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SMART MEDICAL SUCTION UNIT DESIGN AND IMPLEMENTATION FOR CLINICAL APPLICATIONS

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Abstract:

In response to the growing demand for thermal comfort and the growing awareness of indoor air quality, this project focuses on creating a robust indoor air monitoring system. The system is built on the Arduino-Uno microcontroller platform, and integrates various sensors, including gas sensors, humidity and temperature sensors, to continuously monitor air quality. By ensuring a clean and safe environment for residents, the system is particularly beneficial for vulnerable groups such as the elderly and children. As technology rapidly evolves from old phones to smartphones, tablets and even artificial intelligence today, it profoundly impacts our surroundings. We find ourselves increasingly dependent on these technological advances, which shape our daily lives and interactions. However, these advances have also led to the deterioration of our living environment, with air pollution emerging as a major issue. Poor air quality has caused respiratory problems for many newborns, and many disaster films that deal with smog reflect the challenges the world must face. This project, titled "Design and Implementation of Indoor Air Quality Monitoring System", uses Arduino, LCD display, gas sensor, humidity and temperature sensor, servo motor, alarm and GSM module to automatically monitor and improve the air quality inside living spaces. The system is a carefully designed solution to address the social issue of poor air quality in any room. By implementing this innovative approach, we aim to provide clean and safe airflow, prevent diseases such as asthma and ensure the health and well- being of all hospital or medical laboratory occupants, especially the elderly and children.

Keywords: Indoor Air Quality (IAQ), Arduino-based Monitoring System, Gas Humidity and Temperature Sensors, Thermal Comfort and Health, Air Pollution Prevention

1. Introduction

With the rapid development of technology from old phones to smartphones, tablets and even artificial intelligence today, it has a profound impact on our surroundings. We find ourselves increasingly dependent on these technological developments, which shape our daily lives and interactions. However, technological developments have deteriorated our living environment, and various problems have gradually emerged, such as air pollution. Poor air quality has caused respiratory problems for many newborns and many disaster movies have been filmed with a foggy theme, which seems to reflect the problems that the world must face again. In this project, we designed a simple system called "Design and Implementation of Indoor Air Quality Monitoring System" using Arduino, LCD display, gas sensor, humidity and temperature sensor and alarm, which will automatically provide good air monitoring inside our living room.

Design and Implementation of Indoor Air Quality Monitoring System is a carefully designed solution to solve the social problem of poor air quality in any room. It is a new idea of implementation that makes the ordinary air quality monitoring system use these sensors to detect problems.

1.1. Background

By closely examining the cause of many air diseases, asthma or even suffocation problem, we can see that the main reason is poor air quality due to poor room ventilation or lack of air quality monitoring and this problem can lead to death. Which is not good and can be avoided. Considering what has been said above, we have implemented a system that can be useful in avoiding this type of disease and ensuring good health in every room wherever it is needed For example in a student apartment, in a living room, at home, offices and classrooms at the university [1].

1.2. Problem Project

Indoor air quality (IAQ) is a major concern in modern society where people spend a large amount of their time indoors, whether at home, at work or in educational institutions. Poor indoor air quality can lead to a range of health problems, including allergies, respiratory diseases and weakened immune systems. Despite its importance, indoor air quality monitoring is often ignored Due to lack of awareness, complexity of monitoring methods and the cost of professional monitoring systems.

The lack of an easy-to-use, affordable, and comprehensive indoor air quality monitoring system is a major problem, especially in densely populated urban areas and industrial sites 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

A. Overall Objective

The overall objective of this project is to develop a cost-effective, reliable, and easy-to-use indoor air quality monitoring system-using Arduino. This system aims to provide continuous monitoring of various air quality parameters, including temperature, humidity, and the presence of smoke and various gases.

By leveraging the open-source nature of Arduino, the project seeks to keep costs low, making the system accessible and affordable to a wide range of users. Additionally, the system will feature an intuitive interface that allows users to easily understand and interact with the collected data.

