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Design and construction of an Arduino-based smoke detection system

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ABSTRACT

This study describes the design, implementation, and evaluation of an Arduino-based smoke detection system that integrates both hardware and software components for reliable smoke monitoring and alert generation. The system employs an MQ2 gas sensor to detect smoke and combustible gases, including methane, butane, and hydrogen. An Arduino Uno microcontroller serves as the central processing unit and interfaces with an LCD, light-emitting diodes (LEDs), and a buzzer to provide real-time visual and auditory alerts. Smoke concentration levels are classified using predefined thresholds and indicated through color-coded LEDs: green for safe conditions, yellow for moderate levels, and red for high concentrations. In critical conditions, the red LED is activated alongside an audible alarm from the buzzer. The control program, developed using the Arduino Integrated Development Environment, continuously reads sensor data, processes smoke concentration levels, and displays real-time information on the LCD. The system was evaluated under three testing scenarios representing low, moderate, and high smoke conditions. The results demonstrate consistent detection performance and rapid system response across all scenarios, confirming its ability to provide timely alerts. Overall, the proposed system offers a low-cost, practical solution for early smoke detection, with potential applications in residential and commercial environments.

Contribution/Originality: This study contributes to the existing literature by presenting a low-cost, integrated Arduino-based smoke detection system. It employs a new estimation methodology based on calibrated MQ2 sensor thresholds for multi-level alerts. This research is among the few studies that have investigated real-time visual and auditory alert integration using Arduino.

1. INTRODUCTION

Fire poses a significant threat to human health and property, with smoke often being an early indicator of fire [1, 2]. Smoke detectors are essential devices that detect smoke particles in the air and alert building occupants to potential fires [3]. The presence of smoke is not limited to residential areas but can occur in various settings, including offices, industrial sites, and natural environments. Uncontrolled smoke can result in severe health risks and considerable property damage, underscoring the need for effective smoke detection and monitoring systems [4-6].

Traditional fire monitoring methods relied on manual observation, which involved positioning personnel to detect smoke visually at strategic points. However, this approach has limitations in accurately determining smoke concentration and reacting quickly enough to prevent escalation [7]. Technological advancements have introduced digital smoke detectors capable of assessing smoke concentration in real time, providing reliable and immediate alerts to ensure safety.

This study aims to design and construct an Arduino-based smoke detection system that detects smoke levels surpassing safe thresholds and measures smoke concentration in parts per million (ppm). Equipped with an MQ2 smoke sensor and an LCD, the system indicates smoke concentration and triggers an audible alarm if levels exceed safety thresholds. This development enhances early warning capabilities, which are critical for reducing injury, fatalities, and property damage during fire incidents. Studies have reported that smoke detectors are vital in providing advanced warnings, allowing occupants to respond to fire hazards before they become unmanageable [8-10].

In addition to fire safety, smoke detection has applications in monitoring air quality, particularly in indoor environments where pollutants like cigarette smoke can impact health. Passive exposure to cigarette smoke is notably hazardous, especially for individuals with respiratory conditions such as asthma, as exposure can exacerbate their symptoms [11, 12]. Numerous studies have explored Arduino-based smoke detection systems, including indoor cigarette smoke monitoring and automated air quality control [13-15]. This study builds on previous work by implementing an Arduino-based MQ2 gas sensor for accurate, real-time smoke detection and concentration measurement.

2. LITERATURE REVIEW

The detection and control of smoke as a fire indicator have evolved significantly over the years, driven by the need for enhanced safety measures and early warning systems in residential, industrial, and public spaces. Smoke detectors have proven effective in alerting individuals to the presence of smoke, offering crucial time for evacuation and reducing the risk of casualties and property damage [2]. Traditionally, smoke detection systems relied heavily on manual methods, where personnel were stationed to monitor potential smoke or fire hazards visually. However, this method was prone to inaccuracies due to human limitations and often required identifying smoke concentration levels, making it challenging to assess the severity of potential fire hazards [3].

Technological advancements have enabled the development of more sophisticated smoke detection systems that utilize digital sensors to detect smoke with increased accuracy and reliability. Digital smoke detectors are widely implemented in modern safety systems, employing sensors to measure smoke concentration and transmit real-time information, often with embedded alarm mechanisms [16, 17]. The introduction of the Internet of Things (IoT) and microcontroller technology, such as Arduino, has further enhanced smoke detection capabilities. IoT-based smoke detectors can transmit real-time data to remote systems, offering expanded functionalities for fire detection and air quality monitoring in diverse environments [18, 19].

