Combined Beam-type Flame Sensor with ESP32 Module for Early Fire Warning

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Abstract- **This paper presents a research direction and experiment on the application of spark beam sensors combined with ESP32 for spark detection, a factor contributing to the formation of fires causing disasters in residential apartments, offices, schools, enterprises, and manufacturing workshops. The paper also presents the sensor modules and ESP32 modules used for the early fire warning system. The results of the connection and testing within a limited range with the radius of spark appearance from 0.8 meters to 4 meters showed good performance. To avoid false alarms, the author calculated and allocated the time of spark appearance and then issued a warning with better results.**

Index Terms- **Early Fire, ESP32, fire warning, PTIT.**

I. INTRODUCTION

In the current context, fire safety and firefighting issues are becoming increasingly serious and need to be addressed. According to statistics, every year, there are hundreds of major fires in Vietnam, causing severe damage to people and property. Especially in developing cities like Hanoi, Ho Chi Minh City, with high construction density, the risk of major fires is high. Major fires cause particularly serious consequences, with a high number of deaths. Therefore, the development of an early fire warning system is very urgent. From this need, the author researched and experimented with common materials and components on the market and designed and successfully tested an early fire warning system that contributes to reducing fires through the use of the Internet of Things (IoT) module ESP32 [3], spark sensor [4], and gas sensor [5] effectively in enhancing fire safety, reducing the risk of fires and explosions, protecting people's property and lives, improving the quality of life, and creating a safer living environment for the community.

II. THEORETICAL BASIS

The early fire warning system using the IoT ESP32 module allows us to connect with spark sensor modules and gas sensor modules to detect and timely warn of fire and explosion risks. Here, the system monitors and collects data such as sparks and gases formed from fire and explosion agents such as electrical short circuits or small fires when they first form. With the design of ESP32, the characteristics of the sensors, and the program built by the author, it allows to issue warnings by sound, light combined with sending warning messages to the user's phone right from the beginning of the risk of fire outbreak [7].

1. ESP32 Module

The IoT ESP32 module [3] is a popular module nowadays, widely used in various IoT application domains such as smart device control, environmental monitoring, and the development of warning systems. The module is integrated with Wi-Fi, developed by Espressif Systems, designed with a dual-core architecture, allowing multitasking and high performance [3].

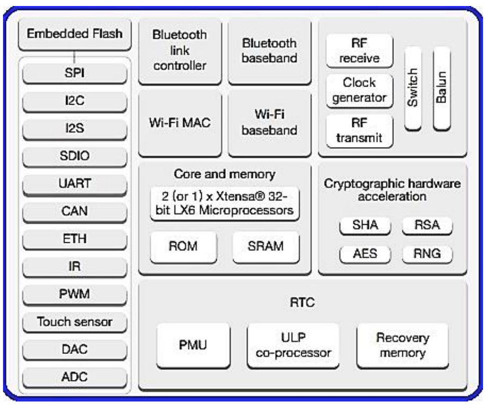

Figure 1. Main components of the ESP32 chip

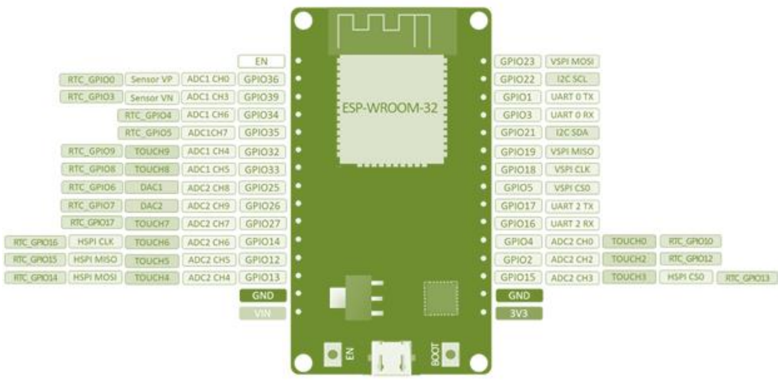

Figure 2. Functions of ESP32 Module pins

In the early fire warning system, the IoT ESP32 module is shown in Figure 1 and Figure 2. This module is used as the processing center and connects with sensors and the Internet via Wi-Fi, used to collect data from gas sensors and spark sensors. This data is processed and analyzed to issue warnings when sparks and flammable gases appear. The system also has the ability to send warning information to users via Wi-Fi connected to the Internet, helping users grasp the situation promptly and have a response plan.

