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ULK POLYTECHNIC

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGENEERING

OPTION OF ELECTRONICS AND TELECOMMUNICATION TECHNOLOGY

ACADEMIC YEAR 2023-2024

P.O.BOX: 2280 KIGALI

FINAL YEAR PROJECT:

DESIGN AND IMPLEMENTATION OF AN INDOOR AIR QUALITY MONITORING SYSTEM.

Research project report submitted to the department of EEE in partial fulfilment for the award of an advanced diploma in Electronics and Telecommunication Technology.

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DECLARATION A

I, ALFREDO MUFANO, declare that This research study is my original work and has not been presented for a Degree or any other academic award in any University or Institution of Learning". No part of this research should be reproduced without the authors’ consent or that of ULK Polytechnic Institute.

Student name: ....

Sign: ....Date: ....

DECLARATION B

I, confirm that the work reported in this research project, was carried out by the candidate under my Supervision and it has been submitted with my approval as the UPI supervisor.

Name of Supervisor: Ir. KARIKURUBU Emmanuel

Sign: …………………………………………. Date: ………/ ……/2024

DEDICATION

I gladly dedicate this project to:

Our might God which makes this possible
My parents who supported me financially
My lecturers who gave me quality skills
My friends and classmates who have motivated me
ULK Polytechnic institute in generally being with us from day 1.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to the department of Electrical and Electronics Engineering of ULK Polytechnic Institute for granting permission and necessary support, we're so thankful to my family especially my father and my mother for supporting me financially and, for the completion of this project, to all these closest friends which has been there to motivate me both psychologically and emotionally.

I would like to express my gratitude to my supervisor Ir. KARIKURUBU Emmanuel for proper guidance from beginning to the end of the project and also for giving me his valuable time in every working day, providing me with new and innovative ideas to continue my project.

ABSTRACT

In response to the growing demand for thermal comfort and increased awareness of indoor air quality, this project focuses on creating a robust indoor air monitoring system. Built on an Arduino-Uno microcontroller platform, the system integrates various sensors, including gas sensors, humidity and temperature sensors, to continuously monitor air quality. By ensuring a clean and safe environment for occupants, the system particularly benefits vulnerable groups such as the elderly and children.

As technology rapidly evolves from old slide phones to today's smartphones, tablet computers, and even artificial intelligence, it profoundly impacts our surroundings. We find ourselves increasingly reliant on these technological advancements, shaping our daily lives and interactions. However, these advancements have also led to the deterioration of our living environment, with air pollution emerging as a significant issue. Poor air quality has caused respiratory problems for many new-borns, and numerous smog-themed disaster films reflect the challenges the world must face.

This project, titled "Design and Implementation of an Indoor Air Quality Monitoring System," utilizes an Arduino, LCD, gas sensor, humidity and temperature sensor, servomotor, buzzer, and GSM module to automatically monitor and improve the air quality inside living spaces. The system is a carefully designed solution addressing the social issue of poor air quality in any room. By implementing this innovative approach, we aim to provide a clean and safe air flow, preventing diseases such as asthma and ensuring the health and well-being of all occupants, especially the elderly and children.

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LIST OF ACCRONYMS AND ABBREVIATIONS

ULK : Université libre de Kigali

LCD: Liquid Crystal Display

GSM: Global system for Mobile communication

IAQ: Indoor Air Quality

IAP : Indoor Air Pollution

EPA: environmental Protection Agency

WHO: Word Health Organisation

PM: Particulate Matter

NO2: Nitrogen Dioxyde

CO: Carbone Monoxyde

IoT: Internet of Things

CIAQI: Comprehensive Indoor Air Quality Indicator

WSN: Wireless Sensor Network

MQ-2: Gas sensor

DHT11: humidity and temperature sensor

ANOVA: Analysis of Variance

MOSFET: Metal-Oxyde-Semiconductor Field Effect Transistor

PCB: Printed Circuit Board

DC: Direct Current

U: Voltage

I: Current

CHAPTER 1: GENERAL INTRODUCTION

1.0. Introduction

As technology rapidly evolves from old slide phones to today's smartphones, tablet computers, and even artificial intelligence, it profoundly impacts our surroundings. We find ourselves increasingly reliant on these technological advancements, shaping our daily lives and interactions. However, the technological advancements have led to deterioration of our living environment, and various problems, such as air pollution have gradually emerged. Poor air quality has caused respiratory problems to many new-borns and many smog-themed disaster films have been shot, which seem to reflect the problems the world must face once again.

In this project we've designed a simple system called ''**design and implementation of an indoor air quality monitoring system**'' using Arduino, LCD, gas sensor, humidity and temperature sensor, servomotor, buzzer, GSM module, which will automatically work to give a good monitoring of the air inside our living room.

The design and implementation of an indoor air quality monitoring system is a carefully designed solution that solves the social issue of poor air quality in any room. it's a new idea of implementation which makes a normal air quality monitoring system using these sensors for issues detection.

1.1. Background of the study

By checking closely to the reason why there's many pneumatic diseases, asthma, or even choking problem, we can see that the main cause is the poor air quality due to the bad room aeration or a lack of air quality monitoring and those problem can lead up to the death. something which is not good and which could be avoided.

Considering what has been said above we've implemented a system which can be helpful to avoid those kind of disease and assuring a good security health in every room where is needed for example in a student apartment, in a living house, in a household, offices and classes of a university, ...

1.2. Statement of the problem

Indoor air quality (IAQ) is a significant concern in modern society as people spend a big amount of their time indoors, whether at home, work, or in educational institutions. Poor IAQ can lead to a range of health issues, including allergies, respiratory conditions, and weakened immune systems. Despite its importance, monitoring indoor air quality is often overlooked due to the lack of awareness, complexity of monitoring methods, and the cost of professional-grade monitoring systems. The absence of a user-friendly, affordable, and comprehensive indoor air quality monitoring system poses a significant problem, particularly in densely populated urban areas and industrial settings where indoor air pollution can be severe. This project aims to address this gap by developing an efficient and cost-effective indoor air quality monitoring system.

1.3. Research objective

1.3.1 General objective

The general objective of this project is to develop a cost-effective, reliable, and user-friendly indoor air quality monitoring system utilizing Arduino. This system aims to provide continuous monitoring of various air quality parameters, including temperature, humidity, smoke presence, and different gases. By leveraging the open-source nature of Arduino, the project seeks to keep costs low, making the system accessible and affordable for a broad range of users. Additionally, the system will feature an intuitive interface that allows users to easily understand and interact with the collected data.

1.3.2 Specific objectives

1. Continuous Monitoring: To provide continuous monitoring of air quality parameters such as temperature, humidity, particulate matter, and various gases.

2. Cost Efficiency: To utilize Arduino, an open-source platform, to keep the costs low and make the system affordable for a wide range of users.

3. User Interface: To develop an interface that allows users to easily understand and interact with the data collected by the system.

4. Data Collection and Analysis: To gather data over time for analysis to identify trends and patterns in indoor air quality.

5. Alert System: To create a system that can alert users when air quality levels exceed a certain threshold, ensuring timely intervention.

6. Educational Resource: To serve as an educational resource for individuals and organizations to learn more about air quality and its impact on health and well-being.

1.4. Research questions

- What are the key pollutants that significantly affect indoor air quality, and how can they be effectively monitored?
- What are the health impacts associated with poor indoor air quality, and how can a monitoring system help mitigate these risks?
- How can the complexity of indoor air quality monitoring be reduced to make it more accessible and user-friendly?
- How can awareness about the importance of indoor air quality be increased among the general public and relevant stakeholders?
- What are the technological challenges in developing an efficient indoor air quality monitoring system, and how can they be overcome?

1.5 Limitations of the study

Designing an indoor air quality system, limitations are so many but let's stay focused on main ones: Affordable sensors may lack the precision of high-end models which can affect data accuracy, regular maintenance is required to ensure system reliability, which can be resource-intensive, sensors can be influenced by environmental factors like humidity, leading to skewed readings, Arduino's limited processing capabilities can restrict complex data analysis and real-time response, expanding the system to cover larger areas or multiple locations could be challenging.