Arduino-based smoke detection systems, in particular, have been explored for their affordability, adaptability, and ease of programming. Studies by Habib et al. [20] and Ilham et al. [21] highlighted the advantages of Arduino in creating modular smoke detection systems that can be tailored to specific needs. Arduino can be used to design smoke detectors that not only sense the presence of smoke but also measure smoke concentration in parts per million (ppm), allowing users to monitor air quality dynamically. In addition, incorporating sensors such as the MQ series enables these systems to differentiate between various gases, adding versatility to their applications in detecting household smoke, industrial emissions, and indoor pollutants like cigarette smoke [22].

The relevance of smoke detection extends beyond fire safety, as prolonged exposure to smoke from sources such as cigarettes has been associated with respiratory and cardiovascular issues. Cigarette smoke, for instance, contains harmful particles that, when inhaled even secondhand, can significantly impact health, particularly in vulnerable populations like children and those with preexisting respiratory conditions [23]. Advanced Arduino-based systems have been developed specifically for monitoring cigarette smoke, enabling real-time air quality tracking and alerting users when pollutant levels exceed safe thresholds. Such systems use MQ sensors, paired with Arduino boards, to detect smoke particles and gases, providing valuable data that supports improved indoor air quality management [13].

In recent years, Arduino-based smoke detection systems have also been combined with GSM and Wi-Fi modules, allowing data transmission to mobile devices and cloud servers, thereby broadening their applicability in residential and industrial contexts. These systems are particularly beneficial for remote locations and larger buildings where traditional fire alarms may be less effective in delivering timely alerts. As demonstrated in studies by Adenan et al. [5] and Ilham et al. [21], incorporating wireless communication in smoke detectors enables notifications to be sent to users' smartphones, offering a proactive approach to smoke monitoring. Such IoT integration supports continuous smoke surveillance, enabling users to respond promptly to fire hazards, even when not physically present at the site [24].

Current developments also highlight the potential for Arduino-based smoke detectors in integrated health environments. Systems capable of tracking cigarette smoke levels are beneficial in hospitals, schools, and workplaces, where air quality plays a crucial role in health and productivity. By implementing smoke detection technologies with display units, alarms, and reset functions, Arduino-based systems can maintain safer indoor environments and assist in enforcing air quality standards that safeguard occupants from smoke exposure risks [25].

This study builds upon these advancements by designing an Arduino-based smoke detection system utilizing the MQ2 sensor to detect and display smoke concentrations. It leverages existing research to create an adaptable, user-friendly smoke detector that can alert occupants to smoke presence while providing valuable data on smoke concentration levels. This system, equipped with a resettable alarm and an LCD for real-time display, addresses fire safety and indoor air quality monitoring, reflecting a comprehensive approach to smoke detection technology.

3. METHOD

The design of this Arduino-based smoke detection system incorporates both hardware and software components, effectively integrating a series of sensors, visual indicators, and an auditory alarm to signal the detection of smoke. The study relies primarily on an MQ2 gas sensor, an Arduino Uno microcontroller, and additional peripherals, such as LEDs, a buzzer, and a liquid crystal display (LCD) for visual readouts. The MQ2 sensor detects gas concentration by measuring changes in its resistance. The sensor's resistance R_s varies inversely with gas concentration and is given by Ajiboye et al. [26].

$$R_s = R_{load}\left(\frac{V_{out}}{V_{in} - V_{out}}\right) \quad (1)$$

R_{load} is the load resistor used in the circuit, V_{out} is the voltage across the sensor output, and V_{in} is the input voltage (typically 5V for Arduino).

The hardware components were selected based on their compatibility and functionality within an Arduino environment. The MQ2 gas sensor is the primary smoke-detection unit due to its ability to sense various gases, including smoke, methane, butane, and hydrogen. Figure 1 illustrates the MQ2 gas sensor module and its key components used for smoke and gas detection. The figure shows the sensing element, which is responsible for detecting smoke and combustible gases, mounted on the sensor head. The module includes a voltage comparator IC that enables digital signal processing, allowing the sensor to provide both analog (AO) and digital (DO) outputs. A sensitivity potentiometer is integrated to adjust the detection threshold, while the power LED indicates module activation and the output LED signals gas detection status. The VCC and GND pins supply power to the module, ensuring compatibility with Arduino-based systems.

