

A Sophisticated Location-based LPG Gas Leakage Detection System with Smart Control and Security

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Abstract

Liquefied Petroleum Gas or LPG is one the important non-renewable fuel in our daily life. LPG is a volatile hydrocarbon gas production from refineries and gas refinery with the major components of propane gas (C_3H_8) and butane (C_4H_{10}). As the LPG gas is heavier than the air, the effects of accidental fires, gas leakage and explosion can occur in an uncertain period. In the most traditional gas supply system for an apartment building or other type of collective housing area, there are cases in which a number of bank cylinders are arranged in a single location and the LP gas is supplied through main gas lines from this single location to each house hold. So, there are high chances of irregular monitoring and dangerous accidents can occur from leakage of LPG or from gas distribution system. There are many possibilities of leakage. To check a specific part regularly is very time consuming. One of the preventive and very though method to stop accident associated with the gas leakage is to install electronic leakage detector at vulnerable places where more possibilities of leakage may occur. Moreover, the inspection for gas leakage must be performed over the entire field and thus save considerable time and effort, so this is a major burden on the LPG gas Supplier or natural gas utility. In light of these problems, the object of the present invention is to provide a location-based and SMS alert based gas leakage detection System that can perform gas detection more easily and reliably. In our proposed gas leakage detection system, it may be used for house hold application with the IOT applications as well as outdoor Gas distribution centre for leakage detection in a specific area.

Keywords: Liquefied petroleum gas • Microcontroller • Global positioning system

Introduction

LPG gas is in the tube in a liquid state and partly intangible steam. For changing the liquid states, the ratio between fresh air and the volume of LP gas varies depending upon the composition, pressure and temperature. The capacity of the gas can be transformed into liquid and it is an excess of material that is gas volume can be reduced. Excess part is applied mainly to store and deliver gas in the tank, which in this way is economically very profitable. So, if there is a mixture of gas and air in the range from bottom to top value, there will be a fire or explosion.

For this issue an advanced control leakage detector is necessary to predetermine the leakage and real time information sharing to its user or for control room of a plant. In case of outdoor application there is a greater number of sub supply valve can be installed. We can define geo stationary latitude and longitude along with the gas concentration for transmitting the information to control centre.

Materials and Methods

Effects of leakage of LPG gas

The explosive limit may be lower concentration of fuel vapour in the air where if no source of fire, the gas will be burned. For upper explosion limit

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when the maximum concentrations of fuel vapour in the air and there is no source of fire, the gas will burn. Flammable Range for propane is between 2.4% to 9.6%, while for butane it is between 1.9% to 8.6%. This means that for example, when a mixture of propane is 2.4% with 97.6% air, then the mixture will be lit, but the amount of propane gas is with minimal amount. If the amount is less than 2.4% propane, the flame will not occur. It will be vice versa, if the amount is more than 9.6% propane and will not turn on, even though there are sources of ignition. At the time of bursting, oxygen in the area will be used so that if there are people in the surrounding area, got burnt and they will also face breathing problem.

If inhaled, it can displace air, deprive their lungs from oxygen and cause hypoxia leading to suffocation. The gas can also affect their brain and nervous system, difficulty in walking or speaking, dizziness, hallucinations, lack of coordination, nausea and loss of consciousness. Repeated exposure may cause mood swings, depression, seizures, brain haemorrhage and impaired memory. It may also damage heart by causing irregular heart beat and high blood pressure. The explosion may also cause injury from fragments and other objects propelled in air [1].

Air quality impact for gas leakage

Explosion and Leakage from LPG may also seriously impact quality of air. Air Quality Index is used for reporting daily air quality. The AQI focuses on health effects that we may experience within a few hours or days after breathing polluted air. When LPG leakage occurs then environment gets affected by Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Formaldehyde (HCHO). If the leakage takes place then surrounding environment and air will be affected by propane and butane properties. Due to excessive emission of the propane and butane anyone may get affected because of lesser oxygen concentration. This is very important factor if we detect air quality index along with lpg gas distribution line, then the leakage detection will be perfect and more reliable.

Control and protection scheme of reticulated gas distribution system

Figure 1 shows the reticulated LPG gas distribution system. It is a centralized piped gas system, which is a way to deliver cooking gas through a network of pipelines that are connected to the main gas cylinder storage

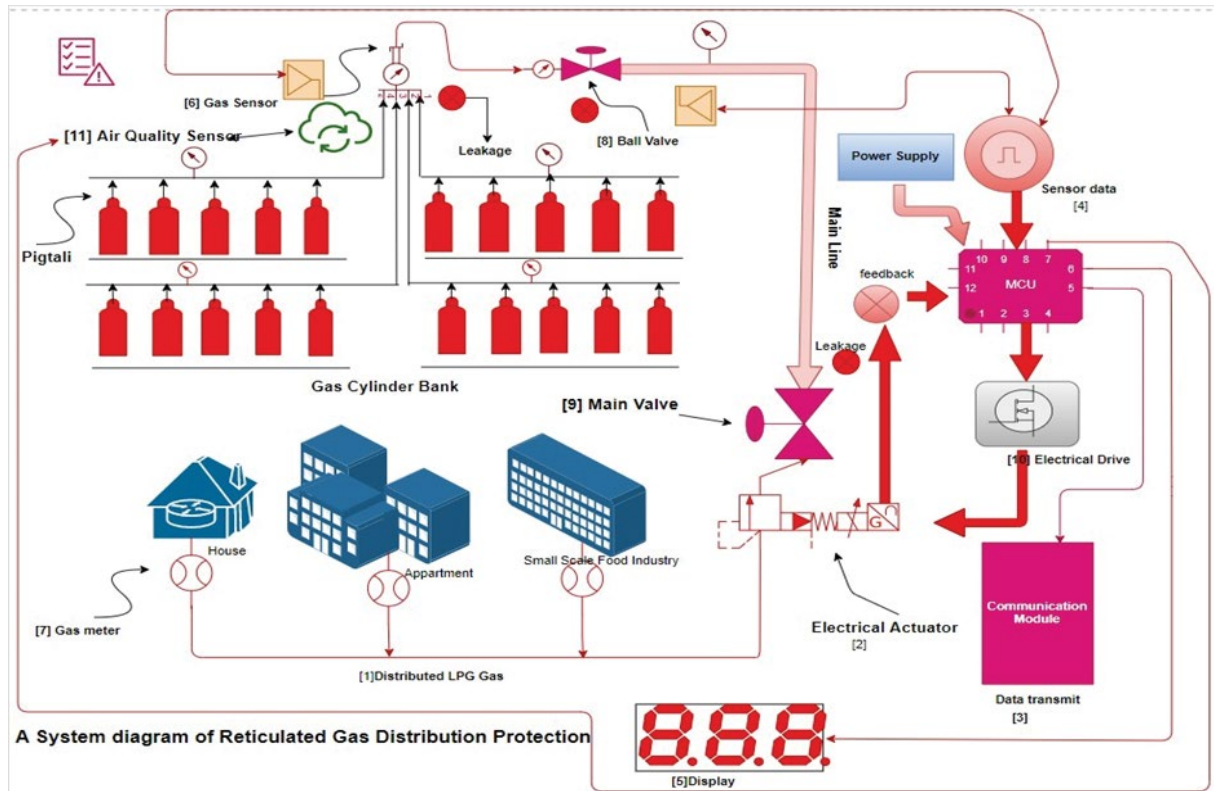


Figure 1. Control and protection scheme of reticulated gas distribution system.

system. The design of this protection scheme works accurately 200 ppm up to 10000 ppm (Parts-per million). The cylinders bank is arranged in such a way that if one small leakage happens then the total system will be affected. There are high possibilities of occurring leakage in main connection valve because of all gas cylinders are connected with a specific pressure and the main ball valve carry the high pressure of the distributive network.

