LAPORAN KERJA PRAKTIK

INTERNATIONAL CLASS PROGRAM REPORT

MODEL DEVELOPMENT OF AN AUTOMATIC INDOOR AIR QUALITY CONTROL SYSTEM USING AN INTEGRATED SYSTEM METHODOLOGY

PREPARED BY:

LAYLA KHOIRANI

238150052

INDUSTRIAN ENGINEERING STUDY PROGRAM

FACULTY OF ENGINEERING

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PREFACE

Praise and gratitude are extended to Allah SWT, the Almighty, for His blessings and grace that have enabled the author to successfully complete the International Class Program report entitled "***Model Development of an Automatic Indoor Air Quality Control Using an Integrated System Methodology***". This report is prepared to fulfill the academic requirements of the Industrial Engineering Study Program for the Internship Course at University of Medan Area. The author realizes that during the preparation of this report, various challenges and obstacles were encountered. However, with the support and encouragement from friends, family, and many other parties, these challenges were successfully overcome.

On this occasion, the author would like to express sincere gratitude to all parties who have provided assistance and support in completing this report, especially to:

1. Dr. Eng. Supriatno, S.T., M.T., as the Dean of the Faculty of Engineering, University of Medan Area
2. Dr. Ir. Chalis Fajri Hasibuan, S.T., M.T., as the Head of the Industrial Engineering Study Program, University of Medan Area.
3. Nukhe Andri Silviana, S.T., M.T., as the as the Internship Advisor for her guidance, support, and valuable advice throughout the completion of this report.
4. All lecturers of the International Class Program, for the knowledge, guidance, and valuable learning experiences provided throughout the academic and program activities, which have greatly contributed to the author's academic and personal development.

5. My beloved mother, for her endless prayers, unconditional love, encouragement, and continuous support that have strengthened and motivated the author throughout the completion of this report and academic journey.
6. My fellow International Class Program colleagues, for the cooperation, teamwork, shared experiences, and mutual support during the learning process and project implementation.
7. My late best friend, Arlodial, whose memory, kindness, and encouragement continue to inspire and strengthen the author throughout her academic journey. Although he is no longer physically present, his support and meaningful impact remain a source of motivation in completing this report.
8. All parties who cannot be mentioned individually but have contributed directly or indirectly to the completion of this report.

In the preparation of this report, the author realizes that there are still several limitations and shortcomings. Therefore, constructive criticism, suggestions, and valuable feedback are highly appreciated for future improvement. Finally, the author sincerely hopes that this International Class Program report will provide meaningful benefits and contribute positively to the advancement of all parties involved.

Medan, 28 February 2026

Layla Khoirani

TABLE OF CONTENT

PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Background of the International Class Program

Current technological developments and global industrialization have a significant impact on improving the quality of human life, yet on the other hand, they also create various environmental issues, such as increased energy consumption, air pollution, and the degradation of residential environmental quality. These challenges demand an engineering approach that is not only oriented toward technical efficiency but also considers aspects of environmental sustainability and public welfare. Therefore, the concept of Green Engineering has become an essential paradigm in the development of modern technical systems, focusing on resource efficiency, the reduction of environmental impacts, and long term sustainability.

In response to these needs, University of Medan Area organizes the International Class Program (ICP) as a multidisciplinary collaborative academic program. This program is designed to integrate various fields of engineering and science to address global issues through a cross, disciplinary approach. The ICP involves students from several study programs, including Civil Engineering, Electrical Engineering, Mechanical Engineering, Architecture, Industrial Engineering, Informatics Engineering, and Biology, thereby creating a collaborative learning environment that mirrors professional work practices in industry and international research.

Under the overarching theme of Green Engineering, the ICP emphasizes the development of engineering solutions that are innovative, adaptive to digital technology advancements, and oriented toward environmental sustainability. Interdisciplinary collaboration is a key factor because modern engineering challenges are complex engineering problems that cannot be solved through a single scientific perspective alone. A multidisciplinary approach allows for the integrated coordination of design aspects, control systems, data analysis, energy efficiency, and system management.

From an Industrial Engineering perspective, student involvement in the ICP provides practical experience in applying systems thinking concepts, process integration, work system design, and system performance optimization based on cross functional team collaboration. Industrial Engineering acts as a bridge between disciplines through system management approaches, process analysis, and increasing the efficiency and effectiveness of the developed engineering solutions. This is particularly relevant in environment, based projects, such as the development of green building systems, environmental quality monitoring, and Internet of Things (IoT) based systems that support the health of residential areas.

The activities within the International Class Program are subsequently converted to fulfill the academic requirements of the Internship course. Through this conversion, students not only gain field practical experience but also conduct academic reflections on the application of Industrial Engineering principles in real world sustainability, based projects. This Internship Report is prepared as a systematic documentation of the learning process, multidisciplinary collaboration, and the implementation of Green Engineering concepts in developing applicable and future oriented technical solutions.

1.2 Objectives of the International Class Program

The objectives of the International Class Program implementation are divided into two categories, which are as follows:

1.2.1 General Objectives

1. Enhancing the ability of students to communicate and collaborate inter-disciplinarily across various study programs to solve complex technical problems.
2. Implementing the principles of Green Engineering in the design of sustainable products or systems.
3. Fulfilling the academic requirements of the Industrial Engineering curriculum at University of Medan Area through the conversion of ICP program credits to the Internship course.

1.2.2 Specific Objectives

1. Designing a system model for an integrated Automatic Smart Air Purifier using the Integrated System Methodology (ISM) approach.
2. Developing an automated control system prototype capable of synchronizing air quality sensor inputs with air purification mechanisms in real time.
3. Analyzing the integration of system components including hardware, software, and users to ensure energy efficiency in accordance with Green Engineering principles.
4. Formulating a smart home system model that is capable of independently adapting to changes in indoor environmental quality.

1.3 Benefits of the International Class Program

1.3.1 Academic Benefits

1. Applying Integrated System Methodology (ISM) to solve complex problems involving various engineering disciplines.
2. Providing a scientific contribution to Industrial Engineering at University of Medan Area in the field of environment based smart product system modeling.
3. Serving as a valid credit conversion medium for the Internship course through a methodologically structured project.

1.3.2 Professional Benefits

1. Training systems thinking skills in viewing a product as part of a larger, integrated system.
2. Enhancing expertise in managing cross functional technical projects using standardized research methodologies.
3. Preparing personal competencies to face Industry 4.0, which focuses on the integration of smart systems.

1.3.3 Environmental Benefits

1. The creation of an air purifier system model capable of reducing excessive energy consumption through automation based on air quality data.
2. Supporting the realization of the Smart and Green Home concept within urban communities.

1.4 Scope and Limitations of the Program

To ensure that the discussion in this report remains focused and aligned with the program objectives, the following scope and limitations have been established:

1. Development Focus: The development of the model is focused on a Smart Air Purifier automation system capable of responding to air quality in real time.
2. Program Context: This project is part of the International Class Program (ICP) assignment, which focuses on the Smart Home ecosystem.
3. Scientific Perspective: The analysis emphasizes the Industrial Engineering viewpoint, specifically regarding system efficiency, component integration, and Green Engineering aspects.
4. Technical Limitations: The developed model is a functional prototype tested within a limited indoor environmental scale.

1.5 Implementation Methodology of the Program

The implementation methodology of the International Class Program (ICP) at University of Medan Area is designed through an international learning approach based on multidisciplinary collaboration and Green Engineering concepts. The program begins with an academic orientation to introduce the program objectives, the international learning system, and the integration of students from various engineering and science disciplines.

The learning method is conducted using English as the medium of instruction with a global standard curriculum to enhance academic competence and student readiness for the international work environment. Program implementation emphasizes an interdisciplinary learning approach through the Green Engineering course, which integrates aspects of technology, energy efficiency, and environmental sustainability.

The learning process applies the Project Based Learning (PBL) method, where students work in cross disciplinary teams to solve real world case studies and develop engineering solutions based on modern technologies such as smart systems and the Internet of Things (IoT). These activities are supported by multidisciplinary faculty with international academic experience to strengthen the global perspective of the students.

Through this methodology, the ICP aims to produce graduates who possess systems thinking abilities, multidisciplinary collaboration skills, and competence in designing sustainable technical solutions in accordance with modern engineering challenges.

1.6 Structure of the Final Report

The structure of this final report is organized systematically to provide a clear description of the International Class Program (ICP) activities, project implementation, and research development process. The report is divided into four main chapters as follows:

CHAPTER I INTRODUCTION

Chapter I presents the general overview of the International Class Program. This chapter includes the background of the program implementation, objectives, benefits, scope and limitations, implementation methodology, and the structure of the final report. It explains the academic and practical foundation underlying student participation in the ICP and its relevance to Industrial Engineering perspectives and Green Engineering concepts.

CHAPTER II OVERVIEWOF INTERNATIONAL CLASS PROGRAM

Chapter II describes the profile and implementation of the International Class Program at University of Medan Area. This chapter explains the multidisciplinary collaboration framework, project theme, developed product, system operation, and the role of Industrial Engineering in integrating various engineering disciplines within the Smart Home for Green Living project.

CHAPTER III SPECIAL ASSIGNMENT

Chapter III discusses the special assignment conducted as part of the internship conversion activity entitled ***Model Development of an Automatic Indoor Air Quality Control System Using an Integrated System Methodology***. This chapter includes the research background, problem formulation, research objectives, benefits, scope of research, literature review, research methodology, system modeling design, hardware and software development, as well as results and discussion related to the development of an IoT-based indoor air quality control system model.

CHAPTER IV CONCLUSION

Chapter IV presents the conclusions derived from the implementation of the International Class Program and the special assignment activities. This chapter summarizes the overall findings, system development outcomes, and the contribution of the project toward smart home technology development and sustainable engineering applications.

CHAPTER II

OVERVIEW OF INTERNATIONAL CLASS PROGRAM

2.1 Overview of the International Class Program

The International Class Program (ICP) is one of the flagship programs organized by University of Medan Area as an effort to improve the quality of international based higher education. This program is designed to address global challenges in the Industry 4.0 era, which is characterized by the development of digital technology, the integration of smart systems, and the increasing need for sustainable and environmentally friendly engineering solutions.

The vision of the International Class Program is to create technical innovations based on Green Engineering principles through collaboration across various study programs, including Civil Engineering, Electrical Engineering, Mechanical Engineering, Architecture, Industrial Engineering, Informatics Engineering, and Biology. This multidisciplinary approach aims to produce engineering solutions that are not only technologically innovative but also take into account aspects of environmental sustainability, energy efficiency, and public welfare.

