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Design of Gas Leak Detection and Fire Hazard Warning Using ESP32 and GPS Module Based on IoT

Nanda Wibowo
Electrical Engineering
Sultan Syarif Kasim Riau State Islamic University,
Pekanbaru, Indonesia
nandawibowo2002@gmail.com

Hilman Zarory, S.T., M.Eng
Electrical Engineering
Sultan Syarif Kasim Riau State Islamic University,
Pekanbaru, Indonesia
hilman.zarory@uin-suska.ac.id

Dian Mursyitah, S.T., M.T
Electrical Engineering
Sultan Syarif Kasim Riau State Islamic University,
Pekanbaru, Indonesia
DMursyitah@gmail.com

Aulia Ullah, S.T., M.Eng
Electrical Engineering
Sultan Syarif Kasim Riau State Islamic University,
Pekanbaru, Indonesia
auliaullah@yahoo.co.id

Abstract **– Type B fires are fires that occur due to the burning of gas-shaped fuels, this type of fire is quite common where in DKI Jakarta this type of fire occurs up to 180 cases and one of the causes of this fire is due to LPG gas leaks then at this time the fire department only has 1 method to find the location of the fire, therefore in this study a tool was created that can detect gas leaks and fires that can send danger warning messages to users, namely building owners and fire departments through the telegram application, from the research conducted the tool created successfully detects the presence of gas leaks when the PPM value of LPG gas exceeds 100 PPM as well as fires when the presence of fire is detected, the value of carbon dioxide in smoke exceeds 100 PPM, and also high temperatures then the tool will identify hazardous conditions and send a hazard warning message to the user along with the coordinates and Google Maps link of the location of the tool when a fire occurs.**

Keywords : Fire, Gas Leak, Internet of Things, ESP32, Telegram.

I. INTRODUCTION

Fire is a sudden unwanted incident where the unwanted and uncontrolled presence of fire has consequences for human life and material loss [1]. Fire can occur when a heat source reaches a critical temperature and undergoes a chemical reaction with oxygen [2]. Fires have 4 classifications, namely, class A fires caused by burning non-metallic solids, class B fires caused by burning liquid fuels or unwanted gases, class C fires caused by electrical voltage, and class D fires caused by metal fuels [3].

Fire with type B is a fire that occurs quite often, in 2020 in DKI Jakarta province there were 180 cases of this type of fire [4]. One of the causes of this type of fire is due to leakage of Liquified Petroleum Gas (LPG) which is a type of fuel commonly used by the public where gas leaks that occur are often caused by a lack of attention in the use of LPG gas such as errors in installing regulators, using gas hoses that are not feasible or because the safety layer on the LPG cylinder is no longer in good condition [5].

Therefore, more attention is needed regarding one of the causes of this type B fire so that this type B fire can be prevented before it occurs, previously several studies have been conducted on this matter, one of which is research that produces an LPG gas leak detector equipped with a hazard warning message via Short Message Service (SMS) [6], then the research was developed where the hazard warning message was sent via the Telegram messaging application [7][8].

Although the cause of the occurrence of type B fires can be detected, it is possible that fires can occur before preventive measures are taken, therefore further action is needed in the event of a fire and in this regard there is research that produces a fire detection device that can send fire hazard warning messages to building owners via the Telegram message application [9].

Furthermore, regarding further action in the event of a fire, the fire department as a party that can anticipate fires is currently very limited, this is known based on the author's interview with the Riau Fire Regional Disaster Management Agency (BPBD) where it was stated that to find the location of the fire, the fire department currently relies heavily on the telephone of the community around the location of the fire.

Therefore, based on the details above, the author conducted research that produced a tool that aims to prevent type B fires and can also take further action in the event of a fire in the form of sending a danger message to the building owner and also the fire department accompanied by the location of the fire through the Telegram messaging application.

The difference between this research and previous research is that in this study gas leak detection and fire are combined into one and the development that the author does is that the resulting tool can read the coordinates of the location of the fire and can send the point to the fire department to help the fire department find the location of the fire faster.

