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Prototyping a Smart Indoor Air Quality Management System

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ABSTRACT

Prototyping a smart Indoor Air Quality (IAQ), monitoring and control system, is proposed in this work so as to maintain the quality of air in the commercial and residential building within the acceptable level. Major indoor atmospheric air pollutants such as carbon monoxide (CO), Carbon dioxide (CO_2), Methane (CH_4) level and temperature are monitored and controlled by the ventilation and purging system. This system is implemented using Arduino UNO development board using ATmega328p microcontroller as central processing unit interfaced with pollutant measuring sensors. Firmware was developed to monitor and control the air contamination level using the signal from various sensor and control modules. Oxygen generation and control system is introduced to maintain acceptable oxygen level in an indoor environment, whereas other work reports only on monitoring IAQ. The whole system was designed and simulated for various test condition in Proteus ISIS simulation environment, and prototype model was also developed and tested.

Keywords: Smart Indoor Air Quality, IAQ, Arduino UNO, Ventilation Unit, Oxygen flow control system, Electrolysis.

I. INTRODUCTION

Indoor air is the air that we inhale inside the environments such as at homes, offices, hospitals, etc. Indoor Air Quality (IAQ) is the term describes the quality of air in a building; especially it refers to the wellbeing and amenity of residents in building, and also it specifies the nature of the comfortable air that circulates all through the space (or) area, where people work and live in. People settlealmost of their time in the indoors where they are unveiled to greater polluted air than at the outdoors. IAQ can be affected by microbial contaminants, gaseous pollutants (includes carbon monoxide, carbon dioxide and some organic compounds, etc) and some personal activities like smoking. These pollutants can cause adverse health effects to building occupants. To avert such an adverse effects, an air quality monitoring system is furthermost required. Indoor air quality monitoring is a crucial part of built-in environment control systems to ensure the indoor environment is in an acceptable condition for living.

Developed a wireless solution for indoor air quality monitoring. It represents the environmental parameters in terms of Air Quality Index (AQI) and gives environmental information [1]. Developed Autoregressive Hidden Markov Model (ARHMM) to model the occupancy pattern, based on the measurements of different sensors given its ability to establish correlations among the observed variables [2].

A simple fiber-optic sensing system to measure the concentration of the methane based on a special catalyst and fiber Bragg gratings (FBGs). The system resulted in a good performance like high resolution and good stability to the environmental temperature [3].

II. SMART IAQ MANAGEMENT SYSTEM

Basically, the system consists four main modules which include a control module that controls the communication of data and control over the channels, a microcontroller which is programmed to monitor

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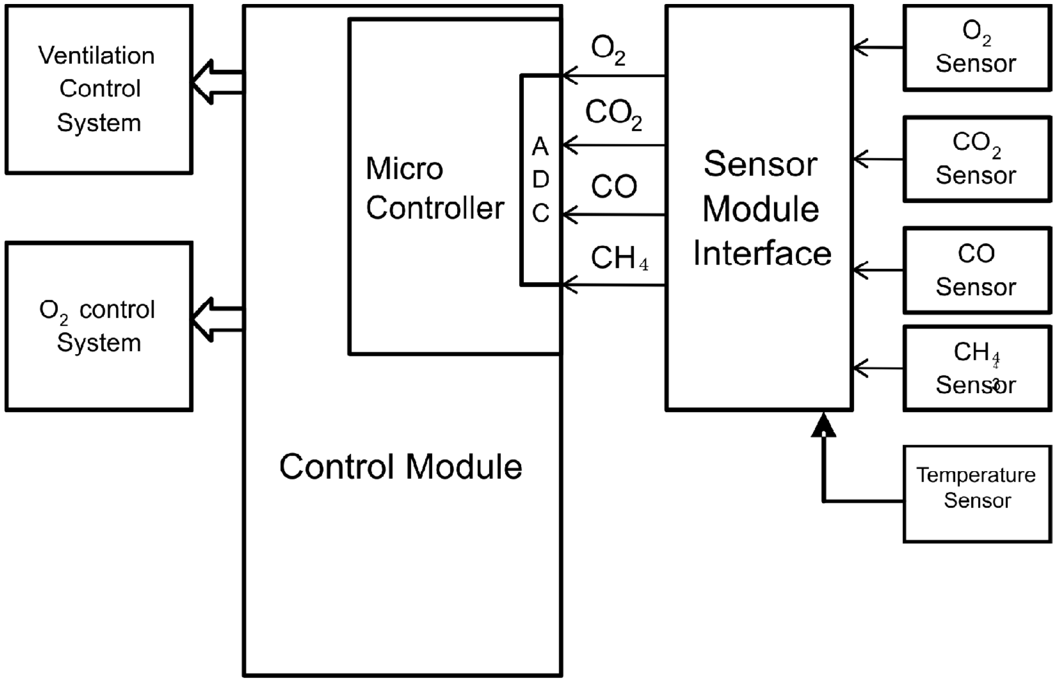

Figure 1: Block Diagram of IAQ Management System

the gas concentration and do necessary action, a sensor module which consists of all the sensors and a power module to provide the required power [4].

(A) Control Module

An Arduino Uno board, in which it has 6 analog pins and 14 digital I/O pins. It also has an analog to digital converter which converts the analog value obtained from the output of the sensor to a digital value. The control module consists of an inbuilt ATmega328p microcontroller. An ATmega328P on the board channels the serial communication over USB and appears as a virtual com port to software on the computer [5].

