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Fire Monitoring System in the Laboratory Using Temperature, Gas, and Light Sensors

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ABSTRACT

Fire is one of the disasters that often occurs due to human negligence, with significant losses both in material and human casualties. This study aims to design and implement a fire detection system based on the Arduino Uno microcontroller that combines three main sensors, namely the TMP36 temperature sensor, the MQ-2 gas sensor, and the LDR light sensor. This system is designed to provide early warnings when early indications of fire are detected such as temperature increases, the presence of dangerous gases/smoke, and abnormal increases in light intensity. Test results show that the system is able to respond to dangerous conditions quickly by activating the buzzer as an alarm and displaying parameter information in real-time via a 16x2 LCD. This system has proven effective and can be applied to high-risk environments such as laboratories, homes, schools, and industrial facilities.

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1. INTRODUCTION

Fire is a disaster that can cause significant losses, both in terms of material and human loss. Every year, thousands of fires occur worldwide, caused by electrical short circuits, gas leaks, human negligence, and natural factors [1-2]. In densely populated areas, high-rise buildings, laboratories, and industrial facilities, the risk of fire is even higher and can cause significant losses in a short time. Therefore, an early warning system capable of detecting potential fires quickly and accurately is needed [3-5].

Fire detection system technology has evolved from conventional systems that use only smoke or temperature detectors to microcontroller-based systems that can integrate multiple sensors. In this research, a microcontroller-based fire detection device was designed and developed that utilizes three main types of sensors: a temperature sensor

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(such as the TMP36), a gas sensor (such as the MQ-2), and a flame light sensor (such as an LDR) [6-8].

The temperature sensor functions to monitor abnormal temperature increases, which are often an early indication of the presence of a heat source or fire [9]. Gas sensors are used to detect the presence of hazardous gases such as carbon monoxide (CO), household gas (LPG), or smoke, which typically arise during the combustion process [10]. Meanwhile, light sensors, or flame sensors, directly detect infrared radiation generated by flames, allowing the system to detect fire more quickly [11].

The system is controlled by a microcontroller such as an Arduino, which processes data from the three sensors and provides a response in the form of an audible alarm using a buzzer or visual notification via a display screen [12].

The goal of developing this tool is to create an efficient and easy-to-use fire detection system that can be applied in various environments such as laboratories, homes, schools, offices, and businesses. By utilizing increasingly affordable sensor technology, this tool is expected to provide early warnings so that preventative measures can be taken before a fire becomes larger.

With this background, the design and testing of a fire detection system based on temperature, gas, and light sensors were carried out to produce a tool that is accurate, reliable, and effective in providing early warning of potential fires.

2. METHOD

A. Fire Monitoring System

A fire monitoring system is a system used to monitor and detect fires early, allowing for rapid preventative and response measures. This system involves various sensors, alarms, and monitoring centers that are interconnected to provide information about fire conditions to the authorities.

B. Software

Software is a computer program that functions as a means of interaction between the user and the hardware. Software can also be described as a translator for commands executed by the computer user, which are then forwarded to or processed by the hardware.

C. Arduino Integrated Development Environment (IDE)

An IDE (Integrated Development Environment) is a computer program that includes several features necessary for software development. The purpose of an IDE is to provide all the tools and utilities necessary for building software.

