Journal of
Microelectronics and Solid State Devices

ISSN: 2455-3336
Volume 12, Issue 1, 2025
January–April
DOI (Journal): 10.37591/JoMSD

https://journals.stmjournals.com/jomsd

Review JoMSD

Design and Implementation of an Automatic Fire Extinguishing System Using Arduino UNO

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Abstract

Fire safety is an essential concern in both residential and industrial spaces. Conventional firefighting techniques frequently call for human assistance, which is not always adequate or timely. This study discusses the design and development of an automatic fire suppression system that uses an Arduino UNO microcontroller, a 5 V single-line relay, an infrared (IR) sensor, a buzzer, and a 5 V DC pump. The system identifies a fire by detecting infrared radiation emitted by flames through the IR sensor. Upon detecting a fire, the system activates the DC pump to spray water to extinguish the fire, and an alarm sounds to alert nearby individuals. The primary aim of this project is to create an efficient, affordable, and simple fire suppression solution suitable for small-scale environments. Fire outbreaks constitute significant hazards to individuals and assets, demanding the establishment of efficient suppression technologies for fires. This study describes the design and development of an efficient fire extinguishing mechanism employing the Arduino UNO microcontroller. The device incorporates flame sensors, temperature sensors, and a servo-controlled extinguisher that can identify and put out fires effectively. Upon sensing a fire, the system generates an alert and launches the fire suppression equipment. The system under consideration offers a cost-effective, productive, and autonomous approach for the prevention of fires in residential and commercial environments.

Keywords: Arduino UNO microcontroller, infrared (IR) sensor, DC pump, water pump, motors

INTRODUCTION

Fire remains one of the most prevalent hazards that pose significant threats to both human life and property. Conventional methods of fire safety typically rely on manual intervention, which may be inadequate, especially in cases where fires occur in areas that are difficult to access or when they break out in unattended locations [1–4]. In recent years, the development of automatic fire extinguishing systems has gained considerable attention within the engineering community. These systems are designed to detect the presence of fire and automatically respond to it, enhancing the possibility of minimizing damage and improving the overall safety of buildings.

The advent of microcontroller-based technologies, like the Arduino platform, has facilitated the creation of affordable and effective fire detection and suppression systems. Arduino provides an open-source platform that empowers users to build a wide range of electronic systems, including fire safety solutions [5]. By integrating inexpensive sensors, relays, and pumps, an Arduino-powered

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Received Date: February 11, 2025
Accepted Date: February 33, 2025
Published Date: February 25, 2025

Citation: Arun Kumar Yadav, Alok Prasad, Atul Kumar Yadav, Satyam, Abhishek Kumar Singh, Abhishek Pratap Singh. Design and Implementation of an Automatic Fire Extinguishing System Using Arduino UNO. Journal of Microelectronics and Solid State Devices. 2025; 12(1): 6–12p.

fire extinguishing system can function autonomously once a fire is detected, activating suppression mechanisms without requiring human input [6–10].

The demand for such systems has particularly increased in environments such as residential homes, laboratories, kitchens, and small businesses, where the risk of fire outbreaks is unpredictable [11]. This study aims to design an automatic fire suppression system that not only detects the fire but also triggers a water pump to extinguish the flames while sounding an alarm to notify individuals in the area [12].

OBJECTIVE

The primary aim of this research is to develop and test an automatic fire extinguishing system that operates using an Arduino UNO microcontroller. This system will utilize an infrared (IR) sensor to detect fire, a water pump to extinguish the flames, and a buzzer to provide an audible warning. The project seeks to create a practical, cost-effective fire safety solution that can be used in small-scale environments, where rapid response to a fire is essential for safety.

Scope

This project focuses on the design, implementation, and testing of a fire detection and suppression system in a controlled setting. The system will be capable of detecting small fires using the IR sensor, triggering the 5 V DC pump to spray water, and activating a buzzer to alert nearby individuals. Several tests will be used to gauge the system's efficacy and determine how well it functions in actual situations. Future versions of the system may introduce advanced features, such as remote monitoring via mobile applications or cloud platforms for enhanced control and visibility.

