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Waste Sorting Machine Automatic of Organic and Inorganic Using Arduino Mega as Microcontroller : Implication for Environmental Sustainability

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Abstract

Increasing waste production worldwide has become a serious environmental and social problem. Waste thrown into traditional landfills can pollute land and water, cause public health problems, and produce greenhouse gas emissions. To overcome the issues above, in this research, a waste sorting machine will be designed that can sort organic and inorganic waste. This sorting is done automatically, a person only needs to put the waste into the machine, and then the waste will be separated according to its category. The organic and inorganic waste sorting system consists of 5 sub-systems. They are metal waste, glass waste, dry waste, plastic waste, and wet waste sorting. The results of this study can produce a success rate of 66.7% in detecting the occupancy of the trash bin, 70% in sorting metal waste, and 44.4% in sorting glass waste. The success rate in sorting wet waste is 40%, while in sorting plastic waste is 70%, and in dry waste is 90%.

Keywords: dry waste; glass waste; metal waste; plastic waste; sorter; wet waste
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INTRODUCTION

Increasing waste production worldwide has become a serious environmental and social problem. As a developing country with a large population and rapid growth, Indonesia always faces serious challenges regarding waste management. Waste thrown into traditional landfills can pollute land and water, cause public health problems, and produce greenhouse gas emissions. DIY province is currently also facing problems due to waste that is not managed properly. Therefore, efforts are needed to manage waste well.

Effective and efficient waste management is a challenge faced by many cities worldwide. According to Sejati (2009), waste management is all activities carried out to handle waste from the time it is generated to final disposal. In general, waste management activities include controlling waste generation, waste collection, transportation, processing, and final disposal (Sejati, 2009). The waste management system is very important today to solve the problem of waste in the city (Kurniawan, et all, 2023). Therefore, many researchers proposed a waste management system. Lange, J.P. designed a plastic waste management system, including sorting, recycling, disposal, and product redesign (Lange, 2021). Adu., et al., (2020) designed a medical waste management system that was implemented in five hospitals in Ghana (Adu et al., 2020). Kumar and Agrawal reviewed some solid waste management (Kumar & Agrawal, 2020).

In DIY province, currently, there is still a buildup of waste in final disposal sites (TPA). Many TPAs have been closed because they can no longer accommodate more waste. This buildup occurs because a lot of waste is not separated properly, so processing the waste will be difficult. Indonesia currently needs good waste separation using new technology to be able to solve waste problems. Currently, waste separation is still mostly done manually so it will take a lot of time to separate it. Separating waste according to its categories will make it easier to process waste according to its use. Wet waste that can rot can be used as plant fertilizer, metal, and glass waste can be resold, and dry waste that can burn can be used as fuel for power plants.

To overcome the problems above, in this research, a waste sorting machine will be designed that can sort organic and inorganic waste. This sorting is done automatically, a person only needs to put the waste into the machine, and then the waste will be separated according to its category.

Because the waste problem is still a concern, research on waste processing is still being carried out by many researchers. Sukarno, S.A. et al designed a household waste sorting machine that can separate organic and inorganic waste (Sukarno et al., 2023). The machine does not separate metal objects. Research conducted by Perdana, A., et al also produced a machine for sorting organic and inorganic waste (Perdana et al., 2023). This research also did not separate metals. The difference between this research and research (Sukarno et al., 2023) is that in this research a conveyor was used, as will be done in this research. However, in the research that will be carried out, the waste sorter can separate metals and non-metals. Alvianingsih, et al. designed an automatic garbage classification system using an Arduino-based controller (G. Alvianingsih, 2022). The system can classify the garbage into organic and inorganic, but it can not classify the wet and dry garbage.

Previously in 2021, the "Design of an automatic waste sorting tool" was created (Puadi & Hambali, 2022). This tool is controlled by Arduino and can separate waste into three categories, namely metal waste, wet waste, and dry waste. Weaknesses of the tool are the waste sorting in this tool is done one by one so it is not efficient if used for piled up waste. The research conducted by Prita et al., (2021) only sorts waste into three groups, namely organic, inorganic, and metal. The sensor used is only a proximity sensor. In the same year 2021, a "Design for Automatic Metal and Non-Metal Waste Sorting Management" was also created (Rozaq et al., 2021). This tool uses Arduino as the controller and NodeMCU to provide information to the user. The weakness of this tool is that it can only sort two types of waste, namely metal and non-metal.

METHOD

The diagram block of the organic and inorganic waste sorting system can be seen in **Figure 1**. The system consists of 5 sub-systems. They are metal waste sorter, glass waste sorter, wet waste sorter, plastic waste sorter, and dry waste sorter. The system is divided into two groups. The first group consists of metal and glass waste sorter. The second group consists of wet, plastic, and dry waste sorter. The diagram block of each group can be seen in **Figure 2** and **Figure 3**. Each group is controlled by a microcontroller. The mechanic designs of each sorter will be discussed below.

