



Design and Construction of an Automatic Smoke Extractor

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ABSTRACT

This project presents the successful design, construction, and testing of an automatic smoke extraction system. In industrial, commercial, and residential environments, the timely detection and removal of hazardous smoke have been persistent challenges, often leading to respiratory issues, property damage, and even loss of life. Traditional manual extraction methods have proven to be inefficient, slow, and largely ineffective. The proposed system addresses these concerns by accurately detecting smoke and automating its extraction process. Experimental results demonstrate that the system operates reliably, swiftly identifying and removing smoke within seconds, thereby significantly reducing its concentration and improving air quality.

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INTRODUCTION

Indoor air pollution is a significant concern in various settings, including industrial and commercial environments. Smoke can pose serious health risks, including respiratory problems and other health issues. Fires in buildings can be devastating, causing loss of life, property damage, and environmental harm. One of the critical factors in fire safety is the rapid removal of smoke, which can spread quickly and hinder evacuation[1].

Smoke exposure can lead to numerous health problems due to its composition of harmful gases, chemicals, and particulate matter. Respiratory issues are among the most immediate effects, as smoke irritates the airways, causing coughing, shortness of breath, and aggravating chronic conditions like asthma and COPD. Long-term exposure can lead to reduced lung function and an increased risk of respiratory infections[2]. Additionally, smoke increases the risk of cardiovascular problems, such as heart attacks and high blood pressure, by introducing toxins into the bloodstream[3]. It can also cause eye and skin irritation, as well as increase the risk of cancer due to the carcinogenic substances it contains, such as benzene. The immune system can be weakened by chronic smoke exposure, making individuals more susceptible to illness, while neurological effects, including headaches,

cognitive decline, and dizziness, are common. Pregnant women and children are particularly vulnerable, with smoke contributing to developmental issues and respiratory complications. Overall, minimizing smoke exposure is crucial, the smoke extractors can significantly reduce health risks by removing harmful pollutants from the air[4].

Currently, many industries rely on manual or semi-automatic methods for smoke extraction, which can be inefficient and ineffective[5]. This project involves the design and construction of an Automatic Smoke Extractor (ASE) system, which detects and removes smoke and harmful particles from the air in real time. The constructed ASE system utilized advanced sensor and machine learning algorithms to detect smoke and automatically activate a high-efficiency extraction Fan. The system was designed to be compact, energy-efficient, and easy to maintain.

Recent advancements in technology, particularly in sensor development, machine learning, and automation, have opened new doors for addressing indoor air pollution more effectively. The introduction of an Automatic Smoke Extractor (ASE) system leverages these technologies to provide a real-time, responsive solution for detecting and removing smoke and harmful particles[6]. ASE systems are equipped with highly sensitive sensors that can detect a range of

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pollutants, from fine particulate matter to hazardous gases, ensuring timely intervention[1]. Coupled with automation and AI-powered algorithms, these systems can adjust airflow and filtration processes dynamically, ensuring optimal air quality without the need for human involvement.

The development of the ASE system offers significant benefits across multiple sectors. First, it dramatically improves indoor air quality by swiftly removing pollutants, leading to a healthier environment for occupants. This, in turn, reduces the risk of health issues, from acute conditions like eye irritation and respiratory distress to chronic diseases caused by long-term exposure. Additionally, the automation and efficiency of the system enhance overall productivity by minimizing downtime caused by smoke-related disruptions, while also ensuring regulatory compliance in environments with strict air quality standards[7]. Most importantly, ASE systems contribute to greater safety by mitigating the risks associated with toxic exposure and improving the overall working conditions in industrial and commercial spaces.