The absence of efficient transmission and distribution pipeline network system may be responsible for loss of natural energy and fault may occur in any situation. Our modular gas leakage detectors are suitable and will be efficiently used for reticulated or in-house gas distribution systems. The system is employed with the embedded sensor networks and electro-technical controlled actuator signal generation during fault time with integrated wireless data communication protocol. The on-board microcontroller is associated to generate control signal during fault detection by MQ gas sensors and air quality sensors. For monitoring the real time status of the in-house distribution system, user can use cloud based api where all data will be appeared graphically to plot in the applets. If suddenly any leakage happens then the MQ sensor and air quality sensor will be modifying their internal resistance and the voltage will be appeared in analog to digital conversion by using analog read pin of microcontroller. The microcontroller (MCU) will generate pulse width signal that will drive the electro-technical actuator which will close the connection immediately. The EMA is involved with the main pressure valve and alternative distribution valves. With the transient moment, the communication module will send a Voice call/SMS alert to the consumers. The cycles are continued until the system remains under a safe zone. The design consideration should be accurate so that all power electronics and sensor products should be calibrated before installation of the system.

Results

Block diagram of gas leakage detector

Figure 2 shows the block diagram of overall LPG gas leakage system where number of systems has been integrated and each of the block played important role for the system. We have used ideal gas sensor as Grove MQ3 [2]. The Grove - Gas Sensor (MQ3) module is useful for gas leakage

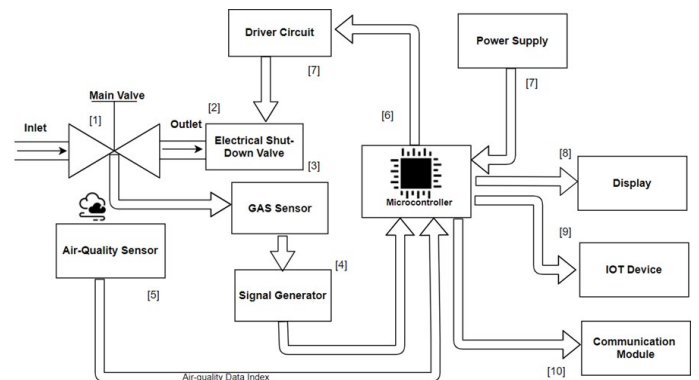


Figure 2. Block diagram of gas leakage detector.

detection (in home and industry). It is suitable for detecting Alcohol, Benzene, CH_4 , Hexane, LPG, CO. Due to its high sensitivity and fast response time; measurement can be taken as soon as possible. The sensitivity of the sensor can be adjusted by using the potentiometer.

Sensitivity Characteristics of MQ3 is shown in Figure 3. Resistance value of MQ-3 is different in various aspect and various concentration gases. So, when using this component, sensitivity adjustment is very necessary. The Grove-MQ3 Gas Sensor is shown in Figure 4. According to MQ3 recommendation that we should calibrate the detector for approximately 200ppm of alcohol concentration in air and use load resistance chart (RL) about 200 $K\Omega$ (100 $K\Omega$ to 470 $K\Omega$). For accurate measurement, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence [3].

The concentration of a gas is in part per million (ppm) according to the resistance ratio of the sensor ($RS/R0$). RS is the resistance of the sensor that changes depending on the concentration of gas. R0 is the resistance of the sensor at a known concentration without the presence of other gases, or in the fresh air.

If we consider, the equivalent circuit where RL and RS are equivalent series resistances than, $(RL+RS)$,

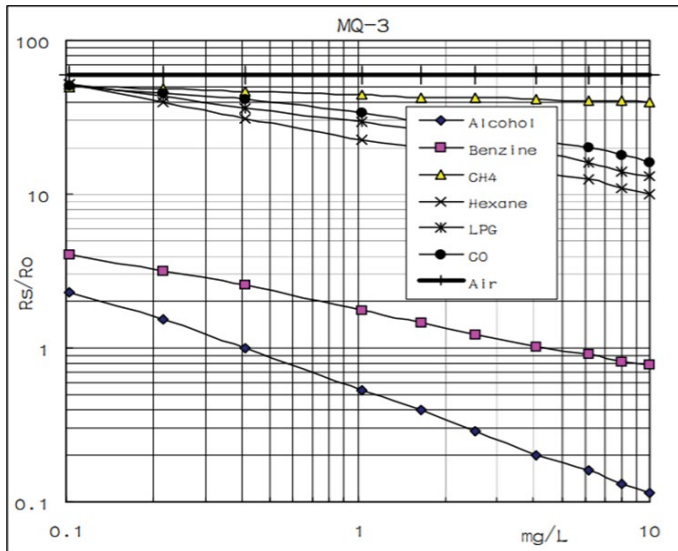


Figure 3. Sensitivity characteristics of MQ3.

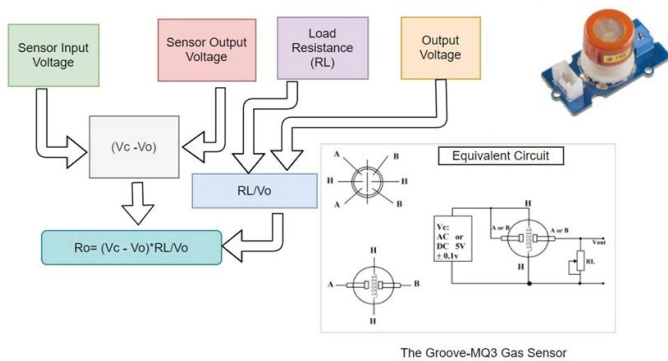


Figure 4. The Groove-MQ3 gas sensor.

From Ohm's Law, we can derive I as follows:

$$I = V/R$$

$$V = I \times R$$

$$VRL = [VC/(RS + RL)] \times RL$$

$$VRL = (VC \times RL)/(RS + RL)$$

So now we solve for RS:

$$VRL \times (RS + RL) = VC \times RL$$

$$(VRL \times RS) + (VRL \times RL) = VC \times RL$$

$$(VRL \times RS) = (VC \times RL) - (VRL \times RL)$$

$$RS = [(VC \times RL) - (VRL \times RL)] / VRL$$

$$RS = [(VC \times RL) / VRL] - RL$$

To calculate Ro, we need to find the value of the RS in fresh air. This will be done by taking the analog average readings from the sensor and converting it to voltage. Then we will use the RS formula to find Ro.

We also derived, $Ro = (Vs - Vo) \times RL / Vo$. So, we can able to calculate the ppm in the LPG Gas Leakage. The following algorithms for Converting Sensor Output to Voltage

$$Ro = 4.04 \text{ ohm for fresh air.}$$

$SenVoltage = Gas_ref / 1023$ // To Convert analog Voltage reference for Microcontroller (10bit)

$$SenVoltage = SenVoltage \times 4.84$$

Variable 1 = 4, 84-SenVoltage

Variable 2 = Variable1/SenVoltage

$Rs = Variable2 \times 20000$

$D = Rs / Ro // \text{Ratio for } Rs / Ro$

Data from Data Sheet Graphic is shown in Figure 5.

[Note: -The designed consideration must be concerned the stable DC Power Supply to the Main Microcontroller and Input Voltage of the GAS sensor, Air quality sensor and others wireless communication module].

System and control diagram of outdoor gas leakage detection

System and Control Diagram of Outdoor Gas Leakage Detection is shown in Figure 6. Most of the reticulated LP gas distribution systems are available remotely and maintain in house operation. The major areas are not protected where the specific location is not remotely monitored by human. The types of areas are very inhospitable where LPG supplier team won't monitor the condition of gas distribution. These types of areas where electronics protection has not taken by suppliers are called unprotected zones. The major impacts

No	Data from Data Sheet Graphic		Percent(%) LPG
	PPM	Rs / Ro	
1	200	2	0.02
2	300	1.8	0.03
3	400	1.6	0.04
4	500	1.5	0.05
5	600	1.4	0.06
6	700	1.3	0.07
7	800	1.2	0.08
8	900	1.1	0.09
9	1000	1	0.1
10	2000	0.75	0.2
11	3000	0.65	0.3
12	4000	0.56	0.4
13	5000	0.50	0.5
14	6000	0.48	0.6
15	7000	0.45	0.7
16	8000	0.43	0.8
17	9000	0.40	0.9
18	10000	0.30	1.0

Source: Primary Data, 2016

Figure 5. Data from data sheet graphic.

