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Industrial oven monitoring with an exhaust system for health improvement and safe working environment: a case of Sosoma industries ltd (Rwanda)

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https://doi.org/10.58694/20.500.12479/1606

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INDUSTRIAL OVEN MONITORING WITH AN EXHAUST SYSTEM FOR HEALTH IMPROVEMENT AND SAFE WORKING ENVIRONMENT: A CASE OF SOSOMA INDUSTRIES LTD (RWANDA)

Olivier Hungurimana

A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Embedded and Mobile systems of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

August, 2022

ABSTRACT

Food processing industry, specifically flour production from cereals like maize, sorghum, millet, and wheat, became more important for value additions in presently according to the cooking restrictions and the quality needed for good products, particularly at SOSOMA industries LTD in Rwanda. To get a quality product, various processing stages including cereals roasting, milling, sieving, fortification and vitamins premixes, and packaging must be monitored and controlled on real time. During roasting, the status of an industrial oven affects the quality of the product, and needs to be considered and followed up on a real time basis. It uses wood fuel as a source of energy, and when not controlled, can produce smoke flames and carbon monoxide in the working environment that may affect the respiratory system of employees who are closer in proximity and the working environment itself. When controlled well, it adds nutrients in the roasted cereals. In this study, a qualitative approach of data collection like unstructured interviews, discussion and field visit observation was used and data have been analyzed using content analysis techniques just to obtain system requirements. Various electronic components such as sensors to capture the physical environment, microcontroller to define tasks, SPI protocol to enable communication between devices, and output devices to react to environmental change have been used to design and develop a fully monitored and controlled industrial oven. Ultimately, the developed system was tested positively and found to meet the industry oven requirements, so it was accepted at SOSOMA industries due to its effective low cost, secured and friendly system.

DECLARATION

I, Olivier Hungurimana do declare to the Senate of Nelson Mandela Africa Institution of Science and Technology that this Project Report is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Olivier Hungurimana

Name and Signature of Candidate Date

The Above declaration is confirmed by:

Dr. Dina Machuve

Name and Signature of Supervisor 1 Date

Dr. Neema Mduma

Name and Signature of Supervisor 2 Date

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CERTIFICATION

The undersigned certify that have read and hereby recommend for acceptance by the Senate of the Nelson Mandela African Institution of Science and Technology, the Project Report titled *"Industrial Oven Monitoring with An Exhaust System for Health Improvement and Safe Working Environment"* in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science in Embedded and Mobile Systems of the Nelson Mandela African Institution of Science and Technology.

Dr. Dina Machuve

Name and Signature of Supervisor 1 Date

Dr. Neema Mduma

Name and Signature of Supervisor 2 Date

ACKNOWLEDGEMENTS

The realization of this project report comprises a mix of endeavors and contributions from several parties and individuals. I would like to express my gratitude to the following for their support and contribution during the entire period of this project work.

I wish to thank the All-powerful God for his blessings, grace and guidance while pursuing my master degree at NM-AIST. I accept that this work makes him pleased.

I wish to offer many thanks to the Center of Excellence for ICT in East Africa together with GIZ who were the full sponsors of my master's studies at NM-AIST. I conviction that, this work will persuade them to help more understudies.

I feel honored of being supervised by Dr. Dina Machuve and Dr. Neema Mduma, I have learnt an advanced and extraordinary deal from them. Their guidance, constructive comments and support throughout the entire process, endeavors in leading and shaping my project towards the right direction were instrumental. I will always be grateful for their help of shaping my career.

I wish to express my gratitude to SOSOMA Industry ltd authority for the acceptance to conduct my project study. Special thanks go to NM-AIST lecturers and classmates for their vast supports during entire period of studies at NM-AIST.

Lastly, I would like to express my sincerely appreciation to my family including parents, sisters and brothers, for the help, prayers and blessings during my studies. May almighty God keep them live long due to their presence is irreplaceable in my daily life.

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LIST OF ABBREVIATIONS AND SYMBOLS

AVR	Advanced Virtual RISC
CENIT@EA	Center of Excellence for ICT in East Africa
CO	Carbon Monoxide
DC	Direct Current
DHT	Digital High Technology
EAC	East African Community
HACCP	Hazards Analysis and Critical Control Point
ICT	Information and Communication Technology
IDE	Integrated Development Environment
ISO	International Standard Organization
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MQ	Mĭngăn Qĭ lai
NM-AIST	Nelson Mandela African Institution of Science and Technology
PCB	Printed Circuit Boards
PPM	Part Per Million
ISC	Reduced Instruction Set Computer
RW	Rwandan Francs
SOSOMA	Sorghum Soybeans Maize
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
°C	Degree Celsius

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Sorghum Soybeans Maize (SOSOMA) Industries is a limited company established on November 1st, 2008 with a capital of Two Hundred Twenty-Six Million Nine Hundred Thousand Rwandan Francs (RWF 226 900 000) divided into 2269 shares of Rwandan Francs (RWF) 100 000 each. Having their primary cereal and pulses grains as sorghum, soybeans and maize, a name was forged as SOSOMA which started value addition to produce flours. The products are prepared in accordance with national, regional which is East African Community (EAC) standards and international standards of food hygiene and food industries management which are International Standard Organization (ISO 22000:2005) and Hazards Analysis and Critical Control Point (HACCP).

Food processing industry is considered to be of a great important for value additions in our days according to the cooking restrictions and the quality needed for good products. Cereals serve as various food products ranging from maize, sorghum, millet, rice, or wheat and as a basic ingredient of baked goods for a human being, either processed or not. From the starch compositions, unprocessed Cereals which are in form of maize, sorghum, millet, rice, or wheat are seeds or grains of grasses which are highly rich sources of nutrients including energy values, cellulose, carbohydrates, proteins, fat composed of minerals and vitamins (Sarwar, 2013).

For cereals value addition is done in industrial, various operations and steps are respected to yield quality end products. Before processing at the industry, the basic operations such as sorting, washing and grading from purchased cereals raw materials are necessary. Other operations including cereals roasting, milling, sieving, fortification and vitamins premixes, and packaging are the important operations needed to yield quality end products (Oghbaei & Prakash, 2016).

For cereals flour production, roasting of cereals as one the necessity step to add nutrients such as crude fiber, carbohydrate, caloric energy value which are not present in the unroasted cereals, wood fuel and charcoal as a source of energy must be use (Kavitha & Parimalavalli, 2014).

In order to acquire the best quality end product, it is necessary to control some of the thermal parameters including heat, smoke transferred during the roasting process.

1.2 Statement of the Problem

Roasting is one of the crucial step used in the production of cereals flours at SOSOMA industries. Wood fuel as a source of energy has been used to add nutrients such as crude fiber, carbohydrate, caloric energy value which ends up providing smoke frame in working environment chamber. Due to the presence of carbon monoxide, smoke which present in the frame, turns working environment precisely chamber into black color. The smell in the chamber is also affected because of chemical composition of smoke frame compared to the normal chamber. Depending on the amount of smoke frame emitted from the ovens, can affect respiratory system and eyes of employee who are closer in proximity (Inyang *et al.*, 2015).

Figure 1: Current industrial oven working place

1.3 Rational of the Project

The implementation of the Research Project is important both economically, socially, and academically for the following:

(i) Conservation of forest and environment by controlling wood fuel and charcoal used in the oven. Once oven monitored, it provides additional income due to reduction of wood and charcoal used in the oven during production of energy.

(ii) The burning of wood fuels as source of energy in the oven results in exposure to high levels of indoor air pollution, with resulting wellbeing impacts. When thermochemical parameters are monitored, it will raise awareness to air pollution control along with an improvement health standard and creating a safe working environment (Garbaccio *et al.*, 2000).

(iii) Since the world is currently facing the issues carbon dioxide emission in the atmosphere (Demirbas *et al.*, 2004) it is desirable to implement government long term sustainable Strategy on Climate Change and Low Carbon (Abeydeera *et al.*, 2019).

1.4 Project Objectives

1.4.1 Main Objectives

The main objective of this Research Project is to develop an industrial oven monitoring with an automatic smoke exhaust system to improve employees' health and create safe working environment.

1.4.2 Specific Objectives

The specific objectives of this Research Project were:

(i) To review and analyze current Engineering requirements used to make an industrial oven monitoring with an automatic smoke exhaust system for small scale industries.

(ii) To design and develop an industrial oven monitoring with an automatic smoke exhaust system for small scale industries.

(iii) To validate the developed an industrial oven monitoring with an automatic smoke exhaust system for small scale industries.

1.5 Project Questions

(i) What are the current engineering requirements for industrial oven monitoring with an automatic smoke exhaust system for small scale industries?

(ii) How will industrial oven monitoring with an automatic smoke exhaust system for small scale industries be designed?

(iii) How the performance of will developed an industrial oven monitoring with an automatic smoke exhaust system for small scale industries be determine?

1.6 Significance of the Project

This Research Project has target to deliver remarkable contribution specifically to the small-scale industry, society, and academic as well in the following ways:

(i) With the developed system, since all environmental conditions is displayed on LCD, employees in industry can be aware of the working environment in the chamber where the industrial ovens are installed with a result of increasing in the productivity. Research shows that the employees performance is affected by several factors including the environmental safeness (Putri *et al.*, 2018).

(ii) Once the industrial ovens conditions are monitored within the industry yield a better quality of end products which is flours in this Research Project as result of being trusted by the customers, national, regional, and international standards of food hygiene and food industries management.

(iii) Since data is essential in the system product development. Researchers could use monitored data that are kept on a database during the improvements of a new or existing system

1.7 Delineation of the Project

The Developed Research Project intends to monitor industrial oven state and the conditions within the chamber such temperature, humidity, smoke and carbon monoxide. However, the quality of produced flours is not intended to be covered with this Research Project.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This literature review contain different articles used to develop the proposed framework. It shows the past and current situation of industrial oven monitoring with exhaust system available in Rwanda, then after evolution on industrial oven monitoring with exhaust system. Finally, similar studies on industrial oven monitoring with exhaust system from other researchers to clarify the strengths and weaknesses in the system.

