Automated Trash Sorting Design Based Microcontroller Arduino Mega 2560 with LCD Display and Sound Notification

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Abstract. Waste has been a long serious problem in everyday life. Until now there has been no appropriate way of handling waste problems. The purpose of this research is to create a system of automatic waste sorting with a special design that can ultimately help government programs to create a clean and healthy environment. This research discusses the method of developing waste selection using sensors. There are two types of sensors used, namely inductive proximity sensor and capacitive proximity sensor. The system of the tool created is successful and can run according to the wishes, and works in accordance with its function, which is able to sort metal and non-metallic waste (wet and dry) one by one the type of waste that is inserted, with the size of the determined waste more than 5 cm. The system of this tool can only work, if the inductive proximity sensor is 0-8 mm and the capacitive proximity sensor is 0-12 mm from the object (waste). Percentage of success gained for the sorting of non-metallic waste (dry) is 100%, non-metallic garbage sorting (wet) is 80% and metal garbage sorting is 100% with testing using 2 waste objects tested 5 times for each place of waste sorting. Another test using 2 waste objects with different materials, i.e. metal and non-metal, that further from the test can be concluded that the signal of the inductive proximity sensors and the capacitive proximity sensors will capture and the closest object.

1. Introduction

Waste is very closely related to human life. Where there are humans, there must be waste. [1] Humans will definitely produce trash or waste in every activity. Population growth, inaccurate and environmentally friendly landfill cause waste to increase. [2] Waste is created because humans are not able to limit their needs. In other words, waste is created from human lifestyles that exceed the limits of their needs. The more advanced and developed technology is, the more increasing needs desired are, so that we will produce more waste. However, human-generated waste will be a big problem, if humans themselves are not able to manage waste and dispose of it arbitrarily.

There are two categories of waste, namely wet (organic) and dry (inorganic) waste. Wet waste (organic) in the form of plant residues, animals or dirt that can be decomposed by microorganisms and can rot, while dry (inorganic) waste is very difficult to decompose because it contains plastic or glass.[3] About this understanding a few people know about the different categories of waste, so people often dispose of waste not in accordance with the type of waste. Besides that, the waste that has been provided so far is only a display that is not cared too much because of the maintained, dirty and less attractive waste bins which might make people reluctant to dispose of waste in its place. The point is that every individual's

awareness of the cleanliness of the surrounding environment is very necessary and must be improved.

By increasing awareness of the cleanliness of the surrounding environment, we must create new innovation that is interesting and useful, so that we can attract the public to dispose of waste in its place, so that the environment becomes clean, beautiful and comfortable. The innovation is by creating smart bins. This bin will open automatically if there are humans around the ultrasonic sensor within a maximum distance of 20 cm, then the servo motor works to open the lid of the waste bins and then sort the waste automatically based on the type of waste, namely wet waste, dry waste and metal waste.

By waste to be disposed of, we can use the dielectric value by using a proximity sensor. To detect metal waste uses inductive proximity sensors. When a magnetic or conductive object, such as a metal placed in a magnetic field around an inductive proximity sensor, the induction of the coil will change. The sensor detection circuit detects the change and produces an output voltage. [4] To detect non-metallic waste (wet and dry) using a capacitive proximity sensor, capacitor capacitance depends on the dielectric between the plates. The plate is the sensor and its surroundings and the nonmetallic object are a dielectric. The proximity capacitive sensor detects objects with a distance of 4 mm to 60 mm from the sensor head. [5] The dielectric value of the waste and the output will be processed by a proximity sensor which is then connected to the microcontroller and then the servo motor will work in the process of sorting waste.

This smart waste bin can also display the type of waste that is disposed of on the 16x2 LCD, detect the capacity of the waste by using an ultrasonic sensor and provide sound notification if the waste bin is full, and provide sound notifications in the form of calls to maintain the cleanliness of the surrounding environment.

