# AUTOMATIC WASTE SEGREGATION SYSTEM USING ARDUINO UNO

**A PROJECT REPORT SUBMITTED TO**

**SRM INSTITUTE OF SCIENCE & TECHNOLOGY**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE**

**AWARD OF THE DEGREE OF**

**MASTER OF COMPUTER APPLICATIONS**

**BY**

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**UNDER THE GUIDANCE**

**OF**

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**Kattankulathur – 603 203**

**Chennai, Tamil Nadu**

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This is to certify that the project report titled **"AUTOMATIC WASTE SEGREGATION SYSTEM USING ARDUINO UNO"** is a bonafide work carried out by GOPINATH R (RA2332241010298), under my supervision for the award of the Degree of Master of Computer Applications. To my knowledge the work reported herein is the original work done by these students.


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## DECLARATION OF ASSOCIATION OF RESEARCH PROJECT WITH SUSTAINABLE DEVELOPMENT GOALS

This is to certify that the research project entitled "**AUTOMATIC WASTE SEGREGATION SYSTEM USING ARDUINO UNO**" carried out by **Mr. GOPINATH R** under the supervision of **Dr**. **D HELEN** in partial fulfilment of the requirement for the award of Post Graduation program has been significantly or potentially associated with SDG Goal No **09 (NINE)**titled **INDUSTRY, INNOVATION AND INFRASTRUCTURE**.

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## ACKNOWLEDGEMENT

With profound gratitude to the ALMIGHTY, I take this chance to thank people who helped me to complete this project.

I take this as a right opportunity to say THANKS to my parents who are there to stand with me always with the words “YOU CAN”.

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A great note of gratitude to friends and people who are known and unknown to us who helped in carrying out this project work a successful one.

**GOPINATH R**

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This is to inform you that **Mr. Gopinath. R (Reg. No. RA2332241010298)** final year MCA (Computer Applications) student of SRM Institute of Science and Technology, Kattankulathur Campus, Chennai has successfully completed his project work titled "**Automatic Waste Segregation System Using Arduino Uno**" during December 2024 to March 2025 (Except Sundays and Holidays) in our organization.

We wish him all success for his future endeavors.

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## AUTOMATIC WASTE SEGREGATION SYSTEM USING ARDUINO UNO

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# ABSTRACT

This project aims to develop an optimized waste management system by streamlining the segregation process, reducing manual effort, and improving recycling efficiency. Waste segregation is a vital process in efficient waste management, significantly improving recycling efficiency and reducing environmental pollution. The system integrates an IR sensor to detect non- metallic dry waste, a proximity sensor inductive type to identify metallic waste, and a raindrop module to differentiate wet waste. When waste is placed on the detection platform, the sensors analyze its properties, and the Arduino Uno microcontroller processes the data to activate a stepper motor, which rotates to direct the waste into the appropriate bin. This automated system enhances efficiency, accuracy, and speed in waste sorting, significantly reducing human intervention and manual labour. It ensures proper handling of recyclable materials, prevents contamination of waste streams, and minimizes landfill waste, promoting an eco-friendly approach to waste disposal. The system is cost-effective, scalable, and adaptable, making it suitable for a wide range of applications, including households, commercial spaces, smart cities, and industrial waste management facilities. It can be implemented in households, public spaces, and industrial waste management units, facilitating effective recycling, conserving resources, and contributing to a cleaner and more sustainable environment.

**Keywords-** Automated Waste Segregation, Waste Management, IR Sensor, Inductive Proximity Sensor, Raindrop Module, Arduino Uno, Stepper Motor, Smart Waste Sorting.

# TABLE OF CONTENTS

# CHAPTER 1

# 1. INTRODUCTION

Waste segregation is a crucial aspect of efficient waste management, playing a key role in reducing environmental pollution, conserving resources, and improving recycling efficiency. Traditional manual waste segregation is often inefficient, time-consuming, and exposes workers to hazardous conditions. Therefore, an automated solution is necessary to enhance the efficiency and accuracy of the segregation process. This project aims to develop an Automated Waste Segregation System using Arduino Uno, which classifies waste into dry, wet, and metallic categories with the help of various sensors. The system employs an IR sensor to detect non-metallic dry waste, a proximity sensor to identify metallic waste, and a raindrop module to differentiate wet waste. When waste is placed on the detection platform, these sensors analyze its properties, and the Arduino Uno processes the data to activate a stepper motor, which rotates to direct the waste into the appropriate bin. This automated process significantly reduces human intervention, enhances accuracy in waste classification, and promotes a cleaner and more efficient waste disposal mechanism. The implementation of this system can have a significant impact on households, public spaces, and industrial waste management units, making the waste disposal process more systematic and effective. it contributes to resource conservation by ensuring that recyclable materials are properly sorted and processed, reducing the strain on natural resources. The integration of smart technology in waste management fosters innovation, making waste handling more efficient, hygienic, and environmentally responsible. This project serves as a step toward sustainable waste management by providing a practical, intelligent, and scalable solution to modern waste disposal.

# CHAPTER 2

# 2. LITERATURE STUDY

## INTRODUCTION

Waste management has become a pressing global challenge, with improper segregation leading to inefficient recycling and increased landfill waste. Traditional waste handling methods are labor-intensive and error-prone. An automatic waste segregation system using Arduino Uno aims to optimize the segregation process, reduce manual intervention, and improve recycling efficiency.

## EXISTING RESEARCH ON WASTE SEGREGATION SYSTEMS

Several studies have explored different techniques for automatic waste classification, employing various sensor-based, mechanical approaches to improve efficiency.

