TITANIUM DIOXIDE GAS SENSOR FOR MONITORING CARBON DIOXIDE WITH IOT

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

2022

DECLARATION

I declare that this report entitled "Titanium Dioxide Gas Sensor for Monitoring Carbon Dioxide with IoT" is the result of my own work except for quotes as cited in the references.

Signature : ....

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Date : 11/1/2022

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : ....

Supervisor Name : DR. SITI AMANIAH BINTI MOHD CHACHULI

Date : 12 JAN 2022

DEDICATION

For my beloved family, friends, supervisor, and lecturers for helping and supporting me during my studies.

ABSTRACT

Nowadays, the dramatic changes in the evolution of technology have immense opportunities to raise the standard of living for people. Technology's efficiency and convenient lifestyle let society appreciate its existence and turn it into a valuable civilization. The main objectives for the advancement of technology are to achieve high accuracy, high sensitivity, and faster response towards detecting the carbon dioxide gas concentration. A higher level of carbon dioxide gas concentration will be harmful to humans. Gas sensors are needed to ensure carbon dioxide gas concentration in real-time by implementing the Internet of Things (IoT). As a result, the sensors to be tested will be able to focus on the detection of gas at certain concentrations. To assure the functionality of the project, the early and end look of the gas sensor was designed before being fabricated by using the screen-printing method. The current gas sensor can be modified by adding the electronics feature to the design of this project. The electronic parts will monitor the gas sensor's performance towards different concentration acts upon the sensor.

ABSTRAK

Pada masa kini, perubahan dramatik dalam evolusi teknologi mempunyai peluang besar untuk meningkatkan kualiti hidup manusia. Kecekapan dan gaya hidup mudah yang disediakan oleh teknologi membolehkan masyarakat menghargai kewujudannya dan mengubahnya menjadi tamadun yang berharga. Objektif utama untuk kemajuan teknologi adalah untuk mencapai ketepatan yang tinggi, kepekaan yang tinggi, dan tindak balas yang lebih pantas terhadap pengesanan kepekatan gas karbon dioksida. Tahap kepekatan gas karbon dioksida yang lebih tinggi akan memudaratkan manusia. Penderia gas diperlukan untuk memastikan kepekatan gas karbon dioksida pada masa nyata dengan melaksanakan Internet of Things (IoT). Hasilnya, penderia yang akan diuji akan dapat memfokuskan pada pengesanan gas pada kepekatan tertentu. Untuk memastikan kefungsian projek, rupa awal dan akhir penderia gas telah direka bentuk sebelum dibuat dengan menggunakan kaedah percetakan skrin. Untuk menambah baik penderia gas semasa, ciri elektronik ditambah dalam reka bentuk projek ini. Bahagian elektronik akan digunakan untuk memantau prestasi penderia gas terhadap tindakan kepekatan yang berbeza pada penderia.

ACKNOWLEDGEMENTS

Alhamdulillah, thanks to Allah for making me perform this Final Year Project together with my supervisor and finish it.

First, I would like to thank my family members for their moral support to complete this project. At this opportunity, I want to thank both of my parents, Hairrizaman Bin Ramli and Jasanah Binti Md. Ali always gives me advice and criticism while completing this project. They always encourage me to finish this project. I am also wanted to thank those who always supported me and helped my problems during the Final Year project.

Furthermore, I would like to give a very special thank you and respect to Madam Siti Amaniah Binti Mohd Chachuli for supervising me with proper guidance and full cooperation in most of my final year project. Thank you for giving me a lot of guidance and tutoring, which eventually aided us to complete this project perfectly.

Do not forget my friends who always helped me when I faced some problems regarding this project. Thank you for helping and encouraging me. Finally, I would like to extend my thanks to the individual involved directly or indirectly in making this project and this project report.

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LIST OF SYMBOLS AND ABBREVIATIONS

IoT	:	Internet of Things
IAQ	:	Indoor Air Quality
PPM	:	Parts per million
OSHA	:	Occupational Safety and Health Administration
NodeMCU	:	(Node MicroController Unit)
SoC	:	System-on-Chip

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CHAPTER 1

INTRODUCTION

This project aims to design and construct carbon dioxide gas sensing that can be used with a variety of Nano-fabricated materials. Project objectives, problem analysis, and a description of the nature of the task are all included in this chapter. The next chapter will describe the background and operation of this gas sensor. This chapter will also include a brief description of the technique and organization structures.

1.1 Introduction

Nowadays, Indoor Air Quality (IAQ) has become a significant wellbeing and safety concern, as clean air is fundamental for good health. Thus, the work environment needs a proper gas detector to ensure the good health of the occupants [1]. Nanotechnology has become advanced with the development of various sensors, which are highly beneficial in terms of health and safety for human life. Several studies have developed the smallest-scale sensor devices for different applications, such as biosensors. In the early 1980s, gas sensors were introduced, consisting of semiconductor materials derived from earth structures offering low price potential, ultra-sensing, sensitivity, and repeatability in gas sensor applications.

Through the years, the sensors' design has become more advanced due to the technology. The needs of the gas sensor are to detect non-flammable gas such as carbon dioxide at different operating temperatures [2]. The title of this project is "Titanium Dioxide Gas Sensor for Monitoring Carbon Dioxide with IoT". This project aims to test carbon dioxide gas at different concentrations. Carbon dioxide gas is a non-flammable gas and odourless [12]. It is naturally occurring in the atmosphere. As indicated by OSHA, the workers cannot expose to the concentration of carbon dioxide gas higher than 5000 ppm more than 8 hours of work per day, which is about 0.5% of carbon dioxide gas noticeable all around. The limit is set to less than 30000 ppm in 10 minutes if the human is exposed in a short time. Carbon dioxide gas is dangerous as it can lead to global warming. It is dangerous to humans when the concentration of carbon dioxide gas achieves 40000 parts per million (ppm).

In this project, titanium dioxide thin film is used. Titanium dioxide, TiO2, is a significant metal oxide semiconductor (MOSs) utilized in numerous electronic applications. One of the most well-known is gas sensor application. Titanium dioxide has been generally applied as a gas sensor to identify different kinds of gases such as nitrogen dioxide [4], hydrogen [5], carbon monoxide [6] and ammonia [7]. Characteristics of titanium dioxide were set up on the surface responses utilizing oxidizing or diminishing gases, thus, impacts the conductivity of the film. Titanium dioxide gas sensors have better sensitivity at high temperatures than the other metal oxides.

The fabrication method of screen printing is used to fabricate the titanium dioxide, TiO_2 gas sensor. This project plans to identify the concentration of carbon dioxide and alert the air quality to the people. A gas sensor is an equipment used to detect the concentration of gases [3]. As the concentration of carbon dioxide gas increases, the higher the risks to humans. Therefore, the expected result obtained from this project is that titanium dioxide, TiO_2 thick film gas sensor can detect carbon dioxide gas concentration. The fabrication method of screen printing is used to fabricate the titanium dioxide, TiO_2 gas sensor. This project plans to identify the concentration of carbon dioxide and alert the air quality to the people. A gas sensor is an equipment used to detect the concentration of gases [3]. As the concentration of carbon dioxide gas increases, the higher the risks to humans. Therefore, the expected result obtained from this project is titanium dioxide, TiO2 thick film gas sensor can detect carbon dioxide gas concentration.

Internet of Things (IoT) is a significant part of improving human's life. It is a combination of advances like remote specialized gadgets and sensors. IoT coherently interconnects and interoperates actual and virtual objects [13]. Internet is being a powerful platform for sending and receiving messages, internet games, social associations or organizing and others. Internet of Things (IoT) is applied in this project to monitor the real-time based concentration of carbon dioxide gas.

1.2 Problem Statements

When carbon dioxide gas and other air pollutants gather in the air and absorb sunlight, sun-oriented radiation that has bounced off the world’s surface can cause global warming. It can be harmful to humans as the gas concentration becomes higher. When the carbon dioxide gas concentration level achieves 1000 ppm, humans will suffer from drowsiness and poor air. As the concentration achieves 40000 ppm, it is very dangerous as it is immediately harmful due to oxygen deprivation. [14]. It can lead to death when humans are exposed to the high-level carbon dioxide gas concentration at 100000 ppm. Maximum carbon dioxide concentration in various nations is between 1000 ppm until 1500 ppm [15]. Occupational Safety and Health Administration (OSHA) has set up a Permissible Exposure Limit (PEL) for carbon dioxide gas of 5000 ppm (0.5% carbon dioxide in the air) in an average of 8-hour work per day. A high concentration of carbon dioxide gas can affect the respiratory function of humans and will lead to a lack of oxygen. In addition, the limited studies on titanium dioxide, TiO2 thick film gas sensor in detecting carbon dioxide gas. Table 1 below shows the various types of materials that can be used as gas sensors to measure carbon dioxide gas concentration.

Table 1.2: Types of materials can be used as a gas sensor.

Material	Concentration (ppm)	Temperature (°C)	Reference
Bismuth (III) oxide, Bi_2O_3 nanostructure	10-100	25	[16]
p-CuO/n-ZnO hetero-surfaces	1000	320	[17]
Poly(ionicliquid) alumina composite	300-3200	250	[18]
Copper oxide nanoparticles, CuO	400-4000	25	[19]

1.3 Objectives of the Project

a) To fabricate the titanium dioxide, TiO_2 thick film gas sensor and detect the level of concentration of the carbon dioxide, CO_2 gas.

b) To design a gas sensor using screen printing.

c) To analyze the gas sensor's performance at room temperature in terms of sensitivity, response time and recovery time.

1.4 Scope of Work

This project required the process of research, collecting data and information regarding the equipment and components to be used to build the measurement of the gas sensor. The development of the gas sensor measurement will be divided into two scopes of work: hardware and software development. For the software part, the coding must be verified and uploaded to the board to perform the tasks. Using Tinkercad software before coding is verified to Arduino IDE software, simulation has been done. As the electrical part is involved with the electronics components, the suitable type of material to avoid any short circuit is focused. Finally, it will be integrated with an Arduino Uno board to develop the hardware.

1.5 Project Significant

Most people did not become aware of the high-level concentration of carbon dioxide gas. When the Indoor Air Quality (IAQ) is bad, the air will be polluted, affecting people's health. As indicated by OSHA, humans cannot expose to the concentration of carbon dioxide gas higher than 5000 ppm more than 8 hours of work per day, which is about 0.5% of carbon dioxide gas noticeable all around [20]. Hence, this project would help users alert with the current situation when the concentration of the carbon dioxide gas is at a higher level by using the alarm. Also, with the advancement of technology, this project can be proposed to install and applied at some places exposed to carbon dioxide gas, such as at restaurants, factories, and in the car. Therefore, this project can be proposed to be compulsory for all buildings as it benefits the people. In addition, the project's hardware will be compact and small as it will be travel-friendly to the user. By implementing the Internet of Things (IoT) in this project, carbon dioxide gas concentration can be monitored 24 hours.

1.6 Thesis Outline

This report consists of five chapters. Chapter 1 briefly describes the introduction of the project, which consists of problem statements, project objectives, the scope of work, significance of study and thesis outline. Chapter 2 explains the project's background, a literature review. It provides a review of the previous work done by other researchers that may have some similarities. While completing this project, some ideas, information, and knowledge has been implemented. Some of the resources have been collected in this section as a guide for the next chapter. The resources come from journals, books, articles, and patents. In Chapter 3, the method carried out in this project will be elaborated more precisely. The methodology used to contribute to the achievement of this project is to ensure that the flow is on track to reach the project's goals. Results and discussion of the project were covered in Chapter 4. The last chapter, Chapter 5, will conclude all the results, analysis, and recommendations for the future improvement of this project.

CHAPTER 2

BACKGROUND STUDY

A brief explanation of the perspective and methods used in the previous research is presented in this chapter. It also contains the collected information for this project to complete the project in the time given. Some sources have been used as resources like journals and websites. A few literature reviews were done to have a brief understanding of the researchers related to the project. A few types of materials can be used as a gas sensor also presented in this chapter.

2.1 Previous Research in Monitoring Carbon Dioxide Gas

The rapid advancement of technology has created enormous opportunities to improve the quality of human life. Technology's efficiency and convenient living allow society to recognize its existence and transform into a valuable civilization. However, the lack of a suitable gas sensor design is noticeable in small devices.

Indoor air quality is affected by several factors, including temperature, relative humidity, and odour. According to Jiri H. et al., indoor surveillance is not a practical approach. It is just a report on what is happening in the monitored flats. Modern communication technology can alter usage patterns while also taking advantage of the building's existing features, such as natural ventilation. For occupied interior spaces, the highest limit is 1000 parts per million. Levels beyond this upper limit can cause drowsiness, and concentrations above 2000 ppm can cause minor headaches. At 5000 ppm, a rapid heartbeat occurs, while 45000 ppm and higher amounts cause unconsciousness and death [11].

This system uses indoor monitoring sensors designed to work with flat users via data transfer protocols. The monitoring technique's primary goal was to demonstrate that carbon dioxide CO_2 levels in residential spaces are generally greater than safe limits. In real-world situations, however, a variety of variables change over time, such as occupancy, outside weather conditions, exhale breath air CO_2 levels, outside fresh air supply rate, and so on, all of which have a direct or indirect impact on CO_2 levels, air mixing, and a variety of other issues. Because of this ever-changing nature, the most effective method may be to measure CO_2 levels in the monitored area and modify ventilation accordingly.

Hanif A. et al. suggested a carbon dioxide gas monitoring system based on a wireless sensor network inside the building. Carbon dioxide concentrations between 0 and 10,000 parts per million can be detected using the sensor. The sensor also comes with a built-in humidity sensor. The data is sent using the Universal Synchronous Asynchronous Receiver Transmitter (USART) method [12]. Carbon dioxide content, temperature, and humidity will all be measured by each node sensor. The radiofrequency transmission will deliver the data to the sink node. The data will subsequently be transferred to the serial Raspberry Pi using the device's built-in serial port. The data from the Raspberry Pi will subsequently be transferred in its entirety to the server node.

The data is created in a tabular format in the server node using a basic RDMS called PostgreSQL. The information for carbon dioxide and other components for each node could be downloaded from the website using the data collected in the server node. PostgreSQL is an open-element database management system [13]. To summarize, Wireless Sensor Network, WSN is a system for remotely monitoring and collecting data on carbon dioxide intensity. It is portable and uses a limited number of resources.

