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Automated Control of DIY Air Purifier with AC Fan

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ABSTRACT This project aims to develop an innovative automated control system for a DIY AC air purifier fan, designed to enhance indoor air quality. By effectively detecting and activating the AC fab with a Filtrete filter based on sensor data, the system efficiently eliminates pollutants like smoke, dust, and allergens from the air. The project addresses the challenge of inconsistent and inefficient performance of homemade air purifiers, which can have adverse on individuals' health and well-being in indoor environments. This project involves the seamless integration of hardware and software components, utilizing Arduino, particulate matter, and air quality sensors, in conjunction with an AC box fan, relay, and LCD display for control and monitoring purposes. Through continuous comparison of sensor data with predefined threshold values, the system intelligently determines the optimal activation of the filter, ensuring the maintenance of high air quality. The results highlight the accuracy and effectiveness of the filtration mechanism, showcasing the system's capability to monitor and control air quality in an efficient manner. In conclusion, this automated control system offers a user-friendly and cost-effective solution, promoting healthier and more comfortable living or working spaces.

KEYWORDS Automated Control, AC Fan, Air purifiers, PMS5003, MQ135, particulate matter.

I. INTRODUCTION

Indoor air quality is a significant factor in maintaining a healthy living and working environment. This project aims to develop an automated control system for an AC air purifier DIY fan that senses specific air pollutants and activates the fan when necessary, using a Filtrete-based filter to effectively remove pollutants like smoke, dust, PM2.5 or greater particulate matter. The absence of automated control in the AC air purifier DIY fan may lead to inconsistent performance and difficulty in maintaining optimal air quality. This could result in health issues for occupants due to exposure to pollutants and allergens. The automated control for an AC air purifier DIY fan holds significant importance as it ensures consistent and efficient air purification. This improvement in indoor air quality can positively impact the health and comfort of individuals, providing a convenient and effective solution to mitigate the adverse effects of air pollution [1-3]. The project uses the Arduino Mega 2560 microcontroller for automated control in AC air purifiers and DIY fans. Its powerful processing, ample memory, and versatile features allow efficient fan speed regulation, air quality monitoring, and implementation of advanced control algorithms, enhancing user-friendliness and efficiency [4]. The project involved implementing an automated air purification system, each with distinct sensors setups. The system utilized an Arduino microcontroller, PMS5003 Particulate matter sensor, and an MQ135 air quality sensor. Both sensors continuously monitored air quality and adjusted purification levels based on specific readings, with the first sensor focused on PM2.5 concentrations and the second sensor on Smoke readings, particularly volatile organic compounds (VOCs) generated from burning incense sticks and talcum powder. Sample 1, sample 2, and sample 3 tests were conducted for each system, measuring the respective pollutants. The results demonstrated that both systems effectively maintained high accuracy and fast response times in controlling purification levels in response to varying air pollutants, including those released by burning incense sticks and talcum powder, enhancing the overall air quality [5-6].

This project implementation focuses on enhancing indoor air purification using a portable air purifier equipped with an AC box fan and a Filtrete filter to efficiently filter dust and other airborne pollutants. It significantly optimizes the circulation of air in the room, thereby enhancing the overall efficiency of the air purification system [7-8]. Implemented with a microcontroller and a solid-state relay (SSR), the low-power air purifier control system efficiently switches the AC air purifier on and off while demonstrating effective control and low power consumption [9]. To further enhance indoor air purification and improve air quality, the system incorporates an AC box fan, making it more efficient in its operation.

II. INTEGRATION OF SENSORS WITH THRESHOLD-BASED ACTIVATION

The comprehensive process of constructing an Automated Control of AC Air Purifier DIY Fan, encompassing components, flowcharts, diagrams, and methodologies employed throughout the project. The system incorporates an Arduino board, sensors including PMS5003 and MQ135, a Filtrete filter, an AC box fan, as well as a relay and LCD display for control and monitoring purposes. The primary objective is to detect and eliminate various pollutants, such as smoke, dust, and particulate matter of PM2.5 or larger size, from the ambient air. Additionally, the system endeavors to offer a versatile and customized solution for enhancing air quality within indoor environments, focusing on the efficient utilization of PMS5003 and MQ135 sensors for pollutant detection and control optimization [10]. This system represents a sophisticated solution to tackle indoor air pollution. Through the advanced sensors incorporation, intelligent control algorithms, and efficient purification methods, the system provides a reliable and user-friendly means to maintain a clean and healthy indoor environment [11]. It offers the potential to improve the overall well-being and comfort of occupants while minimizing energy consumption and contributing to a sustainable living environment.

A. INTEGRATION OF AC BOX FAN DESIGN METHODOLOGY

The integration of the AC box fan and Filtrete filter in the Automated Control of AC Air Purifier DIY Fan system enhances air purification. Figure 1 showcases a flowchart outlining the methodology for monitoring and controlling air quality. The process initiates with assembling the AC box fan and relay, followed by initializing the Arduino Mega board to process data from air quality sensors, including PMS5003 and MQ135. The flowchart guides the system to analyze sensor readings against threshold values, activating or deactivating the AC fan accordingly to optimize air purification. The system further displays threshold values on an LCD screen for real-time monitoring and control. This approach offers a comprehensive solution to ensure a healthy indoor environment.

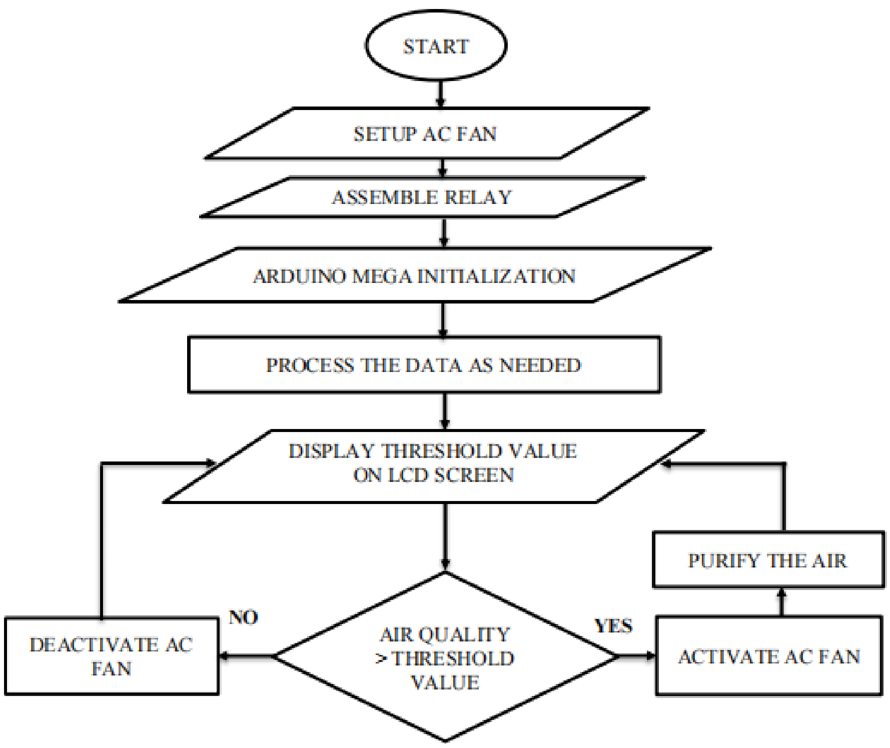

Figure 1: System Design Flowchart of AC DIY Fan

B. INTEGRATION OF MQ135 AIR QUALITY SENSOR DESIGN METHODOLOGY

Figure 2 visually depicts the methodology for monitoring and controlling air quality using an MQ135 sensor, a Filtrete filter, an AC box fan, and a relay. The flowchart outlines the sequential steps, and decision points involved in the process. It begins with initializing the MQ135 sensor, followed by processing the sensor data. Based on specified threshold values, the system determines whether to activate or deactivate the AC fan by triggering the relay. The system continuously monitors and adjusts the air quality, ensuring a healthy environment. Additionally, sensor readings are displayed on an LCD screen, providing comprehensive information to users. To facilitate effective smoke detection, incense sticks were used as a source during testing and data collection. This methodology offers a reliable and efficient approach to air quality management.

