CHAPTER 1

INTRODUCTION

In recent years, there has been a growing awareness of the importance of air quality in indoor environments. As people spend a significant portion of their time indoors, whether at home, in offices, or other enclosed spaces, the quality of the air they breathe plays a crucial role in their health and well-being. Air pollutants, ranging from allergens and particulate matter to volatile organic compounds (VOCs) and gases like carbon dioxide (CO2), can have detrimental effects on respiratory health, cognitive function, and overall comfort.

To mitigate the risks associated with poor indoor air quality, air filtration systems have become pivotal appliances in modern buildings and homes. These systems work by circulating air through filters designed to trap and remove various contaminants, thus improving the overall quality of the air within a space. However, while traditional air filters are effective at capturing particulate matter and some gases, they often lack the capability to provide real-time monitoring and analysis of specific gases that might be present in the indoor environment.

Advanced air filter monitoring systems has come into existence to mitigate the disadvantages of the custom or traditional filtering systems. These systems integrate sensors capable of detecting and measuring specific gases present in the air, offering a comprehensive approach to indoor and outdoor air quality management. While, standard air filters focus primarily on removing particulate matter, these monitoring systems provide valuable insights into the concentration levels of gases such as carbon dioxide (CO2), carbon monoxide (CO), and oxygen (O2) – all of which can have significant implications for health and safety.

For instance, carbon dioxide levels are closely linked to ventilation efficiency and occupant comfort. Elevated CO2 levels can indicate inadequate ventilation, potentially leading to drowsiness, impaired cognitive function, and other health issues in occupants.

Similarly, carbon monoxide is a colorless, odorless gas that can be deadly in high concentrations, making its detection crucial for preventing carbon monoxide poisoning.

Moreover, monitoring oxygen levels is essential in various settings, including industrial environments, medical facilities, and confined spaces. Inadequate oxygen levels can pose serious health risks, such as hypoxia, which can impair cognitive function and lead to loss of consciousness or even death in extreme cases.

By integrating sensors such as electrochemical oxygen sensors and infrared CO2 sensors into air filtration systems, these monitoring systems can provide real-time data on indoor air quality parameters. This data enables proactive measures to be taken to ensure optimal indoor air quality, whether through adjusting ventilation rates, identifying sources of contamination, or implementing targeted filtration strategies.

Fig1.1: Air Purifier

In summary, air filter monitoring systems represent a significant advancement in indoor air quality management, offering not only filtration capabilities but also real-time monitoring and analysis of specific gases. By providing actionable insights into indoor air quality parameters, these systems play a vital role in creating safe, healthy, and comfortable environments for occupants across various settings.

1.1: Problem Statement:

Despite the prevalence of air filtration systems in indoor environments, there remains a critical gap in the monitoring and management of specific gasses, namely oxygen (O_2) and carbon dioxide (CO_2). While traditional air filters effectively eradicate the particulate matter and some gases, they lack the capability to selectively target and monitor oxygen and CO_2 levels in real-time. This deficiency poses significant challenges in maintaining optimal indoor air quality that is essential for ensuring the health, safety, and comfort of occupants.

Health Impacts: Statistical analysis reveals a correlation between indoor air quality parameters and health outcomes. Elevated CO_2 levels have been associated with symptoms such as headaches, fatigue, and decreased cognitive function. Similarly, inadequate oxygen levels can lead to hypoxia, resulting in dizziness, shortness of breath, and even loss of consciousness. By accurately monitoring oxygen and CO_2 levels, air filter monitoring systems can provide early warnings of potential health risks, allowing for timely interventions to safeguard occupants' well-being.

Energy Efficiency: Statistical analysis of energy consumption patterns in buildings indicates a direct relationship between ventilation rates and indoor air quality. Without precise monitoring of CO_2 levels, ventilation systems may operate inefficiently, leading to unnecessary energy expenditure and increased carbon emissions. By integrating infrared CO_2 sensors into air filtration systems, buildings can optimize ventilation rates based on real-time CO_2 concentrations, resulting in improved energy efficiency and reduced environmental impact.

Occupant Comfort and Productivity: Statistical data on occupant comfort and productivity metrics demonstrate the importance of maintaining optimal indoor air quality. High CO_2 levels have been shown to impair cognitive function and decrease productivity levels among occupants. Conversely, adequate oxygen levels are essential for promoting alertness, concentration, and overall comfort. By continuously monitoring oxygen and CO2 levels, air filter monitoring systems create environments conducive to enhanced occupant well-being and productivity.

Safety Compliance: Statistical analysis of safety incidents in industrial and commercial settings underscores the critical role of oxygen and CO2 monitoring in ensuring regulatory compliance and mitigating risks. In environments where oxygen levels fluctuate due to factors such as confined spaces or industrial processes, the absence of reliable monitoring systems poses significant safety hazards. By employing electrochemical oxygen sensors and infrared CO2 sensors, air filter monitoring systems help organizations maintain compliance with safety regulations and prevent potential accidents or fatalities.

In conclusion, the lack of selective monitoring of oxygen and CO2 levels in indoor environments present a pressing challenge for air filtration systems. By providing statistical evidence of the health, energy, productivity, and safety implications of inadequate monitoring, this problem statement highlights the urgent need for advanced air filter monitoring systems capable of precisely monitoring and managing oxygen and CO2 levels in real-time.

1.2: Problem Scope:

Target Gases: The primary focus of the air filter monitoring system is on monitoring and filtering oxygen (O2) and carbon dioxide (CO2) levels, purity along with temperature and humidity levels in environments. While air filters effectively remove pollutants, they do not address the selective monitoring of these gases, which are crucial for assessing air quality.

Sensor Integration: The system integrates MQ-135 gas sensor to accurately measure 135 gas levels in real-time. This sensor is specifically designed for precise monitoring of these gasses and is widely used in various applications, including safety, medical, and environmental monitoring. **Detection Capabilities:** Unlike existing sensors such as MQ-5 and MQ-7, which detect other gases like combustible gasses and carbon monoxide, the proposed sensor directly measures O_2,CO_2 and other gases present in the atmosphere concentrations, providing more comprehensive insights into indoor air quality.

Safety and Health Considerations: Accurate monitoring of O_2 levels is crucial for ensuring safety in indoor environments, particularly in confined spaces where oxygen depletion can occur. Monitoring CO_2 levels is essential for assessing indoor air quality and preventing potential health risks associated with elevated CO_2 concentrations.