2. Methods

A sensor or transducer is a device that can respond to a measured object and convert it into a detectable signal. The sensor is a device that can convert non-electrical signals into electrical signals. [6] Sensors used in this research are ultrasonic sensors, capacitive proximity sensors and inductive proximity sensors. Basically, ultrasonic sensors are used to measure the distance between object obstacles and sensors. The ultrasonic sensor consists of a transmitter and receiver. The transmitter sends a signal in one direction and the transmitted signal is then reflected back whenever there are obstacles and is received by the receiver.[7] Ultrasonic sensor applies the principle of TOF (Time Of Flight) to measure the distance, in a matter of time of the target.[8] Therefore, the performance of ultrasonic sensors is very dependent on the reflective characteristics, for example the shape, surface material of the target surface.[9] Ultrasonic sensor is used to detect whether there are people near the waste bin by measuring a distance of about 10-20 cm, if any, then the servo motor will work and the lid of the waste bin will open automatically. Ultrasonic sensor is also used to measure the level of fullness of the waste.

Proximity sensor, in general serves for contactless detection of various objects, whether metal or not, before the effective area of the sensor. There are three basic types of proximity sensors, namely inductive, capacitive and magnetic. [10] In this research inductive proximity sensor is used to detect metal objects and proximity capacitive sensor is used to detect objects with low dielectric materials such as plastic or glass and higher dielectric materials such as liquids. This sensor can detect the target based on the permittivity value. [11] Basically an inductive proximity sensor with a capacitive proximity sensor bears a

resemblance. The difference is that inductive proximity sensors produce electromagnetic fields, while capacitive proximity sensors produce electrostatic fields. [12]

This research uses 4 design methods, namely design of hardware, design, circuit and software. The design of the hardware is divided into the design of a system of separating metal waste, wet waste, dry waste and sound notification through the initial stages, namely making a flowchart that is designed with reference to the workings of the system and in the design consisting of the design of the tool. Furthermore it is to the software design stage which consists of a C language program design. The specification of tools, components and supporting devices is shown in table 1.

Table 1. Supporting Tool System

No	Parameter	Value
1	Laptop	1 piece
2	Microcontroller	1 piece
3	Program	1 piece
4	Inductive Proximity Sensor	1 piece
5	Capacitive Proximity Sensor	1 piece
6	Ultrasonic Sensor HCSR-04	4 pieces
7	Servo Motor	3 pieces
8	LCD 16x2	1 piece
9	PAM 8403 Amplifier	1 piece
10	Speaker	1 piece
11	Adaptor AC-DC 12 V	1 piece

2.1. Hardware Design

The design of the hardware is divided into the design of a system for separating metal waste, wet waste, dry waste, LCD display and sound notification through the initial stages, namely block diagram making. The goal is to make it easier to analyze the relationships between components of one block with another. The following block of hardware diagram is shown in Figure 1.

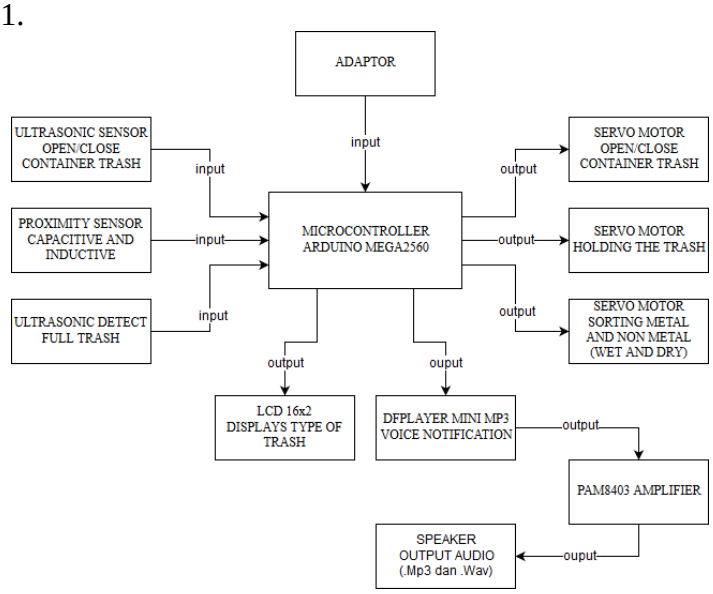

Figure 1. Block diagram system

2.2. Design

A tool design is very important to get a good final result as expected by paying attention to the use of components that are economical, easy to obtain and attractive. Following is the design of the tool shown in figure 2.