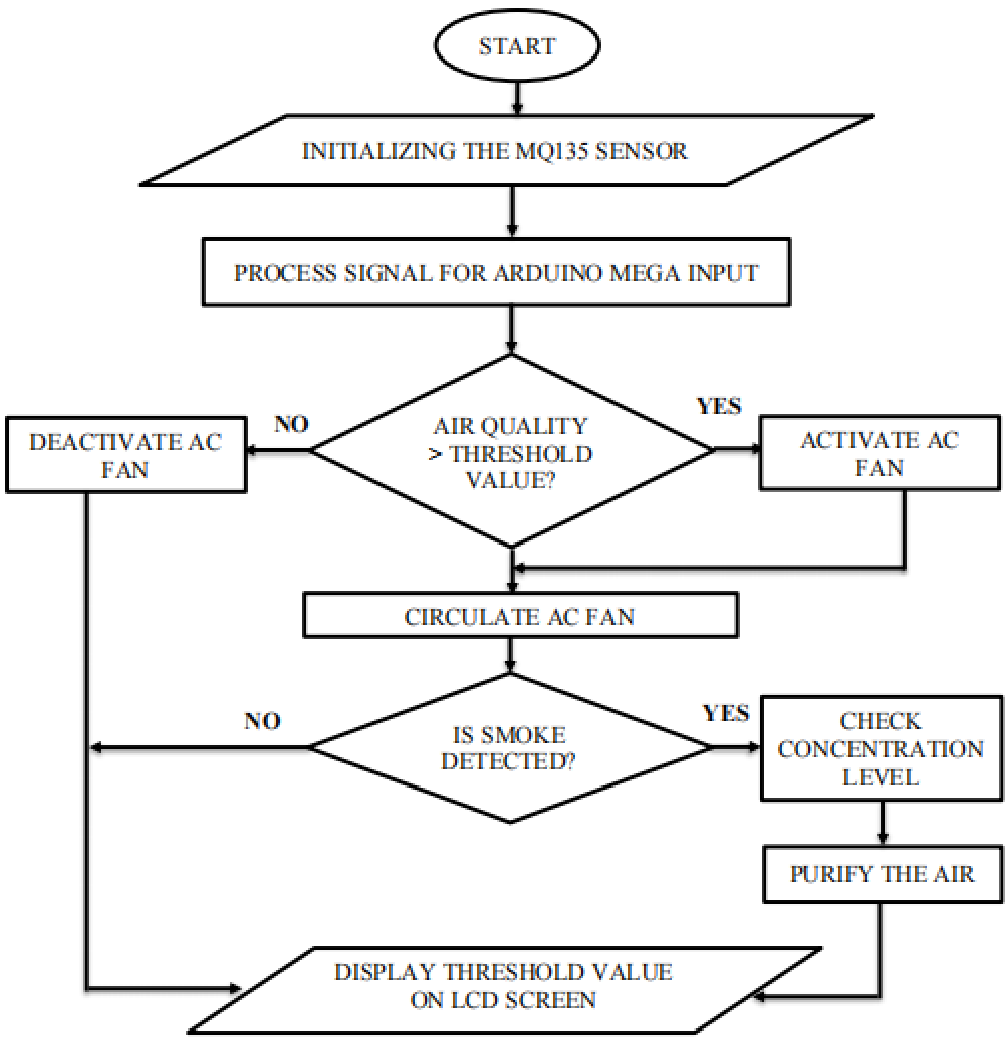

Figure 2: System Design Flowchart of MQ135 sensor

C. INTEGRATION OF PMS5003 PARTICULATE MATTER SENSOR DESIGN METHODOLOGY

The system design illustrates a comprehensive approach to monitoring and controlling air quality using an Arduino Mega board, an AC box fan, a Filtrete filter, a relay, and an LCD display. The process begins with initializing the Arduino and connecting it to the PMS5003 particulate matter sensor for accurate PM2.5 concentration measurements. The Arduino compares the readings with a predefined threshold, activating the AC box fan for air circulation when needed. The system also detects other pollutants like dust and adjusts the filter accordingly. The LCD screen provides real-time monitoring of air quality. Talcum powder was used for testing PM2.5 detection. This integrated design in Figure 3 ensures efficient PM2.5 concentration detection and offers a comprehensive solution for maintaining optimal indoor air quality.

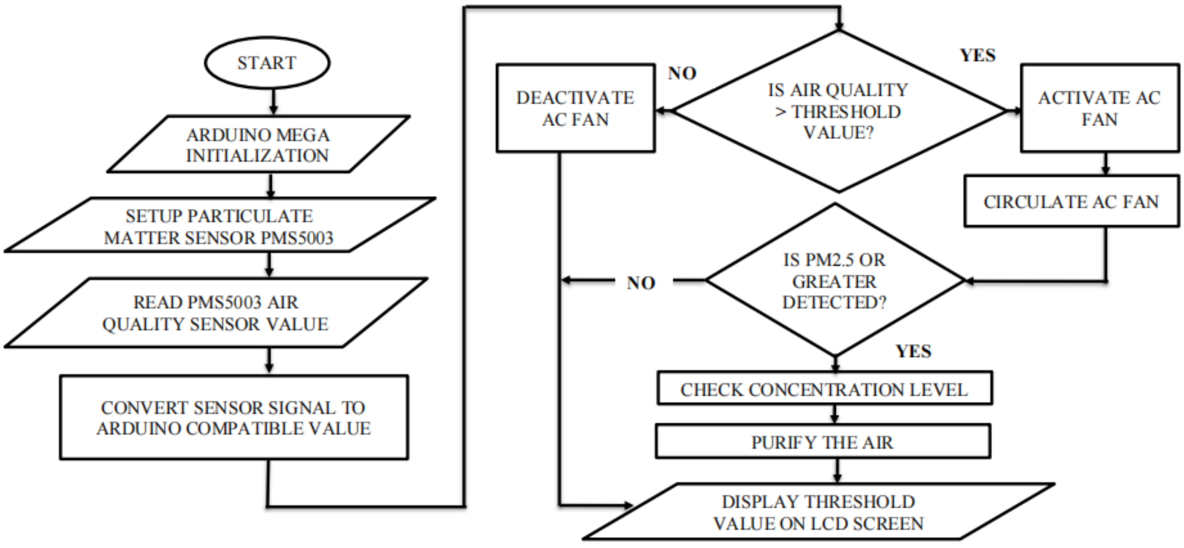

Figure 3: System Design Flowchart of PMS5003 sensor

D. INTEGRATION OF OVERALL SYSTEM DESIGN METHODOLOGY

The flowchart presented in Diagram 3.4 offers a comprehensive overview of the implementation of an Automated Control System for a DIY Fan in an AC air purifier. The system incorporates various components, including the Arduino board, PMS5003 particulate matter sensor, MQ135 air quality sensor, Filtrete filter, AC box fan, Opto-Isolator relay, and LCD display. The primary objective of the system is to detect and address air pollution levels by activating the filtration system. The selection and assembly of hardware components are followed by the programming of the Arduino board using the Arduino IDE and C++ programming language. The Arduino board is configured with a predefined threshold value to detect air pollution, and the PMS5003 sensor is programmed to measure different forms of pollution such as smoke, dust, PM2.5 particles, and larger particles, while the MQ135 sensor monitors air quality. Once the threshold is exceeded, the AC fan is activated to address elevated pollution levels, and the Filtrete filter efficiently captures and retains particles, ensuring the effective elimination of PM2.5 and larger particles from the ambient air. Sensor data is displayed on the LCD monitor, and the regulation of the air purifier fan is achieved through the relay, which is controlled by the Arduino IDE programmed in C++. This implementation allows the fan to activate when pollution levels surpass the predefined threshold and deactivate when the levels subside. The efficacy of the Filtrete filter is assessed by analyzing air quality, with the Arduino board serving as the central controller, managing all system components and handling the input and output of sensor readings. Based on the collected air quality data over time, the system can be further refined and enhanced.

