Design of Smart Door Lock System Based on VLC and Fire Monitoring in Space (Case Study: Chemical Laboratory of SMAN 1 Pacet)

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***Abstract*— The school chemistry laboratory is a public facility for all members. So, good room security system is needed, considering the room stores hazardous chemicals are flammable. Therefore, a solution is offered to development door security system and fire monitoring in space. The purpose of this research to create and design VLC (Visible Light Communication) based door security system and to design a fire monitoring system in space. ESP32 is used as a microcontroller, temperature sensor (DS18B20), MQ-2, photodiode module, and IR Flame Infrared. The result of this research is that the maximum distance for sending passwords that can be received by the receiver is 30cm, lux <123, tilt angle 165°-180°. IR Flame Infrared can detect fire <11cm away, lux < 200. DS18B20 has sensor reading accuracy 99.97%, MQ-2 detects gas more than 300ppm. The IR Flame Infrared sensor reads the wavelength value according to the light source, namely Infrared Spectrometer. Dot have error tolerance 7ms, while dashes are 7.6ms. Overall, the system can run well. The door can be opened in two ways, using smartphone flash from outside and button from inside the room. In addition, the system can also detect fire at temperatures >50°C, wavelength <1100nm, and gases >300ppm.**

Keywords*— *DS18B20, IR Infrared Flame Detection, Module Photodioda, MQ-2, NTP (Network Time Protocol), Smart door lock, VLC

I. INTRODUCTION

According to terminology based on the Big Indonesian Dictionary (KBBI), a laboratory is a certain place or room, etc., which is equipped with equipment to carry out experiments (investigations, etc.) [1]. However, it must be known about the hazards in the laboratory such as 1.) fire, as a result of the use of flammable chemicals such as organic solvents, acetone, benzene, ethyl alcohol, ethyl ether, etc. 2.) Explosion, as a result of explosive reactions from reactive materials such as oxidizing agents [2].

The school chemistry laboratory is a public facility intended for all school members, but permission is required from the party responsible for its use. This is where a good room storage security system is needed, bearing in mind that the chemicals stored in the Chemistry Laboratory contain flammable ingredients and practical tools that are mostly made of glass make this place not easily accessible to just anyone. From these problems, a solution is offered to develop a door security system according to school needs, namely Design of Smart Door Lock System Based on VLC and Fire Monitoring in Space (Case Study: Chemical Laboratory of SMAN 1 Pacet).

Smart door lock is a door lock whose operation can be done in an unusual way [3]. Example in research [4] used arduino uno as a microcontroller, fingerprint to open the door, push button is used to open the door from the inside, buzzer is a sign that the finger print has been received correctly, selenoid lock to open and close the door and there is also an android used as information and controlling door opening.

Besides that, another example from research [5] uses passive infrared (PIR) combined with RFID and arduino uno atmega with SMS-based output used for a security system that will work when the sensor detects theft of a door or window in a house, then the results captured by the sensor will be processed by the microcontroller, then a notification or warning will be sent via SMS, and an alarm will sound.

In this research VLC is used as a method to open the door. In VLC, it consists of a receiving and sending part where the receiver will detect data from the received modulated light beam and convert it into an electrical signal for translation [6] in the sender section VLC uses LED light as a carrier of information in the form of binary data, and then the light that carries the information is received by the light detector. However, in this study Morse code was used as data received with fewer data bits than binary numbers. Morse is a form of codes or signs to communicate [7].

NTP is also used in this system to print the door access time history. NTP stands for Network Time Protocol, which is a protocol for synchronizing the system time (clock) on a computer to an accurate source, via the internet network [8].

There are several studies regarding door opening systems using VLC such as research [9] Using an ATmega328 as a system controller, a light receiving photodiode and an AC

motor as a drive for the garage door rollers. Automatic garage doors can open, stop, and close when the transmitter sends a transmitter with the characters "O" = Open, "S" = Stop, and "C" = Close. Research [10] Used Raspberry Pi3 with source IP-based camera to design door locks, Arduino Mega with ESP8266 Wi-Fi controller to design grid color LED lights. The resulting system is capable of transmitting grid color coded patterns utilizing building lighting. Research [11] using Arduino Promini, Arduino Uno, Photodiode Modules, Micro SD Modules, and Relays. Producing an automatic parking barrier opening system with information sending media is the LED on the vehicle.

