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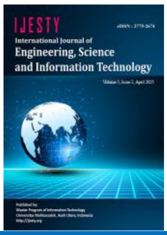

Implementation of Organic and Inorganic Waste Selection System Based on Internet of Things Using MQTT Protocol at Abby Lhokseumawe Hospital

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Abstract

The waste sorting system designed for Abby Hospital in Lhokseumawe aims to improve the efficiency and effectiveness of waste management by automatically separating organic and inorganic materials. This system integrates Proximity sensors as the primary detectors, capable of detecting organic objects within a spatial range of 4 cm and inorganic objects within a range of 5 cm. The main feature of this system is its ability to automatically sort waste, which helps reduce the potential for human error in waste categorization and improve operational efficiency in the waste disposal process. During the testing phase, which focuses on assessing the trash bin's capacity when complete, the system uses ultrasonic sensors to measure and monitor the waste filling levels. The test results show an average data transmission delay of 445.33 ms, which is within the acceptable tolerance for this system. Additionally, the prototype is equipped with an operational status notification feature for users. This notification is delivered with an average delay of just 402.5 ms, ensuring that system status information is provided to users in real time. The combination of sensor detection precision and response speed in the waste sorting process highlights the system's effectiveness in improving waste management at the hospital. This system is expected to support the hospital's efforts in maintaining a clean environment and contribute to a more environmentally friendly and organized waste management program.

Keywords: *Proximity, Ultrasonic, Internet of Things, Blynk, Organic & Inorganic.*

1. Introduction

In everyday life, Abby Lhokseumawe Hospital serves as a place for healing and treatment, but it faces serious challenges related to medical waste management. The large volume of waste, including organic and non-organic waste, requires efficient management. The manual waste selection process faces risks of selection errors, lack of time efficiency, and health risks for medical staff and patients. An innovative solution with Internet of Things (IoT) technology can improve waste management in the hospital. The use of smart sensors with the ability to detect and automatically select organic and non-organic waste is implemented through the MQTT protocol, a lightweight and reliable communication protocol. This enables efficient and real-time information exchange between IoT devices and the waste management system in the hospital. The level of transparency in medical waste management is a serious concern. The current limited monitoring makes it difficult to track and evaluate its effectiveness.

Implementing the IoT-based waste selection system is expected to improve operational efficiency and provide transparency in hospital waste management. Involving Blynk Cloud technology, hospital managers and staff can access information and remotely control the waste selection system [1]. This enhances monitoring and provides greater access and accountability in maintaining cleanliness and safety within the hospital environment. With the increasing volume of medical waste, this research contributes to more efficient and sustainable waste management. It is hoped that the results of this study can serve as a foundation for further innovation in waste management in the healthcare sector, positively impacting public health and the surrounding environment. The innovative waste selection system is expected to improve efficiency, safety, and cleanliness in medical waste management and serve as a basis for similar solutions in other hospitals or the healthcare sector in general.

This research is expected to make a positive contribution to the development of IoT technology in waste management at hospitals, supporting efforts to maintain environmental sustainability and public health. Based on the background above, the author proposes a proposal titled 'Implementation of Organic and Inorganic Waste Selection System Based on Internet of Things (IoT) Using MQTT Protocol at Abby Lhokseumawe Hospital.

2. Literature Review

2.1. Waste Defenition

Waste is a term used to refer to unwanted or unused materials generated by human activities or natural processes. Waste can take various forms, properties, and sources, and can be categorized into several types based on its characteristics. Effective waste management is crucial for maintaining environmental cleanliness and preventing its negative impacts on human health and ecosystems. Waste segregation, recycling, and wise waste management are part of efforts to manage waste more sustainably. Waste can be divided into two main types: organic and inorganic [2].

2.2. Internet of Things

The Internet of Things (IoT) is a concept that involves connecting devices as communication media based on the internet. With IoT, a user can connect and communicate with each other to perform specific activities, search, process, and automatically transmit information [3].