The objective of the ICP implementation is to produce graduates who possess global competencies, specifically the ability to work in multicultural and multidisciplinary teams with international standards. The program also emphasizes the strengthening of systems thinking abilities, cross disciplinary collaboration, international communication, and the application of Green Engineering concepts in the development of modern technical solutions.

2.2 Interdisciplinary Collaboration Framework in ICP

The multidisciplinary collaboration framework within the International Class Program (ICP) is designed to integrate various fields of engineering and science into a single project based collaborative learning environment. This collaboration involves students from Civil Engineering, Electrical Engineering, Mechanical Engineering, Architecture, Industrial Engineering, Informatics Engineering, and Biology study programs working in an integrated manner to develop sustainable engineering solutions.

The ICP collaboration framework consists of several primary components, which are:

1. Multidisciplinary Team Formation: Students are organized into cross disciplinary study program teams to simulate a professional work environment that requires the integration of various technical competencies.
2. Integrated Green Engineering Approach: Each scientific discipline contributes its expertise to the design of Green Engineering based solutions, such as sustainable building design, energy efficiency, control systems, and environmental impact analysis.
3. Collaborative Learning Process: The learning process is conducted through group discussions, case studies, and joint project development to enhance communication skills, coordination, and complex problem solving.
4. Global Academic Environment: The use of English and international learning standards supports multicultural academic interaction and builds student readiness for global cooperation.

Through this collaboration framework, the ICP encourages the integration of cross disciplinary knowledge so that students are able to understand engineering problems systemically and produce innovative solutions oriented toward sustainability.

2.3 Description of the ICP Project

2.3.1 Project Theme

The project developed within the International Class Program (ICP) activities at University of Medan Area carries the theme Smart Home for Green Living, which is a smart residential concept oriented toward energy efficiency, occupant comfort, and environmental sustainability. This theme emphasizes the utilization of smart technology to improve the quality of life while simultaneously reducing the environmental impact of residential activities.

2.3.2 Developed Product

The primary product developed is the Automatic Smart Air Purifier, which is an automated air purification system based on sensor technology and the Internet of Things (IoT). This device is designed as a solution to indoor air quality issues, specifically those caused by air pollution, dust, and hazardous particles that can affect the health of residents.

The development of the tool was carried out through multidisciplinary collaboration, involving aspects of system design, electronics, programming, environmental analysis, and system optimization approaches from an industrial engineering perspective.

2.3.3 System Operation

The Automatic Smart Air Purifier operates on the principle of real time air quality monitoring using pollutant particle detection sensors. The system continuously scans environmental air conditions and performs automated decision making based on the detected air quality levels.

When the outdoor sensor detects excessive smoke and a spike in PM2.5 levels, the system automatically closes the windows and activates the air purifier to normalize the air quality within the room that has been contaminated by outdoor pollution. Conversely, if smoke is detected from inside the room accompanied by an increase in temperature and humidity, the system interprets these conditions as a fire indication. In response, the system automatically opens the windows and activates a buzzer and LED as a warning to the occupants.

This automation approach allows the device to operate efficiently as it does not run for a full 24 hour period, but is only active when necessary. Consequently, the system not only improves indoor air quality but also supports Green Engineering principles through the optimization of energy consumption.

2.4 Industrial Engineering Perspective in the Project

In the Smart Home for Green Living project within the International Class Program (ICP) at University of Medan Area, Industrial Engineering students serve as system integrators who ensure that all project components operate in a unified, efficient, and performance oriented manner.

The primary role of Industrial Engineering students lies in integrated system analysis, which involves ensuring that various subsystems developed by different disciplines are capable of operating harmoniously as a single cohesive system. In the Automatic Smart Air Purifier project, this integration includes:

1. Hardware components designed by Electrical Engineering for sensor and control systems,
2. Spatial design and ventilation aspects from Architecture,
3. Mechanical mechanisms from Mechanical Engineering,
4. Programming systems and data processing from Informatics Engineering,
5. Environmental quality analysis from the field of Biology.

Industrial Engineering students are responsible for analyzing the relationships between these components through a systems thinking approach, ensuring that the flow of information, energy, and device operation processes run optimally without functional redundancy or resource wastage.

Furthermore, Industrial Engineering approaches are utilized to evaluate the operational efficiency of the system, including the optimization of energy consumption, the reliability of automation systems, and the effectiveness of the device response to changes in air quality. With this approach, the developed product not only functions technically but also achieves system performance that is efficient, sustainable, and feasible for application in modern residential environments.

Through this role, Industrial Engineering acts as a system integrator between disciplines in the ICP project, while simultaneously ensuring that the implementation of Green Engineering concepts is achieved comprehensively.

2.5 Project Development Stages

The implementation of the Smart Home for Green Living project in the International Class Program (ICP) at University of Medan Area is conducted through several primary stages that represent a structured engineering product development process, ranging from planning to system refinement.

1. Initiation Stage The initiation stage is the initial phase focusing on identifying smart home system needs, particularly related to the improvement of indoor air quality. During this stage, the team conducts multidisciplinary discussions to determine the development concept of the Automatic Smart Air Purifier as a solution to indoor air pollution problems while supporting the concept of sustainable housing.
2. Conceptual Design Stage After the project idea is established, the cross disciplinary team develops a conceptual design in the form of an initial system schema. This stage includes designing the device architecture, determining primary components, establishing the system workflow concept, and assigning roles among disciplines to ensure functional integration from the design phase.
3. Development Stage The development stage involves the hardware assembly process, control system programming, and the integration of sensors and actuators. Initial functional testing is conducted to ensure the device is capable of detecting air quality and responding automatically according to environmental conditions.
4. Finalization Stage The finalization stage is the system refinement process through device performance adjustments, physical design improvements,

and the optimization of device performance to ensure stable operation, energy efficiency, and readiness for presentation as the final ICP project product.

CHAPTER III

SPECIAL ASSIGNMENT

3.1 Introduction

This special assignment is a component of the internship report that outlines the fundamental framework for the student's final project, "***Model Development of an Automatic Indoor Air Quality Control System Using an Integrated System Methodology***".

3.1.1 Background

In order to preserve human health and increase productivity, indoor air quality, or IAQ, is essential. IAQ is therefore a major concern, particularly in residential settings. Despite being indoors, the outside world can still have an impact on the quality of the air. Smoke from burning garbage or other items from the surrounding environment that enters through open windows, ventilation, and building breaches is one of the frequent issues. Such circumstances have the potential to cause health problems and disrupt the residents' comfort.

Exposure to indoor smoke can cause various disturbances such as eye irritation, respiratory issues, unpleasant odors, and pose long-term health risks. Especially for vulnerable groups, such as children and the elderly. This issue often becomes a complex challenge to address because the solutions used are still manual, such as closing windows or turning on ventilation fans. These solutions are not always effective in responding to emergency situations, especially when the occupants are not at home to take manual actions. Moreover, conventional ventilation systems such as manual HVAC often fail because they do not receive real-time data and are less adaptive to fluctuating pollutants.

Air distribution constraints caused by room partitions often represent a difficult obstacle, potentially triggering the accumulation of indoor pollutants such as CO_2 and organic vapors. These conditions frequently go undetected early due to the limitations of existing monitoring systems. Manual approaches not only incur high operational costs but are also unreliable due to the risk of measurement errors. Therefore, the effectiveness of direct oversight is limited, necessitating a more precise automated sensor system.

The advancement of Internet of Things (IoT) technology offers transformative opportunities to create smart home systems capable of monitoring environmental conditions in real-time. By integrating air quality sensors, actuators, and control algorithms, these systems can eliminate the margin of error inherent in manual measurements. This integration enables residences to respond intelligently and automatically to changes in pollutants, such as smoke or CO_2, ensuring that air quality remains within safe thresholds even when the occupants are away.

The success of such intelligent systems depends heavily on their underlying model architecture. The dynamic interaction between hardware and communication protocols requires a structured design approach to prevent system failures. Utilizing an Integrated Systems Methodology, this research aims to develop an IoT-based air quality control model capable of addressing technical challenges through precise component integration.

3.1.2 Problem Formulation

Based on the background described above, this research formulates several problems as follows:

1. How can an IoT-based automated system be modeled to detect and control the infiltration of smoke into indoor spaces?
2. How can the system components be identified and integrated into a specific unified model?
3. How can the resulting system model represent the automated response mechanisms of a smart home to changes in air quality?

3.1.3 Research Objectives

Based on the research questions above, the objectives of this study are as follows:

1. To develop an IoT-based indoor air quality control system model capable of detecting smoke.
2. To illustrate the integration between subsystems using an Integrated Systems Methodology approach.
3. To produce conceptual, functional, and architectural models as a foundation for developing smart home systems for air quality protection.

3.1.4 Research Benefits

The results of this research are expected to provide both theoretical and practical benefits, including:

1. Theoretical benefits: To contribute to the development of IoT system modeling within the context of smart homes and indoor air quality control, and to serve as an academic reference for the application of integrated systems methodology in IoT-based automated systems.
2. Practical benefits: To serve as a foundation for designing automated systems that prevent smoke infiltration into homes, to provide a reference for

developing smart home technologies that are adaptive to environmental conditions, and to support the improvement of occupant comfort and health.

3.1.5 Research Scope

To maintain the focus and depth of the discussion, the scope of this research is limited to the following:

1. This research is focused on system modeling rather than full prototype implementation.
2. The air quality parameters examined are limited to smoke related indicators, such as particulate matter and specific gases.
3. The research environment consists of indoor residential scales or enclosed rooms.

3.2 Literature Review

3.2.1 Air Quality

Indoor Air Quality (IAQ) is a terminology referring to the air conditions within and around buildings or structures, particularly as they relate to the health and comfort of the occupants within. Given that modern society spends an average of 80% to 90% of their time indoors, air quality has become a primary determining factor for physical health and cognitive efficiency (Kindangen, 2024).

Indoor air quality that is not consistently monitored poses a risk of containing pollutants in the form of particulates, toxic gases, and microorganisms that adversely affect health. On this basis, Indoor Air Quality (IAQ) has become a crucial parameter in ensuring the standardization of hygienic residential and working environments.

Good air quality is determined by low pollutant concentrations and the fulfillment of physical air variables. According to the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023, IAQ monitoring must include physical, chemical, and biological parameters (Kemenkes RI, 2023).

Several key parameters that form the basis for automated control system modeling include:

1. Particulate Matter (PM2.5 and PM10): Exposure to suspended particles poses a serious threat due to their very small size, making them easily inhaled. The presence of these pollutants is often triggered by smoke, outdoor pollution, and poorly filtered domestic dust.
2. Carbon Dioxide (CO2): Although not a toxic pollutant at low levels, high CO2 concentrations above 1000 ppm are often used as a primary indicator of poor ventilation systems within a room (Utami et al., 2025).
3. Temperature and Humidity: Physical parameters that influence the growth rate of microorganisms such as mold as well as the thermal comfort of occupants (Irfani et al., 2025).