2.2 Gas Sensing Technology

The use of sensing applications in home automation, smartphones, and wearable technology has expanded due to the rapid progress of Internet of Things (IoT) technology [4]. In comparison to traditional gas detection methods, the smart gas sensors approach, which includes sensor arrays, data processing, and artificial intelligence techniques, was discovered to be the best way to solve the hurdles by Shaobin F et al. Even though intelligent sensing has played an essential part in life and manufacturing, there will still be a few challenges in creating smart gas sensing that correspond to distinct technical stages. Gas sensing faces several difficulties, including low selectivity and cross-sensitivity. The chemical features of gases, such as redox properties, are used by gas sensors to detect them. While sensing a mixture of comparable gases, the gas sensor will be impacted by non-target gases with similar chemical characteristics.

There is also the problem of low selectivity. Temperature and humidity have a direct impact on the gas sensor's accuracy. Because temperature influences gas behavior, the sensor's capability of absorbing the gas varies with temperature, though most gas sensors perform effectively at degrees of several hundred degrees. The concept of smart gas sensing was created to overcome the challenges.

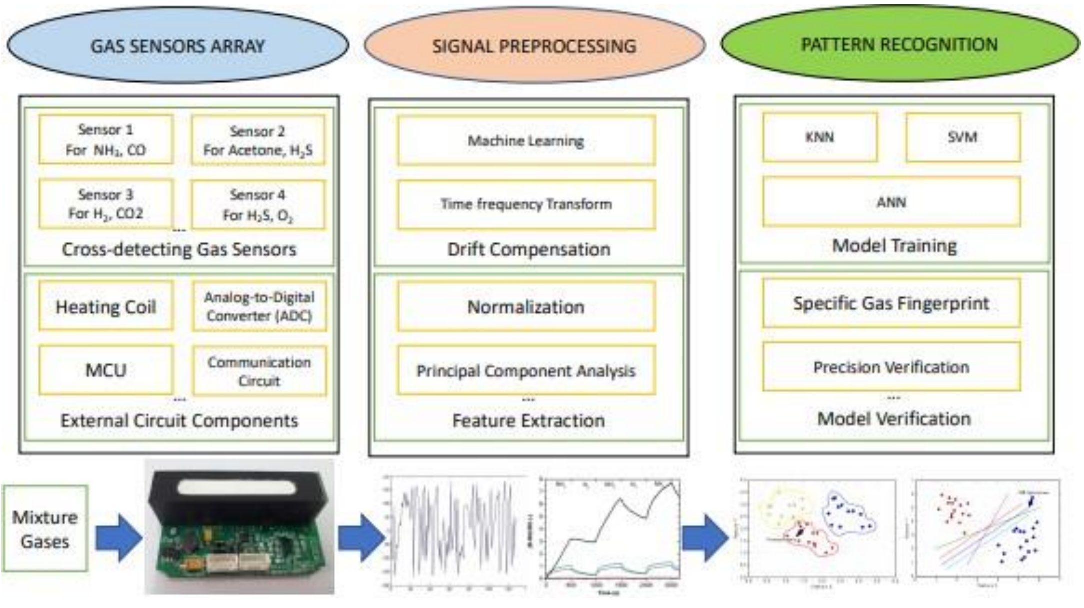


Figure 2.2: Step of Smart Gas Sensing

2.3 Wearable Gas Application

Highly sensitive, flexible, and stretchy electronic gas sensors have recently received a lot of interest due to their importance in wearable electronics applications [5]. The choice of conducting materials and fabrication of those conducting electrodes on wearable substrates are critical in gas sensing. Because the electrodes connect the gas sensing materials to the user interfaces, they must have high electrical conductivity, flexibility, or stretchability. Wearable gas sensors were divided into categories depending on their potential use. Wearable gas sensing technology is advancing quickly, with applications in environmental monitoring, healthcare, public safety and security, and food quality monitoring. Materials, device engineering, signal processing, power catering, and other advances can help established technologies transcend limitations. Wearable gas sensors are also needed for environmental gases, gaseous contaminants, explosive hazards, humidity, exhaled breath gases, body odour, presence of nerve agents or explosives, and food quality and safety.

2.4 IoT-Based Gas Detection System

The Internet of Things (IoT) is a brand-new industry that aspires to connect people, machines, and things to the internet. The world is advancing toward modernization and automation, resulting in excessive pollution [6]. A gas detection system is a device that detects potentially harmful gases.

2.4.1 Ambient Gas Detection through IoT

Ambient gas detection and measurement, according to Neeraj K. et al., has become vital in a variety of industries and applications, such as accident prevention, avoiding equipment malfunction, air quality warnings, and assuring that patients in hospitals receive proper gas mixture. Some gases are required for systems and entire industries to function properly. Other gases, on the other hand, may be a problem in other industries, resulting in the closure of entire manufacturing lines, such as in the food industry, or even destroying lives and explosions [7]. On the Internet of Things (IoT) paradigm, gas sensors are becoming increasingly essential for determining ambient gases, creating warnings about the presence of unwanted gases, and allowing other systems, including such smart windows, automated exhaust systems, and automated heating, airflow, and heating and cooling (HVAC) systems, to react instantly to prevent leakage damages. Due to the necessity for remote monitoring of various properties, wireless sensors have been created in a variety of industries.

Furthermore, the introduction of WSANs and wireless sensors aided in the automation, data gathering, transport, processing, and storage procedures. Other sensing technologies developed over time based on measuring the propagation properties of gases and comparing them to a reference to determine which gas is being detected. To summarize, smart sensors will be developed in response to several contexts, such as residential users, industries, environmental monitoring, and remote electricity distribution stations, because of the Internet of Things. A large smart network can give critical data and operations based on that data to decrease costs in a range of governmental and business sectors, freeing up capital for investment in those other areas.

2.4.2 Indoor Air Quality Based on IoT by Using Carbon Dioxide Monitoring System

Indoor air quality (IAQ) characteristics are strongly linked to occupational health and have a significant impact on quality of life, according to Cristina R. et al., when people spend over than 90% of their time indoors. CO_2 has a substantial effect on the health which can be used as an important indicator of IAQ. CO_2 levels of over 1000 parts per million (ppm) indicate a potential indoor air quality issue. To detect air quality issues and react quickly in the building, CO_2 levels must be monitored in real time [8].

According to recent research published by Rui P. et al., Ambient Assisted Living (AAL) and the Internet of Things (IoT) allow for the development of smart products with advanced sensing and communication capabilities. Ambient Assisted Living (AAL) is defined by Goncalo Marques (2019) as a multidisciplinary field aimed at creating an environment of sensors, laptops, portable devices, cellular routers, and software products for personalized health tracking and telehealth systems [9]. AAL aims to address innovation that can be used to provide a secure and safe living environment for seniors and disabled people. In the planning and evaluation of a successful AAL system, technology architecture, interface design, social contact, ergonomics, usability, and accessibility are all challenges. There are also social and ethical issues to consider, such as acceptability by older individuals and the need for privacy and confidentiality in all AAL devices.

2.4.3 IoT-Based Real Time Environment Monitoring System

Aparajita (2018) found that cities occupy only around 3% of the world's geography out of 50% of the global population, and the number of populations equates to nearly 80% of carbon dioxide emissions. The ability of IoT to be used for real-time monitoring has driven recent innovations and its growth. With the expansion of mobile communication networks into rural parts of the country, IoT-based real-time monitoring of environmental parameters such as temperature, humidity, air pollution, and sunlight intensity and rain is becoming more feasible [10]. This study focuses on simplicity, relatively low cost, and data control. The system takes up extremely little space and can thus be implemented almost everywhere. The usage of sensors is the only way to gain a proper idea of the many environmental conditions. The sensor network's development is crucial since the end user will rely only on the data provided by these sensors.

2.5 Organic Thin Film Transistors (OTFTs)

Organic Thin-Film Transistors (OTFTs) is a miniaturized device that has been developed as a gas sensor device, showing performance for the recognition of significant objective analytes, which are hydrogen sulphide, nitrogen dioxide, ammonia, and volatile organic compounds (VOCs) [2]. An OTFT is made up of three layers consisting of an organic semiconductor thin film, dielectric film and three electrodes of source (S), drain (D) and gate (G). It tends to be created at average temperature and through profitable solution-based techniques concerning a wide scope of minimal expense adaptable and deformable substrates [3].

2.6 Two Different Techniques Used to Synthesize Zinc Oxide (ZnO) Nanoparticles of Ethanol Gas Sensor

Bhatia S et *al.* proposed two different techniques to synthesize zinc oxide (ZnO) nanoparticles: Two-zone furnaces for simple heat treatment and thermal evaporation. Two-zone furnaces are split by varying the zone temperature as 800 ºC for zone 1 and 400 ºC for zone 2 [1]. These two techniques are average techniques with several advantages, including economic effectiveness and simplicity of process control. The film is produced on a glass sub-31strate using 0.17 M zinc acetate dihydrate as the major precursor. Field Emission Scanning Electron Microscope (FESEM), X-Ray Diffractometer (XRD),Fourier Transformation Infrared Spectra (FTIR), UV-Vis spectrophotometer, and LCR32meter were used to analyze synthesized ZnO. Synthesized ZnO (powder and film) is then employed to fabricate nanodevices to investigate the gas sensing capabilities of ethanol gas. Figures 2.6.1 and 2.6.2 below show zinc oxide films produced by simple heat treatment and thermal evaporation were tested in this setup in two different zones split furnaces.

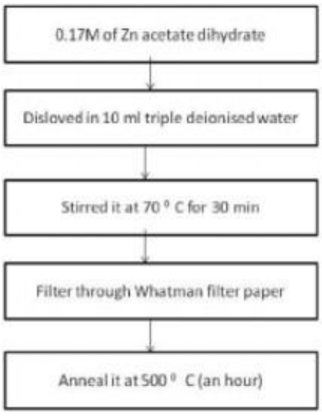


Figure 2.6.1: Experimental Set-Up of Zinc Oxide Films Prepared by Simple Heat Treatment.

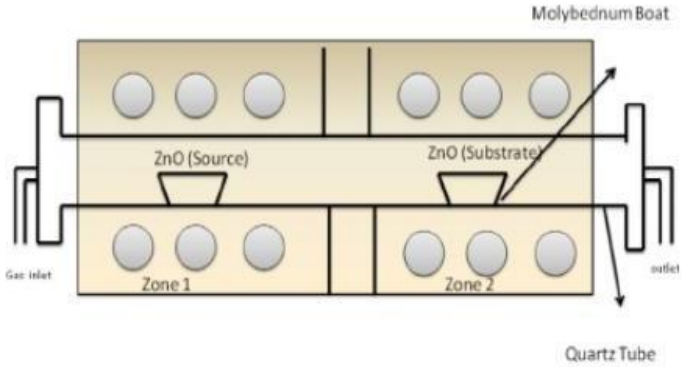


Figure 2.6.2: Experimental Set-Up of Zinc Oxide Films Prepared by Thermal Evaporation Method in Two Different Zones Split Furnace.

Gas sensing properties were obtained using annealed ZnO nanoparticles. The source for the thermal evaporation technique was synthesized nanoparticles using a simple heat treatment method, with glass as the substrate. On exposure to the host gas (ethanol), a static gas sensing setup is employed to measure gas sensing properties as a function of temperature. The gas response of synthesised ZnO to the host gas (S = Ra/Rg), where Ra represents resistance in the absence of gas and Rg represents resistance in the presence of gas, was measured. The surface to volume ratio, particle size, and connections between ZnO nanoparticles were all affected by gas sensing variables.

2.7 Effect of Rare-Earth Metal – Doped Zinc Oxide (Zno) Thin Films in Ammonia (NH_3) Gas Sensing

Rare-earth elements are 17 metallic elements found in the middle of the periodic table with atomic numbers of 21, 39, and 57-71. These metals have unusual luminous, conductive, and magnetic properties, making them extremely advantageous when alloyed (or mixed) with more common metals like iron in small amounts. Ammonia is a colourless, unpleasant gas that is very harmful to human health when inhaled in more than a modest quantity [14]. One of the most difficult problems is detecting ammonia at low temperatures. Recently, metal oxide such as tin oxide SnO2, nickel oxide, NiO and tungsten oxide, WO3, real-time gas sensors have been popular due to their high sensitivity, short response times, and ability to identify many gases like hydrogen and carbon monoxide gas. The sensing method of a metal oxide semiconductor, MOS gas sensors, is usually assumed to comprise a chemical reaction between the absorbed oxygen and the measured gas. When a metal oxide semiconductor is exposed to air, oxygen is absorbed by the sensing materials' surface [15]. To produce an azane, NH3 gas sensor, chemical bath deposition of ZnO thin films doped with rare-earth metals onto In-doped SnO2 substrates was used.

CHAPTER 3

METHODOLOGY

This chapter will briefly discuss the methodology approach performed in the study to solve the project problem. It will be divided into several sections to give a detailed explanation of the methodology of the development of this project. The workflow description is represented in the project flowchart, software flowchart, and hardware flowchart. The process and implementation steps are clearly outlined from beginning till the end. It is important to deliver a successful, smooth, and efficient outcome. This chapter also includes the project design process to explain the overall system.