Fig 1. Internet of Things

Basically, IoT operates by connecting various types of devices, such as software or hardware, to the internet network. There are 3 main components that play a crucial role in the operation of IoT: sensors, gateways, and the cloud. The sensors used in this concept can include motion sensors, light sensors, and other types of sensors [4]. The purpose of these components is to collect data from physical objects connected to the internet. Once the sensors have successfully gathered the data, the gateway component is responsible for transmitting that data to the cloud or the connected internet. The gateway here can also process and take automatic actions on the existing data, such as turning devices on or off. Here, AI can assist IoT in optimizing the device functions. Finally, the transmitted data is then sent to the cloud server. The cloud, which is connected to the internet, will also provide the necessary services and applications to manage IoT. In this way, users can directly give commands to a device to perform tasks by accessing data from the cloud [5].

2.3. Proximity Sensor

A proximity sensor is an electronic device that detects the presence of objects around it without the need for physical contact. This sensor can operate based on principles such as infrared (IR), ultrasonic, or capacitive. Infrared sensors emit infrared rays and detect reflections from objects, while ultrasonic sensors use ultrasonic sound waves to measure the distance to the nearest object. Capacitive sensors, on the other hand, detect changes in capacitance that occur when an object approaches [6]. The applications of proximity sensors are extensive, covering mobile devices, automatic elevators, and smart street lights. The advantages of this sensor include the ability to detect without physical contact, quick response, and good integration within electronic systems. Despite their advantages, proximity sensors also have limitations, such as the influence of direct sunlight or the high reflectivity of objects. In the context of the Internet of Things (IoT) [7], proximity sensors become critical for detecting the presence or movement of objects that can trigger a response within an IoT system, as shown in Figure 2 below.

Fig 2. Proximity Sensor

With widespread use in automation, proximity sensors enhance efficiency and user comfort by automatically activating or deactivating electronic or mechanical devices. A basic understanding of this theory is key to designing and implementing proximity sensors effectively according to the needs of specific applications or systems [8].

2.4. Arduino Mega

The Arduino Mega is a microcontroller board based on the ATmega2560. The Arduino Mega has 54 digital input/output pins, of which 14 pins can be used as PWM outputs, 16 analog inputs, 4 UARTs (hardware serial ports), a 16MHz crystal oscillator, USB connector, power jack, ICSP header, and a reset button [9].

Fig 3. Arduino Mega

The Arduino Software (IDE), along with the ATmega2560 chip on the Arduino Mega 2560, comes pre-loaded with an initial program commonly referred to as the bootloader. The bootloader's role is to simplify the programming process by using the Arduino Software, without the need for additional hardware. Simply connect the Arduino via a USB cable to a PC or Mac/Linux, run the Arduino Software (IDE), and you can start programming the ATmega2560 chip. Even easier, the Arduino Software provides many example programs for microcontroller users [10].

2.5. Power Supply

A power supply is an electrical device that provides electrical energy for other electrical or electronic devices. Essentially, this power supply requires an energy source and then converts it into the electrical energy needed by other electronic devices [11]. The power supply image and schematic can be seen in Figure 4 below.

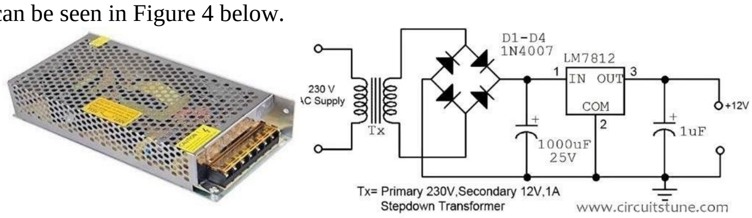


Fig 4. Power Supply and Schematic

Based on its function, power supplies are classified into three types: Regulated Power Supply, which maintains the stability of voltage and current even when there are changes or variations in the load or power source (Input Voltage and Current). An Unregulated Power Supply, on the other hand, may experience changes in voltage and current when the load changes or the power source fluctuates. Meanwhile, an Adjustable Power Supply allows the voltage and current to be adjusted according to the needs using a mechanical knob. There are two types of Adjustable Power Supply: Regulated Adjustable Power Supply and Unregulated Adjustable Power Supply [12].

