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# Automated Recycle Dustbin System with GSM Module for Waste Management

**Jamaludin Jalani**[1*], **Chia Jing Hang**[1], **Amirul Syafiq Sadun**[1], **Zurina Abdul Wahab**[1] and **Roslinda Ali**[2]

[1]Department of Electrical Engineering Technology,
[2]Department of Civil Engineering Technology,
Faculty of Engineering Technology,
Universiti Tun Hussien Onn Malaysia, 86400 Parit Raja Batu Pahat, Johor, Malaysia

[*]Corresponding author: jamalj@uthm.edu.my, Tel: 607-5535247

**Abstract:** Waste management has become a big issue in a society where waste can easily be ignored and neglected. This situation becomes worst when the world population has grown rapidly and improper waste management system is not catered to. This paper is an attempt to provide an Automatic Recycle Dustbin System (ARDS) with GSM Module for the waste management system. The ARDS allows sorting the recyclable waste such as metal, paper and general waste. The Arduino microcontroller is employed to initialize the sensors to detect different types of waste. The experimental results have shown that the proposed ARDS able to accurately 95% sorting the recyclable waste such as aluminum cans and beverage tetra packs. In addition, the GSM Module successfully notifies the level of ARDS to the users such as 'full' and '25% full'. The results show that the ARDS is reliable to be implemented in a modern waste management system that allows the Recycle, Reuse and Reduce (3Rs) activities.

**Keywords**: Recyclable waste, Waste Management, Microcontroller Arduino, Automated Recycle Dustbin System (ARDS) System, 3Rs.



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## 1. INTRODUCTION

The world population has grown rapidly which resulted in generating a huge amount of waste. Serious attention is required to keeping a green environment so that the problem can be controlled. Similarly, according to [1], Malaysians have generated an amount of 38,142 tons of waste daily in 2018 and had increased from 19,000 tons of waste per day from the year 2005 to 2018. This scenario shows that waste management has become a serious issue that needs to be resolved in Malaysia. Several assistant robots have been developed mainly to reduce the mentioned issue. For example, an intelligent dust cleaner robot has been designed and implemented for uneven and nonstructural environments [2]. Moreover, various waste sorting techniques have been proposed such as a smart robotic arm for automatic sorting of objects with different tags [3] and smart waste management with self-describing objects [4]. Different types of waste sorting systems have been developed based on Radio Frequency Identification (RFID) [3,4], Programmable Logic Controller (PLC) [5,6], Raspberry [7], Arduino Uno [9], PIC [11] and Microcontroller 8051 [12]. Moreover, the combination microcontroller between Arduino MEGA (C1) and Particle Photon (C2) can be found in [8] while Raspberry and Arduino can be refereed in [10].

Note that many advanced waste segregation systems utilized the Programmable Logic Controller (PLC) in their applications [5, 6]. These applications have employed a similar hydraulic cylinder as an actuator in the conveyor system. The advantage of a hydraulic cylinder is it can retract back and ready to run other stimulation repetitively until there was no waste present in the sorting process. The summary of the proposed and related waste management projects is tabulated in Table 1.

So far, only a few smart dustbin systems have been developed and many researchers are still investigating and developing a practical smart dustbin system. In this paper, an attempt to develop a new Automated Recycle Dustbin System (ARDS) with GSM Module for Waste Management is presented. The development of ARDS will generate a systematic and regular system in waste management which can be one of the great solutions to resolve the waste issue. With the help of the Global System for Mobile Communications (GSM), the users able to automatically receive the message to inform the status of waste level such as waste is "Full" and "50% Full".

It is expected that the ARDS with the GSM module developed here can be very useful and reliable due to its

practicality. In addition, it is a low-cost device for resolving waste management issues to be used particularly in Malaysia.