3.1 Flowchart

3.1.1 Project Flowchart

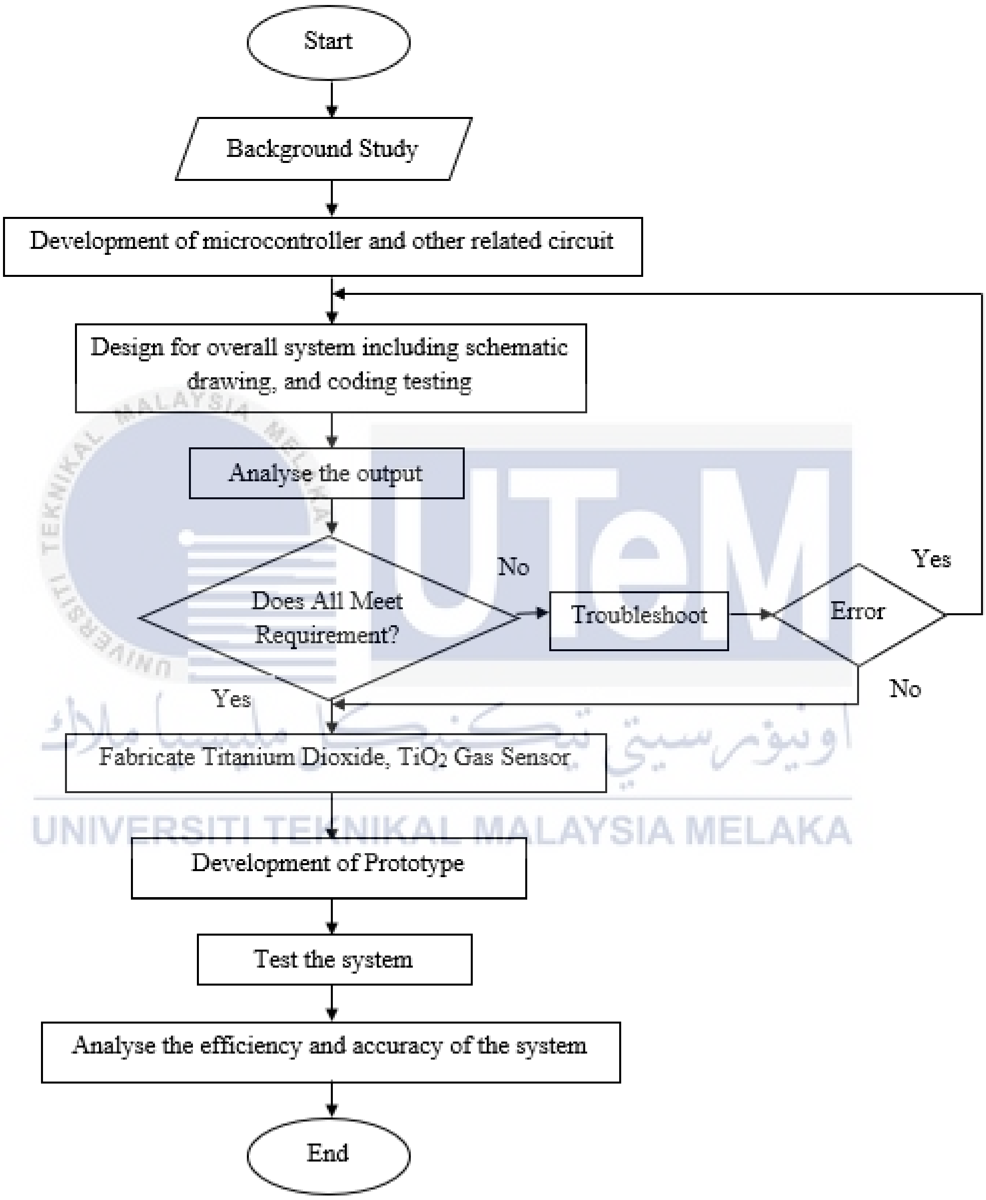


Figure 3.1.1: The project flowchart

Figure 3.1.1 above shows the project flowchart throughout the process to complete this project. For background study, some research regarding the project will be done. The literature review will be done by reading all the relevant papers related to this project. Then, the components and the circuits to be used is determined before developing the circuit. The circuit consists of several parts: the microcontroller circuit, measuring circuit, and notification circuit. This circuit is then combined to make the overall circuit for this project. Hence, the output is analyzed until the desired result is obtained. Some existing research with similarities with this project was reviewed to get some information. When the desired result is obtained, fabricate the titanium dioxide, TiO_2 gas sensor. The prototype is then developed. Hence, the performance system will be tested and analyzed to improve the system's efficiency and accuracy.

3.1.2 Hardware Flowchart

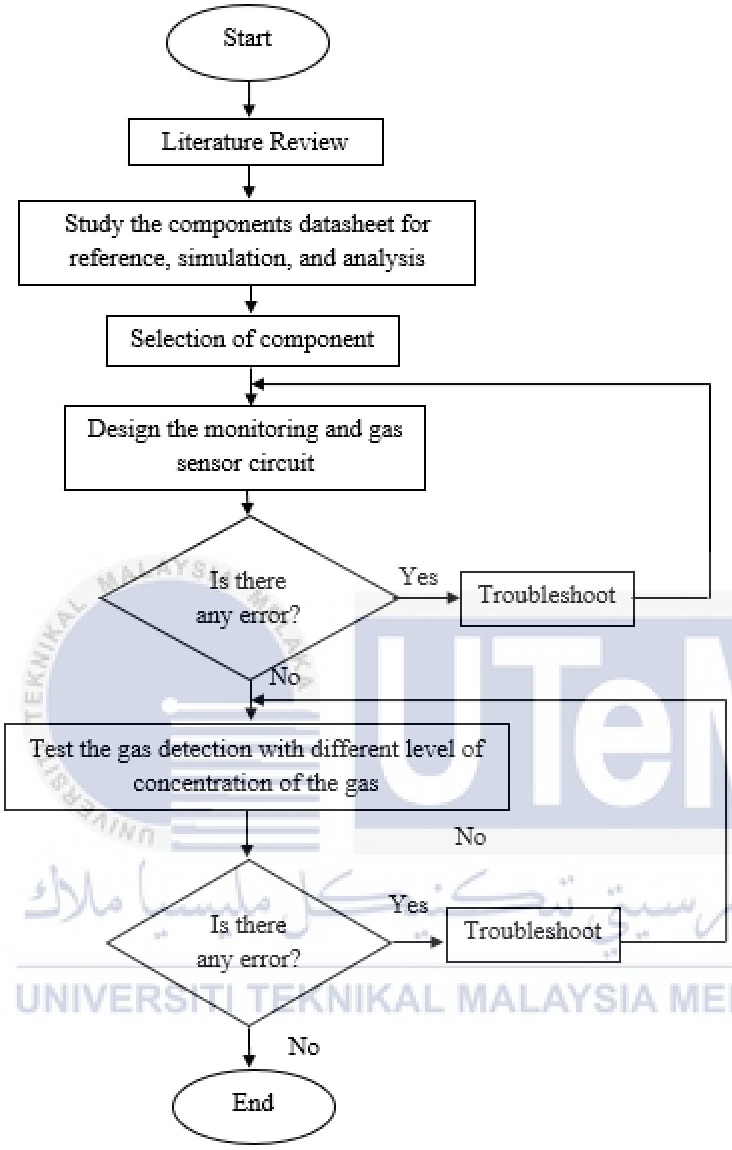


Figure 3.1.2: The hardware flowchart

Figure 3.1.2 above shows the workflow of the hardware of this project. Before starting the hardware part, the literature review will be done by reading all the relevant papers, journals, books, and patents obtained from the trustable resources related to this project. Then, after doing some research, the component is selected based on their capabilities by referring to the datasheet that summarizes the performance and characteristics of each component.

3.1.3 Software Flowchart

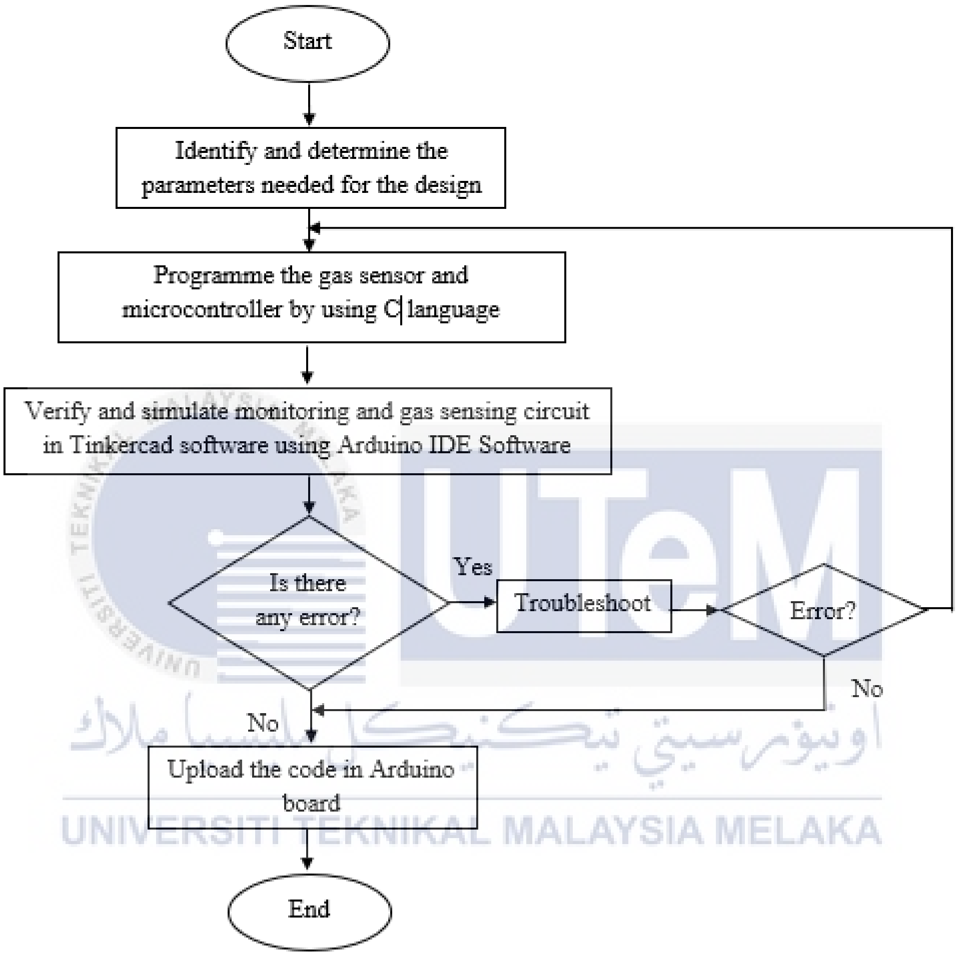


Figure 3.1.3: The software flowchart

Figure 3.1.3 shows the software flowchart of this project. Firstly, the parameters need to identify and determined before the design is constructed. Then, the gas sensor and microcontroller are programmed using C language to test the functionality. Before the coding is verified to the Arduino IDE software, the gas sensing circuit is simulated in the Tinkercad software. The code will be verified and uploaded in Arduino software to connect with the Arduino board when there is no error.

3.2 Project Planning (Gantt Chart)

	SEM I																		
Aktiviti Projek *Project Activities*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Selection of Title and Registration	X	X									SEMINAR PSM I								
Project Briefing and Discussion with Supervisor		X	X																
Hardware Selection		X																	
Proposal Writing		X	X																
Circuit Design			X	X															
Proposal Defense				X															
Thesis Draft Submission to Supervisor					X	X	X	X	X	X									
Software and Simulation						X	X	X	X	X		X	X	X					
Submission of Final Draft to Supervisor													X	X					
Fabrication Titanium Dioxide (TiO_2) Gas Sensor using Screen Printing			X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Integration of Hardware and Software Component																		X	X

Aktiviti Projek *Project Activities*	SEM II															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Integration of Hardware and Software Component	X	X	X	X										SEMINAR PSM II		
Testing the System		X	X	X	X	X	X	X	X							
Analysis of Data (Result)						X	X	X	X	X	X					
Final Test of Project								X	X	X	X	X	X		X	X
Final Thesis	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Submission Final Thesis to Supervisor and Panel																X

3.3 Working Principle

This project is implemented into Arduino Uno as the main controller and control all the system. The analogue input (A0) pins of the MQ135 air quality sensor module is connected to the analogue input (A0). Thus, running the program coding in the Arduino IDE software will program the Arduino Uno. The data of carbon dioxide gas concentration from the MQ135 sensor can be observed from the serial monitor serial plotter of Arduino IDE software. The serial monitor will show the output of the concentration of carbon dioxide gas detected and the output voltage while the serial plotter is used to obtain the graph.

The buzzer will trigger and turn on when the concentration of carbon dioxide gas is higher, and automatically it will display the alert situation on the LCD. On the other hand, when the carbon dioxide gas concentration is low, the buzzer will not turn on, and the LCD will display normal conditions. After observing the commercial sensor of MQ135, the design and fabrication of the titanium dioxide gas sensor need to be done to ensure that the gas sensor can operate well at room temperature.

3.4 Hardware Components

3.4.1 Arduino Uno

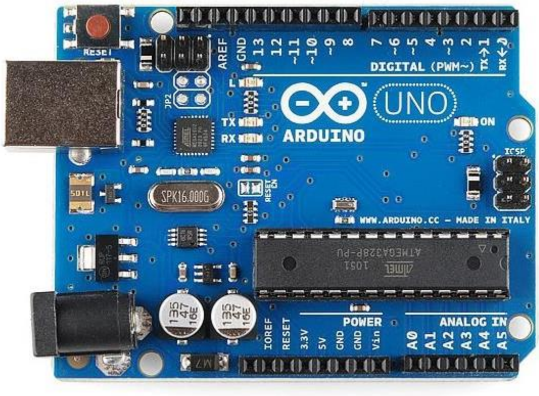


Figure 3.4.1: Arduino Uno

Arduino Uno is a microcontroller with 2KB SRAM, 32KB of flash memory, 1KB of EEPROM. This board has 14 digital input/output pins, 6 analogue inputs and 6 PWM output. As shown in Figure 3.4.1, Arduino Uno is a microcontroller board that is used to test gas existence in the atmosphere. Besides, this Arduino has a 16MHz ceramic resonator. Therefore, no lagging problem to load a program from Arduino Software to the board. Then, to power it up, it can simply connect the USB cable used to transfer the code to the controller using Arduino IDE (Integrated Development Environment) software or power it with AC to DC adapter or battery.

3.4.2 LCD Display

Figure 3.4.2: LCD Display 16X2

The figure above shows the type of LCD used in the monitoring circuit. This type of LCD has a green display screen called LCD 16X2. LCD is used to display the output voltage and carbon dioxide gas concentration. This LCD is simple to operate and has no restrictions on the display of custom characters and animations. It is found in a lot of current watches, computers, and video game screens. A 16x2 LCD means it can display 16 characters per line, and there are 2 such lines. Besides, it can display a character with an ASCII value ranging from 0 to 225. In addition, it can be coded to be a colourful display. The polarizer let the right amount of backlight pass through it to display an attractive screen. At the same time, it consumes less voltage, below 5V. Thus, the power consumption can be reduced.

