IoT Smart Control System: Smoke and Fire Detection Using SIM900A Module

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Abstract – *The main focus of this system is to detect smoke and fire effectively in potential hazard situations. This system utilizes sensor technology to monitor changes in environmental conditions, with the aim of providing quick responses and notifications to users or relevant authorities via a cellular connection. This approach combines feedback signals from sensors and cellular connectivity using the SIM900A module processed with a microcontroller to increase the efficiency and reliability of hazard detection. This system was designed with the aim of providing an efficient and affordable solution for detecting potential fires or other hazardous situations in various environments, including homes, offices and industrial areas. Trial results show that this system is capable of detecting smoke and fire with high accuracy, as well as providing instant notifications via text messages or digital notifications. This innovation is expected to make a positive contribution in improving safety and security in various sectors, while leveraging the potential of IoT connectivity to provide smarter solutions in hazard detection.*

Keywords*: Control Logic, Fire and smoke detection, Flame and MQ2 Sensors, SIM900A GSM Module.*

I. Introduction

Fire hazards refer to conditions or situations that increase the risk of fire, potentially leading to property damage, injury, and loss of life. Fires typically start when a source of ignition comes into contact with flammable materials. Common sources of ignition include open flames (e.g., candles, stoves), electrical faults, sparks, and hot surfaces. In areas with abundant vegetation, wildfires can spread quickly, especially during dry seasons [1].

Smoke can pose a significant danger to human health and safety, especially if the smoke is caused by fires, whether forest fires, building fires, or other combustion events. The following are some of the main dangers of smoke for humans, including respiratory problems, cough and sore throat, shortness of breath, bronchitis and pneumonia, worsening respiratory conditions, exposure to Particulate Matter (PM), *Carbon Monoxide* (CO) poisoning, Eye and Skin Irritation, cardiovascular effects and long term health consequences [2].

Because people are busy carrying out their activities, the house they live in often escapes supervision due to negligence, such as forgetting to turn off electrical equipment, which can cause a fire. These fires can occur intentionally or unintentionally. To avoid losses due to negligence, notification is needed as a reminder that fire or smoke has been detected in the house. Internet of Things (IoT) is a technology in which objects are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet. The main goal of the Internet of things is the real-time operation of devices; as a result, daily life improvement and data collection are without human intervention [3][4][5].

Therefore, this device for detecting fire and smoke is designed to be based on the GSM SIM900A module. Notification of detected fire and smoke is sent via SMS (*Short Message Service*). SMS (Short Message Service), commonly referred to as "text messaging," is a service for sending short messages of up to 160 characters (224 character limit if using a 5-bit mode) to mobile devices, including cellular phones and smartphones. SMS messages are

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transmitted via mobile data over cellular networks starting with 2G to anyone with roaming service capability. SMS technology has been in use for several decades and remains one of the most widely used methods of communication worldwide [6].

GSM 900A module refers to a specific type of GSM (Global System for Mobile Communications) module that operates in the 900MHz frequency band. GSM modules are devices that enable communication over cellular networks and are commonly used in applications such as mobile phones, Internet of Things (IoT) devices, and various embedded systems. This module operates in the GSM 900MHz frequency band, making it suitable for areas where this frequency range is used for cellular communications that already comply with the GSM communications standard, which is a widely used standard for cellular communications. This module supports data transfer over the GSM network, allowing the device to send and receive information, including SMS (Short Message Service) and potentially GPRS (General Packet Radio Service) for data connectivity. The GSM 900A module usually features a serial interface (generally RS232) for communication with external devices, such as microcontrollers or other embedded systems. This module also supports SIM cards (Subscriber Identity Module), which stores user information and is very important for authenticating and connecting to cellular networks and can be controlled via AT (Attention) commands, which are standard commands used for communication between devices and GSM modules. This allows easy integration with microcontrollers and other control systems. This module is also equipped with an antenna interface for connecting an external GSM antenna to improve signal reception. This module is widely used in various applications such as IoT devices, security systems, remote monitoring, and other scenarios that require cellular connectivity [7].

