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Research Article

Designing an Early Fire Detection System for Smart Homes: An IoT Simulation Using Wokwi Integrated with the Blynk Application

Dhoni Setyanto[1]*, Amelia Julianti[2]

1 Computer Systems Engineering Study Program, Faculty of Communication and Information, Garut University; email: dhonisetyanto@uniga.ac.id
2 Computer Systems Engineering Study Program, Faculty of Communication and Information, Garut University; email: 24074122007@fkominfo.uniga.ac.id
*Corresponding Author: dhonisetyanto@uniga.ac.id

Abstract: Fire is a disaster that carries serious consequences, both in terms of human casualties and material losses. Such incidents can occur in various locations, including offices, public facilities, forests, and especially residential areas. Technological advances, particularly the Internet of Things (IoT), present an opportunity to develop automated early fire detection systems. The objective of this study is to design an IoT-based residential fire detection system. The tools utilized in this research include the Blynk application, the Wokwi platform, and various sensors. Based on the results of the design process, simulation, and testing of the IoT-based residential early fire detection system conducted using an ESP32 microcontroller and the Blynk application, it can be concluded that the system is capable of effectively performing early detection of potential fire hazards. Integration with the Blynk application allows this system to be monitored and controlled remotely via smartphone. Through the Blynk dashboard, users can view real-time sensor data, receive hazard notifications, and manually control devices such as windows and water pumps. This feature enhances the system's flexibility in providing early warnings and reduces the risk of fire hazards in residential environments.

Keywords: Blynk Application: ESP32 Microcontroller: Fire Detection: Internet Of Things; Residential Safety

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1. Introduction

Fires are a disaster that has serious impacts, both in terms of human casualties and material losses. These incidents can occur in various locations, including offices, public facilities, forests, and especially residential areas. Data from the Indonesian National Police's DORS SOPS application as of October 14, 2024, shows that between January and October 7, 2024, there were 935 fire cases in Indonesia. A total of 704 cases, or approximately 75.29% of them, were fires that destroyed houses. This indicates that residential areas are the areas most vulnerable to fire disasters. Triggers for fires in homes can vary, from gas leaks and electrical short circuits to negligence such as throwing away lit cigarette butts. Generally, fires are only realized when the fire has grown large or thick smoke is visible, so the response is often delayed. This delay can exacerbate losses and endanger the safety of home occupants [1] .

Technological advances, particularly the Internet of Things (IoT), open up opportunities to create automated early fire detection systems. Such systems can provide faster warnings, allowing response efforts to begin before the fire spreads. Early detection is crucial for minimizing losses and the risk of harm. Several studies have been conducted on IoT-based fire detection, including those using Arduino [2] and blackbox [3] .

With the advancement of IoT, concepts such as *smart cities, smart buildings* , and *smart homes* are increasingly being applied in everyday life. In the context of home fire prevention, this technology enables the development of more effective fire detection and early warning systems. These systems can be realized with IoT-based hardware such as Arduino, NodeMCU ESP8266, or ESP32, and supported by IoT cloud platforms such as ThingSpeak, Blynk.io, and ThingsBoard.io for real-time remote monitoring and control [4] . Considering the magnitude of the potential losses, early detection and prevention of home fires are crucial. Based on this, this study aims to design an IoT-based home fire detection system. This system utilizes ESP32 as the main microcontroller, equipped with a flame sensor to detect fire, an MQ-2 sensor to detect smoke and gas, and a DHT22 sensor to monitor temperature and humidity. For monitoring and sending notifications to users, the Blynk application is used, which presents data in real-time [5] . The application of this technology is expected to be a preventative measure to reduce the risk of fire, especially in homes that do not have an adequate fire safety system.