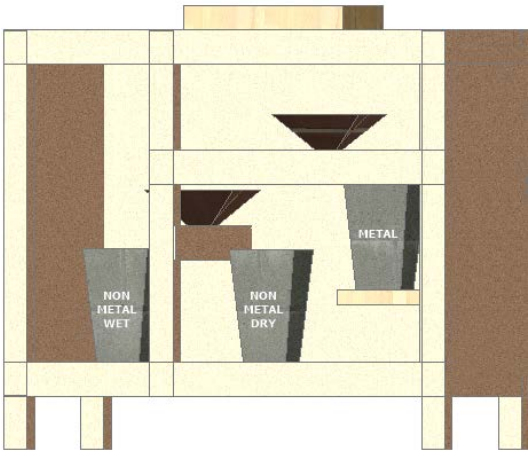

Figure 2. The front view design

2.3. Circuit Design

The circuit design is very necessary before the process of making tools. The following is circuit system shown in figure 3.

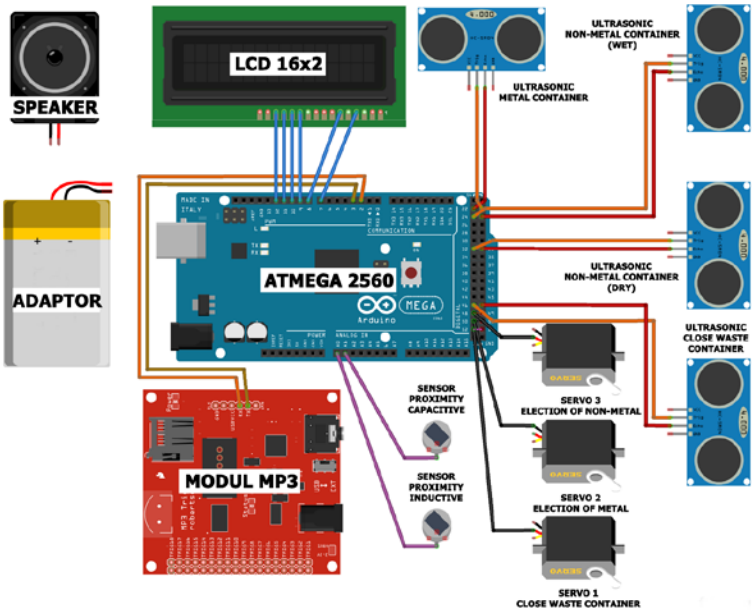

Figure 3. Circuit design

2.4. Software Design

The initial stage before creating a program in the Arduino IDE is to first design a program of flow diagram to produce the program expected. This system has two input components and seven output components. The input component consists of one capacitive proximity sensor, one inductive proximity sensor and four ultrasonic sensors. The output component consists of three servo motors, one LCD 16x2, one DFPlayer Mini mp3, one PAM8403 Amplifier and two speakers. The following flowchart is shown in figure 4.