2.2 Evolution of Oven Cooking Technology

A large number of Rwandans in their daily cooking and heating practices at domestic level have adopted three-stone stove or open stove. Moreover, wood fuels are mainly used as a source of cooking energy. Due to open fire, the three stone fire method is classified in an unmonitored system of cooking. For the same, the fuels used in are not completely burned, which results in high indoor concentrations of pollutants that can harm your health, including particulate matter and carbon monoxide (Jetter & Kariher, 2009; Mazimpaka, 2014). In areas where there is a shortage of biomass, collecting firewood can be a very time-consuming burden for households. This is especially true for children and women, who are typically responsible for this task (Dieu, 2015).

2.3 Industrial Oven Monitoring System in Rwanda

Four seasons agro-climatic conditions available in Rwanda allow it to produce of many varieties of agricultural commodities suitable for processing. Consequently, this field regarded as source of employment and income because the majority of the population are in agriculture sector, thus providing access to food and other necessities to large groups of the population in region and outside the continent. That is has adopted to improve and validate food processing technologies, enforcement of good quality standards, hygiene and regulatory instruments which have assisted local agro-processing industries to compete favorably in the international market place (Siebert *et al.*, 2019). One of the method to achieve good quality standards, grains have to be roasted using cooking stove, traditional unmonitored oven before milling in order to add nutrients in it with the use of wood fuel and charcoal as a source of energy. Current methods are unmonitored industrial oven the industry is introducing fire alarms. However, existing fire alarms have few disadvantages; the alarm battery as result can affect the end products quality.

2.4 Related work

The majority of the existing sensor-based oven frameworks to anticipate dangers in industrial oven focus on fire risk. An existing essential arrangement to detect fire hazard at needs to be replaced on a regular basis. Moreover, false alarms are also generated due to a small amount of smoke produced during a normal cooking (Yared, 2016).

2.5 Factors to Consider During the Design of Industrial Oven Monitoring With Smoke in Exhaust System

With a monitored system, since it has inputs which are sensors to capture the physical environment in the chamber with output devices which are transducers to react on captured environment, it helps to get quality end products. To obtain the best quality of flour products, various physical environment parameters such as temperature, humidity, smoke, and heat exchanged during the roasting must be considered and controlled. These parameters are important for the effectiveness quality of the end product (Bayón *et al.*, 2014).

To keep uniformity and optimum level of accuracy of those parameters. It is necessary to know the size of ovens during design and heating temperature range, mostly are in range of 200^{o}C - 250^{o}C (Yared, 2016), and (Popa *et al.*, 2018). Therefore, Distribution of temperature between relatively close points within the oven, insufficient or excessive temperature during roasting affect more product taste and color. As result, permanent supervision by a worker is required to prevent such losses like heat storage in the oven structure, losses from the outside walls or structure, radiation losses from openings, hot exposed parts, and heat carried through the cold air infiltration into the Oven (Laciak *et al.*, 2011).

The smoke from indoor wood burning consist of complex mixture of gases and fine particles mainly carbon monoxide, methane, and volatile organic compounds when not controlled can affect respiratory system especially lungs. Therefore, monitoring indoor air system with proper ventilation and CO detectors is needed to suppress those smoke's challenges (Torres-Duque *et al.*, 2008).

Smoke parameters are monitored by different Sensors specifically gas sensors in MQ sensor series for information transmission, processing and alerting. For controlling smoke, it is desirable to use gas sensors specifically MQ sensor series, since the emitted light ray is detected in presence of smoke. When the spread light reaches a chemiresistor cell, the device detects a smoke and the alarm is triggered (Song & Chen, 2018).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This section describes materials and methods used to develop a low cost, user friendly and secured monitoring and controlling subsystems which is an integral part of industrial ovens monitoring with an exhaust system. It also describes the study area, design requirements, system design and development procedures, and testing results of the industrial ovens monitoring with an exhaust system.

3.2 Research Project study Area

The project was carried out in SOSOMA industries located in Kigali city of Rwanda. This place was chosen as the study area due to the following reasons: It is small scale industry that contribute to fight against malnutrition in Rwanda. Since one of the objectives of CENIT@EA as a regional innovation hub is to provide the skills for the digital transformation in East Africa, these are ICT based solution in East Africa industries and community. The SOSOMA industries was chosen as one industry, which meets CENIT@EA mission, and it is a small-scale industry where one of its departments, still using manual method that needs to be transformed to ICT based method.

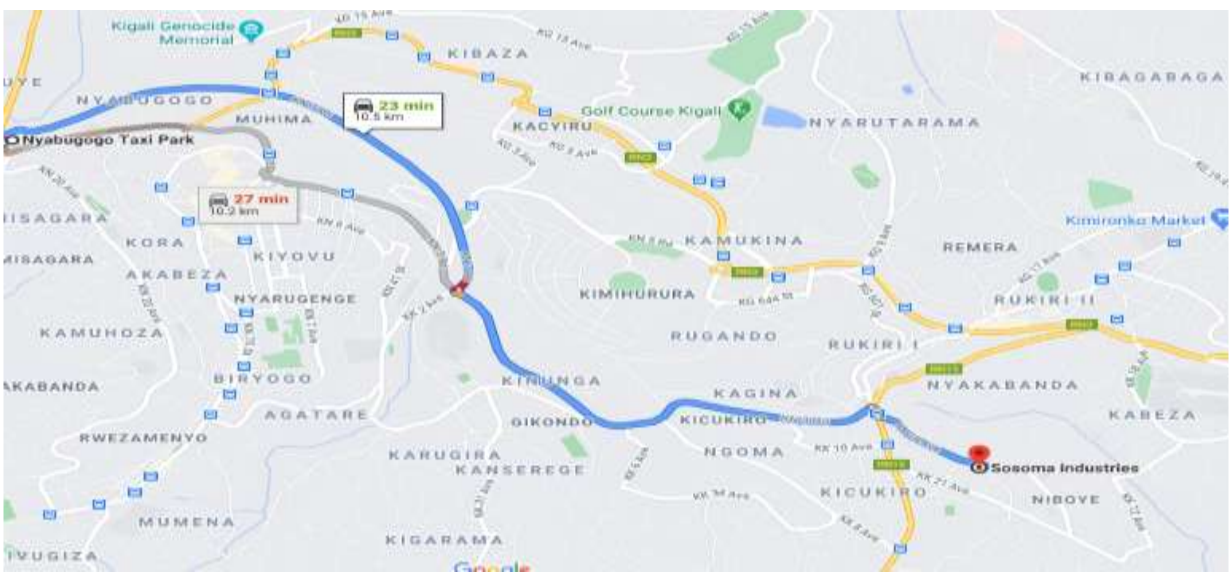

Figure 2: Location of the Research Project study area

3.3 Data Collection

Data gathering activity in the prescribe study area was conducted since November 2020 until February 2021. In order to get sufficient and relevant technical information and other engineering requirements about industrial oven, Data collection activity has been carried out and involved using the qualitative method approach. This approach facilitate the researcher to understand well the concepts of industrial oven, assumptions, and operation experiences with accessing industrial oven. Since data that are needed are related to understand well the working concepts, describes qualities or characteristics of the system, Thus various data collection techniques including unstructured interviews, discussion and field visit observation have been applied in order to achieve the specific requirements required to develop the proposed system (Kiger &Varpio, 2020).

3.4 Data Analysis Methods

Qualitative data gathered from unstructured interviews, discussion, and field visit observation were categorized and analyzed using content analysis technique just to figure out the requirements of the developed system (O'Connor & Gibson, 2003). Moreover, the findings were used to develop the proposed system.

3.5 Design of Industrial Oven Monitoring With an Exhaust System

3.5.1 Design Requirement of the System

Design requirement is basic task to consider when organizing for the development of embedded systems, specifically the system that related with implementation of physical environment. At this stage, to make decision there are several features to be considered during design including power consumptions, security, performance and costs. The system features were fetched through unstructured interviews with the production technical staff, administration staff, field visit observation, and research papers related to industrial oven monitoring with smoke exhaust system. The developed system to be implemented, Functional requirements outlines has been detailed together with non-functional requirements of the industrial oven monitoring with an exhaust system. Functional requirements designate the task of the system as a contribution for a certain conditions of industrial oven monitoring with an exhaust system while non-functional outlines complements effective qualities on the developed system.

(i) Functional Requirements

(a) If the temperature sensor has shown the increase of temperature on the LCD above 36℃ in the working space and the red indicator led light will notify the concerned person that in the industrial oven, wood fuel energy source have exceeded the require point.

(b) If the temperature sensor has shown normal temperature on the on the LCD, in the working space and the green indicator led light blink will notify the concerned person that the industrial oven energy source is perfect.

(c) If the temperature sensor has shown the decrease of temperature on the LCD below 18°C in the working space and the yellow indicator led light will notify the concerned person that the industrial oven needs wood fuel energy source.

(d) If the carbon monoxide sensor has detected carbon monoxide in chamber, the exhaust fan turns to bring fresh air and pull out pollutant air in the chamber.

(e) If the smoke sensor has detected smoke in the chamber, the exhaust fan turns to bring fresh air and pull out fumes in the chamber.

(ii) Non-Functional Requirements

(a) Communication: All the information is displayed on LCD so that employee can view the current state of the industrial oven.

(b) Accuracy: Since all the data are saved on local database, it must be detailed due for future analysis by researchers.

(c) Performance: Since it is there to monitor physical environment, it works on real time basis.

(d) Operational: The system work automatically and various modules are integrated together to provide a significant information.