2. Literature Review

Internet of Things (IoT)

The Internet of Things (IoT) is a technology that utilizes internet networks to automatically control and communicate between devices. IoT is the result of the evolution of information technology and internet connectivity, which allows electronic devices to be easily connected through the network, while meeting the needs in terms of device addressing and connection. In addition, IoT is also defined as a concept where objects equipped with sensors and other hardware can interact with each other and exchange data for a specific purpose. The term "Internet of Things" was first introduced by Kevin Ashton in 1999. In recent decades, this definition has become broader, encompassing various application areas such as health, utilities, and transportation. Although the types of "Things" or connected objects continue to change with technological developments, the main goal of IoT remains the same, namely to automate the collection of information in the computer world without the need for human intervention. The development of IoT began with open wireless devices such as Bluetooth, Radio Frequency Identification (RFID), Wi-Fi, as well as data networks and telecommunication nodes. Since then, IoT has continued to experience rapid progress [6] .

The Internet of Things (IoT) automates the human role in a series of data processes, from acquisition, processing, to dissemination of visualized information. Fundamentally, IoT is a network of various sensor devices interconnected through internet or intranet infrastructure. This network enables automatic communication between devices and machines or servers, without requiring human intervention, by relying on unique Internet Protocol (IP) addresses owned by each entity in the system. [7] . To realize smooth ubicomp computing (ubicomp), the IoT framework is built on three main components. First, Hardware, which includes physical elements such as sensors, actuators, and embedded communication modules. Second, Middleware, functions as a software layer that dynamically provides computing and storage resources to support the data analysis process. Third, Presentation Interface, which is a variety of tools aimed at visualizing and interpreting data in an intuitive way. These tools are designed to be easily accessible across various platforms and can be customized according to application needs. [8]

ESP32

Figure 1. ESP32 (Source: raharja.ac.id).

The ESP32 is the next generation of the ESP8266, offering significant improvements across various aspects. This microcontroller not only supports WiFi connections like its predecessor, but also features Bluetooth Low Energy (BLE), making it more flexible for various IoT applications. In terms of processor, the ESP32 uses the Xtensa LX6 core with a 32-bit architecture, similar to the ESP8266, but its advantage lies in the use of dual-core processors, enabling more efficient and faster processing. Furthermore, the ESP32 is equipped with 128KB of ROM and 416KB of SRAM. For program and data storage, the ESP32 provides up to 64MB of Flash Memory, providing ample space for application development. Overall, the ESP32 is designed as a sophisticated microcontroller with powerful computing and connectivity capabilities that greatly support Internet of Things-based projects. [9] .

Flame Sensor

Figure 2. Fire Sensor (Source: arduinoindonesia.id).

A flame sensor is a fire detection device that works by capturing infrared light radiation emitted by flames. This sensor is capable of detecting fire in the wavelength range of around 760 nm to 1100 nm, which is characteristic of infrared light. Unlike temperature sensors that detect heat, this sensor specifically responds to light from flames, making it more effective for visually detecting the presence of fire in fire early warning systems. This sensor is usually equipped with three pins, namely VCC (input voltage), GND (ground), and a digital output to send signals to the microcontroller.

MQ-2 Gas Sensor

Figure 3. MQ-2 Gas Sensor (Source: andalanelektro.id).

The MQ-2 sensor is a device that functions to detect the presence of flammable gases and smoke in the air, with the measurement results displayed in the form of an analog voltage signal. The sensitivity level of this sensor can be adjusted manually through the available trimpot settings. The MQ-2 is often used in household and industrial security systems to detect gas leaks. Some types of gases that can be detected by this sensor include LPG, i-butane, propane, methane, alcohol, hydrogen, and smoke. Because of its ability to detect various types of dangerous gases, the MQ-2 sensor is ideal for use in emergency systems, such as fire or gas leak detection devices to improve environmental safety [10] .

DHT22 Temperature Sensor

Figure 4. DHT22 Temperature Sensor (Source: core-elektronics.com).

DHT22 is a sensor commonly used to detect temperatures in the range of -40°C to 80°C and relative humidity from 0% to 100%. DHT22 utilizes high-precision resistive sensor technology, so it can provide data with good accuracy and resolution [11] .

Blynk Application

Blynk is a platform designed to control microcontroller devices such as Arduino, Raspberry Pi, ESP8266, and similar devices over an internet connection. This application can be run on both iOS and Android operating systems, making it very flexible for a wide range of users. Blynk's operation is relatively simple and is not limited to a specific chip type. Most importantly, the device used must have WiFi connection capabilities in order to connect and function properly through this application [12] .