3.4.3 MQ135 Air Quality Sensor Module

Figure 3.4.3: MQ135 Air Quality Sensor Module

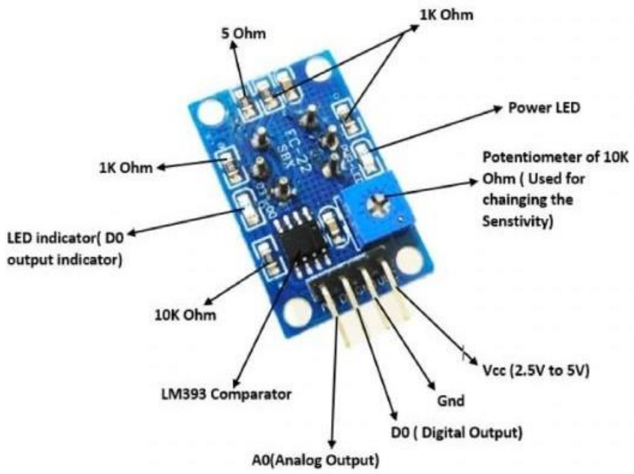


Figure 3.4.3.1: Details of MQ135 Air Quality Sensor Module

As shown in Figure 3.4.3, this gas sensor is used to detect the presence of gas in a wide range. It is a sensor with high sensitivity and fast response towards the various types of gas such as ammonia nitrogen, sulfide, alcohol, smoke, carbon dioxide, and harmful gases. This sensor needs to be pre-heated before it starts working on getting the sensor stable and obtaining accurate measurements of the carbon dioxide gas concentration. Besides, it has a long life and is inexpensive. It is also associated with analogue output (A0) and digital output (D0) pin. Therefore, it is not limited to digital or analogue sensors.

Table 3.4.3: Technical specifications of MQ135 air quality sensor module

Power consumption	150 mA
Operating voltage	2.5V to 5V
Gases detection	Benzene, smoke, carbon dioxide, ammonia nitrogen
Digital output	0V to 5V
Analog output	0V to 5V
Typical operating voltage	5V

3.4.4 Breadboard

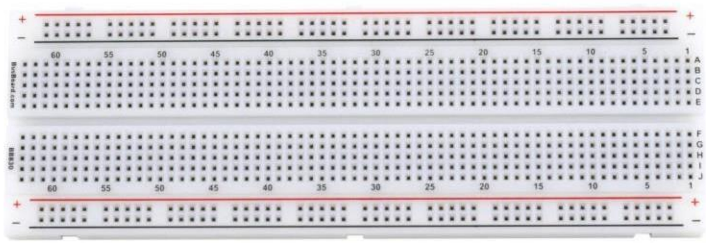


Figure 3.4.4: Breadboard

The figure above shows the breadboard used to build electronics circuits in this project. A breadboard is fundamental in building the circuit.

3.4.5 Jumper

Figure 3.4.5: Jumper

This jumper connects the LCD, gas sensor and other components to the Arduino board. Two types of jumpers have been used to complete this project's circuit: male to female jumper and male to male jumper.

3.4.6 Buzzer

Figure 3.4.6: Buzzer

A buzzer is a device that converts audio signals into sound signals. DC voltage is frequently used to power it. As a sound device, it's found in laptops, printers, alarm clocks, and other electrical equipment. However, the buzzer is mostly utilized as a warning and alert tone. The buzzer will operate when the concentration of the carbon dioxide gas is higher than the reference voltage that has been set in the program coding of Arduino IDE software..

Table 3.4.6: Technical specifications of buzzer

Frequency range	3300 Hz
Operating voltage	3V to 24V
Operating temperature	-20°C to +60°C
Current	< 15 mA
Sound pressure level	85 dBA

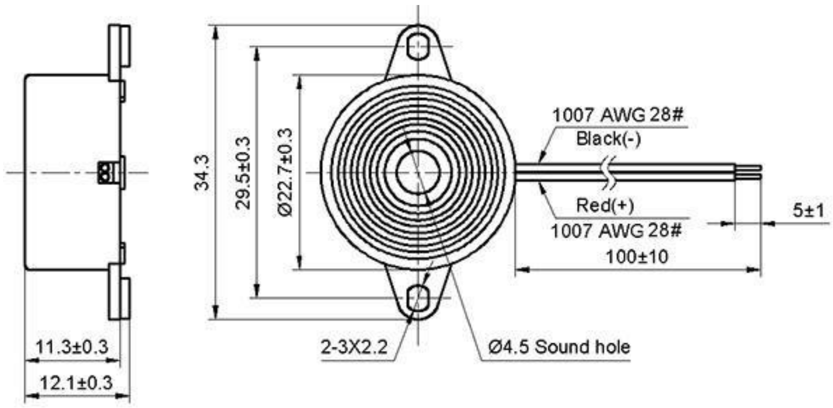


Figure 3.4.6.1: Buzzer dimension

3.4.7 NodeMCU

The ESP8266-based NodeMCU (Node MicroController Unit) is an open-source software and hardware development environment which is a low-cost System-on-a-Chip (SoC). It is Lua-based firmware and development board designed specifically for Internet of Things (IoT) applications. Using this microcontroller, the real-time concentration of the carbon dioxide gas can be seen through the data sent to the IoT analytics platform.

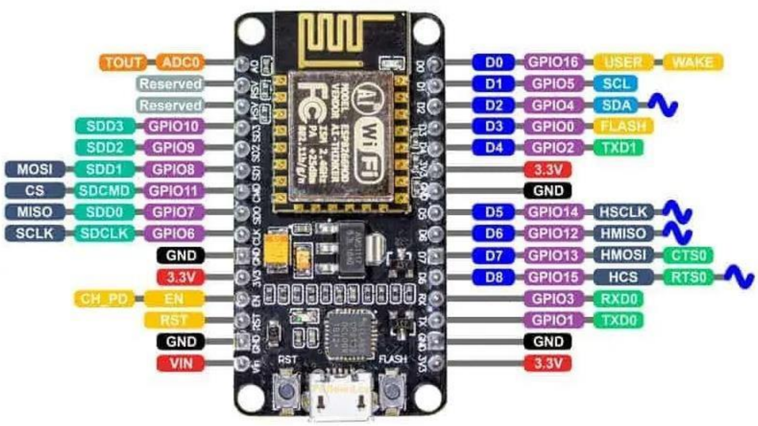


Figure 3.4.7: NodeMCU pinout

3.5 Software Development

3.5.1 Tinkercad Software

Tinkercad is an online software tool that can be used to create the schematic diagram of the project circuit. It can simulate the circuit by writing the code and run. The output will be the same as the hardware development.

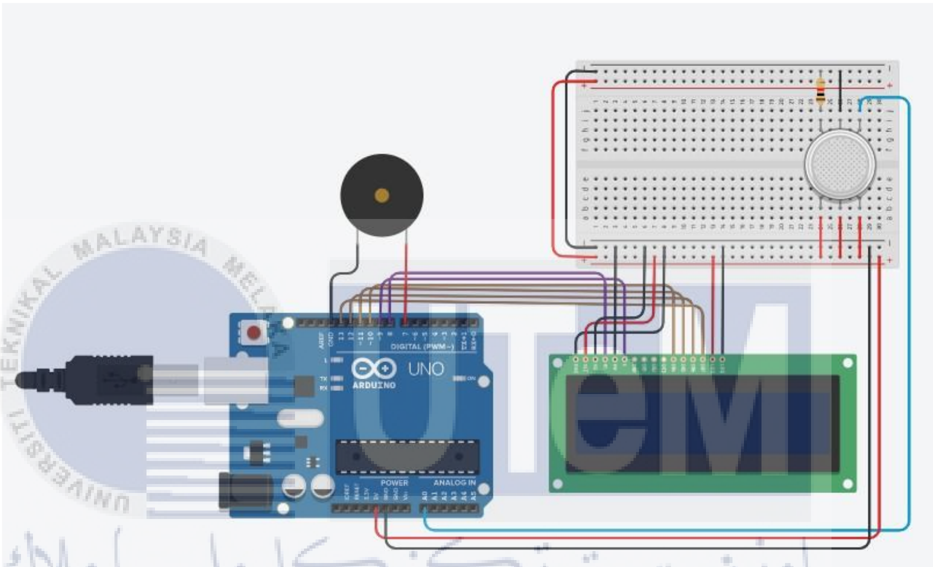
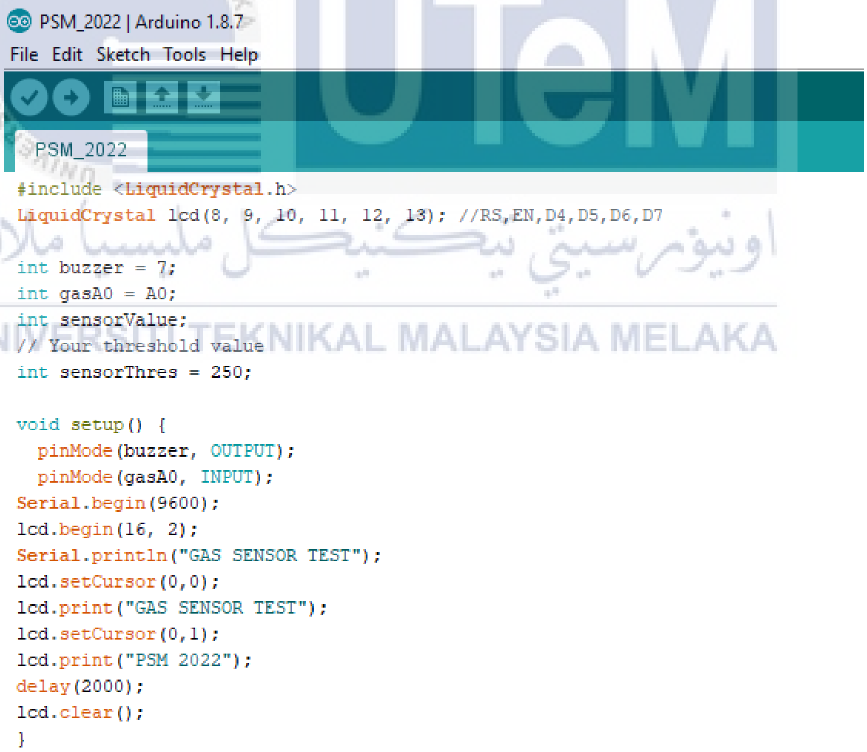


Figure 3.5.1: Schematic diagram in Tinkercad software

Based on Figure 3.5.1 above, after the program coding has been run in the software, as the concentration of the smoke is higher than the threshold value that has been set, the buzzer will trigger, and the LCD will show the alert. But for this schematic diagram, the resistor of 1kΩ need to be added to the leg of the gas sensor to achieve its stability as the gas sensor cannot detect when the concentration of the smoke is low. The gas sensor will always detect the higher concentration and automatically turn on the buzzer all the time. To overcome these problems, one 1kΩ resistor is added to the circuit.

3.5.2 Arduino IDE Software

Arduino IDE (Integrated Development Environment) software is used to write program code lines, verify the code error and upload to Arduino microcontroller board through a communication port connected. The microcontroller in the Arduino board only will operate according to the information and instructions set in the software, as shown in Figures 3.5.2, 3.5.2.1, and 3.5.2.2 below. Besides, to see the display of the serial monitor and plotter, the instruction must be called in the program. If not, only the serial will be open, but the data will not be displayed. The source code gives instructions to the Arduino on what to do next. All components need to be declared in the program code.




```
#include <LiquidCrystal.h>
LiquidCrystal lcd(8, 9, 10, 11, 12, 13); //RS,EN,D4,D5,D6,D7

int buzzer = 7;
int gasA0 = A0;
int sensorValue;
// Your threshold value
int sensorThres = 250;

void setup() {
  pinMode(buzzer, OUTPUT);
  pinMode(gasA0, INPUT);
Serial.begin(9600);
lcd.begin(16, 2);
Serial.println("GAS SENSOR TEST");
lcd.setCursor(0,0);
lcd.print("GAS SENSOR TEST");
lcd.setCursor(0,1);
lcd.print("PSM 2022");
delay(2000);
lcd.clear();
}
```

Figure 3.5.2: Source code of the program

```
void loop() {
  int analogSensor = analogRead(gasA0);

  Serial.print("Gas A0: ");
  Serial.println(analogSensor);
  lcd.print("Gas Level:");
  lcd.print(analogSensor);
  // Checks if it has reached the threshold value
  if (analogSensor > sensorThres)
  {
    lcd.setCursor(0, 2);
    lcd.print("Alert....!!!");
    digitalWrite(12, LOW);
    tone(buzzer, 500, 200);
  }
  else
  {
    lcd.setCursor(0, 2);
    lcd.print(".....Normal.....");
    noTone(buzzer);
  }
  delay(500);
```

Figure 3.5.2.1: Source code of the program


```
  float sensor_volt;
  int sensorValue = analogRead(A0);
  sensor_volt = ((float)sensorValue / 1024) * 5.0;
  Serial.print("sensor_volt = ");
  Serial.println(sensor_volt);
  Serial.print(" PPM~ ");
  Serial.println(sensorValue, DEC); // prints the value read
  Serial.print("\n\n");
   lcd.setCursor(0,0);
  lcd.print("sensor_volt=");
  lcd.print(sensor_volt);
  lcd.setCursor(0,1);
  delay(1000);
  lcd.clear();
  lcd.print(" PPM~");
  lcd.print(sensorValue, DEC);
  delay(1000);
  lcd.clear();

}
```

Figure 3.5.2.2: Source code of the program

3.5.3 ThingSpeak Platform

To get the real-time data of the concentration of carbon dioxide gas, the ThingSpeak platform is used. ThingSpeak is a cloud-based IoT analytics software that enables visualization, aggregate, and analyzing live data streams. ThingSpeak also can analyze and act on the data as well. The web services can deliver data from the devices to ThingSpeak. Thus, build real-time visualizations of live data, and trigger notifications.