(e) Cost: The cost of this system is normal and critical since each small-scale industry can afford it, and materials and components that is made, are available on the local market so that maintenance can be easily done.

3.5.2 System Design Approach

The developed system has five major parts as shown in the Fig. 3. Sensing part also referred as inputs part consists of a set of sensors to capture the real time environment and convert it into electrical signal that is easily processed by microcontroller. Those sensors are located within the chamber around industrial oven to capture and monitor levels of temperature, humidity, smoke, and carbon monoxide. The SPI protocol has been used for Data transfer part, Since It is suited for data transfers between integrated circuits located on the same PCB or neighboring PCBs inside the same device or system. Microcontroller part, a microcontroller is an integrated circuit device used for controlling different segments of an electronic framework, normally through a processor unit, memory, and both internal and external peripherals. Outputs part communicate with microntroller through SPI protocol, and consist of devices that can convert electrical signal into other form of energy.

(i) The System Operating Principle

The system operates by capturing real time environment using temperature, humidity, smoke and carbon monoxide sensors. Once those parameters are taken and processed by microcontroller, and the sensor output value are monitored on the LCD. Alert devices specifically LED and loudspeaker gives alert based on the sensor output. Smoke exhaust device control the level of smoke in the working environment based on smoke sensor output values.

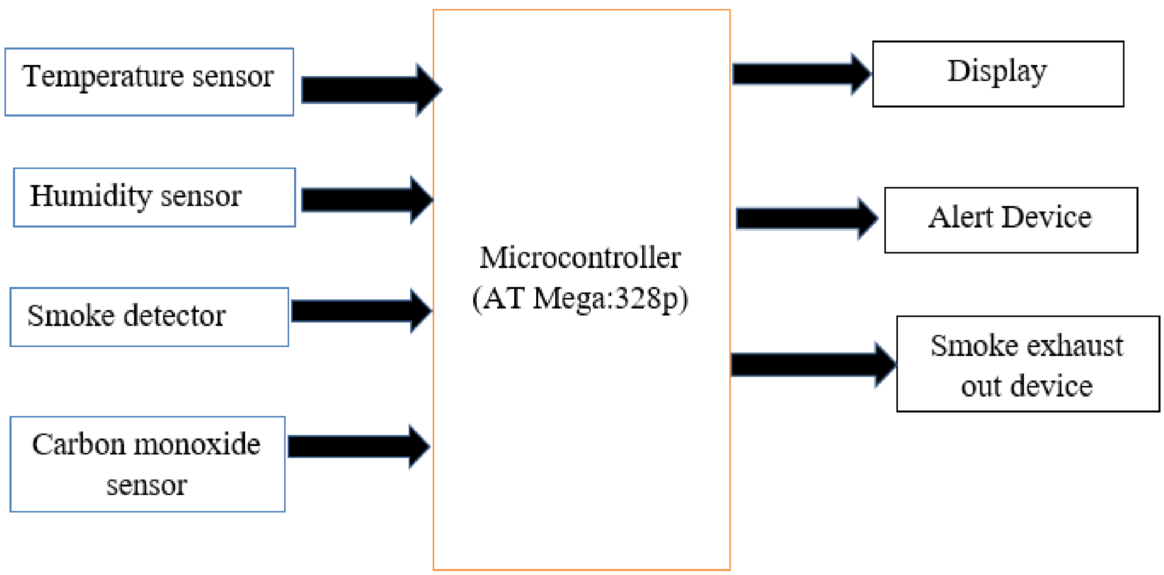

Figure 3: Conceptual system Design of the industrial oven monitoring with an exhaust system

3.6 System's Hardware Components and Technologies

During the implementation of the developed system, various technologies, electronics components, and high level programming languages were used. The system implementation approach of the project has been made of the following hardware components, technologies and software.

3.6.1 AT Mega 328p Microcontroller

It is a single-chip microcontroller which available in Arduino development board. It is manufactured by Atmel in the mega AVR family. It consists of 8-bit RISC processor core with a modified Harvard architecture. It is powered by a voltage in between 1.8v - 5.5 v. Input-output peripherals are both interfaced on it. Arduino is an improved development board with an open-source electronics platform in view of simple to utilize hardware and software. It can be programmed in the Arduino IDE and accepts SPI and UART communication protocols. It uses C and C++ programming languages to control and send a set of instructions to microcontroller (Atmega 328p) available on it (Zeyad *et al.*, 2019; Debele & Qian, 2020).

Figure 4: Arduino Development Board with Microcontroller (328P)

(i) The DHT 11 Temperature And Humidity Sensor

The DHT 11 has ability to measure both temperature and relative humidity simultaneously. It is powered by an electrical signal of voltage between 3v-5v. Humidity is the percentage of water present in the air. Vapor is Water that boiled above 100°C means it is water at gaseous state. More water vapor can be generated with the increments of the temperature in the air. Both Humidity and temperature measurement are necessary as they can affect the quality of the end product and the health and safety of the employee. Since humidity sensors are made of two electrical conductors with a non-conductive polymer film laying between them to create an electrical field between them are regarded as humidity sensors that use capacitive estimation approach to measure the quantity of moisture in the air. Moisture collected on the film from the air causes changes in the voltage levels between the two conductors. The change in resistance is proportional to the relative humidity which is then converted into a digital measurement. Temperature sensor also use the same principle as humidity sensor to capture temperature in the environment.

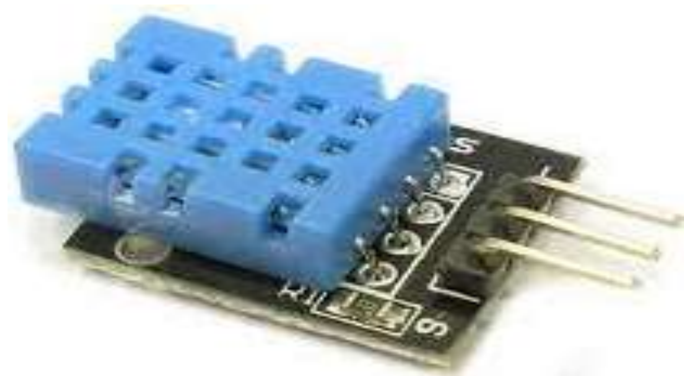

Figure 5: The DT11 (Temperature and humidity sensor)

(ii) The MQ2 Smoke detector

The MQ2 smoke sensor is also known as chemiresistor. It is powered by an electrical signal of 5v voltage. It measures the concentration of smoke within atmosphere. The sensor serves as a reference point and scale, delivering a measurable electric current when a chemical reaction caused by a smoke occurs. It contains a sensing elements whose resistance changes when it comes in contact with the smoke. This change in the value of resistance is used for the detection of smoke and can detect smoke particles in the concentration of range 200 to 10 000 ppm. It is also used for the detection of various gases like propane, methane, hydrogen, and alcohol (Panpaeng *et al.*, 2018).

Figure 6: The MQ2 (smoke detector)

(iii) The MQ7 Carbon monoxide sensor

The MQ7 carbon monoxide sensor is one of MQ family sensor. It is powered by an electrical signal of 5v voltage. It measures the concentration of carbon monoxide in the atmosphere. It shows lower conductivity in clean air. It contains a sensing material specifically silicon dioxide (SnO_2) whose resistance changes when it comes in contact with the carbon monoxide. Cycle high and low temperature method, is used for the detection of carbon monoxide and is proportional to the temperature. The change in temperature conductivity correspond to digital output signal of carbon monoxide concentration (Zaiedi, 2015).

Figure 7: The MQ7 (Carbon Monoxide detector)

(iv) The 16X4 LCD Display

The LCD screen is used to display physical environment parameters through the communication between sensors and microcontroller. It is powered by an electrical signal of 5v voltage. The 16x4 LCD, it has 16 columns and 4 rows, and is used to display temperature, humidity, smoke level, and carbon monoxide level information on the screen (Ge & Wu, 2010; Zhao *et al.*, 2012).

Figure 8: Liquid Crystal Display

(v) Exhaust Fan

The fan consists of the dc motor that run on 5v DC voltage, and it turn its blades to pull pollutant air such as fumes, smoke and carbon monoxide out of the space when received an electrical signal from the microntroller (Najibullah *et al.*, 2019).

Figure 9: Ventilation Fan

(vi) Light Emitting Diodes

Light Emitting Diodes (LEDS) are semiconductors light source of two pin connections that emits light when electrical signal flows through it from microcontroller. It is powered by 0.3v voltage. Depends on state of working space, LEDS are used as warning lights indicator (Abbyasovich & Kamilevna, 2020).

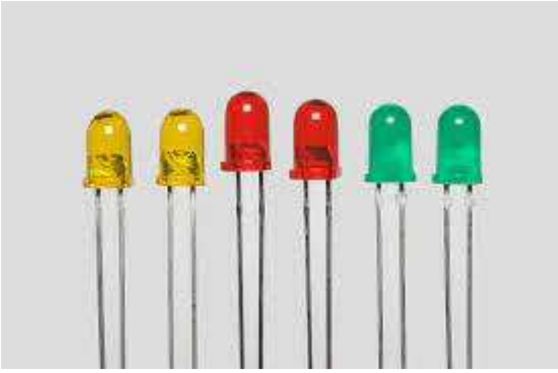

Figure 10: Light Emitting Diode

(vii) Buzzer

It is an electromechanical Device which acts as an alarm. It produces an audio signal when received an electrical from microcontroller (Dqg *et al.*, nd).

Figure 11: Electromechanical Buzzer

(viii) Breadboard

It is constructed in plastics as insulator and copper as conductor. It is used in prototyping of electronics especially during the designing and testing embedded electronic circuit. it is made with two columns, one is power source and other is for ground (Tawfik *et al.*, 2013).