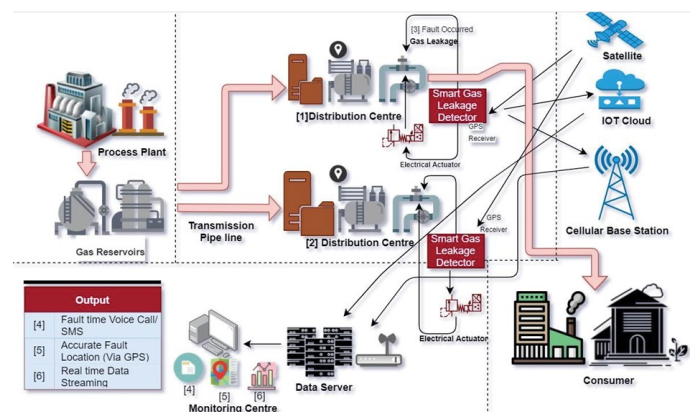


Figure 6. System and control diagram of outdoor gas leakage detection.

are always arising with the mechanical valves or joints where continue routine check-up has not been done. Our proposed model is assuring to check fault condition electronically when LPG is leaked. We have included Global Positioning System (GPS) with each gas detection module which is playing crucial role to identify which areas are protected. All real time information will be sent via wireless module to nearest data centre. If any fault or disturbance occurs then all electronics actuators will be activated as well as can send alert information to the consumer for identifies the faults.

There are separately used communication modules. If the control of data centre is nearer to the distribution centre then the radio frequency wireless transceiver can be set up for communication. For smart notification if internet connectivity is available then the location can be shifted using IOT module and GSM module for Voice Call/SMS automatically [4]. Another model is designed with electronic actuator which is having very high power using power electronics converters for high frequency switching of the actuators. We have used NEO 6 m ublox GPS module during fault conditions to locate latitude and longitude transmission of the users.

The location will appear through the Google map or any others maps applications. The Neo 6 GPS receiver module that can track up to 22 satellites and identifies locations anywhere in the world [5].

GPS receivers are actually work by figuring out how far they are from a number of satellites as shown in Figure 7. The satellites send information about their position and current time in the forms of radio signals towards the earth. The signal identification is done by GPS receivers and serially records their information with the help of serial communication of the microcontroller. The receiver then calculates how far away each satellite is by figuring out how long it looks for the signals to arrive on time. For better location identification minimum three satellites are very important and this process is called Trilateration Process. An antenna is required to use the module for any kind of communication. So, the module comes with patch antenna having-161 dBm sensitivity. The data we get over a serial interface are actually NMEA sentences [6].

NMEA is an acronym for the National Marine Electronic association. This is a standard message format for nearly all GPS receivers. The NMEA sentences always carry all necessary information. The format of NMEA is basically Degree Decimal format. Example-\$GPRMC, 123519, A, 4807.038, N, 01131.000, E, 022.4, 084.4, 240321, 003.1, W*6A (Table 1).

These NMEA sentences are carrying all necessary information but while opening our Google map application the sentences will not work directly. For this notation we need to extract Deg. Decimal to Deg. Min. Sec. Conversion as shown in Figure 8. The Deg. Min. Sec conversions always occur inside microcontroller programming. The format is given below to get location information for specific area when any fault occurs.

Latitude and longitude of fault location

In the proposed LPG Gas leakage detector, the SIM800L V2 logic has been used for the voice call and location detection SMS to the end user. To operate the SIM800L module we need the constant 3.3 Volt 2-amp power supply which are specially designed in this model [7].

TL431 reference voltage generator for GSM module

The SIM800L is a modular cellular module that allows for GPRS transmission, sending and receiving SMS, and making and receiving voice calls. This module is low cost and small size and quad-band frequency supports make this module as perfect solution for any security project that requires long-range connectivity. The module comes with integrated PCB with an antenna but the problem is to connect network if the proper supply not maintained to this module. We have tested our TL431 reference 3.3 volt for this module. It gives constant supply and when the network is connected with the module a bulk burst current drawn from the power source.

TL431 reference formula – $2.5 * (1+R1/R2)$

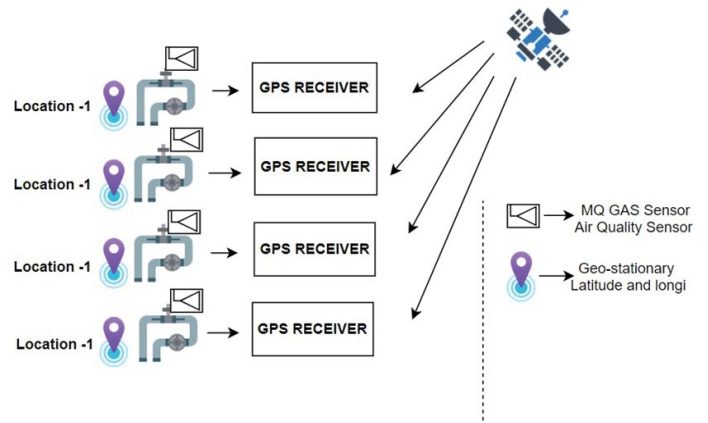


Figure 7. GPS receivers.

Table1. The format of NMEA.

NMEA	
\$	Every NMEA sentence starts with \$ character.
GPRMC	Global Positioning Recommended Minimum Coordinates
123519	Current time in UTC-12:35:19
A	Status A=active or V=Void.
4807.038, N	Latitude 48 deg 07.038' N
01131.000, E	Longitude 11 deg 31.000' E
022.4	Speed over the ground in knots
084.4	Track angle in degrees True
240321	Current Date-22 nd of March 2021
003.1,W	Magnetic Variation
*6A	The checksum data, always begins with *

To convert from decimal degrees to DMS

$$578.5046^{\circ}$$

$$578^{\circ} + .5046^{\circ} * \frac{60'}{1^{\circ}}$$

$$578^{\circ} + 30.276'$$

$$578^{\circ} + 30' + .276' * \frac{60''}{1'}$$

$578^{\circ} 30' 17''$

Figure 8. The Deg. Min. Sec conversion.

Or

$2.5 * (1+1000 \text{ ohm}/1000 \text{ ohm})$ Or 3.5 Volt

For reducing the further voltage level, we have connected 500 ohm series resistance.

To use the TL431 reference generator, the SIM800L module will be able to connect GPRS and cellular connectivity and during leakage condition SIM800L will be able to send voice call and SMS to the end user as shown in Figures 9 and 10.