1.6 Significance of the study

The significance of a study on an indoor air quality monitoring system is multi-faceted:

Health Impact: By monitoring and improving indoor air quality, we can significantly reduce the risk of health issues such as allergies, respiratory conditions, and weakened immune systems. This can lead to improved overall health and well-being for individuals spending time in these indoor environments.

Preventive Measures: A comprehensive monitoring system can help identify potential issues before they become serious, allowing for timely intervention and preventive measures. This can save costs related to health care and property damage in the long run.

Awareness and Education: The study can raise awareness about the importance of indoor air quality, leading to more informed decisions about ventilation, use of certain materials and products, and lifestyle habits that can affect air quality.

Policy and Regulation: The findings from this study could inform policy and regulation related to building design, construction, and maintenance. It could lead to the implementation of standards for indoor air quality, benefiting society at large.

Technological Innovation: The development of a user-friendly, affordable, and effective monitoring system could spur technological innovation in the field of environmental health and safety. This could open up new avenues for research and development, potentially leading to job creation and economic growth.

Sustainability: Improved indoor air quality contributes to the broader goal of sustainability. By ensuring our indoor environments are healthy, we're also taking steps to reduce our impact on the outdoor environment, contributing to the overall health of our planet.

1.7 Organization of the study

Chapter 1: Introduction

Shows the overview of all the project, which include its research objectives, background of the study, problem statement, research question and significance of the study.

Chapter 2: Literature Review

Gives an overview on existing technologies and methodologies related to indoor air quality monitoring, the innovations and some research base on this project.

Chapter 3: Research methodology

It gives and shows the method carried out to get data used in the project

Chapter 4: System design analysis and Implementation

Details the hardware and software used to get the project done. It also discusses the challenges faced and solutions brought during the design phase.

Chapter 5: Conclusion and recommendation

Summarizes the project and suggests areas for future research and development.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

indoor Air Quality (IAQ) is a critical aspect of environmental health sciences. The World Health Organization (WHO) and the United States Environmental Protection Agency (EPA) have identified IAQ as a major health issue. The primary concern is that people spend a significant portion of their time indoors, where they are exposed to a variety of air pollutants. These pollutants can originate from various sources, including building materials, furnishings, cleaning products, heating and cooling systems, and outdoor air. The concentration of these pollutants can be significantly higher indoors than outdoors, leading to potential health risks.

2.1 concepts, Opinions, Ideas from Authors/Experts

Experts in the field have emphasized the importance of continuous monitoring of IAQ to identify potential health hazards. They suggest the use of advanced sensor technologies and data analytics for real-time monitoring and control of IAQ. The key pollutants to monitor include Particulate Matter (PM), Nitrogen Dioxide (NO2), Carbon Monoxide (CO), Sulphur Oxides, polycyclic organic matter, and formaldehyde. The use of Internet of Things (IoT) and Wireless Sensor Networks (WSN) technologies is seen as a promising approach for creating efficient IAQ monitoring systems. They also advocate for the use of wireless technologies and cyber-physical systems for real-time monitoring. Concepts like the Comprehensive Indoor Air Quality Indicator (CIAQI) have been introduced for accurate IAQ assessment. The implementation of GSM Technology, IAQ monitoring systems using off-the-shelf devices is also discussed. Despite potential challenges and limitations, there are numerous opportunities in the field of IAQ monitoring for research and development.

2.2 Theoretical perspectives

The theoretical perspectives on IAQ monitoring systems often revolve around the use of wireless technologies for real-time monitoring. The goal is to identify trends, spot problem areas, and make adjustments accordingly. Theoretical discussions also involve the use of IoT sensor-based systems for a better end-user experience. The focus is on understanding the relationship between IAP exposure and associated risks.

Indoor Air Quality (IAQ) monitoring systems are crucial for public health as they help in identifying and controlling air pollutants within indoor environments. These systems typically consist of hardware like sensors and detectors, software for data analysis, and services to resolve air quality issues. They are particularly relevant in developing countries where indoor air pollution from sources like biomass and coal is a significant health concern. With advancements in technology, the use of GSM and wireless sensor networks has become prevalent in these systems, enabling real-time monitoring and providing high-quality services. However, there are challenges in system design, calibration, and accuracy that need to be addressed. Overall, IAQ monitoring systems play a vital role in improving the living atmosphere and imposing healthy daily routine activities.

2.3 Related study

Several related studies have been conducted in the field of IAQ monitoring systems. For instance, a comprehensive review on indoor air quality monitoring systems for enhanced public health was conducted by Jagriti Saini, Maitreyee Dutta & Gonçalo Marques. Another study focused on the design and implementation of an IoT sensor-based IAQ monitoring system. There are also studies that provide a comprehensive review of different IAQ monitoring systems.

2.4 Components used

2.4.1 Arduino Uno

Figure 1 : Arduino Board diagram

The Arduino Uno is a microcontroller board that serves as an excellent starting point for electronics and coding projects. It's part of the Arduino family, which encompasses various boards with different features and use cases., the Uno is a robust choice to begin your journey, if you're new to tinkering with electronics

Here is some description of the Arduino Uno:

Microcontroller: Based on the ATmega328P, the Uno provides 14 digital input/output pins (with 6 supporting PWM outputs) and 6 analog inputs.

Clock Speed: It operates at a 16 MHz clock speed using a ceramic resonator.

Connectivity: The Uno has a USB connection for programming and communication with a computer. It also includes a power jack for external power sources.

Reset Button: There's a convenient reset button for restarting your projects.

This flexibility combined with the fact that the Arduino software is free, the hardware boards are cheap, and both software and hardware are easy to learn has led to a large community of users who have contributed code and released instructions for a huge variety of Arduino-based projects.

PARTS OF AN ARDUINO UNO

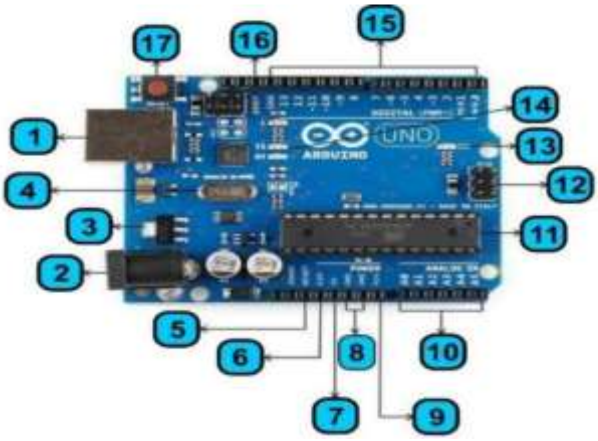

Figure 2 : Arduino board parts

1. USB plug
2. Power jack
3. Voltage regulator
4. Crystal oscillator
5. Reset Pin
6. 3.3V Pin
7. 5V Pin
8. Voltage in Pin
9. Ground Pin
10. Analog pin
11. ATmega328 microcontroller
12. In circuit serial programmer
13. Power led indicator
14. ATmega USB controller
15. Digital IN/OUT Pins
16. Analog reference Pin(AREF)
17. Reset button

2.4.2 GSM Module

Figure 3 : GSM Module board

The GSM module is a versatile cellular module that allows devices to communicate over the Global System for Mobile Communications (GSM) network. It is commonly used in applications that require remote data transmission, such as IoT devices, GPS trackers, security systems, ... there is many types of GSM modules (SIM800, SIM900, SIM7000...)

For us we have used a SIM800l GSM Module and Here is his brief description:

- Communication: The SIM800 module enables devices to send and receive SMS messages, make phone calls, and establish data connections over the GSM network. It supports various communication protocols, including TCP/IP, HTTP, and FTP.