Figure 12: Breadboard

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

This section presents simulation, testing, and the implementation results of the entire industrial ovens monitoring with an exhaust system just to assess the system operations in the real environment. To achieve the main and specific objectives, system requirements formulation, system designing and development has been discussed in details. Simulation and Testing as the fundamental stages in any system development Research Project have been used to guarantee the system has been designed right according to company goals, requirements, specification such that when set in its anticipated environment, must full fill their expectation.

4.2 Research Project Results from the Simulator

Simulation of the Research Project results (Fig. 13) have been done in Proteus software simulator as one of fundamental stages in any system development. The Proteus simulator software is a software tool with the powerful features that mainly used by electronic design engineers and technicians in electronic design automation. It enables them fast design, test and layout of PCB. Generally, the system circuit consist of four parts which are the following: Inputs, Microcontroller, Output parts and the Powers source. The system is supplied by the power source of 5v voltage as well, the system is grounded in order to protect it from high current and extra charges. The inputs part composed by temperature and humidity sensor, smoke sensor, and carbon monoxide sensor. The microcontroller is embedded on Arduino Uno development board, and is programmed through the Arduino IDE which support C and C++ programming languages. It uses SPI protocol to communicate with peripheral. The output part is composed by leds indication lights, buzzers with NPN transistor as amplifier, oven system with relay which acts as a switch, and ventilation fan with a relay also.

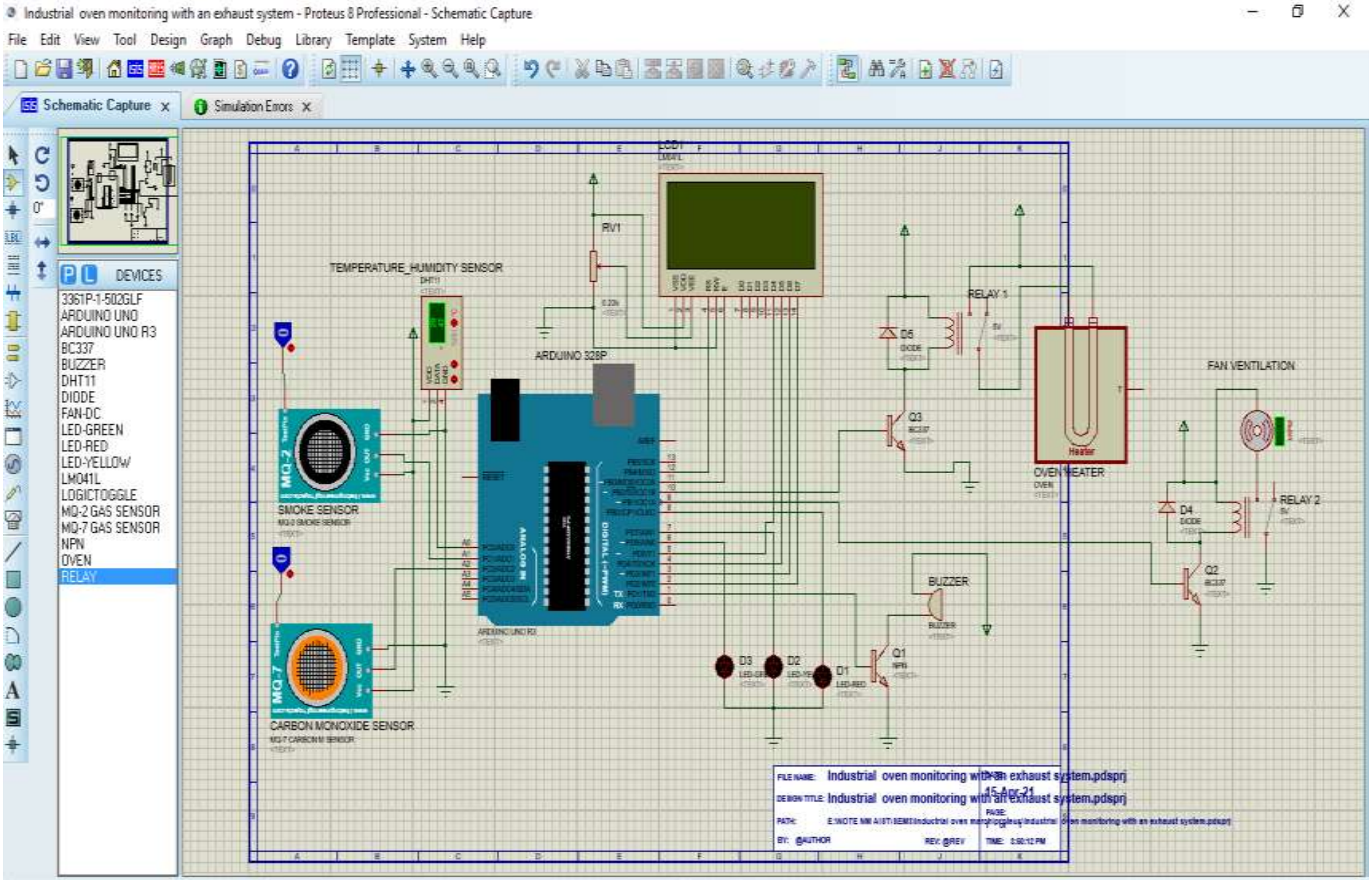

Figure 13: System Design in Proteus Simulator

4.2.1 Normal Function of the System

The Fig. 14 shows the system in normal function. It means there are no presence of both smoke and carbon monoxide in the working space. It shows clear, green led as indication light blink and no alarm is sounding as notifications. But also both temperature and humidity are favorable that is why the ventilation fan turns off since the working space is safe.

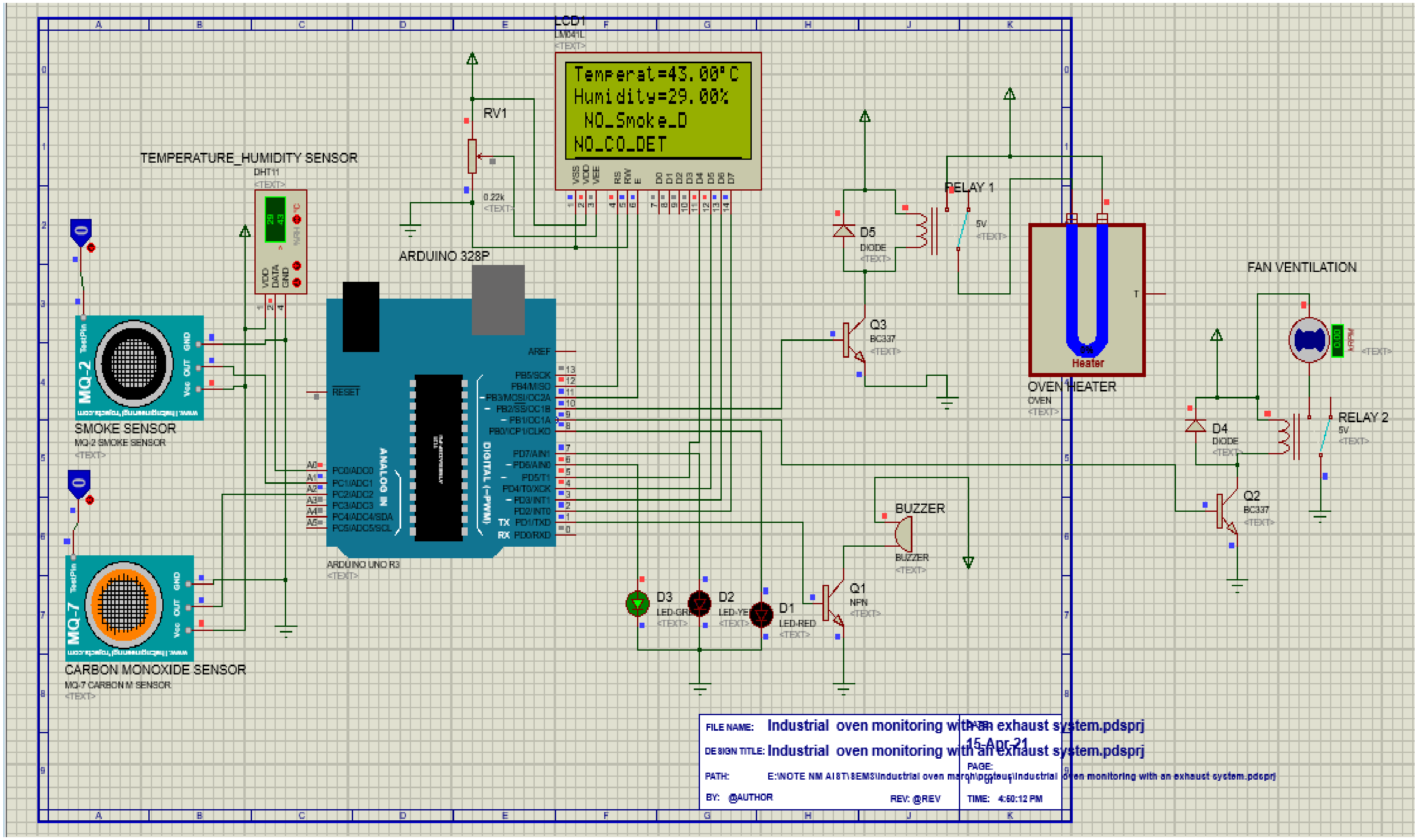

Figure 14: Normal function of the system simulation

4.2.2 Smoke Detection

The simulation has been done with refer to the functional requirements of the system. The Fig. 15 shows the detection of smoke. It shows clear, once smoke is detected, red led indication light blink and an alarm is sounding as notifications, but also the ventilation turns fast in order to push out the flames with exchange of pulling flesh air in the working space.