2. Gas sensor module

To detect early fire and explosion risks, gas sensors are essential components. There are many types of gas sensors on the market; in this experiment, the author uses the MQx sensor [5] (x is the values 1, 3, 7).

Figure 3. Gas sensor module

The MQx gas sensor module [5] is a gas sensor with high sensitivity to LPG (Liquefied Petroleum Gas), Propane, and Hydrogen, methane (CH4), and other flammable vapors, with low cost and suitable for various applications. The sensor outputs both Analog and Digital signals, and the signal level can be adjusted by a potentiometer on the module.

Spark Sensor Module

The spark sensor [4] is used for applications in detecting sparks and many other applications. In the experimental model, the detection distance ranges from 1.2 meters to 4 meters, depending on the intensity of the spark, and the scanning angle of each sensor is 60 degrees. To cover 360 degrees, the author uses 6 sensors.

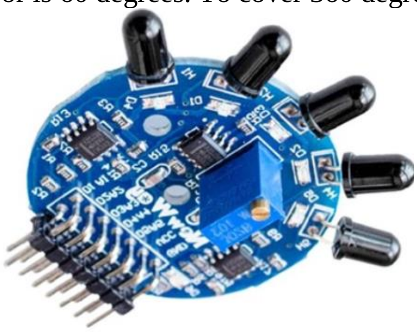

Figure 3. Flame Detection Sensor Module

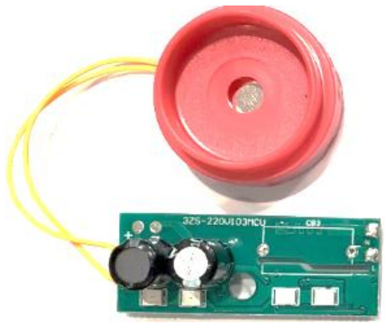

Figure 4. Early fire warning signal module

3. Alarm horn module

The horn and LED warning module [6] has the function of emitting a flashing red light signal and a warning sound to alert the user.

III. EARLY FIRE WARNING SYSTEM DESIGN

The early fire warning system using the IoT ESP32 module [3] is a model that can be widely applied in homes, office buildings, shopping centers, factories, enterprises, and many other environments. The application of this system will contribute to enhancing safety, reducing damage to people and property, and creating a safer living and working environment for the community.

1. Connecting the early fire warning system

In Figure 5 is the block diagram of the early fire warning system that the author experimented with. The system consists of 5 main blocks with the following functions:

Processing block. This block consists of 01 ESP32 board used by the author to build a program to receive signals from sensors received from the sensor block (block 2).

Sensor block (2): when one of the sensors detects a change in physical quantities such as sparks, gas, a signal will be sent to the ESP32 processor (block 1) for processing to issue a warning signal sent to the horn and LED alarm block, simultaneously send a notification to the mobile phone via message, email to alert the user to the occurrence of a fire.

Internal warning block (3). This block receives the warning activation signal from block 1 to emit a warning signal by sound and LED.
Power supply block (4). The power supply block uses a 3.7v Lithium battery to power the system, including a battery and a Lithium battery charging circuit.
Internet block (5). The Internet is used to transmit and receive data from sensors and warning signals to the Blynk cloud server and send messages to Gmail and the Blynk app.

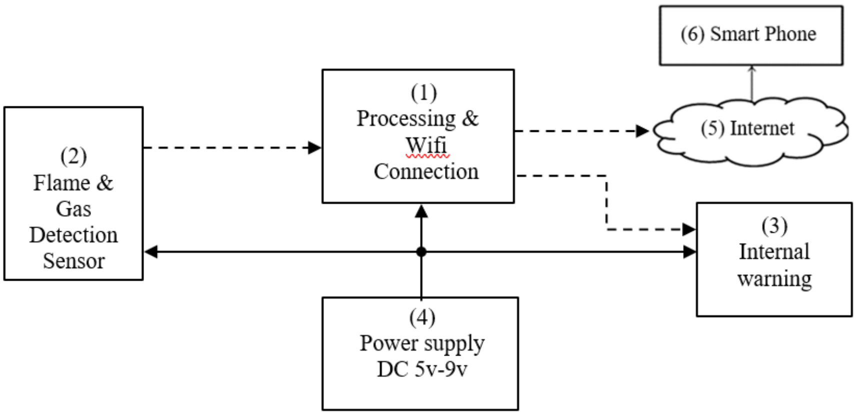

Figure 5. Early fire warning system block

Internet block (6). The user's smartphone is used to receive data from sensors and warning signals when a fire occurs, messages will be sent to Gmail and the Blynk app on the smartphone [5].