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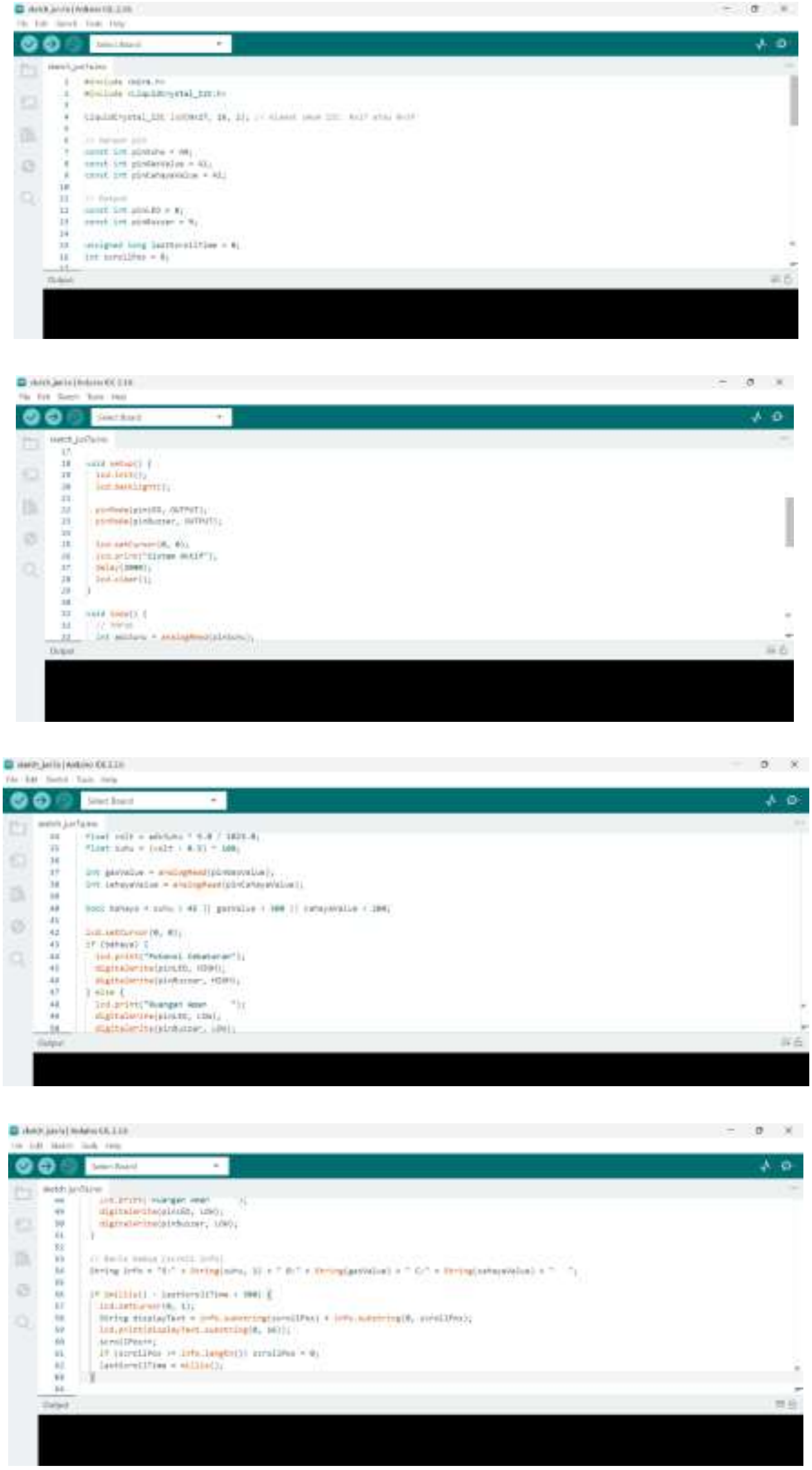

Figure 1. IDE Arduino

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D. Arduino Uno R3

Arduino is the name of a family of microcontroller boards originally created by the Smart Projects company. One of its creators is Massimo Banzi. This board is open-source hardware, allowing anyone to build it. Arduino was created with the aim of facilitating experimentation or the development of various microcontroller-based devices.

E. MQ-2 Smoke Sensor

The MQ-2 smoke sensor is a highly sensitive sensor for cigarette smoke, LPG, propane, hydrogen, carbon monoxide, methane, alcohol, and other flammable gases. It functions to detect the presence of smoke originating from flammable gases in the air. Its primary function is to detect smoke or gases that could potentially pose a fire hazard.

F. Light Dependent Resistor (LDR)

An LDR, or Light Dependent Resistor, is a type of resistor whose resistance value changes according to the intensity of light hitting the sensor. The more light that hits the LDR sensor, the lower its resistance value.

G. Buzzer

A buzzer is an electronic component that converts electrical vibrations into sound vibrations. So, a buzzer also consists of a coil attached to a diaphragm. A current flows through the coil, creating an electromagnet. The coil is pulled inward or outward, depending on the direction of the current and the polarity of the magnet. Because the coil is attached to the diaphragm, each movement of the coil moves the diaphragm back and forth, causing the blood to vibrate, producing sound.

H. Liquid Crystal Display (LCD)

An LCD (Liquid Crystal Display) is a type of display media that uses liquid crystals as the primary display. LCDs are used to display text, letters, numbers, symbols, and images.

I. TMP36

The TMP36 is a sensor used to measure temperature using a microcontroller. This sensor can measure temperatures between -40°C and +125°C.