As a fire detector, a temperature sensor (DS18B20) is installed which has an accuracy of 9 to 12-bits, a range of -55°C to 125°C with an accuracy of +/- 0.1°C [12] . The sensor installed by MQ-2 has a concentration of 300-10000 ppm to detect LPG gas [13]. As well as infrared sensors using transducers to distinguish firelight from other light such as light spectrum, lightning flashes, welding arcs, metal grinding [14]. In previous research [15] Arduino R3, Frame Sensor, LCD, and Buzzer were used to detect fire in a room.

This system has a way of working, namely it will detect Morse light as an opening key, where the Morse light comes from a flash of light which is the output of an application on a smartphone after inputting a password. The password entered must match the word that has been set through the application. If the password is correct, the relay will move the solenoid, and the servo motor will open the door, the green indicator light will turn on and the application will get the door access time. If it is wrong then the red indicator light will turn on. Door access time is obtained through NTP (Network Time Protocol) which is on ESP32 when connected to the internet. As a fire detection, a temperature sensor (DS18B20) is installed, a gas sensor (MQ-2) and an IR Infrared Flame Detection Sensor to detect a fire in the room with an output in the form of a DC motor pump flame connected to a water sprinkler to extinguish the fire, fire warning notifications on application, the buzzer lights up the room and the door lock opens. The purpose of this system is to assist the person in charge of the laboratory in overcoming security problems encountered and detecting fires. Using this system is able to minimize access from people who do not have permission to access the chemical laboratory, passwords that are not easily known by others, locks that are more practical and flexible, higher security than conventional dismantling, and minimize the occurrence of major fires.

II. METHOD

A. Research Stages

This research will discuss Design of Smart Door Lock System Based on VLC and Fire Monitoring in Space (Case Study: Chemical Laboratory of SMAN 1 Pacet). The first thing to do is to conduct a literature study of several reference journals, articles and theses that have been published by various sources regarding the smart door lock system as a room security system. In this second stage, system planning is carried out including inputting passwords via cellphones, successfully inputting passwords so that selenoids can open, conditions when making password input errors, and conditions when a fire trigger is detected. The third stage is to design the system according to the concept. This fourth stage, system integration is carried out, namely connecting microcontroller devices with monitoring applications on mobile phones, so that real-time monitoring can be carried out. The fifth stage is to test the system by trying the system that has been created. Then Analyze the test results of the tool. The next stage is the conclusion and advice of the research that has been done. The last stage is the preparation of a report that is used as evidence that this research has been carried out.

B. Block Diagram

The workings of the block diagram of the system in Figure 1. are as follows: first, the smartphone will send Morse code in the form of light with the photodiode module as the light receiver. From the photodiode module, the light is processed by ESP32 to match whether the password entered is correct or incorrect. If correct, relay 2 will turn on to drive the solenoid, the green led will light up and the servo motor will light up to open the door. The NTP system on ESP32 will send the successful time of accessing the door via the internet to Firebase so that it can be monitored via a smartphone. However, if the password is entered incorrectly, the red led will light up. Button is used to open the door from the inside. For fire monitoring, an IR Infrared Flame Detection Sensor is used to detect infrared light in the fire, a gas sensor to detect the concentration of gas in the room and a temperature sensor to detect the temperature in the room.

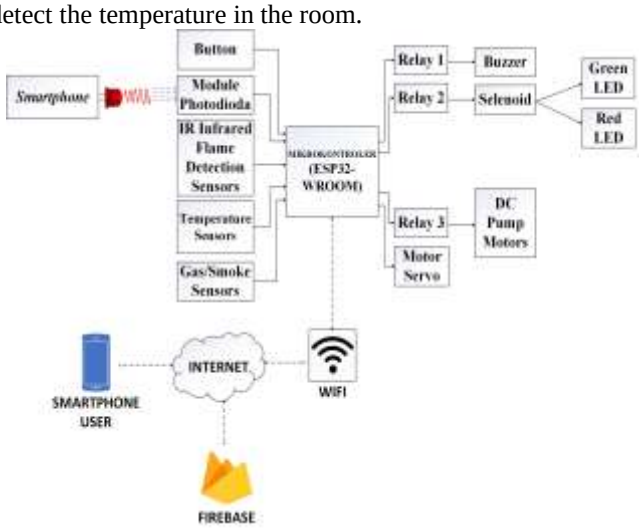

Figure 1. System Block Diagram

The results of sensor readings will be sent via the internet to firebase, where the user application will retrieve the data as one of the features of the application. If the temperature is above 50°C, the wavelength of light detected by the IR Flame infrared sensor is below 1100nm and the gas concentration detected by the gas sensor is above 300ppm then relay 1,2,3 will light up to activate the buzzer, solenoid, and pump motor DC as the first action in the event of a fire. Then, in the application a fire notification will appear in the form of a sound, and the toast "FIRE (CHECK THE ROOM)". However,

if the gas and fire sensors detect the presence of gas and fire but do not detect a change in temperature, the "FIRE CAUTION" toast will appear and relay 1 will make the buzzer light up.