B. Specific Objectives

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

- Cost-effectiveness: Leveraging Arduino, an open-source platform, to keep costs low and make the system accessible to a wide range of users.
- User Interface: Developing an interface that allows users to easily understand and interact with the data collected by the system.
- Data Collection and Analysis: Collecting data over time for analysis to identify trends and patterns in indoor air quality.
- Alert System: Creating a system that can alert users when air quality levels exceed a certain threshold, ensuring timely intervention.
- Educational Resources: To serve as an educational resource for individuals and organizations to learn more about air quality and its impact on health and wellbeing.

1.4. Limitations of the study

- Affordable sensors may lack the precision of high-end models, affecting data accuracy.
- Regular maintenance is required to ensure system reliability, which can be resource-intensive.
- Sensor readings can be influenced by environmental factors such as humidity, leading to skewed results.
- Arduino's limited processing capabilities may restrict complex data analysis in addition, real-time responsiveness.
- Expanding the system to cover larger areas or multiple locations can be challenging.

1.5. Significance of the study

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

1) 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.
2) 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 end.
3) 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.
4) 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.
5) 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.
6) Sustainability: Improved indoor air quality contributes to the broader goal of sustainability.

By ensuring our indoor environments are healthy, we are also taking steps to reduce our impact on the outdoor environment, contributing to the overall health of our planet.

1.6. Organization of the study

Chapter 1: Introduction shows the overview of the entire 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.

2. Literature Review

2.1. Introduction

As the world continues to face growing concerns about environmental pollution, particularly in urban areas, the focus on indoor air quality (IAQ) has intensified. In many cities, people spend a significant portion of their lives indoors, whether in homes, offices, schools, or healthcare facilities.

Unfortunately, indoor air is often more polluted than outdoor air due to various factors such as poor ventilation, use of chemical-based cleaning agents, and insufficient air filtration systems.

The deterioration of air quality can lead to various health issues, especially respiratory problems, which disproportionately affect vulnerable groups like the elderly, children, and those with pre-existing medical conditions. Given the increasing concern regarding air quality, there has been a significant surge in research and development in the field of indoor air monitoring systems.

These systems, which incorporate sensors and microcontrollers such as Arduino platforms, aim to provide real-time monitoring and improvement of indoor air quality (IAQ). Such systems are essential for creating healthy indoor environments, particularly in spaces where individuals with respiratory challenges reside.

This chapter will review relevant studies on the development and application of smart air quality monitoring systems, particularly focusing on their ability to measure and regulate gases, temperature, and humidity in indoor environments [2].

2.2. Studies on smart suction unit

The concept of smart suction unit and air quality monitoring has gained momentum over the last decade as technological advancements have provided new opportunities to monitor and enhance indoor air quality.

A significant contribution to this field was made by Mohamed et al. (2019), who designed a smart air quality monitoring system using an Arduino platform. The system incorporated multiple sensors, including gas sensors, temperature sensors, and humidity sensors, to continuously monitor the air quality within an enclosed environment.

Data from these sensors were transmitted to an LCD display, where users could view real time readings and receive alerts when air quality fell below acceptable thresholds. The system developed by Mohamed et al. demonstrated the effectiveness of using sensor-based monitoring to ensure a healthy environment. In particular, the study highlighted the advantages of integrating Arduino-based systems with gas sensors to detect harmful gases like $CO2$ and $NO2$, which can significantly impact human health.

This innovation allowed users to monitor air quality continuously and make necessary adjustments to ventilation systems when required. This solution not only improves air quality but also minimizes the health risks associated with long-term exposure to indoor air pollution.

The key findings from this study emphasize the importance of integrating multiple sensors for a comprehensive air quality monitoring system that provides continuous, real-time feedback to the user. Additionally, the study pointed out the importance of developing user-friendly interfaces for displaying air quality data, enabling users to take prompt action if necessary [3].