Some existing works are; [3] Presented a smart smoking room gadget, "in and out" exhaust fan ventilator was employed in the room. The amount of carbon monoxide (CO) gas in the room, as determined by a smoke sensor, caused this fan ventilator to rotate. The fan ventilator's input voltage level was managed by an Arduino Uno using the Fuzzy Decision Tree technique. The outcome demonstrated how well the equipment works to reduce cigarette smoke in the space. [4] proposed a novel approach to smoke detection that combines a contemporary convolutional neural network (CNN) with motion and appearance analysis. When compared to fully deep learning-based methods, the suggested hybrid strategy, which was trained and assessed on the suggested dataset, showed a 94% smoke recognition rate while having a significantly reduced false positive rate (14% vs. 100%). [8]. This study introduces a novel image-processing technique for smoke and fire detection. This algorithm looks at every object in a picture and then compares them to determine which ones are

fire and smoke. Fire smoke will cause some or all of the photographs to become blurry. The method that is provided makes use of two-dimensional wavelet analysis. The findings of this study outline the suggested enhancements that can improve system performance and lower the number of false alerts. [2]. This research investigates and develops cigarette smoke detectors for the building's non-smoking areas. The Gas Sensor (MQ-2) is used in the smoke detector's design to detect smoke, and the NodeMCU V2 (ESP8266-12e) stores the sensor's value as a voltage. The NodeMCU V2 (ESP8266-12e) will notify the administrator to push notifications via the LINE API on the LINE Application as soon as the sensor detects fumes till the voltage is surpassed. The gadget can send a message and quickly detect smoke. Inform building employees that someone is smoking in a designated smoking area.

The present project introduces the use of minimum power energy for the system, differentiating it from existing solutions. Its value proposition lies in offering an advanced automatic smoke extraction system, providing enhanced safety, reduced energy consumption, and improved detection accuracy.

METHODOLOGY

An automatic smoke extractor is a device or system designed to remove smoke from a building or enclosed space. These systems play a vital role in maintaining visibility, reducing the risk of respiratory problems and other health issues, and enabling safe evacuation. It's an important component of fire safety and smoke control systems.

Component of the smoke extractor

The following components were used for the hardware implementation of the project:

Arduino Controller

The Arduino Uno is a microcontroller board based on the Microchip ATmega328P microcontroller, an 8-bit AVR core with a clock speed of 16 MHz. It has 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM, providing sufficient memory for most applications. The

board has 14 digital input/output pins and 6 analog input pins, allowing for connection to various sensors, actuators, and devices. It also features UART TTL serial and USB communication,

enabled by the ATmega16U2 chip, which appears as a virtual com port to software on the computer [9]. . Typical picture of arduino Uno is showed in figure 1.

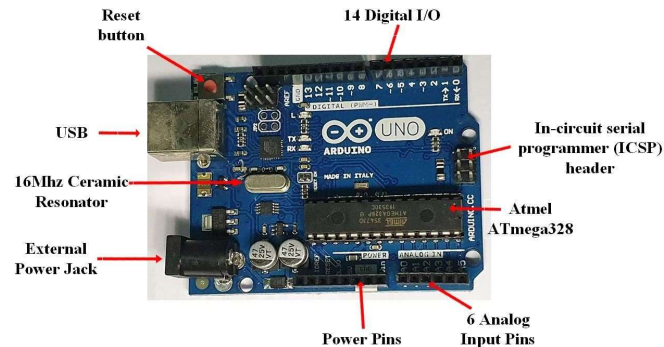


Figure 1: Showing an Arduino UNO twitter

MQ-2 Sensor

The MQ-2 sensor is a metal oxide semiconductor (MOS) gas sensor that detects smoke, LPG, propane, hydrogen, and methane. It boasts high sensitivity, fast response time (~10 seconds), and low power consumption (~20mA)[10]. With a simple analog output and

compact size (14.5x8.5mm), the MQ-2 sensor is suitable for various applications. Key features include an operating voltage of 5V, a temperature range of -20°C to 50°C, and a humidity range of 30% to 90%. Figure 2 showed the picture of MQ-2 sensor[11].



Figure 2: Showing an MQ2 sensor

D.C Fan

The fan component of an automatic smoke extractor is responsible for drawing smoke and gases into the system. D.C. fans are versatile devices that can function as both extractors and blowers, offering high airflow rates, energy efficiency, compact design, low noise levels, and

adjustable speed control. In extractor mode, they remove unwanted air, gases, or particles from confined spaces, while in blower mode, they supply fresh air or gas. D.C. fans as shown in fig. 3, can operate in both modes, providing reversible airflow and dual-speed control[2].