Failure to control indoor air quality can trigger the phenomenon known as Sick Building Syndrome (SBS). SBS is a condition in which building occupants experience acute health symptoms, such as headaches, nausea, and throat irritation, that appear directly related to time spent in the building, yet no specific illness can be identified (Kindangen, 2024).

3.2.2 Automatic Control Systems

The modeling of an effective control system for IAQ generally employs the principles of closed loop control (feedback). In this system, the air quality output is continuously measured by sensors and compared against predetermined threshold values. The difference between the actual condition and the target, referred to as the error, is processed by the controller to adjust the speed or operational status of the actuators (Manesis & Nikolakopoulos, 2018).

Within a closed loop architecture, air quality monitoring is conducted simultaneously and continuously through the integration of various environmental sensors. The information obtained is then compared with a setpoint based on air health standards, where the deviation between real data and the target is processed by the controller as an input signal for corrective action.

In general, the structure of a closed loop based IAQ control system consists of several main components:

1. Sensor (Measurement Unit): The sensor functions as a measuring element that reads air quality parameters in real time. The sensor converts the physical conditions of the environment into digital signals that can be processed by the system.
2. Controller (Control Unit): The controller receives the error signal from the comparison process between the actual value and the setpoint. Based on specific control algorithms, such as proportional control, PID, or rule based control, the controller determines the corrective action to be performed.
3. Actuator (Execution Element): The actuator is the device that executes the controller commands, such as adjusting ventilation fan speeds, activating air filtration systems, opening automatic vents, or turning on air purifiers.
4. Process or System (Indoor Environment): The indoor environment is the controlled object, where changes in actuator operation will affect the concentration of air pollutants.

In the development of an automated control system model for Indoor Air Quality (IAQ), the selection of a control algorithm is a critical aspect as it directly influences system stability, energy efficiency, and the operational lifespan of the actuator devices. One commonly used approach is On–Off control (Bang-bang Control), which is the simplest control method where the actuator has only two operating states, either on or off, based on a specific threshold. In this method, when air quality parameters such as CO2 concentration exceed a determined limit, the system immediately activates the ventilation or fans and turns them off once the air condition is below the threshold. Although easy to implement and requiring low computational power, the On–Off method often causes system oscillation due to repeated on–off processes, increasing energy consumption spikes and accelerating mechanical wear on actuator motors due to high switching frequency.

As a more adaptive alternative, the Fuzzy Logic Control approach introduced by Lotfi A. Zadeh is utilized. Unlike conventional binary control, fuzzy logic allows the system to make decisions based on the degree of uncertainty in environmental conditions through linguistic variables such as low, medium, or high. In an air quality control system, for example, when CO2 levels are in a slightly high condition, the system does not immediately activate the actuator at full capacity but instead adjusts the ventilation speed to a medium level. This approach produces a smoother control response, reduces device operational fluctuations, and enhances the comfort and stability of indoor air quality. Furthermore, the use of fuzzy logic has been proven to improve the operational efficiency of ventilation systems with energy consumption savings of approximately 15% to 20% compared to conventional control methods (Zadeh, 1988).

3.2.3 Arduino Uno

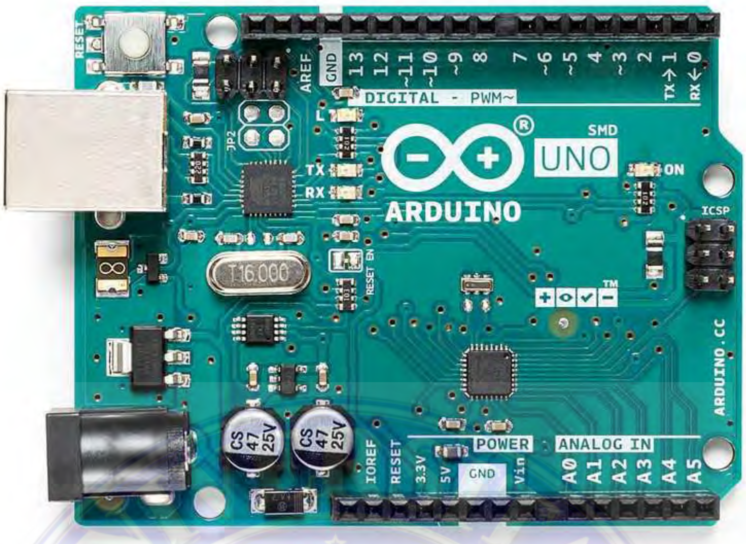

Figure 3.1 Arduino Uno

Arduino Uno is an open source microcontroller platform that serves as a primary pillar in the development of embedded systems and the Internet of Things (IoT). The advantages of this board lie in its ease of programming, hardware flexibility, and comprehensive ecosystem support. Based on the ATmega328P microcontroller by Microchip Technology, the Arduino Uno is capable of integrating digital and analog data processing within a single platform, making it highly effective for applications in automated control, sensor data acquisition, and microcontroller based monitoring systems (Banzi & Shiloh, 2015).

Technically, the effectiveness of this device is supported by the availability of 14 digital input/output pins, 6 of which feature Pulse Width Modulation (PWM) for gradual load adjustment, such as motor speed or lighting intensity. Additionally, there are 6 analog input pins with a 10 bit Analog to Digital Converter (ADC) resolution that allow for precise readings of signals from various environmental sensors, ranging from temperature to air quality. With a clock frequency of 16 MHz at an operating voltage of 5 volts, this board provides adequate performance for executing real-time system monitoring and control functions within small to medium scale IoT environments (Manesis & Nikolakopoulos, 2018).

The software development process for the Arduino Uno is conducted through the Arduino Integrated Development Environment (IDE) using a C/C++ based programming language. Through this development environment, users can write code, compile it, and upload instructions directly to the board via a USB connection. Besides functioning as a data transfer medium, the USB connection also serves as a power source during the system testing phase. In its implementation, particularly in IoT based air quality control systems, the Arduino Uno acts as a central processing unit that integrates all subsystems. Data received from sensors are processed using specific control algorithms, such as On-Off control or fuzzy logic, which are then translated into command signals for actuators such as ventilation fans or air purifiers.

3.2.4 Breadboard

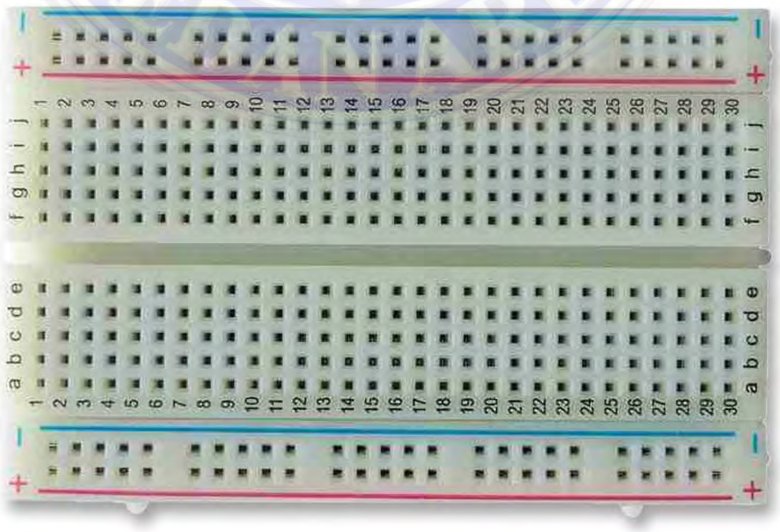

Figure 3. 2 Breadboard

A breadboard is an electronic prototyping board used to design and test electrical circuits without the need for soldering (solderless prototyping). Breadboards are very commonly used in the development of microcontroller systems and the Internet of Things (IoT) because they allow circuit design to be performed quickly, flexibly, and with ease of modification during the experimental and initial testing stages. In microcontroller based systems such as the Arduino Uno, the breadboard serves as a temporary connection medium between sensors, actuators, and other supporting components before permanent implementation on a Printed Circuit Board (PCB).

In terms of physical structure, a breadboard consists of numerous small holes arranged in a matrix pattern and internally interconnected using metal conductor tracks. The breadboard structure is generally divided into two main areas, which are the terminal strips and the power rails. Terminal strips are located in the center and are used for mounting electronic components such as resistors, sensors, and jumper wires, where each row of holes is connected horizontally. Meanwhile, power rails are located on the left and right sides of the breadboard, functioning as distribution tracks for positive voltage and ground to facilitate the provision of power to the entire circuit (Manesis & Nikolakopoulos, 2018).

In the development of IoT systems, the breadboard plays a vital role in the hardware prototyping phase. Users can easily connect the input/output pins from the microcontroller board to air quality sensors, communication modules, and actuators without the risk of damage caused by soldering errors. Furthermore, the use of a breadboard enables the circuit debugging process to be conducted efficiently because connections can be detached and reattached as needed for system testing.

3.2.5 MQ-2

Figure 3.3 MQ-2 Sensor

The MQ-2 sensor is a semiconductor, based gas sensor widely used in air quality monitoring systems and gas leak detection. This sensor is designed to detect various types of flammable gases and smoke, such as LPG, propane, methane, hydrogen, alcohol, and combustion smoke. Due to its high sensitivity and relatively economical price, the MQ-2 is frequently applied in Internet of Things (IoT) systems, home security systems, and microcontroller based environmental monitoring systems.

In terms of operating principles, the MQ-2 utilizes tin dioxide (SnO_2) semiconductor material as the gas sensitive element. In clean air conditions, the sensor resistance remains at a high value. When target gases are detected, the gas concentration affects the conductivity of the semiconductor material, causing the sensor resistance to decrease. This change in resistance is then converted into an analog voltage signal that can be read by a microcontroller such as the Arduino Uno through an analog pin. Through this mechanism, the sensor is able to provide an indication of gas concentration levels in real-time (Khakim et al., 2022).

The MQ-2 sensor generally features two types of outputs, which are analog and digital outputs. The analog output provides a continuous voltage value representing the gas concentration level, making it suitable for air quality monitoring systems that require detailed data analysis. Meanwhile, the digital output operates based on a specific threshold value that can be adjusted via a potentiometer on the sensor module, allowing the system to provide immediate warnings when the gas concentration exceeds safe limits.

In IoT based air quality control systems, the MQ-2 functions as an environmental data acquisition device that detects the presence of hazardous gases or indoor smoke. The data obtained by the sensor are sent to the microcontroller to be processed using automated control algorithms. If the gas concentration increases beyond a specified threshold, the system can automatically activate actuators such as ventilation fans, alarms, or air purifiers to reduce air pollution levels. The integration of the MQ-2 with a microcontroller enables the system to perform continuous and responsive air quality monitoring regarding changes in environmental conditions.