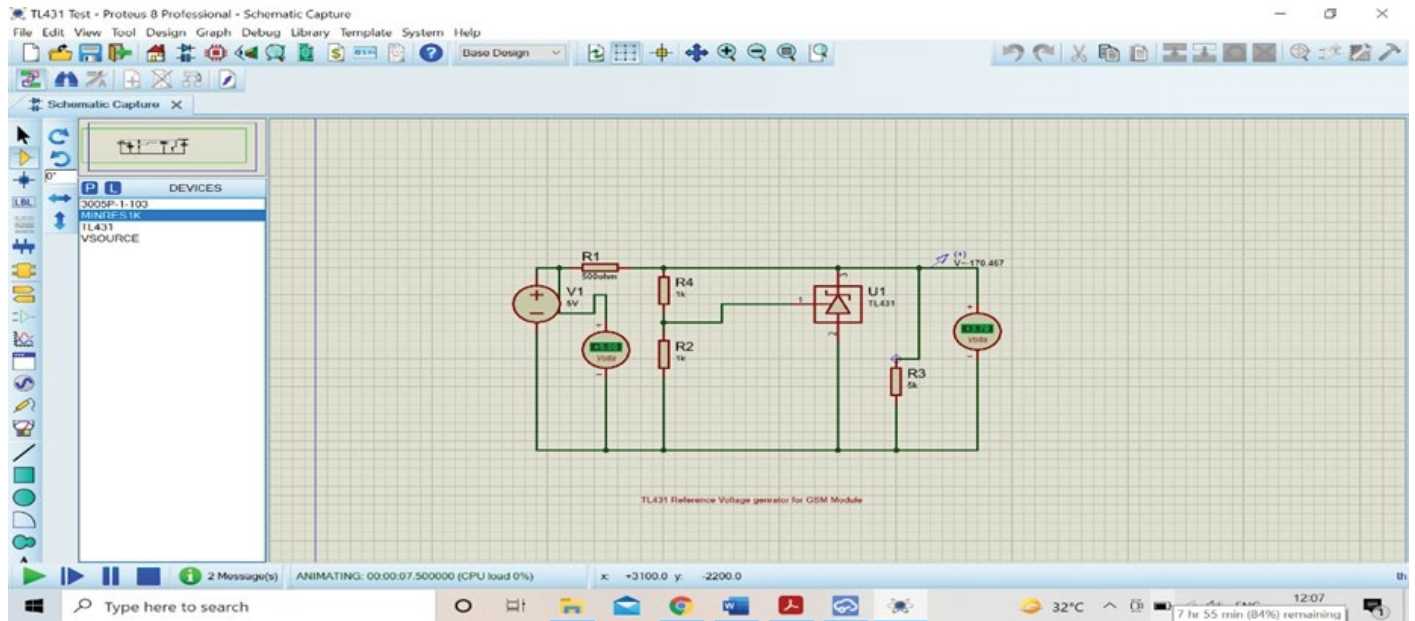


Figure 9. Proteus software simulation.

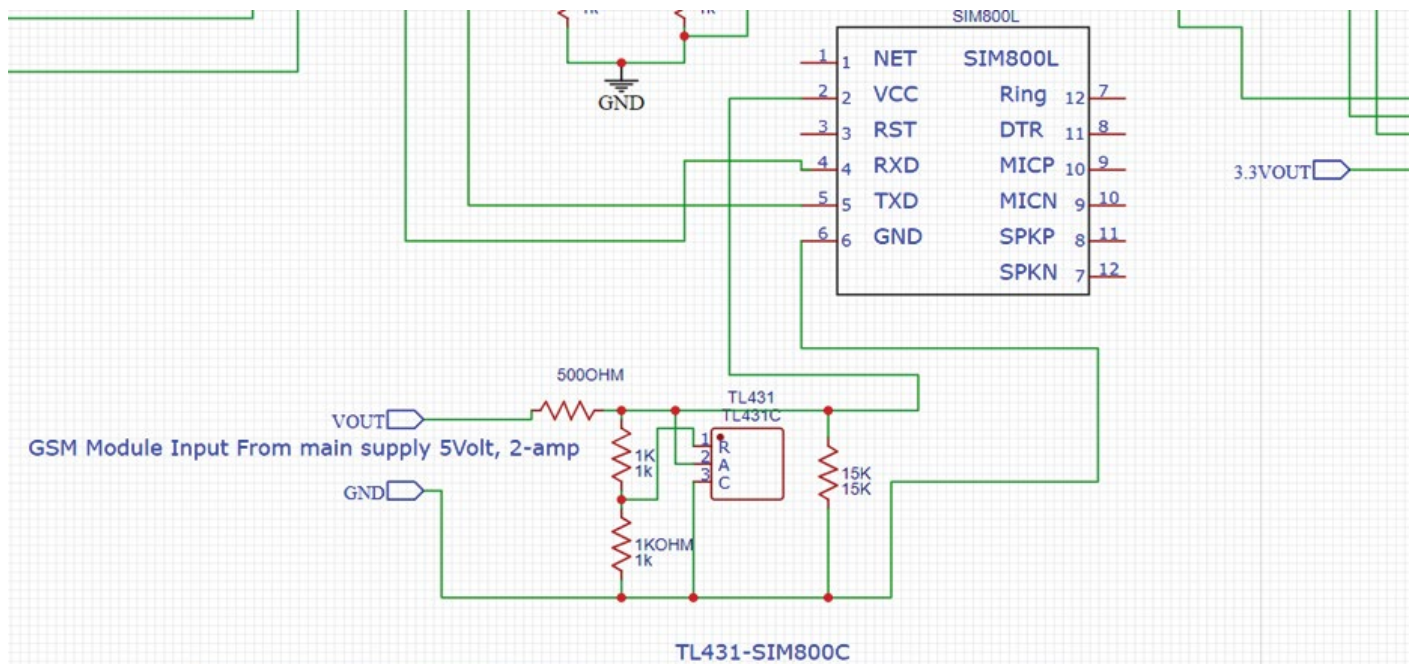


Figure 10. Connection of TL431 with Sim800L GSM module.

Discussion

Connection of internet of things

Block Diagram of Internet of Things Connection with LPG Detector is shown in Figure 11. The LPG Gas leakage detector may be utilised for indoor house hold application where internet is available. In our proposed model we have added the IOT Mode MCU esp8266 module for connecting with the internet. These features are additional if users wish to use internet of things for checking the real-time information of the LPG leakage and air quality of the system. For IOT cloud we can use blynk free IOT cloud or ThingSpeck by Math Works as shown in Figure 12. ThingSpeck provide instant visualization of data posted by our devices to ThingSpeck. With the ability to execute MATLAB® code in ThingSpeck you can perform online analysis and processing of the data as it comes in. ThingSpeck is often used for prototyping and proof of IoT concept based systems that require analytics. We have used Atmel AVR ATmega328pu 8 bit microcontroller for our proposed model. In the

ATmega328pu microcontroller structures, one serial communication pin is available consequently. In the mode mcu there are serial communications which is connected with the microcontroller serial communication. When internet connection is available in the mode mcu the mode data are transferred to the wireless cloud. The user can access all information and alert message using the cloud account. Different types of applets can be decorated for live streaming of the data flow [8].

Bootloader designed for on-board microcontroller

Bootloader Designed for On-board microcontroller is shown in Figure 13. A Bootloader is a program and hardware that allows loading other programs via a more convenient interface like a standard USB cable. When we power-up or reset our microcontroller board, the bootloader checks to see if there is an upload request. If there is, it will upload the new program and burn it into Flash memory. As we have used Atmel AVR Series microcontroller in our detection system, we also included a program bootloader for re- programme the main system. The bootloader allows the USB to Transistor Logic (TTL) and upload