- SIM Card: The module requires a standard SIM card to connect to the GSM network. Users can insert a SIM card into the module to access cellular services.

- Interface: The SIM800 module typically features serial communication interfaces (such as UART) for connecting to microcontrollers or other devices. It also includes GPIO pins for controlling functions like power management and status indicators.

- Power Supply: The module operates on a voltage supply typically ranging from 3.4V to 4.5V. It may include power-saving modes to optimize energy consumption.

- Antenna: To establish a reliable connection with the GSM network, the SIM800 module requires an external antenna. Antenna selection and placement are crucial for signal strength and quality.

- Programming: Developers can interact with the SIM800 module using AT commands sent over the serial interface. These commands control various functions of the module, such as sending SMS messages, making calls, and configuring network settings.

Its versatility and ease of integration make it a popular choice for a wide range of applications requiring remote communication capabilities.

2.4.3 LCD Screen

*Figure 4: LCD Display 16*2 with I2c diagram*

An LCD (Liquid Crystal Display) with I2C (Inter-Integrated Circuit) interface is a popular choice for displaying information in embedded systems due to its ease of use and ability to reduce the number of pins required for communication. Here's a theory on how an LCD with I2C works:

An LCD with I2C typically consists of a liquid crystal display panel and a small circuit board that includes an I2C serial interface. The I2C interface allows the microcontroller to communicate with the LCD using only two wires, SDA (data) and SCL (clock), simplifying the wiring and reducing the number of required I/O pins. When a microcontroller wants to display information on the LCD, it sends commands and data to the LCD module through the I2C bus. These commands can include instructions for initializing the display, setting the cursor position, clearing the display, and writing characters or custom symbols to the screen. The LCD module processes these commands and data, converting them into signals that control the liquid crystal pixels on the display panel. The pixels are arranged in rows and columns, and by selectively activating or deactivating individual pixels, characters, numbers, and graphical symbols can be displayed on the screen.

The I2C interface uses a master-slave communication protocol, where the microcontroller acts as the master device and the LCD module acts as the slave device. The master device initiates communication by sending start and stop conditions on the bus, and then transmits or receives data from the slave device. The I2C protocol also supports multi-master configurations, allowing multiple master devices to communicate with multiple slave devices on the same bus. This feature can be useful in systems where multiple microcontrollers need to interact with a single LCD module.

One advantage of using an I2C interface for an LCD is that it simplifies the hardware design by reducing the number of required connections between the microcontroller and the display. This can be particularly beneficial in space-constrained applications or when using microcontrollers with limited I/O pins.

2.4.4 Humidity and temperature sensor

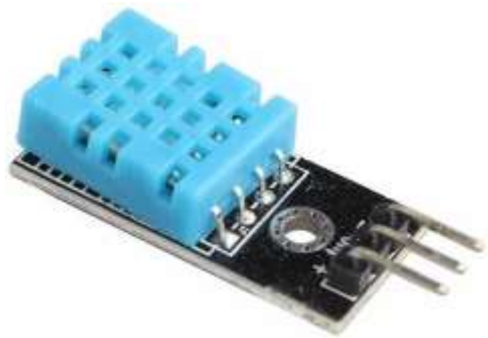

Figure 5: DHT11 sensor

The DHT11 sensor module is a low-cost digital temperature and humidity sensor that is commonly used in various projects and applications. It consists of a capacitive humidity sensor and a thermistor for temperature measurement. The sensor operates on the principle of capacitance and resistance changes in response to variations in humidity and temperature.

The capacitive humidity sensor in the DHT11 detects changes in humidity by measuring the capacitance of a moisture-sensitive polymer film. As the humidity level changes, the dielectric constant of the film changes, leading to a corresponding change in capacitance. This change is then converted into a digital signal that can be read by a microcontroller while the thermistor in the DHT11 is used to measure temperature by sensing changes in resistance with temperature variations. The resistance of the thermistor decreases as the temperature increases, allowing the sensor to accurately measure temperature changes. This information is also converted into a digital signal for processing by the microcontroller.

The DHT11 sensor module has a single-wire digital interface for communication with microcontrollers, making it easy to integrate into various projects. It requires only one digital pin for both data transmission and power supply, simplifying the wiring and reducing the number of required connections. One of the key features of the DHT11 sensor module is its low cost, making it an affordable option for hobbyists, students, and enthusiasts looking to add temperature and humidity sensing capabilities to their projects. However, it is important to note that the DHT11 has limitations in terms of accuracy and precision compared to more expensive sensors.

Despite its limitations, the DHT11 sensor module is suitable for many applications where precise measurements are not critical. It is commonly used in weather stations, environmental monitoring systems, home automation projects, and other applications where monitoring temperature and humidity levels is important.

Figure 6: DHT11 parts

The DHT11 sensor module has three pins: VCC, DATA, and GND.

1. VCC (Power): The VCC pin is used to provide power to the DHT11 sensor module. It typically operates at 3.3V to 5V, depending on the specific model. This pin is connected to the positive terminal of the power supply.

2. DATA (Data Signal): The DATA pin is used for bidirectional communication between the DHT11 sensor module and the microcontroller. This pin is used to transmit temperature and humidity data from the sensor to the microcontroller and receive commands from the microcontroller. It is a single-wire digital interface for data transmission.

3. GND (Ground): The GND pin is connected to the ground of the power supply. It completes the circuit and provides a reference point for the voltage levels in the system.

2.4.5 Gas sensor

Figure 7: MQ-2 sensor

The MQ-2 sensor is a gas sensor module that is commonly used to detect a variety of gases such as methane, propane, butane, alcohol, smoke, and carbon monoxide. It operates on the principle of the chemical reaction between the target gas and the sensing element inside the sensor. The MQ-2 sensor consists of a sensing element made of a semiconductor material that changes its electrical conductivity in the presence of different gases.

When the target gas comes into contact with the sensing element, it causes a change in the resistance of the element, which can be measured and converted into a gas concentration value. The MQ-2 sensor module typically has four pins: VCC (power supply), GND (ground), AOUT (analog output), and DOUT (digital output).

The VCC pin is used to provide power to the sensor module, typically operating at 5V.

The GND pin is connected to the ground of the power supply.

The AO pin provides an analog voltage output proportional to the gas concentration detected by the sensor, which can be read by an analog-to-digital converter on a microcontroller.

The DO pin provides a digital output signal that changes its state (high or low) based on a predefined threshold gas concentration level set by a potentiometer on the sensor module. This digital output can be used to trigger an alarm or other actions when the gas concentration exceeds a certain level.

Figure 8: MQ-2 sensor parts

The MQ-2 sensor module requires a warm-up time before it can provide accurate readings, typically around 24-48 hours. It is important to calibrate the sensor module for accurate gas detection measurements and compensate for environmental factors such as temperature and humidity.

2.4.6 Servo motor

Figure 9: Electronic servomotor

A servomotor is a type of motor that is designed to provide precise control of angular position, velocity, and acceleration. It is commonly used in applications requiring high precision and reliability, such as robotics, CNC machinery, and automated manufacturing systems. The fundamental principle behind a servomotor is the closed-loop control system that regulates its movement based on feedback from sensors.

Servomotors typically consist of a DC or AC motor, a feedback device (like an encoder or potentiometer), and a controller. The controller sends signals to the motor based on the desired position, speed, or torque, while the feedback device continuously monitors the actual position or speed of the motor. This feedback loop allows for real-time adjustments, ensuring that the motor responds accurately to changes in input commands.

Servomotors are characterized by their high torque-to-weight ratio, rapid response times, and the ability to maintain a specific position under varying loads. They can be operated in various modes, including position control, speed control, and torque control, making them versatile for different applications. In position control mode, the servomotor accurately moves to a specified angle and holds that position until instructed otherwise. In speed control mode, it adjusts its rotational speed according to the input signal. Torque control mode allows for maintaining a specific torque level, which is crucial for applications like robotic arms that need to manipulate objects delicately.