(B) Sensor Module Interface

The sensor module interface is a multichannel signal conditioning circuits which provide supply voltage to the sensor module and analog signal processing circuit. This module has five input channels to interfaceoxygen, carbon dioxide, carbon monoxide, methane and temperature sensor. These pre-processed analog signals connected to the analog input pins ADC0 to ADC4 of ATmega328p. For monitoring Carbon Monoxide (CO) sensor, MQ-7 is used due to high sensitivity and fast response time, can measure the CO concentrations from 20 to 2000 ppm in the air[6]. MQ-135 sensor have fast response and high sensitivity, stable and long life CO, sensor and consumes low power is used in the design. It can sense for CO, concentration for the range of 350-10,000 ppm which is ideal for indoor air quality monitoring applications[7]. MQ-4 gas sensors can be used for sensing methane concentration in air has SnO, material, which with clean air exhibits low conductivity on compared with combusted gas[8]. ME3- O, sensor has low consumption, high sensitivity and Wide range of linearity. It can sense for O, concentration for the range of 0-25% vol[9]. In addition to these temperature sensor is interfaced to measure the indoor temperature. LM35 sensor is used to measure temperature range from “55°C to 150°C[10].

(C) Ventilation Control System

Ventilation unit provides rapid exchange of indoor air, when the indoor air is contaminated with one or more contaminant sources such as CO, CO_2, CH_4. Indoor air is exhausted rapidly by switching ON ventilation

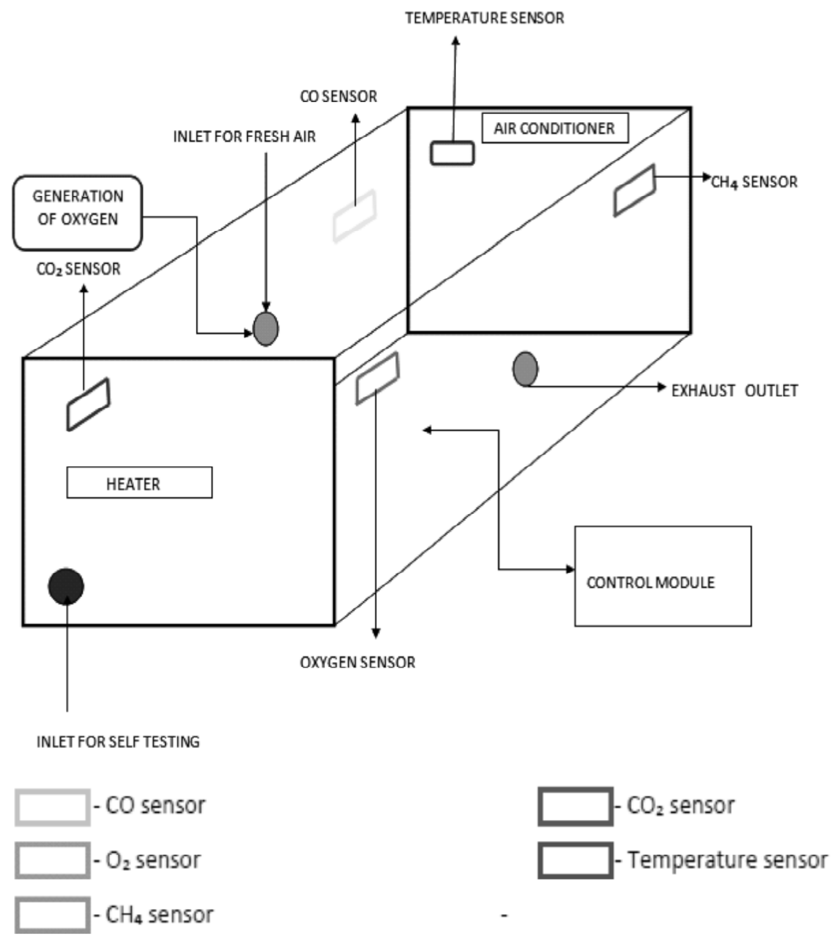

Figure 2: Schematic diagram of experimentsetup of IAQ Management System

system for 1 minute, then switch ON both ventilation and purging unit to exhaust and pump fresh air from outdoor in other direction. Then switch OFF both exhaust and inlet air control system.

(D) Oxygen Flow Control System

When the oxygen content in the indoor air falls below 20.9% in air, this system will be activated to provide oxygen flow control to maintain sufficient level. Oxygen gas can be liberatedthrough the electrolysis method.

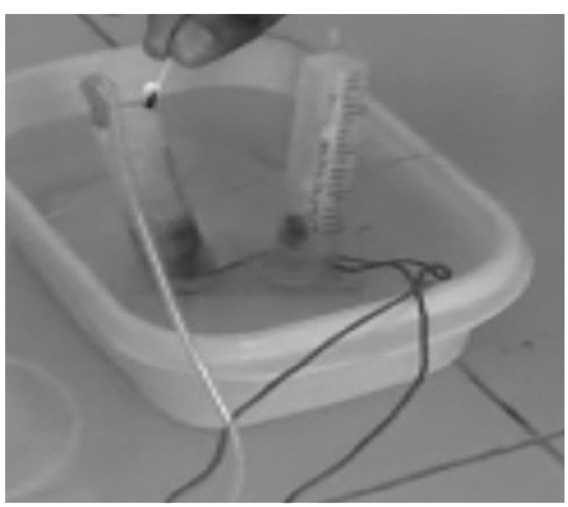

Figure 3: Generation of Oxygen through Electrolysis process

Water is made up of two main constituents H, O (two parts hydrogen and one part oxygen) is broken down forcibly with the help of electric current. Normally adding catalyst like salt to this process results in the speedy process, to generate pure oxygen, the catalyst should not be added. But it is impossible because the bond between the H, O components is so great, it might become impossible to disintegrate them into parts. This can be done through using low power DC, which might force the liquid to separate into its pure forms.