J. Research Method

The design of the fire detection system uses three sensors as input: an MQ-2 sensor, which detects gas/smoke, and an LDR sensor, which detects light intensity. The input from both sensors is then processed by an Arduino Uno, sending the sensor readings to a buzzer, thus triggering the buzzer.

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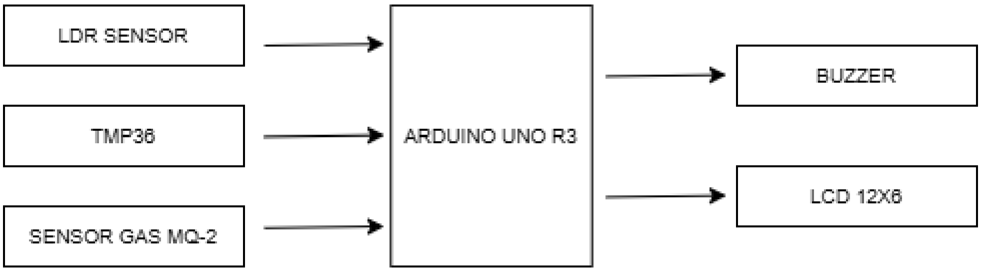

Figure 2. Block Diagram of Fire Detection System

B. Hardware Design

This fire detection circuit is equipped with a flame sensor, a smoke sensor, and a buzzer, all connected by a microcontroller. To activate the fire detection function, the first step is to connect the microcontroller to the power supply terminal using an Arduino adapter to enable the microcontroller system to function. When the light sensor detects a fire, the detected light will be displayed on the LCD. The gas sensor detects the presence of gas/smoke, and the microcontroller will send a signal to the buzzer, which will then sound.

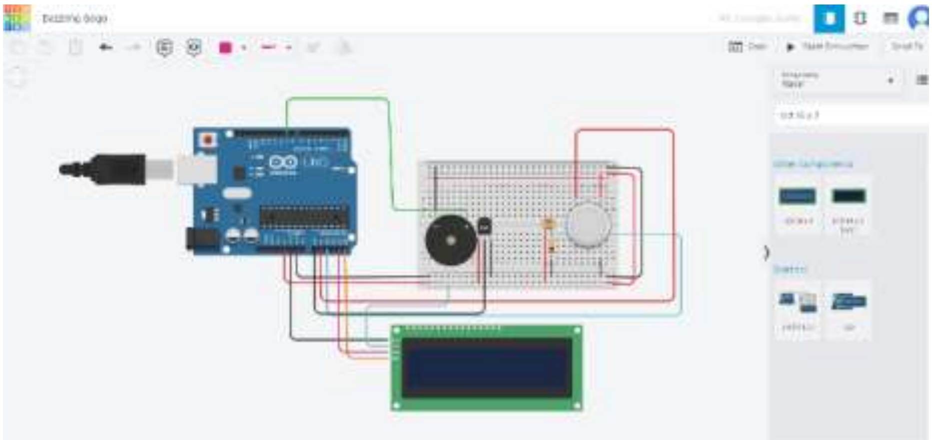

Figure 3. Fire Detection Device Design Using Tinkercad Application

The Fire Detection System works in the following stages:

1. **Sensor Input**

   The system uses three types of sensors to detect potential fires:

   TMP36 Temperature Sensor:

   - Reads the ambient temperature.
   - Connected to the Arduino analog pin (usually A0).
   - If the temperature exceeds a limit (e.g., 50°C), the system will trigger an alert.

   MQ-2 Gas Sensor:

   - Detects smoke, LPG, CO, etc.
   - Connected to the analog pin (e.g., A1).

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- If the gas concentration is high, this indicates the presence of smoke or hazardous gases.

LDR (Light Dependent Resistor):
- Detects light levels.
- Connected to the analog pin (e.g., A2).
- If the light drops drastically (due to smoke obscuring the light source), this is considered a danger signal.

2. Process in Arduino

The Arduino reads analog values from all sensors. The system compares sensor values to thresholds:
- Temperature > 50°C
- Gas value > danger threshold
- Light value < safety threshold
- If one or more parameters exceed the limits:
- Buzzer activates to provide an audible warning.

The 16x2 LCD displays a warning message such as:
- DANGER! HIGH TEMPERATURE
- SMOKE DETECTED

If all conditions are normal:
- Buzzer does not sound.
- LCD displays the normal status and sensor values.