3.6 Breadboard development

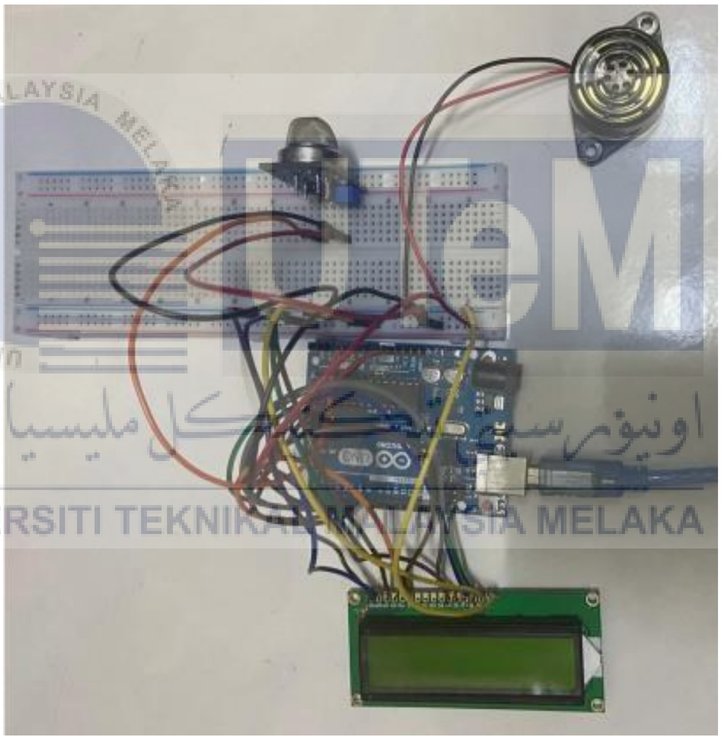


Figure 3.6: Breadboard development

Before obtaining the carbon dioxide gas concentration, the MQ135 air quality sensor module needs to be preheated first before it starts working on getting the stable and accurate output. Figure 3.6.1 below shows the program coding used to check the stabilization of the gas sensor.

Figure 3.6.1: Source Code of the Program to Check the Stabilization of the Gas Sensor

Then, figure 3.6.2 below shows the output serial monitor of the carbon dioxide gas concentration during the stabilization of the gas sensor to get the accurate value of air quality at that time.

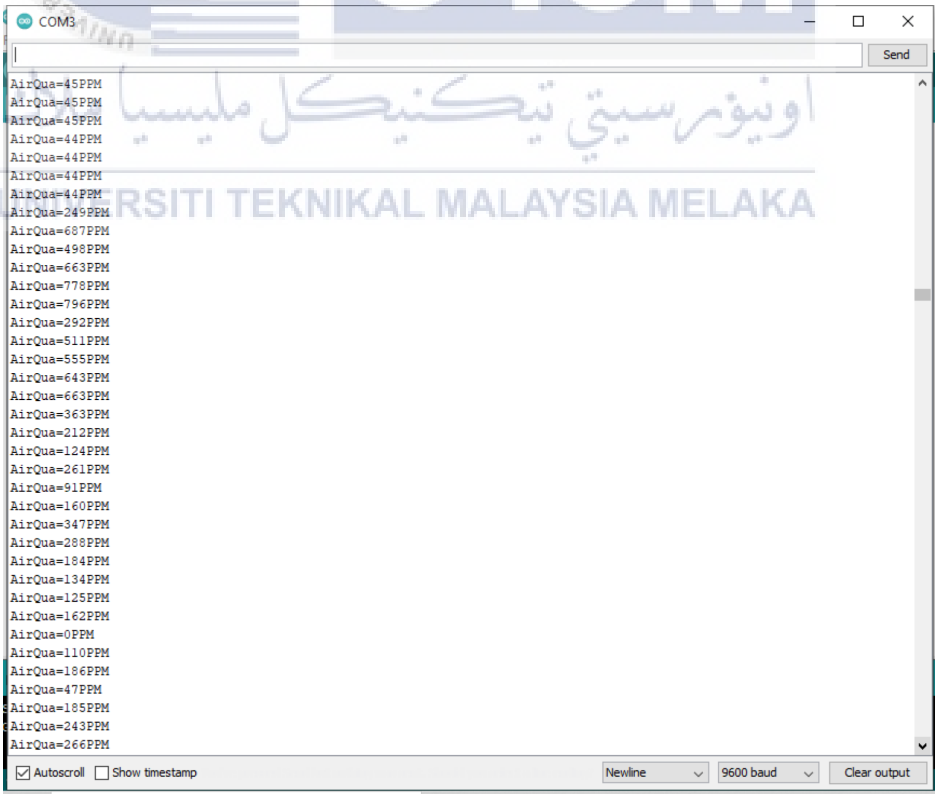


Figure 3.6.2: Output serial monitor during stabilization of the gas sensor

CHAPTER 4

RESULTS AND DISCUSSION

This chapter will discuss the results of the project. Analysis and the results are very important to know whether this project succeed. In addition, this testing helps determine the cause of the problem that exists on its hardware and the components. Finally, it will discuss the outcomes, collected details, and the research's explanation.

4.1 Analysis and Project Result

This project is expected to sense the carbon dioxide gas and detect the concentration of the carbon dioxide. When the concentration of carbon dioxide is low, the LCD will display a low gas level, which is normal, and the buzzer will remain silent. Still, when the concentration of the carbon dioxide is higher than the sensor threshold voltage, the LCD will display high and alert people by triggering the buzzer to turn on the tone. The sound of the buzzer will alert people when the concentration is higher than the sensor threshold voltage that has been set. Other than that, the LCD will also show the concentration on the display. It can also calculate the sensor voltage using the formula of sensor value divided by 1024, then multiplied by 5. This is because the Analog to Digital Converter (ADC) of Arduino Uno is 10-bit ADC, which means it can detect 1,024 (2^{10}) discrete analogue signals. The analogue input range of 0v to 5v is divided into 1024 discrete output values by the ADC. It returns a number between 0 and 1023, with 0 denoting 0 volts and 1023 denoting 5 volts. To find a value in the middle, take the reading and multiply it by 5/1024.

For this project, the simulation has been constructed in Tinkercad software. Then, the circuit was constructed on the breadboard based on the connection made in Tinkercad software.

4.2 Result of Circuit Simulation in Tinkercad Software

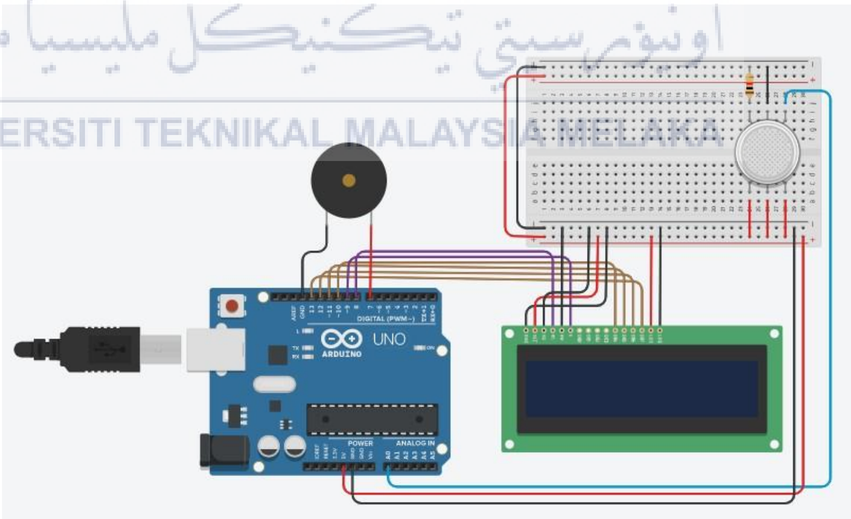


Figure 4.2: Schematic diagram in Tinkercad software

4.2.1 Circuit Simulation Result

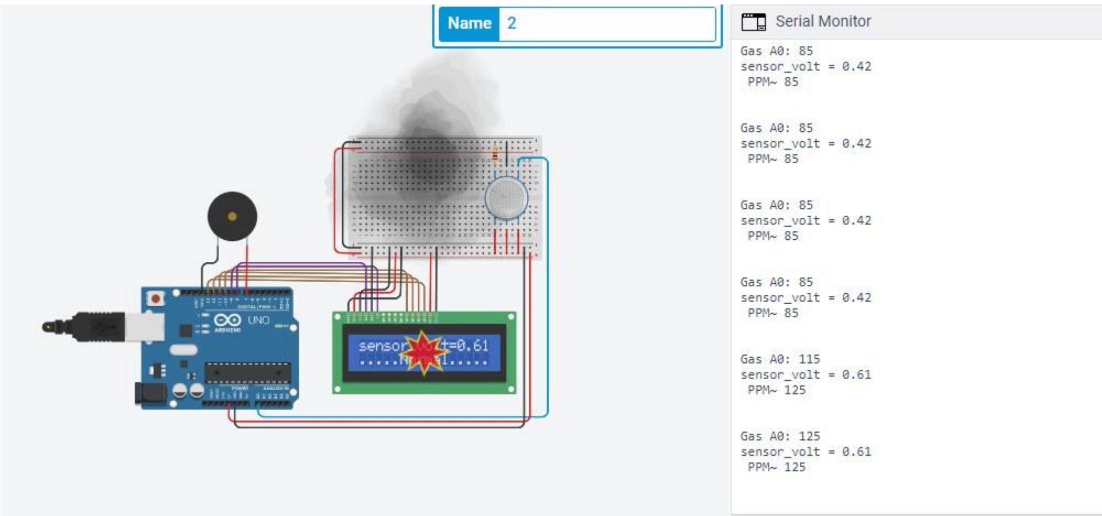


Figure 4.2.1: Circuit simulation result when the concentration of the carbon dioxide gas is low or in normal condition

Based on the figure above, the serial monitor shows the output sensor voltage and carbon dioxide gas concentration in PPM (parts per million). As the sensor voltage increases, the concentration also increases. The buzzer will not trigger, and the LCD will display the normal condition.

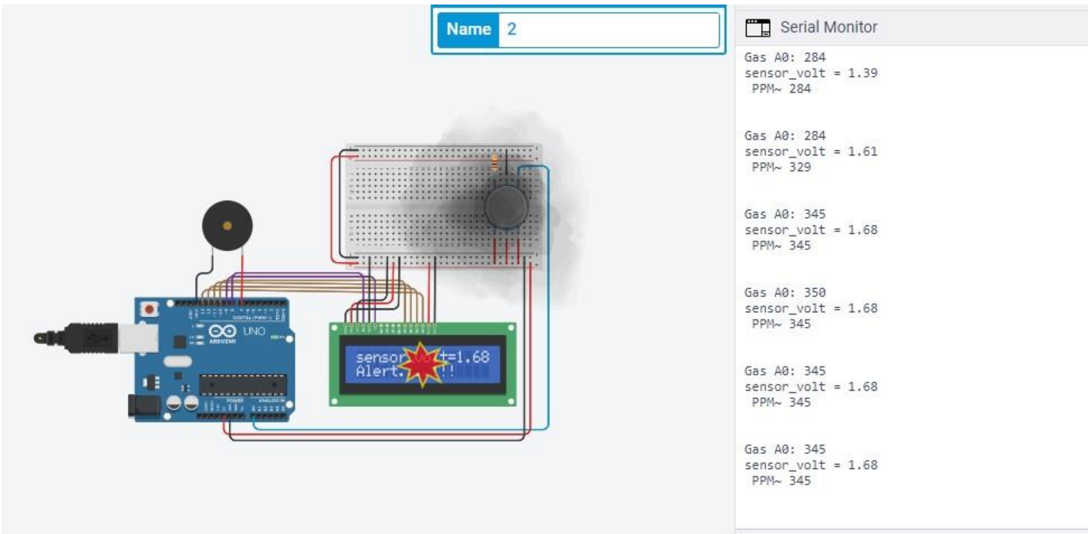


Figure 4.2.2: Circuit simulation result when the concentration of the carbon dioxide gas is high or in alert condition

The buzzer will turn on when the gas sensor detects the concentration of the carbon dioxide gas getting higher than the threshold value set. The LCD will display an alert condition that shows that the concentration of carbon dioxide gas is high.

4.3 Result of Circuit Construction on Breadboard

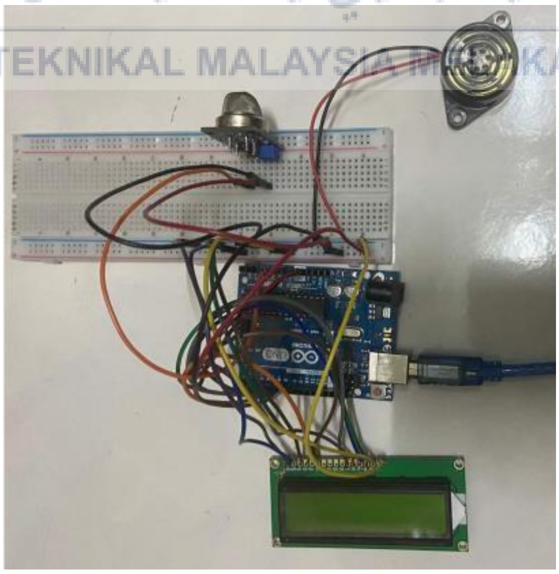


Figure 4.3: The Circuit Constructed on Breadboard

Construction of circuit is constructed on the breadboard as in Figure 4.3. It is to ensure that the circuit can be operated as the simulation. The connection of each pin is referred to based on the simulation in Tinkercad software circuit development. The power (VCC) and ground are connected to the breadboard to observe the results. From the observation, all the components function well when the breadboard is supplied with 5V. The gas sensor senses the presence and absence of carbon dioxide gas. Buzzer does not trigger and does not have tone if the gas level of carbon dioxide gas is low. LCD shows the display output of the gas level and the sensor voltage. Troubleshooting is done for the circuit. The port of the Arduino Uno does not recognize in Arduino IDE software. This is because the wire of the ground disconnected from the breadboard. Other than that, the buzzer keeps turning on even when the gas level is normal. After troubleshooting, the connection is wrong at the negative leg. The negative leg is connected to the 5V. The negative leg should be connected to the digital input of number 7 on the Arduino Uno board as defined in the program coding. When the connection changed, the buzzer worked as it should. The breadboard development for this circuit is working. During this construction, some of the components broke down during the testing, so the component needs to change to the new one.