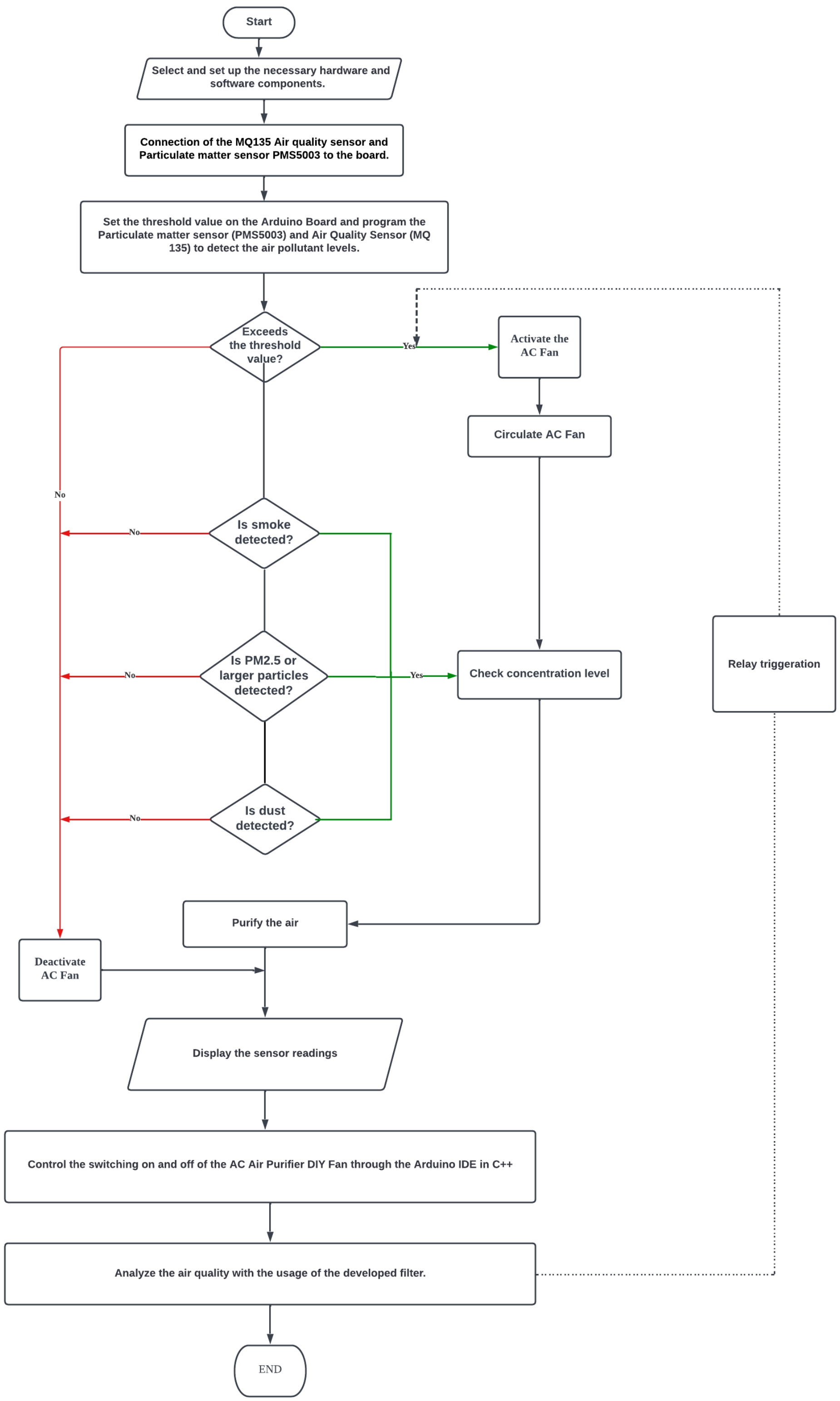

Figure 4: Entire Process System Flowchart

III. CONNECTION OF SENSORS ON THE BOARD

The project presents a comprehensive air purification system utilizing sensors, filters, fans, and an Arduino board to monitor and eliminate pollutants like incense stick smoke, talcum powder dust, and PM2.5 particles. It incorporates the PMS5003 and MQ135 sensors to gather pollutant data, which is processed by the Arduino board to activate the AC Box Fan through the relay when necessary. The Filtrete filter efficiently removes pollutants while the AC Box Fan circulates purified air. Real-time monitoring is facilitated by the LCD display, and programming and system monitoring are achieved using the Arduino IDE and C++. Integration of various components with the Arduino Mega 2560 board enables efficient AC fan control and sensor data display.

A. SYSTEM BLOCK DIAGRAM

The innovative system depicted in Figure 5 utilizes an integrated array of sensors, filters, fans, and an Arduino board to diligently monitor and enhance indoor air quality by accurately detecting and eliminating a diverse range of pollutants, encompassing incense stick smoke, talcum powder dust, and particles of PM2.5 or larger size. Employing the advanced capabilities of the particulate matter sensor PMS5003 and the MQ135 air quality sensor, the system intelligently gathers crucial data concerning pollutant levels present in the air. The Arduino board acts as the intelligent brain of the setup, meticulously processing the collected data and making precise comparisons with predetermined threshold values, effectively transmitting signals to the relay to initiate timely activation of the AC Box Fan when deemed necessary for efficient purification. The Filtrete filter assumes a crucial role in this purification process, diligently removing pollutants, while the AC Box Fan masterfully circulates the purified air throughout the entire room, resulting in a thoroughly purified environment. Additionally, to provide real-time insights into air quality, the LCD display acts as a user-friendly interface, enabling instant monitoring of the system's effectiveness. Notably, the Arduino IDE and C++ programming language form the cornerstone of the system, facilitating seamless programming and code uploading, along with continuous monitoring of the system's operational status, thereby ensuring consistent air quality improvements.

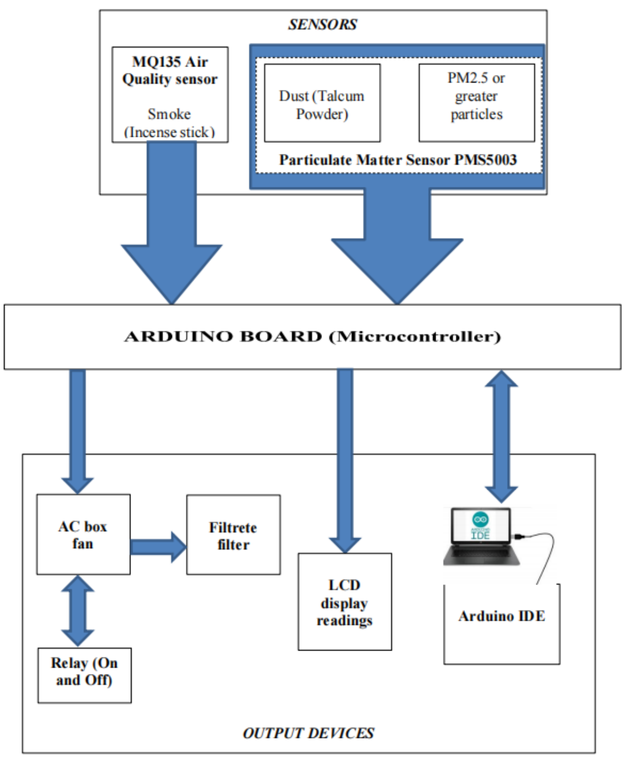

Figure 5: Block Diagram of air purifying system

B. SYSTEM CIRCUITRY DIAGRAM

The showcased project employs an Arduino Mega 2560 board integrated with various input and output components, including an optocoupler relay, an LCD display, a Bluetooth HC-05 transmitter, a PMS5003 particulate matter sensor, and an MQ135 air quality sensor, as depicted in Figure 6. The system enables control of an AC fan and the display of sensor data. The optocoupler relay regulates the AC fan's operation, and the Bluetooth HC-05 transmitter facilitates communication with connected devices. The LCD display is used for data transfer and synchronization. The PMS5003 sensor is connected to the Arduino's RXD0 and TXD1 pins, while the MQ135 air quality sensor is linked to the A0 pin as an analog input. All components receive power from the Arduino's 5V pin, with ground connections made through the ground busbar on the breadboard. The circuit incorporates resistors and capacitors for circuit protection and performance optimization.