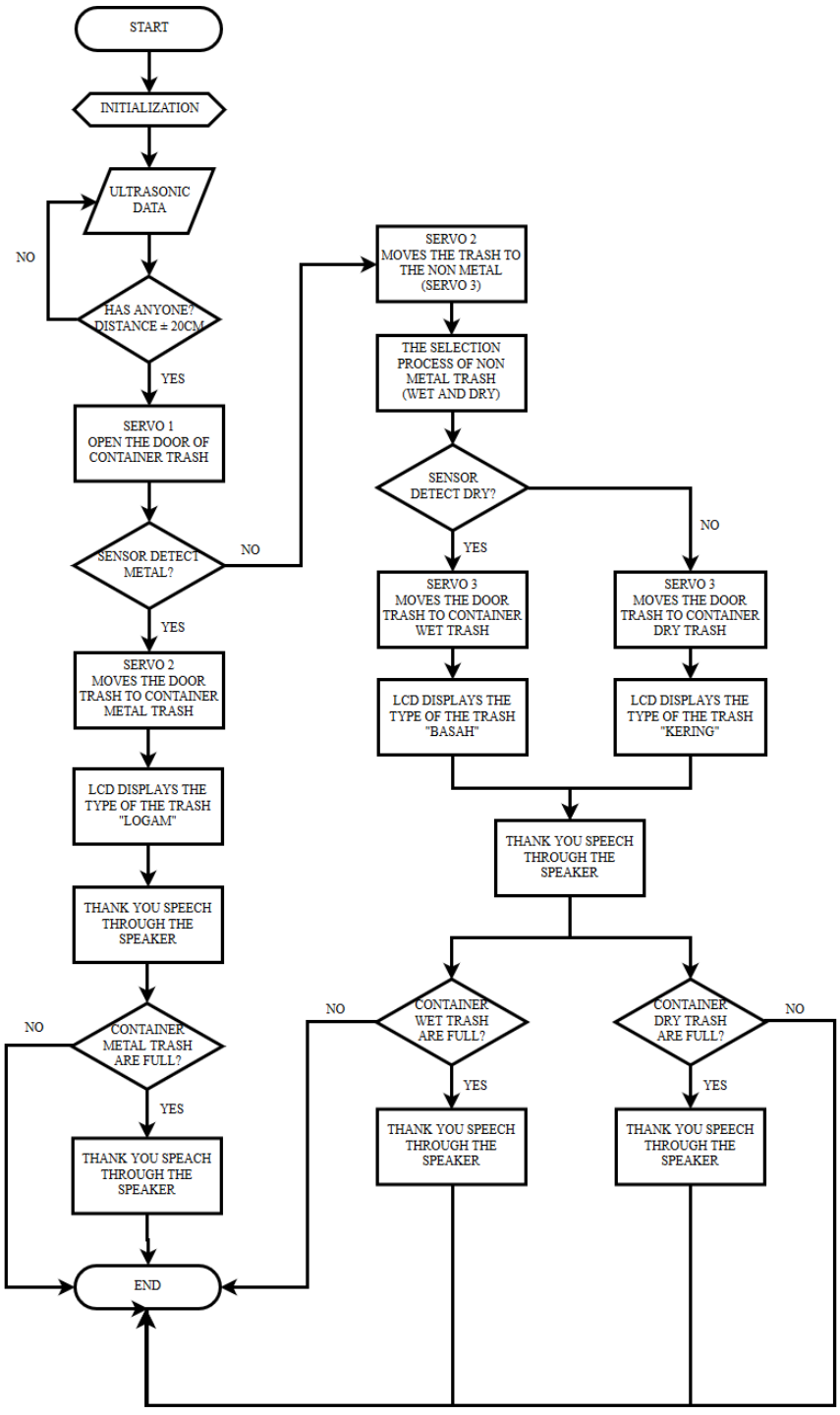

Figure 4. Flowchart

Information about the working system of the tool as follows:
When the appliance is turned on, the first ultrasonic sensor detects the presence of a person or object within 10-20 cm, if detected, the output command in the form of servo motor movement will open the lid of the waste bin. Furthermore the proximity capacitive sensor and inductive proximity sensor will detect metals and non-metals (dry and wet) then the output command in the form of LCD will display a description of the type of metal or non-metal waste and the output command in the form of sound notification containing thank you for putting waste. Furthermore, the second, third and fourth ultrasonic sensors in each waste bin function to detect the waste bin is full or not, if it is full there will be an output command in the form of sound notification containing information that the waste bin is full.