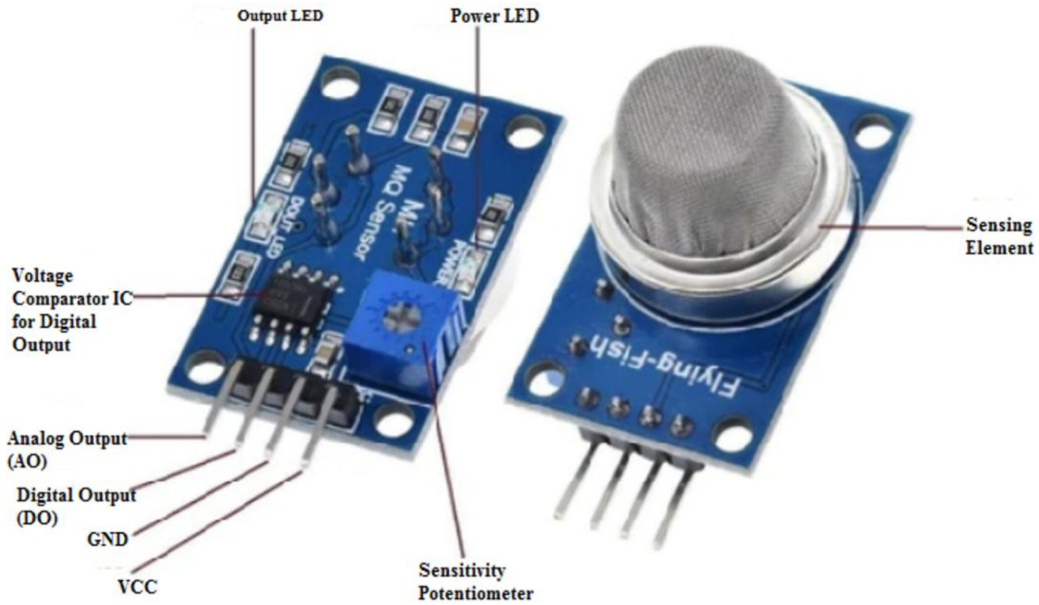

Figure 1. MQ2 gas/Smoke sensor.

The sensor's analog output is connected to the Arduino's analog pin to enable precise readings of gas concentrations. The gas concentration C (in ppm) detected by the MQ2 sensor can be modeled by a logarithmic relation [27]:

$$log\,(C) \;=\; a.log\left(\frac{R_S}{R_0}\right) + b \qquad (2)$$

R_0 is the sensor resistance in clean air, a and b are empirically determined constants specific to the gas type and sensor.

Additional hardware components include a 5V power supply, a 16x2 LCD for displaying sensor readings, and three LEDs (green, yellow, and red), which serve as visual indicators of smoke levels. Figure 2 shows the 16×2 liquid crystal display (LCD) module used to present real-time sensor readings and system status information. The figure highlights the pin configuration of the LCD, including power supply pins (VSS, VDD), contrast control (V0), control pins (RS, RW, and E), and data pins (D0–D7) for communication with the Arduino microcontroller. The backlight connections (A and K) provide display illumination, ensuring clear visibility of information. This display module enables continuous monitoring of smoke concentration levels and system alerts, supporting effective user interaction with the smoke detection system.

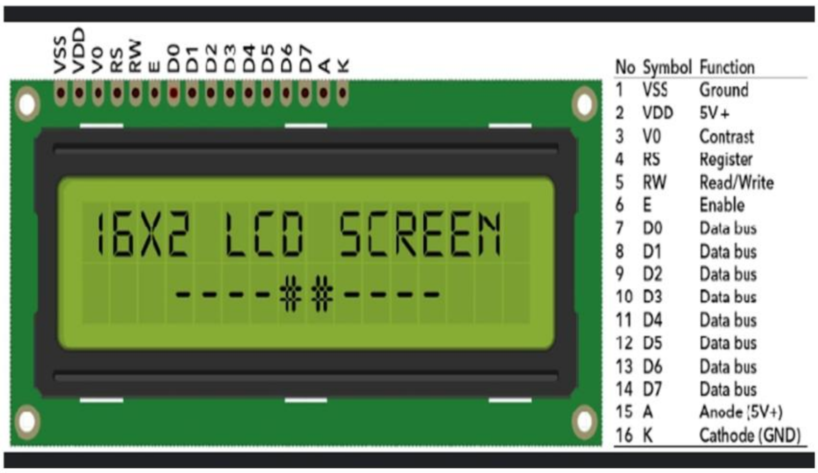

Figure 2. 16 by 2 LCD.

The buzzer, controlled by the Arduino, emits an audible alarm when smoke concentrations surpass a specified threshold. The LEDs are color-coded to represent different smoke density levels: green for safe levels, yellow for moderate concentrations, and red for high concentrations that require immediate attention. These components are interconnected using resistors and jumper wires to complete the circuit and prevent damage to the microcontroller. Figure 3 depicts the image of Arduino Uno R3, a popular microcontroller development board based on the ATmega328P chip used in the study. The visible key components include digital and analog I/O pins, the USB Type B port, the power jack, and the reset button, making it ideal for various electronic and IoT projects.