Despite its high sensitivity, the MQ-2 sensor requires an initial calibration process and a preheating time of approximately 24 to 48 hours to ensure stable sensor readings. Furthermore, the MQ-2 is not capable of identifying specific types of gas but rather indicates the presence of flammable gases in general. Therefore, in more complex air quality monitoring systems, the MQ-2 is often combined with other gas sensors to enhance measurement accuracy.

3.2.6 DHT22

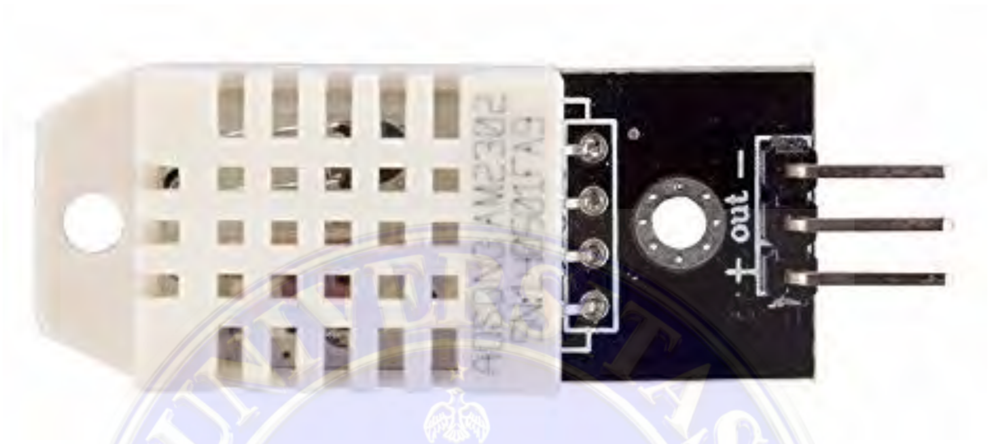

Figure 3.4 DHT22

The DHT22 sensor is a digital sensor used to measure temperature and humidity simultaneously within a single device module. This sensor is widely utilized in microcontroller based environmental monitoring systems and the Internet of Things (IoT) because it offers better accuracy compared to its predecessor series, such as the DHT11. In indoor air quality (IAQ) control systems, the DHT22 plays a vital role in providing data on environmental thermal conditions that affect air comfort and the effectiveness of automated ventilation systems (Puspasari et al., 2025).

The DHT22 was developed by the sensor company Aosong Electronics and operates using a combination of a capacitive humidity sensor and a thermistor for temperature measurement. This sensor is equipped with an internal processing chip that performs automatic signal calibration, ensuring that the resulting data is already in digital form and does not require additional conversion circuitry. Data communication is conducted via a single wire serial communication protocol, therefore requiring only one data pin to transmit temperature and humidity information to a microcontroller such as the Arduino Uno.

In terms of technical specifications, the DHT22 is capable of measuring temperature within a range of −40°C to 80°C with an accuracy of approximately ±0.5°C, as well as relative humidity within a range of 0% to 100% RH with an accuracy of ±2% to 5% RH. This sensor possesses high measurement resolution and good long term stability, making it suitable for applications in air quality monitoring, smart building systems, smart agriculture, and room automation systems.

In IoT based air quality control systems, the DHT22 functions as an environmental data acquisition device providing information on indoor microclimate conditions. The temperature and humidity data obtained by the sensor are sent to the microcontroller to be analyzed alongside other air quality parameters, such as gas or particulate concentrations. Based on the results of this analysis, the system can make automated decisions, such as activating ventilation, adjusting fan speeds, or optimizing air purifier operations to maintain thermal comfort while enhancing building energy efficiency.

3.2.7 Servo Motor

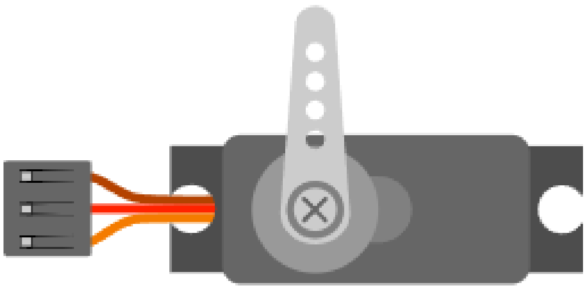

Figure 3.5 Servo Motor

A servo motor is an electromechanical actuator used to produce rotational movement with precisely controlled angular positions. Unlike standard DC motors that rotate continuously, servo motors are designed to move to specific angles according to control signals provided by a microcontroller. Due to its capacity for accurate positioning, the servo motor is widely utilized in automation systems, robotics, mechanical control devices, and Internet of Things (IoT) applications that require automated position adjustment (Manesis & Nikolakopoulos, 2018).

In general, a servo motor consists of three primary components: a DC motor, an internal control circuit, and a feedback system in the form of a potentiometer. This feedback system allows the servo to continuously read the shaft position and adjust its movement until it reaches the commanded angle. The control mechanism of a servo motor utilizes Pulse Width Modulation (PWM) signals generated by a microcontroller such as the Arduino Uno. The pulse width of the PWM signal determines the rotation angle; for instance, a pulse of approximately 1 ms produces a 0 degrees angle, 1.5 ms produces a center position (90 degrees), and 2 ms produces a maximum angle of approximately 180 degrees (Wokwi, 2021).

Figure 3.6 Range of Motion Servo Motor

Most servo motors have three main wires: the power wire (VCC), the ground wire (GND), and the control signal wire. The operating voltage typically ranges from 4.8 to 6 volts, allowing the servo to be connected directly to a microcontroller system without requiring additional amplification circuits. Integrating a servo motor with a microcontroller is relatively straightforward because Arduino provides a servo library that enables angle adjustment through simple programming commands (Puneeth, 2023).

In IoT based air quality control systems, the servo motor functions as a mechanical actuator that regulates the position of physical components, such as opening and closing air vents, directing airflow, or automatically adjusting air circulation valves. Data from air quality sensors are processed by the microcontroller, which then sends a PWM signal to the servo motor to adjust the ventilation position according to environmental conditions. Through this mechanism, the system is capable of maintaining adaptive air circulation without manual intervention, thereby improving energy efficiency and indoor comfort.

3.2.8 Relay Module

Figure 3.7 Relay Module

A relay is an electromechanical device that functions as an automatic electrical switch, allowing a low voltage control system to manage higher voltage electrical devices. This component operates based on electromagnetic principles, where an electric current flowing through a coil generates a magnetic field that moves mechanical contacts to open or close an electrical circuit (Politeknik Port Dickson, 2013). Consequently, relays are widely used in industrial automation systems, microcontroller, based control systems, and Internet of Things (IoT) applications that require isolation between the control circuit and the power circuit.

In microcontroller based systems such as the Arduino Uno, the relay serves as an interface between 5V digital logic signals and external devices such as ventilation fans, air pumps, or air purifiers that operate at higher AC or DC voltages. When the microcontroller sends a HIGH logic signal, the relay coil is activated, causing the switch contacts to change position and allow current to flow to the load device. Conversely, when a LOW signal is provided, the contacts return to their original state, thus cutting off the electrical flow.

Modern relay modules are typically equipped with driver transistors and optocouplers as electrical isolation systems. This isolation serves to protect the microcontroller from voltage spikes, known as back electromotive force, which can occur when a load device is suddenly deactivated. The use of relays in IoT systems enables the automated and safe control of electrical devices while remaining integrated with sensor, based monitoring systems (Manesis & Nikolakopoulos, 2018).

In indoor air quality (IAQ) control systems, the relay acts as a switching actuator that activates or deactivates air processing devices based on the results of sensor data analysis. When gas or pollutant concentrations increase beyond a threshold, the microcontroller activates the relay to turn on ventilation or air purifiers. This mechanism allows the system to perform environmental control automatically without manual intervention, while simultaneously enhancing the operational efficiency of smart building systems.

3.2.9 Buzzer and LED

Figure 3.8 Buzzer

Figure 3.9 LED

The buzzer and Light Emitting Diode (LED) function as a local alarm system that provides direct information to the user regarding the indoor air quality conditions. This warning system is an essential component in the design of Internet of Things (IoT) based monitoring systems because it can communicate environmental status quickly without relying on internet connections or external monitoring applications. Audio and visual indicators allow users to receive an instant response when environmental changes occur that could potentially endanger the health of room occupants.

The buzzer operates as an audio indicator that generates a sound signal when the system detects abnormal conditions, such as an increase in hazardous gas concentrations or a decrease in air quality below safe standards. The sound produced by the buzzer is designed to attract the user's attention so that mitigation actions can be taken immediately, such as opening ventilation or vacating the room.

Meanwhile, the LED serves as a visual indicator showing the continuous operational status of the system. LEDs are typically configured with specific color codes, such as green for normal air conditions, yellow for caution, and red for hazardous conditions. The combination of sound and light indicators enhances the effectiveness of system communication with the user because information can be received through more than one sense simultaneously.

In a microcontroller, based air quality control system, the activation of the buzzer and LED is performed based on the results of sensor data analysis processed by the main control unit (Manesis & Nikolakopoulos, 2018). When air quality parameter values exceed a predetermined threshold, the microcontroller sends a digital signal to activate the buzzer and light the warning LED. This mechanism enables the system to provide real-time local notifications without data transmission delays. According to Cahyono (2024), the use of audio and visual indicators in environmental monitoring systems is vital because it can increase the situational awareness of occupants and accelerate the response to the potential dangers of air pollutant exposure.

3.2.10 PM2.5

Particulate Matter 2.5 or PM2.5 is an air pollutant consisting of solid and liquid particles suspended in the atmosphere with an aerodynamic diameter of less than 2.5 micrometers. The primary characteristic of these particles is their extremely fine size approximately 30 times smaller than a strand of human hair, resulting in a very long residence time in the air and the ability to be carried by the wind hundreds of kilometers from their original source (World Health Organization, 2021). Based on its physical properties, PM2.5 is considered more hazardous than

PM10 due to its capability to penetrate the alveolar membranes in the lungs and enter the human circulatory system, which triggers systemic inflammatory reactions.