MATERIALS AND METHODS

Arduino UNO

The Arduino UNO is an open-source microcontroller board based on the ATmega328P chip. It is commonly used in prototyping due to its user-friendly interface and versatile functionality. In this project, the Arduino UNO acts as the central controller, processing inputs from the IR sensor and controlling the pump and buzzer based on fire detection. The Arduino UNO is equipped with a 16 MHz clock speed, 14 digital I/O pins, 6 analog inputs, and a USB connection for programming, making it an ideal component for managing the fire extinguishing system. Its large library of resources simplifies development and experimentation.

5 V Single-Line Relay

A relay is an electrical switch that enables low-voltage circuits to control high-power devices. In this system, a 5 V single-line relay is used to activate the DC pump. When the Arduino sends a signal to the relay, it allows current to flow to the pump, activating it to spray water. The relay is crucial because it prevents the high current needed by the pump from interfering with the low-voltage Arduino circuits, ensuring safe and reliable operation [13–18].

Relays are widely used when controlling high-power devices such as pumps, motors, and lights with low-power microcontrollers [19]. They act as a barrier, protecting the controller from high voltages and currents while enabling control over powerful devices.

IR Sensor

The IR sensor is a key component for fire detection. It works by sensing the infrared radiation emitted by flames, as fires generate unique infrared patterns. The sensor used in this project is a basic infrared flame sensor that can detect flames from up to 1 m away.

The IR sensor consists of an infrared LED that emits infrared radiation and a photodiode that detects the reflected radiation. If a flame is present, the photodiode generates a signal that is sent to the Arduino for processing, triggering the appropriate fire suppression actions.

Buzzer

The buzzer is an essential part of the alarm system in the fire extinguishing setup. Upon detecting a fire, the Arduino activates the buzzer to sound an alarm, warning individuals nearby of the fire hazard. The buzzer serves to quickly alert people to evacuate or take safety measures in response to the detected fire. Buzzers are simple yet effective devices that produce loud sound when powered, making them ideal for use in alarm systems where immediate notification is necessary to ensure safety.

5 V DC Pump

The 5 V DC pump is responsible for spraying water to extinguish the detected fire. Once the relay is activated by the Arduino, the pump pulls water from a reservoir and sprays it directly at the fire, effectively cooling and suppressing the flames [20–23].

In small-scale fire suppression systems, DC pumps are preferred due to their reliability, low voltage operation, and affordability, making them suitable for integration with the Arduino platform. The pump plays a crucial role in minimizing damage by immediately combating the fire with water, offering a direct response to the threat.

CIRCUIT DIAGRAM

The circuit of the automatic fire extinguishing system consists of a few core components that work together seamlessly to detect and extinguish fires (Figure 1). Here is a breakdown of each part of the system.

Arduino UNO Microcontroller

- The Arduino UNO is the central control unit in this system. It processes signals received from the IR sensor and controls the relay and buzzer.