Figure 1. The diagram block of the organic and inorganic waste sorting system

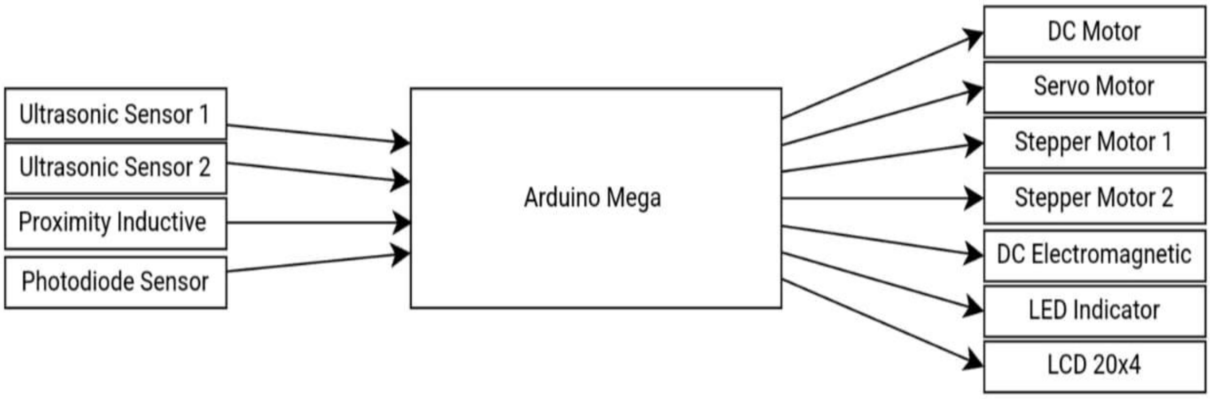


Figure 2. The diagram block of the first group

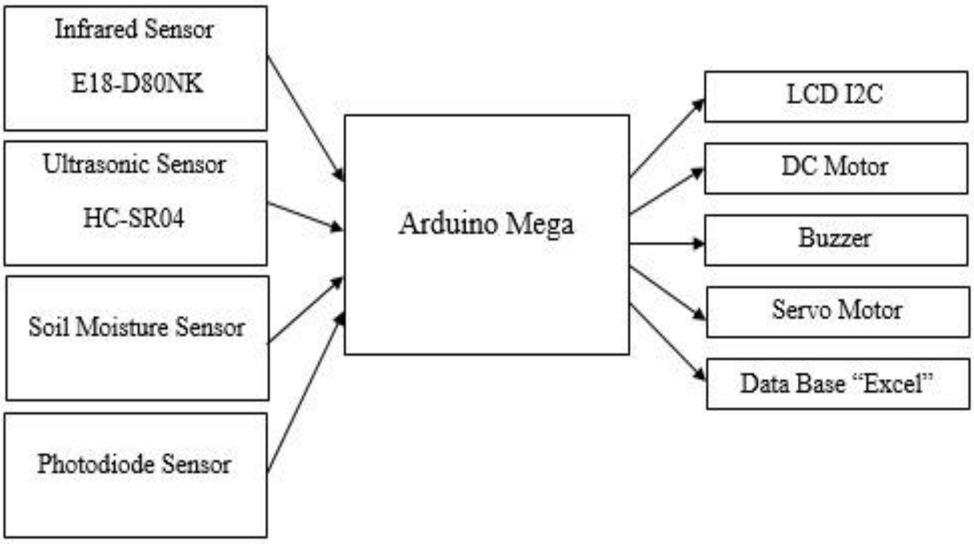


Figure 3. The diagram block of the second group

Metal Waste Sorter

The mechanic design of the metal waste sorting system is seen in **Figure 4**. The metal sorting system works when the Inductive Proximity sensor, shown in no. 3, detects the presence of metal waste objects. If metal is detected, DC motor 1, shown in no. 4, and DC motor 2, shown in no. 6, will move to direct the DC electromagnetic, shown in no. 5, to the conveyor and then activate the DC electromagnetic so that it can attract metal waste. If the DC electromagnetic is active, the waste object will be attracted to the DC electromagnetic and will be directed to the metal waste container using DC motors 1 and 2. If it is already in the metal waste container, the DC electromagnetic will automatically deactivate and the system will continue to the next waste sorting by running the conveyor to the next stage.

Glass Waste Sorter

The mechanic design of the glass waste sorter is shown in **Figure 5**. The non-metallic waste system will run through the conveyor from the metal waste sorting to the glass waste sorting system. The waste will be detected by the photodiode sensor whether the waste object is glass waste or not. If the object is glass waste, the servo motor will move and direct the object into trash bin 2 as a glass waste container. If it is detected that the object is not glass waste, the waste will run through the conveyor to the next stage. In this system, a photodiode sensor is placed as a detector of light intensity on the sorted glass bottles. The light received by the sensor is light from a white LED that shoots its light towards the photodiode sensor. Sorting will occur if the light intensity value entering the photodiode sensor has a value between the two thresholds that have been set in the glass waste sorting program. The first threshold value that has been set is 350 - 500, and the second threshold value is 600 - 900.

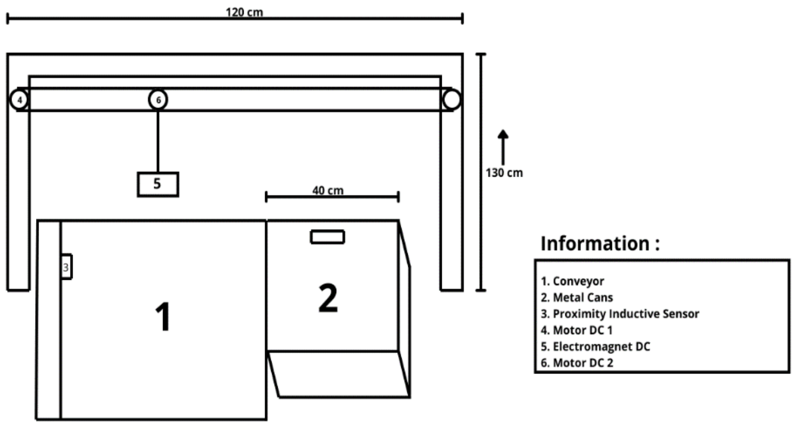


Figure 4. The mechanic design of the metal waste sorter

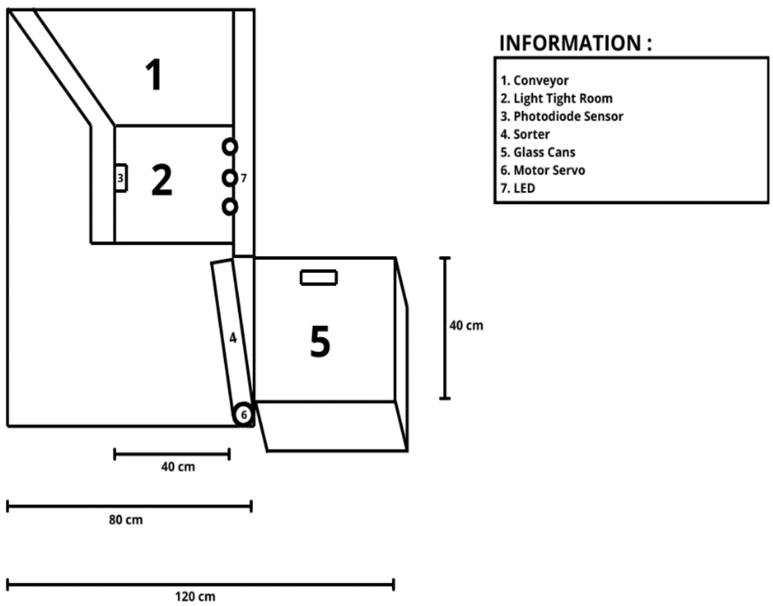


Figure 5. The mechanic design of the glass waste sorter

Wet Waste Sorter

The mechanic design of the wet waste sorter is shown in **Figure 6**. The conveyor runs from the sorting of metal waste and glass waste then it will pass through the barrier in the sorting of wet waste. This barrier can widen and narrow because there is a spring on the back to adjust the barrier. In this wet waste sorting, the barrier will direct the waste to the soil moisture sensor to detect the level of wetness. If the waste is detected as wet, it will make the servo motor move the sorter to direct the waste to the wet waste bin. The soil moisture sensor detects with a digital signal so that if the waste is detected as wet, it will produce a signal of 1 and if the waste is dry, it will produce a signal of 0.