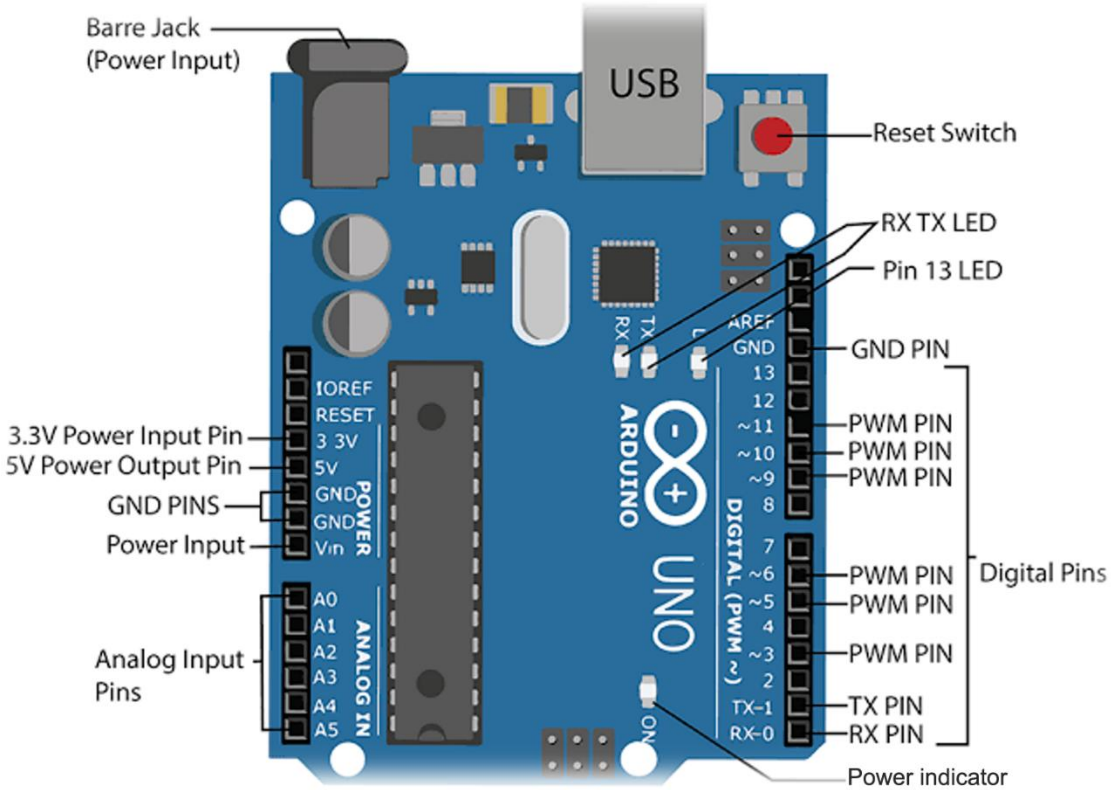

Figure 3. Arduino Uno R3 microcontroller board.

The software component is implemented using the Arduino Integrated Development Environment (IDE), where the code is written to control the system's functionality. It features a simple code editor, a message area, a text console, a toolbar with standard functions, and a set of menus. The Arduino IDE supports C++ programming, enabling users to manage hardware components like sensors and actuators, create interactive projects, and connect with various Arduino-compatible boards.

The LiquidCrystal.h library is included to enable communication between the Arduino and the LCD. The code initializes the MQ2 sensor, LEDs, and buzzer, configuring their input/output pins, and continuously monitors the sensor output. Analog signals from the MQ2 are translated into readable smoke concentrations displayed on the LCD, while predefined thresholds trigger the LEDs and buzzer. When smoke levels exceed 200 ppm, the system shifts from a visual alert (red LED) to a dual-alert mode, activating both the red LED and the buzzer to signal hazardous conditions.

Figure 4 shows that the Arduino Integrated Development Environment (IDE) is used for writing, compiling, and uploading programs to the Arduino Uno. Key elements include the menu bar, verify and upload buttons, text editor, and serial monitor. These components support the implementation of the LiquidCrystal.h library, sensor initialization, pin setup, continuous monitoring, and alert activation.