The performance of a servomotor is influenced by several factors, including the quality of the controller, the type of feedback mechanism used, and the characteristics of the motor itself. Proper selection and tuning of these components are essential for achieving optimal performance in any application.

2.4.7 Buzzer

Figure 10: electronic buzzer

A buzzer is an electronic device that produces sound, typically used for signaling, alerts, or notifications. There are two main types of buzzers: passive and active. Here's a breakdown of each type, their working principles, applications, and characteristics:

Types of Buzzers

1. Active Buzzer

An active buzzer contains a built-in oscillator. When voltage is applied, it generates a sound on its own without needing an external signal. It works by converting electrical energy into sound energy through piezoelectric or electromagnetic principles. The internal circuitry oscillates at a specific frequency to produce a tone. It is commonly used in alarm systems, timers, and simple notification systems where a continuous sound is required.

2. Passive Buzzer:

A passive buzzer does not have an internal oscillator and requires an external signal (like a square wave) to produce sound. It operates similarly to a speaker; when an AC voltage signal is applied, it vibrates to create sound. The frequency of the input signal determines the pitch of the sound produced. It is commonly used in alarm systems, timers and clock, Medical devices ...

A buzzer can be easily integrated into electronic circuits. For active buzzers, simply connecting them to a power source will activate them. For passive buzzers, a microcontroller or timer circuit can be used to generate the necessary square wave signal to produce sound.

2.4.8 Fan

Figure 11: DC Fan

A DC fan motor is a type of electric motor that operates on direct current (DC) electricity. These motors are commonly used in various applications, including cooling systems, computer fans, and household appliances. Here’s a brief overview of the theory behind DC fan motors:

The fundamental principle behind a DC motor is electromagnetism. When an electric current flows through a coil of wire (the armature), it generates a magnetic field. This magnetic field interacts with the permanent magnets or the stator's magnetic field, creating torque that causes the rotor to turn. It consists of two main part which are ***Stator*** (The stationary part of the motor, which can consist of permanent magnets or electromagnetic windings) and ***Rotor*** (The rotating part of the motor, which contains windings connected to a commutator.). It works as follows, when DC voltage is applied, current flows through the brushes into the commutator and then into the rotor windings, the interaction between the magnetic fields of the stator and rotor produces torque, causing the rotor to spin, as the rotor turns, the commutator periodically reverses the current direction in the rotor windings, maintaining motion.

Advantages of DC Fan Motors
- Speed Control: The speed of a DC fan motor can be easily adjusted by varying the voltage applied to it.
- High Starting Torque: They provide high torque at startup, making them suitable for applications requiring quick acceleration.
- Compact Size: DC motors are generally smaller and lighter than their AC counterparts.

Applications

DC fan motors are widely used in:
- Cooling systems (e.g., computer cooling fans)

- Automotive applications (e.g., radiator fans)
- Home appliances (e.g., exhaust fans)
- HVAC systems

2.4.9 Resistor

Figure 12: 10k resistor

A **resistor** is a fundamental electronic component that introduces resistance to the flow of electric current in a circuit. It is considered a **passive two-terminal element**. Here's how it works:

Ohm's Law and Resistance:

Ohm's Law states that the voltage across a resistor is **proportional to the current flowing through it**.

Mathematically :

$V=I \cdot R$

- (V) represents voltage (in volts)
- (I) represents current (in amperes)
- (R) represents resistance (in ohms)

An ideal resistor follows Ohm's Law, where the voltage drop across its terminals is directly related to its resistance.

For our case we have used a 10k resistor which plays a crucial role in limiting the flow of current within our circuit. When voltage and resistance determine the amount of current, the high resistance of a 10k resistor restricts the current passing through it, ensuring that the entire circuit operates with a small current. Remember, the colour code for a 10k resistor typically follows the pattern Brown-Black-Orange-Gold or Brown-Black-Black-Red-Gold.

2.4.9 Diode

Figure 13: Electronic Diode

A diode is a semiconductor device with a PN junction. When an N-type material (doped with impurities like Antimony) is fused with a P-type material (doped with impurities like Boron), it creates a PN junction.

Initially, a large density gradient exists across the junction. Electrons from the N-type side migrate to fill holes in the P-type material, creating negative ions. Simultaneously, holes from the P-type side move across the junction into the region with free electrons.

This charge transfer, known as diffusion, continues until equilibrium is reached, forming a depletion layer around the junction. The depletion layer lacks free carriers due to potential barriers created by donor and acceptor ions.

The diode allows current flow in one direction (from N to P) and blocks it in the reverse direction.

2.4.10 Transistor

Figure 14: N-channel MOSFET

An N-channel MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) is a type of transistor that is widely used in electronic circuits for switching and amplification. Here's a brief overview of its theory:

Basic Structure

- Components:

- Source (S): The terminal where the charge carriers (electrons) enter the MOSFET.

- Drain (D): The terminal where the charge carriers exit.

- Gate (G): The terminal that controls the operation of the MOSFET.

- Body (Bulk): The substrate or the base material, often connected to the source.

- Operation Principle:

- An N-channel MOSFET consists of a p-type substrate with two n-type regions (source and drain) formed within it. The gate is separated from the channel by a thin layer of insulating material, usually silicon dioxide.

Working Principle

- When a positive voltage (greater than the threshold voltage, V_th) is applied to the gate terminal relative to the source, an electric field is generated. This electric field attracts electrons from the source into the p-type substrate, creating a conductive channel between the source and drain. Once the channel is formed, electrons can flow from the source to the drain, the amount of current flowing through the MOSFET can be controlled by varying the gate voltage. Higher gate voltages enhance the channel conductivity, allowing more current to pass.

- Cut-off and Saturation Regions:

In the cut-off region, when the gate voltage is below V_th, the channel is non-conductive, and no current flows from drain to source but in the saturation region, with sufficient gate voltage and drain-source voltage, the MOSFET operates as a closed switch, allowing maximum current flow.

- Characteristics

- High Input Impedance: The gate terminal has very high impedance, meaning it draws minimal current, making it suitable for low-power applications.

- Fast Switching Speed: N-channel MOSFETs can switch on and off quickly, which is beneficial in digital circuits and power electronics.

- Efficiency: They have low on-resistance when turned on, resulting in less power loss during operation.

2.4.11 Jump wires

Figure 15 Jump wires image

Jump wires, also known as jumper wires or DuPont wires, are essential components in electronics. They consist of simple wires with connector pins at both ends, allowing you to connect points in a circuit without soldering. These wires come in various types, including male-to-male, male-to-female, and female-to-female variants. Solid-tip jump wires connect to breadboards or female header connectors, increasing mounting density without causing short-circuits. When placing jump wires, it's advisable to position them on the component side of circuit boards for better organization and reliability.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0. Introduction

The research methodology for the "Design and Implementation of Indoor Air Quality Monitoring system" follows a structured plan to achieve project goals. This approach integrates both theoretical and practical elements, providing a comprehensive and effective execution of the monitoring system. The research process is organized into several phases: research design, target population, sample size determination, sampling methods, research instruments, data collection techniques, data analysis and interpretation, ethical considerations, and study limitations. Each phase employs specific strategies to tackle the challenges of effectively monitoring indoor air quality. This organized methodology ensures the reliability, accuracy, and overall functionality of the final monitoring system.

3.1. Research design

This study adopts an experimental research design to develop and evaluate an indoor air quality monitoring system that utilizes an Arduino Uno, MQ-2 gas sensor, and DHT11 temperature and humidity sensor. The primary focus is on quantitative data to assess parameters such as level of pollution in the environment, temperature, and humidity under various indoor conditions. However, qualitative aspects are also considered through observational notes and user feedback during the testing phase. This mixed-method approach ensures a comprehensive understanding of both the technical and practical implications of the monitoring system. Justification for the experimental design lies in its capacity to yield precise, controlled, and replicable results, which are critical for validating the functionality and performance of the air quality monitoring system. The study will involve constructing the monitoring circuit, programming the Arduino for sensor integration, and conducting a series of tests to gather data on air quality indices, temperature, and humidity levels.