Plastic Waste Sorter

The mechanic design of the plastic waste sorter is shown in **Figure 7**. The conveyor will run after passing through the wet waste sorting and the waste is detected as not wet waste. Then, it will continue to the plastic waste sorting. In this plastic waste sorting system, the waste will go to a light-proof chamber. Inside this chamber, there is a photodiode sensor and 3 LEDs that will detect the level of light penetration of the passing waste. The photodiode sensor uses an analog signal so that the reading of an object will be determined from the output of the numbers read on the sensor. Sorting plastic waste using a photodiode sensor is done by determining the lower threshold and upper threshold of the waste that will pass. The value has been set in the plastic waste sorting program. The first threshold value that has been set is between 40-60, the second threshold value is between 300-500 and the third threshold value is between 800-1010. If the passing waste is at that threshold, it will send a signal to the servo motor to move the sorter toward the plastic waste container. When the plastic waste passes the infrared sensor, it will return the position of the servo motor.

Dry Waste Sorter

The mechanic design of the dry waste sorter is shown in **Figure 8**. The conveyor will run through the sorting of wet waste and plastic waste. If the waste is not wet waste or plastic waste, it will be categorized as dry waste. In this dry waste sorting system, there is no sensor used to detect dry waste. Dry waste that enters will only go through the wet waste and plastic waste sorting system and if it is not both, the waste will go to the dry waste container.

The electronic circuits of both groups are seen in **Figures 9** and **Figure 10**. As seen in **Figure 2** and **Figure 3**, each group is controlled by an Arduino Mega controller that is equipped with several sensors to detect several types of waste, as described above. The flowcharts of both groups are seen in **Figure 11** and **Figure 12**. As shown in Figure 1, the waste fed into the conveyor will go through several detection subsystems. The waste will first be detected by the metal detection subsystem, followed by the glass, wet waste, plastic, and dry waste detection subsystems. If the waste meets the detection criteria, the waste will be fed into the waste container according to its type.