3. Method

This research was conducted from the design process to testing the early detection system. The design was tested using a Wokwi platform simulation using an ESP32 microcontroller and various supporting sensors, including a flame sensor, a gas sensor (MQ-2), and a temperature sensor (DHT22).

Tools and Materials

Tools

To implement this system, several key tools are required to support the function of each component in the circuit. Complete details of the tools used can be seen in Table 1 below:

Table 1. Materials for IoT-Based Home Fire Early Detection System.

No	Tool Name	Specification	Function	Amount
1	Wokwi Platform	https://wokwi.com/ projects/4283602793744424 97	An online platform used for simulating microcontrollers and electronic circuits.	1 access
2	Internet Connection	Stable speed of at least 1 Mbps	Access wokwi and IoT services such as the Blynk app requires an internet connection	1 connection
3	Blynk App	Blynk Console version 1.25.0 [211]	Application used to receive data and notifications from ESP32 in *real time*	1 account

Materials

In addition to the tools required, designing this system also requires various materials to support the function of each component in the circuit. Complete details of the materials used can be seen in Table 1.2 below:

This section presents a system block diagram that illustrates the interrelationships between the main components of an IoT-based home fire early detection system. This diagram was designed using yEd Graph Editor software to provide an overview of the data flow and function of each device, such as sensors, microcontrollers, and actuators, and to provide a comprehensive understanding before entering the simulation implementation phase.

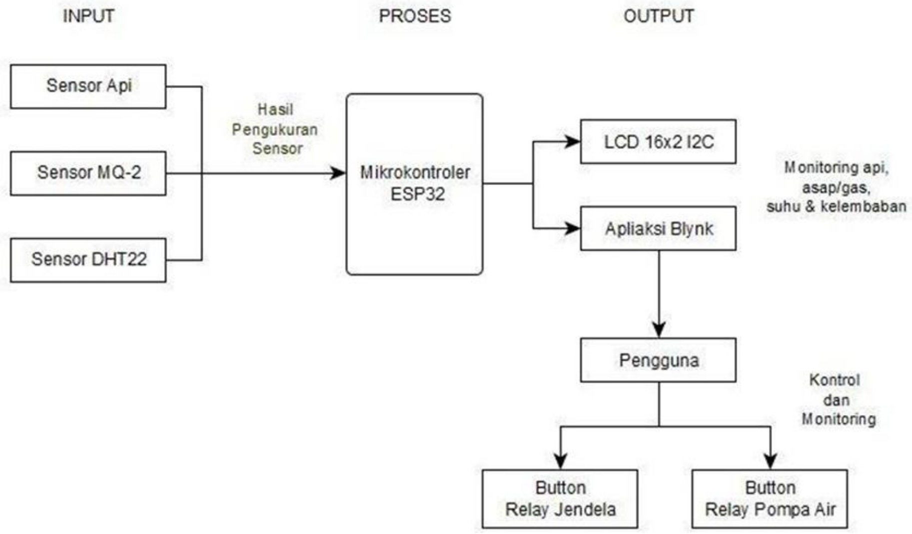

Figure 5. System Block Diagram.

Circuit Workflow (*Flowchart)*

This section is the creation of a workflow or flowchart of the circuit that will be created using the yEd Graph Editor software. This flowchart is made to simplify circuit **simulation so that the resulting output will be as expected.**

