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Smoke Detector with Automatic Exhaust Fan Using Arduino and MQ-2 Sensor

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Abstract : *Smoke accumulation in enclosed environments can cause respiratory discomfort, reduced visibility, and potential safety hazards. Conventional ventilation systems often require manual operation or operate continuously, resulting in delayed responses or unnecessary energy consumption. This paper presents a low-cost automatic smoke detection and ventilation system using an MQ-2 smoke sensor, an Arduino Uno microcontroller, and a 12 V DC exhaust fan. The proposed system continuously monitors the sensor's analog output and compares the measured value with a predefined threshold. When the reading exceeds the threshold, the Arduino activates a buzzer and red LED to provide audible and visual warnings. Simultaneously, a MOSFET switches on the exhaust fan to remove smoke from the enclosed environment. When the sensor reading falls below the threshold, the system returns to its normal operating state. A 12 V DC adapter supplies the system, while a voltage regulator provides the required 5 V supply to the low-voltage components. The proposed design offers automatic operation, simple implementation, and low component cost. Potential applications include kitchens, laboratories, workshops, storage areas, and small industrial environments.*

Keywords: Smoke detection, MQ-2 sensor, Arduino Uno, automatic ventilation, exhaust fan, MOSFET switching, embedded systems, indoor air quality, safety monitoring.

I. INTRODUCTION

Smoke accumulation is a common concern in enclosed environments such as kitchens, laboratories, workshops, basements, and small industrial facilities. Smoke may contain particulate matter and other harmful substances that can affect human health and visibility. In some situations, smoke may also indicate a developing fire or the presence of combustible gases.

Traditional exhaust systems generally depend on manual switching or continuous operation. Manual systems require a person to identify the problem and activate ventilation, potentially causing delays. Continuously operating fans may consume electrical energy even when ventilation is unnecessary. Conventional alarm-only systems can provide warnings without automatically initiating smoke-removal measures.

To address these challenges, an automatic smoke detection and ventilation system can combine sensing, decision-making, warning, and air extraction in a single embedded platform.

The proposed system uses an MQ-2 sensor to detect changes associated with smoke and combustible gases in the surrounding air. The sensor produces an analog output that is read by an Arduino Uno. The microcontroller compares the measured value with a programmed threshold and controls a buzzer, LED indicators, and exhaust fan.

When the threshold is exceeded, the buzzer and red LED indicate a potentially unsafe condition, while a MOSFET switches on the 12 V exhaust fan. Under normal conditions, the green LED indicates the normal operating state and the fan remains switched off.

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The main contribution of this project is the integration of smoke-responsive ventilation and local warning indicators using readily available electronic components. The design emphasizes affordability, straightforward implementation, and reduced dependence on manual operation.

It should be noted that the MQ-2 sensor is sensitive to several combustible gases and smoke-related conditions. Consequently, its output should not be interpreted as a selective measurement of smoke concentration without appropriate calibration and testing.

II. LITERATURE REVIEW

2.1 Conventional Smoke Detection Systems

Conventional smoke detection systems commonly use sensors to identify smoke-related changes and generate audible or visual alarms Their primary purpose is to notify occupants of potentially hazardous conditions. However, a warning system without automatic ventilation does not itself remove smoke from the monitored environment.

2.2 Automatic Ventilation System

Automatic ventilation systems control fans according to measured environmental parameters. Threshold-based control provides a simple method: when a sensor reading crosses a programmed limit the controller activates the fan; when the reading returns to an acceptable range the controller deactivates the fan.

2.3 Microcontroller-Based Smoke Monitoring

Arduino-based systems are frequently used in educational and prototype applications because they offer accessible programming, analog input facilities, and digital output control. The project integrates an MQ-2 sensor, Arduino Uno, buzzer, LED indicators, MOSFET, and DC exhaust fan.

2.4 Research Gap

Questions remain regarding sensor selectivity, threshold calibration, response time, smoke-reduction effectiveness, hysteresis around the threshold, and reliability during power interruptions. The present design establishes the basic detection-and-response mechanism for further experimental evaluation.

III. OBJECTIVES AND SYSTEM SCOPE

3.1 Objectives

The primary objectives of the proposed system are:

1. To detect smoke-related changes using an MQ-2 sensor.
2. To continuously monitor the sensor output using an Arduino Uno.
3. To compare sensor readings with a predefined detection threshold.
4. To activate an audible alarm when the reading exceeds the threshold.
5. To provide visual status indication through red and green LEDs.
6. To operate a 12 V DC exhaust fan automatically through a MOSFET.
7. To deactivate the fan and alarm when the value returns below the threshold.
8. To develop a low-cost prototype using readily available components.

3.2 System Scope

The system is intended for prototype-level smoke-responsive ventilation in kitchens, laboratories, workshops, storage rooms, and basements. It does not include wireless communication, cloud monitoring, or certified fire-alarm functionality and should not replace certified safety equipment.

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IV. SYSTEM ARCHITECTURE AND CIRCUITRY

4.1 System Architecture

The proposed architecture consists of five principal stages: power supply and voltage regulation, smoke sensing, microcontroller processing, alarm and status indication, and exhaust fan switching. A 12 V DC adapter feeds the power distribution block. The 12 V rail supplies the MOSFET and exhaust fan, while a 5 V regulator supplies the Arduino and MQ-2 sensor.

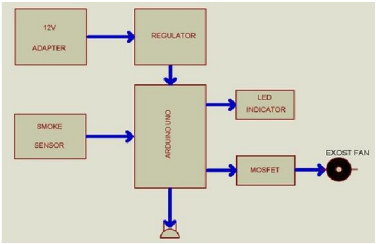


Figure 1. Functional block diagram of the system.