The GSM 900A module was chosen as the communication bridge in the system because this module operates in the 900 MHz frequency range. The 900 MHz frequency range is one of several frequency ranges used in wireless communications technology, including GSM (Global System for Mobile Communications). This range is specifically used for cellular services in Indonesia. Additionally, in the context of IoT technology, some wireless communication devices and modules, such as GSM/GPRS modules, can use this frequency range for data transmission. Figure 1 below shows the plan for mobile broadband spectrum in Indonesia [8].

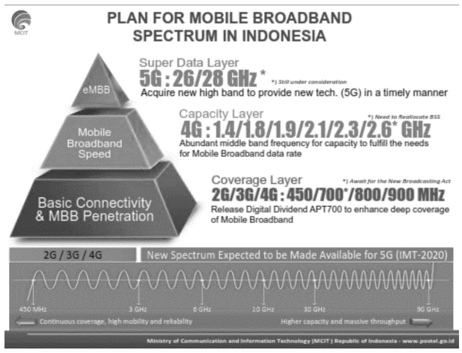

Fig. 1. Plan for mobile broadband spectrum in Indonesia

This fire and smoke detection device based on the GSM SIM900A module uses two fire sensors to detect fire, two MQ2 sensors to detect smoke, a GSM SIM900A module as a medium for sending data from the microcontroller to cellular telephone numbers and a speaker as an alert in the surrounding area.

II. Related Research

May Zaw Tun and Htay Myint in their research designed a fire detection and alarm system using a smoke sensor with Arduino. Fires are detected using various sensors, generally smoke sensors and temperature and humidity sensors. The sensor data input is connected to the Arduino controller. The LCD screen and buzzer are connected to Arduino for output results. The buzzer notifies the fire alarm and the LCD displays the fire detection status. Their system can be applied in residential areas, offices and hotels. With this system safety is guaranteed. The system can measure different parameters for early detection of building fires. There should be a minimum of two or three smoke and detectors in the home. The benefits of the system can help in initial reaction, saving lives and property. It can also protect us and where we live [9].

Various physical parameters like humidity, temperature, raindrop, GSM, atmospheric pressure and LDR can be monitored effectively and can be made more interactive with the help of different sensors that are interfaced with microcontrollers like ATmega328P. All the sensors can be connected to this microcontroller ATmega328P as the center preparing unit for the whole framework and plans can be associated with the microcontroller. The real-time monitoring of the various systems becomes possible with this IoT based system [10].

Pavan Shukla et al, presents the design and implementation of an Alcohol Detection with Engine Locking for cars using the Ultrasonic Sensor and Arduino UNO as the MCU (Master Control Unit).

The system will continuously monitor level of alcohol concentration in alcohol detection sensor and thus turn off the engine of vehicle if the alcohol concentration is above threshold level. The model will also send the message of whereabouts of the vehicle through SIM900A. The project provides an efficient solution to control accidents due to drunk driving [11].

A. Aneesh et al designed an intelligent real-time fire and smoke detection system. They use IR photodiodes to detect fire and MQ2 sensors to detect smoke. All input is processed by a Tensilica ESP8266 microcontroller. Detection results are displayed at the fire station. By using this system, the fighters can subdue fire before it causes damage at a greater extend. This system is one of the useful, costless and fastest systems for safety precautions. Thus an efficient microprocessor based system that provides an early warning to the nearest fire station, if there is a chance of fire is successfully developed [12].

III. Research Methods

In this research, two KY-026 flame sensors were used to detect fire and two MQ2 sensors were used to detect smoke. The data processing system is processed using an Arduino Nano microcontroller. The processed data is sent to cell phones based *Internet of Things* (IoT) via the GSM SIM900A module as notifications that work remotely via *Short Message Service* (SMS). Apart from that, the system also implements voice notifications directly via a 2 Watt speaker using the DFPlayer Mini module. The block diagram of the entire system is shown in Figure 2.