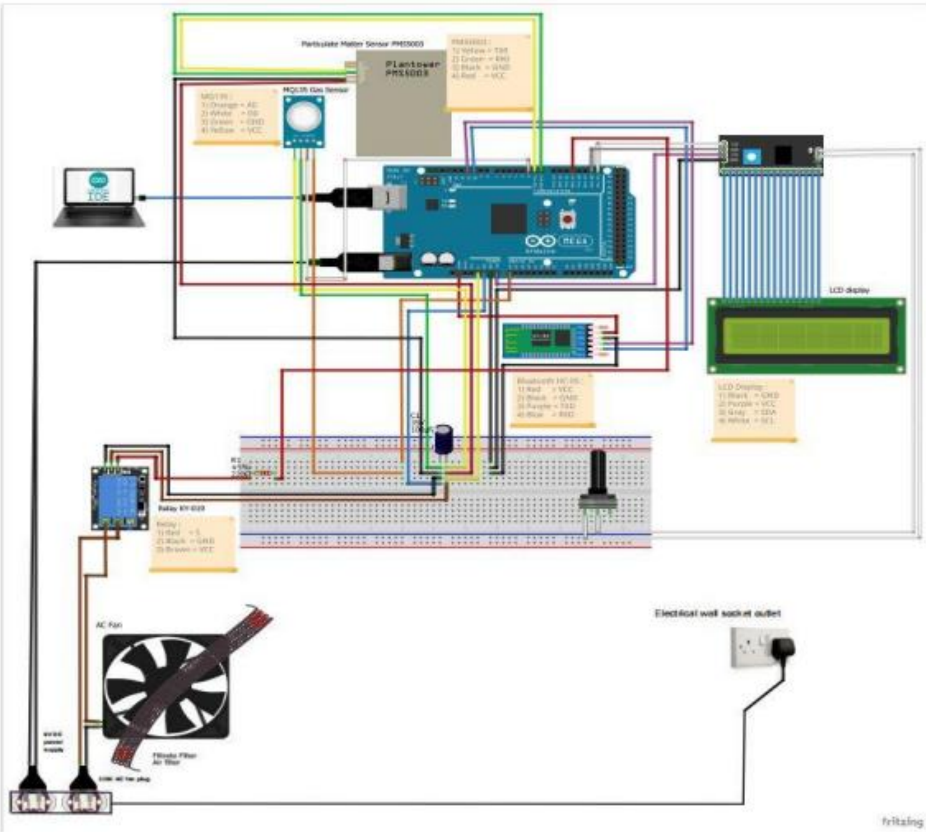

Figure 6: Overall circuitry connection diagram

C. SYSTEM SCHEMATIC CIRCUIT

The schematic circuit diagram in Figure 7 portrays the interconnections between an Arduino Mega 2560 board and various input and output components, aiming to govern the AC fan's operation and display sensor data. Components include an optocoupler relay, an LCD display, a Bluetooth HC-05 transmitter, a PMS5003 particulate matter sensor, and an MQ135 air quality sensor. The relay regulates the AC fan by linking its COM and NO terminals, connected to the L and one fan connection, respectively. The Bluetooth HC-05 transmitter connects to pins 10 and 11 for data communication with Bluetooth devices. The LCD display establishes communication through analog pins SDA20 and SCL21. The PMS5003 sensor connects to RXD0 and TXD1 pins, and the MQ135 sensor links to the A0 pin as an analog input. All components are powered by the Arduino's 5V pin, with negative terminals grounded. To ensure circuit safety and functionality, resistors and capacitors are employed for current limiting, voltage stabilization, and noise reduction. A 220-ohm resistor and a 100µF, 35V capacitor are part of the circuit design.

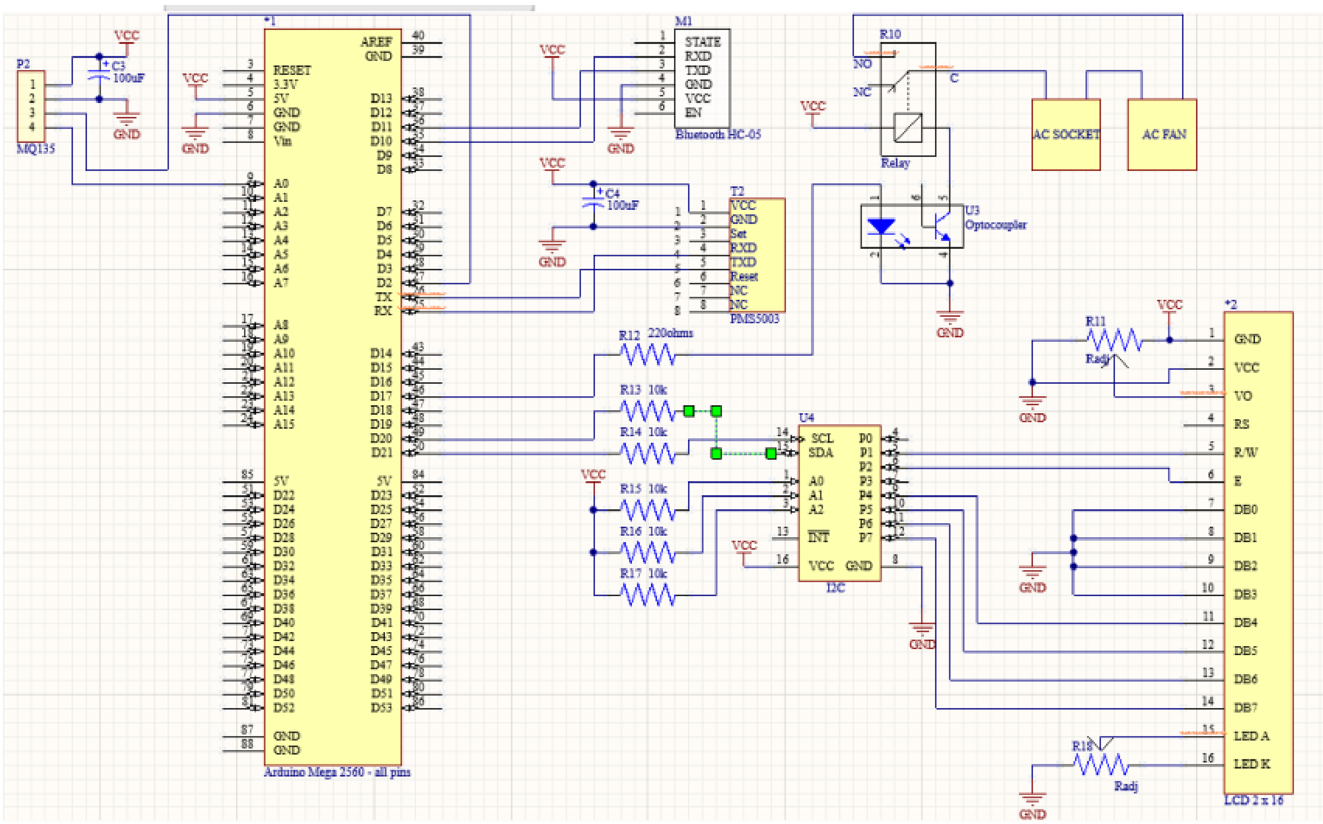

Figure 7: Schematic circuit interconnections

IV. CALCULATIONS OF CONCENTRATIONS

In the context of the code implementation, this analysis section includes calculations for determining the PM2.5 concentration and smoke concentration. These calculations convert raw analog sensor readings into meaningful values that represent the concentration of pollutants in the air. The system aims to measure the concentration of PM2.5 Calculations of concentrations are performed within the Arduino code to determine the PM2.5 concentration and smoke concentration, as it is a vital aspect of the air quality monitoring system implemented in the Arduino IDE using C++ code.

A. PM2.5 CONCENTRATION CALCULATION

The PMS5003 particulate matter sensor provides an analog voltage output that corresponds to the concentration of these particles in the air. The analog value (pm25Value) read from the PM2.5 sensor is of integer type; however, it is converted to a float data type (floating-point number) before performing the calculation to ensure more accurate results with decimal precision in Figure 8.

```
// Initialize PM2.5 and Smoke values
int pm25Value = analogRead(pm25Pin);
float pm25 = (float)pm25Value * 0.1;

```

Figure 8: Datatype Conversion for PM2.5 Concentration

The conversion factor of 0.1 is used to convert the analog value to the PM2.5 concentration in micrograms per cubic meter (µg/m³). This factor is determined based on the sensor's calibration and the relationship between the analog voltage and the actual PM2.5 concentration. The specific value of 0.1 might be derived from the sensor manufacturer's calibration data or experimentation with known PM2.5 concentrations. It represents the number of micrograms of PM2.5 particles per cubic meter of air for every unit increase in the analog value. The calculation for PM2.5 concentration involves converting the analog value read from the PM2.5 sensor into a concentration value expressed in micrograms per cubic meter (µg/m³). The code utilizes the formula in (1) to perform the conversion. As an illustration analysis, a scenario is considered where the analog value retrieved from the PM2.5 sensor registers at 350.

float pm25 = (float)pm25Value * 0.1 (1)