2.5. Blynk

Blynk is an application based on iOS or Android used to control microcontrollers via the internet. The Blynk app can also help administrators monitor tasks conveniently. Blynk is designed for the Internet of Things. It can remotely control hardware devices, either from a mobile phone or a website, allowing users to store and monitor large amounts of data [13]. This can be seen in Figure 5 below.

Fig 5. Blynk Logo

2.6. Ultrasonic Sensor

An ultrasonic sensor is a distance sensor that detects objects by measuring the reflected waves. Ultrasonic sensors emit waves with a frequency higher than that of sound waves, specifically above 20 kHz [14]. This can be seen in Figure 6.

Fig 6. Ultrasonic Sensor

Ultrasonic waves are acoustic waves that have a working frequency above 20 kHz, making them inaudible to the human ear. These waves can be generated by a transducer or sensor, specifically an ultrasonic transducer. The ultrasonic transducer converts electrical signals into ultrasonic waves and vice versa, converts ultrasonic waves into electrical signals. The ultrasonic waves will be reflected when they encounter a boundary between two mediums during propagation. This phenomenon of wave reflection is used as a reference for creating applications that utilize ultrasonic technology, such as determining the distance between the transducer and the reflective medium [15].

2.7. Servo

A servo motor is a DC motor with a closed-loop feedback system, where the position of the rotor is sent back to the control circuit inside the servo motor. This motor consists of a DC motor, a series of gears, a potentiometer, and a control circuit. The potentiometer is used to determine the angular limit of the servo's rotation. Meanwhile, the angle of the servo motor shaft is controlled based on the pulse width sent through the signal pin of the servo motor cable [16].

Fig 7. Servo Motor

Each component in the servo motor above serves a specific function: controller, driver, sensor, gearbox, and actuator. In the image above, several parts of the servo motor components can be seen. The motor in a servo motor is a DC motor controlled by the controller section, while the component that functions as a sensor is the potentiometer, which is connected to the gearbox system of the servo motor. Controlling or operating a servo motor is different from controlling a DC motor. To control a servo motor, both a voltage source and a control signal are required. The magnitude of the voltage source depends on the specifications of the servo motor being used. As for controlling the servo motor’s rotation, it is done by sending a control pulse with a frequency of 50 Hz, a period of 20 ms, and different duty cycles. To move the servo motor by a specific amount, a pulse with a 1.5 ms positive duty cycle is required, while a 2 ms pulse width is needed for the motor to move further [17].

2.8. ESP-01

The ESP-01 wireless module is a low-cost Wi-Fi module with full support for TCP/IP usage. This module is produced by Espressif, a Chinese manufacturer. In 2014, a third-party manufacturer named AI Thinker released the ESP-01 module, which uses AT-Command for configuration. The affordable price, low power consumption, and small module size have made many developers interested in further developing this module. In October 2014, Espressif released a software development kit (SDK) that allowed more developers to work with this module. The ESP-01 module has a 2x4 DIL form factor with dimensions of 14.3 x 24.8 mm. This module requires a 3.3-volt power supply [18]. Below are the specifications of the ESP8266 ESP-01 series.

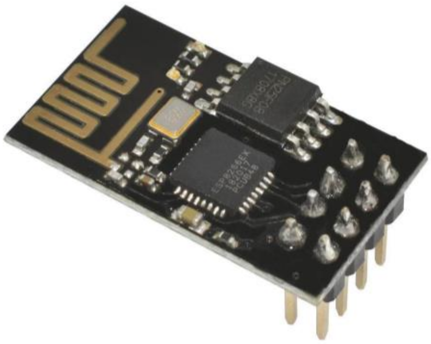


Fig 8. ESP-01 WiFi-Module

The ESP-01 is highly suitable for Internet of Things (IoT) projects. This module can also be used for other applications such as system control, monitoring, and more. The ESP-01 features deep sleep mode to save power by shutting down the module when not in use. It also has a DSP module for fast and efficient signal processing. This module can be programmed using C or C++ programming languages [19].

