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Automatic waste sorting and trash bin capacity monitoring system using solar panels based on Internet of Things (IoT)

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ABSTRACT

Waste management is one of the common issues faced by many cities worldwide. Many people dispose of waste carelessly, failing to separate different types of waste, leading to piled-up and scattered garbage. This problem is caused by a lack of public awareness about environmental preservation and the absence of quick access between garbage bins and waste collectors, resulting in waste accumulation. Based on these issues, a smart trash bin based on the Internet of Things was designed using NodeMCU ESP32 as its microcontroller. The bin lid operates automatically using an infrared sensor as an object detector and is equipped with a DFPlayer module that can produce sound. The waste separator uses three proximity sensors and a DHT22 sensor to differentiate between wet organic, dry organic, and inorganic metal and non-metal waste. In this study, a trash bin was also designed with an ultrasonic sensor to detect the bin's capacity, and the data was then sent via the Blynk platform, allowing waste collectors to access it through a smartphone. From the test results, the three proximity sensors and the DHT22 sensor successfully differentiated between wet, dry, metal, and non-metal waste. The data obtained by the ultrasonic sensor was also successfully transmitted to the collectors via the Blynk application.

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1. INTRODUCTION

Waste is something that is not used, not utilized, not liked or something that is thrown away that comes from human activities and does not happen by itself. Waste can be categorized into two types, namely organic waste and inorganic waste [1]. Waste management is one of the factors that influences the creation of a clean and healthy environment [2]. Ineffective waste management can cause various problems such as health problems [3]. Most of the available trash cans have a cover on the top to avoid the unpleasant odor emitted by the trash. The problem that arises with ordinary trash cans is that the cover must be opened manually which makes the user less clean and if the trash can is full but if it is not immediately thrown into the final container, the trash in the trash can will pile up and be scattered [4]. The problem that often occurs is the process of collecting trash which is delayed and the collection of trash is small. This happens because there is no fast access that can connect the trash bin with the officer [5].

Lack of public awareness of their concern for the cleanliness of the environment around them is one of the causes of ineffective waste management. This can be observed as there is still a lot of garbage scattered on the streets [6]. Although the government through the environmental agency (BLH) has provided trash bins, public awareness in disposing of garbage is not in the right place. Usually what often happens is that if the trash bin is full, people will throw garbage around the trash bin area [7]. There are still many people who do not throw garbage in the right place according to its type, even though different trash bins have been provided for each type of garbage, such as organic and inorganic trash bins. We can see this when garbage is

being transported by garbage officers that organic and inorganic waste is still mixed [8]. The problems described above are the basis for the researcher's thinking to design and create a smart trash bin that can open automatically with a voice in the form of a welcome greeting and an invitation to throw trash in its place and appreciation for throwing trash in its place, and also equipped with an automatic waste sorter and a trash bin capacity monitoring system based on the Internet of Things with alternative/renewable energy. The Internet of Things has the ability to share data, remote control, and control equipment. The Internet of Things can also be applied to identify, track, find, monitor objects and trigger related events automatically and in real time [9]. There are several previous studies that have existed previously regarding smart trash bin tools, which are references for research as well as comparisons for updates, including research by Noordi et al. who succeeded in designing an automatic trash bin using an infrared sensor based on Arduino uno R3. The result is that the trash bin can open and close automatically [6].

In the research of Anas et al. and Hasibuan et al. successfully designed an IoT-based automatic trash can. The result is that the trash can sort wet, dry and metal waste [10],[11]. In the research of Maulana et al. Successfully designed an automatic trash can. The result is that the trash can make a sound [12]. In the research of Dharmansyah et al. and Ramadhan et al. successfully designed a smart trash can based on IoT by utilizing solar panels as a voltage supply. The result is that the trash can provide information in the form of notifications if the trash can capacity reaches 80% to the cleaning staff [13],[14].

2. METHOD

This research was conducted in several manufacturing processes. Starting from hardware manufacturing, programming on NodeMCU and programming the blynk application that can be accessed via android. The components used in the research are generally designed as a block diagram in Figure 1 below.