Table 1. Case Studies of the Project

| Case study | Controller used | Software applied | Limitation and Recommendation listed |
|---|---|---|---|
| [3] : A smart robotic arm for automatic sorting of objects with different tags | RFID tags and reader | • Unstated | • Improved the system with magnetic properties<br>• Constructed with servomotor and program with a certain program |
| [4]: A Smart Waste Management with Self-Describing objects | RFID and QR code system | • Unstated | • It cannot make sure all tags could be detected by the antenna reader<br>• Considering this limitation, an incremental approach with global disposed bag content need to be updated each time |
| [5]: A Review on PLC based Automatic Waste Segregator | Programmable Logic Controller (PLC): PLC s7-300 | • SIMATIC manager<br>• Program can be download from PC into PLC via an RS232 cable | • Implement with more sensors<br>• Implement with a robotic arm<br>• Feeder to separate dry and wet waste<br>• Camera sensor to detect the object entered |
| [6]: Automation of Waste Segregation Via Sensors by Using PLC | Programmable Logic Controller (PLC) | • Micro Win 32 Step 7 Version 4.0 - Siemens Semitic Industrial Software PLC Programming (Ladder Logic) | • Implement with a robotic arm<br>• Implement with more sensors<br>• Camera sensor to detect the object entered<br>• Use a more modern version of PLC software program |
| [7]: Automatic Waste Segregator Using Raspberry Pi | Microcontroller: Raspberry PI 3 | • Unstated | • The system only can sort only one waste at a time |
| [8]: A Smart and Solar-Powered Solid Waste Segregator | Microcontroller<br>• Arduino MEGA (C1)<br>• Particle Photon (C2) | • Unstated | • Image-processing or X-ray imaging<br>• Additional sensor to get a better project and sorting result<br>• Installed with moisture sensor and gas sensor<br>• Incorporate waste into electrical energy generation |
| [9]: Arduino Based Automated Waste Segregator | Microcontroller: Arduino UNO | • Arduino IDE (Integrated Development Environment)<br>• JAVA | • Implemented on a large scale as well<br>• Implement with a robotic arm<br>• Implement with more sensors |
| [10]: Design and Implementation Smart Solar-Powered Automatic Waste Segregating Machine with Image Processing and Monitoring | Microcontroller<br>• Raspberry Pi 3<br>• Arduino Mega 2560 | Arduino Mega 2560<br>• M-Duino (Arduino-based PLC)<br>• Arduino IDE<br>Raspberry Pi 3<br>• Raspbian Stretch<br>Library of Open-source PC vision<br>• Open CV-Library | • All waste must be scanned one at a time (more time consuming) |
| [11]: Implementation of Automated Waste Segregator at Household Level | Microcontroller: PIC16F877 | • Compiler: PIC Basic Compiler<br>• Language: PIC Basic<br>• Programmer Software: PICKit3 | • The moisture sensor is not efficient, replace it with a capacitive plate<br>• Replace microcontroller with Arduino, MSP 430, etc.<br>• The system only can isolate one waste at a time<br>• Implement the project on a bigger scale |
| [12]: Microcontroller Based Automatic Waste Segregator | Microcontroller: 8051 Microcontroller | • Keil Microvision 3<br>• C Program (download tool: Flash magic) | • Consume more time<br>• The limitation with the size of waste (Funnel size)<br>• E-waste cannot be sorted by the system (Sanitary and medical waste) |

## 2. AUTOMATIC RECYCLE DUSTBIN SYSTEM (ARDS) WITH GSM MODULE DESIGN

The design of an automatic waste sorting system with the GSM module is discussed in this section.

### 2.1 Block diagram

Figures 1 and 2 show the block diagram of sorting and level detection with the GSM module respectively. Two units of microcontroller Arduino MEGA 2560 and one unit of microcontroller Arduino UNO were used to receive an input signal from the sensor and program the output to achieve the objectives of the project.

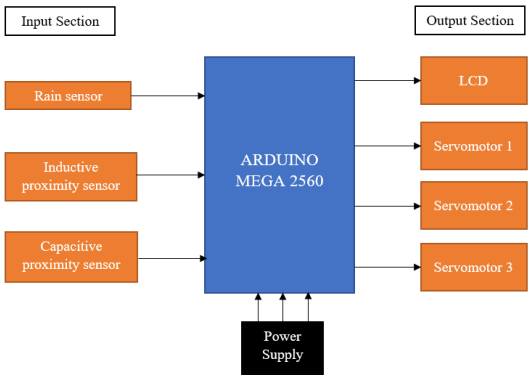


Figure 1. Block Diagram of Sorting System

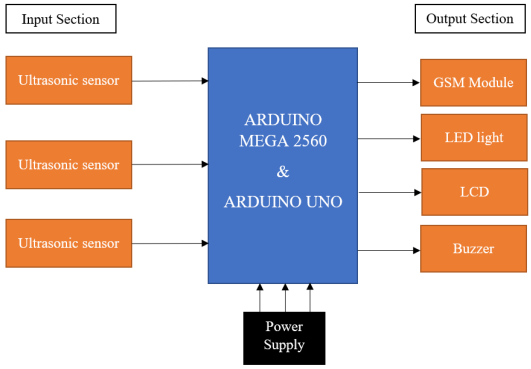


Figure 2. Level Detection System and GSM Module

### 2.2 Flow chart

A complete flow chart of the project development is shown in Figure 3. It clearly shows all the steps and responses of sensors and actuators programmed by the microcontroller Arduino. Table 2 shows the description of the project development.