3.2. Research population

The population for this study encompasses all potential applications and users of indoor air quality monitoring systems in various contexts, including residential, commercial, and industrial environments. The target population specifically focuses on residential houses, student apartments and households that require effective and reliable monitoring solutions for air quality metrics. This population is pertinent as the study aims to generalize the effectiveness and usability of the designed monitoring system in these settings. The sample drawn for this study includes inanimate test environments and devices that simulate typical indoor air quality conditions encountered in these locations. The relevant characteristics of these test environments include their air quality parameters, pollutant levels, and sensitivity to changes in temperature and humidity. Inclusion criteria for the test environments involve having air quality metrics within the sensor's designed capacity, while exclusion criteria eliminate any environments with conditions outside the operational range or those that cannot be safely monitored using the system. This approach ensures that the findings of the study are both applicable and beneficial to the intended users.

3.3. Sample size

Determining an appropriate sample size is crucial for ensuring that the findings of this study on the design and implementation of an indoor air quality monitoring system using Arduino UNO, MQ-2, and DHT11 sensors are representative of the accessible population. The accessible population includes residential houses, student apartments and households interested in monitoring indoor air quality. For this research, a sample size of 15 test systems has been selected. This sample size was calculated to ensure that the results can be generalized with a high degree of confidence.

The selection process involved identifying systems that meet the inclusion criteria, ensuring they operate within the designed capacity of the sensors. This sample size is sufficient to provide reliable and valid data for analyzing the performance and effectiveness of the indoor air quality monitoring system under realistic conditions.

Calculating the sample size depends on various factors, including the population size, desired confidence level, and margin of error. Here's a step-by-step guide to calculating the sample size using a common formula:

- Population size (N): 15
- Confidence level: 97% (Z = 2.17)
- Margin of error: 3% (E = 0.03)
- Population proportion: 60% (p = 0.6)

The sample size (n) is calculated as follows:

$$n=\frac{\frac{Z^2*P(1-P)}{E^2}}{1+(\frac{Z^2\ *P(1-P)}{E^2\quad *N})}$$

After performing the calculations, we find n ≈ 14.5, which rounds to approximately 15 as the size of our sample.

This approach ensures that the findings of the study are both applicable and beneficial to the intended users seeking to monitor indoor air quality effectively.

3.4. Sampling Procedure

To ensure that the sample accurately represents the population, a stratified random sampling strategy was employed. This method was chosen to guarantee that key characteristics of the population, such as various indoor air quality levels and differing environmental conditions, are adequately represented in the sample. The population of interest comprises residential houses, student apartments and households that are interested in monitoring indoor air quality.

The sampling procedure involved the following steps:

Stratification: The population was divided into distinct strata based on their indoor air quality characteristics, such as low, moderate, and high pollution levels. This stratification ensures that each subgroup is proportionately represented in the sample.

Random Sampling: From each stratum, a random sample was selected to ensure that every member of the population had an equal opportunity to be included. This was accomplished using a random number generator to eliminate any selection bias.

Sample Size Determination: The sample size was determined to be 15 monitoring systems. This number is sufficient to provide reliable and valid results, ensuring that the findings can be generalized to the larger population.

Selection Criteria: The inclusion criteria for the selected systems involved their compatibility with the designed monitoring system's specifications and their ability to simulate typical indoor air quality conditions. Systems that did not meet these specifications were excluded to maintain the study's focus and relevance.

3.5. Research instrument

3.5.1. Choice of the Research Instrument

For this study, a researcher-devised instrument was selected to gather data on the performance and efficiency of the indoor air quality monitoring system designed with an Arduino UNO.
The primary research instrument consists of an Observations Checklist and a Performance Measurement Guide. The Observations Checklist is tailored to systematically record operational parameters and behaviors of the monitoring system under various environmental conditions, such as temperature, humidity, and pollutant levels. This checklist was developed based on aspects discussed in the Review of Related Literature, ensuring it encompasses all critical indicators of air quality.

The Performance Measurement Guide includes detailed procedures for measuring air quality metrics, utilizing tools such as gas sensors, ... This guide ensures consistency in data collection and facilitates accurate comparisons across different monitoring setups.
To ensure the reliability and validity of the researcher-devised instruments, they were pre-tested with a small group of 5-10 monitoring systems not included in the actual study. Feedback from this pre-test was instrumental in refining the instruments, ensuring they effectively capture the necessary data.
The response modes for the Observations Checklist include numerical readings and qualitative observations, while the Performance Measurement Guide involves numerical scores that reflect the air quality levels and stability of the monitoring system. The interpretation of scores involves comparing the measured values against expected performance criteria derived from the literature review. This systematic approach guarantees that the research instruments yield comprehensive and reliable data, facilitating a comprehensive analysis of the indoor air quality monitoring system's performance.

3.5.2 Validity and Reliability of the Instrument

Establishing the validity and reliability of the research instruments is vital for ensuring the quality of data collected in this study. Validity refers to how accurately the instruments measure what they are intended to assess, while reliability pertains to the consistency of measurements across different instances. To establish the validity of the Observations Checklist and the Performance Measurement Guide, these instruments were evaluated by a panel of experts in environmental science and sensor technology. Their feedback was utilized to refine the content, ensuring that all critical aspects of air quality monitoring were comprehensively addressed.
To further validate the instruments, a pre-test was conducted with a small group of 5-10 monitoring systems that were not part of the actual study. This pre-test helped identify any potential issues with the instruments and allowed for adjustments to enhance their accuracy and relevance.
Reliability was established through a test-retest method, where the same monitoring systems were evaluated multiple times under similar conditions. Consistency in results across these

tests indicated a high level of reliability for the instruments. Additionally, Cronbach's alpha was calculated to assess the internal consistency of the checklist items, with a value above 0.79 considered acceptable for this study.

For purposes of triangulation, both the Observations Checklist and the Performance Measurement Guide were employed simultaneously to collect data. This approach not only strengthens the robustness of the findings but also ensures that any discrepancies can be identified and addressed, thereby enhancing the overall reliability and validity of the study.

3.6. Data Gathering Procedure

The data gathering process was structured into three distinct phases: Before, During, and After the administration of the research instruments.

Before Data Collection

In preparation for data collection, the researcher undertook a comprehensive literature review to inform the development of the Observations Checklist and Performance Measurement Guide. This foundational step ensured that the instruments were grounded in existing research and best practices. Following this, a pre-test was conducted with a small group of 5-10 test systems to refine the instruments, enhancing their validity and reliability based on initial feedback.

Permissions were secured to utilize the selected monitoring systems, and a test environment was established to replicate typical load conditions experienced by residential houses, student apartments and households. This meticulous preparation aimed to ensure a controlled setting for accurate data collection.

During Data Collection

During the data collection phase, the researcher systematically administered the Observations Checklist and Performance Measurement Guide to a sample of 15 test systems. Each monitoring system was connected to an Arduino Uno, which served as the central processing unit, utilizing a DHT11 sensor for temperature and humidity readings and an MQ-2 sensor for detecting air quality parameters. Performance data was collected under varying environmental conditions to assess the system's responsiveness. The researcher meticulously recorded numerical readings for temperature, humidity, and gas concentration levels, alongside qualitative observations regarding any anomalies or notable behaviors.

To ensure accuracy, all measurements were conducted using calibrated sensors and the Arduino's built-in analog and digital capabilities. The system also controlled outputs such as a fan, a servomotor, and a buzzer based on the sensor readings to maintain optimal indoor air quality. This rigorous approach aimed to capture precise data reflective of the monitoring system's performance across different scenarios, ensuring effective responses to changes in air quality and environmental conditions.