In this study, an ESP32 microcontroller is used that can connect to the internet [10] so that the tools in this study can later connect to the internet as well so that it becomes an Internet of Things (IoT) system [11], then an MQ-6 sensor is used to detect the presence of LPG gas [12], an IR fire sensor used to detect the presence of fire [13], MQ-2 sensor to detect the presence of smoke that can appear when a fire occurs [14], then the DHT22 temperature sensor will be used to read the temperature of the building where high temperature is one of the things that will happen if a fire occurs [15] lastly to find out the location of the fire point this research tool uses the Neo-6M GPS module to read the coordinates of the location of the fire [16].

Furthermore, for sending hazard warning messages and fire location coordinates, the Telegram messaging application is used, although the use of other messaging applications such as Whatsapp is higher, which is around 60% of the use of online messaging applications in the world, Telegram has several features that are better than Whatsapp such as in terms of synchronization, speed, backup, and also security [17] and another reason for using Telegram in this study is the Bot Father feature found in Telegrams so that in this study a Bot account can be created as the identity of the research tool on Telegram to be able to send messages to users, namely building owners and firefighters [18].

It is hoped that with this research type B fires can be prevented and if a fire occurs this tool can notify the location of the fire quickly to the fire department so that anticipation of the occurrence of fire by the fire department can be done more quickly.

II. METHOD

A. System Overview

To make it easier to understand how this research tool works, the author makes an overview of the tool system made in this study, an overview of this research tool can be seen in the figure 1 :

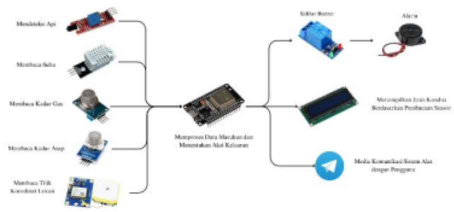

Figure 1. Overview of Gas Leak and Fire Detection System

In this research tool system there are 5 components for input data, namely the Infrared Fire Sensor, DHT22 Temperature Sensor. MQ-6 Gas Sensor, MQ-2 Smoke Sensor, and Neo-6M GPS Module. Then there is an ESP32 as a microcontroller that processes the input data which will affect the output of the system, namely the Relay Module, Buzzer, LCD, and also Telegram messages.

This research tool will use the MQ-6 sensor to detect a gas leak where if a gas leak is detected which is characterized by high levels of butane contained in LPG gas, the ESP32 will instruct the relay module to turn on the danger alarm in the form of a buzzer, then display a hazard status message in the form of a gas leak on the LCD screen, and send the same message to the user's cellphone via Telegram Messenger.

Similarly, in fire detection, if at the location there are 4 fire criteria used in this study, namely Fire, Gas, Smoke, and also High Temperature, the ESP32 will instruct the relay to turn on the buzzer as an alarm, display a fire hazard message on the LCD, and send a fire hazard message to the user where the user in question is the owner of the building and also the local fire department via the Telegram messaging application. besides the fire message, the user will also receive a point of interest for the fire, in addition to the fire message the user will also receive the coordinates of the fire where this location point is found by the Neo-6M GPS Module where by knowing the coordinates of this fire the firefighters have a faster possibility of finding the location of the fire.

B. Hardware Design

As explained in the system overview section, this research uses several electronic components in the system, therefore it is necessary to design hardware for these components so that they can be integrated with each other to work to achieve the desired function, for the hardware design of this research can be seen in the figure below :

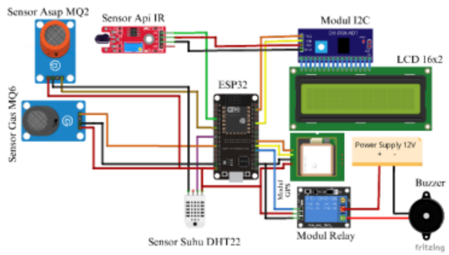

Figure 2. Circuit Schematic of Gas Leak and Fire Detection System

To find out more clearly the relationship between components in the system circuit schematic above, the following is a table of relationships between components that show the connectivity between components in this research tool system :