3. System Output

Buzzer:
- Activated when a danger condition is detected.
- Provides an audible signal to attract attention.

16x2 LCD:
- Displays temperature, gas, and light information.
- Displays a warning message when a danger is detected.

System Duty Cycle
1. The system is powered on.
2. The sensors read environmental values in real time.
3. The Arduino processes the data and determines whether the condition is dangerous.
4. If yes → Activate buzzer + display message on LCD.
5. If no → LCD displays normal condition.

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C. Software Design

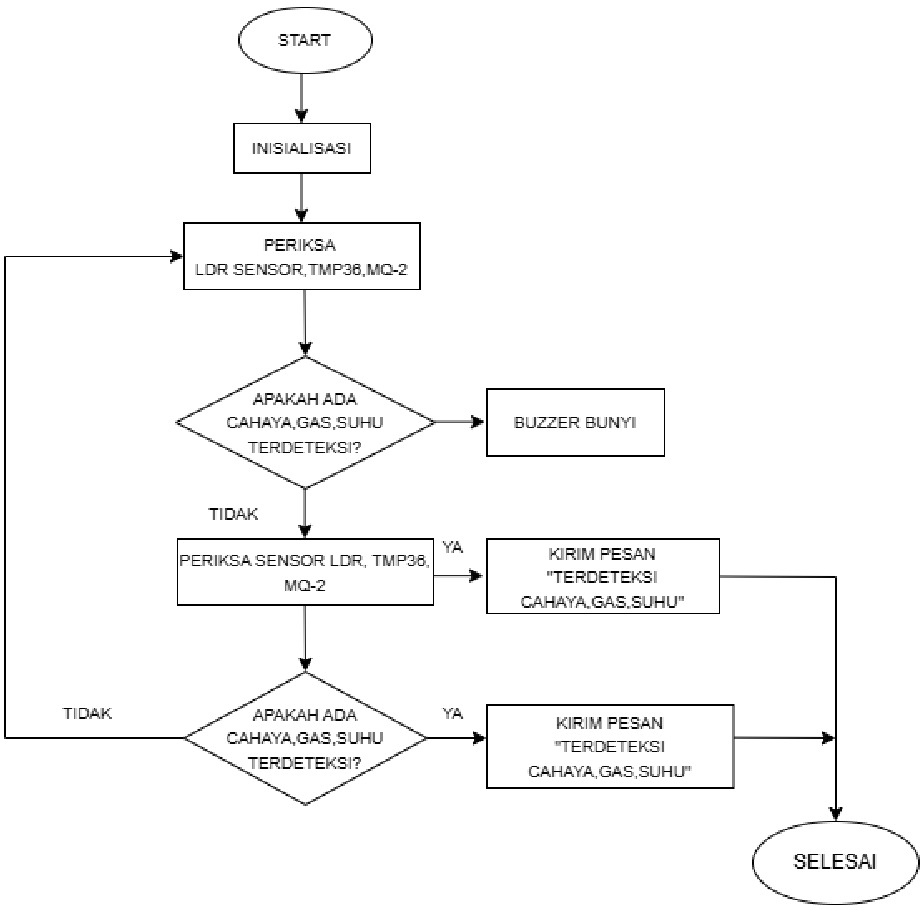

Figure 4. System Flowchart

The following is an explanation of the Fire Detection System flow diagram:

1. Initialize the inputs, using the LDR sensor, TMP36, and MQ-2 as inputs, and initialize the outputs, using the buzzer and 16x2 LCD as outputs.
2. After initialization, the LDR sensor, TMP36, and MQ-2 are checked.
3. If fire is detected, the buzzer will sound, and the LCD will display the detected gas, temperature, and light values. If gas, light, and temperature are not detected, check the LDR sensor, MQ-2, and light.
4. If gas, light, and temperature values are above the maximum limit, the buzzer will sound. If there is no smoke, check the LDR sensor, MQ-2, and light again.

3. RESULTS AND DISCUSSION

3.1.. Equipment Testing Results

The designed fire detection system has been successfully implemented using three main sensors: a temperature sensor (TMP36), a gas sensor (MQ-2), and a light sensor

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(LDR). The device was tested under various conditions to ensure its functionality and accuracy in detecting early signs of fire in a laboratory environment.

The testing was conducted by applying stimuli in the form of high temperature, light intensity, and gas. The test results demonstrated that the system was able to respond quickly to environmental changes through a buzzer as an alarm and displaying detected parameter information on a 16x2 LCD.