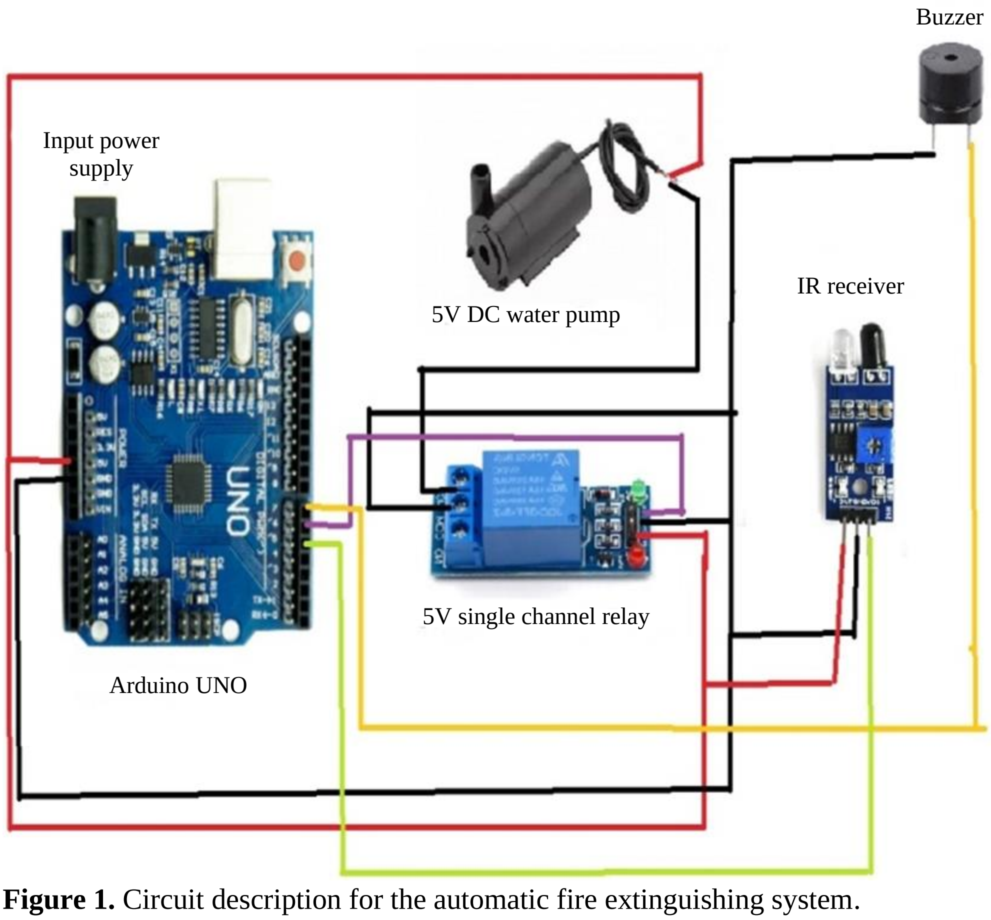

Figure 1. Circuit description for the automatic fire extinguishing system.

- Pin 5 (Digital Input) is connected to the IR sensor, where it receives the signal indicating whether a fire has been detected.
- Pin 6 (Digital Output) connects to a relay, which is used to control the activation of the DC pump responsible for spraying water onto the fire.
- Pin 7 (Digital Output) is connected to a buzzer that will sound when a fire is detected.

Infrared (IR) Sensor

- The IR sensor is designed to detect infrared radiation emitted by flames. When the sensor detects a fire, it sends a signal to the Arduino, alerting the system to act.
- The output pin of the IR sensor is connected to Pin 5 of the Arduino. If the sensor detects infrared radiation, it triggers the system by sending a HIGH signal to the microcontroller.

Relay Module

- The 5 V relay acts as a switch that controls the DC pump. The relay is necessary because the Arduino cannot supply the amount of current needed to activate the pump directly.
- The control pin of the relay is connected to Pin 6 of the Arduino. The relay's NO (Normally Open) terminal is connected to the positive terminal of the DC pump, while the COM (Common) terminal is connected to the positive terminal of the pump's power supply.

DC Pump

- The DC pump is responsible for spraying water to extinguish the fire. It is powered by a 5 V DC power source.
- When the Arduino sends a signal to close the relay, the pump gets powered, and water is sprayed onto the fire.
- The negative terminal of the pump is connected to the ground (GND) of the power supply.

Buzzer

- The buzzer serves as an alarm to alert anyone nearby when the system detects a fire.
- The positive terminal of the buzzer is connected to Pin 7 of the Arduino, while the negative terminal is connected to the ground

Power Supply

- The Arduino UNO is powered by a 5 V DC adapter or through the USB connection.
- The IR sensor and buzzer are powered directly from the Arduino's 5 V pin, as they do not require a high current.
- The DC pump requires its own 5 V DC power supply, which powers the pump separately from the Arduino.

WORKING MECHANISM OF THE CIRCUIT

1. The IR sensor constantly monitors for infrared radiation. When a fire is detected, the sensor sends a HIGH signal to the Arduino.
2. Upon receiving the HIGH signal, the Arduino processes the input and triggers the relay to close. This allows current to flow to the DC pump, which starts spraying water to suppress the fire.
3. At the same time, the Arduino activates the buzzer to produce a loud sound, notifying people in the vicinity that a fire has been detected and is being dealt with.
4. After the fire is suppressed, or once the system is reset, the relay opens, turning off the pump and silencing the buzzer.