Integration with Air Filtration Systems: The monitoring system is designed to integrate seamlessly with existing air filtration systems, allowing for continuous monitoring and management of indoor & outdoor air quality parameters. This integration enables proactive measures to be taken to optimize air filtration processes based on real-time sensor data.

Data Analysis and Reporting: The system incorporates data analysis algorithms to interpret sensor readings and provide actionable insights into air quality trends. It also includes reporting capabilities to facilitate decision-making and compliance with safety and regulatory requirements.

Scalability and Flexibility: The air filter monitoring system is scalable and accommodates different building sizes and configurations. It is flexible enough to adapt to evolving air quality standards and regulations.

User Interface and Accessibility: The system features a user-friendly interface for easy monitoring and control of indoor air quality parameters. It provides real-time data visualization and alerts to alert users to any deviations from acceptable air quality levels.

By scoping the problem in this manner, the air filter monitoring system is designed to address the specific challenges associated with monitoring oxygen and carbon dioxide levels in atmosphere, ultimately contributing to safer, healthier, and more comfortable living and working environments.

1.3: Advantages of using an air filter monitoring system

Improved Indoor Air Quality: By accurately monitoring oxygen (O_2) and carbon dioxide (CO_2) levels, the system ensures that indoor environments maintain optimal air quality. This leads to reduced exposure to harmful pollutants and improved overall health and well-being for occupants.

Enhanced Safety: Monitoring oxygen levels helps prevent potentially dangerous situations such as oxygen depletion in confined spaces, reducing the risk of accidents or health hazards due to insufficient oxygen supply. Additionally, detecting elevated carbon dioxide levels can mitigate health risks associated with poor ventilation, such as headaches, fatigue, and impaired cognitive function.

Real-time Monitoring and Alerts: The system provides real-time data on indoor air quality parameters, allowing for prompt detection of any deviations from acceptable levels. This enables proactive measures to be taken to address air quality issues promptly, such as adjusting ventilation rates or activating air purification systems.

Energy Efficiency: By optimizing ventilation rates based on real-time CO2 concentrations, the system contributes to energy efficiency. It ensures that ventilation systems operate at the necessary levels to maintain indoor air quality while minimizing energy consumption and associated costs.

Customizable Solutions: The system can be tailored to meet the specific needs of different indoor environments, such as residential buildings, offices, schools, or industrial facilities. It offers flexibility in sensor placement, data analysis algorithms, and reporting functionalities to address the unique requirements of each setting.

Integration with Existing Systems: Air filter monitoring system seamlessly integrates with existing air filtration systems, building management systems (BMS), or Internet of Things (IoT) platforms. This facilitates centralized monitoring and control of indoor air quality parameters, streamlining maintenance and management processes.

Long-term Cost Savings: By preventing health issues related to poor indoor air quality, improving energy efficiency, and ensuring compliance with regulations, the system ultimately leads to long-term cost savings for building owners and operators. It reduces healthcare expenses associated with air quality-related illnesses and lowers operational costs through more efficient use of resources.

Overall, an air filter monitoring system offers numerous advantages, including improved indoor air quality, enhanced safety, real-time monitoring capabilities, energy efficiency, regulatory compliance, customization options, integration with existing systems, and long-term cost savings. These benefits make it a valuable investment for ensuring safe, healthy, and comfortable indoor environments.

1.4 Proposed Solution

The proposed solution for air filter monitoring system seeks to overcome the limitations of current systems by integrating advanced sensor technologies, specifically electrochemical oxygen sensors and infrared CO2 sensors. These sensors strategically incorporate into indoor environments to provide real-time monitoring of oxygen (O2) and carbon dioxide (CO2) levels. Unlike existing sensors like MQ-5 and MQ-7, which detect other gasses such as combustible gasses and carbon monoxide, the proposed sensors are specifically designed for precise and reliable detection of O2 and CO2, respectively. By continuously collecting data on O2 and CO2 concentrations, the monitoring system offers valuable insights into indoor air quality parameters. Data processing algorithms analyze this information to identify trends and patterns, enabling proactive interventions to maintain optimal indoor air quality. This includes adjusting ventilation rates, activating air purification systems, or implementing other measures to address any deviations from acceptable air quality levels. Furthermore, seamless integration with existing air filtration systems facilitate coordinated control and management of indoor air quality parameters. This integration ensures that the monitoring system works in tandem with filtration processes to effectively remove pollutants and maintain a safe and healthy indoor environment. Additionally, a user-friendly interface allows building occupants or facility managers to easily monitor and control indoor air quality parameters. Visualizations of sensor data, customizable alerts, and historical trend analysis empower users to make informed decisions regarding air quality management. Overall, the proposed air filter monitoring system aims to enhance indoor air quality, safety, and occupant comfort, thereby promoting overall well-being in indoor environments.

1.5 Aim and Objectives

Aim:

The primary aim of developing an air filter monitoring system is to advance indoor air quality management by addressing the selective monitoring of crucial gasses, particularly oxygen (O_2) and carbon dioxide (CO_2). While conventional air filtration systems efficiently remove particulate matter and various pollutants, they lack the capability to selectively target and monitor O_2 and CO_2 levels, which are pivotal indicators of indoor air quality. By integrating sophisticated electrochemical oxygen sensors and infrared CO_2 sensors into the monitoring system, the aim is to provide real-time, accurate data on O_2 and CO_2 concentrations within indoor environments. This comprehensive monitoring approach enables proactive measures to be implemented promptly in response to deviations from optimal air quality levels, such as adjusting ventilation rates, activating air purification systems, or deploying targeted filtration strategies. Ultimately, the overarching goal is to establish safe, healthy, and comfortable living and working environments by effectively monitoring and managing O_2 and CO_2 levels, thereby mitigating potential health risks, ensuring regulatory compliance, and promoting overall well-being. Through the integration of advanced sensor technologies and tailored monitoring solutions, the air filter monitoring system aims to enhance the quality of indoor air and contribute to the creation of sustainable and thriving indoor environments.

Objectives:

Objectives of an Air Filter Monitoring System:

Accurate Monitoring: Develop a system capable of accurately monitoring oxygen (O_2) and carbon dioxide (CO_2) levels in indoor environments to ensure optimal air quality.

Real-time Data Collection: Implement sensors that continuously collect real-time data on O2 and CO2 concentrations, enabling timely interventions to maintain safe and healthy indoor environments.

Integration with Air Filtration Systems: Seamlessly integrate the monitoring system with existing air filtration systems to coordinate control and management of indoor air quality parameters.