Table 1. Connectivity Between System Components

Component Pin	Connection Pin
IR Flame Sensor Pin	ESP32 Pin 34
MQ-6 Gas Sensor Pin	ESP32 Pin 35
MQ-2 Smoke Sensor Pin	ESP32 Pin 33
DHT22 Temperature Sensor Pin	ESP32 Pin 25
GPS Module RX Pin	ESP32 Pin 17
GPS Module TX Pin	ESP32 Pin 16
Relay Module In Pin	ESP32 Pin 4
SDA Pin of I2C LCD	ESP32 Pin 21
SCL Pin of I2C LCD	ESP32 Pin 22
Buzzer	NO of Relay Module

C. Software Design

Programming is needed on the ESP32 so that the entire system can work according to the desired function, therefore the following is a flowchart that explains how the workflow of the system will be written into the form of a program into the ESP32 :

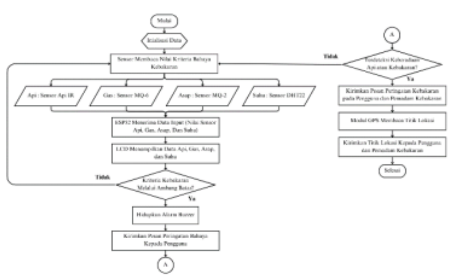

Figure 3. Flowchart of Gas Leak and Fire Detection System

Based on the flowchart shown in Figure 3, the sensor will detect fire and gas leakage criteria in the form of the presence of fire, the presence of smoke, the presence of gas, and also the presence of high temperatures. Some of the criteria mentioned have a threshold value that has been programmed on the ESP32 so that if the sensor reaches the reading up to the threshold value, the presence of the criteria will be considered present.

For the fire sensor because the output used is a digital output, therefore when a HIGH output is detected from the sensor, the presence of a fire will be considered present by ESP32, for the threshold of LPG gas, 100 PPM is used as the limit where as mentioned by the Occupational Safety and Health Administration (OSHA) that the maximum limit of exposure to LPG gas is 125 PPM for a period of 1 hour, therefore values above 100 PPM for a shorter time are marked as dangerous conditions [19].

Then the threshold used for smoke levels is 100 PPM because according to the National Institute for Occupational Safety and Health (NIOSH) the normal limit of smoke limit dioxide levels that can be exposed to a closed room is 200 PPM for 15 minutes, therefore for a shorter time 100 PPM is marked as an abnormal condition and also dangerous if exposed to humans [20], and for high temperatures that are included in the fire criteria in this study are temperatures above 35ºC because the temperature at the temperature is already categorized as abnormal [21].

If the sensor has detected the presence of fire or gas leakage criteria, the ESP32 will turn on the buzzer alarm and will display a danger message on the LCD then the danger message will also be sent to the user's Telegram and if a fire is detected, namely when all criteria are met, the coordinates of the fire location will also be sent to the fire department.

D. Tool Testing

At this stage, testing will be carried out on the tools that have been made in this study where the tests carried out are testing the accuracy of temperature readings, testing the detection of the presence of fire, testing the presence of smoke, and also the presence of gas.

In addition to testing the sensors on the device, the ability of the device to send danger messages to users via telegram will also be tested along with the ability of the device to send the coordinates of the location of the device where the coordinates sent will be compared with the original location to determine the accuracy of the location reading by the device.

After testing the functionality of the tool, accuracy testing between real conditions and conditions found by the tool will also be tested to determine whether this tool works correctly and according to the results with real conditions that occur.