(E) Firmware for IAQ Management system

Execution flow of the system firmware is shown in Figure 3. In this, the threshold value for each contamination level is fixed. Once the system is switched ON, it continuously runs in the closed loop. The threshold value for CO is fixed as 35 ppm, 1000 ppm for CO_2 , 2000 ppm for CH_4, and minimum 16% of O_2 level in the air. If the contamination level exceeds the threshold value the control system and a warning alarm will be switched ON.

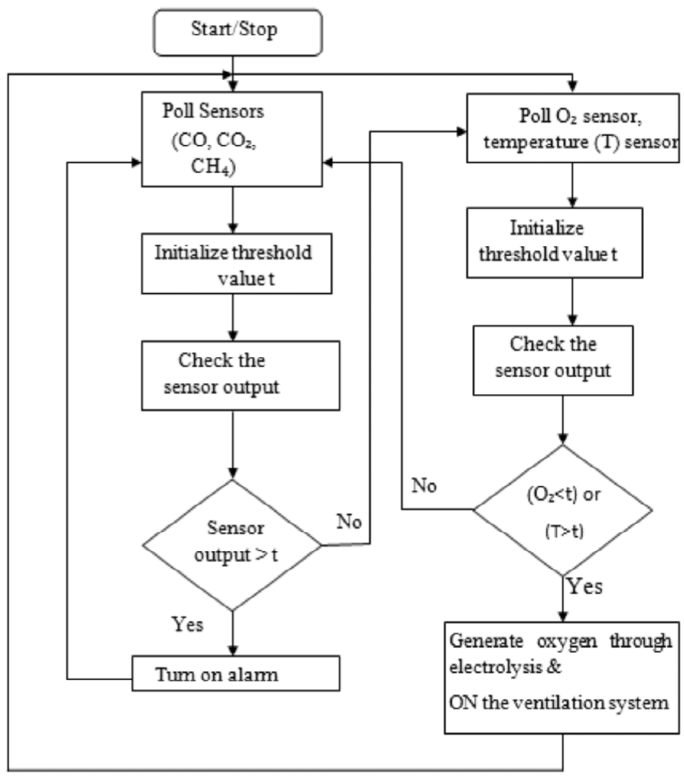

Figure 4: Flow Chart of IAQ Management System

(F) Execution Algorithm

Step 1: Start.

Step 2: Poll sensors (CO, CO_2, and CH_4).

Step 3: Initialize threshold value‘t’ for all the sensors.

Step 4: Check the sensor output.

Step 5: If the sensor output is less than‘t’ then poll oxygen and temperature sensor.

Step 6: Check the sensor output.

Step 7: If the oxygen sensor output is less than‘t’ or temperature sensor is greater than ‘t’ then generate oxygen through electrolysis or the ventilation system will be ON respectively.

Step 8: Go to step 2 and rerun the process.

III. IMPLEMENTATION OF SMART IAQ MANAGEMENT SYSTEM

(A) IAQ system Implementation in Proteus environment

Smart IAQ management system is implemented in Proteus 8.1 ISIS environment at circuit level. The sensor characteristics are replaced with electrical equivalent using variable resistors. The control signal is indicated by turning ON the LED. Firmware is loaded in ATmega328P microcontroller and simulated for various sensor signal inputs and the schematic under simulation is shown in Figure 5.

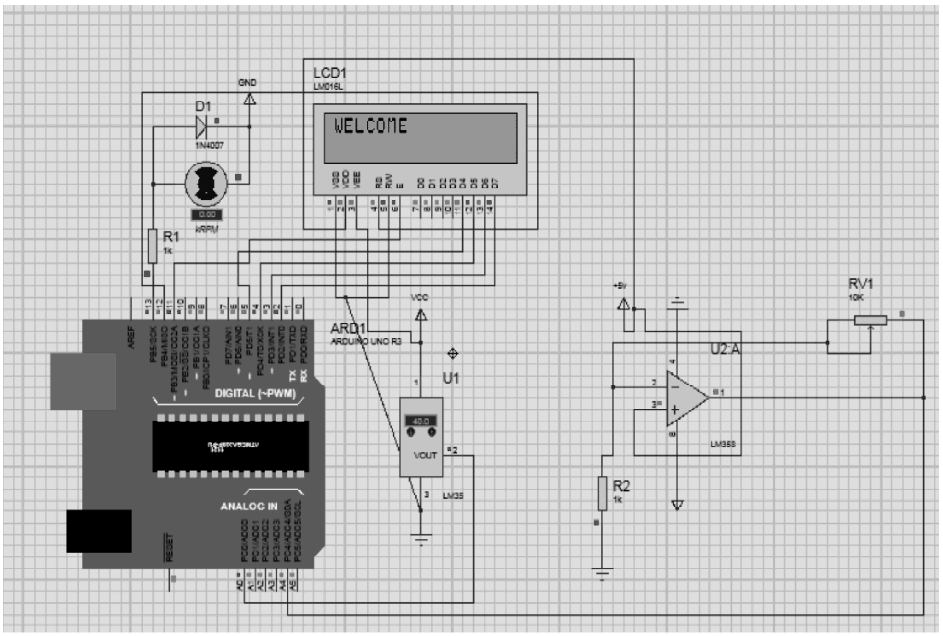

Figure 5: Schematic of IAQ management system

(B) Smart IAQ Hardware Implementation

Proto model implementation of IAQ system for monitoring CO, CO_2, CH_4, O_2 and temperature concentration as shown in Figure 4. It is implemented with MQ-7, MQ-135, MQ-4, ME3-O, , LM35 sensor respectively. All these sensors are interfaced to Arduino UNO board and are interfaced to a personal computer (PC) using USB communication. These sensors are placed in a closed room, and it is fixed with an air conditioner to provide cool air when the temperature is high.