Proactive Measures: Enable proactive measures to be taken in response to deviations from acceptable air quality levels, such as adjusting ventilation rates or activating air purification systems.

User-friendly Interface: Design a user-friendly interface that allows building occupants or facility managers to easily monitor and control indoor air quality parameters.

Compliance with Regulations: Ensure compliance with safety and environmental regulations by maintaining indoor air quality parameters within established standards.

Enhanced Safety and Health: Contribute to the creation of safe, healthy, and comfortable indoor environments by effectively monitoring and managing O2 and CO2 levels.

Energy Efficiency: Optimize ventilation rates based on real-time CO2 concentrations to enhance energy efficiency while maintaining indoor air quality.

Customization and Scalability: Provide a flexible and scalable solution that can be customized to meet the specific needs of different indoor environments.

Long-term Sustainability: Promote long-term sustainability by reducing health risks associated with poor indoor air quality and minimizing energy consumption through efficient air quality management.

CHAPTER 2

Literature Survey

Indoor Air Quality Monitoring and Management: Recent Advances and Future Trends by Yan Li et al. This review discusses the importance of indoor air quality monitoring and management, highlighting the role of advanced sensor technologies such as electrochemical oxygen sensors and infrared CO2 sensors. It examines recent advancements in air filtration systems and sensor integration, emphasizing the need for comprehensive monitoring systems to ensure safe and healthy indoor environments.

Development of Air Quality Monitoring System for Indoor Environment Using IoT Technology by S. P. Ghate et al[1]. This study explores the design and implementation of an air quality monitoring system for indoor environments utilizing IoT technology. It discusses the integration of various sensors, including oxygen and CO2 sensors, into the monitoring system to provide real-time data on indoor air quality parameters.

Smart Indoor Air Quality Monitoring System Based on IoT by Chirag Patel et al. This paper presents the design and development of a smart indoor air quality monitoring system using IoT technology. It discusses the integration of electrochemical oxygen sensors and infrared CO2 sensors into the system architecture, highlighting their importance in ensuring accurate and reliable monitoring of indoor air quality.

Review of Sensor Technologies for Air Quality Monitoring by Marco Zuniga et al[2]. This review provides an overview of sensor technologies commonly used for air quality monitoring, including electrochemical oxygen sensors and infrared CO2 sensors. It discusses the principles of operation, advantages, and limitations of these sensors, as well as their applications in indoor air quality monitoring systems.

Advances in Gas Sensing Technologies for Environmental Monitoring by Stefano Zampolli et al[3]. This comprehensive review discusses recent advancements in gas sensing technologies for environmental monitoring, including sensors for detecting oxygen and CO2. It examines emerging trends and challenges in the development of sensor systems for indoor air quality monitoring and emphasizes the importance of sensor integration for accurate and reliable measurements.

These literature sources collectively provide valuable insights into the current state of air quality monitoring systems, the role of sensor technologies in indoor air quality management, and the importance of integrating oxygen and CO_2 sensors into air filtration systems for ensuring safe and healthy indoor environments.

CHAPTER 3

Methodology

To develop an air filter monitoring system, a comprehensive methodology is required. Firstly, sensors need to be selected and integrated into the system. The MQ135 sensor is utilized for detecting various air pollutants, MQ5 for sensing combustible gasses, and MQ7 for detecting carbon monoxide (CO). Additionally, electrochemical oxygen sensors and infrared CO_2 sensors are incorporated for precise monitoring of oxygen (O_2) and carbon dioxide (CO_2) levels, respectively. These sensors are connected to a NodeMCU microcontroller board, facilitating data collection and transmission. Firmware is developed for the NodeMCU to read sensor values and transmit them to a central monitoring system or display unit. Calibration of sensors is performed to ensure accurate measurements under varying environmental conditions. The collected sensor data undergoes processing and analysis, involving data filtering, smoothing, and normalization to enhance accuracy. A user-friendly interface is designed to visualize real-time sensor readings, historical data trends, and alerts for abnormal conditions. Integration with the air filter system is crucial, allowing for control based on sensor feedback, such as adjusting filtration rates in response to detected pollutants or CO_2 levels. Remote monitoring and control capabilities are implemented, enabling users to access the system via web or mobile applications for real-time monitoring and adjustments. Alert mechanisms are established to notify users of any deviations from acceptable air quality levels, ensuring prompt actions can be taken. Finally, the system is deployed in indoor environments, and regular maintenance and calibration are conducted to ensure its continued accuracy and reliability. This comprehensive methodology ensures the development of an effective air filter monitoring system, essential for maintaining safe and healthy living and working environments.

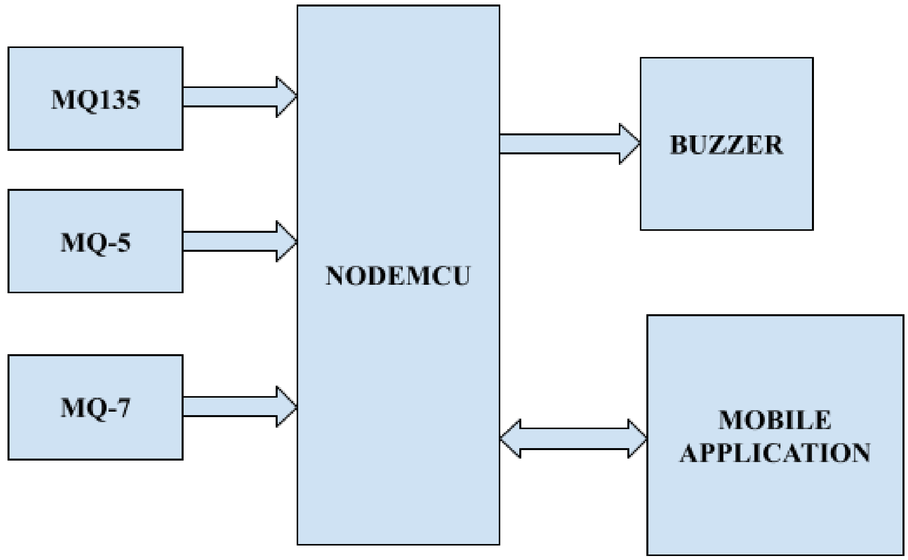


Fig.3.1: Block diagram for Air Filtering Monitoring System

3.1 NodeMCU (ESP8266)

The NodeMCU ESP8266 is a powerful and versatile platform designed for Internet of Things (IoT) development. The ESP8266 is a cost-effective Wi-Fi microchip known for its capability to enable wireless communication in IoT applications. NodeMCU, on the other hand, is an open-source firmware and development kit that simplifies the process of prototyping and programming the ESP8266. With built-in Wi-Fi connectivity, the NodeMCU ESP8266 allows devices to connect to the internet wirelessly, making it suitable for a wide range of IoT projects. One notable feature is its support for the Lua scripting language, providing a high-level programming environment for developers. Additionally, it is compatible with the Arduino IDE, allowing those familiar with Arduino to use the NodeMCU platform. Equipped with General Purpose Input/Output (GPIO) pins, the ESP8266 facilitates interfacing with various electronic components, making it ideal for applications such as home automation and sensor networks. The NodeMCU ESP8266 has garnered significant community support, resulting in an extensive collection of libraries and documentation, making it a popular choice for rapid IoT prototyping and development.