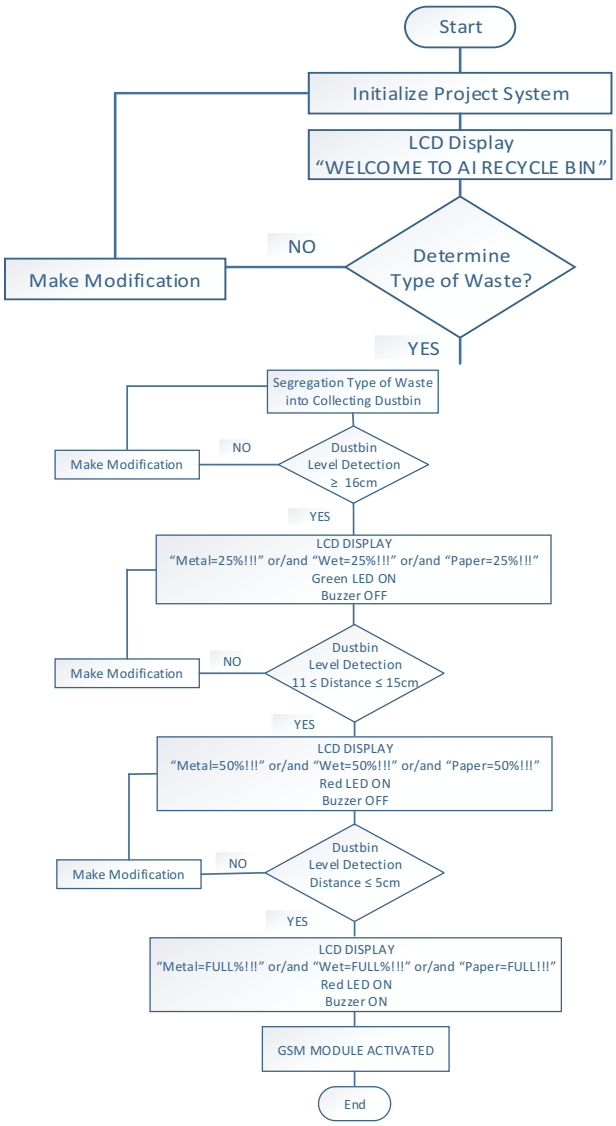


Figure 3: Flowchart of the Project Development

Table 2. Project Description

| Step | Description |
|---|---|
| 1 | Connect the power supply to the project system. |
| 2 | All components and hardware were stimulated and started for the sorting process. |
| 3 | 16 X 2 Liquid Crystal Display (LCD) will display the word "WELCOME TO AI RECYCLE DUSTBINS". |
| 4 | When a single waste is put into the sensing range, inductive proximity sensor, capacitive sensor and moisture sensor are ready to detect the types of waste and continue the sorting process. |
| 5 | When the type of waste is detected by the sensor, the sensor will stimulate the |

| | |
|---|---|
| | microcontroller Arduino MEGA 2560 to program the sorting process. |
| 6 | The servomotor attached with ice cream stick will push the waste into the correct collecting bin based on the type of waste while the LCD will show the types of waste entered and sensed by the project system. |
| 7 | Servomotor 1 and 2 have a moving range of 180$^o$ and they can move on either the left or right side with an angle of 90$^o$. Both of them will move at the same time and same direction. Servomotor 3 only has a moving angle of 90$^o$ downward which drops the waste into the collecting dustbin under the servomotor. |
| 8 | The waste is then dropped into the collecting bins and continues with the waste level detection system. |
| 9 | Each collecting dustbins installed with a single unit of the ultrasonic sensor and the ultrasonic sensor will detect the level of the waste in the collecting bins. |
| 10 | The ultrasonic sensor will stimulate the microcontroller Arduino MEGA 2560 and program the output to LED light, LCD and buzzer to show every status of collecting dustbins. |
| 11 | When the level of the waste exceeding threshold the level, the microcontroller Arduino UNO will program the GSM module. |
| 12 | An alert message will send to the user to have a cleaning process and maintain the good condition of the collecting bins. |