2.9. Protokol Message Queue Telemetry Transport (MQTT)

The Message Queue Telemetry Transport (MQTT) protocol is a very simple and lightweight messaging protocol. MQTT uses a publish/subscribe architecture that is open and easy to implement, capable of handling thousands of remote clients with just one server. MQTT minimizes network bandwidth and device resource requirements while aiming to ensure reliability and delivery. This approach makes MQTT highly suitable for machine-to-machine (M2M) communication, which is a crucial aspect of the Internet of Things concept [20]. As shown in Figure 9.

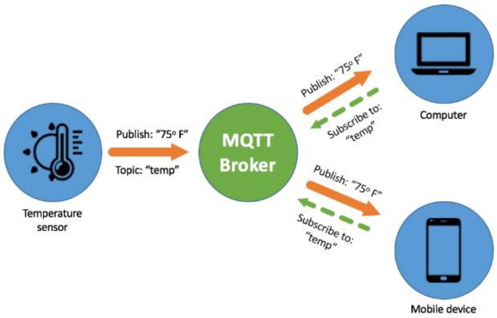


Fig 9. Protokol Message Queue Telemetry Transport

3. Research Method

3.1. Place and Research Period

This research was conducted at Abby Hospital in Banda Sakti District, Lhokseumawe City, to support and strengthen the results of the implementation of an Organic and Inorganic Waste Sorting System Based on Internet of Things (IoT) Using the MQTT Protocol at Abby Hospital. The research period starts from February 2024 to March 2024.

3.2. Data Collecting

In order to collect information for the research on "Organic and Inorganic Waste Sorting System Based on Internet of Things Using MQTT Protocol at Abby Hospital Lhokseumawe," two main data sources were utilized:

1. Primary Data: This was collected directly from the field through observation, interviews, and the distribution of questionnaires to staff and users involved in the waste sorting process. Observation was conducted to understand the waste sorting practices, while interviews and questionnaires aimed to gather their views and experiences regarding the implemented system.
2. Secondary Data: This was obtained from existing sources, such as internal hospital data related to waste management, literature, and previous studies on medical waste management and IoT technology in hospitals, official reports, and technology documentation used. By combining these two data sources, it is expected to create a comprehensive understanding of the implementation of the waste sorting system and its impact on medical waste management at Abby Hospital Lhokseumawe.

3.3. Research Flow

The data collection and research steps were carried out by the researcher to address the research problem. The stages of the research process are shown in Figure 10.