Figure 4.3.1: Output serial monitor from Arduino IDE software after run the coding

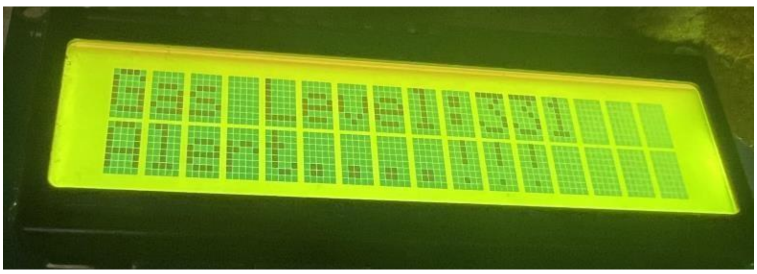


Figure 4.3.2: LCD display output

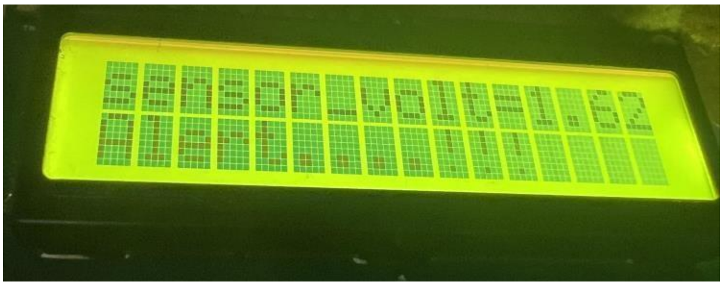


Figure 4.3.3: LCD display output

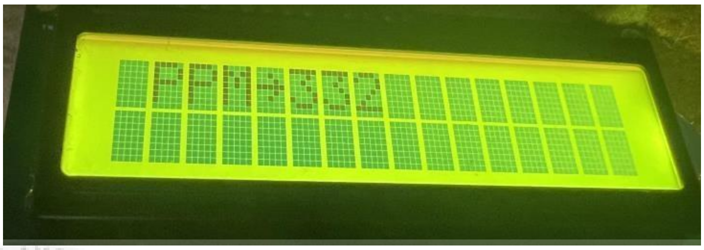


Figure 4.3.4: LCD display output

Figure 4.3.1 shows the output of the serial monitor obtained after the program coding has been run in Arduino IDE software. Figure 4.3.2, 4.3.3, and 4.3.4 shows the LCD that displays the output of the carbon dioxide gas concentration. These are the results for the concentration of carbon dioxide gas obtained from the burning of 10 grams of paper.

4.4 Fabrication of the Titanium Dioxide Gas Sensor

The screen-printing method was used through the fabrication of the titanium dioxide gas sensor process. Other than that, the material that needs to be screened on the glass substrate is selected. The annealing process will be done to achieve the fabrication of the titanium dioxide gas sensor.

4.4.1 Prepare the Binder

Before starting the titanium dioxide gas sensor fabrication, the two different binders of 1 gram need to be prepared.

Table 4.4.1: Chemicals and percentage ratios used to prepare different binders

Binder A	Binder B
2% ethyl cellulose (0.02g)	2% ethyl cellulose (0.02g)
5% linseed oil (0.05g)	10% linseed oil (0.10g)
93% α-terpineol (0.93g)	88% α-terpineol (0.88g)

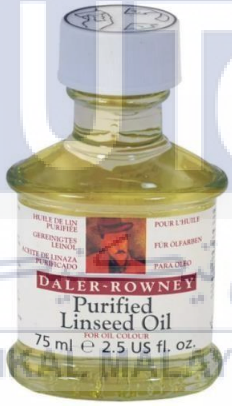


Figure 4.4.1.1: Linseed oil used

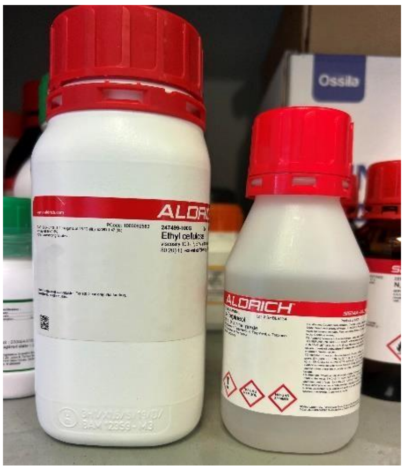


Figure 4.4.1.2: Ethyl cellulose and α-terpineol

To prepare the binder, ethyl cellulose, linseed oil and α-terpineol were combined and then magnetically stirred at a speed of 70 rpm (revolutions per minute) on the magnetic stirrer using a magnetic bar. The stirring procedure was continued until the combination of the ethyl cellulose, linseed oil and α-terpineol mixed well. The moving process takes about 24 to 30 hours to get a sticky liquid form binder.

Figure 4.4.1.3: The preparation of the binder on the magnetic stirrer

Figure 4.4.1.4 below shows that the sticky liquid form binder has been done after the moving process. The white colour in the binder is the magnetic bar used to stir the combination of ethyl cellulose, linseed oil and α-terpineol.

Figure 4.4.1.4: Sticky liquid form binder

4.4.2 Prepare the Titanium Paste

To form a thick film gas sensor paste, semiconducting metal oxide powder and organic binders are added together. For this part, titanium (IV) oxide nanopowder is used. Titanium (IV) oxide is an inorganic substance that is white, and the chemical formula is TiO_2.

Figure 4.4.2: Titanium (IV) oxide nano powder

Two different binders can produce two different pastes. Thus, 2 grams of each paste need to be done. The process of making the paste was the same as the binder, 70% of organic binder and 30% of titanium (IV) oxide nanopowder were mixed using the magnetic stirrer for about 24 hours at a speed of 70 rpm.

Figure 4.4.2.1: Paste obtained from the mixture of binder and titanium (IV) oxide nano powder

4.4.3 Chemical Characterizations by Fourier-Transform Infrared Spectroscopy (FTIR)

Fourier transforms infrared spectroscopy (FTIR) is a useful technique [16]. Unknown components, additives within polymers, and surface contamination on a material can be identified via FTIR analysis. It can also evaluate the molecular composition and structure of the material. An interferometer, a simple device that produces an optical signal with all the infrared (IR) frequencies recorded, is used to identify samples [17]. The technique has been done using Fourier Transform Infrared Spectrometer, as shown in Figure 4.4.3.

Figure 4.4.3: Fourier Transform Infrared Spectrometer

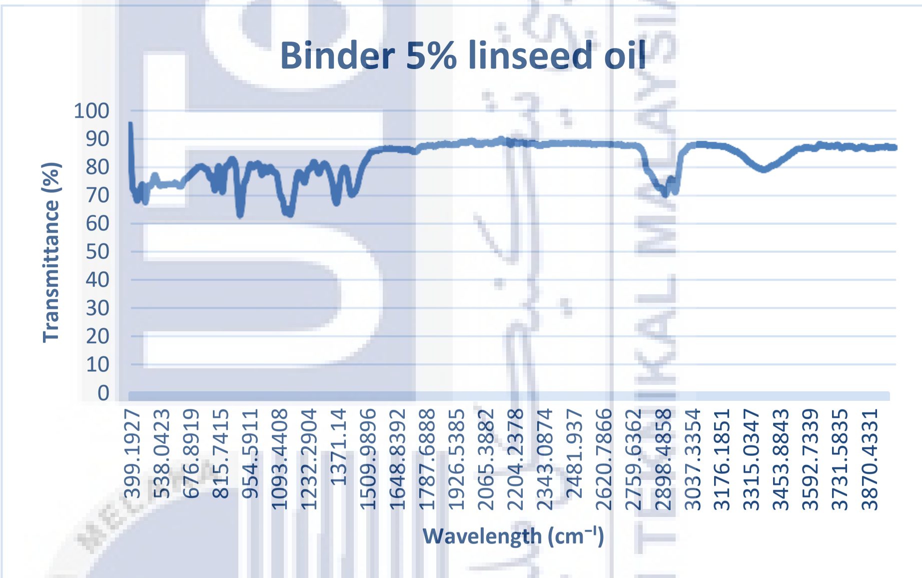


Figure 4.4.3.1: Characterization of binder A which consists of 5% linseed oil

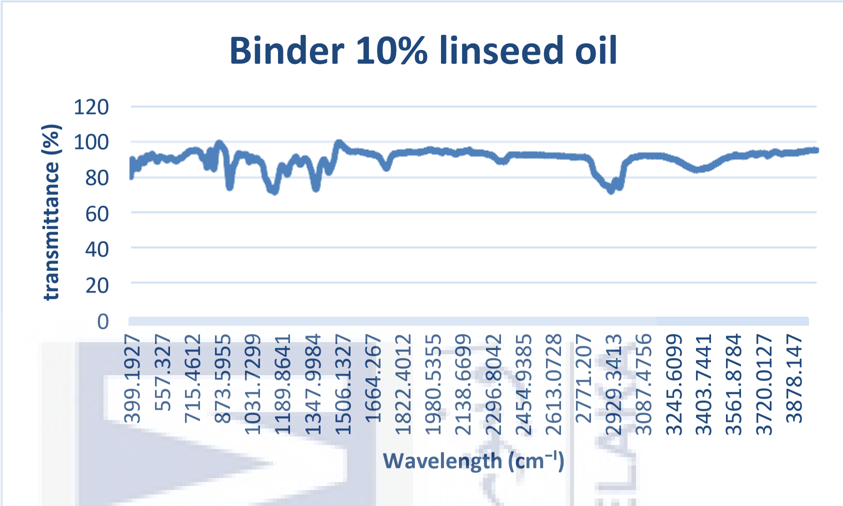


Figure 4.4.3.2: Characterization of binder B which consists of 10% linseed oil

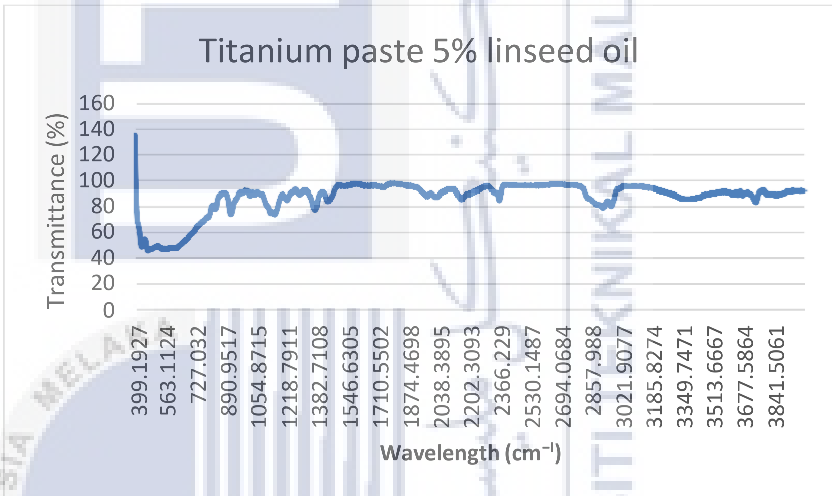


Figure 4.4.3.3: Characterization of titanium paste which consists of 5% linseed oil

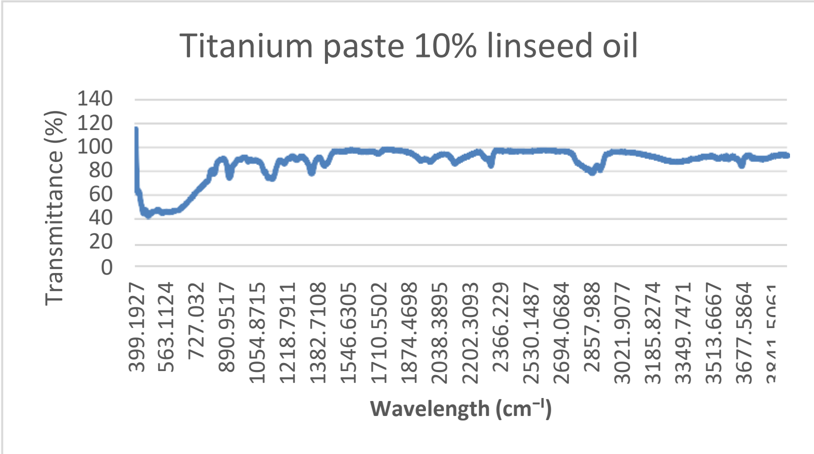


Figure 4.4.3.4: Characterization of titanium paste which consists of 10% linseed oil

Based on Figures 4.4.3.1, 4.4.3.2, 4.4.3.3, and 4.4.3.4 above, the characterization of binders and pastes has been done using the FTIR technique. The characterization process, molecular composition, and structure of the material from the liquid form of binders and pastes can be identified at the peak of the wavelength obtained. The x-axis of the graph indicates the wavelength on a range from 300 to 4000 cm-1. The presence of the structure in the range of the wavelength may occur due to the varying of the mixture in both pastes and binders. Y-axis has indicated the transmittance (%).

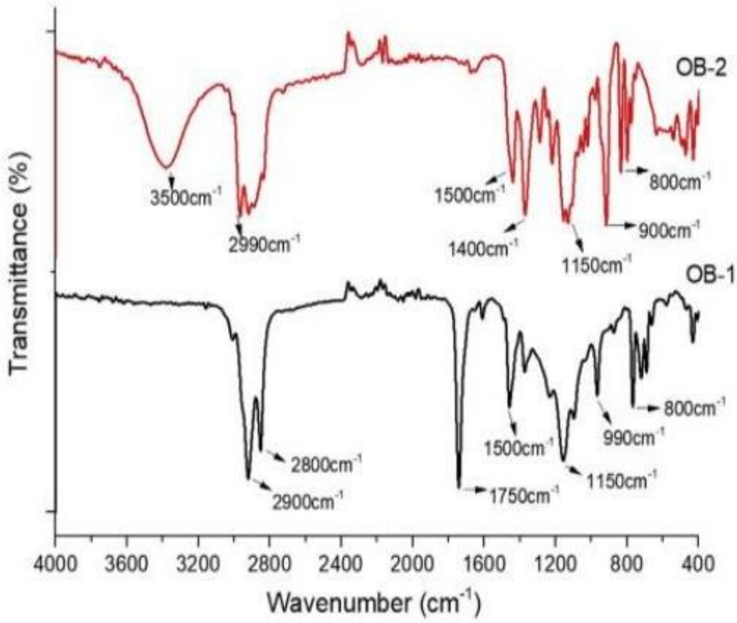


Figure 4.4.3.5: FTIR spectrum of past researchers

Based on figure 4.4.3.5, the graph shows the characterization of past researchers on the response of TiO2/MWCNT/B2O3 gas sensor to hydrogen using different organic binder which consists of the same chemical that has been used for this project which are ethyl cellulose, α-terpineol and linseed oil. It shows that the graph is the same as the characterization that has been done in Figure 4.4.3.1 and Figure 4.4.3.2, where all the peaks are the same. Still, the wavelengths are different as for the past researchers, the wavelength decreases, but for the finding of this project, the wavelength increases. Therefore, the graph is a bit different because of the mirror of the wavelength, but all the peaks on the same wavelength are the same.