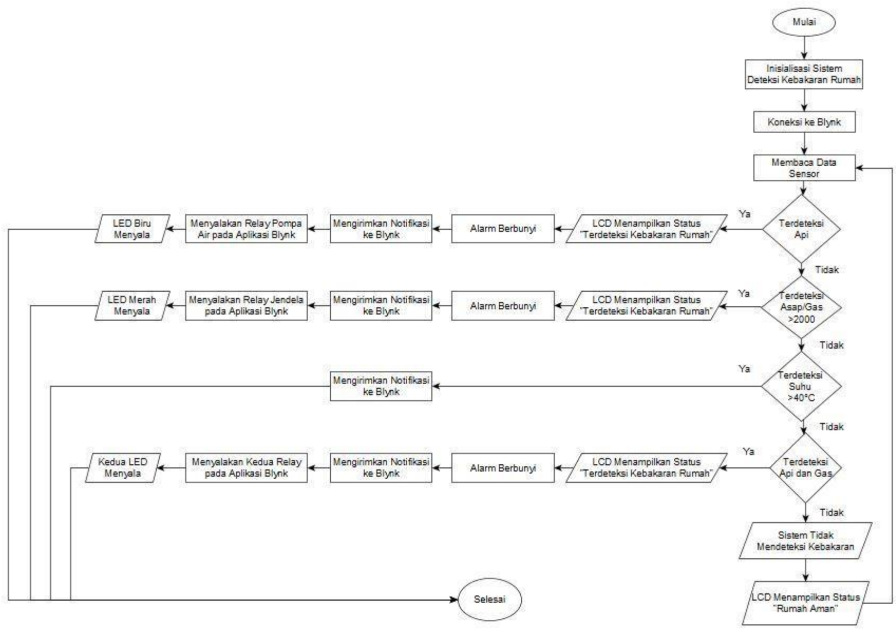

Figure 6. This flowchart.

4. Results and Discussion

Hardware Simulation Design

Hardware simulation design is the stage carried out to design how the IoT-based home fire early detection system will function properly. The design was carried out using Wokwi as the system simulation platform. The schematic can be seen in Figure 7 below.

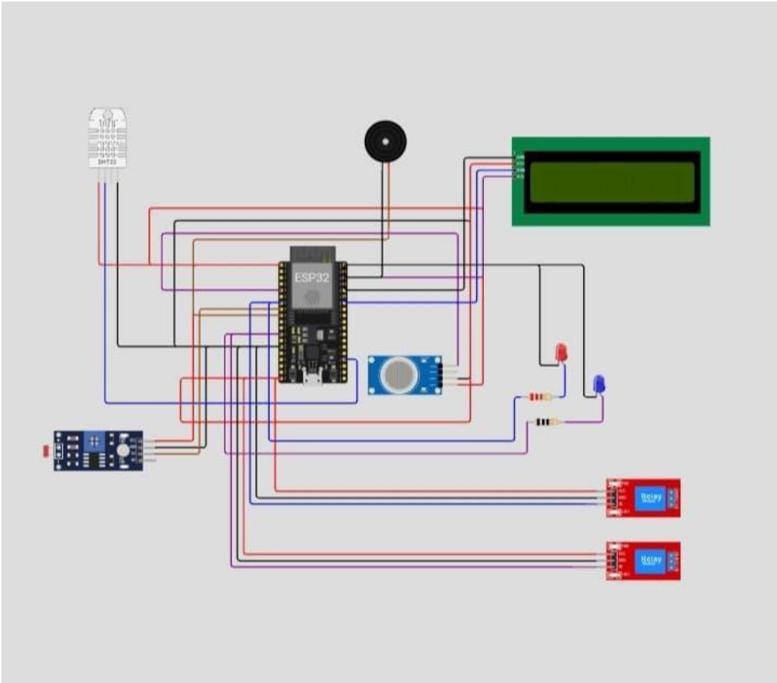

Figure 7. Schematic of the Home Fire Early Detection System.

Design Device Soft (*Software*)

After the simulation of the system for detecting house fires using ESP32 has been designed, then the next stage is do process coding program to run a circuit that has been created using Wokwi software. The system simulation design program code is as follows:

```
#define BLYNK_TEMPLATE_ID "TMPL6ohGQF-2X"
#define BLYNK_TEMPLATE_NAME "Sistem Pendeteksi Kebakaran Rumah"
#define BLYNK_AUTH_TOKEN "iou5jMvZXZcVeR9IkcfsW3ZQgqMEgXYI"

#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include "DHT.h"

// WiFi dan Blynk
char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "Wokwi-GUEST";
char pass[] = "";
```