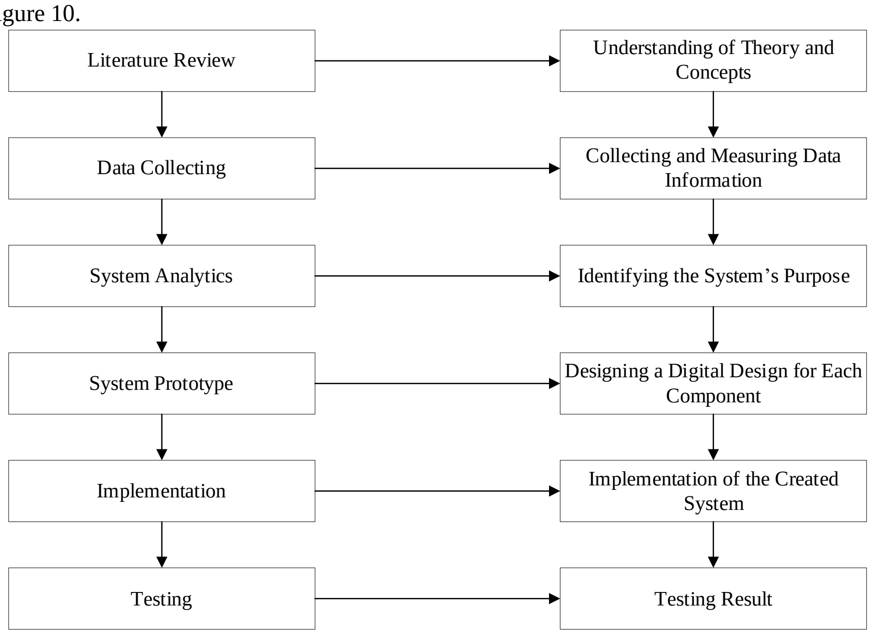


Fig 10. Research Flow

Based on the diagram, the research stages outlined begin with a literature review to gain an understanding of relevant theories and concepts. Next, data collection is carried out to gather and measure the necessary information. Following that, a system analysis is conducted to identify the system objectives that need to be achieved. Afterward, the system design phase takes place, where a digital design is created for each component. The next step is the implementation phase, where the designed system is applied in practice. Finally, the research concludes with testing to measure the results and effectiveness of the implemented system. This process provides a clear and systematic understanding from planning to final evaluation.

4. Result and Discussion

The components used in this research must be interconnected and work together to operate and meet the system's requirements in order to achieve the goals of the waste sorting system, which is connected to the access point and Blynk Cloud. The complete prototype of the tool and the display on Blynk can be seen in Figure 11 below.

Fig 11. Prototype Design Result

The design of the trash bin used as a prototype has a capacity of 15L, made of plastic box material, and equipped with 3 proximity sensors: inductive, capacitive, and infrared, to detect the type of waste. There are also two servo modules, and one ultrasonic sensor to measure the capacity of each trash bin. In the design, the sensors are positioned on top to facilitate scanning when the tool is in use. The servos are placed at the lid openings of each bin, functioning as a mechanism to push the lids open automatically. Lastly, the ultrasonic sensor is placed inside each trash bin to measure the height of the waste, and the data will be processed by the microcontroller, with the help of the ESP-01 in the controller box, to process and send the data to the server.

Fig 12. Design Result Interface Android/IOS

The interface design display on the Blynk application above is the design interface on an Android smartphone. The design consists of several gadgets, namely: two "text boxes" to display waste values, two "vertical bars" to show capacity animation, and finally, one graph that displays the reading data, which can be viewed in a time period according to the selected choice, such as "Live," "Hourly," "Daily," "Weekly," and "Monthly."

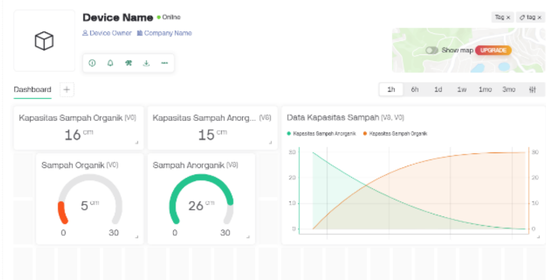


Fig 13. Design and Prototipe Result Website Interface

The interface design display on the Blynk website represents the dashboard design. Above, the dashboard displays several pieces of information such as "Device Name," "Owner," and "Company Name." In the dashboard interface design, there are two "text boxes" that display waste values, two "gauge bars" representing the capacity of both waste bins, and finally, one graph that shows the data readings. This graph can also be viewed in time periods, similar to the Android app, with options for "Live," "Hourly," "Daily," "Weekly," and "Monthly" time intervals.

4.1. Prototype Connectivity to Blynk Server

The connectivity between the prototype and the server is demonstrated in the code created using the Arduino IDE application. First, the Blynk library for Arduino IDE is called. Then, in the "void setup" function, the specific server settings are adjusted with the "BLYNK_AUTH_TOKEN" and Wi-Fi SSID and password. The code can be seen in Figure 14 below.

```
void setup()
{
  // Debug console
  Serial.begin(115200);

  myservo1.attach(5);  // servo1 on pin 4
  myservo2.attach(4);  // servo2 on pin 5
  myservo1.write(90);

  myservo2.write(90);

  // Set ESP8266 baud rate
  EspSerial.begin(ESP8266_BAUD);
  delay(10);

  // You can also specify server:
  Blynk.begin(BLYNK_AUTH_TOKEN, wifi, ssid, pass);
  timer.setInterval(1000L, ultrasonik);
}
```

Fig 14. Code Program Connectivity Prototype to Server Blynk

For the connectivity process, the prototype uses Wi-Fi as programmed in the code above. Afterward, the prototype will connect directly to the Blynk server using the authentication token with the help of the Blynk library in Arduino IDE. An indicator will appear on the Blynk Android app or the website when the prototype is connected to the server, and the data will be displayed on the interface that has been configured.