2.3. Applications in Healthcare Environments

- Air quality in healthcare facilities is critically important due to the presence of patients with weakened immune systems or respiratory conditions.
- Poor indoor air quality can worsen health problems and delay recovery.
- A study by Ali et al. (2018) explored the integration of smart air quality monitoring systems in healthcare environments.
- The system used gas sensors along with temperature and humidity sensors to monitor air in hospital rooms.
- It provided real-time alerts via an alarm system when air quality levels exceeded safe thresholds.
- The system was capable of detecting harmful gases such as carbon dioxide (CO_2), carbon monoxide (CO), and other pollutants.
- These systems help healthcare providers proactively manage air quality, reducing infection risks and promoting better patient outcomes.
- Continuous monitoring and automated air quality management enhance operational efficiency in healthcare settings.
- The study concluded that smart air quality systems are effective in maintaining a safe and healthy environment for both patients and staff.

2.4. Integration of Smart Systems for Thermal Comfort

Thermal comfort is a crucial aspect of creating a healthy indoor environment.

Studies such as Hassan et al. (2017) have explored how smart air quality systems can also enhance thermal comfort within buildings by integrating sensors that monitor both air quality and temperature. In this study, the researchers used temperature sensors to automatically adjust the heating, ventilation, and air conditioning (HVAC) systems in response to fluctuations in the indoor environment.

The study highlighted that maintaining proper thermal conditions alongside clean air significantly affects occupant satisfaction and well-being. It also emphasized the role of smart systems in minimizing energy consumption by optimizing the operation of heating and cooling systems based on real-time sensor data. The integration of smart air quality systems with HVAC systems ensures a stable indoor environment, improving both air quality and temperature regulation, which is essential for enhancing overall comfort.

Additionally, the study pointed out the need for continuous monitoring of both indoor air quality and thermal comfort to ensure that both parameters are balanced optimally, reducing the risks of thermal discomfort and health issues associated with poor air quality [4].

2.5. Applications of Air Quality Monitoring Systems in Educational Institutions

In educational environments, ensuring good air quality is essential for students' health and performance. A study by Ibrahim et al. (2020) focused on integrating smart air quality monitoring systems in classrooms to monitor indoor air quality in real-time [5]. The system used Arduino-based sensors to detect harmful gases such as carbon dioxide ($CO2$), which can accumulate in classrooms with poor ventilation and negatively affect students' concentration.

The study showed that by continuously monitoring air quality and adjusting ventilation levels automatically, the system ensured a healthy learning environment. Additionally, the system displayed real-time data on an LCD screen to alert teachers and students about potential air quality issues. This approach allowed schools to ensure that classrooms remained conducive to learning by optimizing air quality and addressing any issues that arose.

This research demonstrated that smart air quality systems in educational institutions could not only prevent health-related issues but also enhance academic performance by maintaining an optimal learning environment. The study concluded that integrating such systems in schools would contribute to improving air quality and promoting better student outcomes [6].

3. Components & Methodology

3.1 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 [7].

3.2 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 [8].

3.3 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 [9].

3.4 Related

Study several related studies have been conducted in the field of IAQ monitoring systems. For instance, Jaret Saini, Maitreyee Dutta & Gonçalo Marques, conducted a comprehensive review on indoor air quality monitoring systems for enhanced public health. 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 [10].

3.5 Components used

We used the following components to build this device:

1) Arduino Uno

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 is 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 [11].

Figure 1. Arduino Uno

2) LCD Screen

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 is a theory on how an LCD with I2C works:

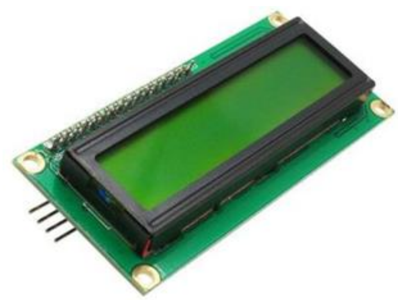

Figure 2. LCD Display 16*2

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 9 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 [12].

3) Humidity and temperature 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.

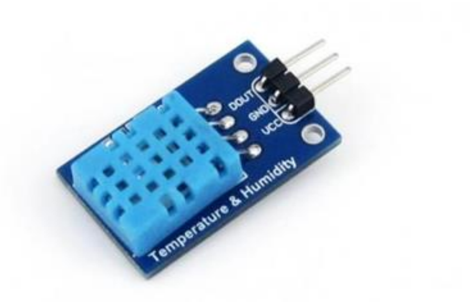

Figure 3. DHT11 sensor

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 10 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.