C. Flowchart System Smart Door Lock

Figure 2 is a flowchart of a VLC-based smart door lock system.

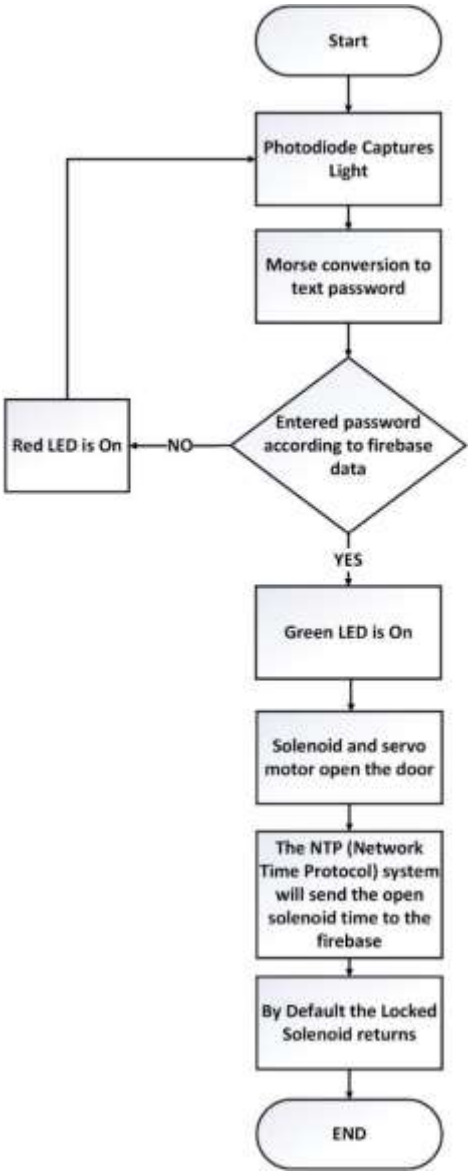

Figure 2. Flowchart System Smart Door Lock

The Smart Door Lock system flowchart which will be made in Figure 2 has an algorithm. First, the system is running. The photodioda module will capture morse light. Next, the system convert morse into text password. There was an adjustment to the conditions, checking the Morse light received by the photodiode module according to the password data stored in the database. If correct, the Green LED will light up. Selenoid and servo motor will open the door. Because ESP32 is connected to the internet, it can use the NTP (Network Time Protocol) system to find out the time when the door is open to be sent to firebase. So that later the door access time can be monitored via a smartphone. By default, the selenoid will be locked again. When the door is locked from the inside it can be opened using the push button button. In contrast, if the password is entered incorrectly, the red LED will light up. Then the system will start again from the process of inputting the password.

D. Flowchart of Converting Morse Light to Text on ESP32

Figure 3 is a flowchart of converting morse light to text on ESP32.