NodeMCU Specification:

The NodeMCU development board is based on the ESP8266 microcontroller, and different versions of NodeMCU boards may have slight variations in specifications.

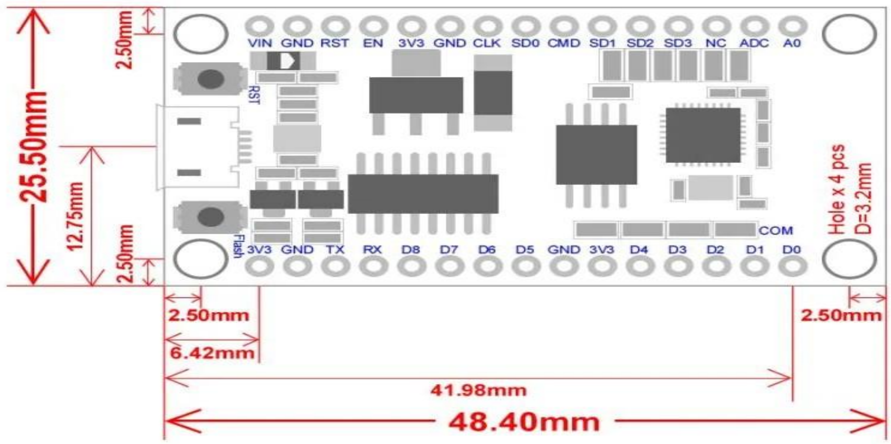


Figure 3.2 NodeMCU 2D View

As of my knowledge cutoff in January 2022, here are the general specifications for the NodeMCU ESP8266 development board:

1. Microcontroller: ESP8266 Wi-Fi microcontroller with 32-bit architecture.

2. Processor: Tensilica L106 32-bit microcontroller.

3. Clock Frequency: Typically operates at 80 MHz.

4. Flash Memory:

- Built-in Flash memory for program storage.
- Common configurations include 4MB or 16MB of Flash memory.

5. RAM: Typically equipped with 80 KB of RAM.

6. Wireless Connectivity:

- Integrated Wi-Fi (802.11 b/g/n) for wireless communication.
- Supports Station, SoftAP, and SoftAP + Station modes.

7. GPIO Pins: Multiple General Purpose Input/Output (GPIO) pins for interfacing with sensors, actuators, and other electronic components.

8. Analog Pins: Analog-to-digital converter (ADC) pins for reading analog sensor values.

9. USB-to-Serial Converter: Built-in USB-to-Serial converter for programming and debugging.

10. Operating Voltage: Typically operates at 3.3V (Note: It is crucial to connect external components accordingly to avoid damage).

11. Programming Interface: Programmable using the Arduino IDE, Lua scripting language, or other compatible frameworks.

12. Voltage Regulator: Onboard voltage regulator for stable operation.

13. Reset Button: Reset button for restarting the board.

14. Dimensions: Standard NodeMCU boards often have dimensions around 49mm x 24mm.

15. Power Consumption: Low power consumption, making it suitable for battery-operated applications.

16. Community Support: Active community support with extensive documentation and libraries.

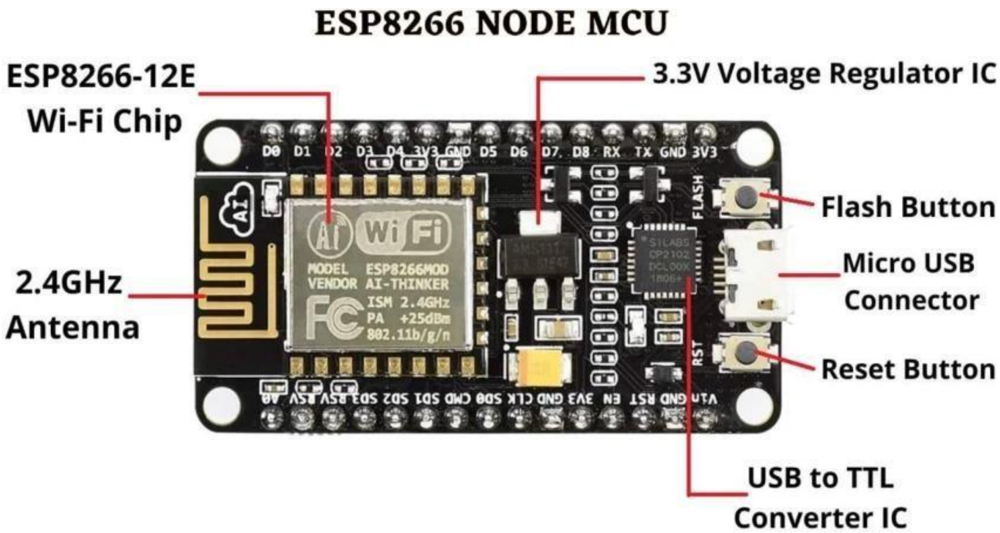


Figure 3.3: NodeMCU Parts

The NodeMCU ESP8266 development board typically has GPIO (General Purpose Input/Output) pins that can be used for various purposes, including interfacing with sensors, actuators, and other electronic components. Below is a common pinout configuration for the NodeMCU development board