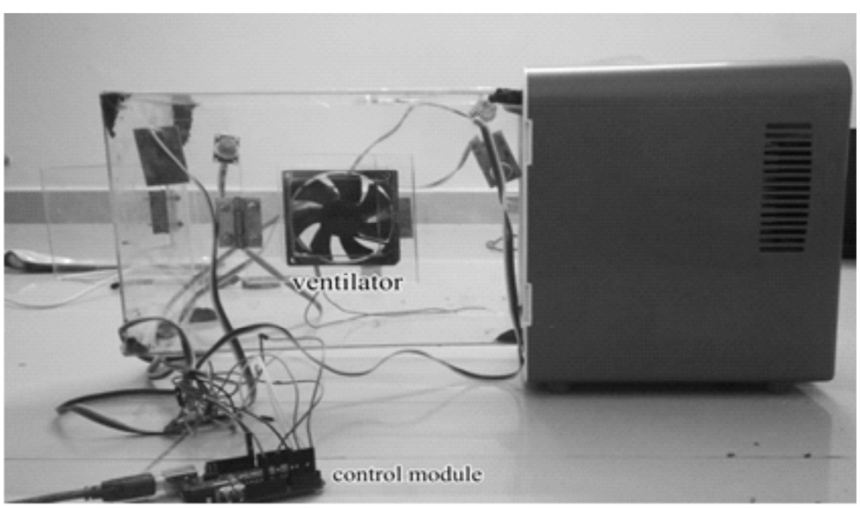

Figure 6: Proto model of Smart IAQ Management system

IV. RESULTS AND DISCUSSION

(A) Proteus Simulation Result

Gas concentration monitoring has been done in Proteus ISIS 8.1 software. This software does not support for a gas sensor. Thus, equivalent electrical output is provided by using a variable resistor. Once simulation starts to run for the first time, the LCD will display text, ‘welcome’ and then reads the CO, CO_2, CH_4, O_2, Temperature concentration and displays the value in their respective units.

CO Management

Case 1: Normal Condition

Indication: LED does not glow.

Inference: The Concentration of CO is less than threshold value. LED does not glows

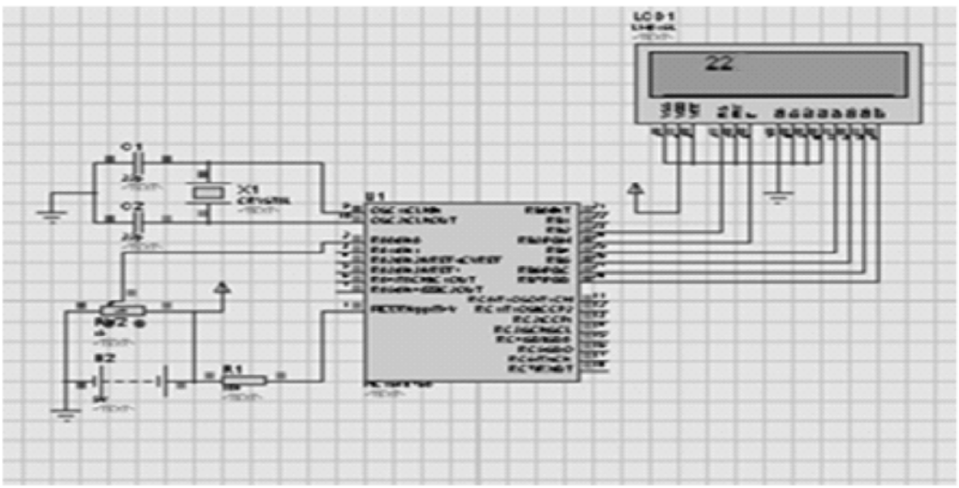

Figure 7 (a): Concentration of Carbon monoxide in Normal Condition

Case 2: Abnormal Condition

Indication: LED glows.

Inference: The concentration of CO is more than threshold value. Green color LED glows.