Code

The Arduino code is designed to monitor the IR sensor for the presence of fire and control the relay and buzzer accordingly. The code continuously reads the sensor input, and when the sensor detects fire, it activates the pump and buzzer as shown in Figure 2. If no fire is detected, the system remains idle.


```
int val = 0;
void setup()
{
        Serial.begin(9600);
        pinMode(5,INPUT); // Rain sensor output pin connected
        pinMode(6,OUTPUT); // Relay
        pinMode(7,OUTPUT); // Buzzer

        digitalWrite(6,HIGH); // Relay
}
void loop()
{
      val digitalRead(5); // Rain sensor output pin connected
      Serial.println(val); // see the value in serial monitor in Arduino IDE
      delay(100);

   if(val == 0)
   {
      digitalWrite(6,LOW); // Relay
      digitalWrite(7,HIGH); // Buzzer
   }
   if(val == 1)
   {
      digitalWrite(6,HIGH); // Relay
      digitalWrite(7,LOW); // Buzzer
   }
   }
```

Figure 2. Implementation.

System Setup

The assembly of the system components was done systematically, with particular attention to the proper wiring and placement of each part. The IR sensor was positioned in such a way that it could effectively detect any flames within its range. The relay and water pump were set up near a water source, ensuring quick access to water for fire suppression. The buzzer was placed in an area where it would be loud and clear enough to alert individuals nearby.

The Arduino UNO microcontroller was used as the central interface for coordinating the various components. All components were connected using jumper wires and a breadboard for ease of testing and adjustments. After completing the hardware assembly, the necessary code was uploaded to the Arduino, and the system was tested.

Testing

During the testing phase, a heat source was used to simulate a fire near the IR sensor. The system successfully detected the heat signature from the source and triggered the water pump to spray water. The buzzer also activated, sounding the alarm as expected. A series of tests were conducted to verify the accuracy of the fire detection, as well as the proper functioning of the pump and alarm.

Several challenges emerged during testing, particularly with the IR sensor's sensitivity. The sensor sometimes responded to environmental heat sources rather than fire. To resolve this issue, the threshold in the software was adjusted to fine-tune the sensor's sensitivity. Additionally, while the water pump worked well for smaller fires, its pressure capacity was found to be insufficient for larger fire scenarios, suggesting that an upgrade might be necessary.

RESULTS

The system successfully detected and suppressed small-scale fires under the test conditions. The IR sensor accurately identified flames within its detection range, and the water pump was capable of extinguishing the flames in most instances. The buzzer reliably emitted an alarm to notify individuals nearby. However, the effectiveness of the system was somewhat limited by the size of the pump and the IR sensor's sensitivity, both of which contributed to the system's range and operational scope.

DISCUSSION

Performance

The system performed well during the controlled tests, quickly detecting fire and activating the suppression mechanism. The response time from detection to the activation of the pump was swift, which could prove valuable in small-scale environments where timely fire suppression is crucial.

Improvements

Several potential improvements could enhance the system's performance:

1. *Upgrading sensors:* Incorporating more advanced detection methods such as smoke detectors or temperature sensors could improve the system's ability to detect fire under various conditions.
2. *Stronger pumps:* Using a more powerful water pump could help handle larger fires more effectively, addressing the system's current limitations.
3. *Wireless monitoring:* Adding wireless communication through technologies like Wi-Fi or Bluetooth would allow for remote monitoring and control, providing greater flexibility in managing the system.

CONCLUSION

This study effectively illustrated how to build and implement an Arduino UNO-based automatic fire extinguishing device. The system was able to detect fire, trigger the water pump to suppress flames, and activate the buzzer to alert nearby individuals. The system's low cost and effectiveness make it a viable solution for enhancing fire safety in small-scale environments.

Future Work

Future developments could focus on enhancing the system’s performance by improving its detection accuracy and expanding its features to include remote monitoring. Additionally, alternative fire suppression techniques could be explored to tailor the system for various environments and situations.

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