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Fire and Smoke Detector Alarm using Arduino and MQ2 Sensor

Srujan H R[1], Srushti S M[2], V Sai Hitesh Gowda[4], Spoorthi G[4], Sudhakara H M[5]
Department of Electronics and Communication Engineering[1-5]
Alvas Institute of Engineering and Technology, Mijar, India

Abstract: *The fire detection system integrates simultaneous monitoring of smoke, carbon monoxide (CO), and carbon dioxide levels. It also addresses campus security by monitoring intruders in areas like laboratories, classrooms, staff rooms, or washrooms. The system comprises fire detectors (such as smoke, heat, or infrared detectors), a control unit, and an alarm system. This fire detection solution is designed based on concurrent measurements of temperature and smoke levels. The alarm algorithm enhances fire detection by identifying fires that traditional smoke sensors might miss, and it provides quicker alerts.*
The primary aim of this research is to mitigate fire risks caused by electrical short circuits and LPG leaks. It offers insights into a fire and smoke detection system built on an embedded platform, utilizing components like an Arduino Uno board, MQ2 sensor, piezo buzzer, 16x2 LCD display, breadboard, and jumper wires. This system outperforms standalone smoke sensors by improving detection accuracy. Previous algorithms relied on sensor data for temperature, smoke, and combustion byproducts. The smoke sensor in this system triggers an alarm when its analog output meets or exceeds the defined threshold value. The node incorporates analog sensors to measure smoke, carbon monoxide, and temperature, ensuring timely and reliable notification to building occupants about potential fire hazards, such as smoke or high temperatures.

Keywords: Arduino UNO, MQ2Gas Sensor, DH-11sensor, GSM Module, LCD, Buzzer, Embedded System, Fire, Smoke.

I. INTRODUCTION

Fire and gas detection alarm systems are crucial for ensuring safety in homes, buildings, offices, markets, and various other locations described in web [1]. A well-designed fire and gas system is developed to identify potential hazards from fires, flammable gases, and toxic gases, and, in some cases, automatically mitigate them. Strategic placement of detectors is vital to ensure comprehensive coverage, enabling the system to detect hazards at an early stage and prevent further escalation.

Forest fires, also referred to as bushfires or hill fires, are uncontrolled blazes that occur in forests or wildland areas. Detecting such fires at an early stage is crucial to mitigating their devastating impact on the environment. Each year, millions of acres of forest are destroyed by fire, leaving the affected land barren and unsuitable for vegetation growth. This occurs because the soil becomes hydrophobic, preventing water absorption and causing a decline in groundwater levels [2].

According to stipanicev et al [3], Fire poses significant risks, leading to loss of life and property. Implementing effective fire detection systems is crucial to minimizing such damage. Advances in fire warning technologies have contributed to a gradual decline in firerelated injuries. Early fire alarms are essential for preventing hazards, enabling prompt responses to dangerous situations. The Internet of Things (IoT) encompasses a network of interconnected sensors, actuators, applications, and embedded electronics in devices like home appliances and vehicles.

According to p.j Vivek et al [4], The fire alarm algorithm uses the rate of increase in smoke, heat, and gas levels to identify the presence of a fire. Smoke sensors play a pivotal role in detecting smoke and providing early fire warnings. Heat detectors, being one of the oldest fire detection devices, activate either when a specific temperature is reached or when there is a rapid rise in temperature directly.

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A fire alarm system is a fundamental safety feature that is mandated for installation in households and buildings across many countries. These systems play a crucial role in providing early warnings about potential fires, alerting occupants, and automatically notifying emergency services and contacts. This reduces response times for fire departments, decreases the risk of false alarms, identifies specific faults in the system, and minimizes fire-related property damage. Such systems are vital for ensuring the safety and security of people and assets described in [5].