Figure 8. Initialization Library & Connection Wi-Fi And Blynk.

```
// DHT setup
#define DHTPIN 15
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);

// Sensor dan aktuator
#define MQ2_PIN 34
#define FLAME_PIN 33

#define BUZZER_PIN 25
#define LED_MERAH 26
#define LED_BIRU 27

#define RELAY_JENDELA 32
#define RELAY_POMPA 14

LiquidCrystal_I2C lcd(0x27, 16, 2);

// Flag kontrol manual dari Blynk
bool control_jendela = false;
bool control_pompa = false;
bool sudahKirimNotifikasi = false;
```

Figure 9. Initialization Sensor And Actuator.

```
void setup() {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass);

  dht.begin();
  lcd.init();
  lcd.backlight();

  pinMode(MQ2_PIN, INPUT);
  pinMode(FLAME_PIN, INPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  pinMode(LED_MERAH, OUTPUT);
  pinMode(LED_BIRU, OUTPUT);
  pinMode(RELAY_JENDELA, OUTPUT);
  pinMode(RELAY_POMPA, OUTPUT);

  lcd.setCursor(0, 0);
  lcd.print("Sistem Deteksi");
  lcd.setCursor(0, 1);
  lcd.print("Kebakaran Rumah");
  delay(1000);

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Membaca Data...");
  delay(1000);
  lcd.clear();
}

// Baca tombol dari Blynk
BLYNK_WRITE(V3) {
  control_jendela = param.asInt();
}
BLYNK_WRITE(V4) {
  control_pompa = param.asInt();
}
```

Figure 10. Function Setup.

```
void loop() {
  Blynk.run();

  float suhu = dht.readTemperature();
  int gas = analogRead(MQ2_PIN);
  int flame = digitalRead(FLAME_PIN); // LOW = api terdeteksi

  bool ada_asap_gas = (suhu > 50 || gas > 2000);
  bool ada_api = (flame == HIGH);

  // Kirim data ke Blynk
  Blynk.virtualWrite(V0, suhu);
  Blynk.virtualWrite(V1, gas);
  Blynk.virtualWrite(V5, ada_api ? 1 : 0);
  Blynk.virtualWrite(V2, (ada_asap_gas || ada_api) ? "BAHAYA!" : "AMAN");
```

Figure 11. Loop Function.

```
  // Tindakan saat bahaya
  if (ada_asap_gas || ada_api) {
    tone(BUZZER_PIN, 250);

    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("   Terdeteksi");
    lcd.setCursor(0, 1);
    lcd.print("Kebakaran Rumah");

    if (!sudahKirimNotifikasi) {
      Blynk.logEvent("kebakaran_terdeteksi", "Bahaya! Kebakaran terdeteksi!");
      sudahKirimNotifikasi = true;
    }
  } else {
    noTone(BUZZER_PIN);

    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Rumah Aman A : 0");
    lcd.setCursor(0, 1);
    lcd.print("S :");
    lcd.print(suhu);
    lcd.print("c G :");
    lcd.print(gas);

    sudahKirimNotifikasi = false;
  }
```

Figure 12. Function Blynk.

```
  // Kendali Relay HANYA lewat tombol Blynk
  if (control_jendela) {
    digitalWrite(RELAY_JENDELA, HIGH);
    digitalWrite(LED_MERAH, HIGH);
  } else {
    digitalWrite(RELAY_JENDELA, LOW);
    digitalWrite(LED_MERAH, LOW);
  }

  if (control_pompa) {
    digitalWrite(RELAY_POMPA, HIGH);
    digitalWrite(LED_BIRU, HIGH);
  } else {
    digitalWrite(RELAY_POMPA, LOW);
    digitalWrite(LED_BIRU, LOW);
  }

  // Debug Serial Monitor
  Serial.print("Suhu : "); Serial.print(suhu);
  Serial.print(" | Gas : "); Serial.print(gas);
  Serial.print(" | Flame : "); Serial.println(flame);

}
```

Figure 13. Control Relay Window And Pump Water.