2.5. Testing Techniques

In the process of making automated trash sorting in each part and component a design and testing process is carried out in order to ensure that the tool is functioning and in accordance with the original plan. The design and testing carried out are as follows:

1. Ultrasonic sensor testing
2. Capacitive proximity sensor and inductive proximity sensor testing
3. Servo motor testing
4. Testing of DF Player Mini mp3 modules , PAM 8403 amplifiers and speakers
5. Overall system testing

2.5.1. Ultrasonic Sensor Testing

Ultrasonic sensor testing aims to determine the minimum and maximum distance that can be measured by the sensor. Ultrasonic sensor testing is carried out by connecting the ultrasonic sensor module with the ATmega2560 microcontroller circuit.

2.5.2. Testing of Inductive Proximity and Capacitive Proximity Sensors

Inductive proximity sensor functions as a metal detector and capacitive proximity sensor serves as a non-metal (wet and dry) detector. Then the calibration of the sensor and measurement of the sensor output are done using a multimeter digital.

2.5.3. Servo Motor Testing

Servo motor testing is by giving digital pulses of different widths. The servo motor 1 is in the position of 35 degrees and 75 degrees, the servo motor 2 is in the position of 10 degrees and 80 degrees, the servo motor 3 is in the position of 20 degrees and 90 degrees.

2.5.4. Testing DFPlayer Mini mp3 module, PAM 8403 Amplifier and Speaker

Testing DFPlayer Mini mp3 module and PAM 8403 Amplifier aims to make the module work according to its function. DFPlayer Mini mp3 module outputs an information signal which then enters the transmitter block system and PAM 8403 Amplifier as an amplifier to generate the signal in the mp3 module. Strengthening function is to prevent attenuation caused by electronic circuits. The incoming current will be converted into voltage because it functions as a current to voltage converter and vice versa and adjusts the input and output impedances so that the system is optimal. PAM 8403 Amplifier also functions as a sound signal amplifier to the speaker.

2.5.5. Overall System Testing

Overall System Testing by using software and hardware, so that the system built can run well. This tool has several features in the form of closing and opening the lid of waste bins automatically by using ultrasonic sensors by detecting the distance of objects (humans) around the waste bins, sorting metal and non-metal waste (wet and dry) using capacitive proximity sensors and inductive proximity sensors, an audio in the form of a thank you for putting the trash and notifying that the waste bin is full using the DFPlayer Mini mp3 module and the speaker. To detect the waste bin is full is by using an ultrasonic sensor utilizing distance detection in the form of the height of waste in the waste bin.

3. Results and Discussion

System testing is the stage where all software components in the form of programs in the Arduino IDE that have been made and the hardware in the form of a series of systems is ready to operate. The goal is to know the system works according to the wishes or not. From this system, conclusions will be obtained in the form of advantages and disadvantages which can be developed later. The following will be explained about the results of the design of the tool and the results of testing the material and the systematic work of the tool with the discussion.

3.1. Tool Design Result

The design of the tool is very important to get a good end result as expected by paying attention to the use of components that are economical, easy to get and attractive. After doing the design and testing tools will get the test results in the form of quantitative data.

3.2. Discussion of Test Results

Before carrying out testing, make sure the entire set of components is well connected and collection of waste materials to test the tool according to its function.

3.2.1. Initial Testing Conditions

First, testing in the form of whether or not the lid of waste bin opens and closes automatically by using an ultrasonic sensor by detecting the presence of objects (humans) around the waste bin. The following is results of the ultrasonic sensor testing of the objects shown in table 2.

Table 2. The result of ultrasonic sensor testing

No	Distance Measuring Instrument using Ruler	Value
1	10	Open
2	20	Open
3	30	Closed
4	40	Closed
5	50	Closed

Second, testing in the form of whether or not the sensor detects waste in accordance with their respective types, namely metals, non-metals (wet and dry) which are then displayed on the LCD of the type of waste. The following is the results of the sensor detection distance testing shown in table 3.