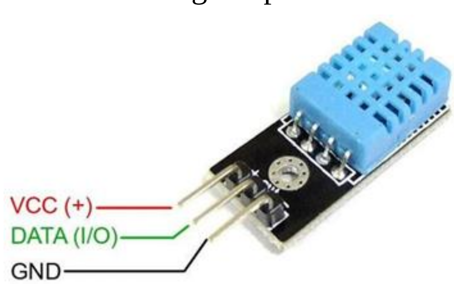

Figure 4. DHT11 Sensor Part

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

- 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.

- 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.
- 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.

4) Gas 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.

Figure 5. MQ-2 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. 11 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.

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.

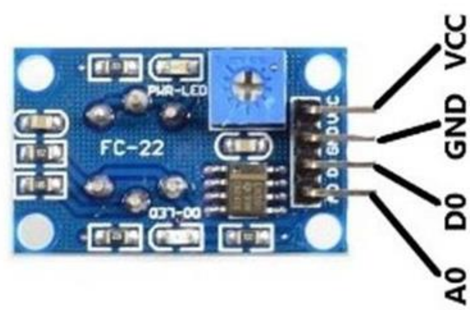

Figure 6. MQ-2 Sensor Part

5) 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 is a breakdown of each type, their working principles, applications, and characteristics:

Figure 7. Electronic Buzzer

6) 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.

Figure 8. DC Fan

3.6 Linkage circuit

The proposed system was built using an integrative approach that combines theory and practice. The project began by identifying the problem of deteriorating indoor air quality and analyzing its causes. The Arduino Uno microcontroller was then chosen as the central platform for interfacing components due to its simplicity and low cost.

The system included an MQ-4 sensor for detecting flammable gases, a DHT11 sensor for measuring temperature and humidity, an LCD display for data display, a relay-activated vacuum pump activation module, and a buzzer for alerting when safe limits were exceeded. All of these components were interconnected in a coordinated manner through precise programming using the Arduino IDE to ensure automatic responses to air quality abnormalities, creating an effective, low-cost system for monitoring and improving indoor air quality in healthy environments.

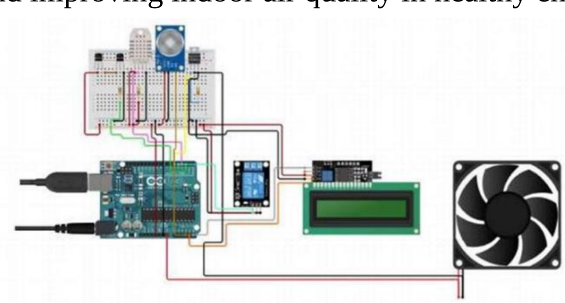

Figure 9. Circuit diagram

4. Results

This chapter outlines the steps taken to implement the air purification device, detailing the integration of each component and the overall operation of the system. The project focuses on developing a device that monitors air quality, detects gas concentration, and regulates air purification. The components include the MQ-4 sensor, DHT11 sensor, Arduino Uno, 16x2 LCD display, a vacuum pump, a relay, and a buzzer, all housed in an MDF structure with a compact plastic box.

4.1 Steps to Implement the System

A. The first stage: involves programming the Arduino Uno microcontroller using the Arduino IDE. The code initializes the MQ-4 gas sensor and the DHT11 temperature and humidity sensor, ensuring accurate data collection. The program processes sensor readings and displays the results on the 16x2 LCD display. The code also controls the activation of the vacuum pump and buzzer based on gas concentration levels.

B. The Second Stage: At this stage, all hardware components are connected to form a fully functional system. The connections are as follows:

   1) Power Supply: A 9V rechargeable battery powers the system through the Arduino Uno. The positive and negative terminals of the battery are connected to the power input (VIN) and ground (GND) pins of the Arduino.