2. Algorithm flowchart

Step 1. Initialize variables, sensor pins, output pins, and threshold parameters.
Step 2. Set up Serial, Wi-Fi, and Blynk connections.
Step 3. Main loop:
a. Read values from sensors.
b. Send data to Serial and send data to Blynk.
c. Check if sensor values exceed the threshold.
d. If there is a value exceeding the sensor threshold, check the time since the last activation (if the time appears continuously
three times per second or continuously exceeds 1 second).
- If the time is less than the time threshold, increase the consecutive activation count (consecutive Count).
- If not, set the consecutive activation count to 1.
e. Set the last activation time to the current time.
f. If the consecutive activation count reaches the consecutive threshold (consecutive Threshold), activate the horn and LED
warning light for the warning duration (alarm Duration).
g. If not, turn off the horn and LED.
h. Wait for a short period (alarm Interval) before repeating the main loop.

3. Program interface

To build the program for the system, the author uses the Arduino IDE tool to perform program construction, compilation, and code loading for ESP32.

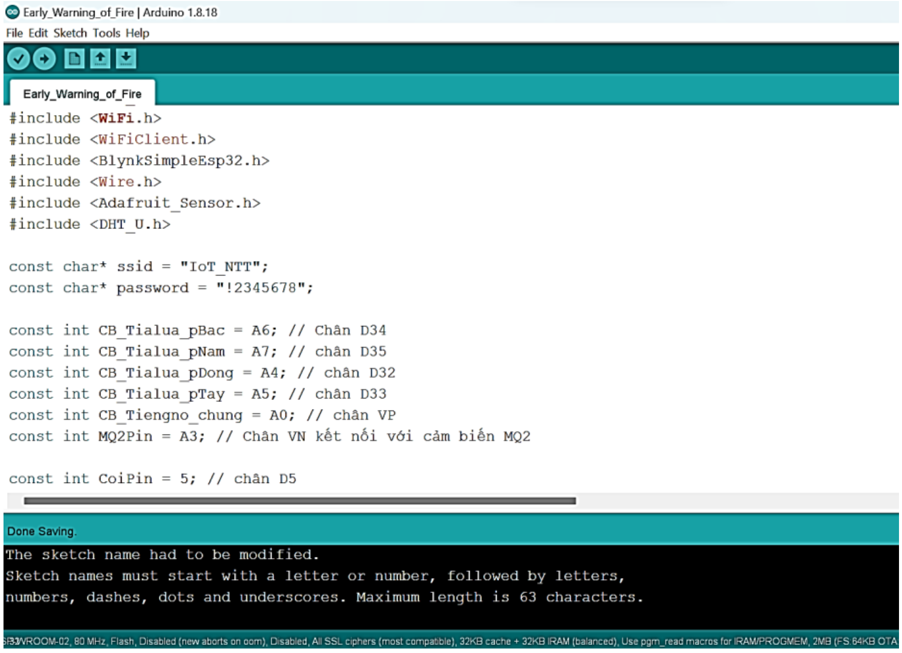

Figure 5. Early fire warning system program interface

4. System display images

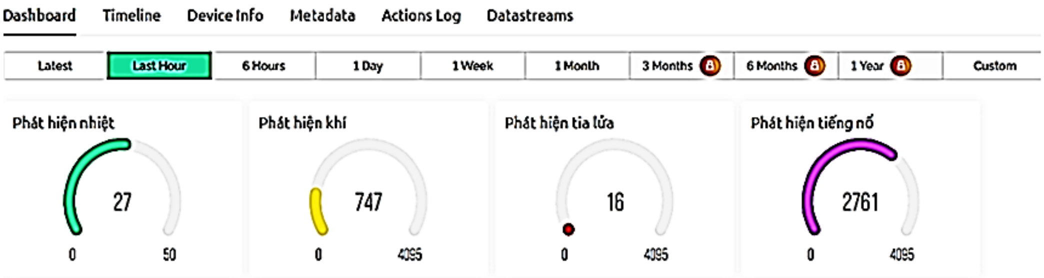

Figure 6. Signal strength display on the system cloud

With the development of the Internet of Things (IoT) technology, the early fire warning system using the IoT ESP32 module offers the ability to connect with other smart systems, such as electrical device control systems like water pumps for fire extinguishing, ventilation systems.