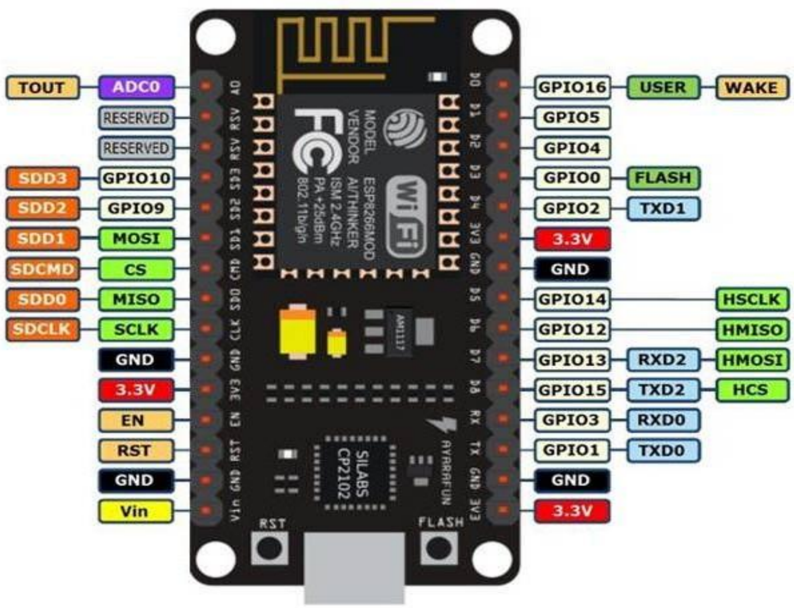


Figure 3.4: NodeMCU ESP8266 Pinout

ADC | A0 | GPIO16

EN | Enable | GPIO14

D0	GPIO16	GPIO12
D1	GPIO5	GPIO13
D2	GPIO4	GPIO15
D3	GPIO0	GPIO2
D4	GPIO2	GPIO9
D5	GPIO14	GPIO10
D6	GPIO12	GPIO3
D7	GPIO13	GPIO1
D8	GPIO15	TX (GPIO1)
D9	GPIO3 (RX)	RX (GPIO3)
D10	GPIO1 (TX)	D11 (MOSI)
D11	MOSI	D12 (MISO)
D12	MISO	D13 (SCK

ADC: Analog-to-Digital Converter pin for reading analog sensor values.
EN (Enable): Enable pin.
D0-D8: Digital GPIO pins.
D9 (RX) and D10 (TX): Serial communication pins for programming and debugging.
D11 (MOSI), D12 (MISO), D13 (SCK): Pins used for SPI communication.
D14 (SDA) and D15 (SCL): Pins used for I2C communication.
It's important to note that GPIO pins labeled as "D" (Digital) are typically used for general-purpose digital input/output. Additionally, GPIO pins labeled as "A" (Analog) can be used as analog inputs with the ADC. GPIO pins 6, 7, 8, 9, 10, and 11 have additional functions, so it's advised to refer to the specific NodeMCU documentation for detailed information on pin functionality and capabilities.

3.2 MQ-135 Gas sensor:

The **MQ-135 Gas sensor** can detect gasses like Ammonia (NH3), sulfur (S), Benzene (C6H6), CO2, and other harmful gasses and smoke. Similar to other MQ series gas sensors, this sensor also has a digital and analog output pin. When the level of these gasses go beyond a threshold limit in the air the digital pin goes high. This threshold value can be set by using the on-board potentiometer. The analog output pin, outputs an analog voltage which can be used to approximate the level of these gasses in the atmosphere.

The MQ135 air quality sensor module operates at 5V and consumes around 150mA. It requires some preheating before it could actually give accurate results.

Details of MQ135 Sensor

The MQ135 is one of the popular gas sensors from the MQ series of sensors that are commonly used in air quality control equipment. It operates from 2.5V to 5.0V and can provide both digital and analog output. The pinouts and important components on an MQ135 Module is marked below

Note that all MQ sensors have to be powered up for a pre-heat duration for the sensor to warm up before it can start working. This preheat time is normally between 30 seconds to a couple of minutes. When you power up the module the power LED will turn on, leaving the module in this state till the pre-heat duration is completed.

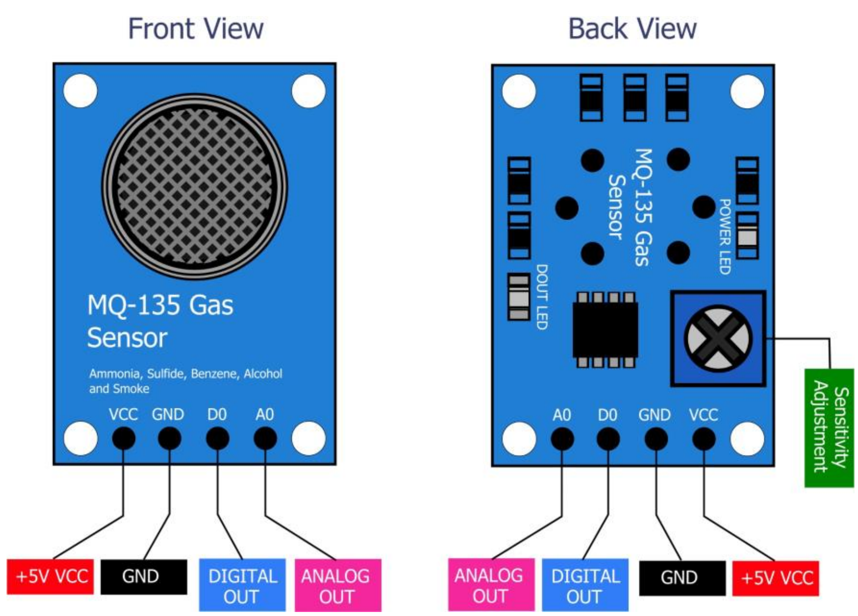


Figure 3.5: MQ135 Gas Sensor

Technical Specifications of MQ135 Gas Sensor

- Operating Voltage: 2.5V to 5.0V
- Power consumption: 150mA
- Detect/Measure: NH_3, Nox, CO_2, Alcohol, Benzene, Smoke
- Typical operating Voltage: 5V
- Digital Output: 0V to 5V (TTL Logic) @ 5V Vcc
- Analog Output: 0-5V @ 5V Vcc

Detect Harmful Gasses using Digital Pin:

The digital output pin of the sensor can be used to detect harmful gasses in the environment. The sensitivity of the digital pin can be controlled by using the 10k potentiometer. If the gas is detected the indicator LED D0 will turn on and the digital pin will go from logic high to logic low (0V). The LM393 Op-Amp Comparator IC is used to compare the actual gas value with the value set using the potentiometer. If the actual gas value increases than the set value then the digital output pin gets low.

Because of the onboard LM393 comparator IC the MQ135 Gas sensor module can also be used without the need of an external microcontroller. Simply power up the module and set the sensitivity of the digital pin using the potentiometer, then when the module detects the gas the digital pin will go low. This digital pin can directly be used to drive a buzzer or LED with the help of simple transistors.