Figure 3: Showing a D.C. fan

Power supply

A power supply is a system that provides electrical energy. 5V DC batteries are widely used in various applications, offering a nominal voltage of 5V and varying current ratings (e.g., 1A, 2A, 5A). These batteries come in

different chemistries, including alkaline, nickel-cadmium (Ni-Cd), nickel-metal hydride (NiMH), and lithium-ion (Li-ion), each with its advantages and limitations[2]. An example of a power source is shown in Figure 4.



Figure 4: Showing a power supply

Jumper Wire

Jumper wires as shown in fig., also commonly referred to as jumper leads or simply jumpers, play a crucial role in the field of electronics and prototyping. These wires are

essentially insulated conductors with connectors or pins at each end, serving as vital components for establishing electrical connections between various elements in electronic circuits[2].



Figure 5: Showing a jumper wire

Breadboard

A breadboard is a reusable, temporary circuit board used for prototyping, testing, and debugging electronic circuits. It consists of a plastic or metal base with rows of holes and metal

strips, allowing users to connect components and wires easily. Breadboards are ideal for fast prototyping, circuit changes, and STEM education, making them a popular choice among

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hobbyists, students, and professionals. An example of breadboard is shown in figure 6[12].



Figure 6: Showing a breadboard

Arduino IDE

The Arduino IDE is a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the Wiring projects. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic

indentation, and is also capable of compiling and uploading programs to the board with a single click.

DESIGN AND ANALYSIS

System planning

This design is made to simplify the process of designing. The series of tools is shown in Figure 7.

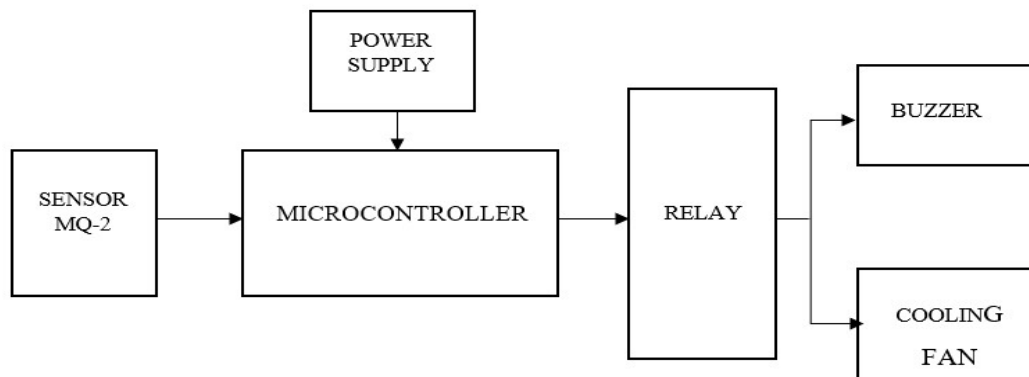


Figure 7: Showing the System design

Block circuit

The project block circuit and flow chart are shown in figure 8 and 9 respectively.