### 2.3 Design of project (3D)

The design of the proposed project is constructed in 3D by using SketchUp Pro 2018 and it can be separated into three parts. The parts are a sensing module to detect and sort the waste, waste level detection to show the status of collecting dustbins and alerting messages with GSM. Figures 4, 5, and 6 show the 3D design of the project for these three parts.

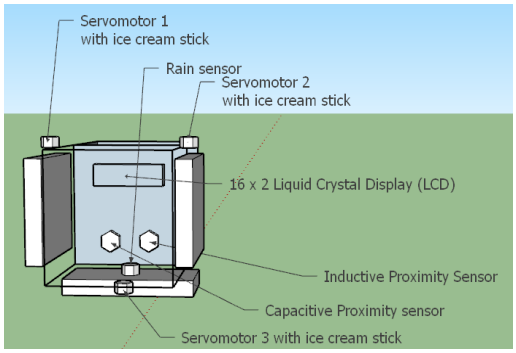


Figure 4. The Sensing Module System

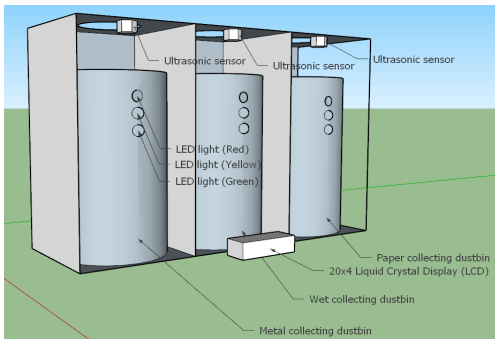


Figure 5. Waste Level Detection System

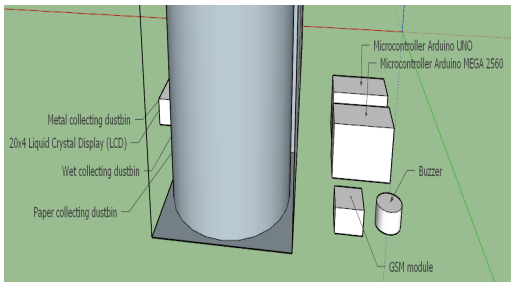


Figure 6. Alerting Message System with GSM Module

### 2.4 List of components

Table 3 shows the components and costs required for this project.

Table 3. Components List and Project Cost

| No. | Components | Qty | Price | Total price |
|---|---|---|---|---|
| 1. | Ultrasonic sensor | 3 units | RM 3.10 | RM 9.30 |
| 2. | Rain sensor | 1 unit | RM 3.90 | RM 3.90 |
| 3. | Capacitive proximity sensor | 1 unit | RM 18.70 | RM 18.70 |
| 4. | Inductive proximity sensor | 1 unit | RM 9.10 | RM 9.10 |
| 5. | Buzzer | 1 unit | RM 3.20 | RM 3.20 |
| 6. | Microcontroller Arduino MEGA 2560 | 2 units | RM 42.50 | RM 85.00 |
| 7. | Microcontroller Arduino UNO | 1 unit | RM 15.00 | RM 15.00 |

| | | | | |
|---|---|---|---|---|
| 8. | 16 X 2 Liquid Crystal Display (LCD) | 1 unit | RM 9.20 | RM 9.20 |
| 9. | 20 X 4 Liquid Crystal Display (LCD) | 1 unit | RM 15.40 | RM 15.40 |
| 10. | Servomotor | 3 units | RM 8.90 | RM 26.70 |
| 11. | Collecting bin | 3 units | RM 2.00 | RM 6.00 |
| 12. | GSM module | 1 unit | RM 34.90 | RM 34.90 |
| 13. | Breadboard | 3 units | RM 4.20 | RM 12.60 |
| 14. | LED light (Red, yellow and green) | 9 units | RM 0.30 | RM 2.70 |
| 15. | Male to male jumper wires (40 pieces) | 3 units | RM 3.90 | RM 11.70 |
| 16. | Female to male jumper wires (40 pieces) | 3 units | RM 3.20 | RM 9.60 |
| 17. | Female to female jumper wires (40 pieces) | 1 unit | RM 3.90 | RM 3.90 |
| 18. | 9V battery snap | 3 units | RM 0.65 | RM 1.95 |
| 19. | 9V battery | 3 units | RM 2.80 | RM 8.40 |
| 20. | 5V DC 2A Power Adapter | 1 unit | RM 8.80 | RM 8.80 |
| 21. | Ice cream stick | 1 unit | RM 2.90 | RM 2.90 |
| **Total Cost** | | | | RM 298.95 |