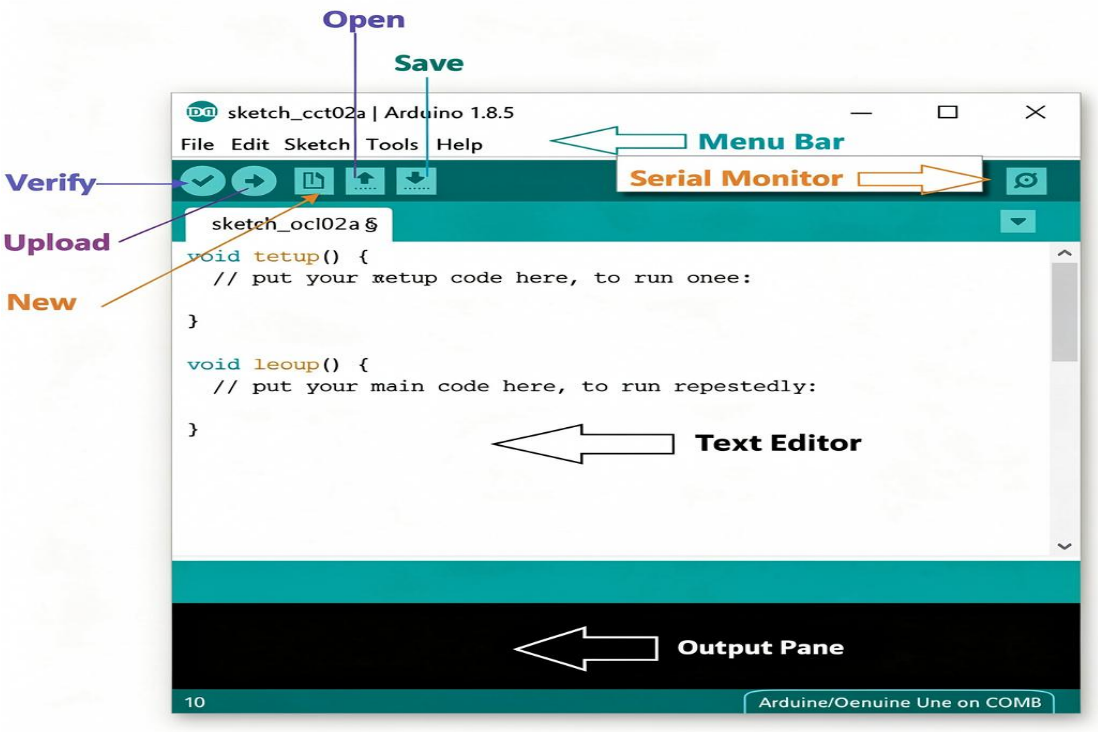

Figure 4. The Arduino integrated development environment (IDE).

The MQ2 sensor was wired to the Arduino's 5V power and ground, while its analog output was connected to the A0 analog input on the Arduino. The LCD's pin setup is as follows: RS is connected to digital pin 12, RW to ground, VSS to ground, VDD to 5V, E to pin 11, and data pins D4-D7 connect to pins 10-7, respectively. A potentiometer adjusts the LCD's contrast. The LEDs were attached to digital pins 3, 4, and 5 via 220-ohm resistors, with their common ground connected to the Arduino's ground. The buzzer connects to digital pin 2, with the push button linked to pin 6 via a pull-up resistor. Table 1 shows the connection of the LCD to the Arduino.

Table 1. Connection of the LCD with the Arduino.

Lcd pins	Connections
RS	Connected to digital pin 12 of the Arduino
RW	Connected to the ground of the Arduino
VSS	Connected to the ground of the Arduino
VDD	Connected to the 5V of the Arduino
Enable (E)	Connected to digital pin 11 of the Arduino
V0 (Contrast Pin)	Connected to a Pot
K (Cathode Pin)	Connected to the ground of the Arduino
A (Anode)	Connected to Arduino 5V through a 10K resistor
D4	Connected to Digital Pin 10 of the Arduino
D5	Connected to Digital Pin 9 of the Arduino
D6	Connected to Digital Pin 8 of the Arduino
D7	Connected to Digital Pin 7 of the Arduino

The overall system operation follows a structured sequence where the Arduino monitors smoke concentrations continuously. The green LED remains illuminated in safe conditions, and the LCD displays the current ppm value. When smoke levels rise, the yellow LED indicates increasing concentration, while the red LED and buzzer activate when the threshold is exceeded. The buzzer sounds until the smoke concentration drops below the set level or the push button is pressed, temporarily silencing the alarm for two minutes.

4. RESULTS AND DISCUSSIONS

Testing the smoke detection system demonstrated that it effectively detects and responds to various smoke levels, transitioning seamlessly through the LED indicators and activating the buzzer at hazardous concentrations. Figures 5a and 5b show the complete setup of the system and the test running of the smoke detector with the program.

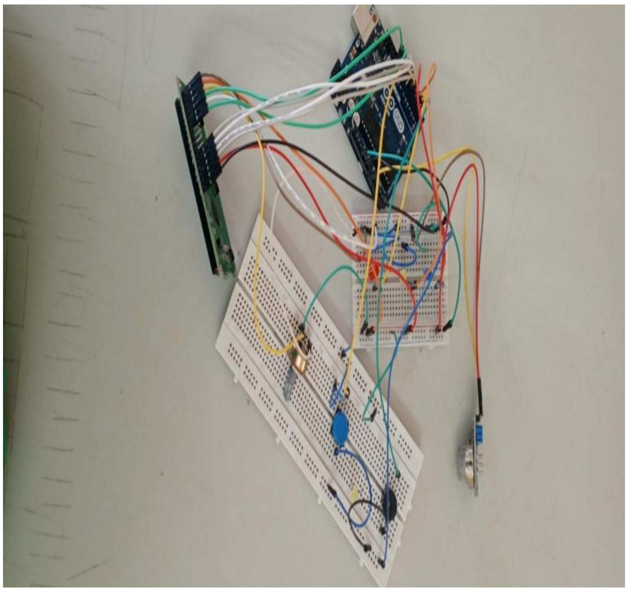

Figure 5a. The complete setup.