Table 3. The result of sensor detection distance testing

Proximity Capacitive Sensor		**Proximity Inductive Sensor**	
Detection Distance (mm)	**Description**	**Detection Distance (mm)**	**Description**
0	Detected	0	Detected
4	Detected	2	Detected
8	Detected	4	Detected
12	Detected	6	Detected
16	Not Detected	8	Detected
20	Not Detected	10	Not Detected
24	Not Detected	12	Not Detected

From the test results obtained, it is concluded that inductive proximity sensors can detect from a distance 0-8 mm while the capacitive proximity sensor can detect from a distance of 0-12 mm.

Third, testing was successful or not, whether the apparatus was made according to the wishes of the researchers. Furthermore, testing of the function of the module used to function and can output an audio in the form of thank you for throwing out the waste and notifying that the waste bin is full, which later will help cleaners and not waste the work time to sort out waste and to ascertain whether the waste has full or not. Here are the results of testing the tool according to the type of waste.

Table 4. The result of non-metallic waste (dry) testing

No	**Waste Type**	**Sensor**			**Time**	**Description**
		Inductive Proximity		Capacitive Proximity		
		Wet	Dry	Metal		
1	Paper		✓		12.43	Successful
2	Paper		□		12.28	Successful
3	Paper		□		13.17	Successful
4	Paper		□		12.21	Successful
5	Paper		□		13.09	Successful
6	Plastic		□		13.42	Successful
7	Plastic		□		12.89	Successful
8	Plastic		□		13.26	Successful
9	Plastic		□		13.15	Successful
10	Plastic		□		13.08	Successful
Percentage of Success						100%
Percentage of Failure						0%

Table 5. The result of non-metallic waste (wet) testing

No	Waste Type	Sensor			Time	Description
		Inductive Proximity		Capacitive Proximity		
		Wet	Dry	Metal		
1	Wet wipes	✓			12.35	Successful
2	Wet wipes		□		13.42	Unsuccessful
3	Wet wipes	✓			13.08	Successful
4	Wet wipes	✓			12.87	Successful
5	Wet wipes		□		13.64	Unsuccessful
6	Wet fabric	✓			13.06	Successful
7	Wet fabric	✓			13.21	Successful
8	Wet fabric	✓			12.43	Successful
9	Wet fabric	✓			12.17	Successful
10	Wet fabric	✓			12.82	Successful
Percentage of Success						80%
Percentage of Failure						20%

Table 6. The result of metallic waste testing

No	Waste Type	Sensor			Time	Description
		Inductive Proximity		Capacitive Proximity		
		Wet	Dry	Metal		
1	Nails		✓		7.79	Successful
2	Nails		□		8.12	Successful
3	Nails		□		7.88	Successful
4	Nails		□		7.67	Successful
5	Nails		□		8.42	Successful
6	Drink cans		□		7.73	Successful
7	Drink cans		□		7.94	Successful
8	Drink cans		□		8.23	Successful
9	Drink cans		□		8.09	Successful
10	Drink cans		□		8.22	Successful
Percentage of Success						100%
Percentage of Failure						0%

Table 7. The result of non-metallic waste (wet and dry) testing

No	Waste Type	Sensor		Time
		Inductive Proximity	Capacitive Proximity	

		Wet	Dry	Metal	
1	Bottle drinking		✓		12.63
2	Bottle drinking		□		12.76
3	Bottle drinking		□		12.29
4	Bottle drinking		□		13.05
5	Bottle drinking		□		12.89

Table 8. The result of non-metallic and metallic waste testing

No	**Waste Type**	**Sensor**			**Time**
		Inductive Proximity		Capacitive Proximity	
		Wet	Dry	Metal	
1	Scissor with plastic handle			□	7.43
2	Scissor with plastic handle		□		8.28
3	Scissor with plastic handle			□	8.17
4	Scissor with plastic handle			□	7.21
5	Scissor with plastic handle			□	8.09

From the results of testing that has been done it can be concluded that the proximity capacitive sensor can detect metal and non-metal waste while the inductive proximity sensor can only detect metal waste. Testing in table 4 and table 6 had a success percentage of 100%. Then in table 5 has a percentage of success 80%, where the garbage objects in the form of wet tissue is a lightweight object and also has a little water content, while the garbage objects in the form of wet fabrics are objects that have water content Sufficient so that the sensor can detect and parse the waste into a non-metallic (wet) trash.