Testing Design System

On part testing This, done process evaluation to system Which has designed to detect potential fire in in House. Testing aim For ensure that Each component functions according to its intended function, from temperature, gas, and flame sensors to actuators like buzzers, LCDs, and relays. Furthermore, system integration with the Blynk application for real-time monitoring and notification was also observed. The following are the stages and results of the overall system testing.

Initialization System

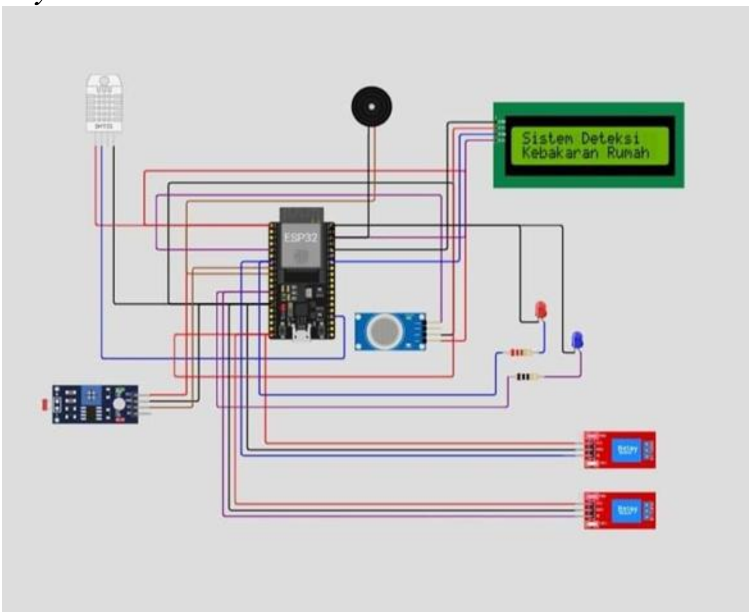

Figure 14. Initialization System.

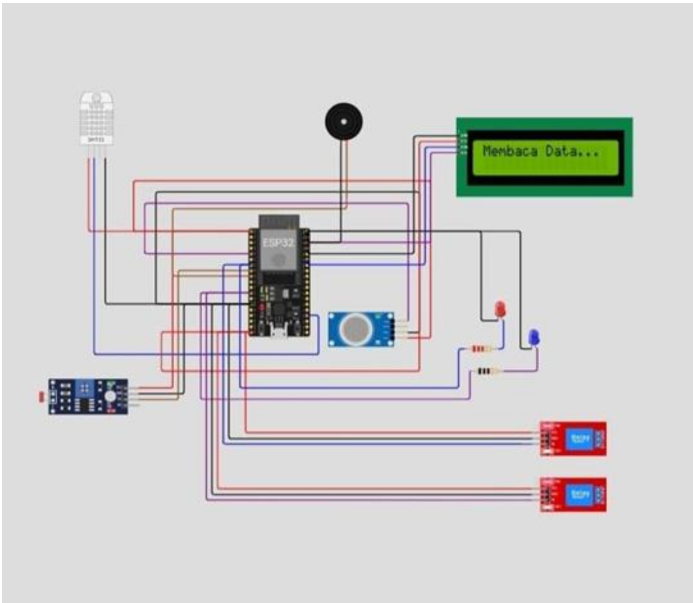

Figure 15. System Read Data Sensor.

Parameter And Condition System

Condition Danger

a. System Detecting Fire

The system will detect the potential for a house fire when it detects the presence of fire with a fire sensor value = 1. In this condition, the LCD will display the status "House Fire Detected", the alarm will sound, and the Blue LED will light up as an indicator that the Water Pump Relay has been turned on.

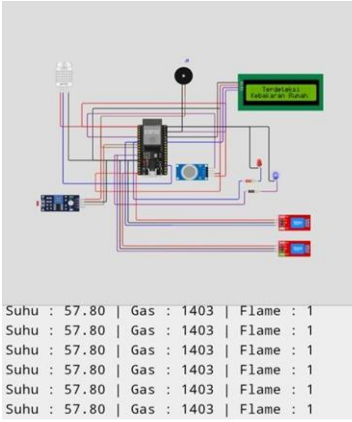

Figure 16. Condition Danger Detected Fire.