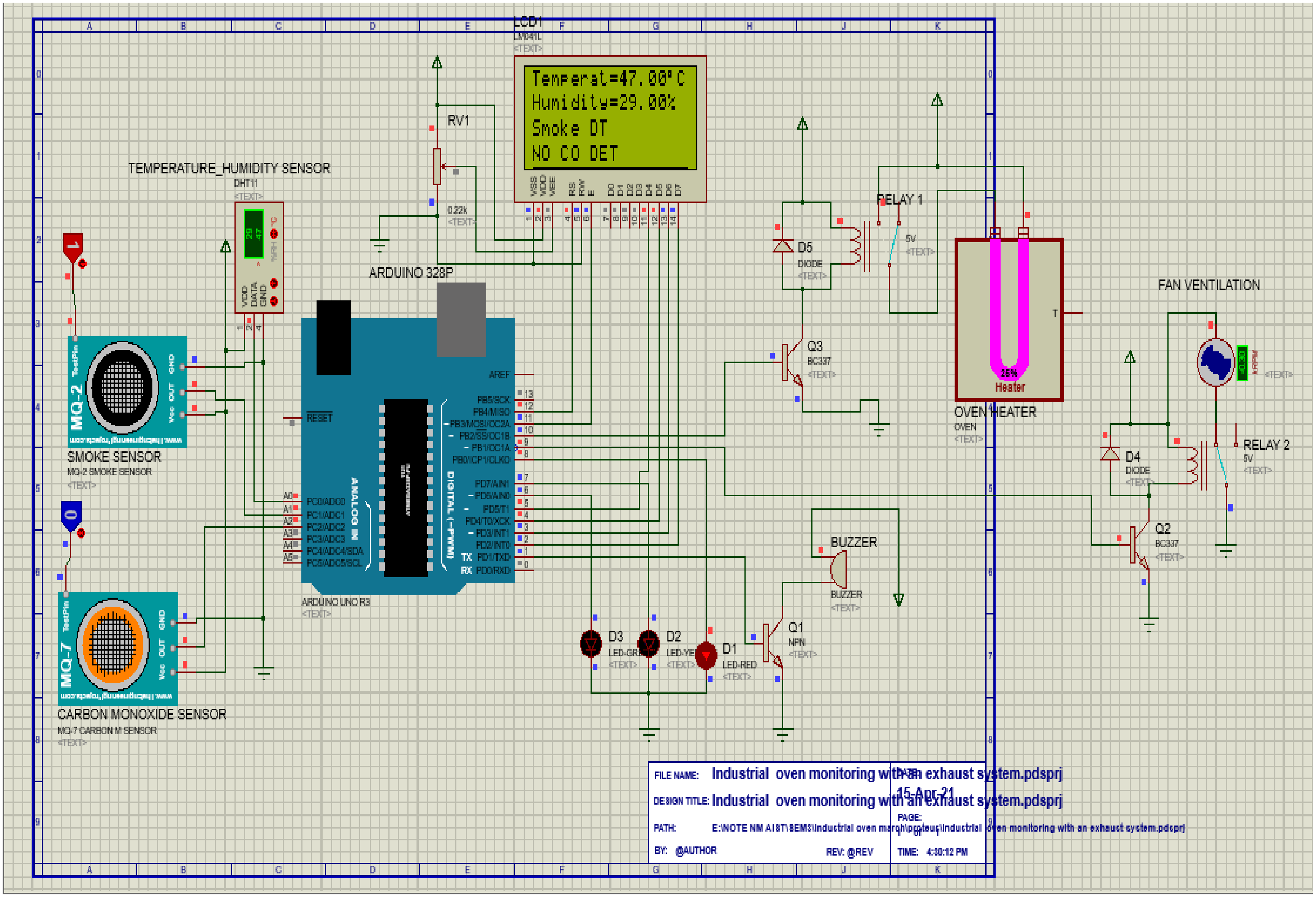

Figure 15: Smoke Detection simulation

4.2.3 Carbon Monoxide Detection

The Fig. 16 shows the detection of carbon monoxide. It shows clear, once carbon monoxide is detected, yellow led indication light blink and an alarm is sounding as notifications, but also the ventilation turns fast in order to pull flesh air in the working space. Remember, the presence of CO cause insufficient of oxygen in the working space that is why fan is there to bring fresh air in case of presence CO.

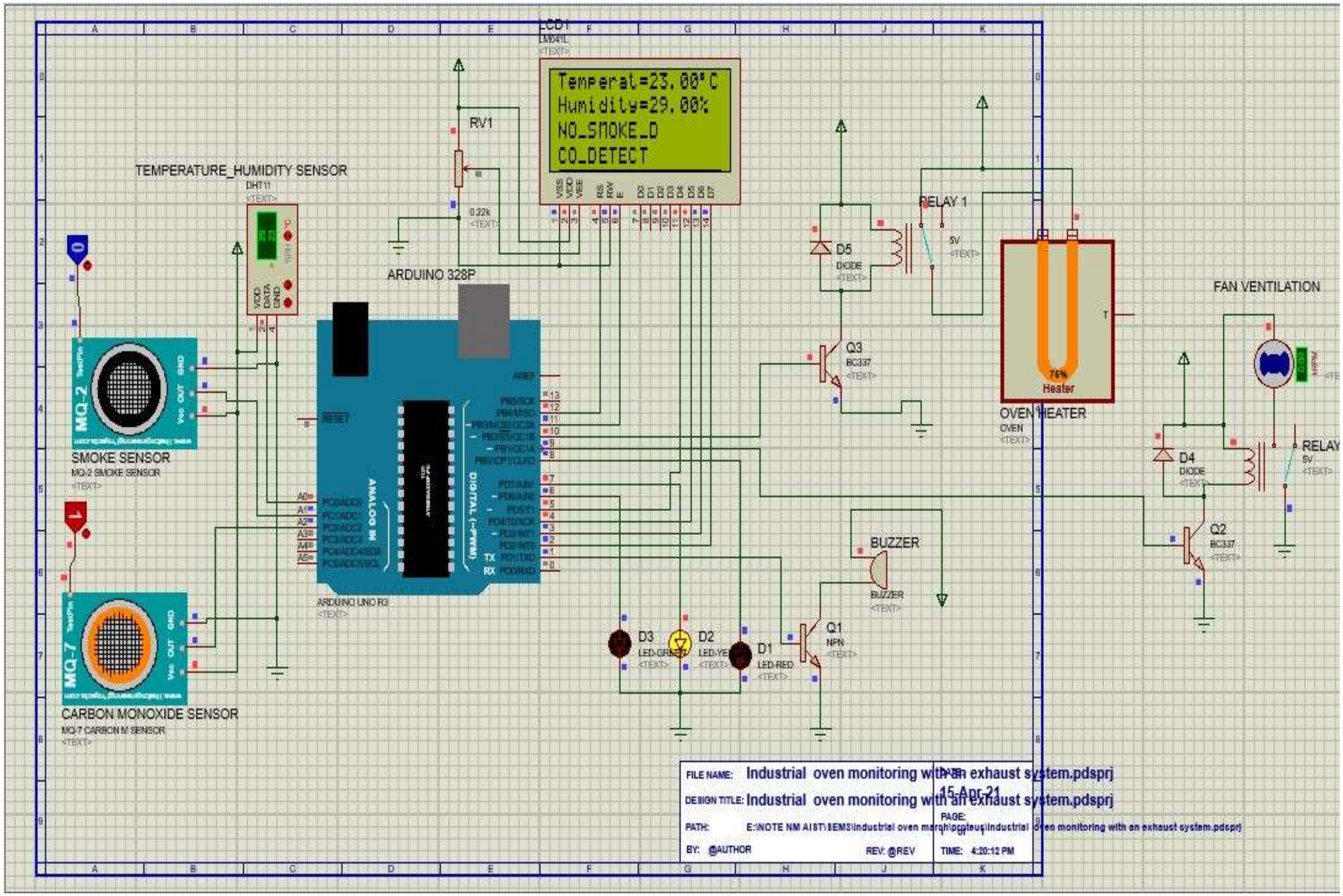

Figure 16: **Carbon Monoxide Detection Simulation**

4.2.4 Heat under Normal Condition of the Oven

The Fig. 17 shows the system function in the under normal condition. It means there are no presence of both smoke and carbon monoxide in the working space. It shows clear, yellow led as indication light blink and alarm is sounding as notifications because in the oven need more wood fuel as energy source that produce heat in it, but both temperature and humidity are lower the normal condition that is why the ventilation fan turns off since the working space need heat instead of fresh air.