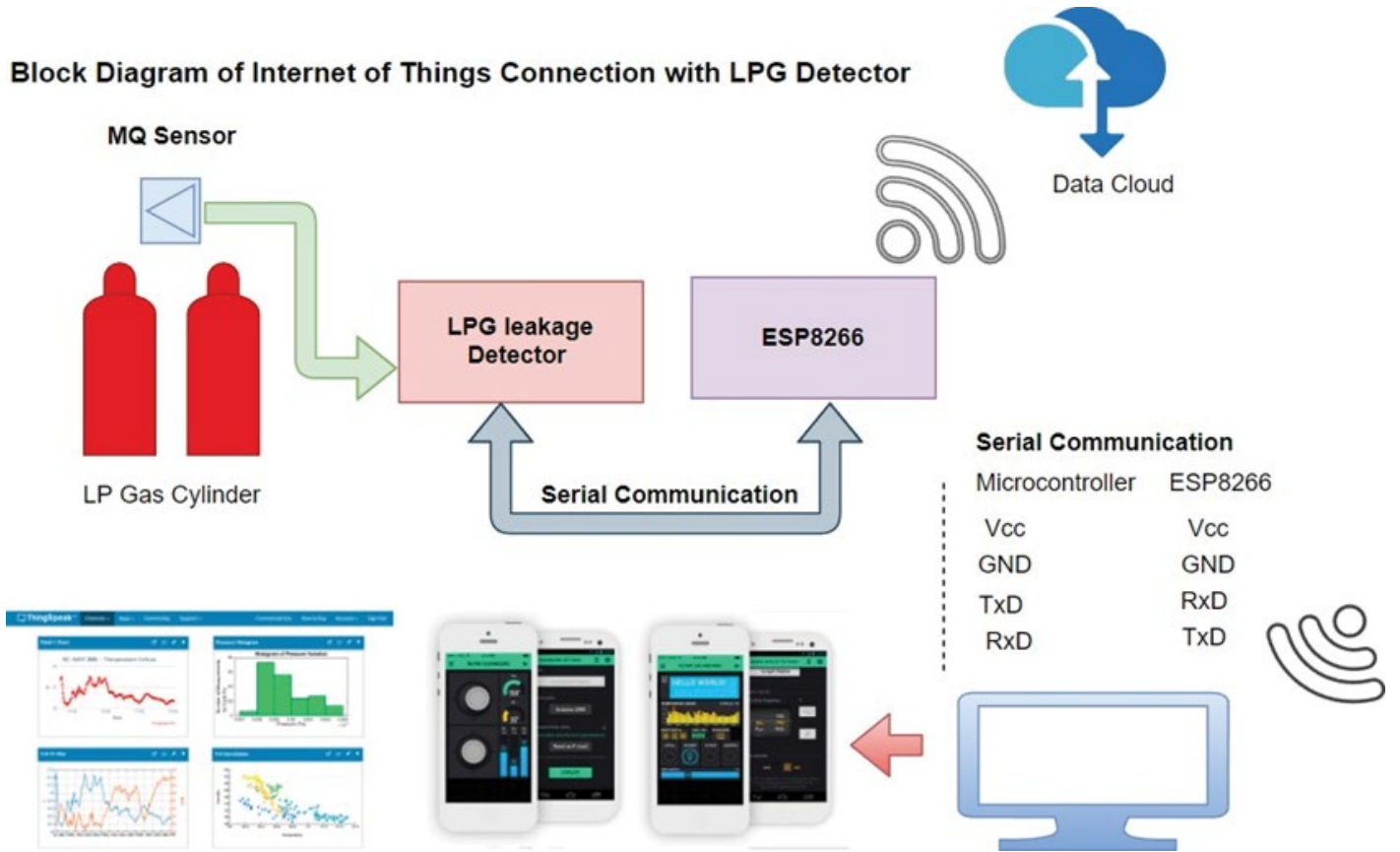


Figure 11. Block diagram of internet of things connection with LPG detector.



Figure 12. Air quality index using Blynk cloud platform.

necessary program to the main microcontroller. In our system we have used FTDI chip and additional circuit for uploading the program to our system. The design is placed to the main pcb board.

The FTDI chip works on 5 volt and 3.3-volt power supply that we arrange from main microcontroller power conversion circuit. An additional driver (FTDI semiconductor) USB to UART should be installed and select the appropriate

COM port during the uploading program to the microcontroller [9]. DTR pin of the FTDI chip should be connected with the reset pin of the microcontroller. For Clock generation we have used RC resonator that maintains the system clock. Another additional 16 MHz crystal oscillator is connected to the microcontroller and for protection from internal disturbance and noise we have route a brown-out reset system of the main microcontroller.

Switched mode DC DC Buck converter design

Switched-mode DC/DC converter is power electronic regulator that supply DC loads with a regulated output voltage, and provide protection against over current and short circuits [10]. Switching DC/DC converter is a circuit uses a power electronic mosfet, an inductor for energy storing, a diode and a capacitor to transfer the energy from the input to the output. These can be arranged in a variety of ways to realize the buck, boost, or buck-boost. In our model, we opted for Buck mode. The Main supply from AC220 volt, 50 Hz to 12 Volt DC SMPS converter, and the 12 Volt DC supply fed to switch mode dc buck converter. In many conventional electronics security products, the linear voltage regulator is used in the system for the purpose of very low cost for products. The switch-mode power electronics dc converters are reliable and have less output ripple and EMI filtered and less heating compared with linear voltage regulators [11]. The Block Diagram of Power Conversion for LPG Gas

Leakage Detector is shown in Figure 14.

The design of Switched mode DC Buck converter is a power electronics integrator and used in the schematic that it produces 180 KHz switching operation and continuous conduction mode [12]. The LM2596 of Texas Instruments chip we have used for switching operation and the additional inductors and capacitors are used using the following formula-

We are figured out for fixed regulated 05 Volt dc output voltage.

Where,

$$V_{in} = 12 \text{ Volt Dc}$$

$$\text{Switching frequency } F_s = 180 \text{ KHz Duty cycle } D = 42\%$$

$$\text{The Average Output Voltage } V_o = V_{in} * D = 12 * 0.42 = 5.04 \text{ Volt dc}$$

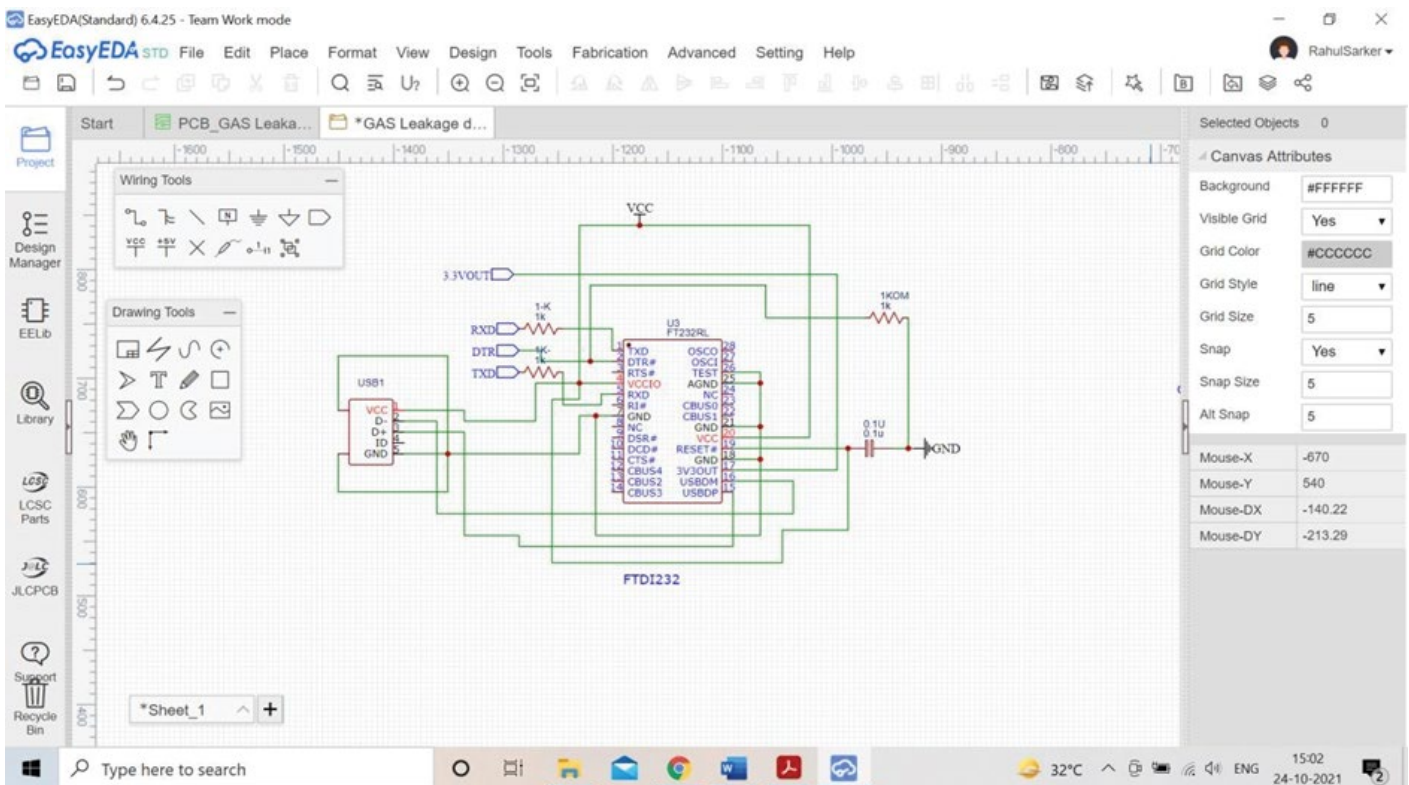


Figure 13. Bootloader designed for on-board microcontroller.