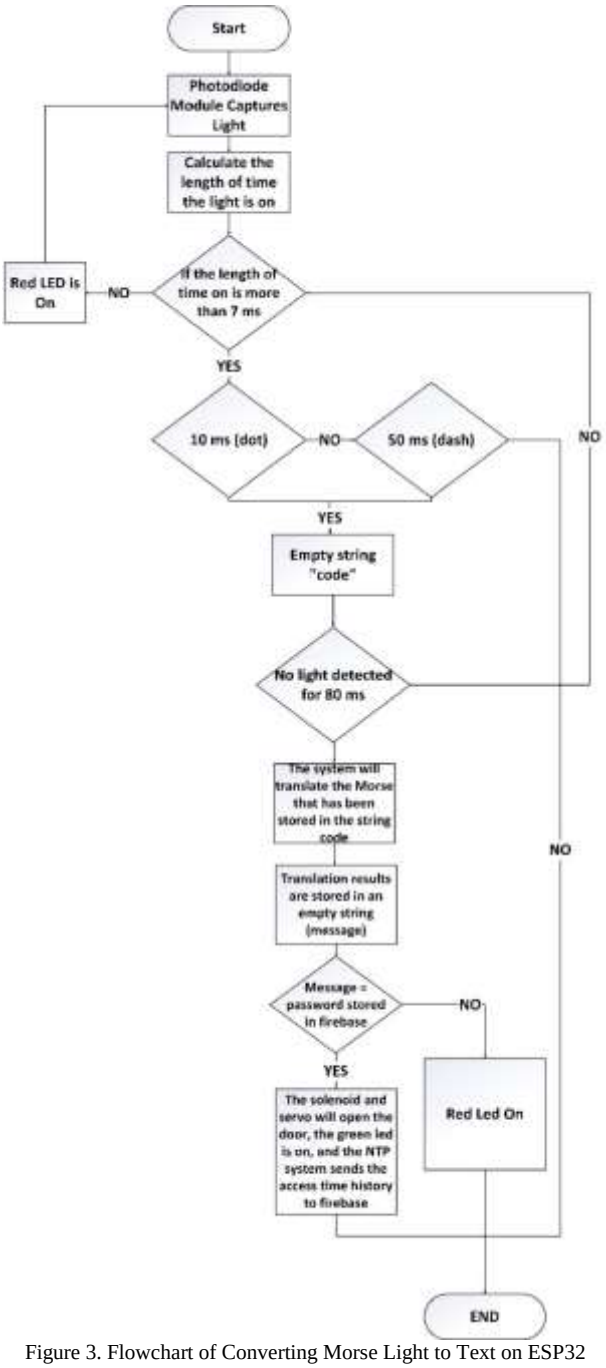

Figure 3. Flowchart of Converting Morse Light to Text on ESP32

The Morse light conversion flowchart into text on ESP32 which will be made in Figure 3 has an algorithm. First, when the system is running, photodiode module sensor detects light. Then, the system calculate the length of time the light is on. If the long time on is more than 7 ms. Then, there is a selection of conditions. Specifies a dot or dash. After that, Dot and dash reading loops occur when the light is on. Morse reading results are stored in the empty string (code). When the light does not turn back on for 80 ms, the loop will stop. The system will start translating the Morse reading results into letters and stored in the empty string (massage) and ESP32 will retrieve data from firebase to check whether the message and password data stored in the database are correct. If true, the selenoid and servo will open the door, the green led lights up, and the NTP system sends a history of access times to firebase. If wrong, the red led will light up.

E. Text Conversion Flowchart into Morse Light through the android application

Figure 4 is a text conversion flowchart into morse light through the android application.

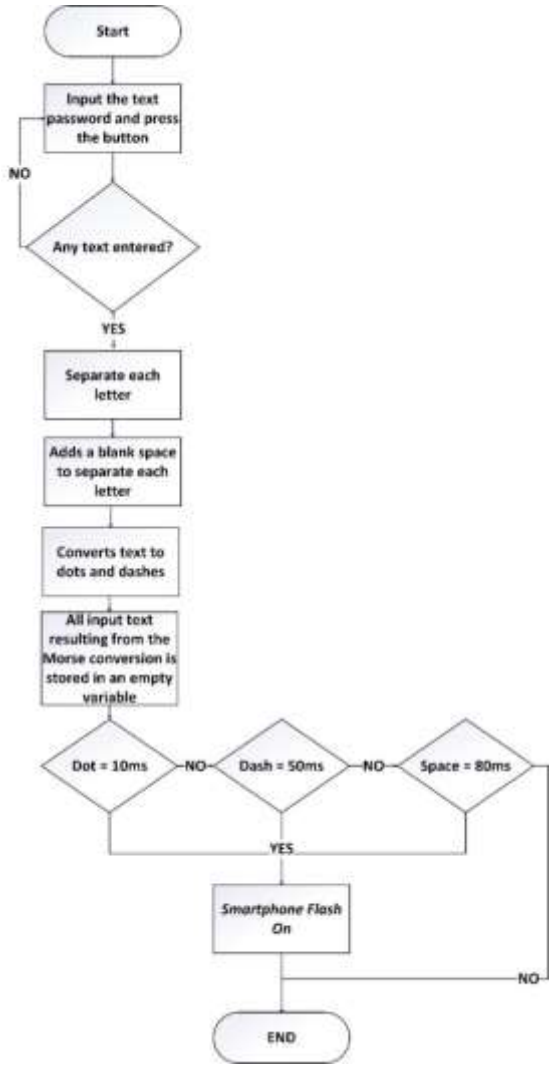

Figure 4. Flowchart of Converting Text to Morse Light through the android application

The flowchart of converting text into Morse light in the android application which will be made in Figure 4 has an algorithm. When, the system is running. The user must be inputs the password in the application, and presses the button and The system will be check the empty string where to input the password, that there is text that has been entered. If there is no text, the user must input the password / text again. If there is text, the text will be converted into morse, separating each letter. After that, the system will be add a blank space to separate each letter. All converted input text is stored in an empty variable. Next, the system select conditions for Morse conversion to flash smartphone. The dot will be on for 10ms, the dash will be on for 50ms and the white space separator between letters will have an off time duration of 80ms. The flash on the smartphone will light up based on the set time.