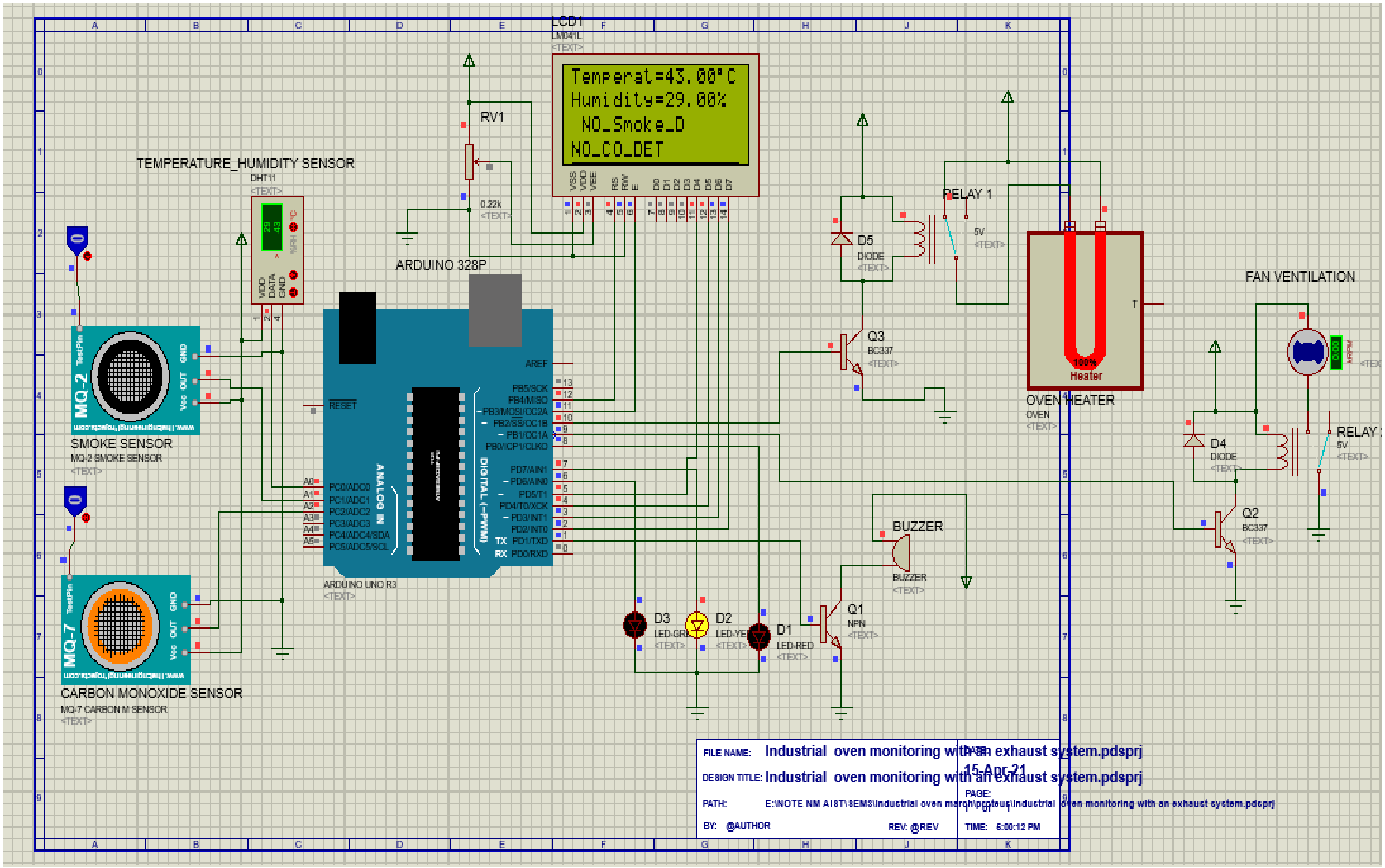

Figure 17: **Under normal function of the system**

4.2.5 Heat over normal condition of the oven

Figure 18 shows the system function in the over normal condition. It means there are no presence of both smoke and carbon monoxide in the working space. It shows clear, red led as indication light blink and alarm is sounding as notifications because in the oven has more wood fuel as energy source that produce heat which needs to be reduced. But both temperature and humidity exceeded the normal condition that is why the ventilation fan turns on in order to bring fresh air and exhaust hot air in the working space.

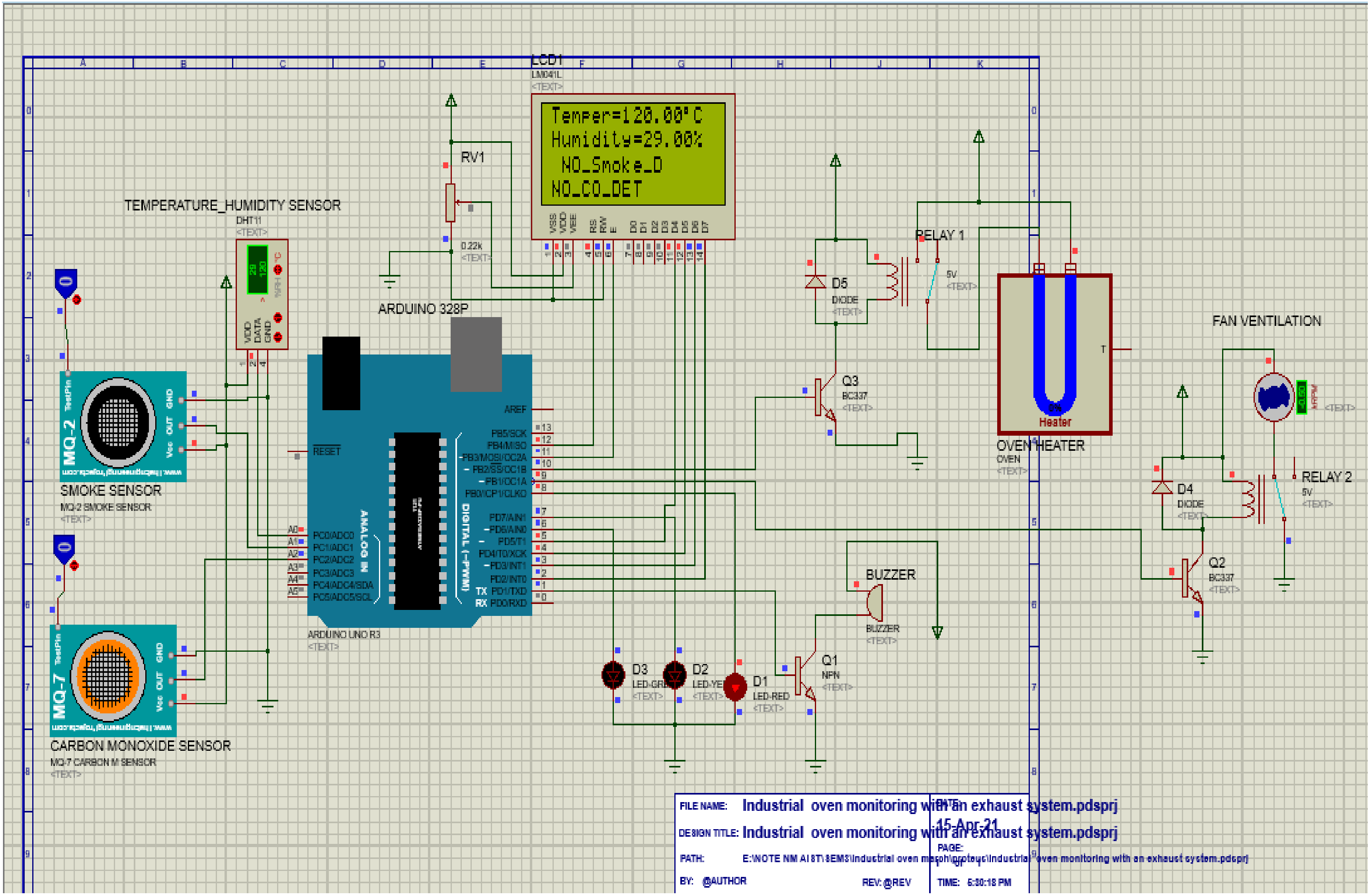

Figure 18: Over Normal function of the system

4.3 System Implementation

Industrial oven monitoring with an exhaust System has implemented by combining the hardware components and software. Hardware parts is composed of sensors as inputs devices, Microcontroller, output devices, jumper wires, and breadboard. Software part is made by Arduino IDE and support c, c++ high level languages. Inputs devices has made of various sensors with capture the physical environment. As it is displayed on the LCD, it shows real time value of surrounding temperature, relative humidity, smoke level and carbon monoxide level which are expressed in ppm. The Fig. 19 shows the implemented system.

Figure 19: Industrial oven monitoring with an Exhaust system

The SPI protocol has been used as a communication protocol between microcontroller and its peripherals. The program instructions have been written using Arduino IDE and uploaded into the microcontroller which is attached on Arduino development Board. It is an open source and is Programmed with the use of Arduino IDE installed in the computer. It uses universal serial port to communicate with microcontroller. The Fig. 20 shows sample program instructions composed in the Arduino IDE.