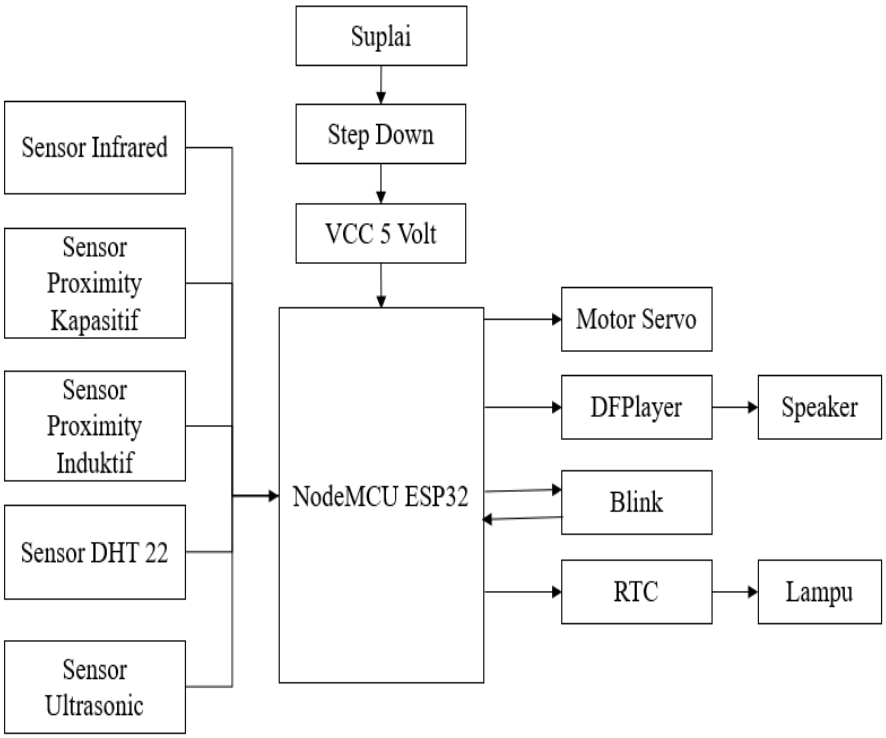


Figure 1. Block diagram of this system.

The system block diagram in Figure 1 above illustrates the system structure consisting of several components with different functions. This tool is made using NodeMCU ESP32 which is a development of NodeMCU ESP8266 as a microcontroller. NodeMCU ESP32 has more GPIO pins and faster wifi compared to ESP8266, and supports Bluetooth [10]. The tool that is made is equipped with a trash cover that can open and close automatically [4]. And equipped with a DFPlayer module that is integrated with a speaker so that it can produce sound [12]. The waste sorter is made using a proximity sensor and a DHT22 sensor. The types of waste that can be sorted are wet and dry organic waste, inorganic metal and non-metal waste. This trash

can is also supported by a trash bin capacity monitoring system [15]. Ultrasonic sensors are used to send information on the capacity of the trash can which is then displayed via the blynk application which can be accessed by cleaning staff via smartphone [5]. In the design, the author also integrated IoT with alternative/renewable energy sources, as a solution to the difficulty of accessing electricity when the trash can is outdoors [13].

Figure 2(a) provides a detailed explanation of the workflow of the automatic trash cover system with a flowchart as a visual representation. The initial process is the sensor initiation, namely all components are activated and prepared so that the system is able to run. The active Ir sensor servo motor that opens the trash cover is followed by an appreciation message "Thank you for throwing trash in the place provided" generated by DFplayer which is integrated with the speaker. Figure 2(b) provides a detailed explanation of the workflow of the automatic waste sorting system with a flowchart as a visual representation. The initial process is sensor initiation, namely all components are activated and prepared so that the system is able to run. The sorting system is carried out in stages, namely starting with the sorting of organic and inorganic waste types. Then continued with the sorting of wet and dry organic waste types or the sorting of metal and non-metal waste types.