After Data Collection

Post-collection, the researcher compiled and organized the gathered data from the indoor air quality monitoring system designed using Arduino Uno, DHT11, and MQ-2 sensors. This process involved entering numerical data into statistical software for quantitative analysis and summarizing qualitative observations for thematic insights related to air quality metrics.

A final review of the data was conducted to identify any inconsistencies or outliers that warranted further investigation. This step was crucial in ensuring the accuracy and reliability of the findings, particularly concerning the system's responses to varying air quality conditions.

The compiled data served as the foundation for evaluating the performance and efficiency of the indoor air quality monitoring system, including the effectiveness of the fan, servomotor, and buzzer outputs in response to sensor inputs. Detailed findings, including graphs and tables illustrating key trends in temperature, humidity, and gas concentrations, were documented in subsequent sections of the study. These insights not only highlighted the system's capabilities but also provided recommendations for potential improvements and future research directions in indoor air quality management ...

3.7. Data Analysis and Interpretation

The analysis of data generated from this study will employ both qualitative and quantitative techniques to provide a comprehensive evaluation of the indoor air quality monitoring system.

Quantitative Analysis

For the quantitative data, numerical readings of temperature, humidity, and level of pollution in the environment statistics will be calculated. These statistics will summarize central tendencies and dispersion within the dataset.

To explore relationships between air quality metrics and the system's responses (fan speed, servomotor position, and buzzer activation), Pearson's correlation coefficient will be utilized. This statistical method will help determine both the strength and direction of the correlation between these variables. Additionally, an Analysis of Variance (ANOVA) will be performed to compare system performance across different air quality conditions (e.g., low, moderate, and high pollution levels). This analysis will ascertain whether statistically significant differences exist in system responses among these groups.

Qualitative Analysis

For qualitative data gathered through the Observations Checklist, thematic analysis will be employed. This involves identifying recurring themes and patterns within the qualitative notes taken during testing. Thematic analysis will provide insights into anomalies, operational behaviors, and user feedback that may impact system performance.

Addressing Research Questions

Each research question will be addressed using appropriate statistical treatments. For example, to evaluate overall system responsiveness to varying air quality conditions, mean response times of the fan and servomotor across different pollution levels will be compared using ANOVA. To understand the relationship between air quality metrics and system activation (e.g., when the buzzer sounds), Pearson's correlation will be applied to relevant datasets.

By employing these statistical techniques and analyses, this study aims to deliver a detailed and reliable interpretation of the indoor air quality monitoring system's performance, ensuring that findings are robust, meaningful, and applicable to real-world scenarios.

3.8. Ethical Considerations

Maintaining the ethical integrity of this study is crucial for protecting the safety, social, and psychological well-being of all participants involved. Although this research primarily focuses on inanimate monitoring systems and does not directly engage human subjects, ethical considerations remain significant. The study was conducted in accordance with the guidelines set forth by the ethical review board of the institution, and necessary approvals were obtained to proceed.

For residential houses, student apartments and households whose systems were part of the testing phase, informed consent was obtained from relevant stakeholders. Participants were well informed about the study’s aims, methodologies, and any potential risks or benefits associated with their involvement. They were guaranteed that their data would be anonymized

and utilized exclusively for research purposes, with stringent confidentiality maintained throughout the process.
Additionally, the researcher implemented measures to ensure that the testing procedures did not interfere with the normal operation of the systems or endanger their functionality. Any risks associated with the testing process were carefully addressed through adherence to established safety protocols and the use of appropriate protective measures.

3.9. Limitations of the Study

This study recognizes several limitations that may influence the validity of its findings. A primary limitation is the relatively small sample size of 15 monitoring systems, which, while adequate, may not fully represent the variability present in the broader population of small to residential houses, student apartments and households. Moreover, the controlled testing environment may not accurately reflect all real-world conditions, potentially constraining the generalizability of the results.
Another limitation involves the possibility of measurement bias arising from reliance on researcher-developed instruments, which, despite comprehensive pre-testing and validation, may still introduce some degree of subjective interpretation in qualitative observations. Furthermore, this study primarily emphasizes the technical performance of the indoor air quality monitoring system, potentially neglecting other critical factors such as long-term reliability and user satisfaction.
To mitigate these limitations, stratified random sampling was employed to ensure a representative sample, and multiple data collection tools were utilized to enhance the robustness of the findings. The pre-testing and expert review of the research instruments also aimed to strengthen their validity and reliability.

CHAPTER FOUR: SYSTEM DESIGN, ANALYSIS AND IMPLEMENTATION

4.0 Introduction

In this chapter, I'm describing how the design of an Indoor air quality monitoring with an Arduino microcontroller and the sensors consists of two designs, namely hardware design which consist of physical part where we found every component used and software design where we found our Arduino source code. This chapter will provide valuable insights into creating a reliable system that keeps our indoor air safe and healthy.

4.1 Calculations

- *DHT11*

U= 5V; Imax= 2,5mA
P= U(v)*I(mA)=5V*2,5A= **12,5mW** (power consumed)

- *MQ-2*

U= 5V; Imax= 150mA

P= 5V*150mA= **750mW**

- *Servomotor*

U= 5V ; Imax=500mA

P= 5V*150mA= **2,5W**

- *Buzzer*

U= 5V ; Imax= 30mA

P= 5V*30mA= **150mA**

- *DC Fan*

U=5V ; Imax= 200mA

P= 5V*200mA= **1W**

- *N-Channel MOSFET*

Rgate=10kΩ ; Vgate= 5V

Igate= V/Rgate = 5V/10kΩ= 0,5mA

P=5V*0,5mA= **2,5mW**

- *GSM Module*

U= 4,2V, Imax= 1,02A

P= 4,2V*1,02A= **4,284W**

- *Freewheeling diode*

Vdrop= 0,7V; Imax= 200mA

P= 0,7V*200mA= **140mW**

- *LCD with I2c*

I(logic circuit)=2mA, V= 5V

I(backlight)= 20mA

It= 20mA+2mA= 22mA

P= 5V*22mA= **110mW**

- *Total power consomption except GSM*

Ptot= 12,5mW+750mW+2,5W+150mW+1W+2,5mW+140mW+110mW

= **4, 665W**

- *Total current consumption from Arduino*

Itot= Ptot/V= 4,665W/5V= **933mA**

Results table

Table 1 Results table

PARAMETERS / COMPONENTS	Voltage	Maximum current	Power consumed
DHT11	5V	2,5mA	12,5 mW
MQ-2	5V	150mA	750 mW
Servomotor	5V	500mA	2,5 W
Buzzer	5V	30mA	150 mW
DC Fan	5V	200mA	1 W
N-Channel MOSFET	5V	0,5mA	2,5 mW
Diode	5V	200mA	140 mW
LCD with I2c	5V	22mA	110 mW
TOTAL		Itot= 933mA	Ptot= 4,665W

Here is a table for GSM as it has his own external 4,2V power supply

Table 2 GSM Calculations result table

PARAMETERS / COMPONENT	Voltage supply (U)	Maximum current (Imax)	Power consumed (P)
GSM Module	4,2V	1,02A	4,284W