Testing in table 7 using a Bottle object, where the sensors working here are inductive proximity sensors and sorting the garbage into non-metallic bins (dry). From testing on table 7, the conclusion is that inductive proximity sensors are only able to detect and capture the closest signal on the outside of the garbage object, which is a plastic bottle.

Testing in table 8 uses scissors with plastic handles, where the sensors working here are inductive proximity sensors and capacitive proximity sensors. When inserting scissors or screwdriver made of iron and the handle of scissors or screwdriver is made of plastic, when the iron scissors or screwdriver is captured by the sensor signal, the servo 2 moves the scissors or screwdriver then goes into the metal waste bin. Because when inserting scissors or screwdriver made of iron and the handle of scissors or screwdriver is made of plastic, when the iron scissors or screwdriver is captured by the sensor signal, the servo 2 moves the scissors or screwdriver then goes into the metal waste bin. Conversely, when the handle part is captured by the sensor signal, then the scissors or screwdriver then goes into the non-metal trash lid (servo 3) which then goes through the selection process and enters the dry waste bin.

test results of all components get a good result and in accordance with the wishes, with the success percentage of non-metallic garbage sorting (dry) is 100%, non-metallic garbage

sorting (wet) is 80% and the sorting of metal waste is 100%. Next by testing the sorting system and testing the sound notification system of gratitude and notifying that the waste bin is full.

3.3. Sorting System Test Results

The following are the results of testing the sorting system consisting of the right servo, left servo and LCD can work properly and accordingly shown in Table 9.

Table 9. Test result of the sorting system

Sorting	Right Servo	Left Servo	LCD	Description
Metal	✓		✓	Corresponding
Non Metal		✓	□	Corresponding
Wet		✓	□	Corresponding
Dry	✓		□	Corresponding

3.4. Sound Notification Test Results

The following is the results of testing the sound notification using DFPlayer Mini mp3 that can work well and accordingly shown in the Table 10.

Table 10. The result of the sound notification

Types of Trash	Thank You Speech	Container Trash Full	Description
Metal	✓	✓	Corresponding
Wet	✓	✓	Corresponding
Dry	✓	✓	Corresponding

4. Conclusion

The system of the tool created is successful and can run according to the wishes as well as work in accordance with its function, which is able to sort metal and non-metallic (wet and dry) waste one by one the type of waste that is included with the size of the specified waste measuring more than 5 cm. The system of this tool can only work, if the inductive proximity sensor is 0-8 mm and proximity capacitive sensor is 0-12 mm from the object (waste). Percentage of success gained for the sorting of non-metallic waste (dry) is 100%, non-metallic garbage sorting (wet) is 80% and metal garbage sorting is 100%. Another test using 2 waste objects with different materials, i.e. metal and non-metal, that further from the test can be concluded that the signal of the inductive proximity sensors and the capacitive proximity sensors will capture and the closest object.

This kind of waste is displayed on the LCD, if the LCD receives input signals of capacitive proximity sensor and inductive proximity sensors. The use of ultrasonic sensors to detect the distance of objects (humans) around the waste and also as a detector of waste that has been full or not by utilizing distance detection in the form of the height of waste in the waste bin. The use of DFPlayer Mini mp3 module, PAM 8403 Amplifier is as sound notification. The DFPlayer Mini mp3 module outputs an information signal which then enters the transmitter block system and PAM 8403 Amplifier as an amplifier to generate the signal in the mp3 module and also as a sound signal amplifier to the speaker.

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