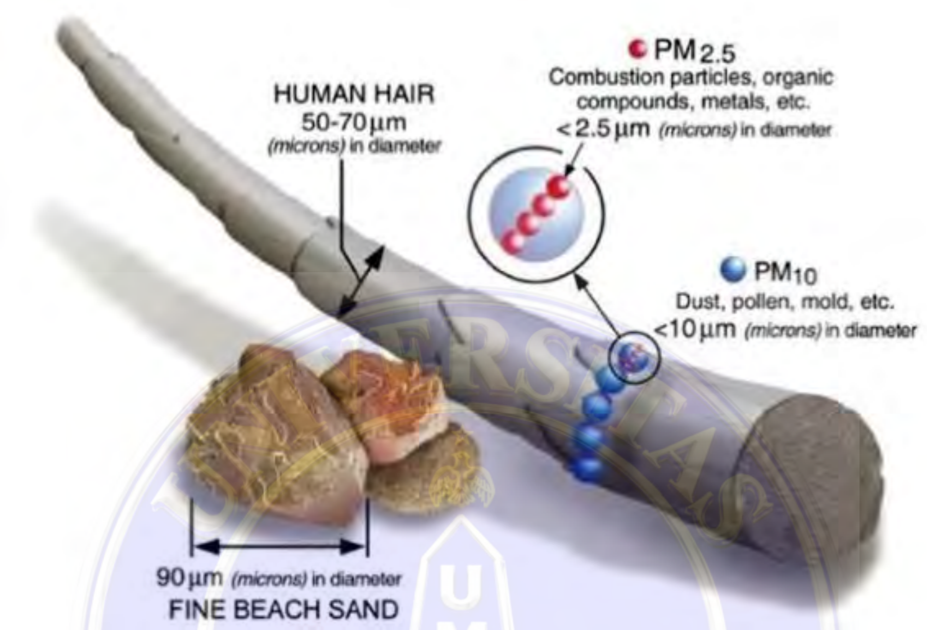

Figure 3.10 Comparison of Particulate Matter Sizes

In general, the presence of PM2.5 in the atmosphere originates from two primary mechanisms, which are primary and secondary emissions. Primary sources are generated directly from incomplete combustion processes, such as motor vehicle exhaust (particularly diesel engines), manufacturing industrial activities, coal based steam power plants, and massive forest fires (ITB digilib, 2023). On the other hand, secondary PM2.5 is formed through complex chemical reactions in the atmosphere involving precursor gases such as sulfur dioxide (SO2), nitrogen oxides (NOx), and volatile organic compounds (VOCs). This causes PM2.5 concentrations in urban areas to tend to be higher due to the accumulation of pollution from the transportation and industrial sectors that interact chemically (Ihsan et al., 2025).

Long term exposure to PM2.5 has been linked to an increased risk of fatal non communicable diseases (NCDs). Clinically, these particles cause oxidative stress that damages respiratory cells, triggering asthma exacerbation, chronic bronchitis, and lung cancer (Fikri et al., 2025). In addition to its impact on the respiratory system, PM2.5 is also a major risk factor for cardiovascular diseases, including hypertension, heart attacks, and strokes, as these particles can disrupt vascular endothelial function. Vulnerable groups such as children, the elderly, and individuals with comorbid conditions are the most affected by the decline in air quality caused by PM2.5 (Ihsan et al., 2025).

Table 3.1 PM2.5 Quality Levels

Criteria	Range
Good	0-15.5 μg/m³
Moderate	15.6-55.4 μg/m³
Unhealthy	55.5-150.4 μg/m³
Very Unhealthy	150.5-250.4 μg/m³
Hazardous	250.5 μg/m³

3.2.11 IUSP

The Air Pollutant Index (ISPU) is a unitless number used to describe ambient air quality conditions at a specific location, based on impacts on human health, aesthetic values, and other living organisms (Permen LHK No. 14, 2020). Unlike raw pollutant concentrations that use micrograms per cubic meter (μg/m³), the ISPU serves as a public communication instrument that simplifies complex technical data into information that is easily understood by the general public. This data transformation is performed through mathematical calculations that compare the measured average concentration of pollutants with nationally established threshold values (KLHK, 2024).

Based on the latest regulations in Indonesia, the parameters used to compile the ISPU figures include seven primary pollutants: particulate matter (PM10 and PM2.5), sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone (O3), and hydrocarbons (HC). The inclusion of PM2.5 in the ISPU calculation through the Minister of Environment and Forestry Regulation Number 14 of 2020 marks the modernization of Indonesia's air quality standards to be better aligned with global health risks. Measurements are conducted using Air Quality Monitoring Stations (AQMS) that operate continuously, where the highest ISPU value from one of these parameters becomes the dominant parameter that determines the air quality category for that day (Ihsan et al., 2025).

Table 3.2 ISPU Quality Levels

Criteria	Range
Good	0-50 PPM
Moderate	51-100 PPM
Unhealthy	101-200 PPM
Very Unhealthy	201-300 PPM
Hazardous	>300 PPM

3.2.12 Integrated System Methodology

Integrated Systems Methodology (ISM) is a systems engineering paradigm that focuses on synchronizing the design and management of various subsystems to operate as a coherent and optimal entity. This approach is designed to address the complexity of contemporary systems involving diverse technological elements by prioritizing a holistic perspective over partial component development. Aligned with the systems engineering standards from INCOSE, this methodology ensures integration capable of accommodating functional, operational, and performance aspects of the system comprehensively from the initiation phase.

The application of Integrated Systems Methodology is vital in IoT development to guarantee alignment between physical and digital components. IoT systems that integrate sensors, processing algorithms, actuators, and user interfaces require precise management of inter-component relationships. Without a robust integration methodology, these intelligent systems are vulnerable to various technical constraints, ranging from communication conflicts between devices to response delays that can degrade overall system performance.

Through the application of ISM, each subsystem is designed based on a unified architecture that ensures data flow occurs consistently and synchronously. Data obtained by sensors are processed using real-time control algorithms, then forwarded to the user interface in the form of easily understandable information while simultaneously serving as the basis for automated system control. This approach enables improvements in communication reliability, efficiency in the use of computational resources, and optimization of overall IoT system performance.

As part of the application of Integrated Systems Methodology (ISM), the process of visual system modeling is a critical stage before physical implementation or software development. Visual modeling serves to translate complex system concepts into structured representations so that the workflow, relationships between components, and control logic can be comprehensively understood by the system designer. In the development of IoT systems, particularly in automated air quality control systems, the use of Unified Modeling Language (UML) helps minimize design errors from the early stages while ensuring that integration between subsystems proceeds systematically.

One of the primary diagrams in UML is the Use Case Diagram, which is used to describe system functionality from the perspective of the user or actor. This diagram shows how the user interacts with the system, such as monitoring air quality, receiving environmental condition notifications, or adjusting control parameters. With a Use Case Diagram, system requirements can be clearly identified so that feature development becomes more focused and aligned with operational needs.

Furthermore, the Activity Diagram is used to explain the system workflow logically and sequentially. This diagram visualizes the steps of the automated control algorithm, starting from the air quality sensor data reading process, data processing by the controller, the decision-making process based on the control algorithm, to the activation of actuator devices such as ventilation or air purifiers. The Activity Diagram helps developers understand the dynamics of system processes and identify potential bottlenecks or workflow errors before the system is implemented.

Subsequently, the Sequence Diagram functions to show the chronological order of message exchange or communication between system components. In an IoT system, this diagram illustrates how data are sent from sensors to the server or cloud platform, then processed and forwarded as control commands to the actuators. Visualizing this communication sequence is essential to ensure data synchronization, network communication reliability, and real-time system response.

3.3 Research Methodology

3.3.1 Research Framework

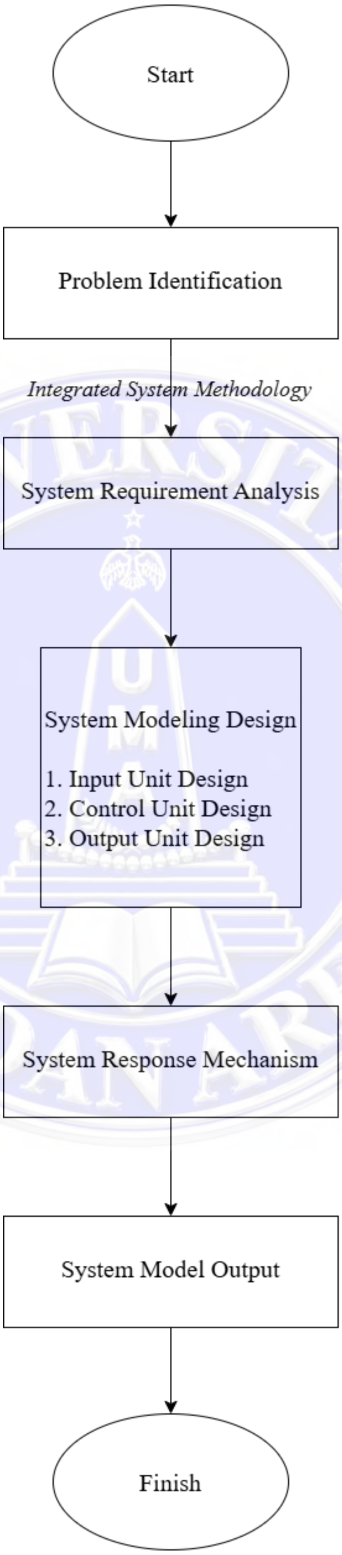

Figure 3.11 Framework Diagram

3.3.2 Integrated System Methodology

This methodology is utilized to ensure that all system elements, including hardware, software, and data communications (networking), function synchronously. This approach divides the development process into several integrated phases:

1. Requirements Analysis: Determining the air quality parameters to be controlled (such as CO2, PM2.5, or humidity) and establishing action thresholds.
2. System Design: Designing the hardware architecture and software logic flow simultaneously to prevent data incompatibility.
3. Implementation (Development): The physical assembly stage based on wiring diagrams and the writing of program codes.
4. Integration and Verification: Testing whether the sensors and actuators (such as fans or air purifier) respond according to the instructions from the control algorithm.