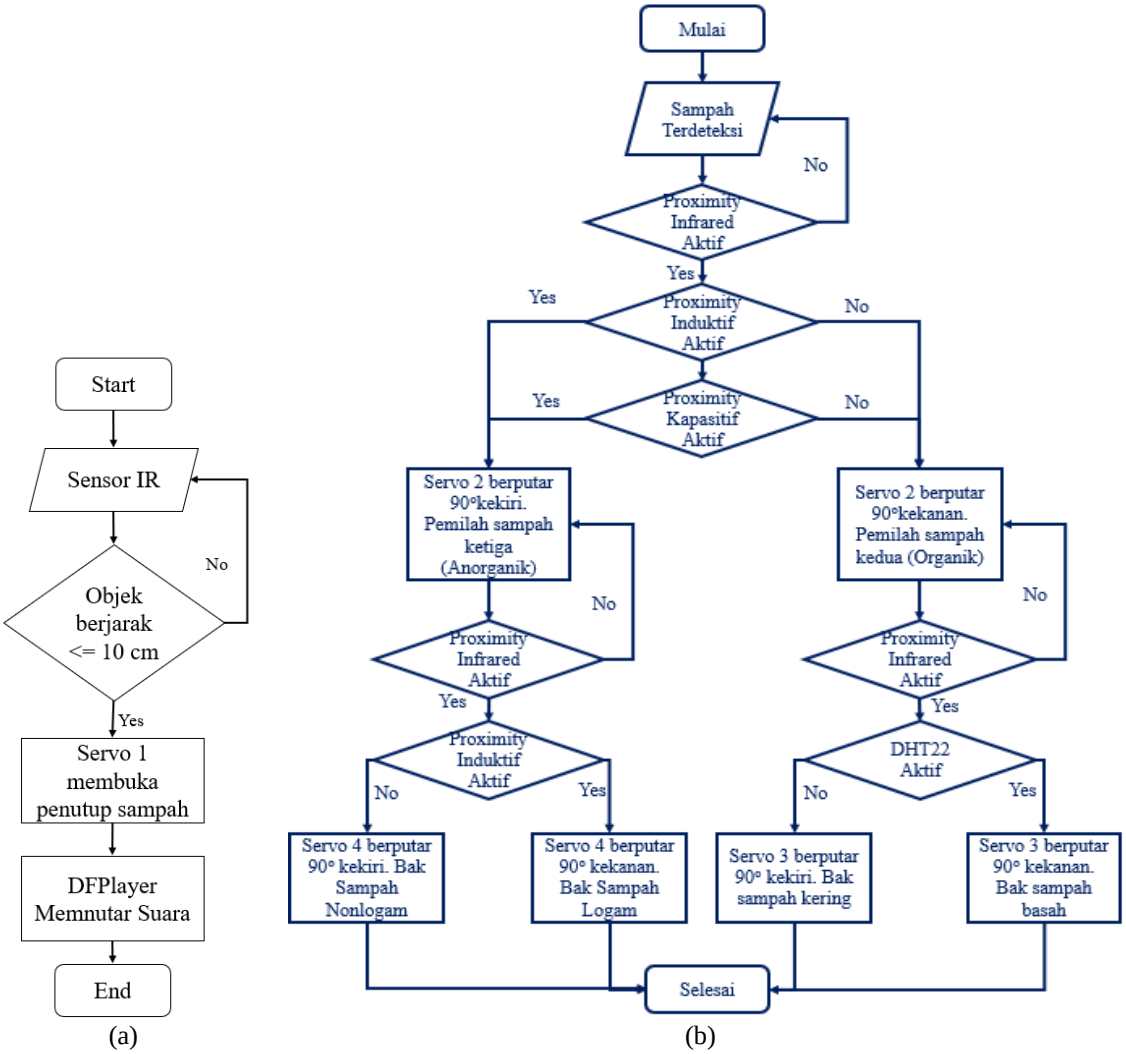


Figure 2. Flowchart, a) Opening and closing the trash can, b) Waste sorting flowchart

Figure 3 provides a detailed explanation of the workflow of the trash bin capacity monitoring system and the tool lighting system with a flowchart as a visual representation. The initial process is sensor initiation, namely all components are activated and prepared so that the system is able to run. Data generated by the ultrasonic sensor will be displayed on the blynk application. Notifications will be sent to officers if the trash bin capacity reaches 80% so that the trash bin is not too full, causing users to throw trash outside the trash bin. The lighting system will be on for ± 4 hours, namely at 18.00 and will turn off again at 22.00.