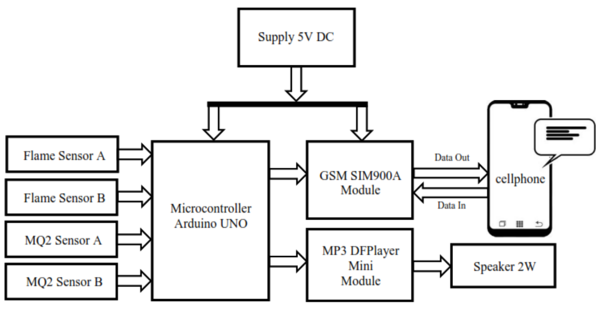

Fig. 2. Block diagram of the entire system

III.1. *Sensors System*

The sensors used in this research are the fire sensor and the smoke sensor. The fire sensor used is KY-026 type. The KY-026 fire sensor module is shown in Figure 3.

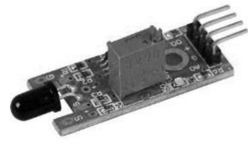
Fig. 3. KY-026 flame sensor module

This sensor physically measures the area and sends a signal to the signal conditioner. The analog signal is sent to the amplifier which aims to amplify the signal according to the resistance value on the potentiometer and sends the module's analog output signal [13]. The amplified signal is then forwarded to the comparator. The type of amplifier IC used in this module is the LM393 type. The signal conditioning circuit is shown in Figure 4.

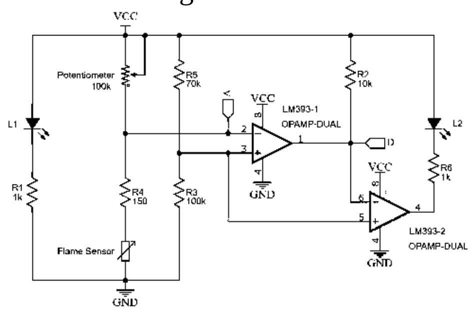

Fig. 4. Flame sensor signal conditioning circuit

The smoke sensor used in this research is of the MQ2 type. This sensor uses Stannic Oxide (SnO_2) material, which has lower conductivity in clean air. The MQ2 sensor is a sensor that can detect gas pollutants in the air, including LPG gas, alcohol, smoke, propane, hydrogen, methane and carbon monoxide [14]. The MQ2 sensor is shown in Figure 5.


Fig. 5. MQ2 sensors

When a smoke target is detected, the sensor conductivity increases as the smoke concentration increases. The signal conditioning circuit in this sensor is the same as that used in the fire sensor module. The signal conditioning circuit on the MQ2 sensor is shown in Figure 6.

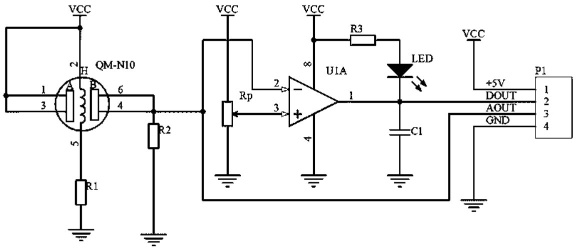

Fig. 6. MQ2 sensor signal conditioning circuit

III.2. *Control System*

In the control system, the Arduino Nano microcontroller is used as the brain of all data processing throughout the system [15]. The analog pin of the flame sensor module in room A (*Flame A*) is connected to Analog pin 0 of Arduino Nano, the Analog pin of the flame sensor module in room B (*Flame B*) is connected to Analog pin 1 of Arduino Nano and the Analog pin of the smoke sensor in room A (*MQ2 A*) is connected to Analog pin 2 of the Arduino Nano, the Analog pin of the smoke sensor in room B (*MQ2 B*) is connected to Analog pin 3 of the Arduino Nano. The placement position of each sensor and microcontroller unit is shown in Figure 7.