Theoretically, by employing the specified calculation method, the corresponding PM2.5 concentration can be determined from the Figure 9. Therefore, the calculated PM2.5 concentration based on the given analog value is 35.0 micrograms per cubic meter. This value represents the level of fine particulate matter in the air, indicating the air quality in terms of PM2.5 pollution. This calculation assumes a linear relationship between the analog value and the PM2.5 concentration, allowing for an estimation of the concentration level based on the sensor reading. By applying this calculation, the code enables users to assess the PM2.5 concentration in the air and monitor its variations over time, aiding in understanding and managing air quality conditions.

```
int pm25Value = analogRead(pm25Pin)
float pm25      = (float)pm25Value * 0.1

pm25            = (float)350 * 0.1
                = 35.00 µg/m³
```

Figure 9: Calculation Equation of PM2.5 Concentration

B. SMOKE CONCENTRATION CALCULATION

The smoke concentration calculation involves converting the analog value acquired from the MQ135 sensor (mq135Value) into a smoke concentration value in parts per million (ppm) in Figure 10.

```
int mq135Value = analogRead(mq135Pin);
float smoke = (float)mq135Value / 1024.0 * 5.0;
```

Figure 10: Datatype Conversion for Smoke Concentration

The value of 1024 used in the calculation for smoke concentration is not an arbitrary choice but rather a fundamental parameter determined by the Arduino's analog-to-digital converter (ADC) resolution. The ADC resolution defines the number of discrete steps the ADC can represent, and in the case of Arduino, it has a 10-bit resolution, allowing it to represent 2^10 = 1024 discrete steps. Upon reading an analog value from the MQ135 sensor using the analogRead() function, the code retrieves a value ranging from 0 to 1023 (inclusive), which signifies the voltage level measured by the Analog-to-Digital Converter (ADC). To establish a normalized range between 0 and 1, ensuring consistent and standardized data representation in (2). This essential normalization process guarantees the data remains within a uniform and comparable scale.

The analog value is scaled between 0 and 5 volts by dividing it by 1024, which is the maximum value of the analog-to-digital converter. Then, the normalized value is multiplied by 5 to obtain the smoke concentration in parts per million. This scaling brings the value to the actual voltage range of 0 to 5 volts, which corresponds to the sensor's sensitivity range for detecting smoke. The voltage level is then used to calculate the smoke concentration in parts per million, where 1 ppm means one part of smoke per one million parts of air.

$$\text{analog value} / 1024.0 * 5.0 \qquad (2)$$

Theoretically, if the analog value read from the MQ135 sensor is 120, the calculation for smoke concentration is determined as in the Figure 11. Therefore, in this case, the smoke concentration is determined to be 0.58 parts per million based on the provided analog value. The value of 1024 used in the calculation is a fixed constant that corresponds to the ADC resolution of the Arduino board and is necessary for proper conversion to smoke concentration. This concentration calculation is obtained by normalizing the analog value and then scaling it to represent a voltage level within the sensor's sensitivity range, which is then converted to parts per million of smoke concentration. These calculations enable precise monitoring of air quality and smoke levels, aiding in decision-making for air purification and fire safety applications.

```
int mq135Value = analogRead(mq135Pin)
float smoke      = (float)mq135Value / 1024.0 * 5.0

smoke           = (120 / 1024.0) * 5.0
                 = 0.58 ppm
```

Figure 11: Calculation Equation of Smoke Concentration

V. ANALYSIS AND RESULTS

This section aims to analyze the findings of the study and discuss their implications. The study sought to develop a system that automatically activates the air filtration system when predefined thresholds for air pollutants are exceeded. It also aimed to provide continuous updates on the pollutants level and filter status through the serial monitor. Additionally, the study evaluated the effectiveness of a filtrete-based air filter in reducing indoor air pollutants. The chapter aims to assess the performance of the automated control system, its contribution to air purification, and potential improvements in indoor air quality management. To fulfill these objectives, a system was designed to automatically trigger the air filtration system upon detecting threshold limits of air pollutants. This feature ensures a prompt response to deteriorating air quality, thereby improving the effectiveness of air purification. Simultaneously, the system continuously updates the pollutants level and filter status on the serial monitor, enabling real-time monitoring and analysis of indoor air quality. This capability facilitates the tracking of the air filtration system's performance and the identification of areas that require enhancement.

A. DATA COLLECTION

The data collection process commences with careful consideration and meticulous planning of the experimental setup. To capture representative air samples, the PMS5003 particulate matter sensor and MQ135 air quality sensor are strategically positioned within the indoor environment, taking into account factors such as airflow patterns and potential pollutant sources. Table 1 presents a comprehensive record of the collected samples, documenting the time-stamped readings of the PM2.5 and smoke sensor outputs over a specific duration. The PM2.5 concentration, which is measured in micrograms per cubic meter (µg/m³), and the smoke concentration, which is measured in parts per million (ppm), are fundamental metrics used for subsequent analysis and rigorous comparisons against the established threshold values.

During the analysis phase, the collected PM2.5 and smoke concentrations are assessed against the Air Quality Index (AQI) standard ranges implemented in Malaysia. Sample 1 exhibits a PM2.5 concentration of 7.50 µg/m³, which falls below the threshold of 8.80 µg/m³, and a smoke concentration of 0.55 ppm, below the threshold of 0.61 ppm. Consequently, Sample 1 is classified as having "Good" air quality. Sample 2 demonstrates a PM2.5 concentration of 11.80 µg/m³, surpassing the threshold of 8.80 µg/m³, and a smoke concentration of 0.75 ppm, exceeding the threshold of 0.61 ppm. As a result, sample 2 is categorized as having "Moderate" air quality. Sample 3 displays a PM2.5 concentration of 16.70 µg/m³, surpassing the threshold of 8.80 µg/m³, and a smoke concentration of 0.86 ppm, exceeding the threshold of 0.61 ppm. Therefore, sample 3 is classified as having "Poor" air quality. This thorough analysis facilitates further investigations into the efficacy of the air filtration system and its ability to maintain air quality within desirable ranges. By comparing the recorded PM2.5 and smoke concentrations against these threshold values and their corresponding indicators, a comprehensive understanding of the indoor air quality can be obtained.

Sample 1 **PM2.5 Reading: 7.50 µg/m³; Smoke Reading: 0.55 ppm**					
Time (seconds)	**PM2.5 Concentration (µg/m³)**	**AQI Indicator**	**Smoke Concentration (ppm)**	**AQI Indicator**	**AC Fan Status**
0	0.00	G	0.00	G	Off
1	7.50	G	0.55	G	Off
2	7.30	G	0.54	G	Off
3	7.50	G	0.53	G	Off
…	…	…	…	…	…
13	7.80	G	0.63	M	On
14	8.10	G	0.64	M	On
15	7.80	G	0.63	M	On

Sample 2 **PM2.5 Reading: 11.80 µg/m³; Smoke Reading: 0.75 ppm**					
Time (seconds)	**PM2.5 Concentration (µg/m³)**	**AQI Indicator**	**Smoke Concentration (ppm)**	**AQI Indicator**	**AC Fan Status**

0	0.00	G	0.00	G	Off
1	11.80	M	0.75	M	On
2	12.10	M	0.75	M	On
3	11.40	M	0.62	M	On
…	….	…	…	…	…
13	8.00	G	0.63	M	On
14	11.30	M	0.73	M	On
15	9.60	M	0.64	M	On
Sample 3 **PM2.5 Reading: 16.70 µg/m³; Smoke Reading: 0.86 ppm**					
Time (seconds)	**PM2.5 Concentration (µg/m³)**	**AQI Indicator**	**Smoke Concentration (ppm)**	**AQI Indicator**	**AC Fan Status**
0	0.00	G	0.00	G	Off
1	16.70	P	0.86	P	On
2	16.60	P	0.86	P	On
3	16.50	P	0.85	P	On
…	…	…	…	…	…
13	15.00	M	0.81	M	On
14	14.70	M	0.80	M	On
15	14.90	M	0.80	M	On

Table 1: Collection of recorded samples of the sensor's readings data

B. DATA ANALYSIS

Following the completion of the data collection phase, the acquired dataset, including the recorded samples as presented in Table 2, undergoes rigorous analysis employing specialized analytical techniques. In the case of the PMS5003 sensor, precise PM2.5 measurements are obtained through meticulous processing and conversion of the raw sensor readings. In order to assess the PM2.5 concentration values, the obtained measurements are compared against a predefined threshold of 8.80 µg/m³. Based on this threshold and the corresponding air quality index, the PM2.5 concentration levels can be categorized. Similarly, for smoke measurements, accurate readings are obtained by processing and converting the raw sensor data. A predefined threshold of 0.61 ppm is used to evaluate the smoke concentration levels. Table 2 summarizes the categorization of PM2.5 and smoke concentration levels based on the provided thresholds and indicators. By comparing the obtained PM2.5 measurements against the threshold of 8.80 µg/m³, the PM2.5 concentration values are categorized into Good, Moderate, or Poor based on the corresponding ranges. Similarly, for smoke measurements, the smoke concentration values are categorized into Good, Moderate, or Poor by comparing them against the threshold of 0.61 ppm. These categories allow for comprehensive analysis and interpretation of the collected data, providing meaningful information about air quality based on the processed sensor readings.

