that allows for precise control of angular position. In this project MG995 servo motor of is used to open and close the window. It can be controlled directly by a microcontroller without any additional electronics, which makes it a great actuator for simple projects such as this project. The automated window will be opened if the gas concentration reaches 3200 ppm.

Figure 9: MG995 Servo motor

8. GSM: GSM shown in Fig 10 known as the Global System for Mobile Communication is the most successful mobile communications system worldwide. In this project the GSM is used to call the user phone number when the temperature exceeds the limit. We use GSM SIM900 in this project (APPEENDIX E).

Figure 10: GSM (SIM900)

9. PIC Microcontroller: An 16F877A PIC microcontroller (shown in Fig 11) is used to control the device, the name PIC initially referred to "Peripheral Interface Controller", we use PIC microcontroller as a connection between the Arduino and the motor in order to control the work of the automated window (APPENDIX F).

Figure 11: 16F877A microcontroller

Fig 12 depicts the I/O model of the proposed design. Furthermore, the design process flowchart and system prototype is presented in Fig 13 and Fig 14, respectively.

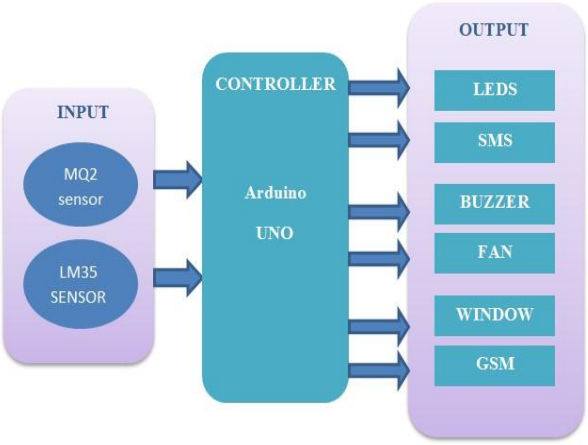

Figure 12: An Input/Output model of the proposed smart system.

A. Validating and Tuning Process

It is crucial to make sure that all components are connected and working correctly, so we use some feature provided by the LabVIEW software which help us to monitor the system. Figure 15 shows a cropped section from the design GUI, the user can check the connectivity of the Arduino, the Phone, and the GSM, if they are working correctly, the LED will be green lighted, otherwise the component is not connected or there is a fail.

The Arduino and the GSM are connected to the computer through COM serial cables, the number of this cable appears on the GUI to help the user to know to which port the mentioned component is connected to as shown in Fig 16.

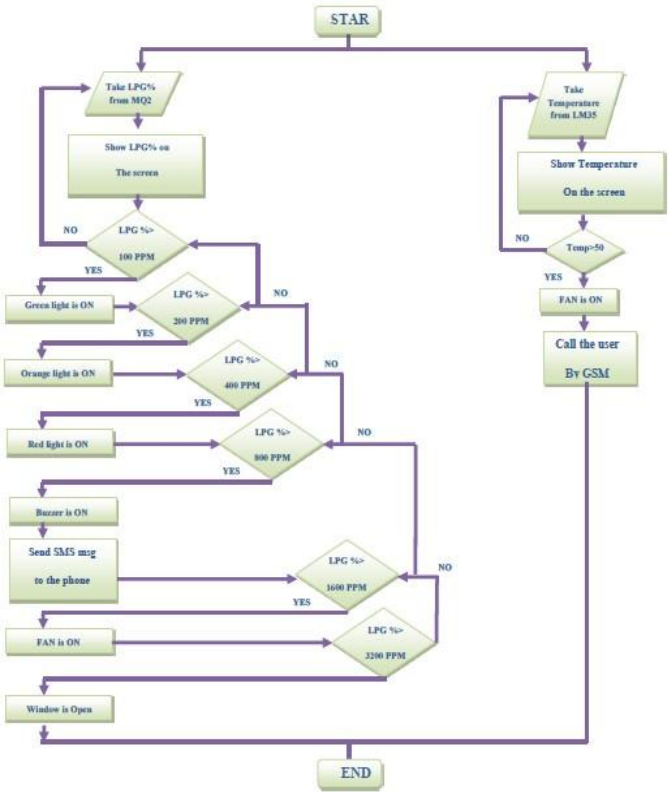

Figure 13: Design Process Flowchart.

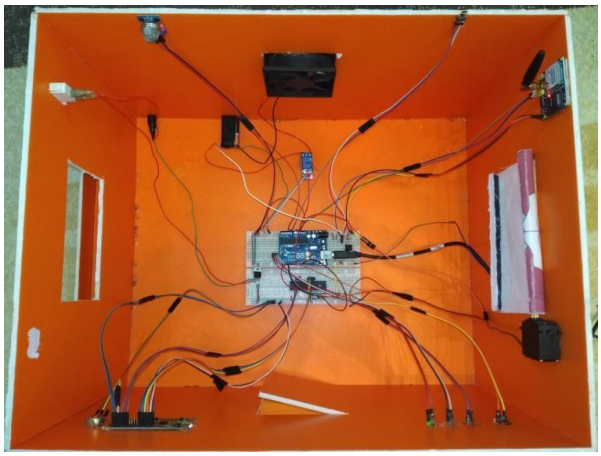

Figure 14: Final Design Prototype.

Figure 15: LEDs indicator.

Figure 16: COM Serial number.