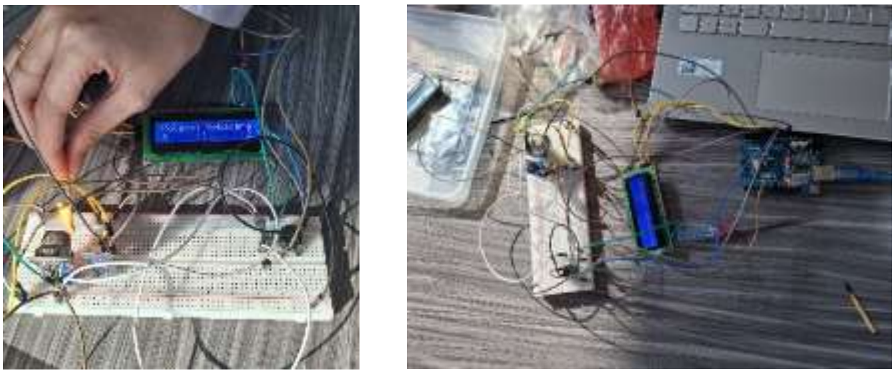

Figure 5. Tool Design Results

The image above shows all the hardware components configured and assembled into one. The first step in creating an IoT-based fire detection system using an Arduino device is to configure the fire sensor, gas sensor, LDR sensor, and temperature sensor connected to the circuit board to increase the ground. As a power pin or negative power and the VCC pin (5 volts) as a positive power pin because the VCC and GND pins are limited on the Arduino. The test results are summarized in Table 1

Table 1. Tool Test Results

NO	Sensor Parameter	Normal Condition	Detection Threshold	System Response
1	Temperature (TMP36)	25 – 30	>45 °C	Buzzer lights up, temperature data appears on the LCD
2	Gas/Smoke (MQ-2)	100 – 200	>300 ppm	Buzzer lights up, gas value appears on LCD
3	Firelight (LDR)	<100 lux	>200 lux	Buzzer lights up, intensity is displayed on the LCD

When one of the sensors detects a value exceeding the threshold, the Arduino Uno will activate the buzzer as an alarm and display sensor information in real-time on the LCD.

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B. Discussion

The developed system is capable of providing effective early warning of potential fires through a combination of three sensors. The TMP36 temperature sensor can detect temperature increases accurately and quickly. In testing, artificial temperatures exceeding 50°C immediately triggered an alarm.

The MQ-2 sensor demonstrated high sensitivity to the presence of flammable gases, such as LPG, carbon monoxide (CO), and smoke. When the sensor detects hazardous gases, the system immediately issues an alert via a buzzer. This is particularly important in laboratories where many volatile and flammable chemicals are present.

The LDR sensor is used to detect changes in light intensity from a flame. Although the LDR is not a dedicated flame sensor, the extreme light changes produced by the flame are sufficient to detect and trigger the warning system.

The Arduino Uno acts as the control center, processing data from the sensors and sending commands to output components such as the buzzer and LCD. This system has also been tested using simulations using the Tinkercad application, with results consistent with the initial design.

Overall, this device has proven capable of detecting potential fires early. The combination of multiple sensors provides better accuracy than using a single sensor type. This system can be widely implemented in laboratories, homes, or places with high fire risks.

4. CONCLUSION

Based on the design, testing, and analysis of the fire monitoring system, it can be concluded that the Arduino Uno microcontroller-based fire detection system, which utilizes three primary sensors—TMP36 (temperature), MQ-2 (gas/smoke), and LDR (light), has been successfully developed and is capable of effectively detecting early signs of fire in a laboratory environment. Each sensor has a specific, complementary function: the TMP36 temperature sensor detects temperature increases, the MQ-2 sensor detects the presence of hazardous gases or smoke, and the LDR sensor detects the light intensity of a flame.

Using the combination of these three sensors increases the system's accuracy and reliability, enabling early detection of potential fires. The system's response was excellent, indicated by the activation of a buzzer as an alarm and the display of real-time data on a 16x2 LCD when sensor values exceed a specified threshold. Implementation and testing through Tinkercad simulations demonstrated that the system performed as designed and provided reliable results. Therefore, this system is very suitable for application in various fire-risk environments, such as laboratories, homes, schools, or industrial facilities, because it is simple, efficient, and uses affordable components.

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