### 2.5 ARDS Prototype

Figures 7, 8 and 9 show the prototype of the ARDS at the front, side and top views respectively. Most of the hardware is constructed by using cardboard and three units of servomotors constructed with ice cream sticks to push the waste toward the collecting dustbins. The circuit is installed and constructed behind the project system.


Figure 7. Front View

Figure 8. Side View

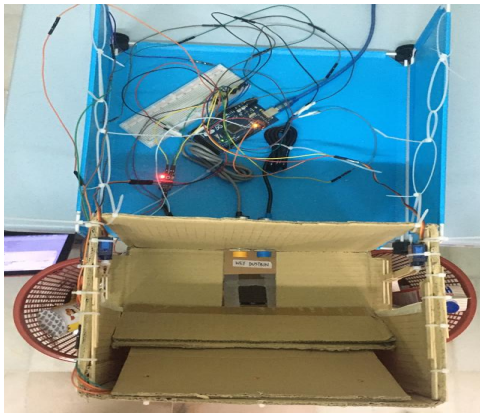

Figure 9. Top View

### 2.6 Wiring diagram

Figures 10 and 11 show the wiring diagram of the project. The wiring diagram is constructed into two parts which are the sorting process, waste level detection and GSM module. The connections are between the input, output, microcontroller and power supply. Red wires represented as power supply, black wires represented the ground while blue and orange wires represented the connection to the microcontroller Arduino board.

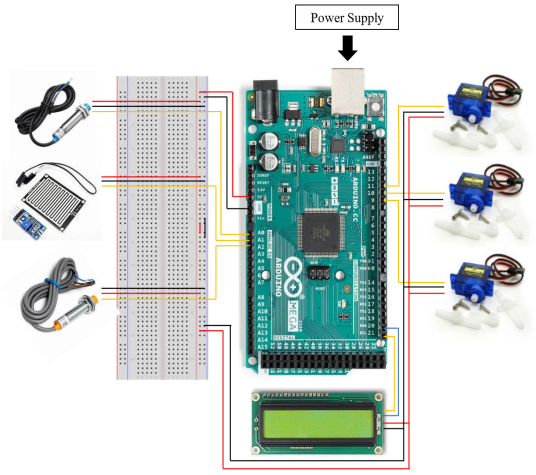


Figure 10. Wiring for Waste Sorting Process

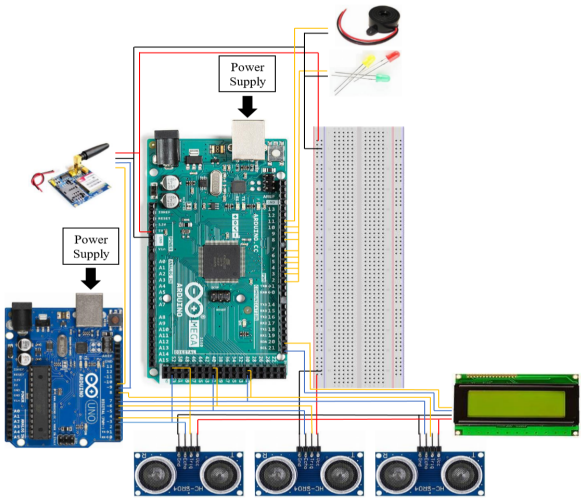


Figure 11. Waste Level Detection and GSM Module

## 3. RESULTS

The result of the sorting process and level detection with the GSM module is discussed in this section.

### 3.1 Result of the sorting process

Three different types of waste are considered for testing which are metal, paper and wet waste.

*3.1.1 Metallic waste*

Different types of metallic waste used for the sorting process are shown in Figure 12. Table 4 shows several testing results of metallic waste with Yes (Y) and No (N) to identify the stability of detection.