III. RESULT AND DISCUSSION

A. Functionality Testing

1. Fire Presence Testing

This test is carried out to determine the ability of the IR fire sensor to detect fire, this test is carried out by bringing the match that is turned on gradually from afar to getting closer to the sensor, the distance in this test is carried out at a distance of 15, 10, and 5 cm, here are the test results of the fire sensor :

Table 2. Fire Sensor Testing Results

Distance	Fire	Buzzer	Telegram Message	Location Coordinate
15 cm	Not Detected	Not Active	Not Sent	Not Sent
10 cm	Detected	Active	Sent	Sent
5 cm	Detected	Active	Sent	Sent

The table above shows that the fire sensor can detect the presence of fire starting from 10 cm down and when a fire is detected, the device will sound a buzzer as an indication of danger accompanied by sending a danger message to the user via telegram. Because the distance of detection of the presence of fire is very close, which is less than 10 cm, the presence of this fire in this study is categorized as a possible fire.

Therefore, when a fire is detected, the device will send a fire warning message to the building owner user and also the local fire department accompanied by a location point and also a link to go to the fire location where the location point and this link can show a location map where the fire occurred using Google Maps.

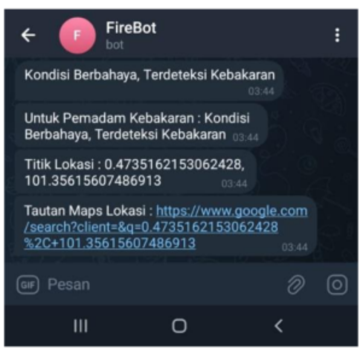

Figure 4. Fire Warning Message

2. Gas Presence Testing

This test is carried out to determine the ability of the MQ-6 gas sensor to detect the presence of gas or gas leaks that occur around the sensor in accordance with a predetermined threshold of 100 PPM, this test is carried out by bringing match gas gradually starting from 15 cm to 5 cm, the following are the results of tests carried out on the MQ-6 gas sensor :

Table 3. Gas Presence Test Results

Distance	PPM	Gas Concentration	Buzzer	Telegram Message
15 cm	4.2	0.00042%	Not Active	Not Sent
10 cm	93.8	0.00938%	Not Active	Not Sent
5 cm	112.6	0.01126%	Active	Sent

From the table above, it is known that the closer the gas distance from the lighter, the PPM value of the gas read by the sensor will increase as well as the concentration level of LPG gas and when the ppm value read by the sensor exceeds the specified threshold value of 100 PPM, the buzzer on the device will sound indicating danger and a danger message will be sent to the user via Telegram.

Figure 5. Gas Leak Warning Message

3. Smoke Presence Testing

This test is carried out to determine the ability of the MQ-2 smoke sensor to detect the presence of smoke in the room occupied by the device, in this test it is the same as testing on fire and gas, the smoke source will be brought gradually closer to the smoke sensor on the device ranging from 15 cm to 5 cm where the smoke source in this test is burned paper. The following is a table of test results for the presence of smoke on the MQ-2 sensor :

Table 4. Smoke Presence Testing Results

Distance	PPM	Smoke Consentration	Buzzer	Telegram Message
15 cm	2.8	0.00028%	Not Active	Not Sent
10 cm	76.1	0.00761%	Not Active	Not Sent
5 cm	103.7	0.01037%	Active	Sent

From the tests carried out, it is known that the device detects the presence of smoke that passes the PPM threshold value for the presence of smoke, namely 100 PPM, when the smoke enters a distance of 5 cm from the smoke sensor and from the table it is known that the closer the smoke, the PPM value and the concentration of carbon dioxide in the smoke will also increase, when the presence of smoke the PPM value has reached or passed the threshold value, the buzzer will turn on to indicate danger and a warning message will also be sent to the user via telegram.