4.4.4 Fabrication of Titanium Dioxide (TiO_2) Gas Sensor

The fabrication process of the titanium dioxide gas sensor starts with the deposition of the silver conductive paste on the first layer of the glass substrate by using the screen-printing method. The screen-printing film comprises masks that are customized to the type of gas to be detected and the metal oxide to be deployed [18]. Then, the annealing process was done at 150˚C for 5 minutes.

Figure 4.4.4: Silver conductive paste

Figure 4.4.4.1: Screen-printing film used to deposit the silver

Figure 4.4.4.2: Silver paste has been deposited on first layer of glass substrate

The process is then continued by adding the titanium paste on the second layer of the glass substrate by using the same method of screen-printing, but different film and it was annealed in the oven at 200˚C for 30 minutes.

Figure 4.4.4.3: Titanium paste added on second layer of glass substrate

Figure 4.4.4.4: Screen-printing film used to add the titanium paste on a second layer of glass substrate

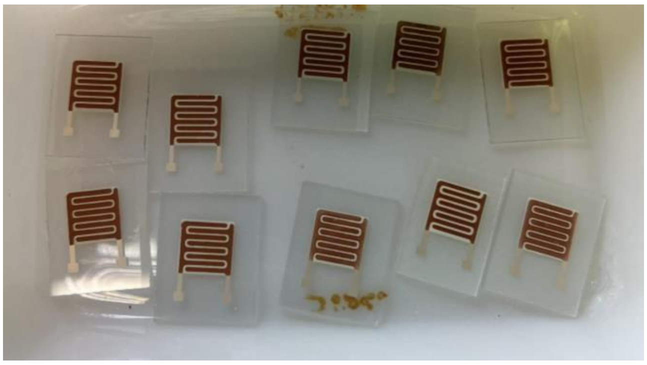


Figure 4.4.4.5: The gas sensor after the annealing process

After finishing all the processes, including the annealing process, the wire is attached to each leg of the gas sensor to connect to the hardware development with the commercial sensor (MQ135 air quality sensor module). Each gas sensor has been done for 5 samples to ensure that it has another sample if one of them is facing the short circuit.

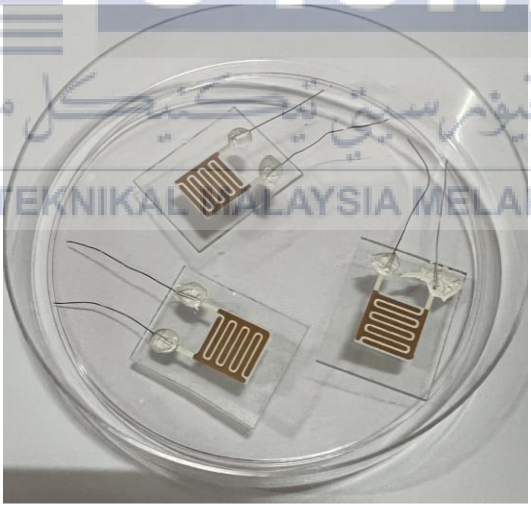


Figure 4.4.4.6: The Wire Has Been Attached to the Gas Sensor

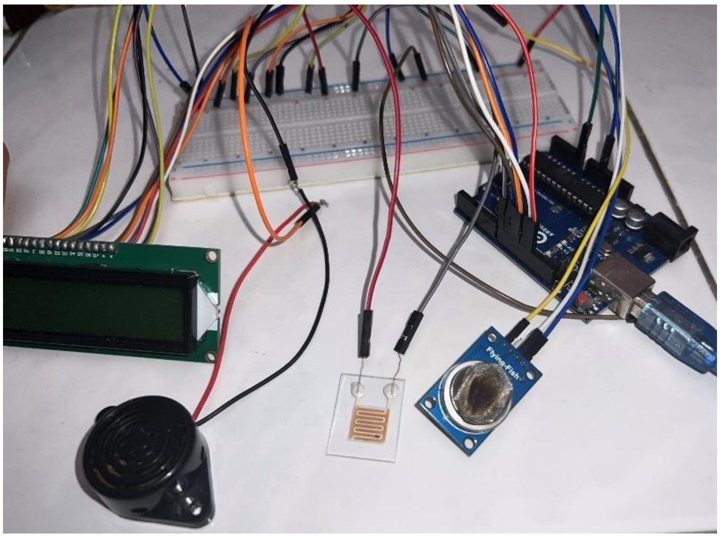


Figure 4.4.4.7: Hardware development of the gas sensor with the titanium dioxide gas sensor attached to the ground and V_{cc} of 5V.

4.5 Analysis on the Output Sensor Voltage and Concentration of Carbon Dioxide Gas

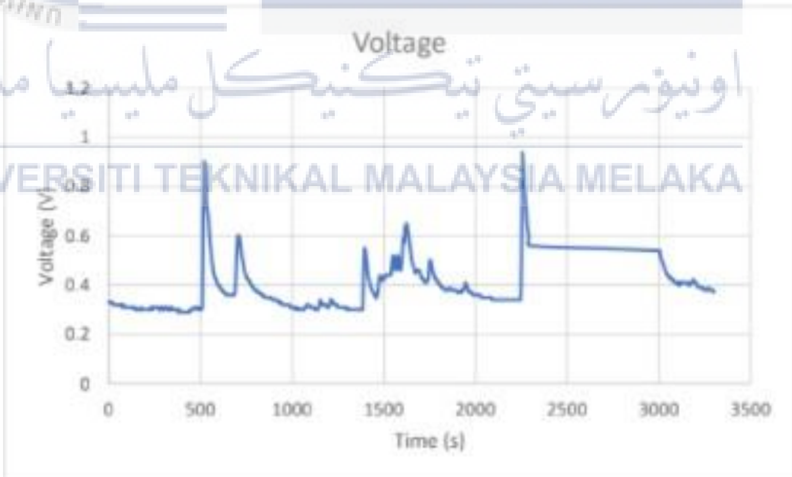


Figure 4.5: Output voltage graph obtained from the commercial gas sensor

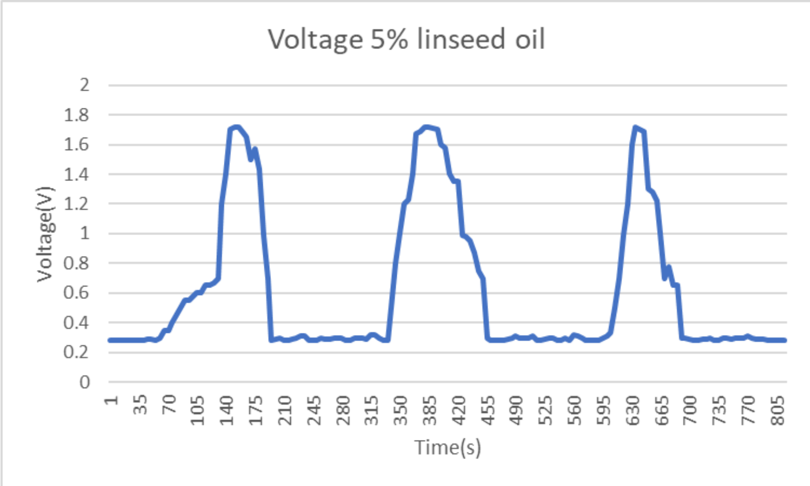


Figure 4.5.1: Output voltage graph obtained from the titanium gas sensor of 5% linseed oil

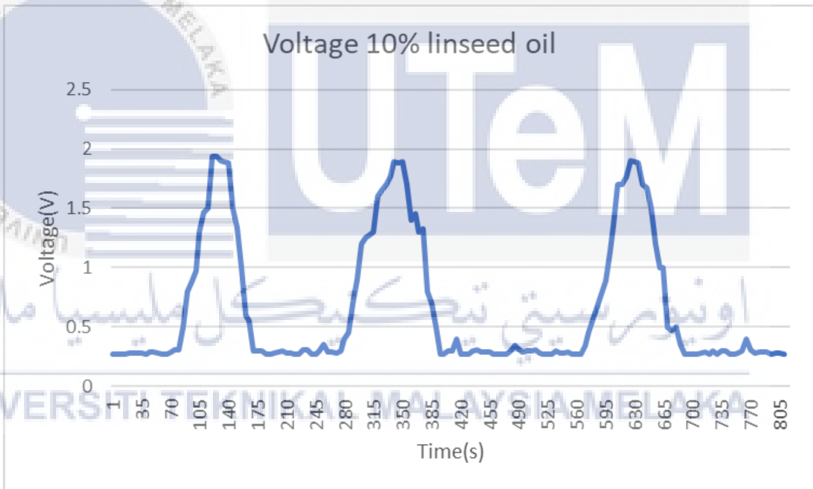


Figure 4.5.2: Output voltage graph obtained from the titanium gas sensor of 10% linseed oil

From the graph obtained, the output voltage of the commercial gas sensor is not stable, and the response time is different between the three times of burning paper of 10 grams compared to the output voltage of titanium gas sensor of 5% and 10% linseed oil. The output voltage of 5% and 10% linseed oil can be seen that only a little different as the percentage differences of the linseed oil is small. From the graph, as shown in Figure 4.5, 4.5.1, and 4.5.2 above, the sensitivity of the gas sensor to detect the concentration of carbon dioxide gas can be obtained by using the formula of **sensitivity (S)** $= \frac{R_g}{R_a}$ for the oxidation of the gas [18] where the resistance of gas sensors in the ambient air is called Ra. In contrast, the resistance in the reference gas with target gases is called Rg. The resistance in the reference gas, which contains carbon dioxide gas, is represented by the graph's peak, while the constant voltage represents the resistance of gas sensors in the ambient air. Commercial gas has a sensitivity of 2.29, 5% linseed oil has a sensitivity of 7.19, and 10% linseed oil has a sensitivity of 6.14. It may be concluded that Binder A's gas sensor is superior, as the higher the gas sensor's sensitivity, the better the gas sensor. It also ensures that the gas sensor is stable. The sensitivity of a gas sensor is also affected by its surface.

Table 4.5: Sensitivity of the Gas Sensor

Commercial Gas (MQ-135)	**2.29**
Binder A	**7.19**
Binder B	**6.14**

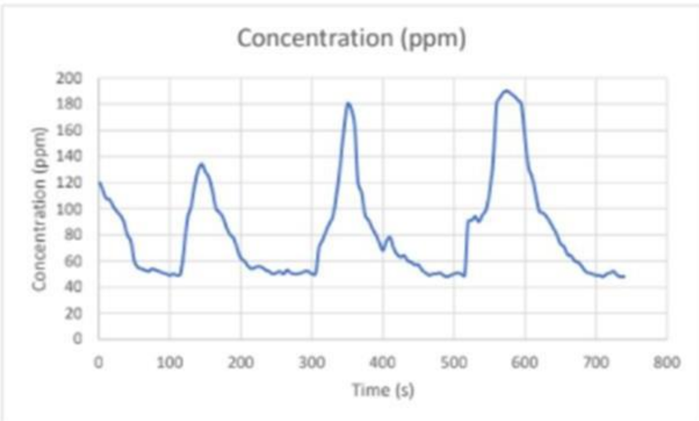


Figure 4.5.3: Concentration of Carbon Dioxide Gas Graph Obtained from the Commercial Gas Sensor

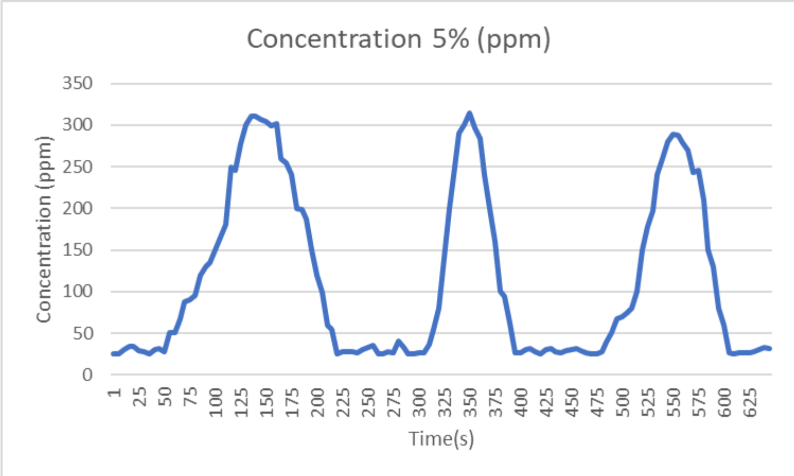


Figure 4.5.4: Concentration of carbon dioxide gas graph obtained from the titanium gas sensor of 5% linseed oil

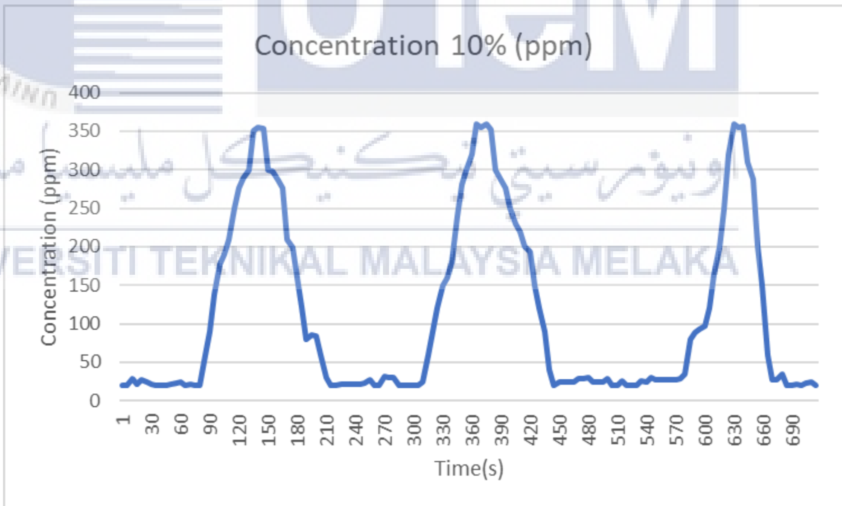


Figure 4.5.5: Concentration of carbon dioxide gas graph obtained from the titanium gas sensor of 10% linseed oil

The figure above shows different carbon dioxide gas graph concentrations obtained from the commercial gas titanium gas sensor of 5% linseed oil and 10%

linseed oil. The graph was also obtained from the three times burning of 10 grams of paper.