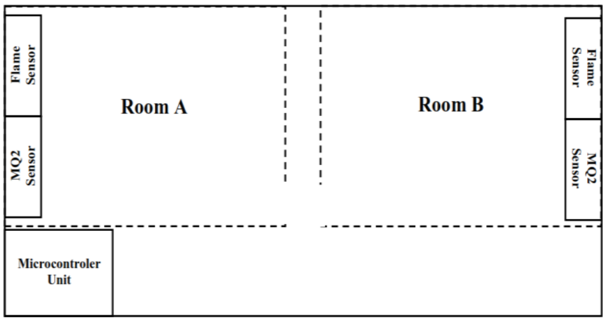

Fig. 7. Position of sensor and microcontroller unit placement

The analog signal from the flame and smoke sensors is sampled into a digital signal using an *Analog to Digital Converter* (ADC). The analog signal is sampled with 10-bit resolution found on the Arduino Nano microcontroller. Mathematically, the ADC process can be expressed in the equation [16]:

$$ADC = \left(\frac{Vin}{Vref} \times ADC\ bit\ resolution\right) - 1 \quad (1)$$

Where, *Vin* is the output analog voltage of the sensor, *Vref* is the reference voltage, generally 5 Volts DC. The 5V DC source is obtained using a DC to DC buck converter by reducing the input voltage of 11.1 V DC from the 3S 2200 mAh Lithium Polymer battery to 5V DC [17].

A control system with closed feedback is applied to this system.. The controller sends data when the ADC values from all sensor inputs are met. The ADC value of each sensor is made based on the calibration value before the system is programmed. After the calibration is carried out, the control logic for each sensor is obtained in the table 1.

TABLE 1
FLAME AND MQ2 SENSOR CONTROL LOGIC

Sensors	ADC value (10-bit)	Logic output
Flame A	>= 800	0
	< 800	1
Flame B	>= 800	0
	< 800	1
MQ2 A	>= 400	1
	< 400	0
MQ2 B	>= 400	1
	< 400	0

Fire and smoke are detected when the logic value is 1 and are not detected when the logic value is 0. From the control logic of each sensor, an algorithm with IF-ELSE function conditioning with the AND operator is applied to the system. The IF-ELSE function with the AND operator aims to make the system capable of precisely and accurately detecting fire and smoke based on the space of each sensor placement. From the results of this conditioning, conclusions were obtained as shown in table 2.

TABLE 2
SENSOR INPUTS CONDITIONING LOGIC

Sensor Inputs			
Flame A	Flame B	MQ2 A	MQ2 B
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1
0	0	1	1
1	1	0	0
0	1	1	0
1	0	0	1
1	0	1	0
0	1	0	1
0	1	1	1
1	0	1	1
1	1	0	1
1	1	1	0
1	1	1	1

Based on the conditioning logic table 2, when the logic complies with the algorithm and the values are met, there will be a sound notification through the 2 watt speaker installed in the system. The sound emitted by the system is adjusted to the sound of each sensor when it detects fire and smoke according to its placement as shown in table 3. The DFPlayer Mini module is used as a voice data reader in mp3 format which is forwarded to the speakers. DFPlayer Mini's Rx pin is connected to Arduino Nano pin 11 and DFPlayer Mini's Tx pin is connected to Arduino Nano's pin 12 using serial software with a baud rate of 9600.

TABLE 3
SOUND NOTIFICATION BASED ON CONDITIONING LOGIC

Sensors Logic (Flame A, Flame B, MQ2 A, MQ2 B)	Notifications
0, 0, 0, 0	"no notifications"
1, 0, 0, 0	Fire detected in room A
0, 1, 0, 0	Fire detected in room B
0, 0, 1, 0	Smoke detected in room A
0, 0, 0, 1	Smoke detected in room B
0, 0, 1, 1	Smoke was detected in rooms A and B
1, 1, 0, 0	Fire was detected in rooms A and B
0, 1, 1, 0	Fire detected in room B, Smoke detected in room A
1, 0, 0, 1	Fire detected in room A, Smoke detected in room B
1, 0, 1, 0	Fire detected in room A, Smoke detected in room A
0, 1, 0, 1	Fire detected in room B, Smoke detected in room B
0, 1, 1, 1	Fire detected in room B, Smoke was detected in rooms A and B
1, 0, 1, 1	Fire detected in room A, Smoke was detected in rooms A and B
1, 1, 0, 1	Fire was detected in rooms A and B, Smoke detected in room B
1, 1, 1, 0	Fire was detected in rooms A and B, Smoke detected in room A
1, 1, 1, 1	Fire and smoke were detected in rooms A and B

The results of the fulfilled control logic from the fire and smoke sensor inputs are forwarded to the SIM900A module to be sent to the destination number. The sound notification that comes from the speaker is the same as the SMS notification sent to a cell phone. The control logic flowchart is shown in Fig 8.