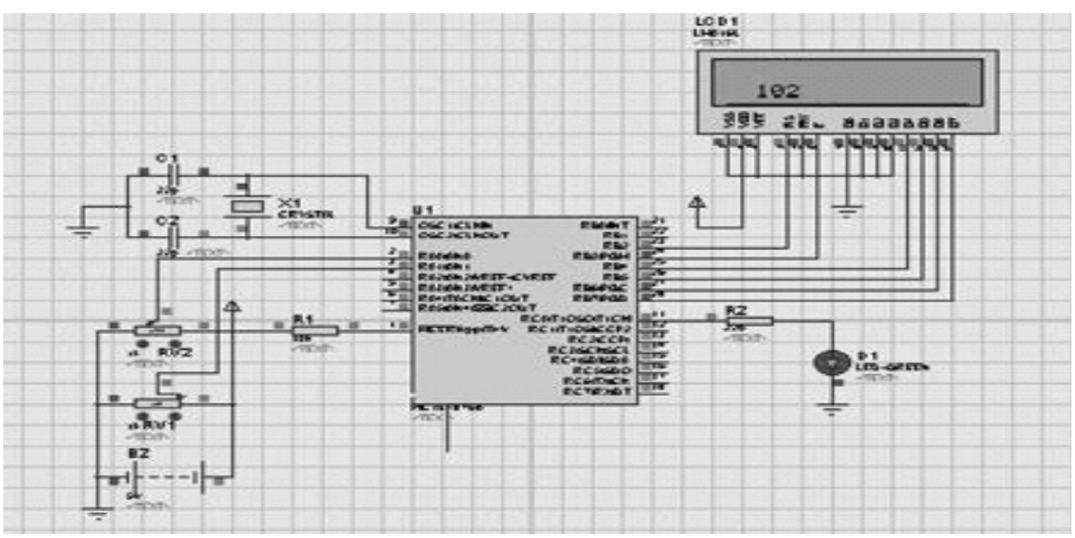

Figure 7 (b): Concentration of Carbon monoxide in Abnormal Condition

CO_2 Management

Case 1: Normal Condition

Indication: LED does not glow.

Inference: The Concentration of CO_2 is less than threshold value. LED does not glow.

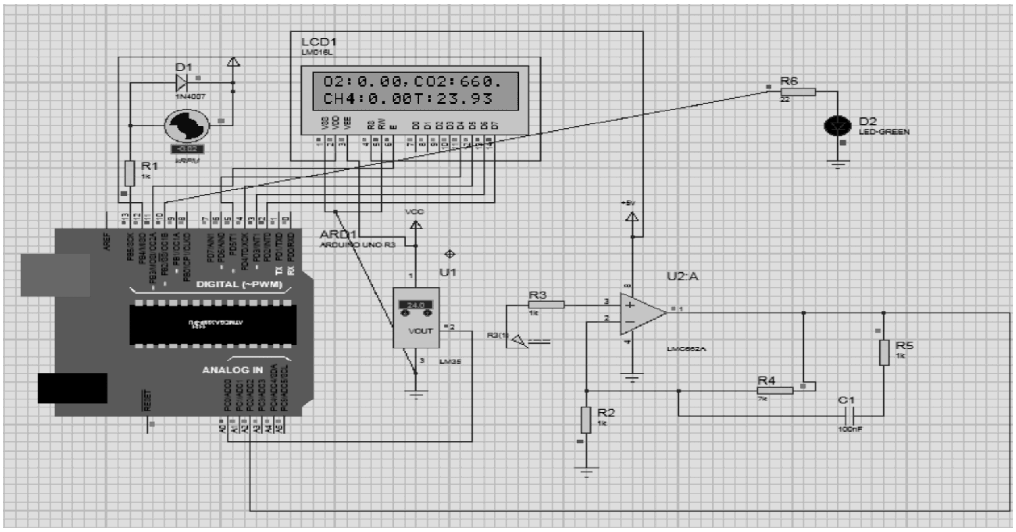

Figure 8 (a): Concentration of Carbon dioxide in Normal Condition

Case 2: Abnormal Condition

Indication: LED glows.

Inference: The concentration of CO_2 is more than threshold value. Red color LED glows.

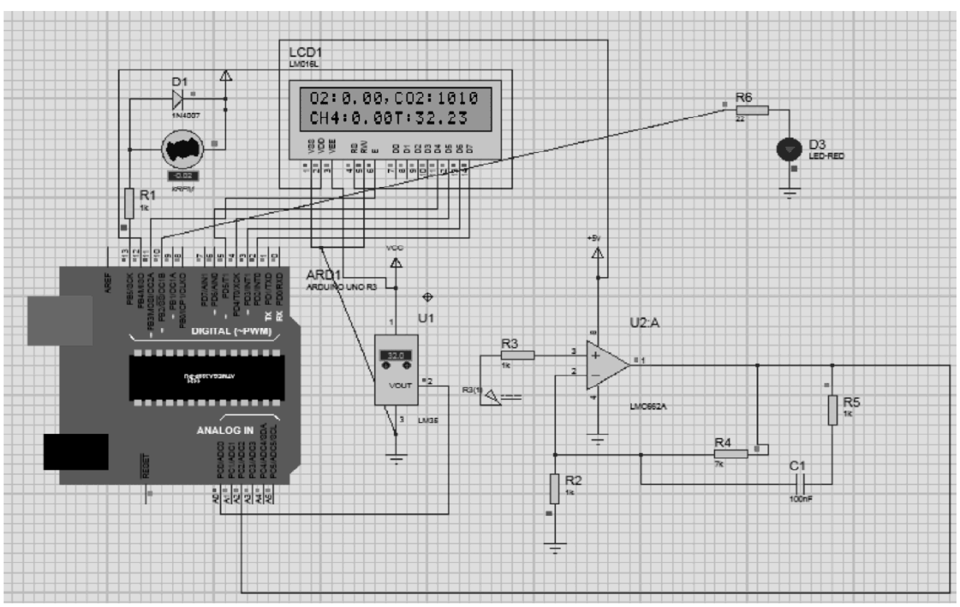

Figure 8 (b): Concentration of Carbon dioxide in Abnormal Condition

CH_4 Management

Case 1: Normal Condition.

Indication: LED does not glow.

Inference: The concentration of CH_4 is less than threshold value. LED does not glow.