4.6 Result Obtained from Internet of Things (IoT)

Internet of Things (IoT) has been applied to this project to get real-time data on carbon dioxide gas concentration. The thingspeak platform sends the current data from the NodeMCU into the Thingspeak. This platform can alert people whenever the concentration of carbon dioxide gas becomes higher. Thus, it will harm the people.

```
#include <ESP8266WiFi.h>
#include <SPI.h>
#include <Wire.h>
#include "MQ135.h"

String apiKey = "9YC8M8LAHDOACA09"; // Enter your Write API key from ThingSpeak
const char *ssid = "AndroidAP025F";     // replace with your wifi ssid and wpa2 key
const char *pass = "Jasanah56";
const char* server = "api.thingspeak.com";

WiFiClient client;

void setup()
{
  Serial.begin(9600);
  Serial.println("Connecting to ");
  Serial.println(ssid);

  WiFi.begin(ssid, pass);

  while (WiFi.status() != WL_CONNECTED)
  {
    delay(500);
    Serial.print(".");
  }
    Serial.println("");
    Serial.println("WiFi connected");

}
```


Figure 4.6: Source code for Internet of Things (IoT)

```
void loop()
{
  MQ135 gasSensor = MQ135(A0);
  float air_quality = gasSensor.getPPM();
  Serial.print("Air Quality: ");
  Serial.print(air_quality);
  Serial.println("  PPM");
  Serial.println();

  if (client.connect(server, 80)) // "184.106.153.149" or api.thingspeak.com
{
  String postStr = apiKey;
  postStr += "&field1=";
  postStr += String(air_quality);
  postStr += "r\n";

  client.print("POST /update HTTP/1.1\n");
  client.print("Host: api.thingspeak.com\n");
  client.print("Connection: close\n");
  client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
  client.print("Content-Type: application/x-www-form-urlencoded\n");
  client.print("Content-Length: ");
  client.print(postStr.length());
  client.print("\n\n");
  client.print(postStr);
```

Figure 4.6.1: Source code for Internet of Things (IoT)

```
    Serial.println("Data Send to Thingspeak");
  }
    client.stop();
    Serial.println("Waiting...");

    delay(2000);      // thingspeak needs minimum 15 sec delay between updates.
}
```

Figure 4.6.2: Source code for Internet of Things (IoT)

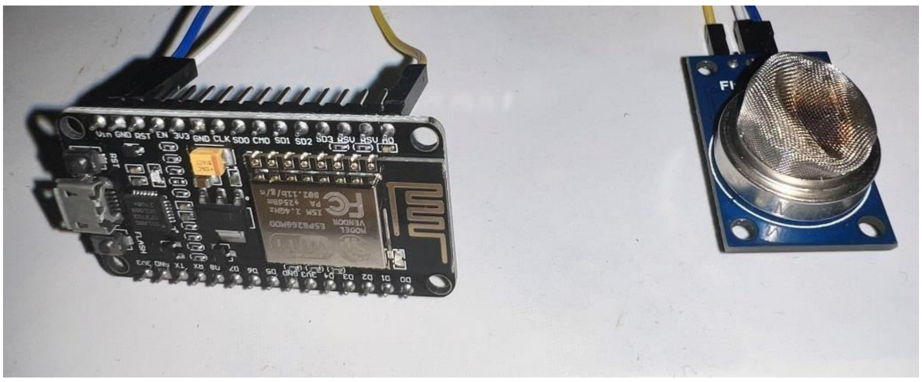


Figure 4.6.3: Connection of Gas Sensor with NodeMCU

Figure 4.6.4: Serial monitor obtained

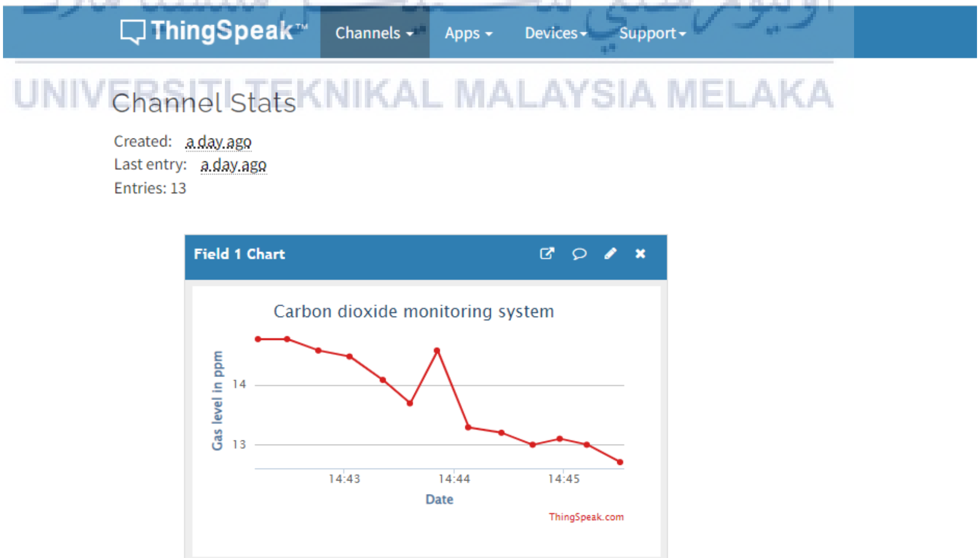


Figure 4.6.5: Data Obtained from the Thingspeak Platform

4.7 Limitation

In the process of completion of this project, some limitations affect the project. One of them is the serial plotter and monitor unable to be displayed at the same time when the sensitivity test of the gas is conducted. This has become a limitation, as if the experiment has been conducted twice. The result may be different. Other than that, the serial plotter only can achieve at a certain time, then the previous graph obtained will be missing, so the initial graph cannot be seen.

Furthermore, the jumper has been used to connect the component in the electrical circuit. This may cause some error as the jumper itself to have its resistance. This might give a small imprecise data transfer for the responses of the gas detected.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

This final chapter will summarize and conclude all the findings, and the overall progress of the project will be concluded from the simulation and the hardware part. In addition, the recommendation or improvement for the future project based on this project also will be discussed in this chapter to make this project more reliable and precise towards the upcoming technology.

5.1 Conclusion

At the end of this final year project, the progress achieved in the literature review selected project title and some progress work of hardware development. All the references in the literature review can be implemented in this project. The concept of this project is to alert the people about the unwanted higher concentration of carbon dioxide gas. This also can avoid leading to coma and death. The main objective, which is to sense carbon dioxide gas concentration, was also a success. While working on the project, some limitations have been faced, yet able to overcome them by improvising the current situation by considering many things.

Through this project, the student can learn about the program code in detail because some students did not know how to make a program code. Other than that, the student also can study the hardware development with the help of a supervisor. They can also study the importance or functions of each component. Some experience in software knowledge like Thinkercad and Arduino IDE software had been achieved. The student also learns how to troubleshoot the circuit and check the condition of components through this project.

Moreover, the development of "Titanium Dioxide Gas Sensor for Monitoring Carbon Dioxide with IoT" able to create by using MQ-135 gas sensor and titanium dioxide gas sensor. The gas sensor detects the presence of carbon dioxide gas by connecting the leg to the ground and Vcc. Thus, the LCD is functioning well.

As a result, the gas sensor with titanium dioxide, TiO_2 was achieved. The fabrication method was used to develop the gas sensor. The sensitivity of commercial gas is 2.29, 5% linseed oil is 7.19, and 10% linseed oil is 6.14. Thus, it shows that Binder A with 5% linseed oil is the better gas sensor compared to the other two.

Finally, implementing this titanium dioxide gas sensor can help boost the development of technology as it helps maintain the quality as demanded by the modernization lifestyle by identifying the quality of the tested product.

5.2 Recommendation (Future Works)

For the future recommendation, to upgrade this project is by installing the heating stage. This is because some gases only can be detected at certain temperatures. Thus, adding a heating stage can be used to sense various types of gases, hence increasing its functionality. This is to ensure the accuracy of the data and safety and avoid any unwanted incident whenever the gas's content and pressure is too high. Lastly, this project also can be improved by using the Blynk application, where the application will notify the user through email about the real-time concentration of carbon dioxide gas. This will give a more alert to the people.

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APPENDICES

Appendix A

	SEM I																		
Aktiviti Projek *Project Activities*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Selection of Title and Registration	X	X																	
Project Briefing and Discussion with Supervisor		X	X								SEMINAR PSM I								
Hardware Selection		X																	
Proposal Writing		X	X																
Circuit Design			X	X															
Proposal Defense				X															
Thesis Draft Submission to Supervisor					X	X	X	X	X	X									
Software and Simulation						X	X	X	X	X		X	X	X					
Submission of Final Draft to Supervisor													X	X					
Fabrication Titanium Dioxide (TiO_2) Gas Sensor using Screen Printing			X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Integration of Hardware and Software Component																		X	X

	SEM II															
Aktiviti Projek *Project Activities*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Integration of Hardware and Software Component	X	X	X	X										SEMINAR PSM II		
Testing the System		X	X	X	X	X	X	X	X							
Analysis of Data (Result)						X	X	X	X	X	X					
Final Test of Project								X	X	X	X	X	X		X	X
Final Thesis	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Submission Final Thesis to Supervisor and Panel																X

Appendix B

Program coding of concentration of gas sensor and output voltage

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(8, 9, 10, 11, 12, 13); //RS,EN,D4,D5,D6,D7



int buzzer = 7;

int gasA0 = A0;

int sensorValue;

// Your threshold value

int sensorThres = 250;
```

```
void setup() {
  pinMode(buzzer, OUTPUT);
  pinMode(gasA0, INPUT);
Serial.begin(9600);
lcd.begin(16, 2);
Serial.println("GAS SENSOR TEST");
lcd.setCursor(0,0);
lcd.print("GAS SENSOR TEST");
lcd.setCursor(0,1);
lcd.print("PSM 2022");
delay(2000);
lcd.clear();
}

void loop() {
  int analogSensor = analogRead(gasA0);
```

```
Serial.print("Gas A0: ");
Serial.println(analogSensor);
lcd.print("Gas Level:");
lcd.print(analogSensor);
// Checks if it has reached the threshold value
if (analogSensor > sensorThres)
{
  lcd.setCursor(0, 2);
  lcd.print("Alert....!!!");
  digitalWrite(12, LOW);
  tone(buzzer, 500, 200);
}
else
{
  lcd.setCursor(0, 2);
  lcd.print(".....Normal.....");
```

```
  noTone(buzzer);
}
delay(500);


float sensor_volt;
int sensorValue = analogRead(A0);
sensor_volt = ((float)sensorValue / 1024) * 5.0;
Serial.print("sensor_volt = ");
Serial.println(sensor_volt);
Serial.print(" PPM~ ");
Serial.println(sensorValue, DEC); // prints the value read
Serial.print("\n\n");
  lcd.setCursor(0,0);
lcd.print("sensor_volt=");
lcd.print(sensor_volt);
lcd.setCursor(0,1);
delay(1000);
```

```
  lcd.clear();

  lcd.print(" PPM~");

  lcd.print(sensorValue, DEC);

  delay(1000);

  lcd.clear();



}
```

Appendix C

Program coding for the Internet of Things (IoT)

```
#include <ESP8266WiFi.h>

#include <SPI.h>

#include <Wire.h>

#include "MQ135.h"


String apiKey = "9YC8M8LAHDOACA09"; // Enter your Write API key from ThingSpeak

const char *ssid = "AndroidAP025F";     // replace with your wifi ssid and wpa2 key
```

```
const char *pass = "Jasanah56";

const char* server = "api.thingspeak.com";



WiFiClient client;



void setup()

{

  Serial.begin(9600);

  Serial.println("Connecting to ");

  Serial.println(ssid);



  WiFi.begin(ssid, pass);



  while (WiFi.status() != WL_CONNECTED)

  {

    delay(500);

    Serial.print(".");
```

```
  }

   Serial.println("");

   Serial.println("WiFi connected");



}



 void loop()

 {

   MQ135 gasSensor = MQ135(A0);

   float air_quality = gasSensor.getPPM();

   Serial.print("Air Quality: ");

   Serial.print(air_quality);

   Serial.println("  PPM");

   Serial.println();


   if (client.connect(server, 80)) // "184.106.153.149" or api.thingspeak.com
```

```
{
  String postStr = apiKey;
  postStr += "&field1=";
  postStr += String(air_quality);
  postStr += "r\n";

  client.print("POST /update HTTP/1.1\n");
  client.print("Host: api.thingspeak.com\n");
  client.print("Connection: close\n");
  client.print("X-THINGSPEAKAPIKEY: " + apiKey + "\n");
  client.print("Content-Type: application/x-www-form-urlencoded\n");
  client.print("Content-Length: ");
  client.print(postStr.length());
  client.print("\n\n");
  client.print(postStr);

  Serial.println("Data Send to Thingspeak");
```

```
  }

   client.stop();

   Serial.println("Waiting...");



   delay(2000);      // thingspeak needs minimum 15 sec delay between updates.

}
```