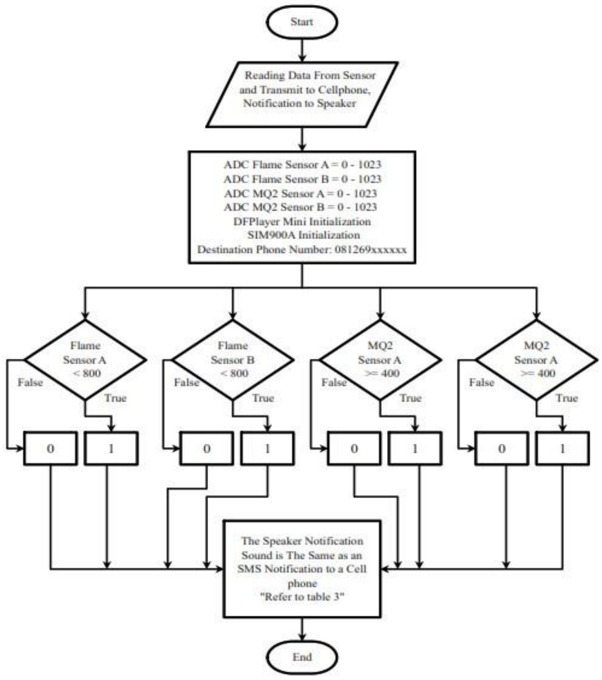

Fig. 8. Control Logic Flowchart

III.3. *Connectivity System*

After the data is processed and the control logic function is created, the data is forwarded by the microcontroller to the SIM900A GSM module. The SIM900A module is a GSM/GPRS module used to communicate with GSM cellular networks and send and receive data via GPRS. The GSM SIM900A module functions as a communication bridge between the microcontroller and cellular phones via SMS (Short Message Service). The number used to receive data from the microcontroller to the cell phone is the researcher's own telephone number. The SIM900A module is shown in Fig 9.

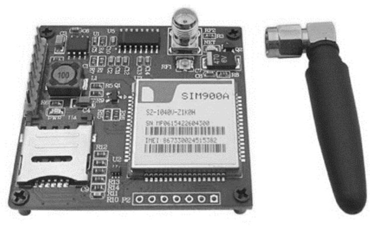

Fig. 9. SIM900A GSM module

The GSM SIM900A module is connected to the Arduino Nano microcontroller using serial software with a baud rate of 9600. The Rx 5V SIM900A pin is connected to pin 9 and the Tx 5V SIM900A pin is connected to pin 10 on the Arduino Nano. The Arduino Nano communication wiring diagram with SIM900A is shown in Fig 10.

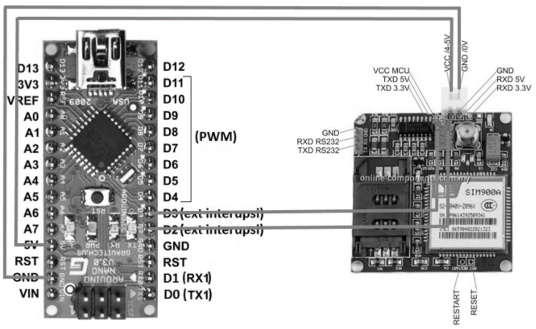

Fig. 10. Wiring diagram of microcontroller with SIM900A module

All components and devices used in this research are supplied with 5V DC voltage. The Wiring diagram of the system is shown in Fig 11.