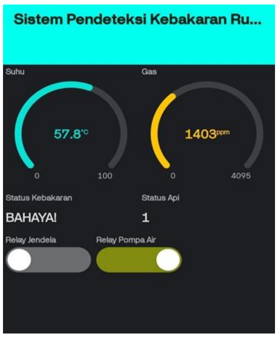

Figure 17. Appearance Condition Danger Detected Fire.

b. System Detecting Smoke/Gas

The system will detect the potential for a house fire when it detects a concentration of smoke/gas exceed threshold limit 2000 ppm. On condition The LCD will display the status "House Fire Detected", the alarm will sound, and the Red LED will light up as an indicator that the Window Relay has been turned on.

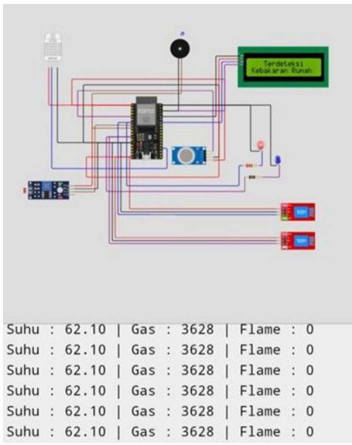

Figure 18. Condition Danger Detected Smoke/Gas.

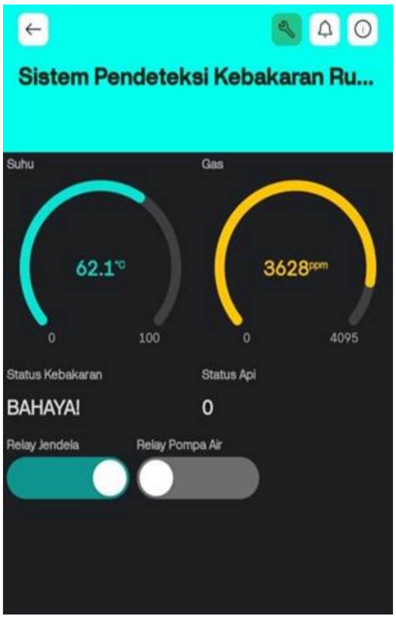

Figure 19. Display Condition Danger Detected Smoke/Gas.

c. System Detecting Fire and Smoke/Gas

The system will detect the potential for a house fire when it detects the presence of fire with mark sensor fire = 1 And concentration smoke/gas exceeding the threshold limit 2000 ppm. On condition the LCD will display "House Fire Detected" status, alarm sounds, Red LED and Blue LED light up as an indicator that the Window Relay and Pump Relay are working. The water has been turned on.

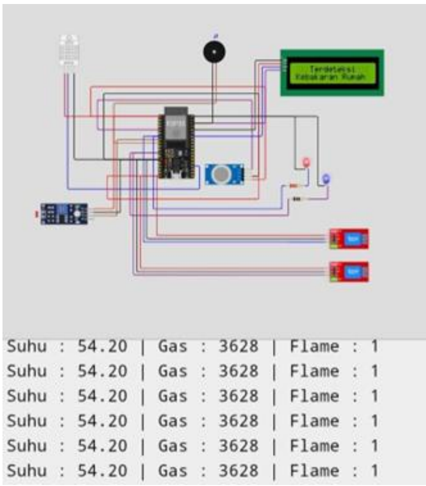

Figure 20. Condition Danger Detected Fire And Smoke/Gas.

Figure 21. Display Condition Danger Detected Fire And Smoke/Gas.

d. Condition Safe

The system will not detect the potential for a house fire when it detects the presence of fire with a fire sensor value = 0 and the smoke/gas concentration does not exceed threshold limit 2000 ppm. On condition the LCD will displays the status "Home Safe" by displaying a description of the 3 sensors contained within system detection early fire House Which has made. Information The sensors in the system are: A = Fire, S = Temperature, G = Gas.