   2) MQ-4 Gas Sensor: The MQ-4 gas sensor is connected to the Arduino Uno. Its analog output pin (AO) is connected to one of the analog input pins (e.g., A0) on the Arduino. The VCC and GND pins of the sensor are connected to the 5V and GND pins of the Arduino, respectively. This sensor detects methane and other combustible gases in the air.

   3) The DHT11 sensor's signal pin is connected to a digital pin on the Arduino (e.g., pin 7). Its VCC and GND pins are connected to the 5V and GND pins of the Arduino, respectively. The sensor measures the temperature and humidity levels of the surrounding environment.

   4) 16x2 LCD Display: The LCD display is connected to the Arduino using I2C communication or parallel wiring. The display shows real-time readings of the gas concentration, temperature, and humidity. Its VCC and GND pins are connected to the 5V and GND pins of the Arduino.

   5) Relay and Vacuum Pump: A relay module is used to control the vacuum pump. The signal pin of the relay is connected to a digital pin on the Arduino (e.g., pin 8). The pump activates when the gas concentration exceeds a predefined threshold. The relay ensures safe and efficient control of the vacuum pump.

   6) Buzzer: The buzzer is connected to a digital pin on the Arduino (e.g., pin 9). When the gas concentration exceeds the safe limit, the buzzer activates to alert the user.

   7) Enclosure: All components are housed in an MDF structure for durability, with the MQ-4 sensor and vents placed strategically to ensure accurate air sampling. A small white plastic box is used to enclose the relay and other sensitive connections for safety.

4.2 Implementation Summary

The system operates by continuously monitoring the environment using the MQ-4 gas sensor and the DHT11 sensor. The Arduino Uno processes the sensor data and displays the gas concentration, temperature, and humidity on the 16x2 LCD screen.

If the gas concentration exceeds the predefined safe level, the vacuum pump is activated via the relay to purify the air, and the buzzer sounds an alert to notify users.

The device is powered by a 9V rechargeable battery to ensure portability and ease of use. The design focuses on modularity, allowing for easy assembly, maintenance, and future upgrades. This makes the system an efficient and reliable solution for improving indoor air quality.

4.3 Results

After implementing the system, we achieved the following results:

1) The system successfully monitors air quality using the MQ-4 gas sensor to detect gas concentration levels and the DHT11 sensor to measure temperature and humidity.
2) The electrical circuit was fully developed, integrating the Arduino Uno, MQ- 4 sensor, DHT11 sensor, LCD 16x2 display, relay module, vacuum pump, and buzzer.
3) The system effectively displays real-time gas concentration, temperature, and humidity data on the 16x2 LCD screen.
4) The vacuum pump and buzzer respond automatically when gas concentration exceeds a predefined threshold, ensuring efficient air purification and user safety.

5. Conclusions

5.1. Recommendations and Future Work

To enhance the system’s functionality and performance, we propose the following future improvements:

1. Incorporating additional sensors such as PM2.5/PM10 dust sensors to monitor particulate matter in the air, providing a more comprehensive air quality assessment.
2. Adding IoT capabilities to connect the system to the internet for real-time monitoring and remote notifications via a mobile application.
3. Implementing data logging to store gas concentration and environmental readings over time for analysis and trend visualization.
4. Improving power efficiency by integrating a solar-powered or rechargeable battery system to ensure continuous, eco-friendly operation.

5.2. Difficulties

During the implementation of the system, the following challenges were encountered:

1. Sensor Calibration: Difficulty in calibrating the MQ-4 gas sensor to ensure accurate gas concentration readings in varying environments.
2. Component Integration: Challenges in synchronizing the relay, vacuum pump, and buzzer to operate efficiently without delay.
3. Hardware Limitations: Limited resources and technical constraints when testing the system’s real-time performance and durability.
4. System Housing: Ensuring proper placement and protection of components within the MDF structure to maintain functionality and air circulation.

5.3. Conclusion

The air purification system was successfully designed and implemented. The integration of the MQ-4 gas sensor, DHT11 sensor, Arduino Uno, and control components like the relay, vacuum pump, and buzzer demonstrated effective results in monitoring and improving air quality. The system automatically detects gas concentration levels, alerts users through sound, and activates the purification mechanism, achieving the project’s primary objectives.

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