Figure 12. Paper Waste

Table 4. Result of Metallic Waste

| No | Types of waste | Detection of waste based on the sensor (red light) | | | | | Waste drop into the correct collecting dustbin | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 1. | 100 Plus can | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 2. | Potato chip can | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 3. | Mocha Coffee can | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 4. | Chrysanthemum can | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 5. | Koh-Kae Peanut can | Y | Y | Y | Y | Y | N | N | N | N | N |

*3.1.2 Paper waste*

Different types of paper waste used for testing are shown in Figure 13. Table 5 shows several testing results of paper waste with Yes (Y) and No (N) to identify the stability of detection.


Figure 13. Paper Waste

Table 5. Result of paper waste

| No. | Types of waste | Detection of waste based on the sensor (red light) | | | | | Waste drop into the correct collecting dustbin | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 1. | HL paper bottle | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 2. | Makeup paper box | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 3. | White Glo paper box | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| 4. | Normal paper | Y | Y | N | N | Y | Y | Y | N | N | Y |
| 5. | Paper card | Y | N | N | Y | N | N | N | N | N | N |

*3.1.3 Wet waste*

Similarly, different types of wet waste used to be sorted is shown in Figure 14. Table 6 shows several testing results of wet waste with Yes (Y) and No (N) to identify the stability of detection.

Figure 14. Wet Waste

Table 6. Result of Wet Waste

| No. | Types of waste | Detection of waste based on the sensor (Serial Monitor) | | | | | Waste drop into the correct collecting dustbin | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 1. | Wet tissue | Y | N | Y | Y | Y | Y | N | Y | Y | Y |
| 2. | Wet paper | Y | N | N | N | Y | Y | N | N | N | Y |
| 3. | Wet cloth | Y | Y | N | Y | Y | Y | Y | N | Y | Y |
| 4. | Wet cardboard | N | N | N | N | N | N | N | N | N | N |

### 3.2 Result of waste level detection

The result of waste level detection will involve LED light, Liquid Crystal Display (LCD), Buzzer, Ultrasonic sensor and Serial Monitor in Arduino IDE.

*3.2.1 LED light*

Each of the collecting dustbins is constructed with three units of LED light which are red, orange and green. Table 7 shows the relationship between the level of waste and the responses of the LED light.

Table 7. Level of Waste and Responses of LED Light

| Level of waste | 18 cm – 28 cm | 13 cm – 17 cm | 0 cm – 12 cm |
|---|---|---|---|
| LED light responses |  Red LED |  Yellow LED |  Green LED |

*3.2.2 Liquid Crystal Display (LCD)*

Figures 15 and 16 show the responses of the LCD based on different levels of waste. Meanwhile, Table 8 shows the relationship between the level of waste and LCD.

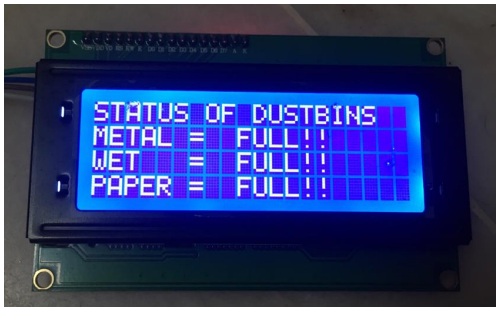


Figure 15. Status of Dustbins (FULL!!)

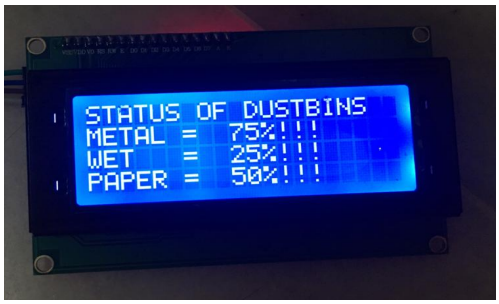


Figure 16. Different Status of Dustbins

Table 8. Level of Waste and LCD

| No. | Level of waste | Status of LCD (25%, 50%, 75% and FULL) |
|---|---|---|
| 1. | 0 cm – 12 cm | 25% |
| 2. | 13 cm – 17 cm | 50% |
| 3. | 18 cm – 22 cm | 75% |
| 4. | 23 cm – 28 cm | FULL |

*3.2.3 Buzzer*

Figure 17 shows the buzzer which is constructed behind the collecting dustbins. When the level of waste is between the range of 23 cm and 28 cm (i.e. Full), the buzzer will receive input from the microcontroller to start buzzing.