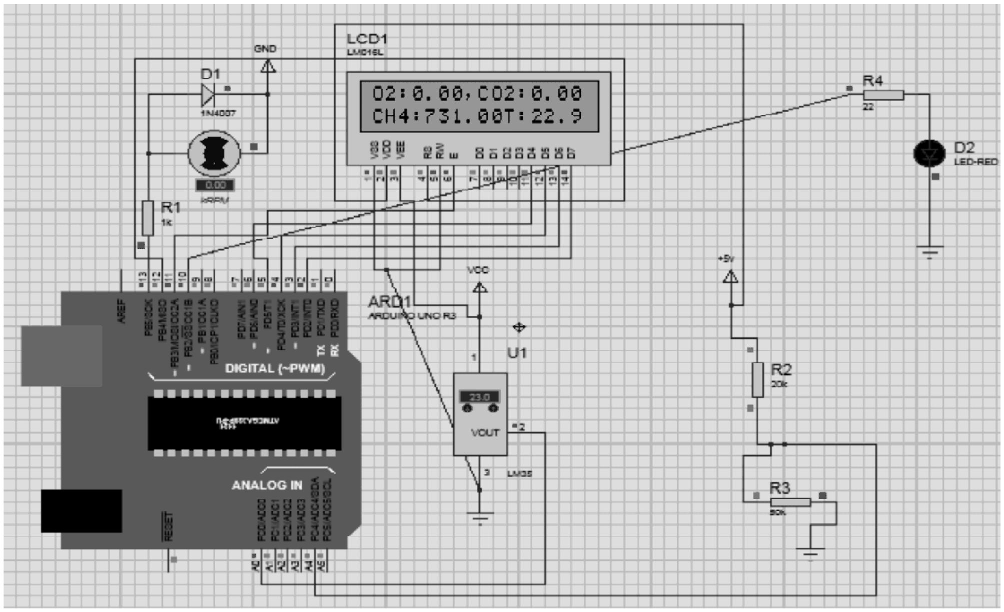

Figure 9 (a): Concentration of Methane in Normal Condition

Case 2: Abnormal Condition

Indication: LED glows

Inference: The concentration of CH_4 is more than threshold value. Red color LED glows.

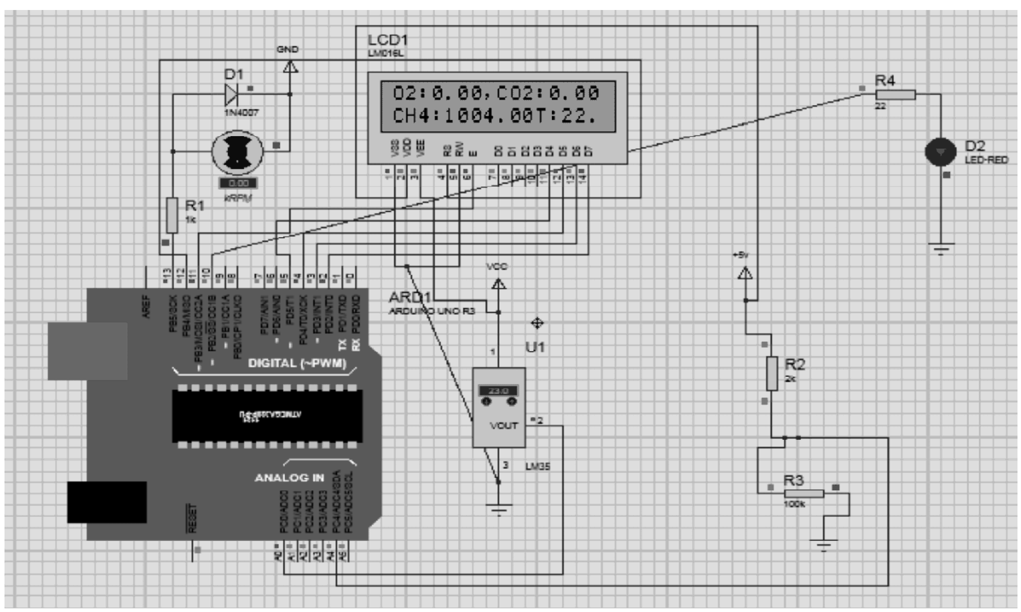

Figure 9 (b): Concentration of Methane in Abnormal Condition

O_2 Management

Case 1: Normal Condition.

Indication: LED does not glow.

Inference: The concentration of O_2 is more than threshold value. LED does notglow.