F. Room Fire Monitoring System Flowchart

Figure 5 is a flowchart of room fire monitoring system uses for early warning in the event of a fire.

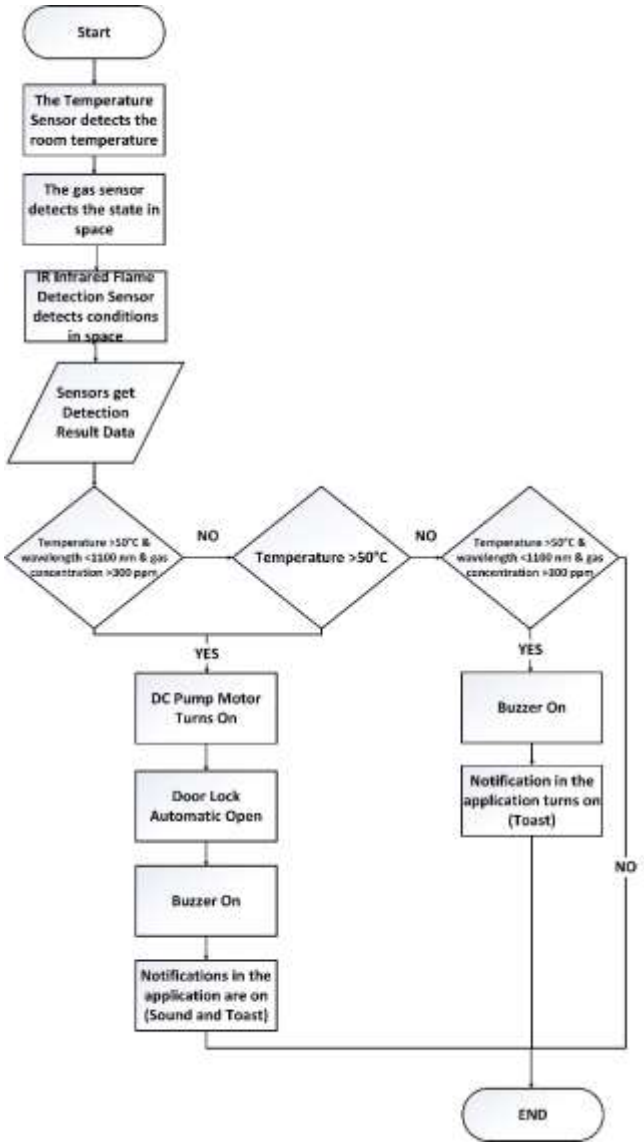

Figure 5. Room Fire Monitoring System Flowchart

The fire monitoring system flowchart in the room that will be made in Figure 5 has an algorithm. When, the system is running. The temperature sensor will detect the room temperature, the smoke sensor will also detect smoke, IR Infrared Flame Detection Sensor detects a fire and the sensors will get the detection data. The system program to fire conditions, when the temperature sensor is above 50°C, then it detects fire (below 1100 nm) and gas (above 300 ppm). Here the main indicator is temperature, when the temperature is above 50 °C but fire and smoke do not detect any data then it will still be considered a fire condition, the DC motor pump will turn on, The door lock in the room will automatically open, Buzzer turns on, and fire notification will be sent to the room in the application (sound and toast). If it does not meet fire conditions, check the fire alert condition. Fire alert condition detected fire (below 1100 nm) and gas (above 300 ppm). So, the buzzer will turn on and toast appears as a warning in the application.

G. Flow Diagram Lvl 0

The level 0 flow diagram in Figure 6 shows the flow of the database in the application to be made.

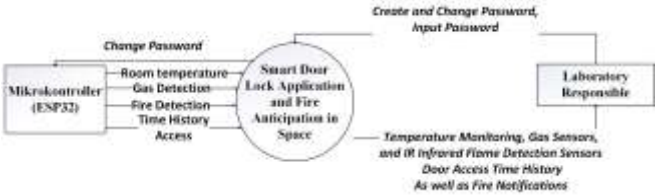

Figure 6. Flow Diagram Lvl 0

The database of the microcontroller process will store temperature measurement data in the room, gas concentrations in the room, infrared light wavelengths in the room, and access time history which can be monitored via an application on a smartphone. In the process on the smartphone the database will store password changes when the user changes the password. The result of changing the password will be used on ESP32 to match the correctness of the password with the smartphone's flash light input

H. Flowchart Application System

The flowchart application system in Figure 7. When the application is opened, it will display the main page consisting of the Open The Door Menu, Access History Menu, Change Password Menu, Monitoring Sensors Menu. The Open The Door Menu is used to open the door on the system. By entering the password to open the door, later in the application an output will appear in the form of a flash from the smartphone. The Access History menu is used to find out the real time the door was successfully opened. The Door Opener Change Password menu is used to change the password on the system at the door (Hardware) by filling in the data already available in the application. The fire monitoring menu is a menu that is used to monitor temperature sensors, smoke sensors and also IR Infrared Flame. If the sensor indicates a fire, the application will display a fire notification (Sound and Toast).