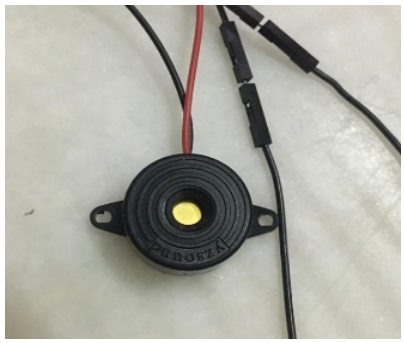

Figure 17. Buzzer

*3.2.4 Ultrasonic sensor*

Figure 18 shows the ultrasonic sensor is installed at the top of the collecting dustbin for waste level detection and continues with the further process.

Figure 18. Ultrasonic Sensor at Top of the Collecting Dustbin

*3.2.5 Serial Monitor in Arduino IDE*

Figure 19 shows the result of Serial Monitor in Arduino IDE. It displays the current waste level when the ultrasonic sensor is ON.

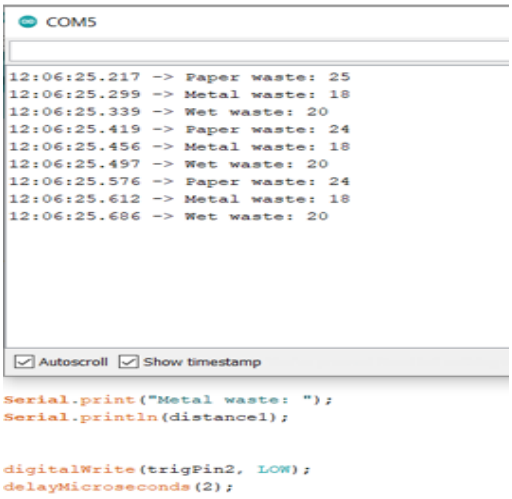


Figure 19. Serial Monitor in Arduino IDE

### 3.3 Alerting message system

Figure 20 shows the result of the alerting message to the user's phone. Users can set the phone number in the GSM module as "ARDS" to clearly show the sender details as correct. The message clearly shows the status of collecting dustbins to indicate the current distance between waste and ultrasonic sensors. The ARDS is full when the distance between waste and ultrasonic sensors is 4 cm.

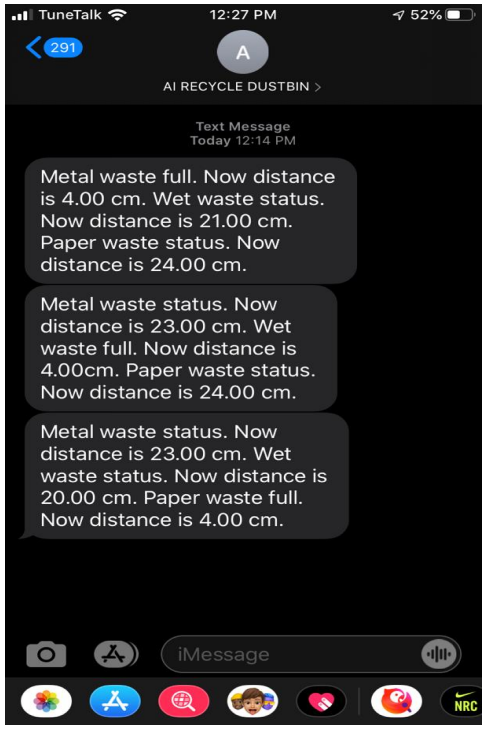


Figure 20. Alerting Message to User's Phone

All processes run automatically, and function successfully as expected. The GSM module able to send an alerting message to the user for collecting dustbins when it is full of waste.

## 4. CONCLUSION

An Automated Recycle Dustbin System (ARDS) with the help of a GSM module system has been developed successfully. The device is very useful to assist the user in the waste management process. Different types of wastes such as metal, paper and wet are successfully detected and segregated. However, the project can be further improved for future applications. The recommendations of the project are:

- Construct with long-range detection sensor
- Construct with high power servomotor
- Construct the system with a PLC controller
- Construct the hardware with wood-based
- Possible to use the solar panel as a power supply

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