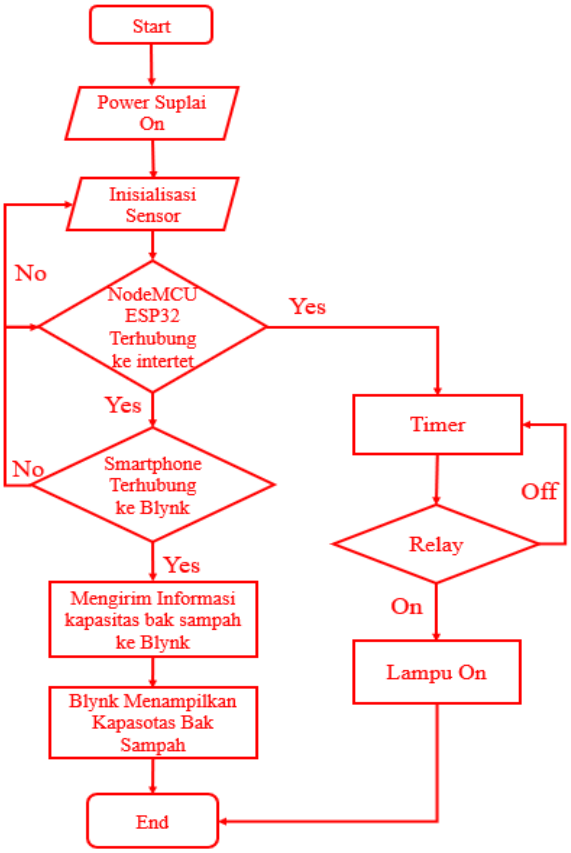


Figure 3. Flowchart of the waste bin capacity monitoring system

3. RESULTS AND DISCUSSION

This section contains the results of testing Alternative Energy, Step Down Module, NodeMCU ESP32 control system, and monitoring system through the blynk platform that has been designed. The following is the hardware that has been designed can be seen in the following image shown in Figure 4.

Figure 4. Hardware Implementation

The first test was conducted by measuring the voltage generated by Photovoltaic with a peak power of 10wp monocrystalline with a battery load of 12volt 12ampere. Measurements were conducted at 08.00 WIB to 17.00 WIB. Data collection was carried out when the weather conditions were sunny and cloudy. Measurements were carried out using a Multimeter connected between the Solar Charge Controller (SCC) and the battery. The results of the data from the measurement of voltage, current, and power generated by Photovoltaic can be seen in Figure 5.