Figure 5b. Test running of the smoke detector with the program.

The LCD provided real-time feedback on smoke concentration in ppm, offering a clear visual display of changes in smoke density. The red LED and buzzer alert successfully engaged once the concentration surpassed 200 ppm, providing a reliable signal for intervention. The push button also functioned as expected, muting the alarm temporarily during testing. Figure 6 depicts the testing of the smoke detector functionality.

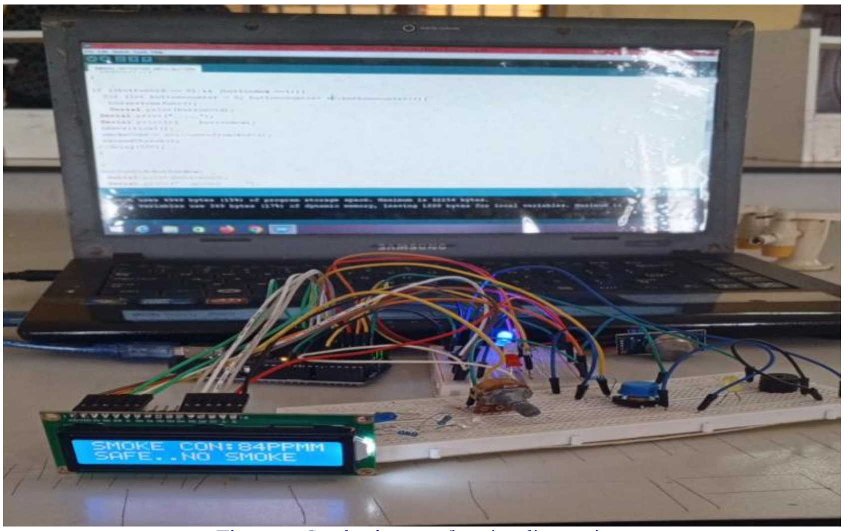

Figure 6. Smoke detector functionality testing.

The system consistently responded to varying smoke densities in multiple simulated smoke tests within seconds, confirming its sensitivity and prompt response rate. This rapid detection and signaling make it a viable solution for early smoke detection in residential or commercial settings. The system remained stable throughout testing, with no interference or false alarms, highlighting the selected components' reliability and the Arduino-based design's efficacy.

Three tests were conducted at varying smoke concentrations to assess the system's effectiveness. Each test measured the system's response time, accuracy in displaying smoke levels, and the activation of visual and audible alerts. The tests confirm the system's ability to detect and signal hazardous conditions, providing consistent, early warnings.

Test 1: Baseline Smoke Detection

The system was exposed to a controlled environment with minimal smoke during the initial test. The MQ2 sensor recorded smoke concentrations below 100 ppm. The green LED remained on, the yellow and red LEDs stayed off, and the buzzer was inactive. This test confirmed that the system correctly identifies safe conditions without triggering unnecessary alarms. The LCD accurately displayed low concentration levels, and no false alarms were observed.

Test 2: Warning Threshold Response

The second test introduced moderate smoke levels to evaluate the system's response as concentrations approached the warning threshold. As the smoke concentration increased to 150 ppm, the yellow LED illuminated, indicating a warning state. The red LED and buzzer remained off, as the concentration had not reached critical levels. This test validated the accuracy of the yellow LED warning mechanism and the system's ability to distinguish between safe and warning levels. The LCD displayed the concentration level in real-time, matching expected sensor readings with a delay of less than one second.

Test 3: Critical Alert Activation

In the final test, smoke levels exceeded 200 ppm, crossing the critical threshold. The red LED illuminated, and the buzzer was activated, providing a clear and immediate alert. The system transitioned from warning to critical state as concentrations increased, with the buzzer and red LED remaining active until the concentration fell below the threshold. This test demonstrated the system's responsiveness in critical situations, with an alert delay of approximately 0.8 seconds.

The tests confirmed that the Arduino-based smoke detection system reliably detects and signals varying smoke concentration levels. With minimal delay, the LEDs and buzzer activate accurately at the pre-set thresholds. The system's functionality across safe, warning, and critical states suggests it can be an effective early smoke detection tool for home and industrial applications. Table 2 summarizes the three tests assessing the Arduino-based smoke detection system's performance.