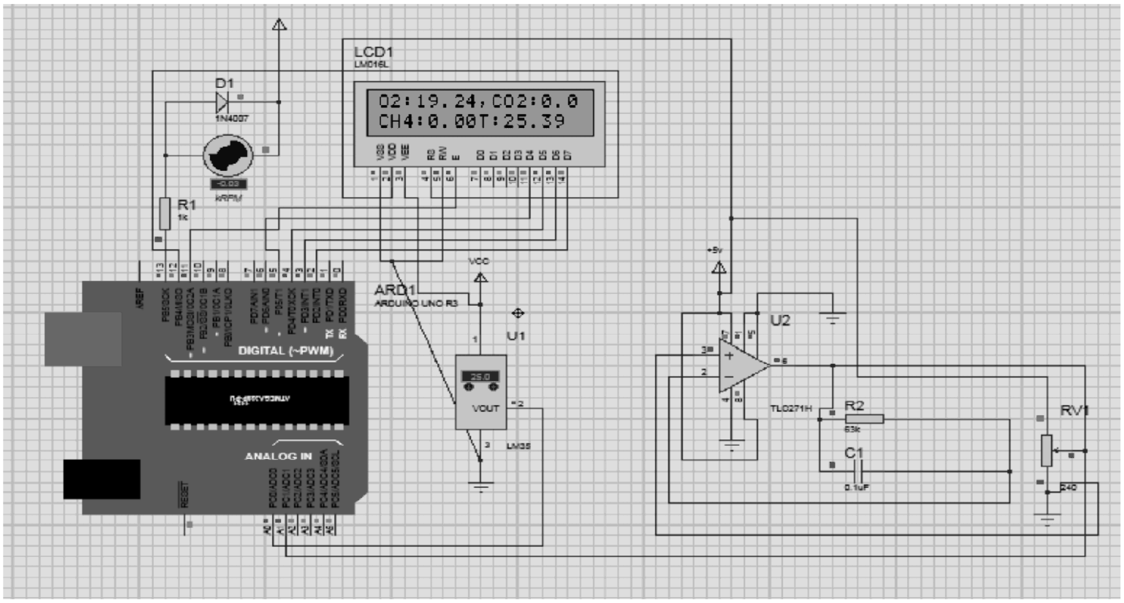

Figure 10 (a): Concentration of Oxygen in Normal Condition

Case 2: Abnormal Condition

Indication: LED glows

Inference: The concentration of O_2 is less than threshold value. Green color LED glows.

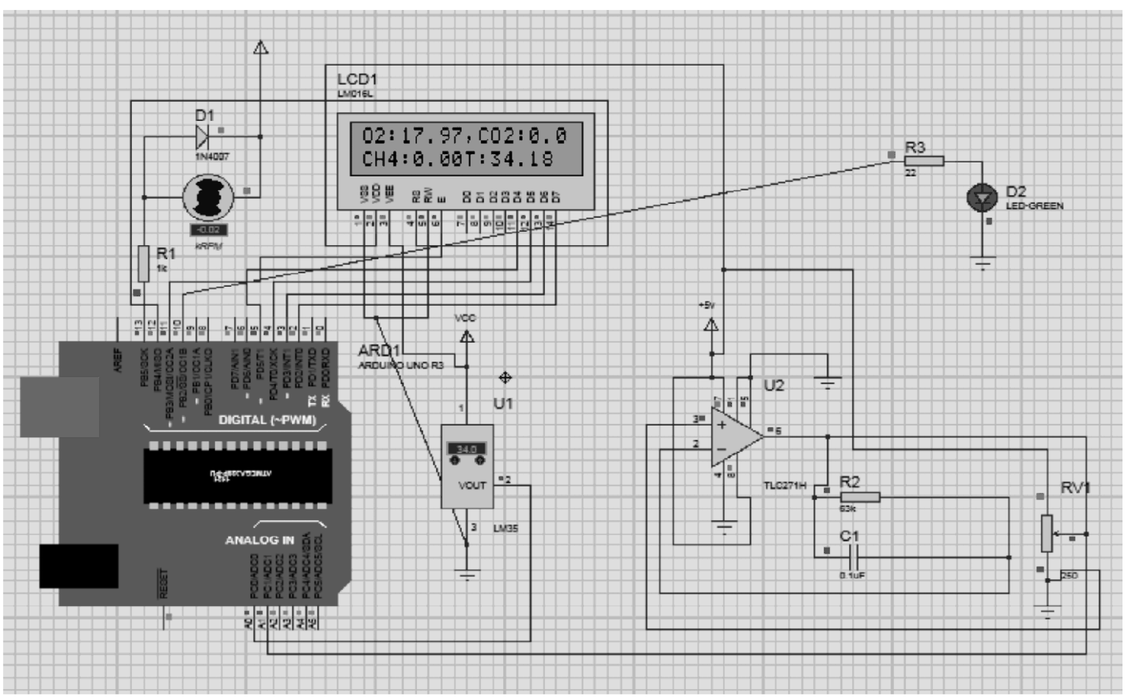

Figure 10 (b): Concentration of Oxygen in Abnormal Condition

(B) Smart IAQ Hardware Result

The concentration of oxygen, carbon dioxide, Carbon monoxide, methane gas and temperature has been monitored using ME3-O_2, MQ-135, MQ-7, MQ-4 and LM35 sensors by creating gaseous cloud artificially as shown in Figure 6. The output of the O_2, CO_2, CO, CH_4 and temperature sensor is fed to the analog input pin A0, A1, A2, A3, A4of the board respectively. The ADC converts the analog output voltage of the sensor to a digital value communicated to PC through serial communication.