3.3.3 System Design

3.3.3.1 Block Diagram

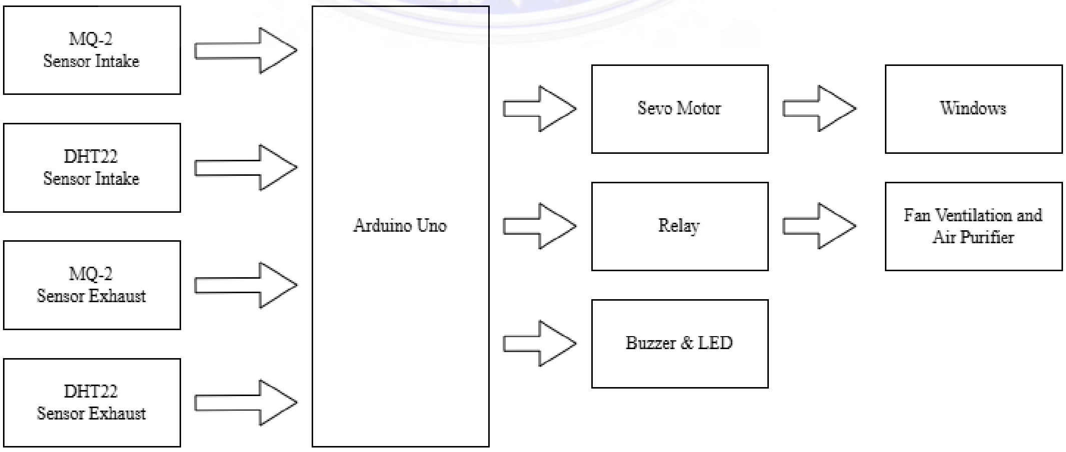

Figure 3.12 Block Diagram

The architecture of this system is designed into three integrated primary functional blocks. In the input section, the system utilizes a sensor array consisting of two gas sensor units (MQ Series) to detect chemical pollutants and one DHT22 sensor unit for precise temperature and humidity monitoring. All analog and digital data from these sensors are processed by an Arduino Uno R3 as the central processing unit. Subsequently, the output section is implemented through warning mechanisms in the form of LED indicators and a buzzer, as well as actuation units that include a servo motor for mechanical ventilation control and a 2 channel relay for the operation of AC loads, such as ventilation fans and air purifier.

3.4 Result and Discussion

3.4.1 Hardware Design

This system model is designed into three integrated primary functional blocks based on the Integrated System Methodology. This approach ensures that each block has a specific role in maintaining the stability of Indoor Air Quality (IAQ).

1. Input Unit (Sensor Array)

The input section acts as the environmental data acquisition unit. The use of a sensor array aims to cover a broad spectrum of parameters, ranging from chemical pollutants to thermal variables.

a. MQ Series Gas Sensors (MQ-2): These sensors operate based on changes in the conductivity of the tin dioxide (SnO_2) layer when exposed to pollutant gases. The resulting analog data represent gas concentrations in Parts Per Million (PPM). The placement of two sensor units (Indoor and Outdoor) allows the system to perform data comparisons to determine air isolation strategies (Syafyul et al., 2021).

b. DHT22 Sensor (AM2302): Unlike the DHT11, the DHT22 utilizes a capacitive humidity sensor and a thermistor to measure the surrounding air. This sensor transmits calibrated digital signals, which are crucial for validating fire conditions through precise monitoring of extreme temperatures (Holis, 2021).

2. Processing Unit

The Arduino Uno R3 serves as the control center or brain of the system. This ATMega328P based microcontroller is responsible for:

a. Data Conversion: Processing analog signals (0 to 5V) into digital values (0 to 1023) via the internal Analog to Digital Converter (ADC).
b. Algorithm Execution: Running the control logic that compares real-time data against predetermined thresholds. According to IoT system design principles, this processing unit ensures data integrity before instructions are sent to the actuators (Susanto et al., 2022).
c. Current Management: Providing low current control signals to trigger high power switches in the output unit.

3. Output and Actuation Unit

The output block serves as the executor of system decisions, divided into indicator units and mechanical units:

a. Warning Mechanisms (Visual and Audio): LED indicators and passive buzzers function as the Human Machine Interface (HMI). These components provide early warnings if gas concentrations exceed safe limits, in accordance with building safety standards.

b. Servo Motor (Ventilation Control): Utilizing a Pulse Width Modulation (PWM) control system, the servo acts as an actuator to regulate window or vent openings automatically. Its advantage lies in high angular precision compared to standard DC motors.

c. 2 Channel Relay (AC Loads): The relay acts as an isolator between the low voltage (DC) and high voltage (AC) circuits. This component drives ventilation fans for circulation and air purifiers for active filtration. Following automation principles, the relay allows the microcontroller to safely control household loads (Fatoni and Nugroho, 2020).

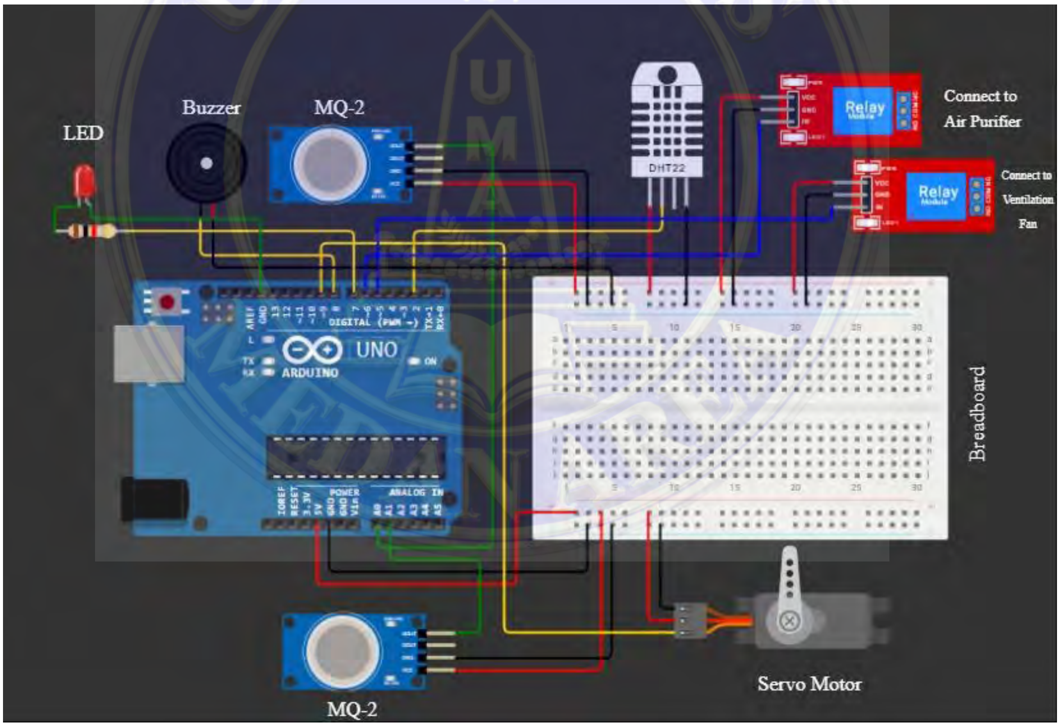

Figure 3.13 Wirring Diagram

To ensure synchronization between the hardware and the program instructions, the microcontroller pin mapping is organized systematically. Based on the previously designed wiring diagram, the connection details for each sensor and actuator are as follows:

Table 3.3 Connection Details

Component	Pin Arduino	Describtion
MQ-2 (Top)	A0	MQ-2 Indoor Gas Sensor: Detects indoor gas and smoke concentrations in real time.
MQ-2 (Bottom)	A1	MQ-2 Outdoor Gas Sensor: Detects outdoor gas and smoke concentrations in real time.
DHT22	Digital Pin 2	Reads indoor temperature and humidity data.
Servo Motor	Digital Pin 9	Drives the automated windows mechanism.
Relay Module	Digital Pin 7 & 8	Acts as an automated switch for power devices such as ventilation fans and air purifier.
Buzzer & LED	Digital Pin 12 & 13	Provides visual and audio warning alarms if there is a fire indication.

The use of a breadboard serves as a parallel power distribution path (5V VCC and GND) to ensure that all sensors receive a stable voltage from the Arduino.

3.4.2 Software Design

The control logic to be embedded in the microcontroller is organized as follows:

1. Initialization: Activating serial communication and defining pin modes.
2. Data Acquisition: Reading analog values from pins A0 and A1, as well as digital data from Pin 2.
3. Decision Making:

a. Fire Condition This is the highest priority condition triggered if both the indoor smoke concentration and room temperature exceed the thresholds (indoorSmoke > 700 AND temperature > 35.0°C).

1. Warning System: The buzzer and red LED are activated to provide an early warning.
2. Ventilation: The ventilation fan is turned on and the servo motor moves to 0 degrees (Opening Ventilation) to exhaust smoke out of the room.
3. Filtration: The air purifier is turned off because the primary focus is smoke evacuation rather than filtration.

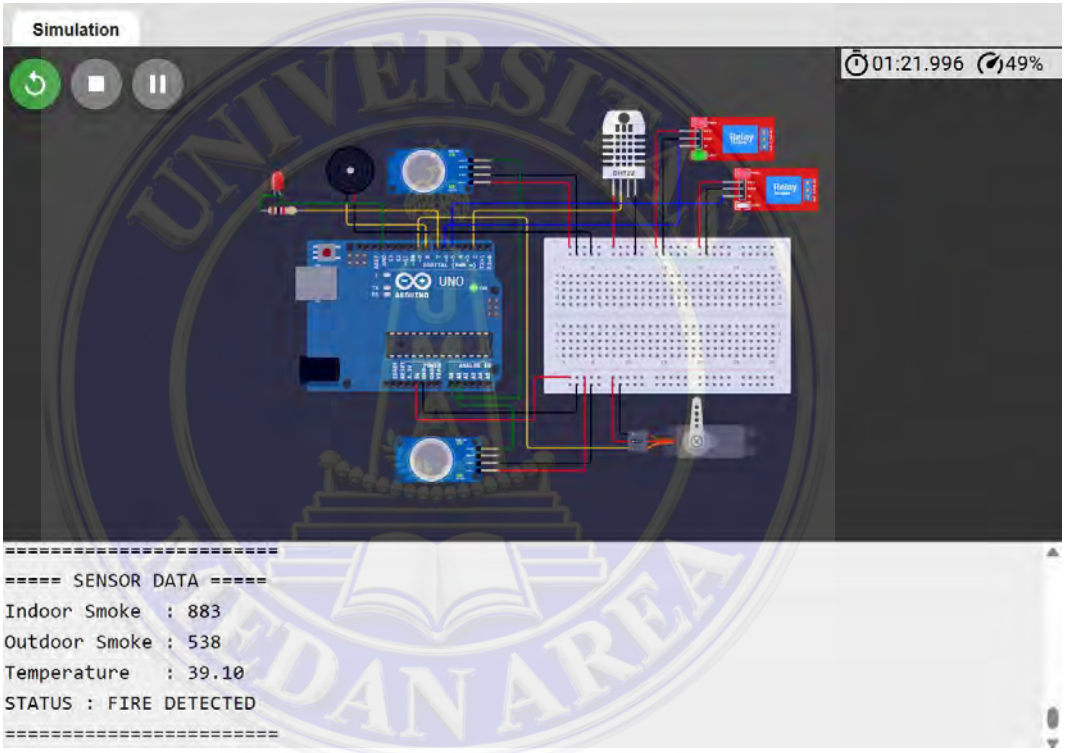

Figure 3.14 Fire Indication Respond

b. Outdoor Pollution Condition This condition is triggered if the outdoor sensor detects pollutants (outdoorSmoke > 700), but no indoor fire is detected.