Figure 6. Warning Message for High Smoke Levels

4. DHT22 Temperature Sensor Testing

This test is carried out to determine the accuracy of temperature readings by the DHT22 temperature sensor with the original temperature read by a digital room thermometer, this test is carried out by comparing the temperature readings of the two devices for 3 hours every 30 minutes, the following are the test results of the temperature sensor :

Table 4. Smoke Presence Testing Results

Time	Measurement Results		Difference	Buzzer	Telegram Message
	DHT22	Termometer			
12.00	34	34	0	Not Active	Not Sent
12.30	35	34	1	Active	Sent
13.00	35	35	0	Active	Sent
13.30	33	32	1	Not Active	Not Sent
14.00	33	32	1	Not Active	Not Sent
14.30	31	31	0	Not Active	Not Sent
15.00	31	30	1	Not Active	Not Sent

From the table above, it is known that the DHT22 sensor can have a difference of 1 degree of temperature reading with the original room temperature reading using a room thermometer having a difference of 1 degree. and when the sensor detects the room temperature exceeds the specified threshold of 35 degrees, the buzzer will sound and a hazard warning message will be sent to the user via telegram.

Figure 7. Warning Message for High Temperature

5. Neo 6-M GPS Module Testing

This test was conducted to determine the accuracy of location readings obtained by the Neo-6M GPS module in the device produced. The test was performed by comparing the readings from the Neo-6M GPS module with the GPS readings on a smartphone using the Google Maps application. Below are the test results of the GPS module :

Table 5. Test Result Coordinate

Latitude		Longitude	
Neo-6M	Google Maps	Neo-6M	Google Maps
0.4735162153062428	0.47354833577225697	101.35615607486913	101.35596385423133

From the test table above, it can be observed that there are slight differences in the readings between the Neo-6M GPS module and Google Maps. These differences in distance can also be measured using Google Maps. Below is a comparison image showing the exact location according to Google Maps and the location as read by the Neo-6M GPS module :

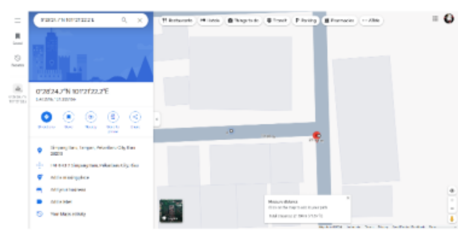

Figure 8. Comparison of Location Readings Using Google Maps

From the picture above, it is known that the reading result of the GPS module with Google Maps has a slight difference, where there is a distance of 21.84 meters between the exact location shown by Google Maps and the location shown by the Neo-6M GPS module.

6. Real-Time Condition Comparison Testing

Testing. This testing is conducted to determine whether the conditions detected by the device and sent to the user are consistent with the actual conditions, and in this testing, the response time of the device in responding to its surrounding conditions in sending messages about the conditions to the user via telegram is also measured.

Table 5. The Results of Real-Time Condition Suitability Testing

Telegram Message	Real Condition	Tool Response Speed	Speed of Message Delivery	Message According to Real Conditions
Dangerous condition, fire detected.	The Fire Source (Lighter) Ignited Within a Distance of ≤10 cm.	1.18 Second	1.52 Second	✓
Dangerous condition, possibility of gas leak.	The Lighter Gas is Brought Close to the Device at a Distance of ≤5 cm	1.23 Second	2.09 Second	✓
Dangerous condition, high smoke levels.	The smoke source (burning paper) is brought close to the device at a distance of ≤5 cm.	0.89 Second	3.31 Second	✓
Dangerous condition, temperature too high.	The fire source (candle) is placed near the device for 10 minutes.	1.19 Second	2.13 Second	✓

From the experiments conducted on the device, it is known that the response results from the device correspond to the actual conditions occurring near the device, where each experiment per fire criterion has different response times. The referred response time is the time the device responds to dangerous conditions when a fire criterion is detected. From the experiments conducted, it is known that the device has an average response time of 1.12 seconds and an average warning message delivery time of 2.26 seconds.

IV. Conclusion

From the research conducted, the author concludes that the device produced in this study successfully detects the presence of gas leaks as well as fires. When either of these conditions is detected, the device effectively sends a warning message reflecting the real-time situation via the Telegram messaging application. In the event of a fire, the device also successfully sends the coordinates of the fire location along with the danger warning message.

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