5. Experiment

When sparks appear, the sensor receives the signal, converts it into an electrical signal, transfers it to ESP32 for processing, emits a warning signal to activate the horn and LED, and simultaneously sends a warning to the Blynk server to send notifications to Gmail and the Blynk app installed on smartphones or computers for timely detection and extinguishing of the fire.

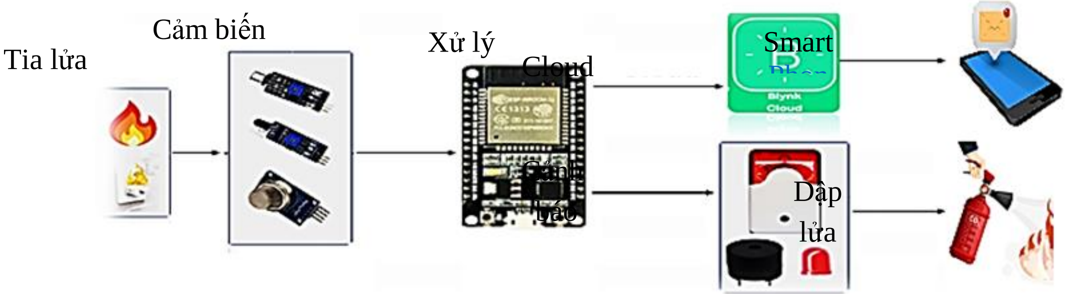

Figure 7. Early fire warning system test diagram

VI. COMMENTS AND EVALUATIONS

The early fire warning system using the IoT ESP32 module is a useful and potential solution in enhancing safety, reducing damage to people and property, and protecting the lives of people. With the development of IoT technology, this system also has the ability to connect with other smart systems, creating a complete and convenient smart home. However, to ensure the efficiency and stability of the system, it is necessary to overcome some limitations in the accuracy of sensors, system stability, and information security.

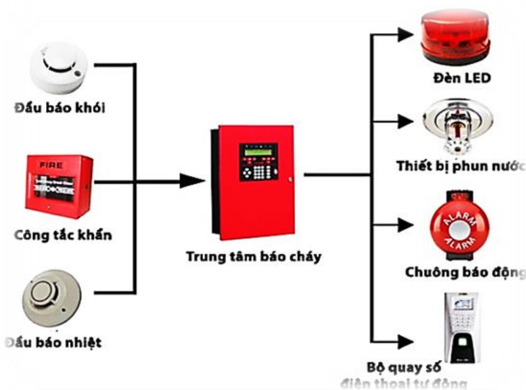

Figure 7a. Current fire alarm system diagram

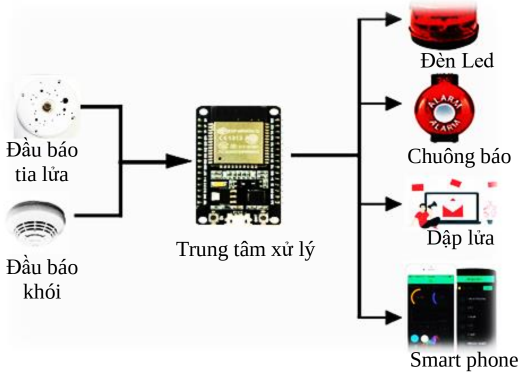

Figure 7b. Early warning system diagram

In Figure 7a, the current fire alarm system is triggered when a fire has formed or when there is a lot of smoke. From the formation of the fire to the detection of the fire, it is calculated in minutes and depends on the spread of the fire.
In Figure 7b, the early fire warning system triggers a warning signal when a spark appears. Therefore, from the formation of the fire to the detection of the spark, it is calculated in seconds.

V. CONCLUSION

The early fire warning system proposed by the author using the IoT ESP32 module combined with gas sensors and spark sensors and tested shows that the spark detection process is calculated in seconds, while the current fire alarm devices have a fire detection time calculated in minutes.
The research and development of this system not only bring scientific benefits but also contribute to improving the quality of life and creating a safer living environment for the community. To achieve the best results, the author has selected suitable sensors, designed circuits and effective programming, and conducted experiments and system testing in real environments such as testing in apartment buildings, schools, and offices.

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