   1. Room Isolation: The servo motor moves to 90 degrees (Closing Ventilation) and the ventilation fan is turned off to prevent outdoor pollution from entering the interior.

2. Filtration: The air purifier is turned on to clean the air already trapped inside the room.
3. Warning: The buzzer and LED remain in the off state.

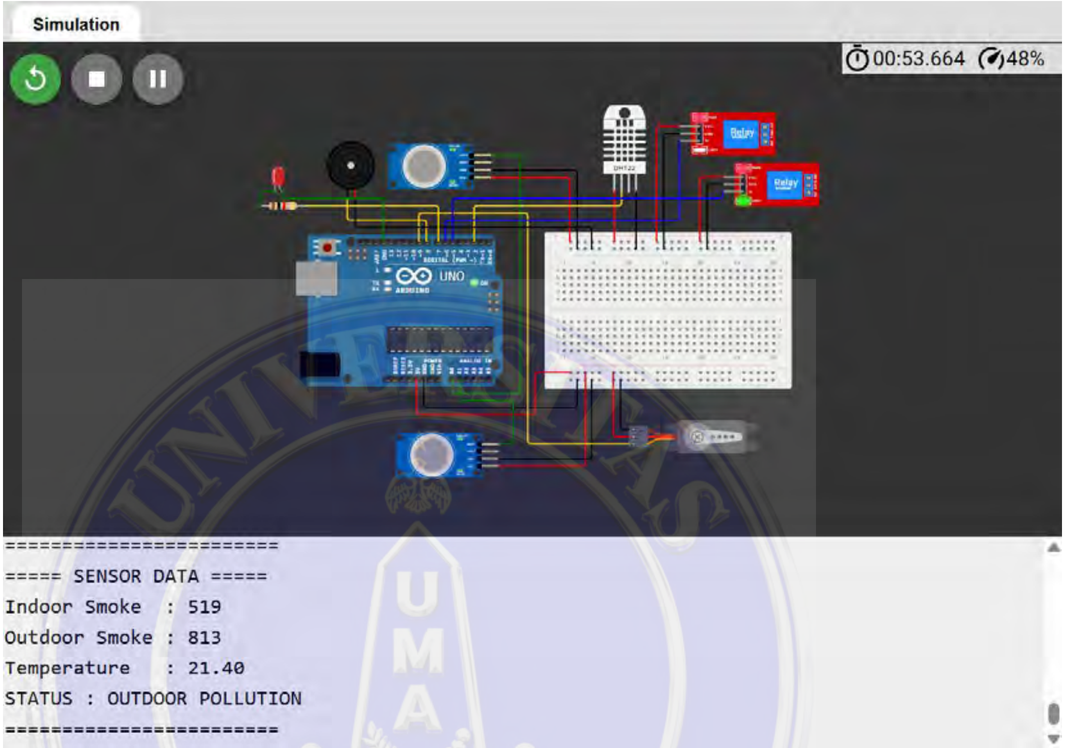

Figure 3.15 Outdoor Pollution Respond

c. Normal Condition This condition is active when all sensors are below the danger thresholds.

1. Efficiency: The air purifier is turned off to conserve energy.
2. Circulation: The ventilation fan remains on and the window or vent is opened by the servo (0 degrees) to maintain air freshness through natural air exchange.

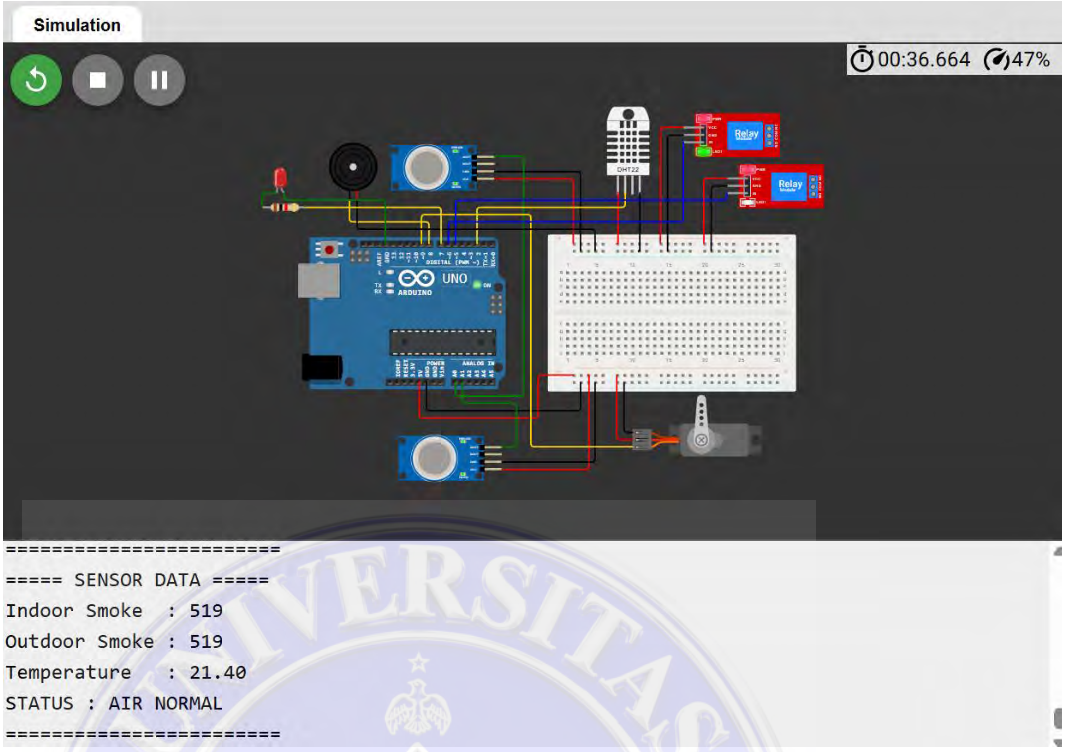

Figure 3.16 Normal Condition Respond

3.4.3 Microcontroller Program Design

The software design for the microcontroller is developed using a structured programming approach to ensure the reliability and responsiveness of the air quality control system. The program is written in the C/C++ based Arduino programming language and is organized into several functional blocks that manage data acquisition, logic processing, and actuator control.

The program is designed with three primary stages, which include device initialization in the setup() function, the sensor data reading process in the loop() function, and decision making based on the detected environmental conditions. Smoke data are obtained from the MQ-2 gas sensor, while room temperature is read using the DHT22. Based on the specified threshold values, the microcontroller subsequently controls the ventilation system, warning alarms, and air purifier via the relay module and the SG90 servo motor.

The implementation of the system control logic is written into the microcontroller program as follows:

```
#include <Servo.h>
#include <DHT.h>

/* ====== PIN CONFIG ====== */
#define DHTPIN 2
#define DHTTYPE DHT22

#define MQ_INDOOR A0
#define MQ_OUTDOOR A1

#define RELAY_PURIFIER 6
#define RELAY_FAN 5

#define BUZZER 8
#define FIRE_LED 7

#define SERVO_PIN 9

/* ====== OBJECT ====== */
Servo windowServo;
DHT dht(DHTPIN, DHTTYPE);

/* ====== THRESHOLD ====== */
int smokeThreshold = 700;
```

```
float tempThreshold = 35.0;

/* ====== SETUP ====== */
void setup() {

  Serial.begin(9600);

  pinMode(RELAY_PURIFIER, OUTPUT);
  pinMode(RELAY_FAN, OUTPUT);
  pinMode(BUZZER, OUTPUT);
  pinMode(FIRE_LED, OUTPUT);

  windowServo.attach(SERVO_PIN);
  dht.begin();

  // Kondisi awal
  digitalWrite(RELAY_PURIFIER, HIGH);
  digitalWrite(RELAY_FAN, HIGH);
  digitalWrite(BUZZER, LOW);
  digitalWrite(FIRE_LED, LOW);

  windowServo.write(90); // ventilasi terbuka
}

/* ====== LOOP ====== */
void loop() {
```

```
bbb.
ccc.        int indoorSmoke = analogRead(MQ_INDOOR);
ddd.        int outdoorSmoke = analogRead(MQ_OUTDOOR);
eee.        float temperature = dht.readTemperature();
fff.
ggg.        /* ===== SERIAL MONITOR ===== */
hhh.        Serial.println("===== SENSOR DATA =====");
iii.   Serial.print("Indoor Smoke  : ");
jjj.   Serial.println(indoorSmoke);
kkk.
lll.   Serial.print("Outdoor Smoke : ");
mmm.        Serial.println(outdoorSmoke);
nnn.
ooo.        Serial.print("Temperature   : ");
ppp.        Serial.println(temperature);
qqq.
rrr.   /* ===== FIRE DETECTION ===== */
sss.   if (indoorSmoke > smokeThreshold && temperature > tempThreshold) {
ttt.
uuu.          Serial.println("STATUS : FIRE DETECTED");
vvv.
www.          digitalWrite(BUZZER, HIGH);
xxx.          digitalWrite(FIRE_LED, HIGH);
yyy.
zzz.          digitalWrite(RELAY_PURIFIER, HIGH); // purifier OFF
aaaa.         digitalWrite(RELAY_FAN, LOW);       // fan ON
```

```

    windowServo.write(0); // ventilasi buka
  }

  /* ===== OUTDOOR POLLUTION ===== */
  else if (outdoorSmoke > smokeThreshold) {

    Serial.println("STATUS : OUTDOOR POLLUTION");

    digitalWrite(RELAY_PURIFIER, LOW);  // purifier ON
    digitalWrite(RELAY_FAN, HIGH);      // fan OFF

    digitalWrite(BUZZER, LOW);
    digitalWrite(FIRE_LED, LOW);

    windowServo.write(90); // ventilasi tutup
  }

  /* ===== NORMAL CONDITION ===== */
  else {

    Serial.println("STATUS : AIR NORMAL");

    digitalWrite(RELAY_PURIFIER, HIGH); // purifier OFF
    digitalWrite(RELAY_FAN, LOW);       // fan ON

```

```
bbbbb.      digitalWrite(BUZZER, LOW);
ccccc.      digitalWrite(FIRE_LED, LOW);
ddddd.
eeeee.      windowServo.write(0); // ventilasi buka
fffff.    }
ggggg.
hhhhh.    Serial.println("========================");
iiiii.    delay(2000);
jjjjj.  }
kkkkk.
```

CHAPTER IV

CONCLUSION

4.1 Conclusion

Based on the results of the special assignment entitled ***Model Development of an Automatic Indoor Air Quality Control System Using an Integrated System Methodology***, it can be concluded that the development of an IoT-based system model provides an effective approach for detecting and controlling smoke infiltration in indoor environments.