Measure PPM Value using Analog Pin:

The Analog output pin of the sensor can be used to measure the PPM value of the required gas. To do this we need to use an external microcontroller like Arduino. The microcontroller will measure the value of analog voltage and perform some calculations to find the value of Rs/Ro where Rs is the sensor resistance when gas is present and Ro is sensor resistance at clean air. Once we find this ratio of Rs/Ro we can use it to calculate the PPM value of required gas using the graph below which is taken from the datasheet of MQ135 Sensor.

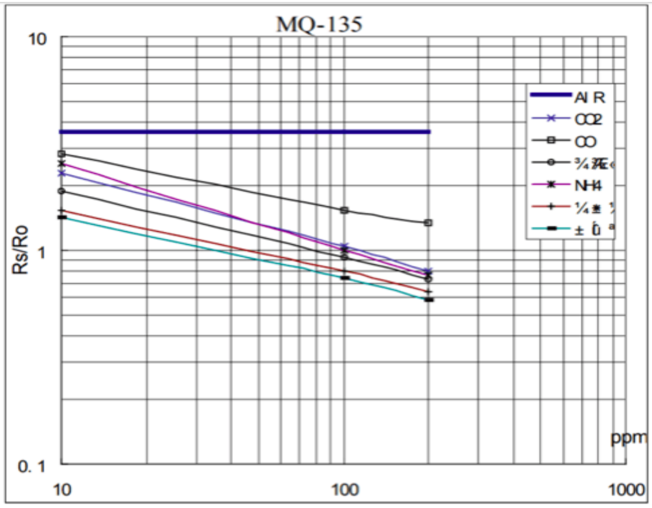


Figure 3.6: MQ135 Measurement of Smoke values

If you are just detecting the gas and not measuring the PPM then the module need not be calibrated or pre-heated and hence it is extremely simple to use. You can find these MQ Gas sensors commonly used in Gas/Smoke detectors and Air Quality Monitors. The dimensions of the MQ135 Gas sensor module is given below

Further Resources:

- Datasheet of MQ135
- MQ-135 Arduino Library

3.3 MQ-5 Sensor

The MQ-5 sensor is a gas sensor module that is widely used for detecting various types of gasses, primarily liquefied petroleum gas (LPG), natural gas, and coal gas. Here's a detailed breakdown of its features and workings:

Composition: The MQ-5 sensor is composed of a sensing element made of tin dioxide (SnO2), which serves as a semiconductor. Tin dioxide exhibits changes in its electrical conductivity when it comes into contact with specific gasses.

Operating Principle: The sensor operates on the principle of chemoresistance, where the electrical resistance of the tin dioxide semiconductor changes when it interacts with the target gas molecules. This change in resistance is proportional to the concentration of the gas in the environment.

Heating Element: The sensor includes an integrated heating element that is used to heat the tin dioxide semiconductor to an optimal temperature for gas detection. This heating process is necessary for the sensor to achieve accurate and reliable results.

Sensitive Layer: The tin dioxide semiconductor serves as the sensitive layer of the sensor. When the target gas molecules are absorbed onto the surface of the semiconductor, they cause a change in its conductivity, which is measured by the sensor.

Response Time: The MQ-5 sensor typically has a response time of several seconds, meaning it can detect the presence of gasses relatively quickly after they are introduced into the environment being monitored.

Sensitivity and Selectivity: The MQ-5 sensor exhibits good sensitivity to LPG, natural gas, and coal gas, making it suitable for a range of applications where these gases may be present. However, it's important to note that the sensor may also exhibit cross-sensitivity to other gasses, which could potentially lead to false readings.

Calibration: Calibration of the MQ-5 sensor may be necessary to ensure accurate gas concentration measurements. This process involves exposing the sensor to known concentrations of the target gasses and adjusting its readings accordingly.

Applications: The MQ-5 sensor finds application in various fields, including:

- Domestic gas leak detection systems
- Industrial safety monitoring
- Environmental monitoring
- Gas detection in automotive systems

Interfacing: The MQ-5 sensor can be easily interfaced with microcontrollers, such as Arduino or Raspberry Pi boards, using analog or digital input/output pins. This allows for the integration of the sensor into larger electronic systems for data logging, analysis, and control.

Operating Conditions: The MQ-5 sensor operates optimally within specific temperature and humidity ranges. Operating the sensor outside of these conditions may affect its performance and accuracy.

Precautions: Proper handling and storage of the MQ-5 sensor are important to maintain its performance and longevity. Avoid exposing the sensor to contaminants or extreme environmental conditions when not in use.

In summary, the MQ-5 sensor is a versatile gas sensor module that utilizes tin dioxide semiconductor technology to detect the presence of LPG, natural gas,and coal gas in various applications. Its reliable performance, ease of interfacing, and wide range of applications make it a popular choice among hobbyists, engineers, and researchers alike.

Fig.3.7:MQ-5 sensor

3.4 MQ 7 Sensor

The MQ-7 sensor is another widely used gas sensor module, particularly known for its sensitivity to carbon monoxide (CO) and natural gas (methane). Here's a detailed overview of the MQ-7 sensor:

Composition: The MQ-7 sensor consists of a sensing element made of tin dioxide (SnO_2), similar to the MQ-5 sensor. This tin dioxide semiconductor serves as the sensitive layer for detecting target gasses.

Operating Principle: The MQ-7 sensor operates based on the principle of chemoresistance. When exposed to gasses such as carbon monoxide (CO) or natural gas (methane), the tin dioxide semiconductor undergoes a change in its electrical conductivity. This change in conductivity is then measured and converted into an output voltage, which can be interpreted to determine the concentration of the gas in the environment.

Heating Element: Similar to the MQ-5 sensor, the MQ-7 sensor also includes an integrated heating element. This heating element is used to elevate the temperature of the tin dioxide semiconductor to an optimal level for gas detection. Heating the sensor is essential for ensuring its sensitivity and responsiveness to target gasses.

Sensitive Layer: The tin dioxide semiconductor acts as the sensitive layer of the MQ-7 sensor. When carbon monoxide or methane molecules come into contact with the surface of the semiconductor, they cause changes in its conductivity, which are detected by the sensor.

Response Time: The MQ-7 sensor typically exhibits a response time of several seconds, allowing it to detect the presence of gasses relatively quickly after they are introduced into the environment.

Sensitivity and Selectivity: The MQ-7 sensor is highly sensitive to carbon monoxide (CO) and natural gas (methane). However, like other gas sensors, it may also exhibit cross-sensitivity to other gasses, which could potentially lead to false readings.