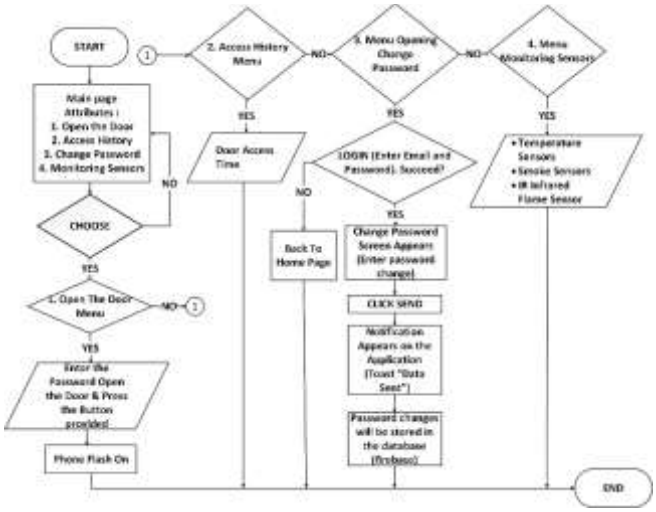

Figure 7. Flowchart Application System

III. RESULTS AND DISCUSSION

A. Prototype system

The results of the prototype system are shown in Figure 8 to representing the front view of the product, followed by the rear view design in Figure 9.

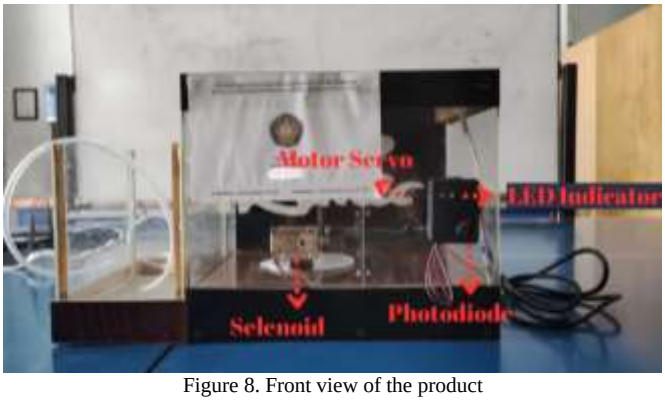

Figure 8. Front view of the product

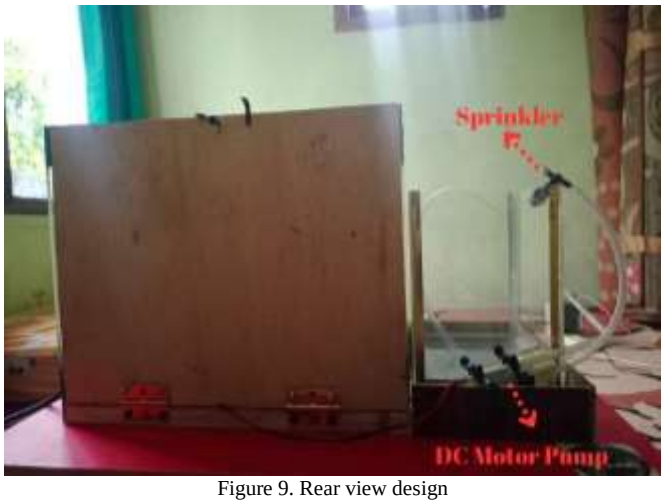

Figure 9. Rear view design

B. Implementation Aplication to the system

The application on the Design of Smart Door Lock System Based on VLC and Fire Monitoring in Space (Case Study: Chemical Laboratory of SMAN 1 Pacet) is used to convert text in the form of a password into Morse code light, display the time the door was successfully accessed, change the password, monitor sensors in the room, and provide fire alert and fire caution notifications. Figure 10 shows the available menu options.