Category	PM2.5 Concentration (µg/m³) Range	PM2.5 Indicator	Smoke Concentrations (ppm) Range	Smoke Indicator
Good	0.00 – 8.79	G	0.00 – 0.60	G
Moderate	8.80 – 15.00	M	0.61 – 0.80	M
Poor	15.01 and above	P	0.81 and above	P

Table 2: Air Quality Categorization: PM2.5 and Smoke Concentration Level

C. PM2.5 CONCENTRATION DATA ANALYSIS

This section involves analyzing the data collected from the PMS5003 sensor to determine PM2.5 concentrations. The analysis includes assessing raw sensor readings and applying calibration techniques to convert them into PM2.5 concentration values. The results of this analytical analysis are extensively discussed, highlighting significant findings and observations. Table 3 provides a summary of the PM2.5 readings for each sample, along with their corresponding air quality categories. Specifically, Sample 1 shows a PM2.5 reading of 7.50 µg/m³, Sample 2 exhibits a PM2.5 reading of 11.80 µg/m³, while Sample 3 displays a higher PM2.5 reading of 16.70 µg/m³.

Figure 12: Sample 1 PM2.5 Concentrations Waveform Graph

Sample	**PM2.5 Reading (µg/m³)**	**Smoke Reading (ppm)**
1	7.50	0.55
2	11.80	0.75
3	16.70	0.86
PM2.5 threshold: 8.80 µg/m³		Smoke threshold: 0.61 ppm

Table 3: Sample PM2.5 and Smoke Readings

Figure 12 depicts the plot analysis of PM2.5 concentrations in Sample 1 offers valuable insights into the levels of PM2.5 and the corresponding indicators of air quality recorded at each time interval. The analysis of PM2.5 concentrations in Sample 1 provides valuable insights into the air quality indicators recorded at different time intervals. At the start of the sample, the PM2.5 reading is 7.50 µg/m³, falling within the "Good" air quality category with an AQI indicator denoted as "G." Throughout the monitoring period, the PM2.5 concentration remains relatively stable, displaying minor fluctuations within a narrow range, indicating a consistently low pollution level. The AQI indicator for PM2.5 consistently remains "G," indicating good air quality. Individual readings show a persistence of the initial air quality condition at time 1 and consistent PM2.5 concentrations of 7.50 µg/m³ at times 2 to 5. A slight decline to 7.30 µg/m³ occurs at time 6 but returns to 7.50 µg/m³ until time 10. At time 12, the PM2.5 concentration drops to 7.20 µg/m³, transitioning to the "Moderate" air quality category with the AQI indicator changing from "G" to "M." Subsequent readings at times 13, 14, and 15 consistently show PM2.5 concentrations below the threshold, confirming the transition to the "Moderate" category. The AC fan status for PM2.5 remains "M" during this period. Overall, Sample 1 exhibits mostly stable PM2.5 concentrations within the "Good" air quality category, indicating a clean and healthy atmosphere with minimal fine particulate matter presence. However, there is a brief period of transition into the "Moderate" air quality category, as indicated by the PM2.5 and smoke readings.

Figure 13: Sample 2 PM2.5 Concentrations Waveform Graph

The comprehensive plot analysis of Sample 2, as shown in Figure 13 provides valuable insights into the PM2.5 concentrations and their corresponding air quality indicators at each recorded time. Sample 2 initiates with a PM2.5 reading of 11.80 µg/m³, falling within the "Moderate" air quality category based on the provided thresholds, as denoted by the AQI indicator "M." Throughout the monitoring period, the PM2.5 concentration exhibits fluctuations within a range, indicating varying levels of fine particulate matter in the air. The AQI indicator for PM2.5 consistently remains within the "Moderate" range during this period. Individual readings at different times demonstrate minor fluctuations, with values ranging from 12.10 µg/m³ to 10.80 µg/m³. At time 6, the PM2.5 concentration declines to 10.60 µg/m³, followed by a further decrease to 10.00 µg/m³ at time 7, still within the "Moderate" air quality category. The PM2.5 concentration continues to fluctuate within the "Moderate" range at times 8 to 13, varying from 8.30 µg/m³ to 11.30 µg/m³. The AQI indicator for PM2.5 consistently remains within the "Moderate" category during this period. Towards the end of the sample, at time 14, the PM2.5 concentration reaches 11.30 µg/m³, representing a relatively higher value within the "Moderate" range. The AQI indicator for PM2.5 remains "M" during this period. Sample 2 maintains an "On" AC fan status, indicating active air circulation and potential air purification measures. However, the recorded PM2.5 concentrations consistently fall within the "Moderate" air quality category, despite these efforts. The in-depth analytical results of Sample 2 reveal varying levels of PM2.5 concentrations, consistently within the "Moderate" air quality category, suggesting fluctuations in fine particulate matter levels potentially influenced by environmental factors.

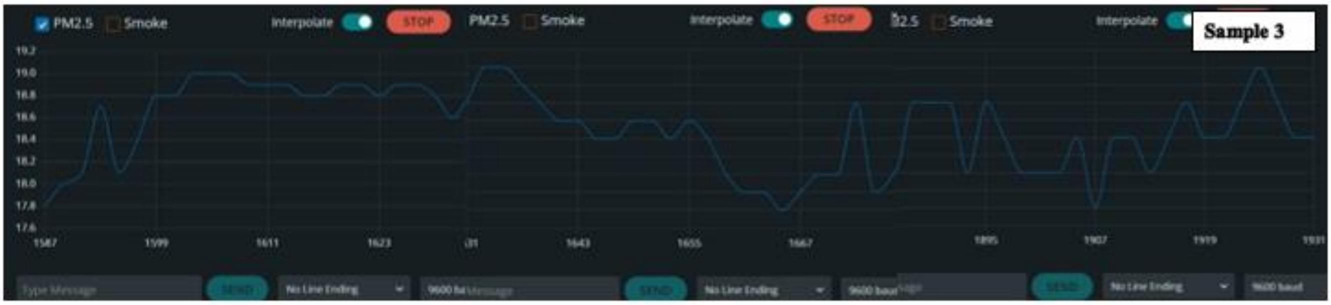

Figure 14: Sample 3 PM2.5 Concentrations Waveform Graph

A thorough examination of Sample 3 was conducted based on the plot analysis in Figure 14 to gain a comprehensive understanding of PM2.5 concentrations and their corresponding air quality indicators at each recorded time. The sample commences with a PM2.5 reading of 16.70 µg/m³, surpassing the threshold of 8.80 µg/m³ and categorizing it as "Poor" air quality. The AQI indicator for PM2.5 is labeled "P," signifying poor air quality conditions. Throughout the monitoring period, the PM2.5 concentration remains consistently high, exhibiting minimal fluctuations within a narrow range, suggesting a persistent presence of fine particulate matter and indicating poor air quality conditions. The AQI indicator for PM2.5 consistently remains in the "Poor" range during this duration. Analyzing individual readings, the PM2.5 concentration remains steady at 16.70 µg/m³ during time 1, representing a consistent level of high particulate matter in the air. Subsequent readings at times 2, 3, 4, and 5 show minor fluctuations, yet the PM2.5 concentration remains elevated, varying from 16.60 µg/m³ to 16.30 µg/m³. Continuing the analysis, the PM2.5 concentration gradually decreases from time 6 to time 10, ranging from 15.90 µg/m³ to 15.40 µg/m³. However, these values still indicate poor air quality conditions, as indicated by the persistent AQI indicator of "P" for PM2.5. As the monitoring progresses, the PM2.5 concentration hovers around the 15.00 µg/m³ range, consistent with the "Poor" air quality category, and the AQI indicator for PM2.5 remains "P." Towards the end of the sample, at time 13, a transition occurs as the PM2.5 concentration decreases to 15.00 µg/m³, falling within the range of 8.80 µg/m³ to 15.00 µg/m³ specified for the "Moderate" air quality category. This leads to a change in the AQI indicator for PM2.5 from "P" to "M," indicating a shift from poor to moderate air quality conditions. The subsequent readings at times 14 and 15 demonstrate further decreases in the PM2.5 concentration, reaching values of 14.70 µg/m³ and 14.90 µg/m³, respectively. The AQI indicator for PM2.5 consistently remains "M" during this period, indicating a moderate air quality condition. Throughout Sample 3's recorded time, the AC fan status remains "On," implying active air circulation and potential air purification measures. However, despite these efforts, the recorded PM2.5 concentrations consistently fall within the "Poor" air quality category, transitioning to the "Moderate" category towards the end of the sample. Sample 3 reveal consistently high PM2.5 concentrations, signifying poor air quality conditions. Towards the end of the sample, a transition occurs, leading to a shift from poor to moderate air quality conditions.