Two type of indicators used in this design, the first one called Thermometer indicator which show the temperature measured by LM35, the other one is a Meter indicator used to show the concentration of the LPG gas in the surrounding area measured by the MQ-2 sensor (as shown in Fig 17)

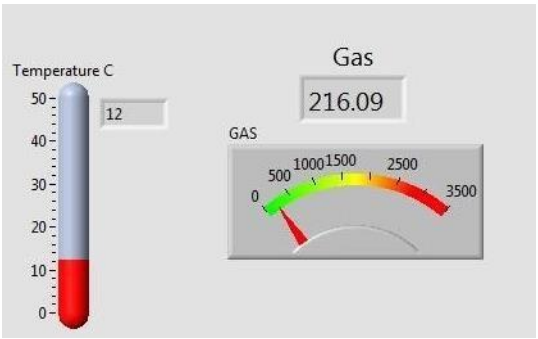

Figure 17: Temperature and Gas indicators.

As mentioned before when the gas concentration reaches 3200 ppm then the Buzzer will start whistling, also the device should send a message " Gas Leakage Detected " to the user number, the message sending operation is done using (GSM Modem

Emulator) application, this is an Android application use your Android phone as a GSM modem to send and receive SMS messages from a PC or server. This application require that the Android phone and the computer both are connected to the same wireless network, so the user have to enter the same Host IP 'which is appeared on the home screen of the application' to the GUI in the Phone IP block. In addition to the Phone IP, the user has to enter the phone number and the SMS center number as shown in Figure 18. So, when the concentration reaches 3200 ppm the message will be sent to the entered number on the device which has the application installed on. The last block shown in Fig 18 bellow, allow the user to enter the number that the GSM will call when the device measure a temperature degree that exceeds the limit.

Fig 19 shows the home screen of the used application, this screen allow the user to know the IP address which the phone is already use, also the 'client connected' status show that your if your phone is correctly has been connected to the computer. The other buttons appeared on the GUI called numeric controls (see Fig 20), these button used to enable the user to change the levels of the concentrations and the temperature degree related to the mentioned actions.

Figure 18: Phone IP, SMS center, SMS number, and the Call number block.

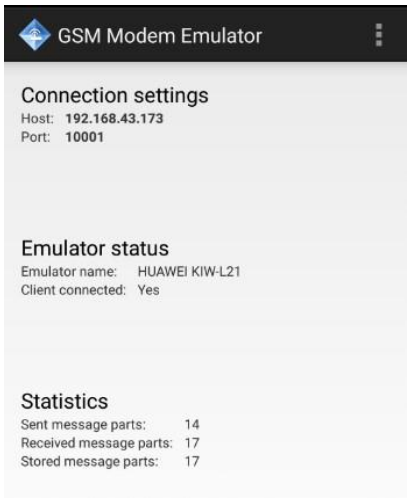

Figure 19: GSM Modem Emulator application home screen.

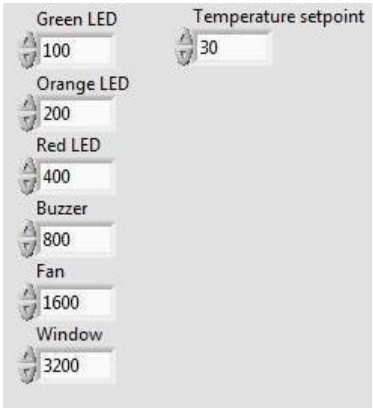

Figure 20: Numeric control buttons.

B. Performance Evaluation

The performance of the project after testing through these points is summarized as follows:

- Respond very well to gas concentration and temperature degree.
- The present a cost effective and speedy solution to protect from gas leak repercussions by lowering the factors leading to make human life in risk.
- Doesn't respond to any strange gases that are not specified for it.
- The speed of the Fan and the Motor will be degraded if the voltage decreased which reduce the efficiency of the device.

C. Relevance to Poor Countries and Societies

In the third world countries no awareness about the danger of hazardous gases. Many countries that use stoves work on fuel and the LPG for warming the houses during winter. These stoves produce gases which considered as a threat. These gases effect on environment and health of human living. So, creation of hazardous gas detector will make those countries safe from those threats.

Here are some environmental threats could be solved by the hazardous gas detector [21]:

1. Explosion Protection: in presence of hazardous situations or the presence of combustible gases, a smart detection method is crucial to present and be reliable.
2. Sniffing-out Gases protection: Flammable gases and vapors may rise to reach hazardous concentrations in air, and in turn causing insufficient oxygen, and hence results in a threatening on human life's. Hence, a reliable smart system similar to the proposed one that can detect to a numerous of gases, measure their concentration in the surrounding air is crucial. A refugee camping environment is a typical targets of such low cost smart systems

IV. CONCLUSION AND FUTURE WORK

Gas leakage is one of the major threats that exist in every home; it may cause suffocation or even dangerous fires that could lead to huge injuries or lots of losses and damage. From this point we can see how much the importance of existence of a device that can detect the gas leakage and act at the same time. In this paper, a low cost smart gas leakage detection scheme has been successfully proposed, and implemented targeting a considerable safety in homes and industrial environments and applications. It can detect the leakage of the gas and alarms the customer concerning the threat of leak in question.

The device has been designed to detect 6 stages of LPG concentration in surrounding air and to detect the temperature degree as well. The measurements are then appearing on GUI

screen that manipulated by the LabVIEW program then accordingly take appropriate action related to detected level. The proposed Gas Detecting device depends on two sensors, the first one is MQ2 which can detect the LPG concentration, the second is LM35 that detect the temperature degree in the surrounding air, both of them is connected to an Arduino, they send the signal through the wires to it, then the Arduino is responsible to make a decision based on that readings. It has been proved that the presented smart system was able detect and act appropriately.

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