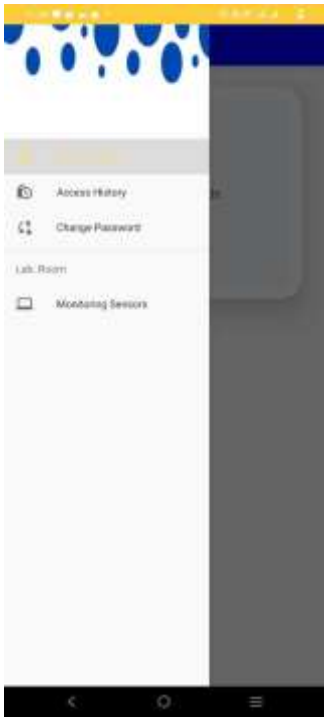

Figure 10. Available menu options

C. Password reading sent by smartphone flash to ESP32

In testing the entire system, the first is testing the accuracy of reading the password in the form of Morse light sent by a smartphone flash and captured by the photodiode module. TABLE I is a table of the results of testing the distance and light intensity on the acceptance of the photodiode module.

TABLE I
TESTING THE DISTANCE AND LIGHT INTENSITY ON THE ACCEPTANCE OF THE PHOTODIODE MODULE

Distance (cm)	Light Intensity (lux)	Success	Fail
Attaching a funnel	77	√	
1	47	√	
5	40	√	
10	59	√	
15	35	√	
20	65	√	
25	40	√	
30	46	√	
40	40		√
42	46		√
5	123	√	
10	117	√	
15	120		√
20	112		√
20	130		√

TABLE II is a table of the results of testing the angle and light intensity on the acceptance of the photodiode module.

TABLE II
TESTING THE ANGLE AND LIGHT INTENSITY ON THE ACCEPTANCE OF THE PHOTODIODE MODULE

Distance (cm)	Angle (°)	Light Intensity (lux)	Succed	Fail
3	180	110	√	
3	175	108	√	
3	170	112	√	
3	165	96	√	
3	160	122		√

TABLE III is the result of testing the accuracy of reading the password in the form of a morse light sent by a smartphone flash and captured by the photodiode module with an output in he form of a green indicator light that turns on, the door can open automatically and prints the history of door access time.

TABLE III
TESTING THE ACCURANCY OF READING THE PASSWORD IN THE FORM OF A MORSE SENT BY SMARTPHONE FLASH AND CAPTURE BY YHE PHOTODIODE MODULE

No	Distance (cm)	Light Intensity (lux)	Green Indicator Light on & Door Open	Red Indicator Light is on & Door is locked
1.	5	36	√	
2.	5	44	√	
3.	5	46	√	
4.	5	57	√	
5.	5	78	√	

To determine the level of accuracy of receiving passwords by the photodiode module on smartphone flash, a test is carried out to examine the effect of the distance and angle between the smartphone flash and the photodiode module as well as the influence of other light intensities.

It is shown in TABLE I and TABLE II that the reception of passwords by the photodiode module on a smartphone flash can be carried out until the maximum lux produced by room light is 123, the distance is 5 cm, and the tilt angle is between 165 and 180 degrees. As for the maximum distance, it can be done up to 30cm with a light lux of 0 to 50 with a tilt angle of 165° to 180°.

It is shown in TABLE III that the accuracy of receiving a password by the photodiode module has an accuracy of 100% with a maximum lux of up to 78, a distance of 5cm and a tilt angle of 165° to 180°.

This shows that, to receive a password by the photodiode module against a smartphone flash with 100% accuracy, it must be carried out provided that the room light has a lux between 0 to 123, a distance of 5cm and an inclination angle of 165° to 180°.

D. Testing Takes Action to Change the Temperature

In this overall test, action was taken to increase the temperature on the temperature sensor (DS18B20) using the help of a hairdryer/match. The action of changing the

temperature on the temperature sensor continues until it reaches a condition of more than 50°C. Then, the next step is to ensure the system output can work properly. TABLE IV shows the test results changing the temperature in the room.

TABLE IV
TEMPERATURE CHANGE

Room Temperature (°C)	Selenoid Open	Sprinkler On	Buzzer On	Notification App on & Toast Appears
27.34	×	×	×	
29.15	×	×	×	
34.62	×	×	×	
39.0	×	×	×	
47.19	×	×	×	
53.53	√	√	√	√
55.12	√	√	√	√
59.24	√	√	√	√
61.06	√	√	√	√
64.42	√	√	√	√

TABLE IV shows that the system can respond as desired. when the temperature is 53.53 °C, the DC motor pump turns on, the door can open automatically, the buzzer turns on, and the application will issue a warning notification in the form of a sound and toast "KEBAKARAN(PERIKSA RUANGAN)".