4.2 Drawings

4.1.1 Block diagram

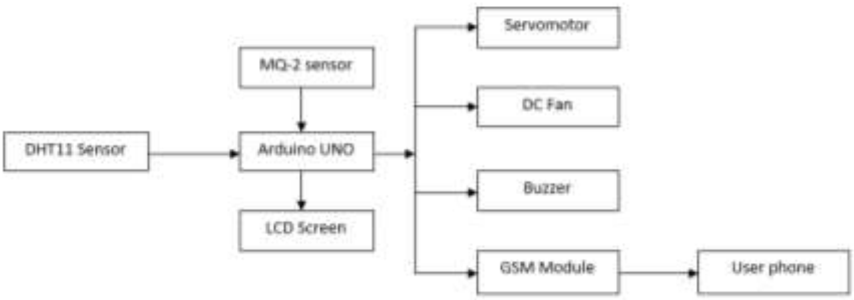

Figure 16 : Indoor air quality monitoring block diagram

4.1.2 flow chart

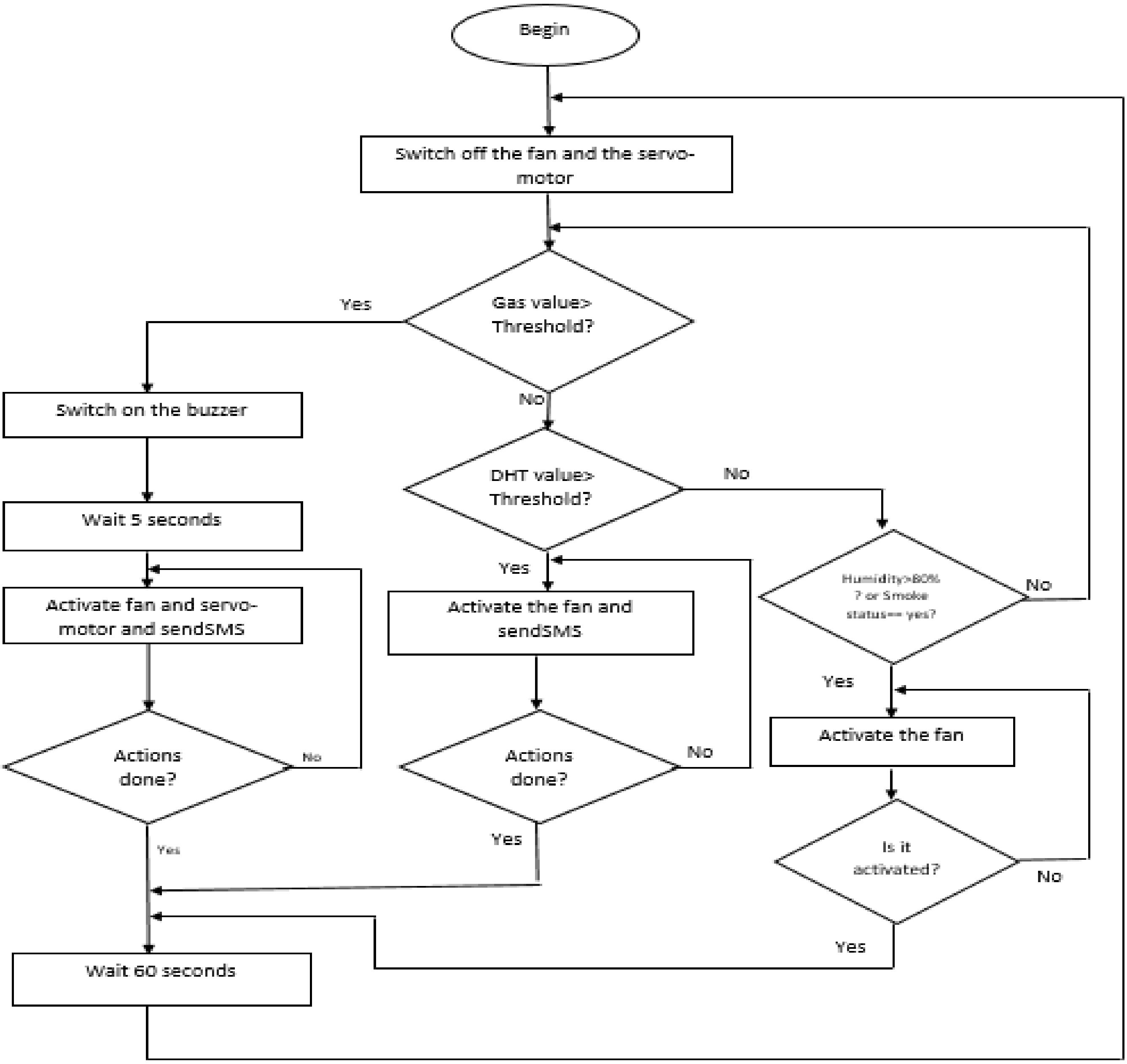

Figure 17 : Indoor air quality monitoring system flowchart

4.1.3 circuit diagram

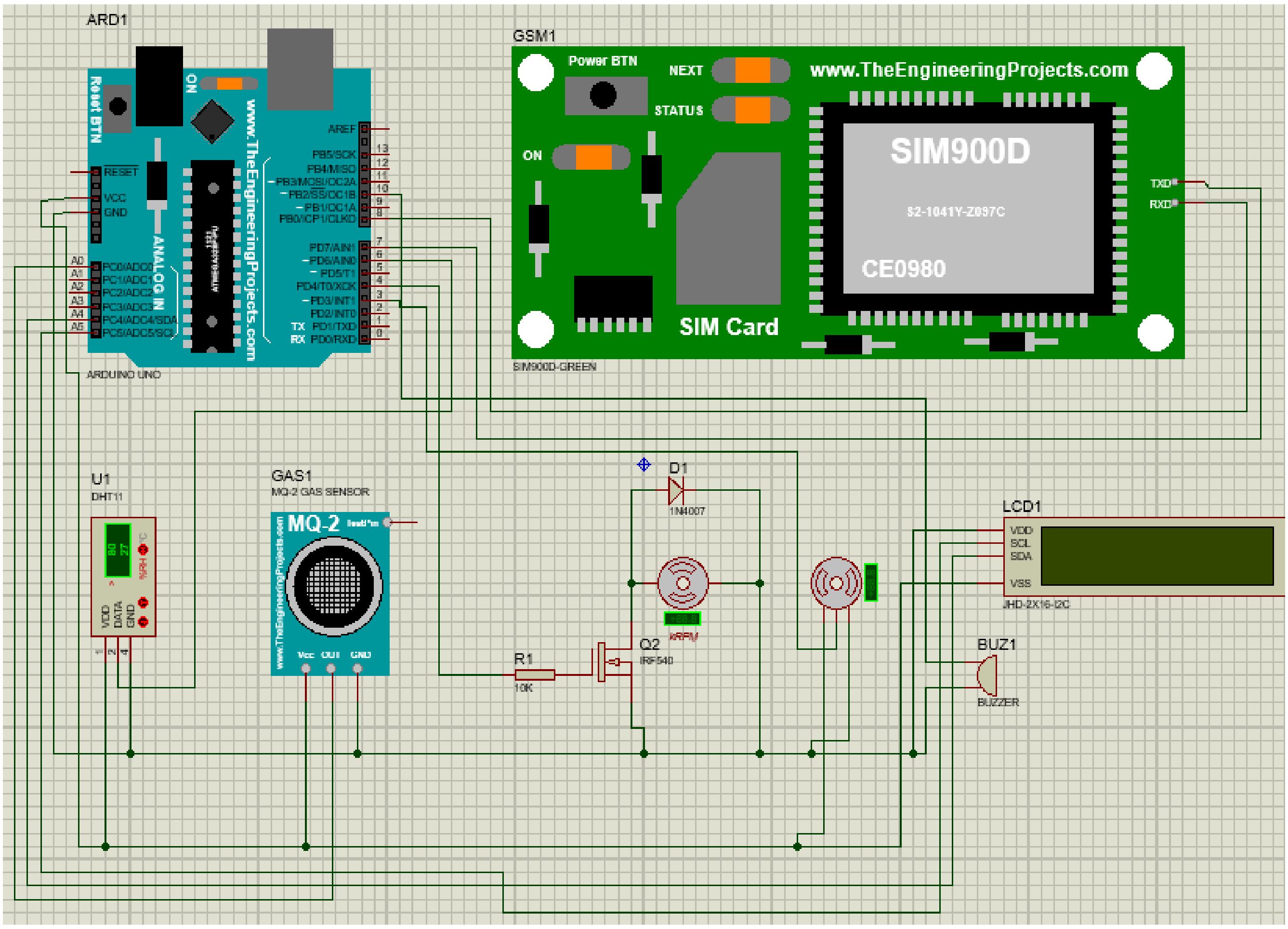

Figure 18 : Indoor air quality monitoring system circuit diagram

4.2 Cost estimation

Indoor air quality monitoring budget

Table 3 Cost estimation table

Qty	Materials	Total price(RWF)
1	Arduino UNO	15000
1	GSM Module SIM800l	12000
1	LCD +I2c	11000
1	DHT11	3000
1	MQ-2	3400
1	Servomotor	3800
1	Buzzer	1000
1	DC fan	2500
1	Resistor	1000
1	MOSFET N-Channel	1000
1	Diode	300
3	Jump wires	4000
1	PCB	1500
1	12V Power supply	5000
2	Iron+ solder wire	17500
2	Silicone Glue	2000
	Total	74000