4.2. Results of Sensor Reading Distance Test with Trash Objects

The proximity sensor reading distance test on the prototype was conducted to determine the maximum reading distance of the proximity sensors, both for organic and inorganic waste. Three types of proximity sensors were used in this distance reading test: inductive, capacitive, and infrared, to read and scan the waste to be disposed of. Below, in Figure 15, is the program code for scanning the waste using the three proximity sensors.

File Edit Sketch Tools Help

TES_RINA §

```
void sensor() {
  valIn = analogRead(sensor_pinIn);
  valKapas = analogRead(sensor_pinKapas);
  valInduk = analogRead(sensor_pinInduk);

  Serial.print("NILAI infrared = ");
  Serial.println(valIn);
  Serial.print("NILAI induktif = ");
  Serial.println(valInduk);
  Serial.print("NILAI kapasitif = ");
  Serial.println(valKapas);
}
```

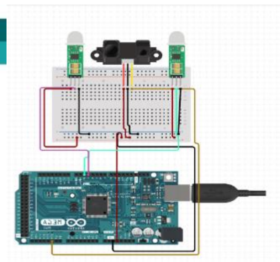


Fig 15. Program Code for Sensor Reading and Circuit Diagram

From the code above, the values from the three sensors are scanned, and then the results are printed in decimal form. After that, the program is incorporated into the logic for separating organic and inorganic waste as shown in Figure 16.

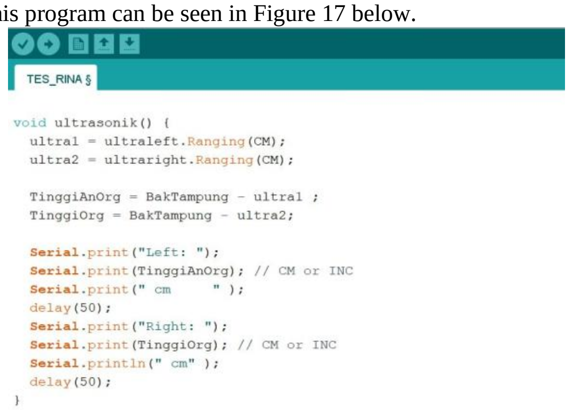
```
File Edit Sketch Tools Help
TES_RINA §
void loop() {
  mod = 0;
  sensor();
  ultrasonik();

  if (valIn < 500 && mod == 0)
  {
    //Organik Kapasitif & induktif OFF
    Serial.println("Sampah Organik");
    mod = 1;
    Buka2();
  }

  else if ((valIn > 500 || (valInduk > 500 && valKapas > 300 )) && mod == 0)
  {
    //Anorganik Kapasitif atau induktif ON
    Serial.println("Sampah Anorganik");
    mod = 1;
    Buka1();
  } else {
    Serial.println("Sampah Tidak Terdeteksi");
  }
  delay(3000);
}
```

Fig 16. Code for the Logic of Separating Organic and Inorganic Waste

The logic above represents the code program for reading organic and inorganic waste. The first step is to classify the waste using the sensor readings. If the infrared sensor detects the waste, it is classified as organic waste. On the other hand, if the capacitive or inductive proximity sensor detects the waste, it is classified as inorganic waste. The second step occurs when the infrared sensor reading reaches a threshold of 500, with a reading range from 0 to 1024. In this case, the lid of the waste bin will open using the servo function Buka2();. For inorganic waste, the capacitive and inductive sensors are used to differentiate between metal and non-metal inorganic waste. The waste is scanned, and if the reading value falls within the threshold of 500, the lid will open using the servo control Buka1();. After this, multiple tests will be conducted to check the performance and accuracy of the waste classification process.