According to may zaw tun [6], Fire and gas detection alarm systems are essential for protecting homes, buildings, offices, markets, and other spaces. A well-designed fire and gas detection system is built to identify potential hazards such as fires, flammable gases, and toxic gases, and in some cases, it can automatically mitigate these risks. Proper placement of detectors is crucial to ensure adequate coverage and the early detection of hazards to prevent their escalation. The system uses the rates of increase in critical parameters to determine the presence of a fire through an advanced fire alarm algorithm. Smoke sensors play a vital role by detecting smoke and providing early warnings of a fire. Heat detectors, among the oldest types of automatic fire detection devices, activate when the sensing element reaches a specific fixed temperature or when there is a rapid change in temperature.

II. LITERATURE SURVEY

The literature on fire and smoke detection using the MQ2 sensor highlights its reliability in sensing changes in gas concentration, triggering alarms when thresholds are exceeded. Arduino-based systems are widely discussed for their affordability, simplicity, and ability to integrate with other components like buzzers, LEDs, and communication modules. These features enhance the system's functionality, allowing for local alerts and remote notifications via GSM, Wi-Fi, or IoT-based platforms.

1.Jinan (2018) [7], developed and implemented a factory security system incorporating a smoke sensor, a GSM (Global System for Mobile Communication) module, and a sound module. When gas leakage is detected, the system sends an SMS alert to a designated number. However, a limitation of this system is the lack of a mechanism to stop the gas leakage. Additionally, the system does not include any fire suppression devices, which could potentially lead to property damage in the event of a fire outbreak.

2.Poonam et al. (2014) [8] developed an Intelligent Fire

Extinguisher System with several key features, including intelligent fire detection and suppression, the ability to locate the fire's origin, efficient power control for electricity, and reporting via SMS or email. The system also optimizes the use of water supply. One of the sensors used is a gas sensor that detects smoke, but it may sometimes trigger false alarms, making it less reliable.

3.In 2016, Md Iftekhar Mobin et al [9], introduced a comprehensive fire protection system designed to prevent the spread of fire and carry out essential actions. The system collects input signals from various sensors placed throughout the monitored area and utilizes integrated fuzzy logic to identify the location and severity of the fire outbreak.

4.Qin et al [10], developed an intelligent smoke alarm system utilizing a wireless sensor network based on ZigBee technology. The system comprises a smoke detection module, a wireless communication module, and an intelligent identification and data visualization module. However, a drawback of this system is its high cost and the complexity involved in its design.

5.Izang et al [11], developed an SMS-based fire alarm and detection system. When the sensors detect fire or gas, the Arduino triggers the GSM module to send an SMS, activate the alarm, and operate the servo motor. However, a limitation of this system is that the servo motor operates at an angle of 170 degrees, which is less effective in controlling a fire compared to using a pump motor.

6.This paper provides an in-depth review of various fire and smoke detection methods using machine vision, with a focus on deep learning techniques like Convolutional Neural Networks (CNNs). The growing risk of fires, driven by urbanization and increasing building structures, demands effective and fast fire detection systems. While traditional smoke sensors work well in smaller areas, they face limitations in large spaces and delays in detection. The advent of video surveillance systems presents a new opportunity to detect fire and smoke from distant locations, but processing the vast amount of data generated by such systems is a major challenge [12].

7.The authors of [13] described, In recent years, fire detection has become a critical area of research due to its significance in public safety and its potential to mitigate damage in the event of a fire emergency. Traditional fire

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detection methods often struggle with issues such as false alarms and limitations in computing power, which have driven the development of more advanced technologies.

Convolutional neural networks (CNNs), apopular deep learning method, have shown promising results in improving the accuracy of fire detection. However, CNN-based systems still face challenges, such as susceptibility to false alarms and computational complexity.

8.Parag Naik et al,.[14] Gas Sensor Using ArduinoUNO MQ2 Sensor, International Journal of Advanced Research in Computer and Communication Engineering reported that Fire alarm systems are categorized into several types: conventional fire alarm systems, addressable fire alarm systems, analogue addressable fire alarm systems, and wireless fire alarm systems. Among these, wireless fire alarm systems offer a practical alternative to traditional wired systems for a wide range of applications. They are based on a straightforward concept, providing numerous advantages as fully analogue addressable fire detection systems without requiring cables.