Table 2. System performance at varying smoke concentration levels.

Test	Smoke Concentration (ppm)	LED Status	Buzzer Status	LCD Display	Response Time	Observations
Test 1	Below 100 ppm	Green LED on; Yellow and red off	Inactive	Low concentration levels	Immediate	The system accurately identifies safe conditions without triggering alarms; no false alarms were observed.
Test 2	150 ppm	Yellow LED on; Red and green off	Inactive	Real-time concentration display	< 1 second	The system enters a warning state at the correct threshold; the LCD concentration is accurate.
Test 3	Above 200 ppm	Red LED on; Green and yellow off	Active	Critical concentration display	0.8 seconds	The system transitions to a critical state with immediate visual and audible alerts until the smoke is reduced.

These results showed that the system responds accurately to varying smoke concentration levels, with LED and buzzer alerts activating reliably at each threshold level. This makes it a viable early smoke detection tool for practical applications.

5. CONCLUSION

In conclusion, the design and construction of an Arduino-based smoke detection system have demonstrated its efficacy in detecting varying levels of smoke concentration, ensuring timely alerts in potentially hazardous situations. The system integrates hardware components such as the MQ2 gas sensor, LEDs, buzzer, and LCD, coupled with a responsive software framework to provide visual and auditory warnings. The system consistently responded to smoke concentrations during testing, accurately signaling safe, warning, and critical states within seconds. Incorporating clear LED indicators, a buzzer, and real-time LCD feedback enhances the system's reliability and usability, making it suitable for early smoke detection in residential and industrial settings. The test results confirm that this system effectively distinguishes between different smoke density levels and alerts users accordingly, highlighting its potential as a practical and cost-effective solution for enhancing safety measures. Future improvements include expanding sensor compatibility and integrating wireless connectivity for remote monitoring, increasing its versatility and applicability.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] D. M. J. S. Bowman and F. H. Johnston, "Wildfire smoke, fire management, and human health," *EcoHealth*, vol. 2, no. 1, pp. 76-80, 2005. https://doi.org/10.1007/s10393-004-0149-8

[2] C. Black, Y. Tesfaigzi, J. A. Bassein, and L. A. Miller, "Wildfire smoke exposure and human health: Significant gaps in research for a growing public health issue," *Environmental Toxicology and Pharmacology*, vol. 55, pp. 186-195, 2017. https://doi.org/10.1016/j.etap.2017.08.022

[3] F. Khan, Z. Xu, J. Sun, F. M. Khan, A. Ahmed, and Y. Zhao, "Recent advances in sensors for fire detection," *Sensors*, vol. 22, no. 9, p. 3310, 2022. https://doi.org/10.3390/s22093310

[4] M. F. Ballesteros and M.-J. Kresnow, "Prevalence of residential smoke alarms and fire escape plans in the US: Results from the Second Injury Control and Risk Survey (ICARIS-2)," *Public Health Reports*, vol. 122, no. 2, pp. 224-231, 2007. https://doi.org/10.1177/003335490712200212

[5] M. S. M. Adenan, A. N. M. Erwan, and M. N. H. M. Alfian, "Smart smoke detector," *International Journal of Recent Technology and Applied Science*, vol. 3, no. 1, pp. 16-31, 2021. https://doi.org/10.36079/lamintang.ijortas-0301.198

[6] M. Sinha, S. Solanki, S. Batra, Y. Arora, and A. Tewatia, "Fire alarm system through smoke detection," *International Journal of Innovative Research in Computer Science and Technology*, vol. 11, no. 4, pp. 1–4, 2023. https://doi.org/10.55524/ijircst.2023.11.4.1

[7] S. N. Saydirasulovich, M. Mukhiddinov, O. Djuraev, A. Abdusalomov, and Y.-I. Cho, "An improved wildfire smoke detection based on YOLOv8 and UAV images," *Sensors*, vol. 23, no. 20, p. 8374, 2023. https://doi.org/10.3390/s23208374

[8] K. S. Reisinger, "Smoke detectors: Reducing deaths and injuries due to fire," *Pediatrics*, vol. 65, no. 4, pp. 718–724, 1980. https://doi.org/10.1542/peds.65.4.718

[9] D. Rohde, J. Corcoran, M. Sydes, and A. Higginson, "The association between smoke alarm presence and injury and death rates: A systematic review and meta-analysis," *Fire Safety Journal*, vol. 81, pp. 58-63, 2016. https://doi.org/10.1016/j.firesaf.2016.01.008

[10] S. Festag, "Analysis of the effectiveness of the smoke alarm obligation–Experiences from practice," *Fire Safety Journal*, vol. 119, p. 103263, 2021. https://doi.org/10.1016/j.firesaf.2020.103263