D. SMOKE CONCENTRATION DATA ANALYSIS

In this section, the collected data from the MQ135 air quality sensor is analyzed using specific analytical techniques to determine the concentrations of air pollutants. The analysis involves processing and interpreting the raw sensor readings based on established principles and algorithms tailored to the MQ135 sensor. Table 3 summarizes the smoke readings for each sample along with their corresponding air quality categories. Sample 1 demonstrates a smoke reading of 0.55 ppm, Sample 2 exhibits a smoke reading of 0.75 ppm, and Sample 3 displays a higher smoke reading of 0.86 ppm.

The comprehensive plot analysis of smoke concentrations in Sample 1, as presented in Figure 15 revealed valuable insights into the indoor air quality. Initially, the smoke concentration measured at 0.55 ppm, indicating favorable air quality. Throughout the monitoring period, the smoke concentration consistently remained below the threshold for moderate air quality, demonstrating effective management of smoke particles. The AC fan remained off during the monitoring, indicating successful smoke particle filtration. The recorded readings consistently fell within the moderate air quality range of 0.61ppm to 0.80 ppm, signifying an acceptable level of smoke particles indoors. Towards the end of the monitoring period, the smoke concentration increased to 0.61 ppm, activating the AC fan to enhance air circulation and filtration. Subsequent readings indicated a slight rise, peaking at 0.64 ppm, remaining within the moderate air quality category. The analysis highlights the effectiveness of the implemented measures in managing smoke levels and maintaining satisfactory indoor air quality. The consistent activation of the AC fan during heightened smoke concentration underscores a proactive approach to ensuring a healthier indoor environment. Despite minor fluctuations, the smoke concentrations remained within the moderate air quality range, emphasizing the crucial role of the AC fan in mitigating the impact of increased smoke levels and maintaining optimal air quality indoors.

Figure 15: Sample 1 Smoke Concentrations Waveform Graph

Figure 16 shows the plot analysis of smoke concentrations recorded for Sample 2 with a 1-second delay provide essential context for the analysis. The in-depth analysis reveals that the initial smoke reading was 0.75 ppm, indicating a moderate air quality level. Throughout the monitoring period, the smoke concentration consistently remains within the moderate air quality category, ranging from 0.61 ppm to 0.80 ppm. The continuous operation of the AC fan from the start reflects a proactive approach to enhance air circulation and filtration in response to the observed moderate smoke levels. Minor fluctuations in smoke concentration occur during monitoring, but the AC fan's consistent activation effectively maintains an acceptable indoor environment. Towards the end of the monitoring, there is a slight increase in smoke concentration, reaching 0.73 ppm, briefly exceeding the upper threshold for moderate air quality. However, the persistent activation of the AC fan helps mitigate the impact and prevent further escalation. The analysis emphasizes the efficacy of the AC fan in managing smoke levels and maintaining a moderate air quality level. Consistent air quality control measures and proactive interventions are crucial for ensuring a healthier and more comfortable indoor environment.

Figure 16: Sample 2 Smoke Concentrations Waveform Graph

Figure 17 depicts the plot analysis of smoke concentrations for Sample 3 with a 1-second delay, and corresponding data in the table provides insights into smoke levels, AQI indicators, and AC fan status. The analysis focused on using incense sticks and MQ135 sensors to detect smoke concentrations in an indoor environment. The MQ135 sensor effectively measured smoke concentrations, aligning with qualitative observations of smoke intensity. The quantitative measurements categorized smoke levels into different air quality levels. The smoke concentration in Sample 3 initially measured 0.00 ppm with an AQI of ‘G’ but progressively increased, peaking at 0.86 ppm with an AQI of ‘P’. The AC fan remained activated throughout but did not effectively reduce smoke concentrations, emphasizing the need for better air quality management. The integration of incense sticks and MQ135 sensors enables real-time monitoring for maintaining a smoke-free and healthy indoor environment. Overall, this approach proves effective for in-depth smoke concentration analysis, offering valuable insights for indoor air quality management.

Figure 17: Sample 3 Smoke Concentrations Waveform Graph

E. AC FAN ACTIVATION DATA ANALYSIS

Table 4 illustrates a range of scenarios for AC fan activation based on PM2.5 and smoke concentrations, thereby offering a comprehensive overview of the relationship between pollutant levels and the activation of the fan. The table succinctly summarizes distinct scenarios and their consequential implications for AC fan activation, delineating the concentrations of PM2.5 representing powder dust and smoke pollutants emanating from incense sticks. Each scenario represents combinations of PM2.5 and smoke concentrations that fall either below or above their respective threshold values.

Sample	PM2.5 concentration	Smoke concentration	AC fan activation	Implication
Sample 1	Below 8.80 µg/m³	Below 0.61 ppm	Off	Satisfactory air quality
Sample 2	Above 8.80 µg/m³	Below 0.61 ppm	On	Presence of powder dust, potential filtration need
	Below 8.80 µg/m³	Above 0.61 ppm	On	Presence of smoke pollutants, filtration need
Sample 3	Above 8.80 µg/m³	Above 0.61 ppm	On	Presence of both pollutants, filtration need

Table 4: AC Fan Activation Scenarios Based on PM2.5 and Smoke Concentrations

In Sample 1, where both PM2.5 and smoke concentrations are below their thresholds, the AC fan remains off, indicating satisfactory air quality, as depicts in Figure 17(a). Sample 2 occurs when the PM2.5 concentration exceeds its threshold while the smoke concentration remains below the threshold. In this case, the AC fan is turned on, suggesting the presence of powder dust and the potential need for improved air filtration. In other cases of Sample 2 concentration readings between time intervals represents situations where the PM2.5 concentration remains below the threshold, but the smoke concentration exceeds its limit, as shown in Figure 17(b). Here, the AC fan is activated to address the presence of smoke pollutants, highlighting the need for better filtration. Sample 3 occurs when both PM2.5 and smoke concentrations surpass their respective thresholds. In this case, the AC fan is turned on to tackle both pollutants, indicating the requirement for enhanced air filtration and improved air quality, as demonstrated in Figure 17(c).

Taking into account the aforementioned samples, the activation of the AC fan assumes a pivotal role as an indicator of air quality. The absence of fan activation indicates a state of relatively clean air characterized by low levels of pollutants. Conversely, when the fan is turned on, it signifies the presence of one or both pollutants exceeding their respective threshold values, necessitating the circulation of air and potentially demanding remedial measures tailored to the specific pollutant(s) detected.