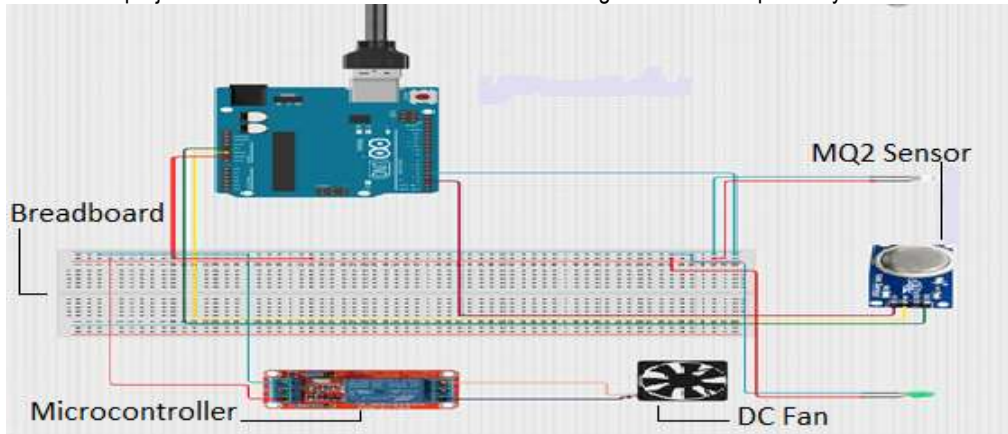


Figure 8: Showing the blocks circuit

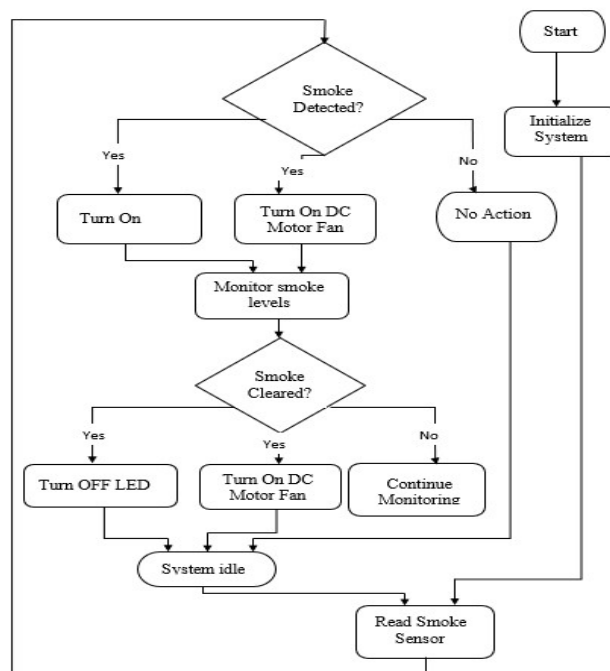


Figure 9: Showing the flow chart of system operation

Design Components

The system needs to detect smoke concentration, process that information using the

Arduino, and then turn on the fan to clear the air. Here is a breakdown of the key aspects;

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1. Smoke Detection with MQ2 Sensor
MQ2 Sensor detects gases like LPG, butane, methane, alcohol, and smoke. It outputs an analog signal that corresponds to the concentration of the gas detected. The sensor has a sensitivity range for different gases and gives an output voltage relative to the concentration.
2. Control System (Arduino)
The Arduino reads the analog signal from the MQ2 sensor using one of its analog input pins. The signal is then processed using an IF condition to check whether the voltage exceeds a threshold value, indicating the presence of dangerous smoke levels. Once the threshold is crossed, the Arduino sends a signal to activate the fan.
3. Fan as the Extraction System (DC Motor Fan Control)
The fan is driven by a DC motor, and the Arduino controls the fan using a transistor or relay. A transistor like TIP120 can be used as a switch. The Arduino sends a digital HIGH signal to the base of the transistor to turn on the fan.

Summary of Calculations:

- i. Power consumed by the fan: 1 watt.
- ii. Output voltage from MQ2 sensor at 1000 ppm: 2.1V.
- iii. ADC value for 1000 ppm: 430.

- iv. Fan activation threshold at 1500 ppm: ADC value of 441.
- v. Fan speed at 60% PWM duty cycle: 1800 RPM.
- vi. Total power consumption of the system: 1.5 watts.

CONSTRUCTION OF THE PROTOTYPE

The Automatic Smoke Extractor was fabricated using wood as the casing to provide a steady structure for housing the components. The wooden pieces were securely joined with glue gum and A & B gum, ensuring a stable and reliable enclosure. A DC motor fan was integrated to serve as the extraction system, which is responsible for pulling smoke into and out of the casing when activated. The Arduino microcontroller was employed to control the system, reading data from the MQ2 sensor, which detected the presence of smoke or gases. Based on the sensor's readings, the Arduino would trigger the fan to operate when necessary.