4.3. Results of Testing Waste Bin Capacity with Ultrasonic Sensor to Blynk

The distance test of the sensor calculated is the result of readings from two ultrasonic sensors, where the height readings are input into the height formula and sent to the server. The reading formula is calculated by subtracting the ultrasonic sensor value from the total height of the waste bin. The code for this program can be seen in Figure 17 below.



```
TES_RINA §

void ultrasonik() {
  ultra1 = ultraleft.Ranging(CM);
  ultra2 = ultraright.Ranging(CM);

  TinggiAnOrg = BakTampung - ultra1 ;
  TinggiOrg = BakTampung - ultra2;

  Serial.print("Left: ");
  Serial.print(TinggiAnOrg); // CM or INC
  Serial.print(" cm      " );
  delay(50);
  Serial.print("Right: ");
  Serial.print(TinggiOrg); // CM or INC
  Serial.println(" cm" );
  delay(50);
}
```

Fig 17. Code for Capacity Reading

4.4. Results of Servo Testing on Trash Can Lid Opener

In the process of opening the trash can lid, a servo motor is used as the actuator for opening and closing. The angle is used to set the initial position for both the opening and closing processes. The two servos used in the prototype, along with the circuit and the corresponding code, can be seen in Figure 18 below.

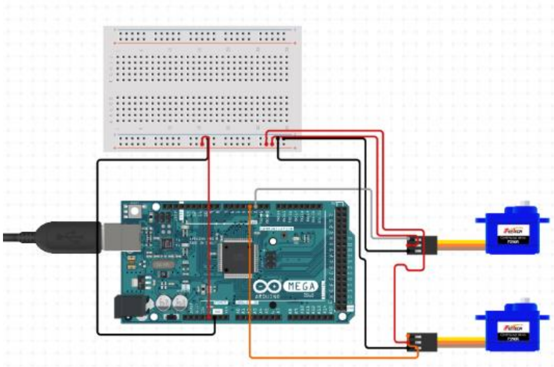


Fig 18. Circuit for Opening and Closing the Inorganic Trash Can Lid

The servo testing needs to be carried out to ensure that the prototype works and the trash can lid opens. This test is conducted on two trash cans, organic and inorganic, which are mounted on two doors or lids, with five trials performed on each trash can.

4.5. Results of User Notification Testing

The notification code program is created in the Blynk application. The first step is to call the Blynk library for Arduino IDE. After that, the specific server is adjusted in the "void setup" with the "BLYNK_AUTH_TOKEN," along with the Wi-Fi SSID and password. The program code can be seen in Figure 19 below.

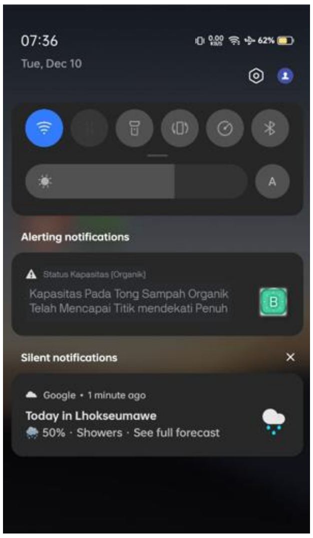


Fig 19. Notification Screenshoot

User notification testing is necessary to determine the delay time from the scanning phase to the time the notification is sent. This test is performed by scanning a trash can that is more than 85% full in terms of height. During the test, the scan time and the sending time will be displayed on the serial monitor until it reaches the real-time database.

5. Conclusion

This research successfully developed and implemented an organic and inorganic waste sorting system based on the Internet of Things (IoT) using the MQTT protocol at Rumah Sakit Abby Lhokseumawe. Based on the test results, it can be concluded that the waste sorting system using proximity sensors works well according to the design. These sensors are able to detect organic objects at a maximum distance of 0 - 4 cm, while inorganic objects can be detected at a maximum distance of 0 - 5 cm. In addition, the testing related to the delay in reading the waste bin capacity revealed an average delay of 0.45 seconds or 445.33 ms. Finally, the notification sending test from the prototype to the user application showed an average delay of 402.5 ms. Thus, this system demonstrates efficient and responsive performance in supporting waste sorting in the hospital.

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