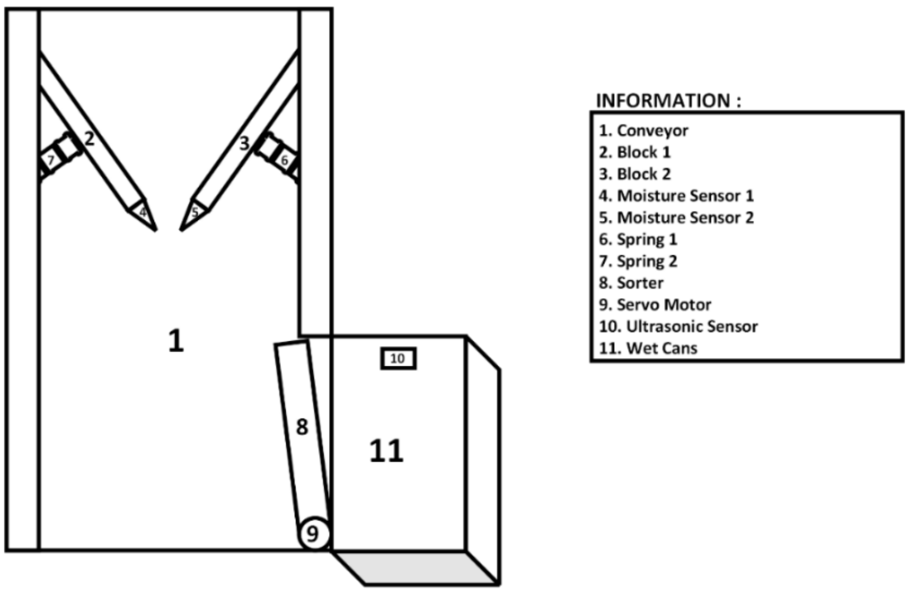


Figure 6. The mechanic design of the wet waste sorter

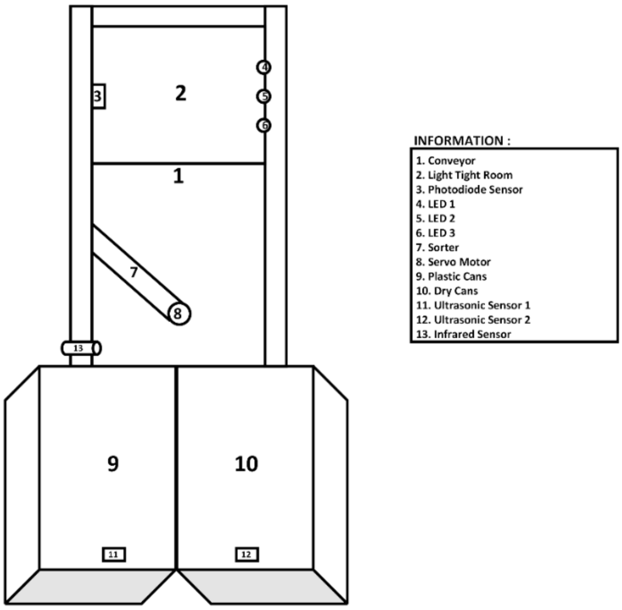


Figure 7. The mechanic design of the plastic waste sorter

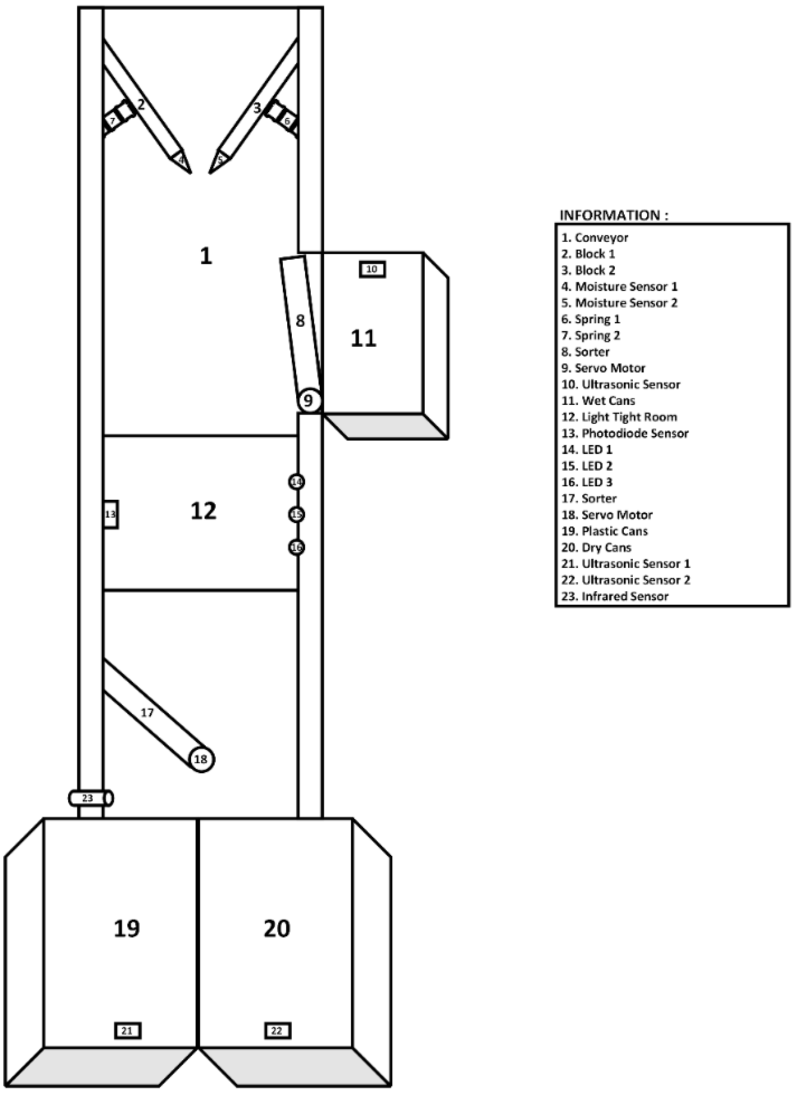


Figure 8. The mechanic design of the dry waste sorter

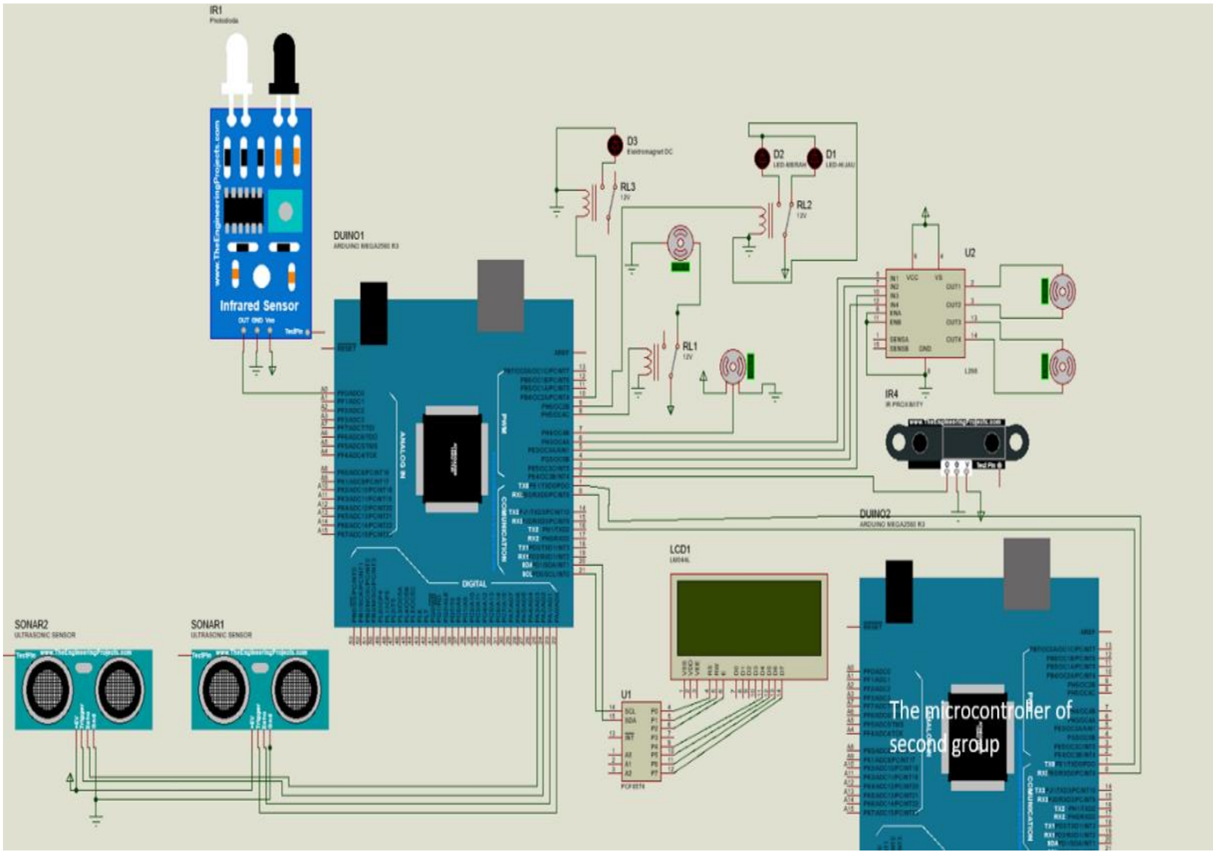


Figure 9. The electronic circuit of the first group

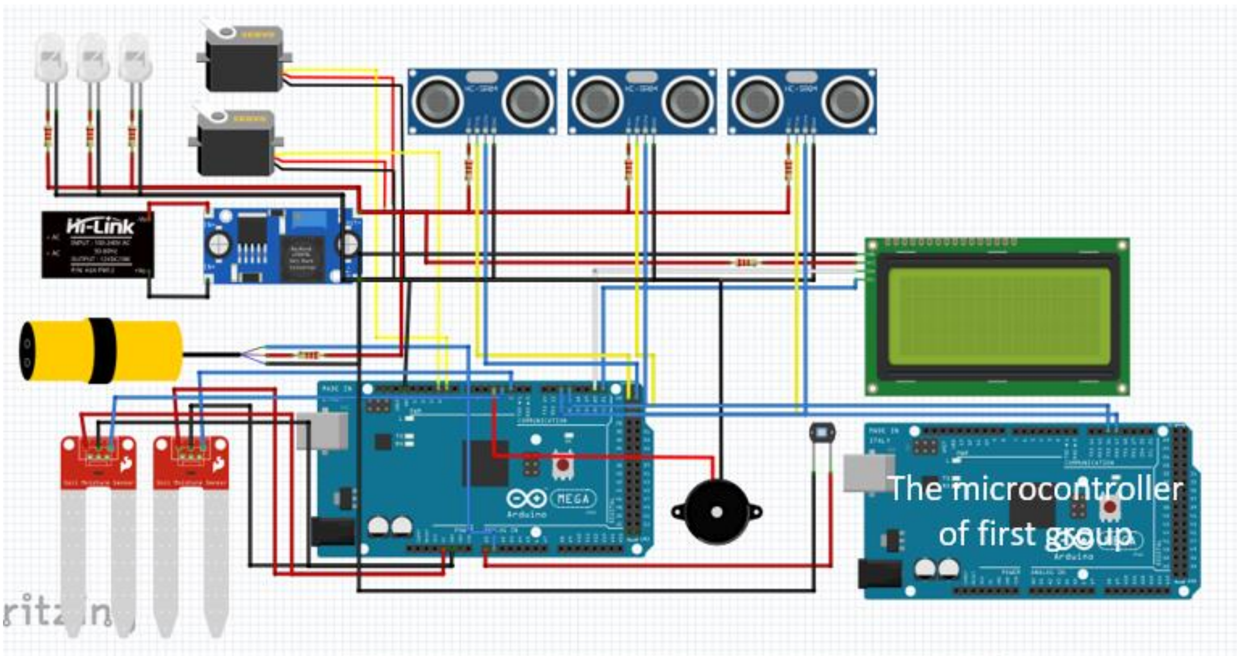


Figure 10. The electronic circuit of the second group

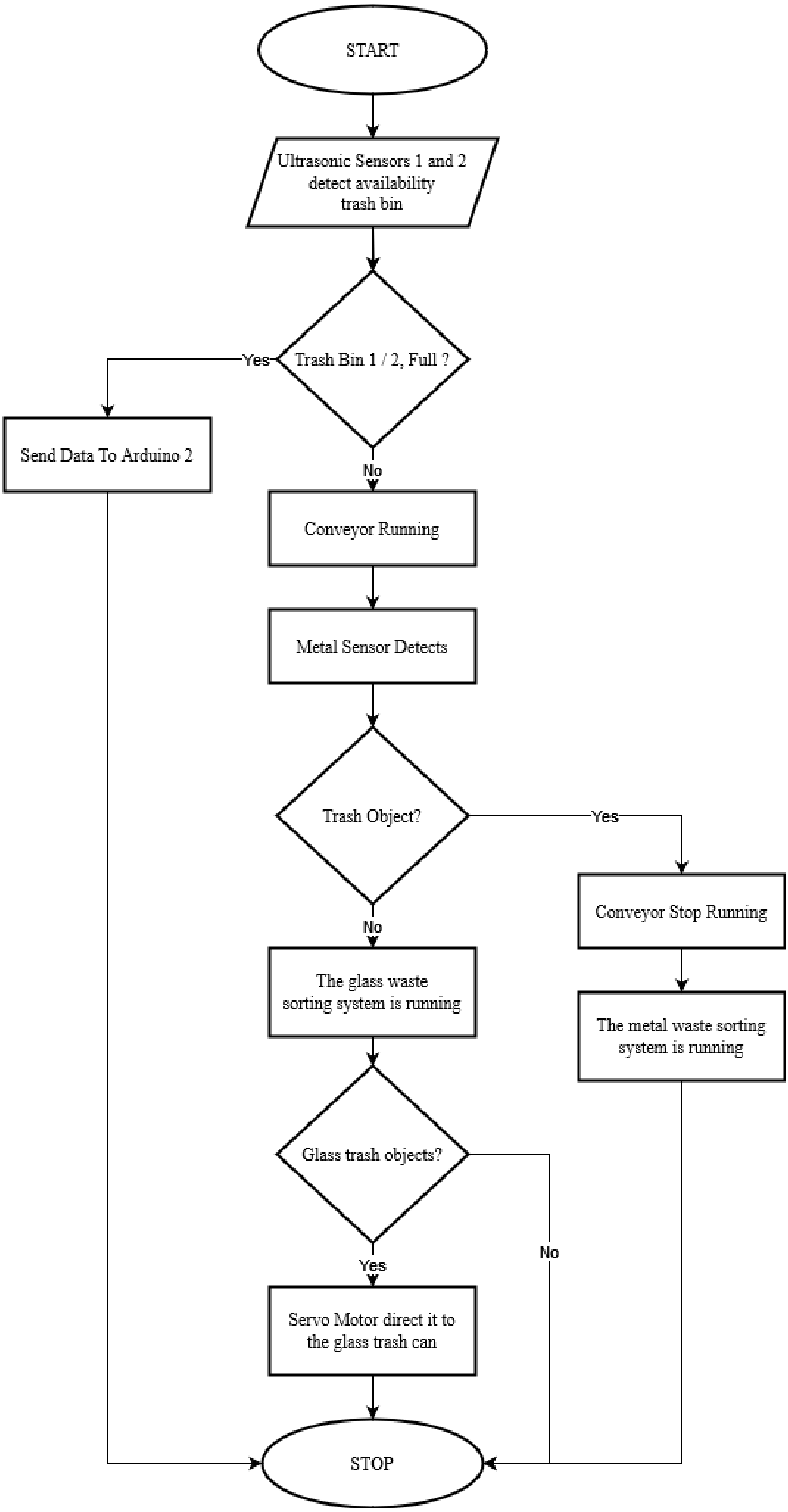


Figure 11. The flowchart of the first group

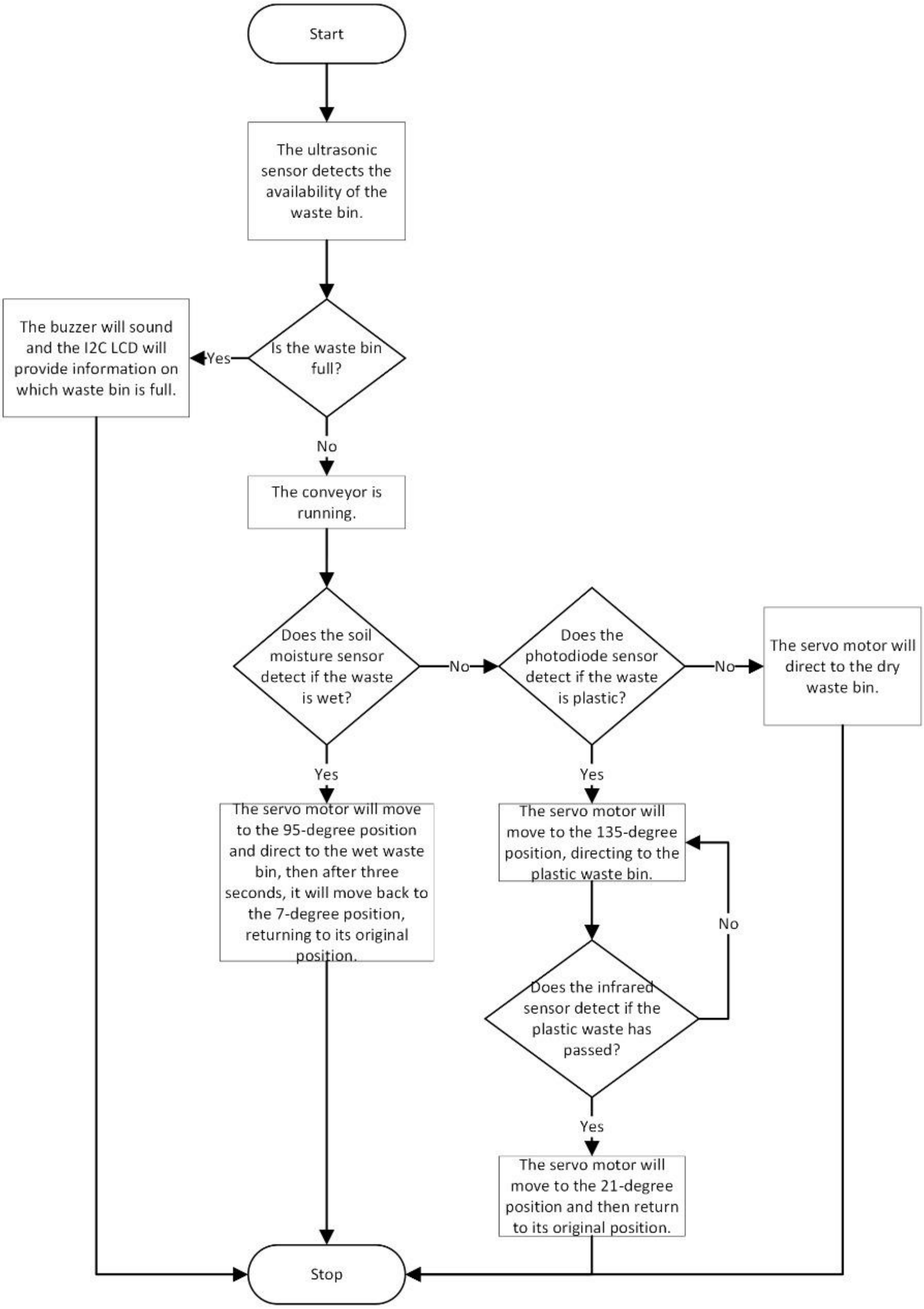


Figure 12. The flowchart of the second group

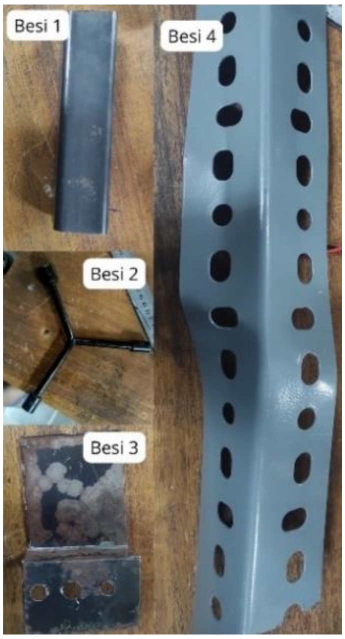
RESULTS AND DISCUSSION