Block Diagram of Power Conversion for LPG Gas Leakage Detector

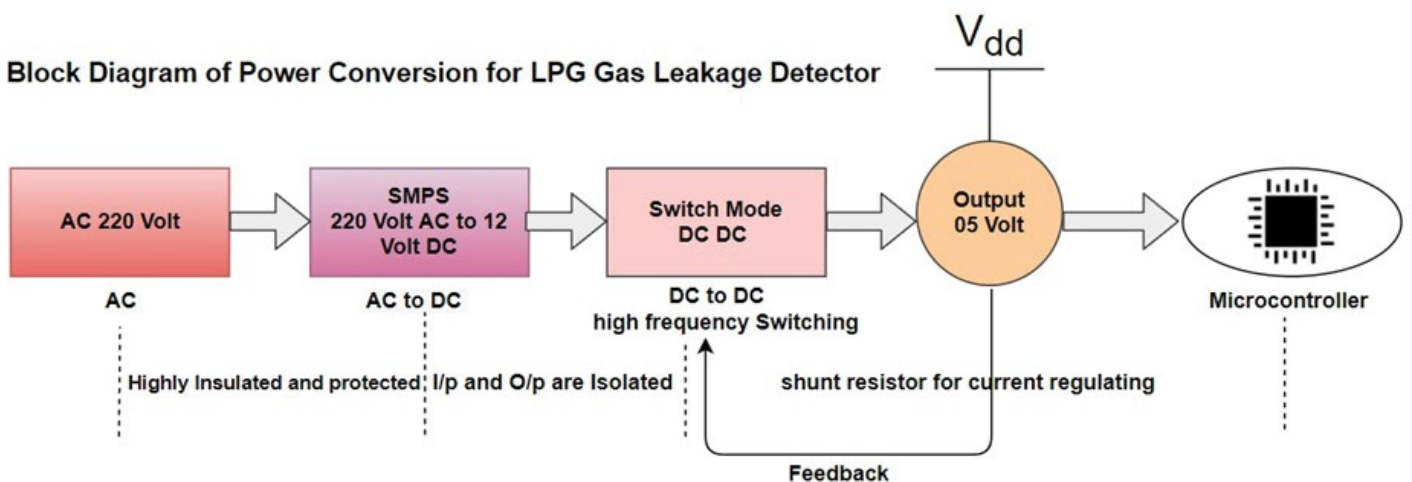


Figure 14. The Block diagram of power conversion for LPG Gas leakage detector

Inductor Current $I_L = I_R = V_o/R$ and continuous current is always considered minimum current of the inductor whereas,

$$I_{min} = (1-D) I_R/2f$$

Output ripple can be formulated, $I_c = I_L - I_R$

$\Delta Q = T_s * \Delta I_L / 8C // \Delta I_L$ is the bounded inductor current and C is the Value of Capacitor.

Proteus simulation model

Proteus Simulation Model is shown in Figure 15. In this simulation model,

we have found the DC average output voltage using simple switching power Electronics MOSFET and we have found the value of inductor that can be operated with maximum 3A current. For the freewheeling path, we have introduced a Schottky diode for protecting the maximum amount of reverse current saturation. The switched-mode dc converter is non-feedback based and asynchronous. For better results, we have used an LM2596 power integrator which is offering hysteresis current loop controlled or feedback output voltage [13]. If sudden unwanted current flows through the mainboard when all electronics modules are activated then feedback loop allows the flow of current and allotment of the maximum current is 3A. The LM2596 Schematic

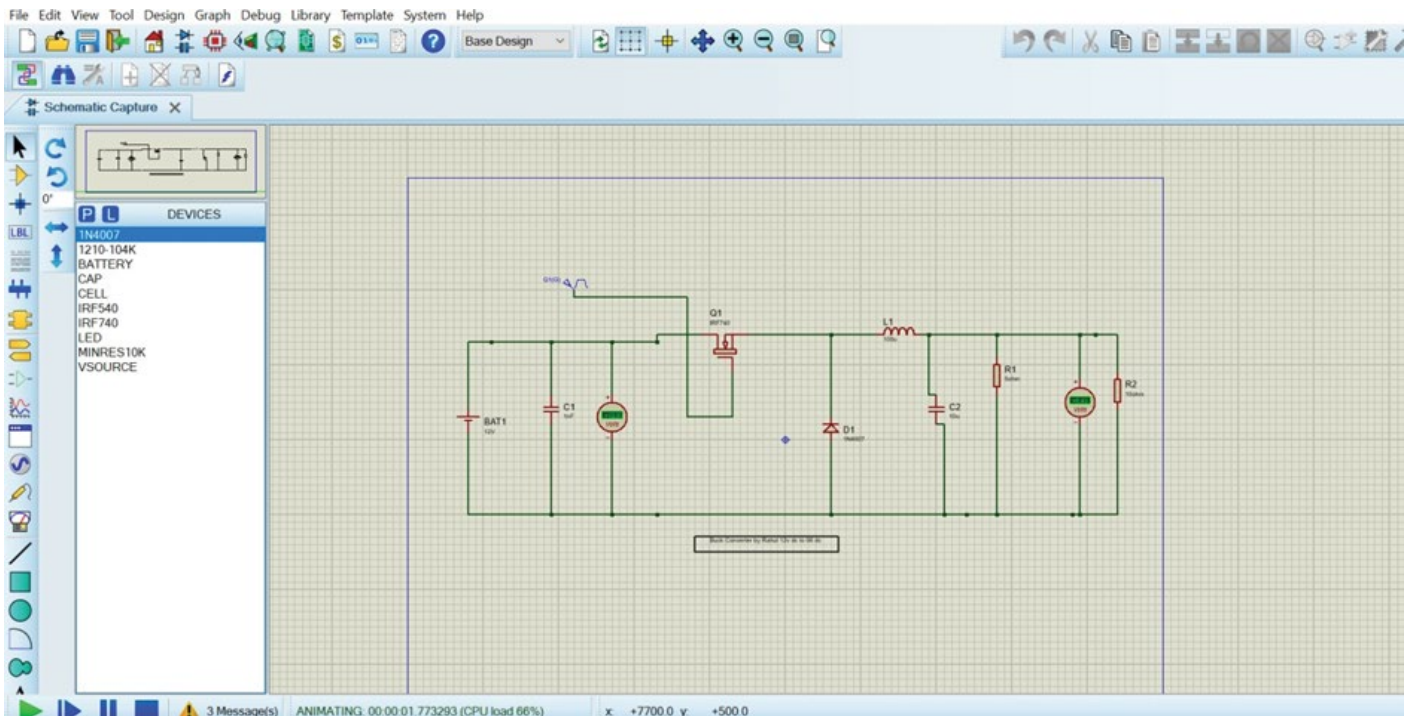


Figure 15. Proteus simulation model.