Figure 17(a): Sample 1 on AC Fan Remains Off in Response to Satisfactory Air Quality and Both Concentrations 'G' for Good

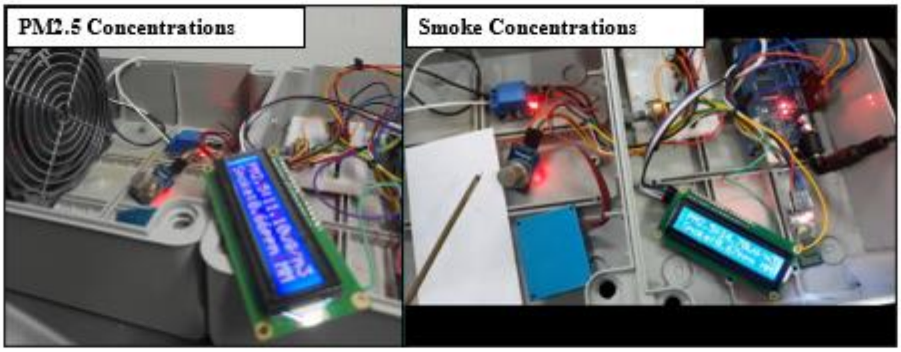

Figure 17(b): Sample 2 on activation of AC fan in response to elevated both concentrations and 'M' for moderate air quality

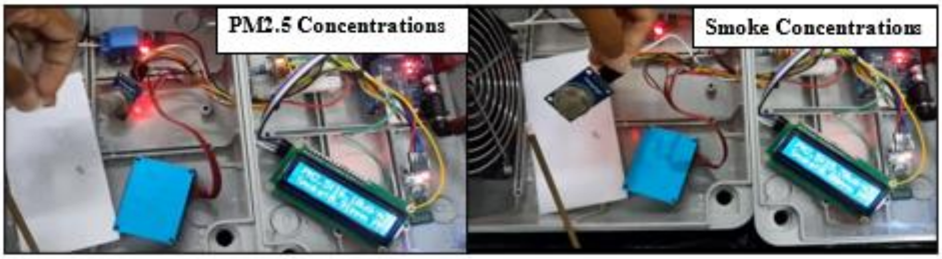

Figure 17(c): Sample 3 on activation of AC fan in response to elevated both concentrations and 'P' for poor air quality

F. BLUETOOTH TRANSMISSION DATA ANALYSIS

This analysis focuses on Bluetooth transmission, a crucial element that facilitates the exchange of air quality information between an Arduino board and a smartphone. Through the analysis of the Bluetooth HC-05 module with the Arduino Mega2560, it is essential to consider the distance limitations of the Bluetooth communication. During the analysis of the Bluetooth HC-05 module in conjunction with the Arduino Mega2560, it is imperative to consider the distance limitations associated with Bluetooth communication. Adhering to the recommended distance range of 10 meters helps minimize signal interference and ensures accurate transmission of air quality information. Understanding these factors helps to gain insights into how Bluetooth enables efficient communication and accurate data exchange for monitoring air quality. The transmission of air quality information, including the PM2.5 concentration, smoke concentration, and their corresponding air quality indicators, to a smartphone via Bluetooth allows users to monitor the air quality remotely and receive real-time updates on their mobile devices. The data is carefully organized to be easily readable and comprehensible to the receiving device, which is the smartphone in this context. This information includes two key parameters: the PM2.5 concentration and the smoke concentration, both of which are essential indicators of the air quality level.

As an illustrative example in Figure 18, let's assume the measured PM2.5 concentration is 3.80 µg/m³, and the corresponding air quality indicator is labeled as "Good." When transmitted, the smartphone would display the following message: "PM2.5:3.80 µg/m³, Air Quality: G." This detailed transmission mechanism ensures that the smartphone accurately interprets and presents the air quality data to the user in a clear and informative manner.

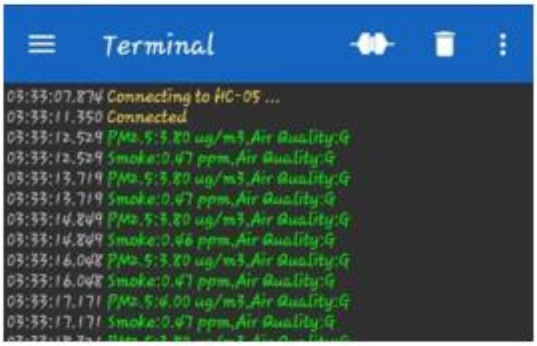

Figure 18: PM2.5 Concentration Readings through Bluetooth Terminal

Figure 19 assumed that the measured smoke concentration is 0.89 ppm, and the corresponding air quality indicator is categorized as "Poor". The smartphone would display the following message: "Smoke: 0.89 ppm, Air Quality:P." during transmission. This detailed Bluetooth transmission mechanism ensures accurate interpretation and presentation of the smoke concentration and corresponding air quality information on the smartphone, enabling users to make informed decisions regarding air quality monitoring and management. This process ensures that relevant air quality data is efficiently transmitted and presented to the user in a user-friendly and easily understandable format on their smartphone, enabling them to monitor and assess the air quality levels with ease.

Figure 19: Smoke Concentration Readings through Bluetooth Terminal

G. POWER SUPPLY FUNCTIONALITY DATA ANALYSIS

Figure 20 reveals the use of a 6V DC power supply instead of the standard 5V DC. This decision was made to counteract potential voltage drops that may occur when multiple DC components are powered simultaneously. By increasing the voltage to 6V DC, the power supply compensates for these voltage drops, ensuring stable and reliable power distribution throughout the circuit. This stable power supply is paramount for the proper functioning of the circuit. It enables the Arduino Mega 2560 board to effectively control the AC fan and accurately display sensor data. The circuit's various interconnected components, including the LCD display, a relay, Bluetooth HC-05 transmitter, PMS5003 particulate matter sensor, and MQ135 air quality sensor, rely on a consistent power supply to operate optimally and maintain reliable communication with the Arduino board. This setup enables the relay to control the flow of electricity to the AC fan, turning it on or off based on the circuit's requirements.

Figure 20: Utilizing a 6V DC Power Supply to Address Voltage Drops

The relay coil is powered by the Arduino's 5V pin, which ensures a stable and regulated power supply for controlling the relay. This connection allows the Arduino board to actively trigger the relay when the smoke concentration exceeds the threshold, indicating the need to circulate the polluted indoor air environment. In terms of sensor integration, the power supply contributes to the overall safety of the circuit. By providing regulated voltage, it minimizes the risk of voltage spikes or irregularities that could potentially harm the components. The PMS5003 particulate matter sensor is connected to the Arduino board via its RXD0 and TXD1 pins. This connection enables the transmission and reception of data between the sensor and the Arduino, allowing real-time monitoring of PM2.5 readings. The MQ135 air quality sensor, on the other hand, is connected to the A0 pin of the Arduino, serving as an analog input for detecting air quality levels. This is particularly important for sensitive elements such as the PMS5003 and MQ135 sensors, which require accurate and reliable power to ensure precise data acquisition and effective air quality monitoring. All components in the circuit, including the LCD display, PMS5003 sensor, and MQ135 sensor, are powered by the Arduino's 5V pin. In order to establish appropriate ground connections, the negative terminals of the components are linked to the ground busbar on the breadboard. This grounding setup helps stabilize voltage levels and reduce noise or fluctuations in the circuit, contributing to the overall functionality and accuracy of the system. The Bluetooth HC-05 transmitter connected to pins 10 and 11 of the Arduino board, enables communication and data transmission with external devices such as smartphones. The inclusion of the Bluetooth module allows for remote monitoring and control of the circuit, enhancing its usability and convenience. Table 5 confirmed that the 6V DC power supply successfully mitigates voltage drops, providing consistent power to the Arduino Mega 2560 board, LCD, MQ135 air quality sensor, PMS5003 PM sensor, and the relay control circuit. As a result, the system can accurately compare the PM2.5 and smoke concentration levels with their respective threshold values.

Components	**Voltage (5V DC)**	**Voltage (6V DC)**	**Analytical Result**
Arduino Mega 2560	5V DC	6V	Increased voltage prevents voltage drops, ensuring stable power supply
LCD	5V DC	6V	Prevents voltage drop, maintaining LCD functionality
MQ135 sensor	5V DC	6V	Sustains accurate readings for smoke concentration
PMS5003 PM sensor	5V DC	6V	Maintains reliable measurements for PM2.5 levels
Relay control circuit	5V DC	6V	Ensure voltage drop across the relay coil is within acceptable limits
Bluetooth HC-05 module	5V DC	6V	Ensure a stable power supply and avoid voltage drops to maintain reliable communication and functionality over Bluetooth.

Table 5: Influence of 6V DC Power Supply on Component Functionality

VI. CONCLUSION

As a conclusion, the successful development and implementation on an Automated Control of AC Air Purifier DIY Fan have effectively achieved the outlined objectives. The system adeptly activates the air filtration mechanism upon detecting pollutant thresholds being surpassed with the employment of real-time monitoring of PM2.5 and smoke concentrations. This proactive approach ensures the maintenance of a healthy indoor environment. The continuous updates on the filter status enable users to stay informed about pollutant levels, facilitating timely responses and necessary measures. Moreover, the study's analysis confirms the air filter's efficiency in reducing indoor pollutants, contributing significantly to improved air quality. The incorporation of automated systems in air purification processes opens new avenues for sophisticated air quality management in smart homes. Moving forward, continued research and development efforts are encouraged to enhance the system's adaptability, ensuring its long-term effectiveness in combating indoor air pollution and promoting overall well-being in indoor environments.

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