The results of each subsystem of the organic and inorganic waste sorting system will be described below. Each subsystem was tested several times with different types of waste.

Metal Waste Sorter

The result of the metal waste sorter is shown in **Figure 13.a**. **Figure 13.c.** shows the display when the metal waste container is full. **Table 1** shows the metal waste sorting test results. In this metal waste sorting test, it was determined that the metal that can be detected is iron so the specified metal can be attracted by a DC electromagnet and sorted into a special metal waste container.

a



b

c

Figure 13. The result of the metal waste sorter; **a.** Implementation result; **b.** Iron waste to be sorted; **c.** Display

The iron code is shown in **Figure 13.b**, is given so that the test can be carried out randomly, iron code 1 is used for 4x4 cm square iron and has a length of 20 cm. Iron 2 is used for Y-shaped socket iron. Iron 3 is used for 1 mm thick iron plate pieces that have been bent. Iron 4 is used for a 30 cm long angle iron. **Table 1** shows the test results for sorting metal waste.

From the table, it can be seen that the success rate in the metal waste sorting test is 70%. In this test, the failure rate of 30% can be caused by iron that is not detected by the inductive proximity metal sensor because the sensor distance reading is only 0.8 cm. Failure is also caused by iron that has been detected by the sensor, but the DC electromagnet fails to pull because the position when the electromagnet goes down to the conveyor does not match the iron being pulled so the iron fails to be pulled by the DC electromagnet.