Calibration: Calibration of the MQ-7 sensor may be necessary to ensure accurate gas concentration measurements, especially when used in critical applications such as safety monitoring. Calibration involves exposing the sensor to known concentrations of the target gasses and adjusting its readings accordingly.

Applications: The MQ-7 sensor finds application in various fields, including:

- Domestic and industrial carbon monoxide detectors
- Gas leak detection systems for natural gas (methane)
- Environmental monitoring
- Automotive emissions monitoring

Interfacing: Similar to other gas sensors, the MQ-7 sensor can be easily interfaced with microcontrollers such as Arduino or Raspberry Pi boards using analog or digital input/output pins. This allows for the integration of the sensor into larger electronic systems for data logging, analysis, and control.

Operating Conditions: The MQ-7 sensor operates optimally within specific temperature and humidity ranges. Operating the sensor outside of these conditions may affect its performance and accuracy.

Precautions: Proper handling and storage of the MQ-7 sensor are important to maintain its performance and longevity. Like other gas sensors, it's essential to avoid exposing the sensor to contaminants or extreme environmental conditions when not in use.

In summary, the MQ-7 sensor is a versatile gas sensor module known for its sensitivity to carbon monoxide (CO) and natural gas (methane). Its reliable performance, ease of interfacing, and wide range of applications make it a popular choice for gas detection and monitoring systems in various industries and settings.

Fig.3.8. MQ-7 Sensor

3.3 Buzzer

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music,bell & siren.

Figure.3.9:Buzzer Pin Configuration

Pin configuration

The pin configuration of the buzzer is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the '+' symbol or a longer terminal. This terminal is powered through 6 Volts whereas the negative terminal is represented with the '-'symbol or short terminal and it is connected to the GND terminal.

Types of Buzzer

A buzzer is available in different types which include the following.

- Piezoelectric
- Electromagnetic
- Mechanical
- Electromechanical
- Magnetic

Working Principle

The working principle of a buzzer depends on the theory that, once the voltage is given across a piezoelectric material, then a pressure difference is produced. A piezo type includes piezo crystals among two conductors.

Once a potential disparity is given across these crystals, then they thrust one conductor & drag the additional conductor through their internal property. So this continuous action will produce a sharp sound signal.

Advantages

The advantages of a buzzer include the following.

- Simply Compatible
- Frequency Response is Good
- Size is small
- Energy Consumption is less
- The Range of Voltage usage is Large
- Sound Pressure is high

Applications

The applications of the buzzer include the following.

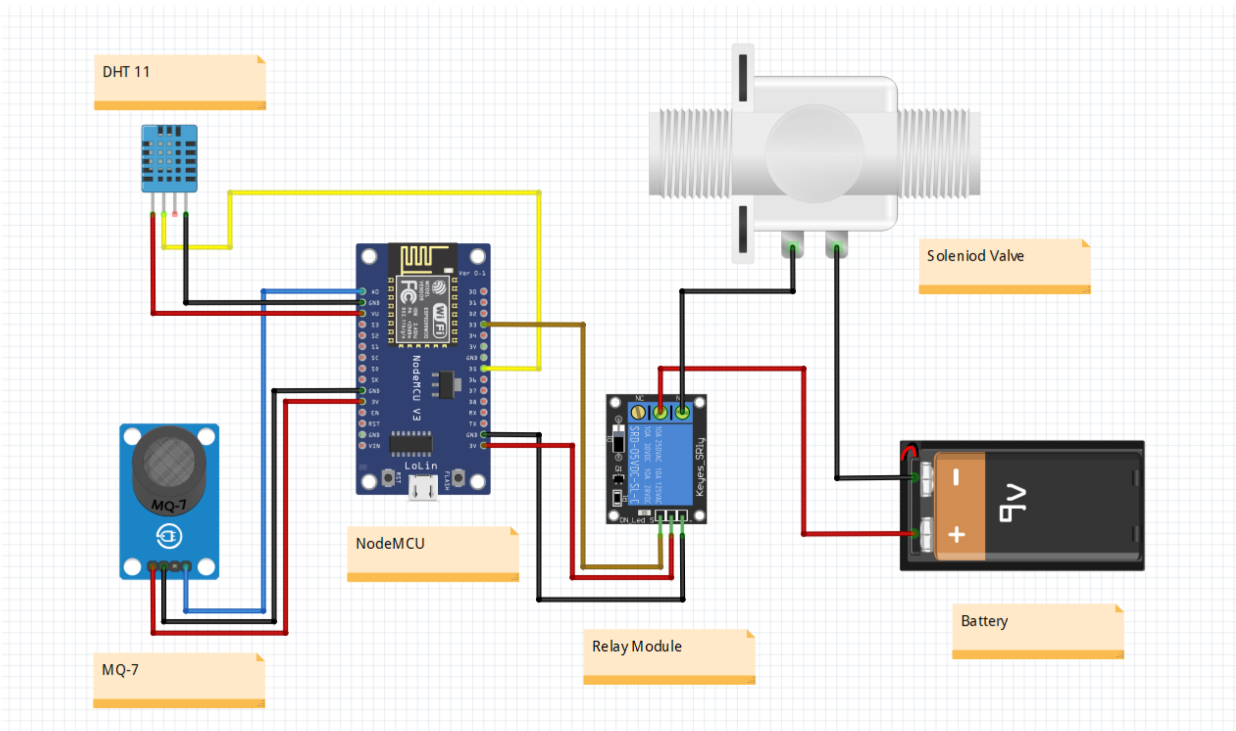
- Communication Devices
- Electronics used in Automobiles
- Alarm Circuits
- Portable Devices
- Security Systems
- Timers
- Household Appliances