4.2 MQ-2 Smoke Sensor

The MQ-2 sensor responds to smoke and several combustible gases. Its analog output connects to Arduino pin A0. The program uses a threshold of 400 (ADC units 0–1023). This value is not a calibrated concentration and must be determined by testing. The sensor requires warm-up before reliable readings.

4.3 Arduino Uno Microcontroller

The Arduino Uno reads the sensor, compares the value with the threshold, controls the buzzer and LEDs, drives the MOSFET gate, and reports status over the serial interface.

Table I: Arduino Pin Assignments

Component	Pin	Function
MQ-2 analog	A0	Sensor input
Buzzer	D8	Audible alarm
Red LED	D7	Smoke alert
Green LED	D6	Normal status
MOSFET gate	D5	Fan control

4.4 Power Supply and Voltage Regulation

A 12 V DC adapter is the primary supply. The 12 V line feeds the exhaust fan and the regulator input. A 5 V regulated output supplies the Arduino and low-voltage components. All grounds share a common reference.

4.5 MOSFET Switching and Circuit Diagram

The Arduino cannot supply the fan current. A MOSFET acts as a low-side switch. A flyback diode protects against inductive spikes. A logic-level MOSFET is preferred for reliable 5 V gate drive.

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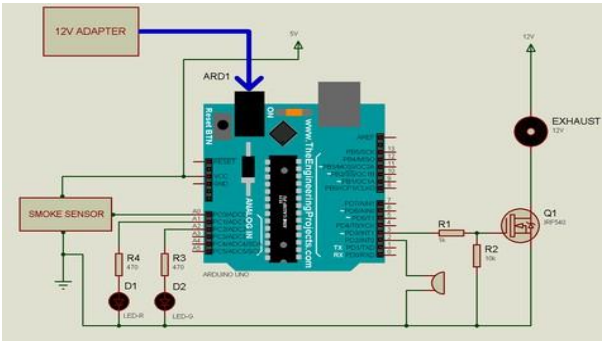


Figure 2. Circuit diagram of the smoke detector system.

4.6 Alarm and LED Circuitry

The buzzer provides an audible warning. The red LED indicates smoke detection; the green LED indicates the normal state. Current-limiting resistors are used with each LED.

V. POWER MANAGEMENT MATRIX

Power is distributed to sensing, control, warning, and ventilation sections. Exact currents should be measured from datasheets.

Table II: Power Management Summary

Component	Supply	Note
DC adapter	12 V	Main supply
Regulator	5□12 V	Thermal care
Arduino Uno	5 V	Stable supply
MQ-2 sensor	5 V	Heater load
Buzzer / LEDs	5 V	Limit current
MOSFET	Gate 5 V	Logic-level
Exhaust fan	12 V	Startup current

VI. ALGORITHMIC WORKFLOW AND PROTECTION LOGIC

6.1 Algorithmic Workflow

After sensor warm-up the microcontroller repeatedly reads pin A0 and compares it with threshold 400. If the value exceeds the threshold, the red LED and buzzer turn ON and the MOSFET switches the exhaust fan ON. Otherwise the outputs remain in the normal state. A 500 ms delay separates successive readings.

6.2 Protection Logic

Recommended measures include hysteresis, detection of implausible readings, adequate startup-current capacity, fusing, reverse-polarity protection, a flyback diode, and a defined safe default for the fan-control output.

VII. DATA ANALYSIS AND OBSERVATIONS

Under normal conditions the reading stays below the threshold: red LED and buzzer OFF, green LED ON, fan OFF. When the reading exceeds 400 the red LED, buzzer, and fan turn ON. When the reading falls to 400 or below the outputs return to the normal state.

Table III: Functional State Analysis

Condition	ADC	Red	Green	Buzzer	Fan
Normal	400□	OFF	ON	OFF	OFF

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Smoke detected	>400	ON	OFF	ON	ON
Recovery	400□	OFF	ON	OFF	OFF

VIII. ENGINEERING ADVANTAGES

- Automatic Operation: Fan runs according to the sensor reading, reducing manual switching.
- Combined Warning and Ventilation: Audible and visual warnings accompany fan activation.
- Potential Energy Savings: Fan operates only when the detection condition is met.
- Low Component Cost: Uses readily available Arduino, MQ-2, LEDs, buzzer, MOSFET, and fan.
- Simple Implementation: Threshold-based algorithm is easy to implement and modify.
- Modular Architecture: Sensing, processing, warning, and ventilation can be updated independently.

IX. SYSTEM LIMITATIONS

- Limited Sensor Selectivity: MQ-2 responds to several gases and cannot identify every hazard.
- Dependence on Threshold Calibration: A fixed threshold may not suit every room or sensor unit.
- Warm-Up Requirements: Readings before stabilization may be unreliable.
- No Certified Fire-Safety Function: The prototype is educational and is not a certified life-safety system.
- Electrical and Thermal Constraints: Regulator heating, startup current, and switching transients must be managed.

X. FUTURE RESEARCH DIRECTIONS

- Sensor Calibration: Relate ADC readings to independently measured concentrations.
- Hysteresis-Based Control: Separate activation and deactivation thresholds.
- Intelligent Fan-Speed Control: PWM or motor-controller speed adjustment.
- Multi-Sensor and IoT Integration: Particulate sensors and wireless remote alerts.
- Fault Detection and Backup Power: Sensor/fan fault checks and temporary supply backup.

XI. CONCLUSION

This paper presents a smoke detector with automatic exhaust fan using an MQ-2 sensor and Arduino Uno. The system integrates sensing, threshold-based decision-making, audible and visual warnings, and MOSFET-controlled 12 V fan ventilation. The design is affordable, modular, and easy to implement. Further work should address experimental validation, detection accuracy, response time, ventilation effectiveness, and improved control algorithms.

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