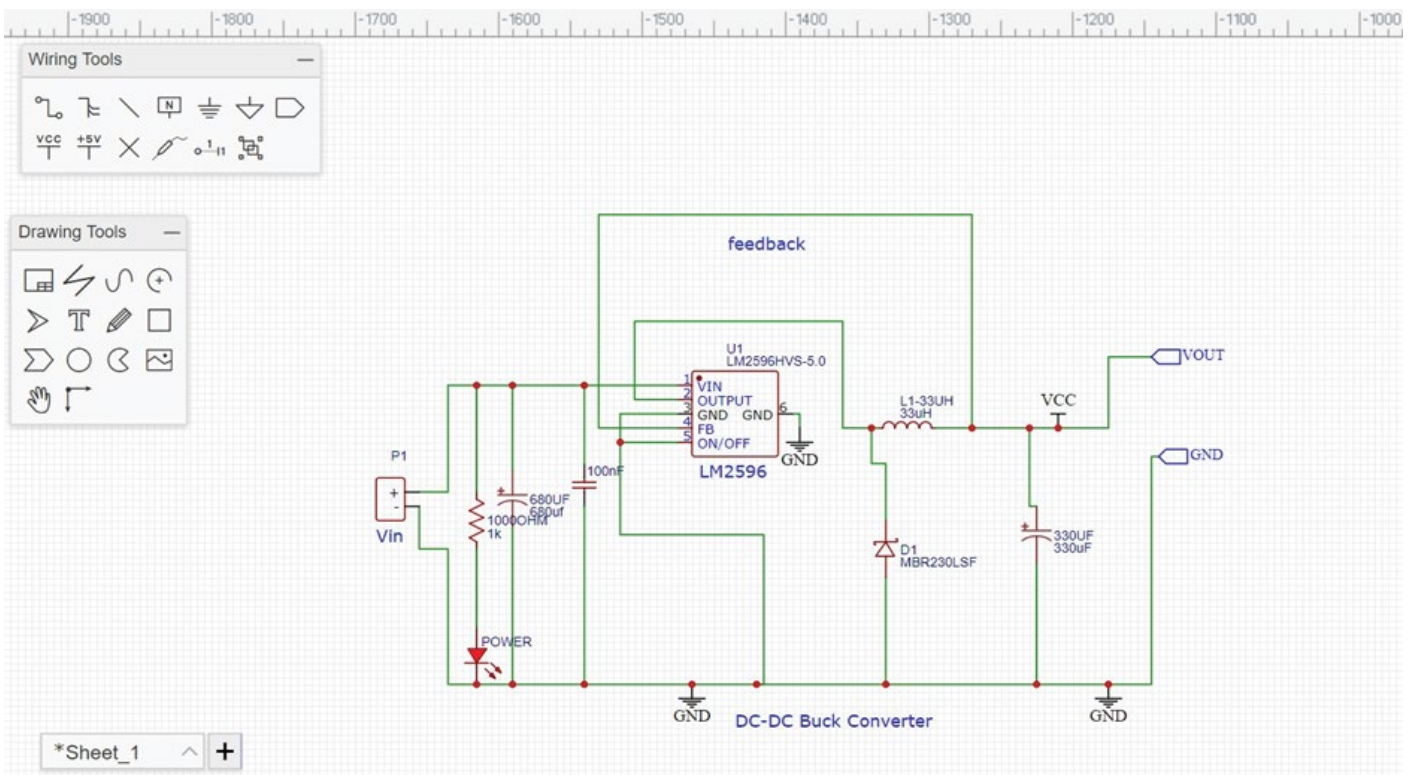


Figure 16. The LM2596 schematic diagram.

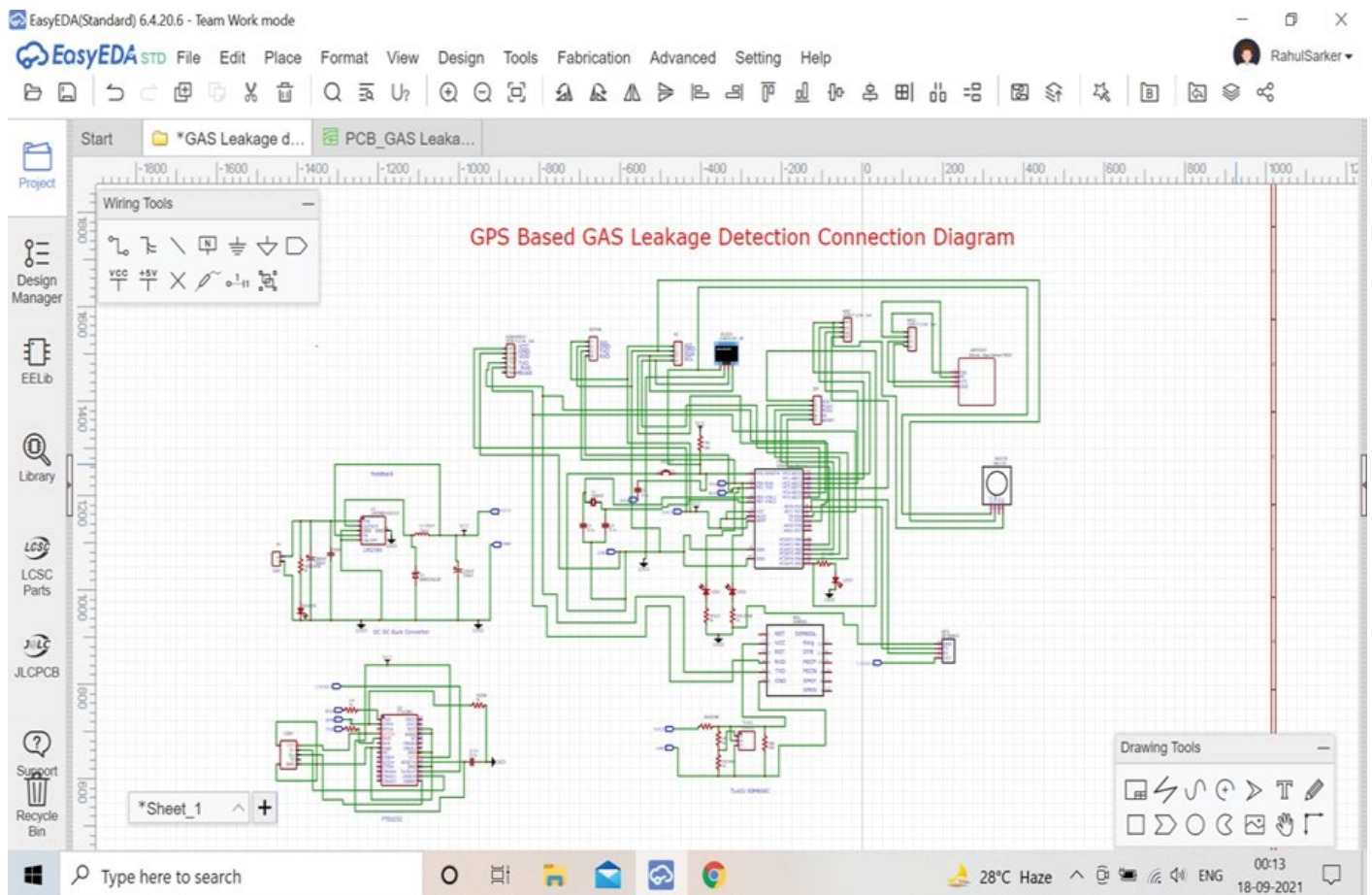


Figure 17. The Schematic and wiring diagram of location based LPG gas leakage detector.