LEDs were used as indicators to signal the system's status, such as whether smoke had been detected or if the system was idle. The entire setup worked efficiently to detect smoke, process the information, and extract it automatically, with the visual feedback provided by the LEDs. This combination of materials and electronic components resulted in a functional and cost-effective automatic smoke extractor. The connections of the system are shown in plate 1.



Plate 1: Showing the fabricated system

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The performance of the automatic smoke extractor was evaluated under various conditions to determine its efficiency and reliability in real-world scenarios as shown in table 1.

RESULT AND DISCUSSION

Smoke from a burning mosquito coil was used to test the ability of the system to sense

the presence of smoke and activate the fan accordingly. Smoke distance was varied and the sensors response time and energy consumption were recorded. The experiments were repeated five (5) times and the average result are as presented in table 1.

Table 1: Experimental result of average values of five Successive trials

S/N	Range (m)	Response Time (s)	Energy Consumption (mAh)
1	0.5	2.0	0.45
2	1.0	4.0	0.9
3	1.5	5.0	1.35
4	2.0	6.0	1.8
5	2.5	8.0	2.25
6	3.0	10.0	2.7

- Smoke Detection Accuracy:** The automatic smoke extractor's ability to detect smoke was tested using mosquito coil. Results showed that the smoke sensor could detect smoke effectively, responding within an average of 5 seconds in the range of 0 – 3 (m) distance from the device.
- System Responsiveness:** The automatic smoke extractor was equipped with sensor that allowed for autonomous operation. The smoke sensor triggered the extraction system in real time once smoke was detected. The delay between detection and fan activation was negligible (less than 1 second), making it highly responsive in emergency situations.
- Energy Consumption:** Energy efficiency was also a critical factor evaluated during the tests. The system's energy consumption was monitored during continuous operation. In standby mode, the system used 2.7W for 10s of operation, which is energy-efficient for continuous monitoring.

Limitations

While the automatic smoke extractor showed promising results, there were some limitations observed:

- Smoke Detection in Larger Spaces:** In larger spaces (above 30 square meters), the smoke extraction process took significantly longer. This suggests that either the suction power of the fan and detection system needs to be increased, or multiple units need to be deployed to effectively cover larger areas.
- False Positives:** In some instances, the smoke detector responded to steam (from cooking) rather than smoke, which could lead to unnecessary activation of the system. This could be improved by integrating more sophisticated sensors that can distinguish between different types of particles.

CONCLUSION

The Automatic Smoke Extraction System project successfully demonstrated the feasibility of utilizing an MQ-2 gas sensor, a microcontroller, and a DC motor fan to detect and extract smoke in real time. This system was designed to enhance safety in industrial, commercial, and residential environments by providing an automated solution for smoke detection and removal.

The system's effectiveness was rigorously tested through a series of controlled experiments. These tests confirmed that the MQ-2 gas sensor could accurately detect varying levels of smoke concentration, triggering the microcontroller to activate the DC motor fan for immediate extraction. The system consistently responded within seconds of smoke detection, ensuring that hazardous smoke was efficiently removed and indoor air quality was significantly improved.

Additionally, the automated response mechanism eliminates delays associated with traditional manual extraction methods, reducing the risks of respiratory issues, fire hazards, and property damage. The system's real-time operation makes it a reliable and practical solution for enhancing safety in environments where smoke accumulation poses a serious threat.

Overall, the project highlights the practical application of sensor-based automation in smoke management, demonstrating its potential for integration into smart buildings, industrial facilities, and residential spaces to improve safety and air quality.

RECOMMENDATIONS

To further enhance the Automatic Smoke Extraction system, several technical recommendations are suggested

1. Improve Sensor Accuracy: Explore alternative sensors (e.g., MQ-135, MQ-309) for enhanced sensitivity and selectivity.
2. Fan Optimization: Investigate more efficient fan designs or configurations to increase airflow and extraction efficiency.
3. System Integration: Integrate the Automatic Smoke Extraction System with existing building management systems (BMS) or fire alarm systems.

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