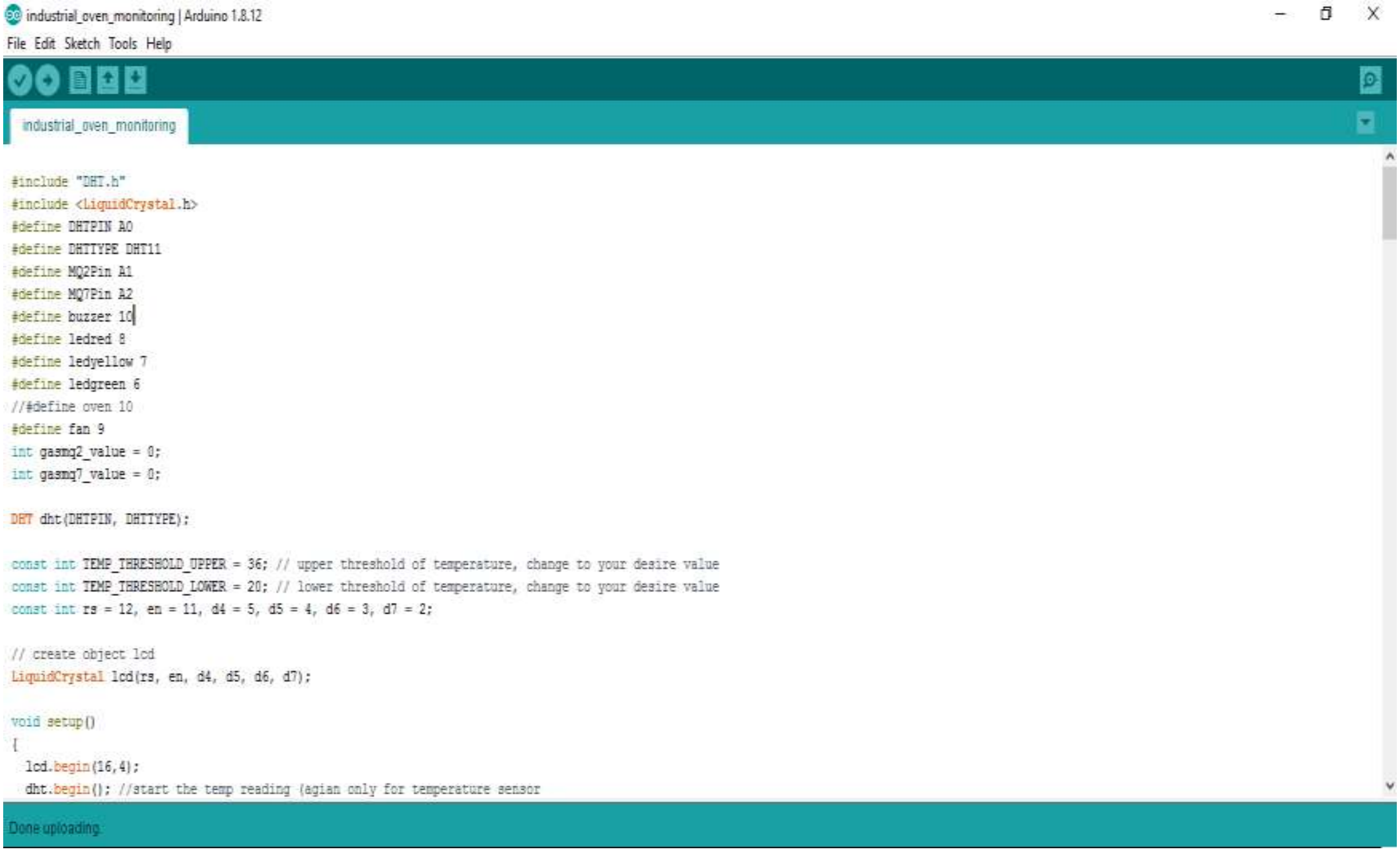

Figure 20: Sample Program Instructions of the system

The industrial oven monitoring with an Exhaust system control the oven under various condition which are: normal functions of the system, detection of the smoke, detection of carbon monoxide, heat under normal condition of the ovens, and heat over normal condition of the ovens. Detail results on each condition is similar as the one found in the proteus software simulator during testing. The Fig. 21 shows a case when the system detects smoke. It is clear that, once system detects smoke, the number of ppm increase fast. The red led blink as notification, buzzer play sound as an alarm, and ventilation fan run in order to exhaust out the smoke and pull fresh air in the working environment until the system return on the normal condition.

Figure 21: Case of smoke detection by the system

4.4 System Testing and Validation

Testing and validation has been done to guarantee the reliability and effectiveness of the system performance. It is intended to check whether it is made as per company functional requirements and comply the company standards when ready to be installed in the working environment. During the implementation of the industrial oven monitoring with an exhaust system, inspection of the system performance and validity has done with the help of various testing proceedings.

4.4.1 Unit Testing

Unit testing target to test each piece of electronic component independently. During code development, it important to ensure the program code that it meets its requirements by setting apart each piece and testing if it works perfectly. In this project, unit testing has been performed to check whether each module of electronic component works effectively before connecting to others modules of the system. The electronic component modules that has been checked include DHT 11, MQ2, MQ7, and LCD (Mukkavilli, 2012).

4.4.2 Integration Testing

Integration testing is done by connecting together each piece of modules that have been tested separately. It is performed after completing the unit testing. It targets to check data communication between the modules and to conclude whether each module is still functioning well after integrating together with other components. In this project, the integration testing has been performed to inspect whether the entire electronic component modules are functioning effectively and the communication between them are done appropriately. Through SPI communication protocols, the electronic component modules that has been checked include all sensors, and output devices (Kara, 2014).

4.4.3 System Testing

The system test has been performed to test the entire system by checking if all the integrated modules are performing tasks effectively and efficiently. It is also tested to check whether the functional and nonfunctional requirements are complementing each other within the system (Mourad & McCluskey, 1988; Ernst *et al.,* 1989).

CHAPTER FIVE

CONCLUSSION AND RECOMMENDATIONS

5.1 Conclusion

This Research Project shows an approach for industrial oven monitoring with an exhaust system. It has been designed using both Engineering and production requirements from the administration staff of the industry, and it is tested using proteus software simulator made by Lab center to enable fast electronic circuit design and automation, test and layout of PCB. Moreover, it is implemented using different kinds of sensors regarded as inputs devices, Microcontroller, SPI protocols, and outputs devices. The developed system is able to monitor in real time the crucial parameters of the system which are temperature, humidity, smoke level and carbon monoxide level. In food processing industry domain where an employee played a role for monitoring and controlling, Automatism of the developed system in monitoring and controlling can bring a significant contribution in it.

Since all parameters of the system can be monitored simultaneously, As the main objective of this Research Project was to develop a system to improve employees' health and creating safe working environment has been achieved. Due to real time monitoring and controlling of the developed system, has presented an added benefit such as reduction of wood fuel energy consumed with an increase of end product quality.

5.2 Recommendations

Production process in food processing industry involves many processing sub departments and stages. Each sub department and stages has an employee in charges. As this Research Project was focus on industrial oven monitoring which located in roasting sub department that is where is only full automatic, and other sub departments remain using traditional method. In order to speed up production process in all sub departments and make it fully automatic. It is necessary for the process engineers' developer to interact with both product operator and technicians from all sub departments during all the phases of an improvement.

This Research Project has targeted to monitor and control of a physical environment in the working chamber including temperature, humidity, smoke and carbon monoxide levels. Based on the trending technologies, internet of things can also be included in monitoring and visualizing industrial oven data. It does not deal with the quality of product, which is flour in the case of this

Research Project. For future improvement, the quality of flour need its own automatic system to monitor quality of product. Image processing technologies can help to determine flour’s quality.

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APPENDICES

Appendix 1: Sample Code used to Develop the System

```
#include "DHT.h"

#include <LiquidCrystal.h>

#define DHTPIN A0

#define DHTTYPE DHT11

#define MQ2Pin A1

#define MQ7Pin A2

#define buzzer 10

#define ledred 8

#define ledyellow 7

#define ledgreen 6

//#define oven 10

#define fan 9

int gasmq2_value = 0;

int gasmq7_value = 0;

DHT dht(DHTPIN, DHTTYPE);

const int TEMP_THRESHOLD_UPPER = 36; // upper limit of temperature, change to your
craving esteem

const int TEMP_THRESHOLD_LOWER = 20; // lower limit of temperature, change to your
longing esteem

const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

// create object lcdd

LiquidCrystal lcdd(rs, en, d4, d5, d6, d7);

void setup()

{

  lcdd.begin(16,4);

  dht.begin(); // begin the temp perusing (agian just for sensing temperatures

  pinMode(MQ2Pin , INPUT_PULLUP);

  pinMode(MQ7Pin , INPUT_PULLUP);

  pinMode(buzzer, OUTPUT);
```

```
  pinMode(ledred, OUTPUT);
  pinMode(ledyellow, OUTPUT);
  pinMode(ledgreen, OUTPUT);
  //pinMode(oven, OUTPUT)
  pinMode(fan, OUTPUT);

}
void loop(){

  // start reading  the temperatures and humidities from dht11
  float h = dht.readHumidity();
  float t = dht.readTemperature();
  gasmq2_value = analogRead(MQ2Pin);
  gasmq7_value = analogRead(MQ7Pin);
 if (isnan(t)&& isnan(h)) {
    lcdd.clear();
    lcdd.setCursor(0,0);
    lcdd.print("Failed!");
  }
  // normal working condition of the system
else if ((t < TEMP_THRESHOLD_UPPER)&& (t > TEMP_THRESHOLD_LOWER)){
    digitalWrite(buzzer, 0);
    digitalWrite(ledgreen, 1);
    digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 0);
    digitalWrite(fan, LOW);

    lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
```

```
lcdd.print("%");
lcdd.setCursor(0,0);
lcdd.print("Temperat=");   //temperature (C)
lcdd.print(t);   //temperature (C)
lcdd.print( (char)223); // symbol for degree Celsius  (°).
lcdd.print("C");
lcdd.setCursor(5,2);
lcdd.print("SMOKE_level=");
lcdd.print(gasmq2_value);//humidity
lcdd.print("ppm");
lcdd.setCursor(5,3);
lcdd.print("Carbon M= ");
lcdd.print(gasmq7_value);//humidity
lcdd.print("ppm");

if ((gasmq2_value > 470)|| (gasmq7_value>250)){
digitalWrite(buzzer, 1);
digitalWrite(ledgreen, 0);
digitalWrite(ledyellow, 1);
digitalWrite(ledred, 1);
digitalWrite(fan, 1);
 }

 else {
 digitalWrite(buzzer, 0);
digitalWrite(ledgreen, 1);
digitalWrite(ledyellow, 1);
digitalWrite(ledred, 0);
digitalWrite(fan, 0);
 }
 delay(1000);
```

```
     }

else if ((t > 100)&& (t > TEMP_THRESHOLD_LOWER)){
    digitalWrite(buzzer, 1);
    digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 0);
    digitalWrite(ledred, 1);
    digitalWrite(fan, 1);
     lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcdd.setCursor(0,0);
    lcdd.print("Temperat=");   //temperature (C)
    lcdd.print(t);   //temperature (C)
    lcdd.print( (char)223); //  symbol for degree celsius (°).
    lcdd.print("C");
    lcdd.setCursor(5,2);
    lcdd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
    lcdd.print("ppm");
    delay(1000);

}

   else if ((t > TEMP_THRESHOLD_UPPER)&& (t > TEMP_THRESHOLD_LOWER)){
```

```
    digitalWrite(buzzer, 1);
    digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 0);
    digitalWrite(ledred, 1);
    digitalWrite(fan, 1);
     lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcd.setCursor(0,0);
    lcd.print("Temperat=");   //temperature (C)
    lcd.print(t);   //temperature (C)
    lcd.print( (char)223); //  symbol for degree celsius (°).
    lcd.print("C");
    lcd.setCursor(5,2);
    lcddd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
    lcdd.print("ppm");
    delay(1000);

}
//undernormal condition of the oven
else if ((t < TEMP_THRESHOLD_UPPER)&& (t < TEMP_THRESHOLD_LOWER)){

    digitalWrite(buzzer, 0);
```

```
    digitalWrite(ledgreen, 0);
    digitalWrite(ledred, 1);
    digitalWrite(fan, 0);
    lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcdd.setCursor(0,0);
    lcdd.print("Temperat=");   //temperature (C)
    lcdd.print(t);   //temperature (C)
    lcdd.print( (char)223); // symbol for degree celsius (°).
    lcdd.print("C");
    lcdd.setCursor(5,2);
    lcdd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
    lcdd.print("ppm");

if ((gasmq2_value > 200)|| (gasmq7_value>200)){
    digitalWrite(buzzer, 1);
    digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 1);
    digitalWrite(fan, 1);
     }
     else {
     digitalWrite(buzzer, 0);
```

```
    digitalWrite(ledgreen, 1);
    digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 0);
    digitalWrite(fan, 0);
     }
   delay(1000);
}

else  {

    digitalWrite(buzzer, 0);
     digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 0);
    digitalWrite(ledred, 1);
     lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcdd.setCursor(0,0);
    lcdd.print("Temperat=");   //temperature (C)
    lcdd.print(t);   //temperature (C)
    lcdd.print( (char)223); // symbol for degree celsius (°).
    lcdd.print("C");
    lcdd.setCursor(5,2);
    lcdd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
```

```
    lcdd.print("ppm");
    delay(1000);
}
}
```