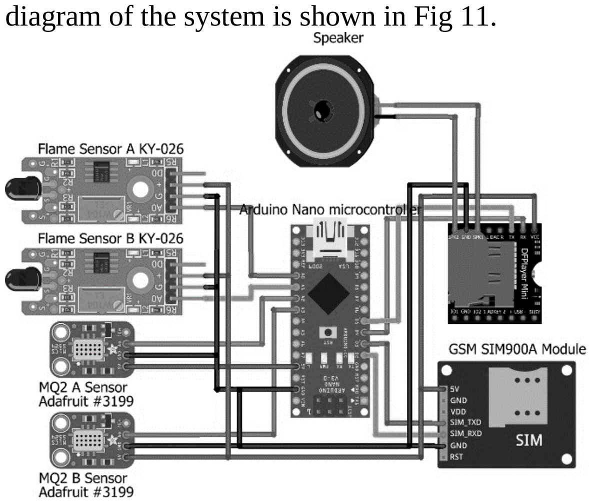

Fig. 11. Wiring diagram of the system

IV. Experimental Results and Discussion

After all components have been implemented in the system, calibration is then carried out. This calibration aims to adapt the tool to the surrounding environmental conditions.

Testing was carried out in several stages including, the system's ability to detect fire, the system's ability to detect smoke, the system's ability to send SMS notifications to cell phones and the system's ability to send notifications to speakers. The system's capabilities were tested to find out how sensitive and accurate the sensors were in detecting fire and smoke and how quickly notifications were sent to speakers and cell phones.

IV.1. *Flame Sensor Detection*

Fire detection is tested by determining the flame sensor from a distance of 0 cm to 22 cm with a scale of sensor displacement per 2 cm from the fire point. The fire detection algorithm is created by declaring the variable "*FlameA and FlameB*" with an Integer data type. The sensor reading values are collected into these variables. Then the sensor reading data is displayed to the serial monitor with the algorithm *"FlameA = analogRead(A0); and FlameB = analogRead(A1)*, *Serial. println(FlameA); Serial. println(FlameB);*". The results of the flame sensor readings to the distance of the fire point are shown in table 4.

TABLE 4
FLAMEA AND FLAMEB SENSORS READINGS TO THE DISTANCE OF FIRE POINTS

Distance	ADC value (10-bit)
0 cm	0
2 cm	148
4 cm	273
6 cm	398
8 cm	523
10 cm	648
12 cm	773
14 cm	819
16 cm	898
18 cm	995
20 cm	1023
22 cm	1023

From the results of reading the ADC value of the flame sensor above, the range of the fire sensor to detect fire points is at a distance of 0 cm – 22 cm. However, the level of sensitivity and accuracy of the fire sensor in reading fire points is at a distance of 0 cm – 12 cm. Thus, the reading value of the flame sensor in detecting fire points is determined by the ADC *FlameA* value = 800 and the ADC *FlameB* value = 800. The flame sensor sensitivity curve in detecting fire spots is shown in Figure 12.

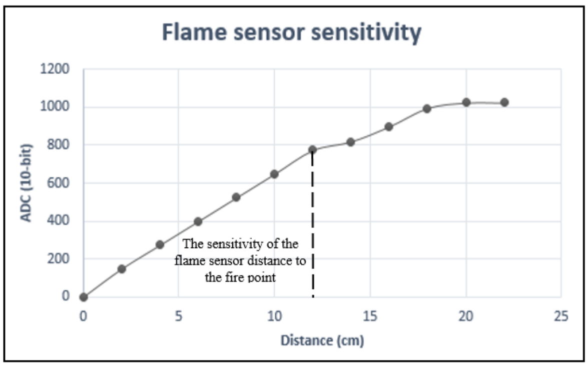

Fig. 12. The flame sensor sensitivity curve

IV.2. *MQ2 Sensor Detection*

Smoke detection was tested by exhaling carbon monoxide (*CO*) compounds towards the MQ2 A and MQ2 B sensors. Smoke testing is carried out by exhaling carbon monoxide compound four times in a row under closed room conditions with normal room temperature. The smoke detection algorithm is created by declaring the variables "*MQ2A*" and "*MQB*" with integer data type. The sensor reading values are collected into these variables. Then the sensor reading data is displayed to the serial monitor with the algorithm "*MQ2A = analogRead(A2); Serial. println(MQ2A)*; and *MQ2B = analogRead(A3); Serial. println(MQ2B)*;". The results of the MQ2 sensor readings on smoke detection are shown in table 5.