9.T. L. Floyd [15], says that the system operates by continuously collecting data from sensors and comparing the readings against predefined thresholds. If the monitored parameters exceed these thresholds, the system identifies a potential fire hazard and triggers an alarm using a buzzer. For enhanced functionality, advanced systems incorporate GSM modules to send SMS notifications or connect to IoT platforms for remote monitoring. Real-time feedback is often displayed on an LCD, allowing users to stay informed about the system's status and any detected hazards.

10.Divya et al[16], highlighted the recognized importance of forests as essential resources, with forest fires continuously threatening ecosystems and environmental balance. Rapid detection of forest fires is critical for effective prevention. The use of wireless sensor networks presents a promising solution, as sensors collect data that is transmitted wirelessly for analysis. This data is then relayed by satellites to ground stations for evaluation, underscoring the significance of wireless sensor networks in early forest fire detection.

11.Mehta et al[17], emphasize the critical need for timely fire detection to minimize its destructive impact on the environment and living organisms. They discuss the potential of IoT technology in fire detection, highlighting its advancements and applications in the firefighting sector. The paper also presents a survey that identifies research trends and challenges in fire detection projects. Furthermore, it introduces a fire detection system developed using Arduino, which includes smoke and temperature sensors and is designed to activate a buzzer alarm upon detecting a fire.

12.The article by Lozano et al[18],outlines a system design for monitoring temperature and humidity to prevent forest fires through the use of wireless sensor networks. A thorough understanding of forest fire causes and prevention techniques is essential for creating an effective network design that can detect environmental changes. The goal of implementing such a system is to avert potential disasters like forest fires, thereby reducing the loss of valuable natural resources.

III. METHODOLOGY

This project focuses on a Fire and Smoke Detection System. When smoke is detected in the indoor environment, the MQ2 sensor senses it as an analog input. This data is processed by an Arduino program, which converts it into a digital output. As a result, a red LED is illuminated, a piezo buzzer sounds an alarm, and the 16x2 LCD displays the message" ALERT!! Smoke detected." The MQ2 sensor provides an analog input value, which is connected to the A4 pin of the Arduino, along with VCC and Ground. The output devices, including a piezo buzzer, a 16x2 LCD, and two LEDs (red and green), are connected to the digital pins of the Arduino Uno board. This methodology outlines the process of designing and implementing a fire and smoke detection alarm system using an Arduino microcontroller and the MQ2 sensor. [19] The system is designed to detect smoke and hazardous gases and trigger an alarm to alert users in case of fire or gas leakage. Below is the step-by-step methodology for the project.

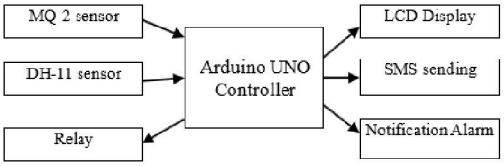

Fig. 1. block diagram

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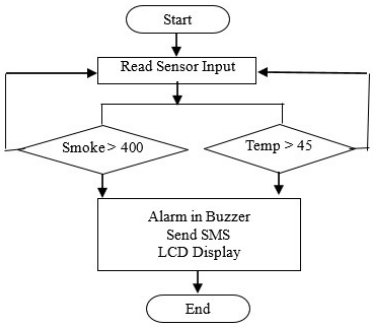

Fig 2 Flowchart

1.Requirement Analysis - System Objective: The primary objective is to develop a fire and smoke detection system that provides early warnings using sensors to detect smoke and gases. Upon detection, the system triggers an alarm and displays a message on an LCD. - Functional Requirements: - Real-time smoke detection. Trigger alarm and alert systems (LED, piezo buzzer). - Display smoke detection status on an LCD. - Hardware Requirements: - MQ2 Sensor for detecting smoke and gases. -

Arduino UNO to process sensor data and control outputs. - Piezo

Buzzer to sound an alarm. - 16x2 LCD Display to show status. Red and Green LEDs for visual indication. - Wiring, Breadboard, and Power Source.