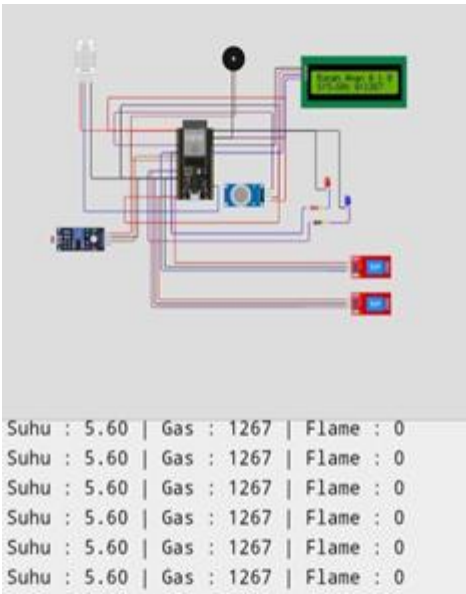

Figure 22. No Detected Fire.

Figure 23. Appearance Condition Safe.

Results Sensor Reading

Table 3 following This show results reading sensor Which done for 4 time system testing process:

Table 3. Results Reading Sensor.

No	Temperature (°C)	Gas (PPM)	Fire	Fire Status	Alarm Active	Status LCD	Blynk Status	Window Relay	Pump Relay Water	Notification Sent
1	57.80	1403	1	Yes (Fire)	Yes	“Fire Detected House"	Danger!	Off	On	Yes
2	62.10	3628	0	Yes (Gas)	Yes	“Fire Detected House"	Danger!	On	Off	Yes
3	54.20	3628	1	Yes (Fire and Gas)	Yes	“Detected House Fire”	Danger!	On	On	Yes
4	5.60	1267	0	No	No	"Status House Safe"	Safe	Off	Off	No

Analysis Response Sensor

Based on data on table 1.3, can seen that system capable detect temperature tall, Dangerous gases and fire are detected accurately. The flame sensor successfully detects fire when it is on, the MQ-2 sensor demonstrates good gas sensitivity, and the DHT22 sensor successfully measures temperatures up to 40 ° C, where the system will send a notification to the user via application Blynk that temperature in in House the currently in condition tall. The combination of these three sensors is used as the basis for decision making by the system.

Analysis Response Actuator

When a fire is detected (either due to gas or flame), the system automatically activates a buzzer as a warning alarm, the LCD will display a warning message to the occupants of the house, and a notification is also sent to the Blynk application. Window relays and water pumps can be manually controlled via virtual buttons in the Blynk application, and indicator LEDs light up when each actuator is activated.

Integration Application Blynk

System This integrated with application Blynk For give convenience in remote monitoring and control. Temperature data is sent to virtual pin V0, data gas to V1, and fire status to V5, status overall system displayed on V2 with label 'SAFE' or 'DANGER'. Blynk accepts input from users through the control buttons on V3 (for open window) and V4 (to activate the water pump). The system also utilizes the Blynk log event feature to send notifications to users when a fire is first detected.

Evaluation Performance System

During testing system show performance Which Good in detect condition Dangerous events are detected quickly and accurately. The system's response time to sensor readings and output command execution is less than 1 second, indicating that the system can provide real-time early warning. The LCD is quite helpful as a local display, and the Blynk application is also very supportive. monitoring And control from distance Far. However thus, system This Still depends on the stability of the internet connection which may affect data delivery and notifications.

4. Conclusion

Based on the results of the design, simulation, and testing process of *an Internet of Things* (IoT)-based home fire early detection system that has been carried out using an ESP32 microcontroller and the Blynk application, it can be concluded that the system is capable of early detection of potential fires well. Integration with the Blynk application allows this system to be monitored and controlled remotely using a smartphone. Through the Blynk dashboard, users can view sensor data in real time, receive hazard notifications, and can control devices such as windows and water pumps manually. This feature increases the flexibility of the system in providing early warnings and reducing the risk of fire hazards in the home environment. With this system, it is hoped that it can help the community in detecting potential fires early automatically, while providing fast notifications to users so they can take countermeasures as quickly as possible.

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