TABLE 5
MQ2A AND MQ2B SENSORS READINGS ON SMOKE DETECTION

Number of blows	ADC value (10-bit)
1 time	380
Twice	480
Three times	682
Four times	890

From the results of reading the ADC value of the MQ2 sensor above, the level of sensitivity and accuracy of the MQ2 sensor in detecting smoke is two to four times the exhalation. Thus, the reading value of the MQ2 sensor in detecting smoke is determined by the ADC *MQ2A* value = 400 and the ADC *MQ2B* value = 400. The MQ2 sensor sensitivity curve in detecting smoke is shown in Fig 13.

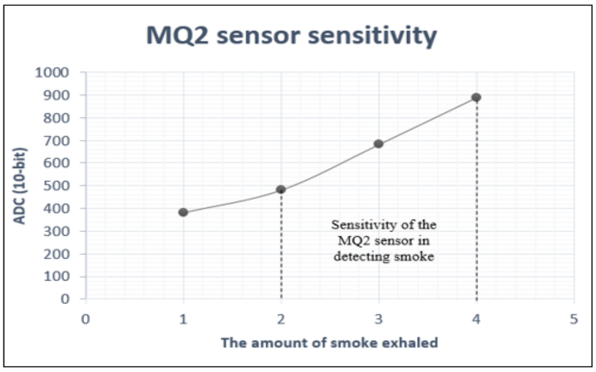

Fig. 13. The MQ2 sensor sensitivity curve

IV.3. *Notification*

Notification testing is carried out by looking at how fast the data read by the fire sensor in detecting hotspots and MQ2 in detecting smoke is sent to a cellular phone via SMS using the SIM900A GSM module. Data transmission testing was carried out over distances of 4 km, 380 km and 2455 km between the device and the cellular phone. From the test results it was found that the device was able to send data to cellular phones quickly and accurately. The time required by the device to send notifications to the mobile phone is 2 seconds. Notification of flame and MQ2 sensor readings to cellular phones is shown in Figure 14.

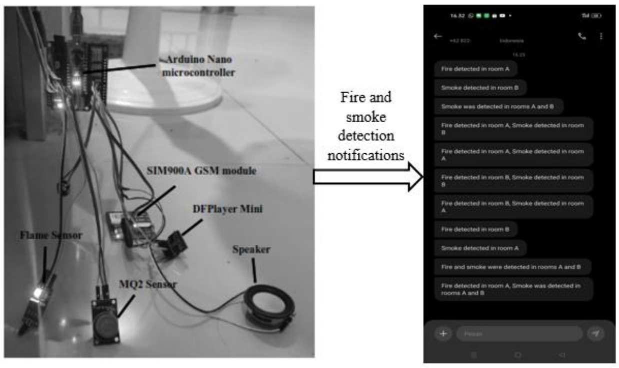

Fig. 14. Notification of flame and smoke sensor readings to cellular phones

V. Conclusion

This research successfully implemented a comprehensive fire and smoke detection system using KY-026 flame sensors and MQ2 smoke sensors controlled by an Arduino Nano microcontroller. The data processing and notification system, integrated with the GSM SIM900A module, demonstrated efficient communication via SMS notifications to cell phones and direct voice notifications through a 2 Watt speaker using the DFPlayer Mini module. The microcontroller processed the analog signals from the sensors through an Analog to Digital Converter (ADC). Calibration was conducted to adapt the system to environmental conditions, and testing verified the system's ability to detect fire and smoke, send SMS notifications, and deliver notifications through the speaker. Fire detection sensitivity and accuracy were observed within a range of 0 cm to 12 cm, while smoke detection demonstrated sensitivity two to four times the exhalation of smoke. Data transmission tests, conducted at varying distances, demonstrated the system's capability to rapidly and accurately send notifications to cell phones via SMS through the SIM900A GSM module. The entire process, from data processing to notification, took approximately 2 seconds. The research findings indicate that the implemented system effectively addresses fire and smoke detection requirements, providing timely notifications and demonstrating reliable communication capabilities over cellular networks. The entire system works according to its function without any reading errors on each sensor.

Acknowledgements

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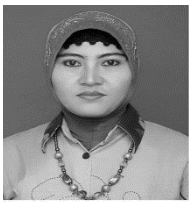

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