Component Selection and Circuit Design - MQ2 Sensor: The MQ2 gas sensor is capable of detecting a wide range of gases, including smoke, LPG, methane, and other flammable gases. It provides an analog output, which is processed by the Arduino. - Arduino UNO: The Arduino UNO acts as the central controller for the system. It reads input from the MQ2 sensor and controls output devices based on sensor data. Piezo Buzzer: The buzzer emits a loud sound to alert users when smoke or gas is detected. - 16x2 LCD: The LCD displays the message" ALERT!! Smoke detected" when smoke or gas levels exceed predefined thresholds. - Red and Green LEDs: The red LED turns on to indicate the presence of smoke, while the green LED can indicate normal operation (no smoke detected). - Circuit Design: - Connect the MQ2 sensor to the analog input (e.g., A4 pin) of the Arduino. -

Connect the piezo buzzer to a digital output pin (e.g., D3 pin). - Connect the LEDs to two digital output pins (e.g., D4 for red, D5 for green). Connect the LCD display to the appropriate pins (e.g., RS, EN, D4, D5, D6, and D7 pins).

Software Development - Programming Environment: The system is programmed using the Arduino IDE, which supports C and C++ programming languages. - Sensor Data Processing: - The Arduino continuously reads analog values from the MQ2 sensor. - If the analog value exceeds a threshold (indicating the presence of smoke), the Arduino triggers the alarm. Thresholds for Alarm Activation: The threshold values for the MQ2 sensor are set based on the expected smoke levels, which will trigger the piezo buzzer and the red LED. - Output Control: - When smoke is detected, the Arduino activates the piezo buzzer, turns on the red LED, and displays the "ALERT!! Smoke detected" message on the LCD. - When no smoke is detected, the green LED lights up, indicating normal conditions.

System Integration - Hardware Integration: All components are connected according to the designed circuit. The sensors and output devices are connected to the respective pins on the Arduino board. - Software Integration: The Arduino program is uploaded to the microcontroller. The program reads inputs from the MQ2 sensor and controls the alarm and display outputs accordingly.

Testing and Calibration - Testing the System: - Simulate fire or smoke conditions by introducing smoke near the MQ2 sensor. - Check that the system responds correctly by activating the buzzer, turning on the red LED, and displaying the alert on the LCD. - Sensor Calibration: Calibrate the MQ2 sensor by adjusting the threshold in the code to ensure accurate detection and minimize false alarms. - Performance Evaluation: Evaluate the system's performance by testing it in different conditions, including varying levels of smoke and gas.

Deployment - Install the system in the desired location, ensuring that the MQ2 sensor is placed in a position where it can accurately detect smoke. - Ensure that the system is powered properly, and that the components are securely connected.

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Documentation and Reporting - Document the design, programming code, and testing procedures. - Create a user manual for the system, including installation, calibration, and troubleshooting instructions.

A. SYSTEM COMPONENTS

Arduino UNO The Arduino Uno is a microcontroller board based on Atmel's ATmega328 microcontroller. The term" Uno" means" one" in Italian, signifying its place as the first in a series of USB-based microcontroller boards. The board has 32 KB of flash memory, of which 0.5 KB is reserved for the bootloader, 2 KB of SRAM, and 1 KB of EEPROM. It operates at a clock speed of 16 MHz. The it also provides serial communication interfaces for loading programs from a computer. The Arduino IDE (Integrated Development Environment) supports C and C++ programming languages, enabling users to develop and upload codes to the board efficiently

MQ-6Smoke and Gas Sensor the MQ series of gas sensors consist of a small heater and an electro-chemical sensor. These sensors are sensitive to a wide range of gases and are designed to operate at room temperature, typically in indoor environments.

Temperature and Humidity Sensor Humidity plays a crucial role in fire detection systems. During a fire, the air tends to become dry, leading to a decrease in humidity levels, which can serve as an important indicator of a potential fire, particularly in forested areas. The DHT-11 sensor is commonly used for detecting humidity levels within the range of 20-90perc relative humidity (RH), with an accuracy of ±5perc RH. The sensor uses a resistive type humidity measurement component to assess the moisture level in the environment.