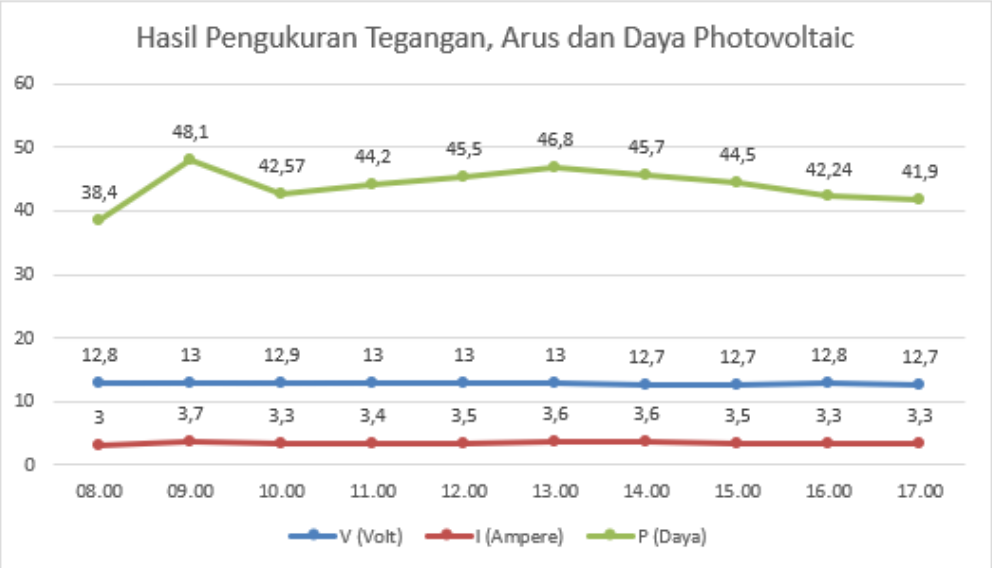


Figure 5. Results of Photovoltaic Voltage, Current and Power Measurements

Testing is done by measuring the output voltage produced by the step down module. The voltage reduction is done because the microcontroller and module work at 5 volts so a regulator is needed to reduce the output voltage from the battery. The regulator used is the LM2596 step down module. To regulate the output of this step down module, simply rotate the trimport on the module until the output becomes 5 volts. Testing is done by measuring the output voltage from the step down module as shown in Figure 6.

Figure 6. Stepdown module output voltage

The tool that is made is equipped with a trash cover system that can open automatically. The IR sensor is used to detect infrared radiation. The tool is also equipped with a DFPlayer module that can produce a sound in the form of a welcome greeting and an invitation to throw away trash to the user as well as an appreciation of gratitude to the user. Testing of this automatic trash cover system is done by approaching an object/moving near the sensor at a certain distance. Figure 7 shows the IR sensor testing process and Table 1 describes the data generated from the tests that have been carried out.

(a) (b)

Figure 7. IR Sensor Testing, a) Distance >10 cm, b) distance <10 cm

Table 1. The results of the trash can cover test

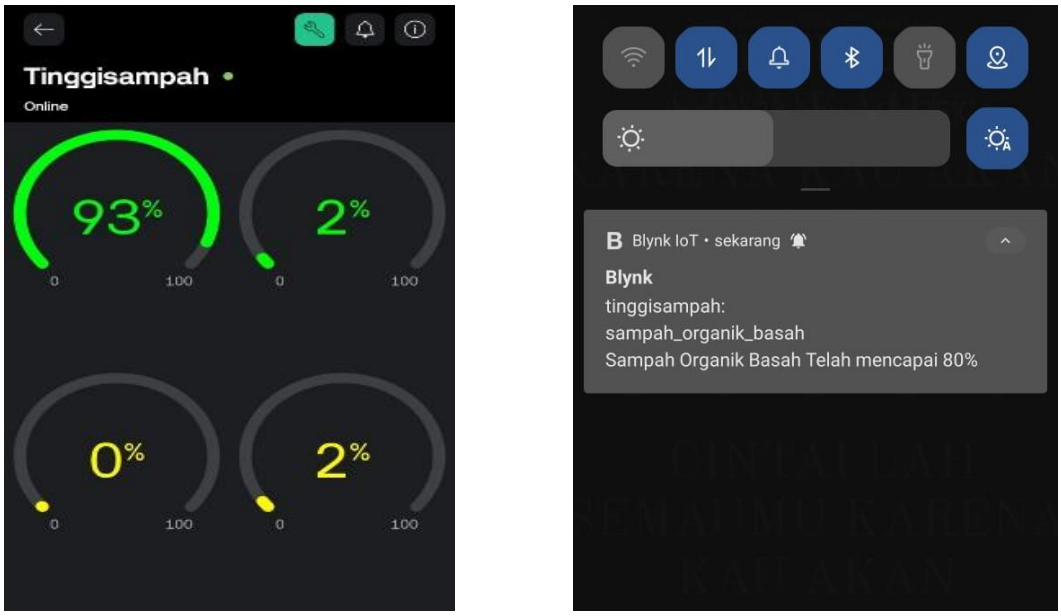
No	Condition (Object)	Distance (Cm)	Servo	DFPlayer	Test Results
1	None	-	Off	Off	Suitable
2	Yes	>10	Off	Off	Suitable
3	Yes	<10	On	On	Suitable

Based on table 1, it can be seen that the IR sensor can work well. The sensor will only detect objects with a distance of <10 cm. When the sensor is active, the servo motor will be on and the trash can opens with a delay of 5 sec. When the trash can opens, the DFPlayer makes a sound of gratitude for throwing trash in its place. From the tests that have been carried out, the test results are in accordance with the initial design. Next, an experiment was carried out to separate the types of wet and dry organic waste, inorganic metal and non-metal waste, with the results described in Table 2.