[11] N. Korsbæk, E. M. Landt, and M. Dahl, "Second-hand smoke exposure associated with risk of respiratory symptoms, asthma, and COPD in 20,421 adults from the general population," *Journal of Asthma and Allergy*, vol. 14, pp. 1277-1284, 2021. https://doi.org/10.2147/JAA.S328748

[12] L. S. Flor *et al.*, "Health effects associated with exposure to secondhand smoke: A Burden of Proof study," *Nature Medicine*, vol. 30, no. 1, pp. 149-167, 2024. https://doi.org/10.1038/s41591-023-02743-4

[13] M. A. Al Ahasan, S. Roy, A. Saim, R. Akter, and M. Z. Hossain, "Arduino-Based real time air quality and pollution monitoring system," *International Journal of Innovative Research in Computer Science & Technology*, vol. 6, no. 4, pp. 1-6, 2018. https://doi.org/10.21276/ijircst.2018.6.4.8

[14] J. H. Cho, "Detection of smoking in indoor environment using machine learning," *Applied Sciences*, vol. 10, no. 24, p. 8912, 2020. https://doi.org/10.3390/app10248912

[15] F. M. F. Siqueira and L. de Sousa Santos, "Use of Arduino for monitoring the air quality of indoor environments," *The Journal of Engineering and Exact Sciences*, vol. 8, no. 11, pp. 15050-01e, 2022. https://doi.org/10.18540/jcecvl8iss11pp15050-01e

[16] O. O. Khalifa, A. Albagul, S. Khan, M. R. Islam, and N. M. Usman, "Wireless smoke detection system," presented at the 2008 International Conference on Computer and Communication Engineering, IEEE, 2008.

[17] Q. Wu *et al.*, "Intelligent smoke alarm system with wireless sensor network using ZigBee," *Wireless Communications and Mobile Computing*, vol. 2018, no. 1, p. 8235127, 2018. https://doi.org/10.1155/2018/8235127

[18] A. Sungheetha and R. Sharma, "Real time monitoring and fire detection using internet of things and cloud based drones," *Journal of Soft Computing Paradigm*, vol. 2, no. 3, pp. 168-174, 2020.

[19] S. H. Park, D. H. Kim, and S. C. Kim, "Recognition of IoT-based fire-detection system fire-signal patterns applying fuzzy logic," *Heliyon*, vol. 9, no. 2, p. e12964, 2023. https://doi.org/10.1016/j.heliyon.2023.e12964

[20] M. R. Habib *et al.*, "Quick fire sensing model and extinguishing by using an Arduino based fire protection device," presented at the 2019 5th International Conference on Advances in Electrical Engineering, 2019.

[21] D. N. Ilham, R. A. Candra, M. S. Talib, M. di Nardo, and K. Azima, "Design of smoke detector for smart room based on Arduino Uno," *Brilliance: Research of Artificial Intelligence*, vol. 1, no. 1, pp. 13-18, 2021. https://doi.org/10.47709/brilliance.v1i1.1079

[22] M. T. Jacob *et al.*, "Low-cost air quality monitoring system design and comparative analysis with a conventional method," *International Journal of Energy and Environmental Engineering*, vol. 12, no. 4, pp. 873-884, 2021. https://doi.org/10.1007/s40095-021-00415-y

[23] H. M. Tran *et al.*, "The impact of air pollution on respiratory diseases in an era of climate change: A review of the current evidence," *Science of the Total Environment*, vol. 898, p. 166340, 2023. https://doi.org/10.1016/j.scitotenv.2023.166340

[24] M. Abdennabi *et al.*, "IoT-enabled fire detection for sustainable agriculture: A real-time system using flask and embedded technologies," *Results in Engineering*, vol. 23, p. 102705, 2024. https://doi.org/10.1016/j.rineng.2024.102705

[25] M. Z. Tun and H. Myint, "Arduino based fire detection and alarm system using smoke sensor," *International Journal of Advances in Scientific Research and Engineering*, vol. 6, no. 4, pp. 89-94, 2020. https://doi.org/10.31695/IJASRE.2020.33792

[26] A. T. Ajiboye, J. F. Opadiji, A. O. Yusuf, and J. O. Popoola, "Analytical determination of load resistance value for MQ-series gas sensors: MQ-6 as case study," *ELKOMNIKA Telecommunication, Computing, Electronics and Control*, vol. 19, no. 2, pp. 575-582, 2021. http://doi.org/10.12928/telkomnika.v19i2.17427

[27] D. I. Sohibun, R. G. Hatika, and D. Mardiansyah, "MQ-2 gas sensor using micro controller Arduino Uno for LPG leakage with short message service as a media information," *Journal of Physics: Conference Series*, vol. 2049, no. 1, p. 012068, 2021. https://doi.org/10.1088/1742-6596/2049/1/012068