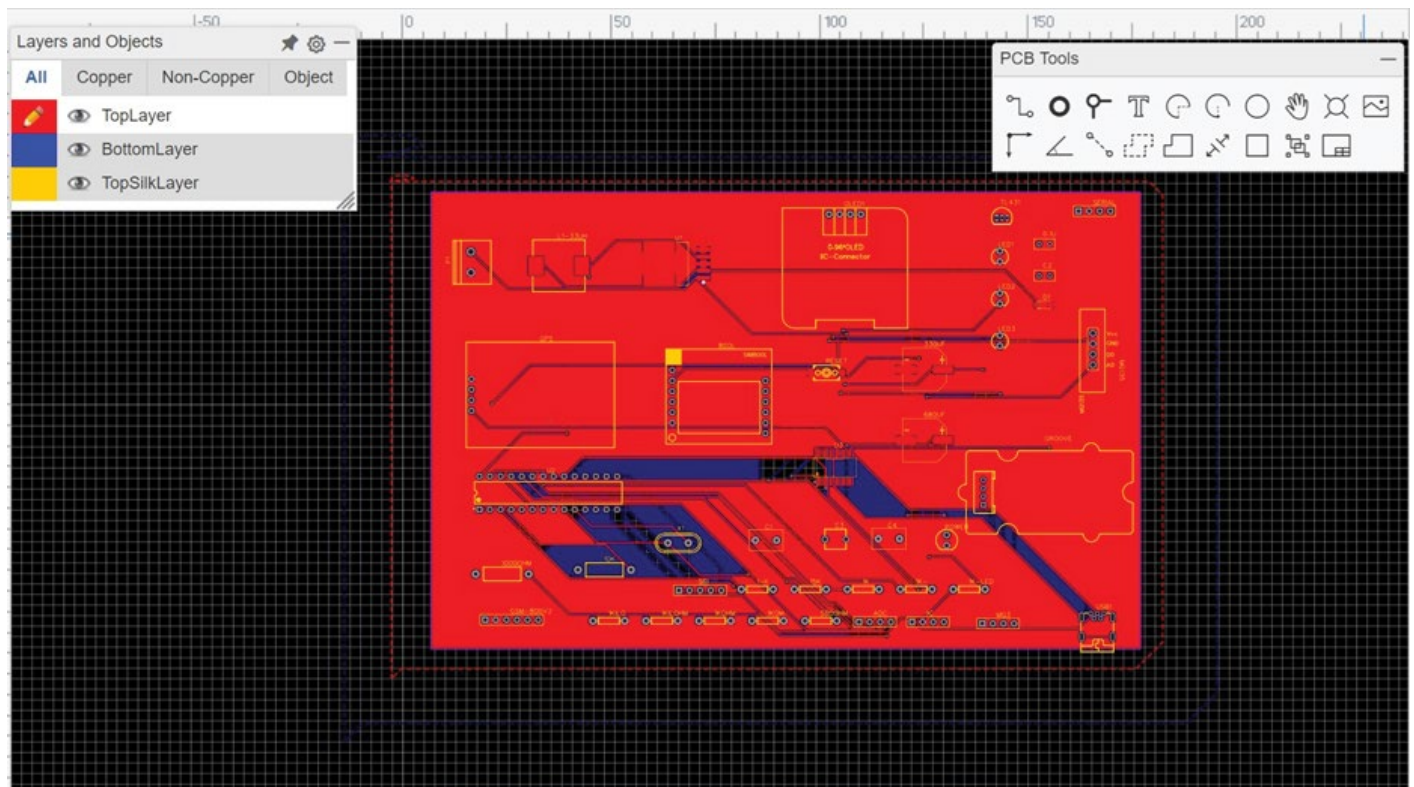


Figure 18. Printed circuit of location based LPG gas leakage detector.

has been shown in Figure 16. The Schematic and wiring Diagram of Location Based LPG Gas Leakage Detector is shown in Figure 17. Printed Circuit of

Location Based LPG Gas Leakage Detector is shown in Figure 18. 3D PCB Model of the LPG GAS Leakage Detector is shown in Figure 19. Hardware Model is shown in Figure 20.

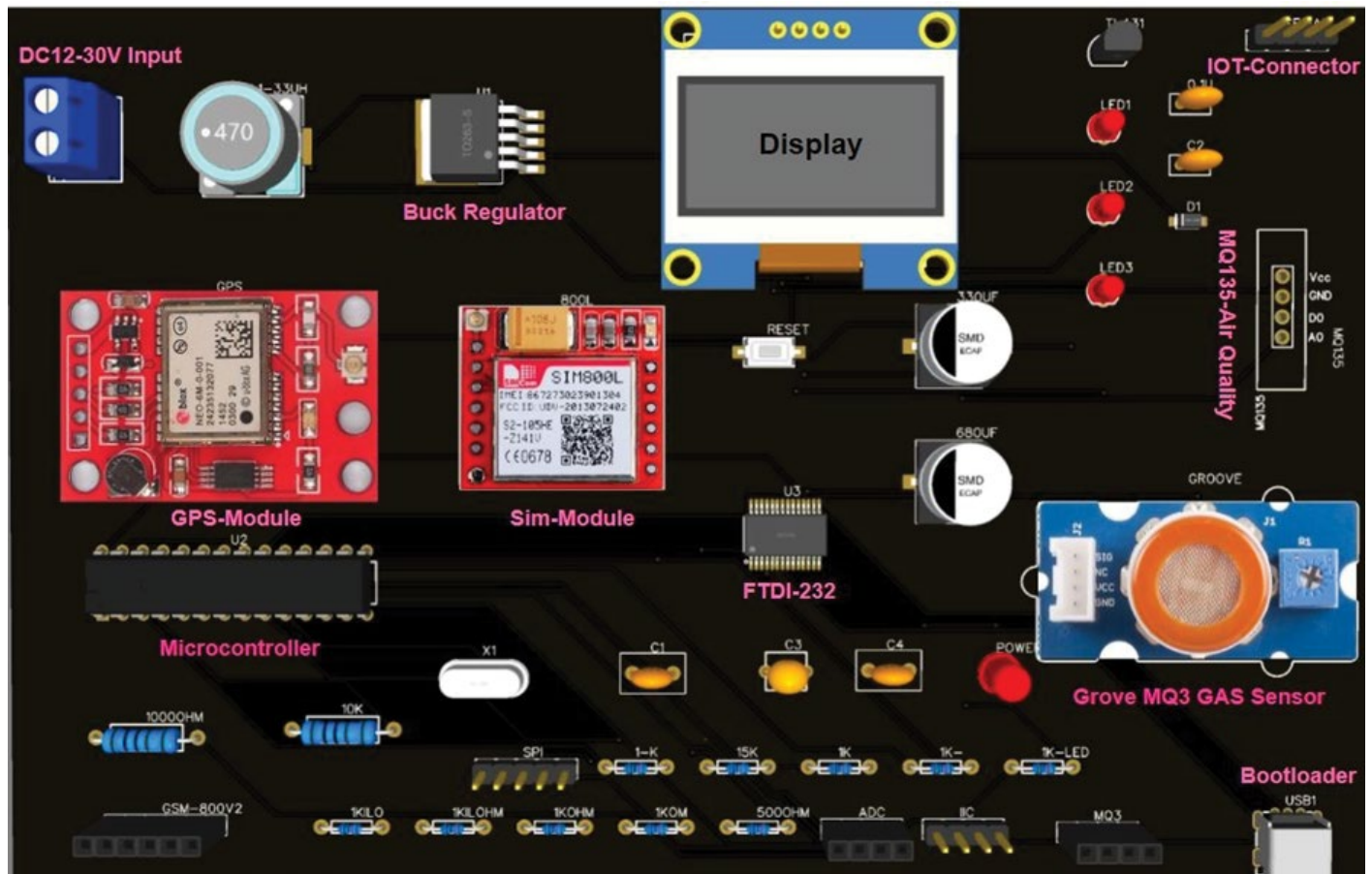


Figure 19. 3D PCB model of the LPG gas leakage detector.



Figure 20. Hardware model.

Conclusion

The Liquefied petroleum Gas is important fuel for human beings. We know leakage occur due to lack of proper observation. Only solution if we conscious and prevent this unwanted leakage accident of LP gas. We need to use smart

control and protective leakage detector which ensure the alert information during danger time.

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