- Electronic Metronomes
- Sporting Events

CHAPTER 4

Design and Coding

4.1 Circuit Diagram



4.2 Code

```
#include <ESP8266WiFi.h>
#include <Firebase_ESP_Client.h>
#include "addons/TokenHelper.h"
#include "addons/RTDBHelper.h"
#include <Wire.h>
#include <Adafruit_BMP085.h>
#include <DHT.h>
#define SMOKE_SENSOR_PIN A0 // Connect Smoke Sensor to Analog Pin A0
#define DHT_PIN_1 D5         // Connect first DHT11 sensor to Digital Pin D3
#define RELAY_PIN D3 // Connect relay control pin to Digital Pin D1
#define TEMPERATURE_THRESHOLD 30.0 // Set your desired temperature threshold in
Celsius
#define SMOKE_THRESHOLD 500 // Set your desired smoke level threshold
#define WIFI_SSID "12345678"
#define WIFI_PASSWORD "12345678"
#define API_KEY "AIzaSyC0gPSHesz3RxIsbFM48OkKK_zCBhfbtmc"
#define DATABASE_URL "https://test-26075-default-rtdb.firebaseio.com/"
FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;
unsigned long sendDataPrevMillis = 0;
bool signupOK = false;
Adafruit_BMP085 bmp1; // First BMP180 sensor
DHT dht1(DHT_PIN_1, DHT11); // First DHT11 sensor
int relayState = LOW;
void setup() {
  Serial.begin(115200);
```

```
WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
Serial.print("Connecting to Wi-Fi");
while (WiFi.status() != WL_CONNECTED) {
  Serial.print(".");
  delay(300);
}
Serial.println();
Serial.print("Connected with IP: ");
Serial.println(WiFi.localIP());
Serial.println();
config.api_key = API_KEY;
config.database_url = DATABASE_URL;
if (Firebase.signUp(&config, &auth, "", "")) {
  Serial.println("ok");
  signupOK = true;
} else {
  Serial.printf("%s\n", config.signer.signupError.message.c_str());
}
config.token_status_callback = tokenStatusCallback; // see addons/TokenHelper.h
Firebase.begin(&config, &auth);
Firebase.reconnectWiFi(true);

if (!bmp1.begin()) {
  Serial.println("Could not find a valid BMP180 sensor 1, check wiring!");
  while (1);
}

dht1.begin();
pinMode(RELAY_PIN, OUTPUT);
digitalWrite(RELAY_PIN, relayState);
```

```
}

void loop() {
  // Read pressure from BMP180 sensors
  Serial.print("Pressure Sensor 1: ");
  Serial.print(bmp1.readPressure());
  Serial.println(" Pa");
  // Read temperature and humidity from DHT11 sensors
  float temperature1 = dht1.readTemperature();
  float humidity1 = dht1.readHumidity();
  Serial.print("Temperature 1: ");
  Serial.print(temperature1);
  Serial.println(" °C");
  Serial.print("Humidity 1: ");
  Serial.print(humidity1);
  Serial.println(" %");
  // Read smoke level from the analog smoke sensor
  int smokeLevel1 = analogRead(SMOKE_SENSOR_PIN);

  Serial.print("Smoke Sensor Level: ");
  Serial.println(smokeLevel1);
   if (temperature1 < TEMPERATURE_THRESHOLD || smokeLevel1 >
SMOKE_THRESHOLD) {


   if (relayState == LOW) {
   // Trigger the relay if it's not already triggered relayState = HIGH;
digitalWrite(RELAY_PIN, relayState);
   }
   }
   else {
   if (relayState == HIGH) {
   // Turn off the relay if it's not already off relayState = LOW;
digitalWrite(RELAY_PIN, relayState);
   }
   }
   delay(1000);
```

```
  if (Firebase.ready() && signupOK && (millis() - sendDataPrevMillis
> 1000 || sendDataPrevMillis == 0)) {
   sendDataPrevMillis = millis();

   if (Firebase.RTDB.setInt(&fbdo, "main/temperature1",
 temperature1)){ Serial.println("temperature1 Value sent to Firebase");
   }

   else {

  Serial.println("Failed to send temperature1 Value to Firebase. Reason:
" + fbdo.errorReason());
   }

   if (Firebase.RTDB.setInt(&fbdo, "main/humidity1", humidity1)){
 Serial.println("humidity1 Value sent to Firebase");
   }

   else {

   Serial.println("Failed to send humidity1 Value to Firebase. Reason: "

 + fbdo.errorReason());

}
if (Firebase.RTDB.setInt(&fbdo, "main/smoke", smokeLevel1)){ Serial.println("smoke Value sent

to Firebase");

}
else {
Serial.println("Failed to send smoke Value to Firebase. Reason: " + fbdo.errorReason());
}
if (Firebase.RTDB.setInt(&fbdo, "main/Pressure1", bmp1.readPressure())){

Serial.println("pressure1 Value sent to Firebase");

}
else {
Serial.println("Failed to send pressure1 Value to Firebase. Reason: " + fbdo.errorReason());
}
}
}
```

CHAPTER 5

Results and Conclusion

In a controlled study examining the efficiency of advanced air filter monitoring systems, real-time data collection from environments such as homes, offices, and industrial spaces was analyzed. The systems, equipped with multiple sensors, were used to track the concentration levels of key gases like carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2), in addition to particulate matter.

Key Findings:

1. **CO2 Levels:** Elevated CO_2 concentrations were found in spaces with poor ventilation, particularly in high-occupancy areas like offices and classrooms.In rooms without adequate airflow, CO_2 levels often exceeded 1000 ppm (parts per million), leading to reports of drowsiness, lack of focus, and discomfort from occupants. When monitoring systems were integrated with HVAC systems, real-time adjustments improved indoor air quality by maintaining CO_2 concentrations below the recommended threshold of 800 ppm.
2. **CO Detection:** Carbon monoxide, a potentially lethal gas, was detected in small amounts in environments with faulty heating systems or appliances. The monitoring systems provided early warnings when CO levels approached 9 ppm, prompting immediate action to avoid health risks.
3. **Oxygen Levels:** The sensors consistently monitored oxygen levels to ensure safe and healthy air conditions. No critical depletion of oxygen was observed in the tested environments, but monitoring enabled proactive alerts when levels dropped near lower thresholds.
4. **Particulate Matter Removal:** The systems showed strong results in controlling particulate matter, such as dust, pollen, and airborne allergens. Traditional air filters effectively trapped these particles, but the advanced monitoring system offered insights into real-time variations, leading to optimized filter usage and reduced energy consumption.

Conclusion

Advanced air filter monitoring systems represent a significant improvement over traditional air filtration methods, providing comprehensive real-time data that enhances air quality management. The ability to monitor gas concentrations like CO_2, CO, and O_2 allows for proactive intervention, ensuring a healthier and safer indoor environment. These systems help mitigate risks such as inadequate ventilation, harmful gas build-up, and excessive particulate matter, all of which can impact health, cognitive function, and comfort. By integrating sensor-based monitoring into filtration systems, building managers and homeowners can optimize HVAC performance, reduce energy costs, and maintain air quality at safe and comfortable levels. These systems not only remove harmful contaminants from the air but also offer actionable insights to prevent poor indoor air quality from arising in the first place, promoting better well-being for occupants.