The proposed system is modeled using the Internet of Things (IoT) framework, where the Arduino Uno functions as the central processing unit that integrates environmental sensors and actuator devices into a unified automated control system. Through continuous monitoring of particulate matter, gas concentration, temperature, and humidity, the system is capable of maintaining indoor air quality within safe limits by executing real-time automated responses without requiring manual intervention.

Following the Integrated Systems Methodology (ISM), the system architecture is successfully identified and organized into three main functional blocks. The input unit consists of a sensor array, including MQ-series gas sensors for smoke and pollutant detection and a DHT22 sensor for monitoring thermal environmental conditions. The control unit utilizes the Arduino Uno to process sensor data and execute decision-making algorithms based on predefined thresholds. Meanwhile, the output or actuation unit performs system responses through LED indicators and buzzers as warning mechanisms, servo motors for automatic ventilation control, and relay modules that regulate operational devices such as ventilation fans and air purifiers.

The developed model represents an adaptive smart home automation mechanism capable of responding dynamically to environmental conditions. In outdoor pollution scenarios, the system isolates indoor spaces by closing ventilation openings and activating the air purifier to prevent contaminated air from entering the room. Conversely, in fire indication scenarios characterized by high indoor smoke concentration and elevated temperature, the system prioritizes occupant safety by opening ventilation pathways for smoke evacuation while simultaneously activating visual and audible alarms.

Furthermore, the system emphasizes efficiency and sustainability by ensuring that operational devices function only when required. This operational logic supports Green Engineering principles through optimized energy consumption and reduced unnecessary device operation. Overall, the developed system model successfully demonstrates the integration of IoT technology and Integrated Systems Methodology as a conceptual and functional foundation for future smart home air quality control systems that enhance environmental safety, energy efficiency, and residential comfort.

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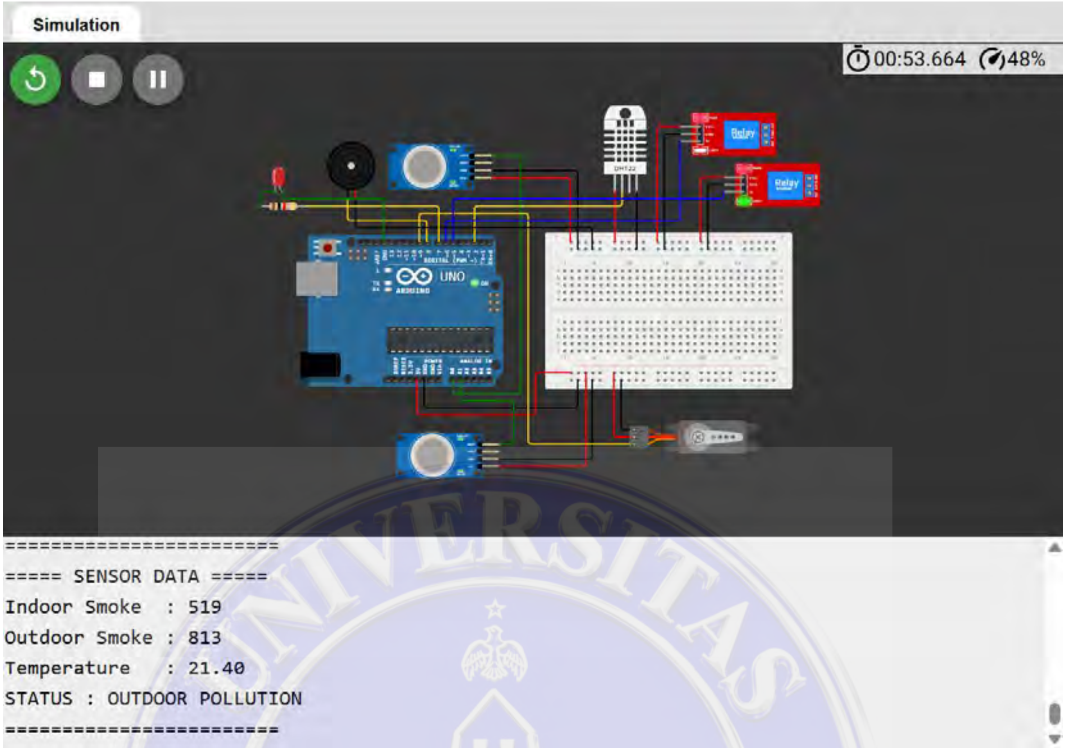
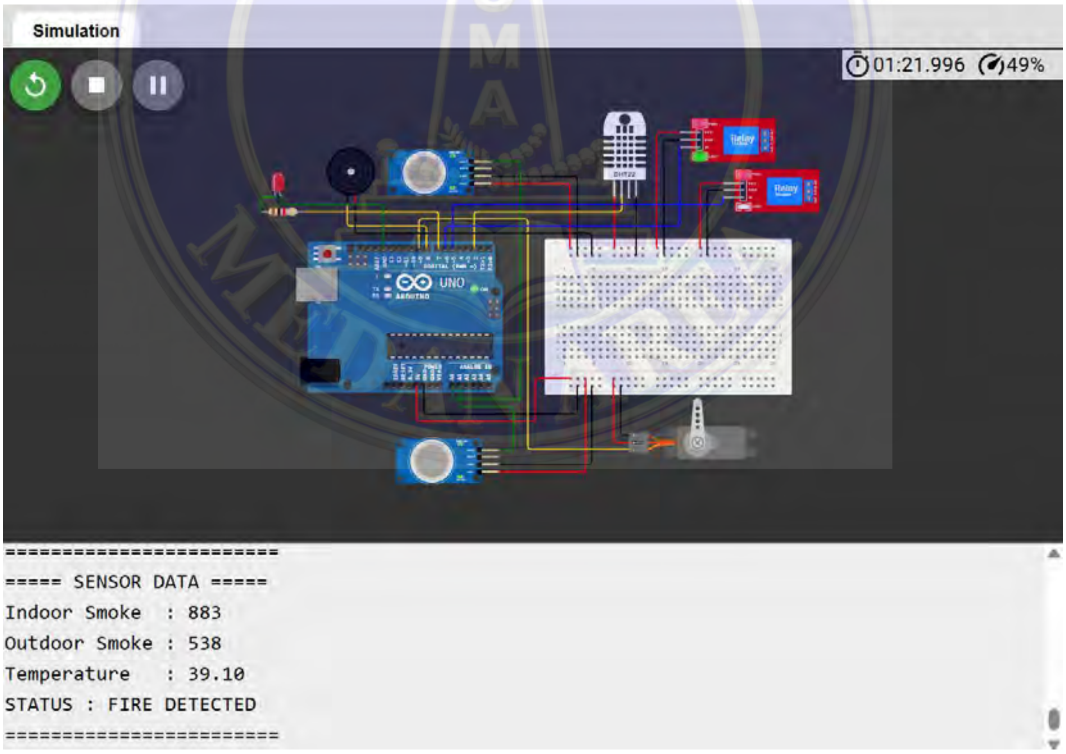
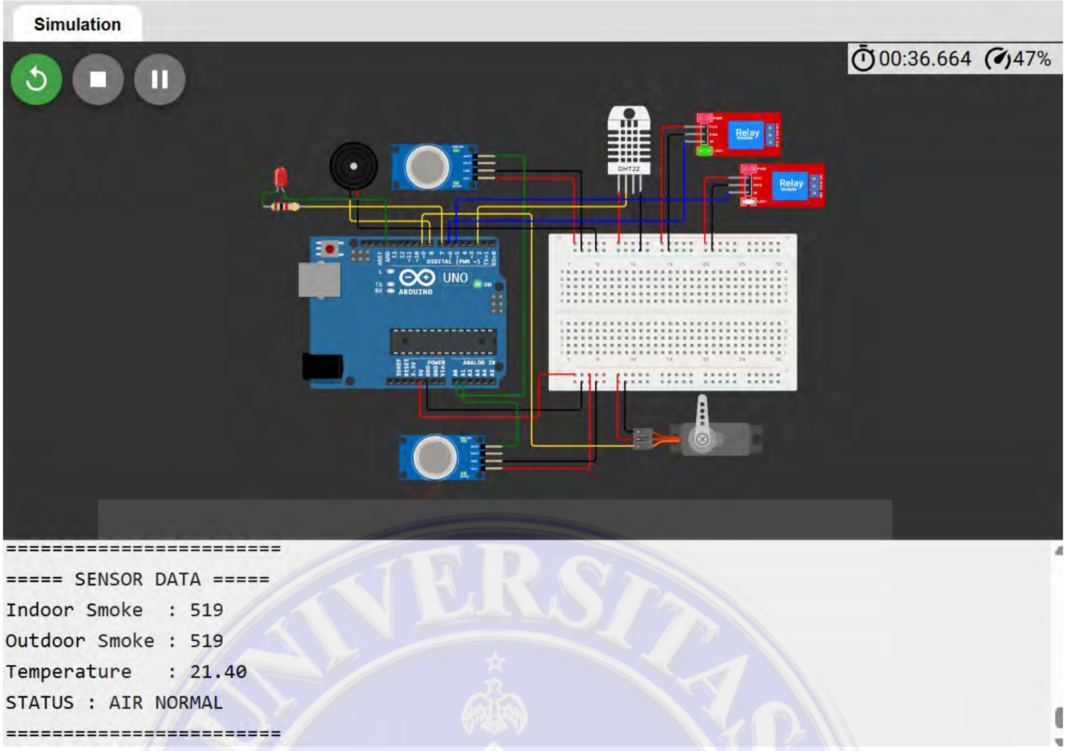
ATTACHMENT


Simulation
00:53.664
48%
UNO
========================
===== SENSOR DATA =====
Indoor Smoke : 519
Outdoor Smoke : 813
Temperature   : 21.40
STATUS : OUTDOOR POLLUTION
========================


Simulation
01:21.996
49%
UNO
========================
===== SENSOR DATA =====
Indoor Smoke : 883
Outdoor Smoke : 538
Temperature   : 39.10
STATUS : FIRE DETECTED
========================


Simulation
00:36.664
47%
UNO
ARDUINO
Relay
DHT22
========================
===== SENSOR DATA =====
Indoor Smoke : 519
Outdoor Smoke : 519
Temperature   : 21.40
STATUS : AIR NORMAL
========================


MAIN CONTROL HUB
AIR QUALITY
WINDOW SENSOR
MOTDOIN/OCUPANCY SENSOR
ENVIRONMENT
PRESENCE
SECURITY
CLIMATE
Smart Air Quality Protection System
Prepared by group 2