GSM Module The GSM modem module is powered by the AMR926EJS processor, which manages various functions, including phone communication, data communication (via an integrated TCP/IP stack), and communication with external circuits through both UART and TTL serial interfaces. This processor also controls the SIM card, which can be either 3V or 1.8V, and is placed on the outer wall of the module.

Liquid Crystal Display Unit (LCD) This unit features a 16×2-character LCD, which is connected via a variable resistor (10k). The LCD is programmed to display temperature and relative humidity values, providing real-time information about the environmental conditions and any detected threats, such as smoke or fire. The following program will display these values on the 16×2-character LCD, helping users monitor the system effectively.

Buzzer A buzzer is an audio signalling device that can be mechanical, electromechanical, magnetic, electromagnetic, electro-acoustic, or piezoelectric in nature. A piezoelectric buzzer, for instance, can be driven by an oscillating electronic circuit or another audio signal source. It generates sounds such as clicks, beeps, or rings to indicate actions like a button press. Typically, a buzzer consists of various switches or sensors connected to a control unit, which determines which button was pressed or if a preset time has elapsed. It often illuminates a light on the relevant button or control panel and emits a warning sound, either continuous or intermittent, in the form of a buzzing or beeping noise.

B. Working Principle

The working principle of a buzzer, particularly a piezoelectric buzzer, involves the conversion of electrical signals into mechanical vibrations, which generate sound. Here's a breakdown of the process: 1. Electrical Signal Input: The buzzer is connected to a circuit that provides an oscillating electronic signal, often generated by a microcontroller (like Arduino) or an external signal source. This signal is typically in the form of a square wave or a similar frequency that determines the tone and frequency of the sound.

2.Piezoelectric Effect: Inside a piezoelectric buzzer, there is a piezoelectric material (often a ceramic disc). When the electrical signal passes through this material, it causes the material to deform (expand or contract) due to the piezoelectric effect. This mechanical deformation produces vibrations.

3.Sound Production: The vibrating piezoelectric material causes the surrounding air molecules to vibrate, producing sound waves. The frequency of the oscillating signal determines the pitch of the sound, while the amplitude of the signal affects the volume of the sound.

4.Audible Sound: These vibrations travel through the air as sound waves, which we hear as beeps, buzzes, or other auditory signals. The buzzer can emit a continuous sound or intermittent sound depending on how the signal is applied (e.g., steady tone or a pulsed beep).

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5.Activation and Control: The buzzer is typically activated by an input from a sensor or control unit (e.g., a smoke detector, fire detection system, or button press). The control unit determines when the buzzer should sound, such as when smoke or gas is detected, or when a certain event occurs in the system. This working principle is the basis for piezoelectric buzzers used in many applications, such as alarm systems, warning devices, and notifications.

IV. CONCLUSION

This paper presents the design and implementation of a cost effective and reliable automated GSM-based fire alarm system. The system utilizes various sensors, including smoke, temperature, and humidity sensors, to detect fire hazards. These sensor inputs are connected to an Arduino controller, which processes the data and triggers appropriate responses. The system includes a buzzer to alert users to the presence of fire, an LCD display to show the fire detection status, and a GSM module that sends notifications to specific users, informing them about potential fire hazards in their homes, offices, or buildings. This fire alarm system can be applied in residential areas, offices, and hotels, ensuring enhanced safety for occupants. The system performs real-time monitoring and early detection of fire through multiple sensor measurements, which are crucial for preventing significant damage and loss. It is recommended to have a minimum of two or three smoke detectors installed on each floor of a building, with a smoke detector and fire alarm system present in every home for maximum safety. The key advantages of this system lie in its ability to prompt early reactions, thereby saving lives and property. By providing timely alerts and proactive fire detection, the system contributes to protecting both people and their residences from potential fire hazards.

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