E. Testing Perform Action to bring the flame closer to the flame infrared sensor and use a match as a gas trigger to test the MQ-2

In this overall test, action was taken to increase the ppm value on the gas/smoke sensor (MQ-2) and reduce the IR Flame infrared sensor's light waves using the help of a match. The action of changing the ppm value is carried out until it reaches a condition of more than 300 ppm by giving gas around the sensor. TABLE V is the result of testing to change the gas concentration on the MQ-2 sensor and change the wavelength value of infrared light on the IR Flame Infrared sensor.

TABLE V
TESTING TO CHANGE THE GAS CONCENTRATION AND CHANGE THE WAVELENGTH VALUE

Wavelength (nm)	Gas Concentration (ppm)	Buzzer On	Toast Appears
2215.0	121.22	×	×
1476.0	300.9	×	×
1140.0	324.03	×	×
947.0	206.0	×	×
843.0	319.11	√	√
734.0	410.73	√	√
751.0	321.38	√	√

TABLE V shows that the system can work properly, namely the Buzzer will turn on and the application will issue a warning (toast) “WASPADA KEBAKARAN”.

F. Testing Carrying out the action of bringing the fire closer to the flame infrared sensor, gas to test MQ-2, and taking action so that the room temperature

In this overall test, action was taken to increase the temperature of the temperature sensor (DS18B20) to more than 50°C, increase the value of the gas/smoke sensor (MQ-2) to above 300 ppm and decrease the wavelength of the IR Flame infrared sensor to less than 1100 nm. Then ensure that the output can work properly. TABLE VI is the result of testing by taking action to change the reading value on the DS18B20, IR Flame Infrared, and MQ-2 sensors.

TABLE VI
TESTING BY TAKING ACTION TO CHANGE THE READING VALUE ON THE DS18B20, IR FLAME INFRARED, AND MQ-2 SENSORS

Temperature (°C)	Wavelength (nm)	Gas Concentration (ppm)	Selenoid Open	Sprinkler On	Buzzer On	Notification App on & Toast Appears
26.11	1892	213.5	×	×	×	×
31.33	1121	126.41	×	×	×	×
49.0	898	115.18	×	×	×	×
64.17	725	402.9	√	√	√	√
58.19	810	444.43	√	√	√	√
50.96	1077	325.94	√	√	√	√
57.0	943	328.11	√	√	√	√

TABLE VI shows that the system can detect the presence of fire, gas and temperature in the room. when the temperature is 64.17°C, wavelength 725 nm and gas concentration less than 1100 ppm the DC motor pump turns on, the door can open automatically, the buzzer turns on, and the application will issue a warning notification in the form of a sound and toast "KEBAKARAN(PERIKSA RUANGAN)".

G. Testing Changing Door Access Passwords Through Android

The next test is to change the password through the smartphone application that has been made. TABLE VII is the result of changing the password 5 times with 5 different words.

TABLE VII
CHANGING PASSWORD

Attemp To-	Captions		Capture
	Success	Fail	
1	√		BUKAK
2	√		ORRIN
3	√		LOGIN
4	√		ALIMA
5	√		DESTA

TABLE VII shows that the system can properly accept password changes using a smartphone

H. Testing Opening the Door from the Inside using a button

TABLE VIII is a table of test results for opening the door from inside the room using the button.

TABLE VIII
OPEN THE DOOR USING THE BUTTON

Attemp To-	Captions	
	Success	Fail
1	√	
2	√	
3	√	
4	√	
5	√	

TABLE VIII shows the test results of opening the door using a button that works well. Apart from using the flash light from a smartphone, opening the door can be done using the button available on the door in the room. This shows that the door can be opened using two ways, namely using a smartphone flash from outside the room and a button from inside the room

IV. CONCLUSION

Through various testing and data collection processes, conclusions can be drawn that, reception of passwords by the photodiode module against the smartphone flash has an accuracy rate of 100% with conditions of lux between 0 to 123, distance of 5cm and tilt angle of 165° to 180°. At the level of accuracy of sensor readings in detecting fires, temperature sensors have an accuracy of up to 99.97%. Meanwhile, the reading accuracy of the IR Infrared Flame Detection sensor when it detects a light of fire is 100. As well as the MQ-2 sensor, it is capable of detecting gas. Overall, the system can run well. The door can be opened in two ways, namely using a smartphone flash from outside and a button from inside the room. In addition, the system can also detect a fire when the temperature is above 50°C, light waves are below 1100nm and gas is above 300 ppm.

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