Appendix 2: Sample Testing Code of Proteus

```
#include "DHT.h"
#include <LiquidCrystal.h>
#define DHTPIN A0
#define DHTTYPE DHT11
#define MQ2Pin A1
#define MQ7Pin A2
#define buzzer 10
#define ledred 8
#define ledyellow 7
#define ledgreen 6
//#define oven 10
#define fan 9
int gasmq2_value = 0;
int gasmq7_value = 0;

DHT dht(DHTPIN, DHTTYPE);

const int TEMP_THRESHOLD_UPPER = 36; // upper threshold of temperature, change to your desire
value
const int TEMP_THRESHOLD_LOWER = 20; // lower threshold of temperature, change to your desire
value
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

// create object lcdd
LiquidCrystal lcdd(rs, en, d4, d5, d6, d7);

void setup()
{
  lcdd.begin(16,4);
  dht.begin(); //start the temp reading (agian only for temperature sensor
  pinMode(MQ2Pin , INPUT_PULLUP);
  pinMode(MQ7Pin , INPUT_PULLUP);
```

```
  pinMode(buzzer, OUTPUT);
  pinMode(ledred, OUTPUT);
  pinMode(ledyellow, OUTPUT);
  pinMode(ledgreen, OUTPUT);
  //pinMode(oven, OUTPUT)
  pinMode(fan, OUTPUT);

}
void loop(){

  //read the temperature and humidity (temperature sensor specific code)
  float h = dht.readHumidity(); //read humidity
  float t = dht.readTemperature(); //read temperature (C)
  gasmq2_value = analogRead(MQ2Pin);
  gasmq7_value = analogRead(MQ7Pin);

 if (isnan(t)&& isnan(h)) {
    lcdd.clear();
    lcdd.setCursor(0,0);
    lcdd.print("Failed!");
  }
  // normal working condition of the system
else if ((t < TEMP_THRESHOLD_UPPER)&& (t > TEMP_THRESHOLD_LOWER)){
    digitalWrite(buzzer, 0);
    digitalWrite(ledgreen, 1);
    digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 0);
    //digitalWrite(oven, 1);
    digitalWrite(fan, 0);

    lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
```

```
lcdd.print(h);//humidity
lcdd.print("%");
lcdd.setCursor(0,0);
lcdd.print("Temperat=");   //temperature (C)
lcdd.print(t);   //temperature (C)
lcdd.print( (char)223); // displaying degree symbol (°).
lcdd.print("C");
lcdd.setCursor(5,2);
lcdd.print("SMOKE_level=");
lcdd.print(gasmq2_value);//humidity
lcdd.print("ppm");
lcdd.setCursor(5,3);
lcdd.print("Carbon M= ");
lcdd.print(gasmq7_value);//humidity
lcdd.print("ppm");

if ((gasmq2_value > 470)|| (gasmq7_value>250)){
digitalWrite(buzzer, 1);
digitalWrite(ledgreen, 0);
digitalWrite(ledyellow, 1);
digitalWrite(ledred, 1);
//digitalWrite(oven, 1);
digitalWrite(fan, 1);
 }

 else {
 digitalWrite(buzzer, 0);
digitalWrite(ledgreen, 1);
digitalWrite(ledyellow, 1);
digitalWrite(ledred, 0);
//digitalWrite(oven, 1);
digitalWrite(fan, 0);
 }
```

```
    delay(1000);
    }

else if ((t > 100)&& (t > TEMP_THRESHOLD_LOWER)){
   digitalWrite(buzzer, 1);
   digitalWrite(ledgreen, 0);
   digitalWrite(ledyellow, 0);
   digitalWrite(ledred, 1);
   //digitalWrite(oven, 0);
   digitalWrite(fan, 1);
    lcdd.clear();
   lcdd.setCursor(0,1);
   lcdd.print("Humidity=");//humidity
   lcdd.print(h);//humidity
   lcdd.print("%");
   lcdd.setCursor(0,0);
   lcdd.print("Temperat=");   //temperature (C)
   lcdd.print(t);   //temperature (C)
   lcdd.print( (char)223); // displaying degree symbol (°).
   lcdd.print("C");
   lcdd.setCursor(5,2);
   lcdd.print("SMOKE_level=");
   lcdd.print(gasmq2_value);//humidity
   lcdd.print("ppm");
   lcdd.setCursor(5,3);
   lcdd.print("Carbon M= ");
   lcdd.print(gasmq7_value);//humidity
   lcdd.print("ppm");
   delay(1000);

}

  else if ((t > TEMP_THRESHOLD_UPPER)&& (t > TEMP_THRESHOLD_LOWER)){
```

```
    digitalWrite(buzzer, 1);
    digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 0);
    digitalWrite(ledred, 1);
    //digitalWrite(oven, 0);
    digitalWrite(fan, 1);
     lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcdd.setCursor(0,0);
    lcdd.print("Temperat=");   //temperature (C)
    lcdd.print(t);   //temperature (C)
    lcdd.print( (char)223); // displaying degree symbol (°).
    lcdd.print("C");
    lcdd.setCursor(5,2);
    lcdd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
    lcdd.print("ppm");
    delay(1000);


}
//undernormal condition of the oven
else if ((t < TEMP_THRESHOLD_UPPER)&& (t < TEMP_THRESHOLD_LOWER)){


    digitalWrite(buzzer, 0);
    digitalWrite(ledgreen, 0);
```

```
    //digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 1);
    //digitalWrite(oven, 1);
    digitalWrite(fan, 0);
    lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcdd.setCursor(0,0);
    lcdd.print("Temperat=");   //temperature (C)
    lcdd.print(t);   //temperature (C)
    lcdd.print( (char)223); // displaying degree symbol (°).
    lcdd.print("C");
    lcdd.setCursor(5,2);
    lcdd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
    lcdd.print("ppm");

if ((gasmq2_value > 200)|| (gasmq7_value>200)){
    digitalWrite(buzzer, 1);
    digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 1);
    //digitalWrite(oven, 1);
    digitalWrite(fan, 1);
     }

     else {
```

```
     digitalWrite(buzzer, 0);
    digitalWrite(ledgreen, 1);
    digitalWrite(ledyellow, 1);
    digitalWrite(ledred, 0);
    //digitalWrite(oven, 1);
    digitalWrite(fan, 0);
     }
   delay(1000);
}

else  {

    digitalWrite(buzzer, 0);
     digitalWrite(ledgreen, 0);
    digitalWrite(ledyellow, 0);
    digitalWrite(ledred, 1);
     lcdd.clear();
    lcdd.setCursor(0,1);
    lcdd.print("Humidity=");//humidity
    lcdd.print(h);//humidity
    lcdd.print("%");
    lcdd.setCursor(0,0);
    lcdd.print("Temperat=");   //temperature (C)
    lcdd.print(t);   //temperature (C)
    lcdd.print( (char)223); // displaying degree symbol (°).
    lcdd.print("C");
    lcdd.setCursor(5,2);
    lcdd.print("SMOKE_level=");
    lcdd.print(gasmq2_value);//humidity
    lcdd.print("ppm");
    lcdd.setCursor(5,3);
    lcdd.print("Carbon M= ");
    lcdd.print(gasmq7_value);//humidity
```

```
  lcdd.print("ppm");
  delay(1000);
}
}

#include "DHT.h"
#include <LiquidCrystal.h>
#define DHTPIN A0
#define DHTTYPE DHT11
#define MQ2Pin A1
#define MQ7Pin A2
#define buzzer 10
#define ledred 8
#define ledyellow 7
#define ledgreen 6
//#define oven 10
#define fan 9
int gasmq2_value = 0;
int gasmq7_value = 0;
DHT dht(DHTPIN, DHTTYPE);
const int TEMP_THRESHOLD_UPPER = 36; // upper threshold of temperature, change to your
desire value
const int TEMP_THRESHOLD_LOWER = 20; // lower threshold of temperature, change to your
desire value
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
// create object lcdd
LiquidCrystal lcdd(rs, en, d4, d5, d6, d7);
```

POSTER PRESENTATION