Table 2. Results of the waste sorting experiment

Test	Waste Name	Detection Results					Conformity
		Wet	Dry	Metal	Non metal	Not Detected	
0	-	-	-	-	-	-	
1	Clear/black plastic					√	Not suitable
2	Paper		√				Suitable
3	Plastic Cup				√		Suitable
4	Canned Bottle			√			Suitable
5	Knife			√			Suitable
6	Plastic Bottle				√		Suitable
7	Cardboard				√		Suitable
8	Wet Leaves	√					Suitable
9	Plastic Spoon				√		Suitable
10	Cloth				√		Suitable
11	Wet Tissue	√					Suitable
12	Breadfruit	√					Suitable
13	Vegetables	√					Suitable
14	Drink Glass				√		Suitable
15	Wood		√				Suitable

Based on Table 2, it can be seen that the proximity sensor cannot detect objects with clear and dark black colors. The use of capacitive proximity sensors, objects must weigh more than 10g to be detected by the sensor, this is because the use of capacitive sensors must have a little pressure on the sensor. While inductive sensors will also detect several types of plastic that contain heavy metals. The DHT 22 sensor can also sort wet and dry waste. Where if the humidity of the waste is >85 then the waste is categorized as wet and vice versa if <85 then it is classified as dry waste. If someone throws away inorganic waste in wet conditions. The sorting system will not include waste in the wet waste category. This is because the sorting system works by separating organic or inorganic waste first. Then it will be continued by separating wet and dry waste or metal and non-metal. In the blynk application, the percentage of the contents of the trash bin is displayed. The blynk display can be seen in Figure 8 below.



(a) (b)

Figure 8. Monitoring system, a) Blynk display, b) Notification display

Further testing was carried out by observing the lighting system. The results of the lighting system testing can be seen in Table 3. Table 3 shows that the lights are only on at 18:01-22:00. The lighting system is only turned on for ±4 hours which aims to make the energy stored in the battery last longer. Thus reducing the risk of running out of energy when the weather is dark and/or rainy for several days in a row.

Table 5. Results of observations of the lighting system

No	Hour	Lamp Condition	Conformity
1	00.01 - 02.00	Off	Suitable
2	02.01 - 04.00	Off	Suitable
3	04.01 - 06.00	Off	Suitable
4	06.01- 08.00	Off	Suitable
5	08.01 - 10.00	Off	Suitable
6	10.01 - 12.00	Off	Suitable
7	12.01 - 14.00	Off	Suitable
8	14.01 - 16.00	Off	Suitable
9	16.01 - 18.00	Off	Suitable
10	18.01 - 20.00	On	Suitable
11	20.01 - 22.00	On	Suitable
12	22.01 - 00.00	Off	Suitable

The tool that is made has the following functional limitations: 1) Garbage disposal cannot be done by throwing it from a distance. This can happen because the garbage opening system can only open when the detection distance is <10 cm. 2) The sorting system can only detect garbage individually. So if someone throws out different types of garbage at the same time. The system can only detect garbage that is detected by the sensor. 3) Garbage that is too light can get caught in the sorting tool so that the garbage cannot be thrown into the trash bin. 4) The garbage bin capacity monitoring system requires a stable wifi network so that the system can be in blynk online status.

4. CONCLUSION

Based on the results of research in making tools in the form of automatic waste sorting and monitoring systems for the capacity of trash bins based on the Internet of Things with alternative energy, it can be concluded that the smart trash bin system with an automatic cover can be designed by utilizing an Ir sensor integrated with a servo as a driver and so that the tool can produce sound can be made by utilizing the DFPlayer Module as a sound player module. While the waste sorting system can be designed by utilizing the Proximity sensor and the DHT22 sensor as a detector of trash objects. The working system of the tool can be made by programming the NodeMCU ESP32 using the Arduino IDE. The distance sensor integrated with the NodeMCu ESP32 is used to measure the volume of the trash bin. So that the data obtained from the distance sensor is sent to the NodeMCU ESP32, it can be displayed via the blynk application which can be easily accessed via a smartphone.

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