Table 1. Metal waste sorting test results

No	Iron Code Number	Sensor Reading	Electromagnetic Conditions	Put into the Metal Waste Container	Conveyor Condition	Indicator Light Condition
1	1	Detected	pulled	Succeed	Stop	Red
2	2	Detected	pulled	Succeed	Stop	Red
3	3	Detected	pulled	Succeed	Stop	Red
4	4	Detected	pulled	Succeed	Stop	Red
5	1	Detected	pulled	Succeed	Stop	Red
6	2	Not detected	-	-	Stop	Green
7	3	Detected	-	-	Stop	Red
8	4	Detected	pulled	Succeed	Stop	Red
9	1	Not detected	-	-	Stop	Green
10	4	Detected	pulled	Succeed	Stop	Red

(**Source :** Data in this study)

Glass Waste Sorter

The result of the glass waste sorter is shown in **Figure 14.a**. **Figure 14.c.** shows the display when the glass waste container is full. Glass waste sorting was tested with three glass bottle samples that have different colors. The glass waste samples to be sorted are shown in **Figure 14.b**. The three glass bottle samples to be sorted have different colors and color densities. Table 2 shows the glass waste sorting test results. From **Table 2**, it can be seen that out of 9 attempts, 5 of them failed to enter the glass trash bin. This can happen because the change value on the photodiode is too small, the value is not readable because the bottle is too close to the photodiode or light-emitting LED, or the bottle is stuck. The success rate in glass sorting is 44.4%.

a

b

c

Figure 14 The result of the glass waste sorter; **a.** Implementation result; **b.** Glass waste to be sorted. **c.** Display

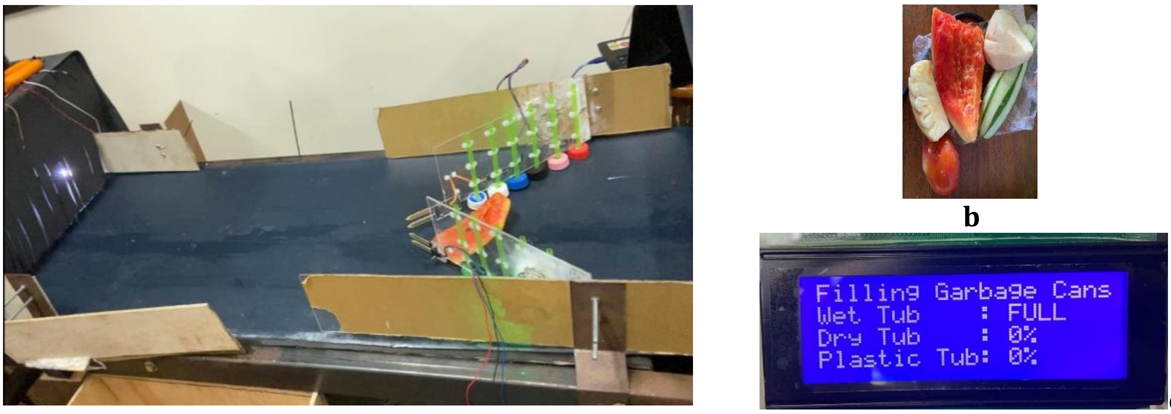
Table 2. Glass waste sorting test results

No	Glass Type	Photodiode Output	Sorting Movement	Put into the Glass Waste Container
1	Clear Bottle	30	-	-
2	Brown Bottle	854	Succeed	Succeed
3	Green Bottle	21	-	-
4	Clear Bottle	21	-	-
5	Brown Bottle	825	Succeed	Succeed
6	Green Bottle	429	Succeed	Succeed
7	Clear Bottle	32	-	-
8	Brown Bottle	646	Succeed	Succeed
9	Green Bottle	383	Succeed	-

(**Source :** Data in this study)

Wet Waste Sorter

The result of the wet waste sorter is shown in **Figure 15.a**. **Figure 15.c.** shows the display when the wet waste container is full. The waste to be sorted is shown in Figure 15.b which is fruits that have a fairly high water content. Data taken is done by placing the fruit on a conveyor so that it can run towards the soil moisture sensor. The test results can be seen in **Table 3**.



b
c
a

Figure 15. The result of the wet waste sorter; **a.** Implementation result; **b.** Glass waste to be sorted; **c.** Display.

In the test data in **Table 3**, it is known that the success rate in testing is 60%. In this test, the failure rate in detecting wet waste is 40%. This is because the waste is difficult to detect by the soil moisture sensor. After all, it is not wet enough or the data is not read on the Arduino. Failure is also often caused by waste that does not pass through the barrier because the barrier has a spring that is too hard so it is difficult to widen.

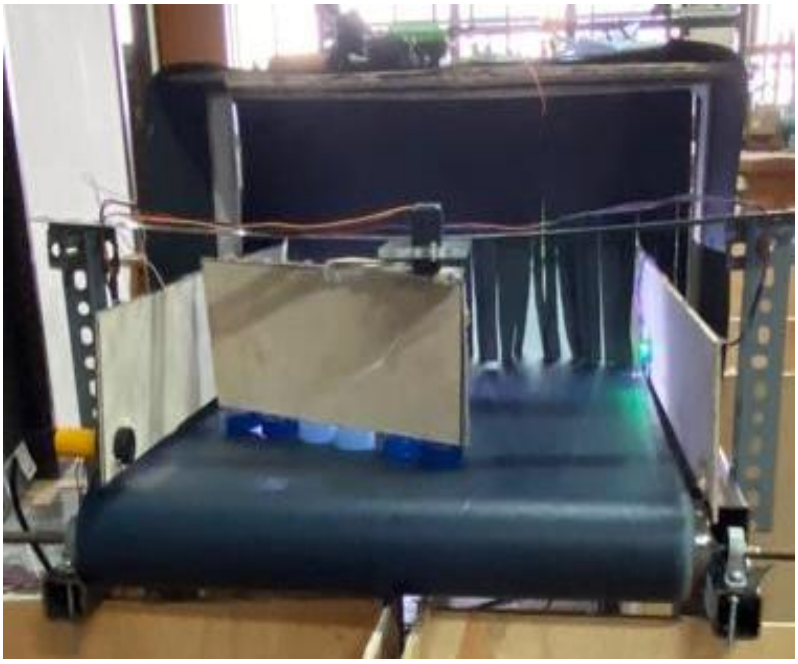
Table 3. Wet waste sorting test results

Testing Number	First Soil Sensor Output	Second Soil Sensor Output	Information
1	1	0	Succeed
2	1	1	Succeed
3	1	1	Succeed
4	0	0	Not Succeed
5	0	0	Not Succeed
6	1	0	Succeed
7	0	0	Not Succeed
8	1	1	Succeed
9	0	0	Not Succeed
10	1	0	Succeed

(**Source :** Data in this study)

Plastic Waste Sorter

The result of the plastic waste sorter is shown in **Figure 16.a**. The plastic waste samples to be sorted are shown in **Figure 16.b**. **Figure 16.c.** shows the display when the plastic waste container is full. Data collection is done by inserting plastic waste into the conveyor so that it can run through the wet waste barrier toward the photodiode sorting. The waste to be inserted has previously been checked for its darkness level. So that the upper and lower thresholds that will be used to detect waste can be estimated. This test is carried out to determine the level of success of the system in sorting plastic waste. **Table 4** shows the plastic waste sorting test results.



a

b

c

Figure 16. The result of the plastic waste sorter; **a.** Implementation result; **b.** Glass waste to be sorted; **c.** Display.