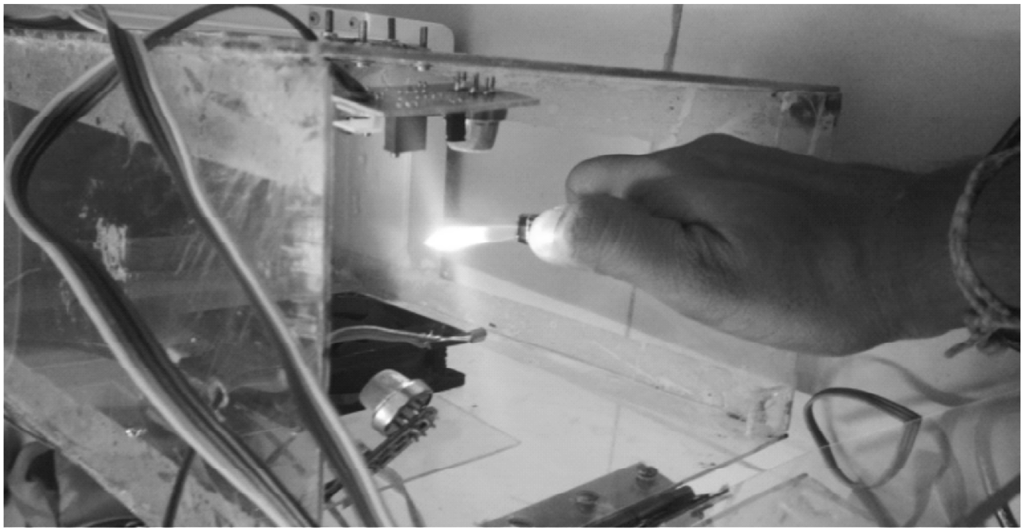

Figure 11: Testing of Smart IAQ System

Case 1: Concentration of gases under normal condition

```
COM12 (Arduino/Genuino Uno)

O2:21.00%,CO2:293.76ppm,CH4:1807.00ppb,CO:0.77
Temperature:31.74C
O2:21.00%,CO2:285.60ppm,CH4:1768.00ppb,CO:0.74
Temperature:31.74C
O2:21.00%,CO2:277.44ppm,CH4:1729.00ppb,CO:0.72
Temperature:31.74C
O2:21.00%,CO2:277.44ppm,CH4:1703.00ppb,CO:0.70
Temperature:31.25C
O2:21.00%,CO2:269.28ppm,CH4:1690.00ppb,CO:0.69
Temperature:31.25C
O2:21.00%,CO2:269.28ppm,CH4:1664.00ppb,CO:0.67
Temperature:31.25C
O2:21.00%,CO2:261.12ppm,CH4:1638.00ppb,CO:0.66
Temperature:31.25C
O2:21.00%,CO2:261.12ppm,CH4:1625.00ppb,CO:0.65
Temperature:31.25C
O2:21.00%,CO2:269.28ppm,CH4:1638.00ppb,CO:0.64
Temperature:31.25C
O2:21.00%,CO2:269.28ppm,CH4:1638.00ppb,CO:0.62
Temperature:30.76C
O2:21.00%,CO2:269.28ppm,CH4:1625.00ppb,CO:0.62
Temperature:31.25C
```

(a)

Case 2: Concentration of gases under Abnormal (test) condition

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COM12 (Arduino/Genuino Uno)

 IMPLEMENTATION OF SMART INDOOR AIR QUALITY MANAGE MENT SYSTEM

O2:21.00%,CO2:465.12ppm,CH4:2860.00ppb,CO:2.85
Temperature:31.25C
O2:21.00%,CO2:456.96ppm,CH4:2847.00ppb,CO:2.83
Temperature:43.95C
O2:14.00%,CO2:440.64ppm,CH4:2795.00ppb,CO:1.72
Temperature:31.74C
O2:17.50%,CO2:432.48ppm,CH4:2756.00ppb,CO:0.99
Temperature:29.30C
O2:17.50%,CO2:432.48ppm,CH4:2730.00ppb,CO:0.65
Temperature:46.88C
O2:21.00%,CO2:416.16ppm,CH4:2691.00ppb,CO:0.62
Temperature:79.31C
O2:24.50%,CO2:399.84ppm,CH4:2639.00ppb,CO:0.77
Temperature:51.25C
O2:21.00%,CO2:408.00ppm,CH4:2626.00ppb,CO:0.76
Temperature:34.16C
O2:21.00%,CO2:399.84ppm,CH4:2574.00ppb,CO:0.76
Temperature:31.25C
O2:21.00%,CO2:489.60ppm,CH4:2210.00ppb,CO:1.15
Temperature:41.02C
O2:21.00%,CO2:399.84ppm,CH4:2756.00ppb,CO:0.67
Temperature:44.92C
O2:24.50%,CO2:375.36ppm,CH4:2665.00ppb,CO:0.64
Temperature:35.64C
O2:24.00%,CO2:367.20ppm,CH4:2600.00ppb,CO:0.72
Temperature:23.93C
O2:24.50%,CO2:350.88ppm,CH4:2522.00ppb,CO:0.70
Temperature:31.74C
```

(b)

Figure 12: (a) Test result under normal condition, (b) Test results under Abnormal condition (shaded region)

Figure12(a) shows the concentration of gases under normal condition. After lightening to test the systemwhich is shown in figure 11, the concentration of CO, CO_2, CH_4 and temperature rises abruptly and oxygen level reduces which is shown in Figure 12 (b). Then the ventilator system will be activated so that it again reduces level of concentration after reaching its threshold value and oxygen will be pumped in when it is reduced through the electrolysis which is shown in figure 12(b).

V. CONCLUSION

Smart Indoor Air Quality (IAQ) management system is to maintain IAQ for commercial and residential building was developed. The system proposed in this paper could not only monitor the indoor air quality, but also auto-control if the quality is poor, which is a high performance indoor environment control system using Arduino UNO board. Major indoor air pollutants such as CO, CO_2, CH_4, temperature and O_2 level are monitored using discrete sensors MQ7, MQ135, MQ4, LM35and ME3-O, sensors respectively are used in simulation implementation. Firmware is loaded in ATmega328p microcontroller, to monitor the air contamination level using signal from various sensors and generate the control signal to the ventilation and oxygen flow control system. Smart IAQ management system is implemented in Proteus environment and tested the system performance for different pollution level. It is observed, that the concentration of gases in air increases drastically even with a small amount of the pollutants in air. So considerations have to be taken to eliminate such pollutants so as to lead a healthy life.

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