4.3 Specifications

Table 4 Specifications table

Components	Specifications	Quantity
Arduino UNO	Operating temp: -5 to 40ºC Supply voltage: 7-12V Operating voltage: 5V Input voltage: 7-12V I(dc) per I/O pin: 20 mA I(dc) for 3,3V pin: 50mA	1
GSM Module	Operating Temperature: -40 to 85ºC Supply Voltage: 3.4V to 4.4V1 Current Peak (Pulse): Up to 2 Amps2 Current Continuous: Around 500mA Frequency Bands: Quad-band (850/900/1800/1900 MHz)	1
DHT11	Operating voltage: 3,5V to 5,5V operating current: 0,3mA Tº range: 0 to 50ºC Humidity range: 20% to 90%	1
MQ-2 Sensor	Operating Voltage: 5V DC Analog output voltage: 0V-5V Digital output Voltage: 0V-5V Weight: 8gm	1
Buzzer	Operating Tº: -20 to 45ºC Rated voltage: 5V Operating voltage: 4V-8V Max rated current: ≤ 32mA Minimal sound output: 80dB	1
Servo-motor	Operating Tº: -30ºC to 60ºC Operating voltage: 4,8V to 6V Dead set: 7mS Weight: 9g	1
Fan	Operating voltage: 5V Power: 1W Maximum current: 0,20 mA Speed: 2300RPm Type: Brushless DC fan	1
LCD Screen	Operating Tº: 0ºC to 55ºC Operating voltage: 5V Operating Current: 2mA Resolution: 128*64 pixels Type: 16*2 with I2c	1

4.4 Working principle

The Indoor Air Quality monitoring system utilizes a combination of sensors, including the DHT11 for temperature and humidity, and the MQ-2 gas sensor for detecting gases and smoke, which continuously collect data and send it to an Arduino microcontroller for real-time processing. The system displays critical information on an LCD, such as current temperature, humidity, gas concentration, and smoke status. When thresholds are exceeded—like temperatures above 30°C or gas concentrations over 500 ppm—it triggers SMS alerts via a GSM module, activates a fan for ventilation, and engages a servo motor to open a window for increased airflow. Additionally, if humidity exceeds 80% or smoke is detected, the fan operates for one minute to mitigate these conditions. This integration of sensors, actuators, and communication technologies ensures timely alerts and proactive responses, enhancing safety in places given above.

4.5 Implementation

Figure 19 Implementation

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

The development of smart houses, especially in the development of smart indoor air quality monitoring tends to increase, this due to the trend of the existence of intelligent technology. The test results state that overall, the indoor air quality monitoring system works and functions properly

5.1 Conclusions

I chose to do this project and its research to create an efficient, low-cost, real-time indoor air quality monitor suitable for homes and student apartments. This project meets that goal. The system costs less than I expected, and the code is open source. Users can monitor their indoor air in real-time and get alerts if gas, humidity, temperature levels, or smoke exceed set limits.

All important tasks were completed, and the work matched the project's initial scope. We noticed some problems and will fix them next time.

I gained experience with GSM technology and learned about harmful indoor chemicals. Technically, I understood how to use Arduino IDE/code to read sensors and send SMS via GSM.

5.2 Recommendations

This project provided an excellent opportunity to apply the knowledge and skills we learned in class. It not only benefited me but also helped all students understand the essential needs of society and the marketplace. I encourage any student planning a project to carefully consider societal needs to find solutions that help make society's dreams a reality.

During the design and implementation of my project, I discovered that some components are quite expensive. Therefore, I strongly recommend that ULK and the government increase support for final year projects. Additionally, I suggest that REMA (Rwanda Environment Management Authority) utilize this project, as it aids in understanding and monitoring indoor air quality.

5.3 Suggestions for further study

To further improve my indoor air quality monitor project, consider enhancing sensor accuracy by using more advanced sensors for reliable data, and expanding monitoring capabilities to include pollutants like VOCs and particulate matter for a comprehensive view. Improve the user interface by developing a user-friendly mobile app or web interface for real-time data and historical trends, and implement machine learning algorithms to predict air quality trends and provide proactive alerts. Optimize the system for energy efficiency to make it suitable for long-term use. Provide educational resources about indoor air quality and its health impacts to raise awareness, and integrate the monitor with smart home systems for automated responses like turning on air purifiers or adjusting ventilation based on readings

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APPENDIX

1. Project source code

```
#include <SoftwareSerial.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>
#include <Servo.h>

const int dhtPin = 6;
const int mq2Pin = A0;
const int servoPin = 3;
const int fanPin = 4;
const int buzzerPin = 10;
Servo myservo;
const float tempThreshold = 30;
const int gasThreshold = 500;
DHT dht(dhtPin, DHT11);
LiquidCrystal_I2C lcd(0x27, 16, 2);
int displayState= 0;
SoftwareSerial gsm(7, 8);
void setup() {
  Serial.begin(115200);
  gsm.begin(9600);
 myservo.attach(3);
myservo.write(0);
pinMode(servoPin, OUTPUT);
  pinMode(fanPin, OUTPUT);
  pinMode(buzzerPin, OUTPUT);
  dht.begin();
  lcd.init();
  lcd.backlight();
```

```
  lcd.print("T:");
}
void loop() {
  float temperature = dht.readTemperature();
    float humidity = dht.readHumidity();
    int smokeValue = analogRead(A1);
    int gasValue = analogRead(mq2Pin);
   int humidityPercentage = int(humidity);
    int gasPPM = map(gasValue, 0, 1023, 0, 1000);
    String smokeStatus = (smokeValue > 500) ? "Yes" : "No";
    lcd.setCursor(0, 0);
    lcd.print("T:" + String(temperature) + "C H:" + String(humidityPercentage) + "%");
    lcd.setCursor(0, 1);
    lcd.print("G:" + String(gasPPM) + "ppm F:" + smokeStatus);
    if (temperature > tempThreshold) {
        sendSMS("+250796148297", "HIGH t");
        digitalWrite(fanPin, HIGH);
        myservo.write(180);
        delay(60000);
        myservo.write(0);
        digitalWrite(fanPin, LOW);
    }
      if (gasValue > gasThreshold) {
        sendSMS("+250796148297", "gas detected");
        lcd.setCursor(0, 1);
        lcd.print("GAS DETECTED  ");
        digitalWrite(buzzerPin, HIGH);
        delay(5000);
        digitalWrite(buzzerPin, LOW);
        digitalWrite(fanPin, HIGH);
        myservo.write(180);
        delay(60000);
```

```
        myservo.write(0);
        digitalWrite(fanPin, LOW);
    }
if (humidityPercentage > 80 || smokeStatus == "Yes") {
        digitalWrite(fanPin, HIGH);
        delay(60000);
        digitalWrite(fanPin, LOW);
    }
}
void sendSMS(String number, String message) {
  gsm.println("AT");
  delay(1000);
  gsm.println("AT+CMGF=1");
  delay(1000);
 gsm.print("AT+CMGS=\"");
  gsm.print(number);
  gsm.println("\"");
  delay(1000);
  gsm.print(message);
  delay(100);
  gsm.write(26);
  delay(1000);
   while (gsm.available()) {
    String response = gsm.readString();
    Serial.println(response);
  }
}
```