From the test data in **Table 4**, it is known that the success rate in testing is 70%. In this test, the failure rate in detecting plastic waste is 30%. This can be caused by the position of the waste on the conveyor which is not right, it could be because the waste is too close to the photodiode or the waste is too close to the LED light, causing the waste to be detected with an incorrect value, it could exceed the upper threshold or be less than the lower threshold. So that it produces data that is not appropriate. Failure in sorting plastic waste can also be caused by the waste being too heavy so that it cannot pass through the barrier in the wet waste sorting so that the waste is stuck there.

Table 4. Plastic waste sorting test results

Testing Number	Photodiode output when not detecting	Photodiode detection when there is an object	Information
1	28	37	Succeed
2	27	36	Succeed
3	28	45	Not Succeed
4	25	428	Succeed
5	28	528	Not Succeed
6	29	438	Succeed
7	27	488	Succeed
8	28	490	Succeed
9	25	953	Succeed
10	27	1015	Not Succeed

(**Source :** Data in this study)

Dry Waste Sorter

The result of the dry waste sorter is shown in **Figure 17.a**. The dry waste samples to be sorted are shown in **Figure 17.b**. **Figure 17.c.** shows the display when the dry waste container is 50%. **Table 5** shows the dry waste sorting test results.

In the test data in **Table 5**, it is known that the success rate in the test is 90%. In this test, the failure rate in detecting dry waste is 10%. This is caused by the position of the waste on the conveyor which is not right because it is too close to the photodiode or too close to the LED light, causing the waste to be detected with an incorrect value. The incorrect data causes the waste can be detected as plastic waste. Failure in sorting plastic waste can also be caused by the waste being too heavy so that it cannot pass through the barrier in the sorting of wet waste so that the waste is stuck there.

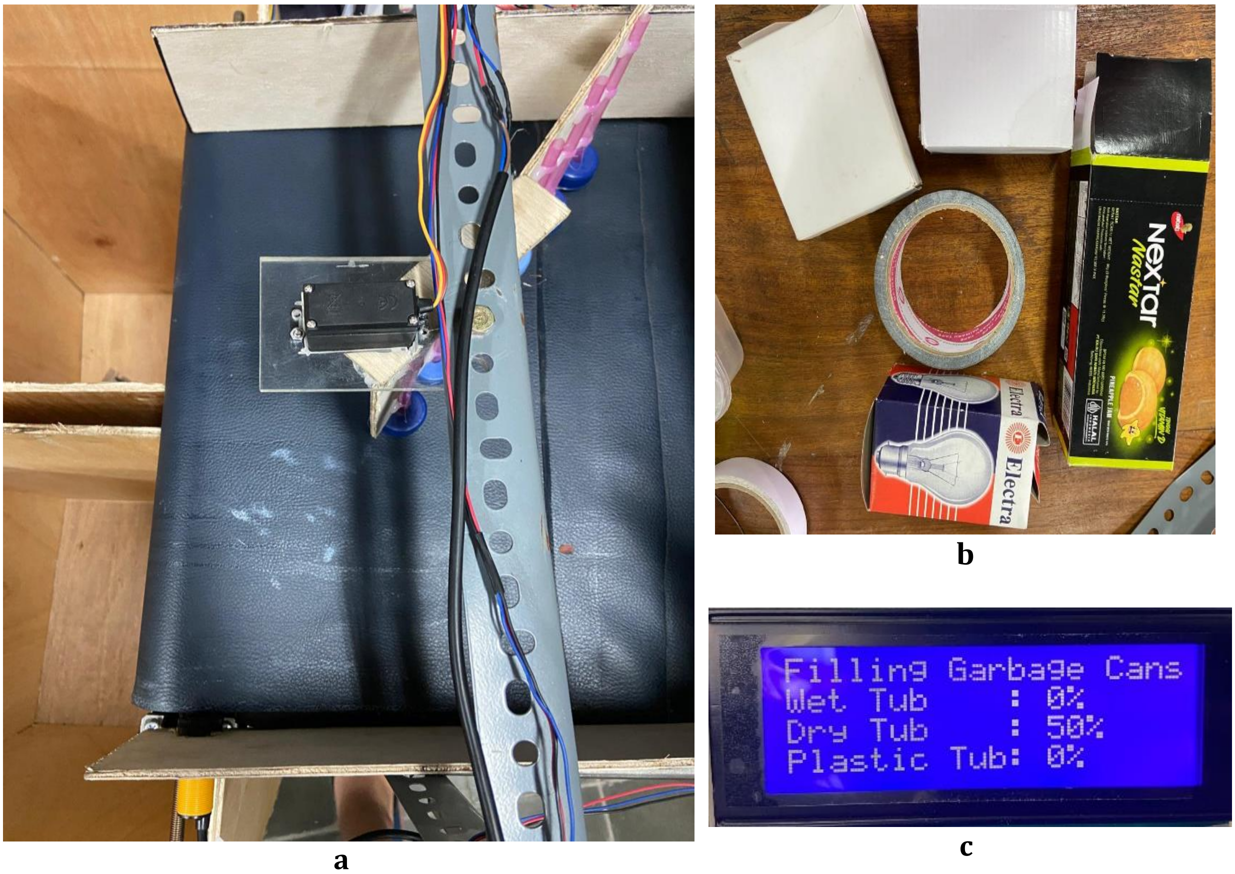


Figure 17. The result of the dry waste sorter; **a.** Implementation result; **b.** Dry waste to be sorted; **c.** Display.

Table 5. Dry waste sorting test results

Testing Number	Information
1	Succeed
2	Succeed
3	Succeed
4	Succeed
5	Succeed
6	Succeed
7	Not Succeed
8	Succeed
9	Succeed
10	Succeed

(**Source :** Data in this study)

CONCLUSION

The organic and inorganic waste sorting system that was designed consists of 5 sub-systems. They are metal waste, glass waste, dry waste, plastic waste, and wet waste sorting. The results of this study can produce a success rate of 66.7% in detecting the occupancy of the trash bin, 70% in sorting metal waste, and 44.4% in sorting glass waste. The success rate in sorting wet waste is 40%, while in sorting plastic waste is 70%, and in dry waste is 90%.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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