### 1. SENSOR-BASED WASTE SEGREGATION SYSTEMS

- Modern waste segregation systems incorporate different sensors to classify waste based on physical and material properties
- IR Sensors- Used to detect non-metallic dry waste by analyzing infrared reflection (Kumar et al., 2020).
- Inductive Proximity Sensors- Identify metallic objects by detecting changes in electromagnetic fields (Patil & Deshmukh, 2021).
- Moisture Sensors (Raindrop Module)- Differentiate wet waste from dry waste by measuring conductivity and humidity (Chavan et al., 2019).
- Reference "Development of an Arduino-based automatic waste sorting system" (Jan 2025), Bulletin of the Tomsk Polytechnic University Geo, discusses how Arduino-based control of sensors improves waste classification accuracy.
- "Development of Home Applied Waste Segregation and Management System" (June 2024), Dutse Journal of Pure and Applied Sciences, highlights real-world implementation of a household-level automated waste sorting system.

## 2. MECHANICAL AND AUTOMATED WASTE SORTING SYSTEMS

- To ensure accurate segregation, mechanical automation is integrated with sensor-based detection. Stepper motors or servo motors direct waste to the appropriate bin.
- Design and Fabrication of an Automatic Waste Segregation and Monitoring System (Aug 2024) discusses stepper motor integration for sorting mechanisms.
- Design and development of an automatic dry waste segregator (March 2022) explores conveyor belt-based waste movement for large-scale operations.

## 3. IOT AND AI IN WASTE MANAGEMENT

- The integration of Internet of Things (IoT) and AI enhances waste classification and monitoring efficiency.
- Automatic Waste Segregator and Monitoring System (Jan 2016) developed a real-time monitoring system for waste levels in bins, reducing overflow issues.
- Development of Automatic Waste Identification and Segregation System (Jan 2021) proposed AI-driven image processing for waste classification.
- Seasonal characterization of municipal solid waste (Dec 2021) suggested the use of data analytics for efficient waste treatment technology selection.

## 4. CHALLENGES AND LIMITATIONS

- Despite advancements, automated waste segregation systems face challenges such as:
- Sensor Limitations: Variability in sensor readings due to environmental factors.
- Cost and Scalability: Higher costs for large-scale adoption in municipal waste management.
- Public Adoption: The need for public awareness and participation in smart waste disposal.

## 5. FUTURE SCOPE

Future research should focus on

- Enhanced AI-powered waste recognition using deep learning and computer vision.
- Integration of IoT-based real-time monitoring for smart city waste management.
- Sustainable waste treatment methods to complement automated segregation systems.

## CONCLUSION

Arduino-based automatic waste segregation systems significantly improve efficiency, reduce labor, and promote recycling. By leveraging sensor technology, mechanical sorting, and IoT integration, these systems offer a scalable and eco-friendly solution for waste management. However, challenges such as sensor accuracy, cost-effectiveness, and large-scale implementation need to be addressed for widespread adoption.

# CHAPTER 3

# 3. SYSTEM REQUIREMENTS

## 3.1 SOFTWARE REQUIREMENTS

| COMPONENT | SPECIFICATION |
|---|---|
| **IDE** | Arduino IDE |
| **Library for Arduino** | Install the Servo and CheapStepper library in a Arduino IDE |
| **C Programming language** | used for writing Arduino firmware. |
| **Serial Communication** | for debugging via Arduino Serial Monitor. |

## 3.2 HARDWARE REQUIREMENTS

| Component | Quantity | Specification/Function |
|---|---|---|
| Arduino Uno | 1 | Microcontroller for processing sensor data and motor control |
| IR Sensor | 1 | Detects non-metallic dry waste |
| Inductive Proximity Sensor | 1 | Identifies metallic waste |
| Raindrop Sensor Module | 1 | Differentiates wet waste |
| Cheap Stepper Motor | 1 | Rotates to direct waste into the appropriate bin |
| Stepper Motor Driver | 1 | Controls the stepper motor for precise movement |
| Motor Driver Module (L298N/L293D) | 1 | Controls motor operation and direction |
| 1-Watt LED | 1 | Provides visual indication of system operation |
| Buzzer (Optional) | 1 | Alerts when waste is detected or for notifications |
| Power Supply (9V/12V Adapter or Battery) | 1 | Provides power to the Arduino and sensors |
| Jumper Wires | Multiple | Used for electrical connections |

# CHAPTER 4

# 4. SYSTEM ANALYSIS

## 4.1 EXISTING SYSTEM

The existing waste sorting system faces significant challenges due to its dependence on manual labour and inefficient separation techniques. In most households and public places, waste is disposed of in mixed bins, leading to contamination and reducing the effectiveness of recycling efforts. Workers are then required to manually sort waste into categories such as organic, recyclable, and non-recyclable materials, which is both time-consuming and hazardous due to potential exposure to harmful substances. Additionally, the lack of awareness and improper waste disposal habits among individuals further complicate the sorting process. Communities also played a significant role in traditional waste management. In some villages, waste was collected through door-to-door methods, where waste pickers or municipal workers manually sorted materials. In others, designated waste pits or collection points were used, allowing people to separate wet and dry waste at the source. However, in the absence of proper disposal facilities, burning and open dumping were common practices, leading to environmental pollution and health risks. Many communities burned plastic, paper, and other non-biodegradable materials as a quick disposal method, while others disposed of waste in open fields, rivers, or unregulated landfills, contributing to long-term ecological damage. While traditional waste segregation methods were effective in low-waste societies, they became insufficient as industrialization and consumerism increased waste production. The lack of structured collection systems, proper recycling infrastructure, and scientific disposal methods led to severe environmental issues, including plastic pollution, landfill overflows, and toxic emissions. As waste generation continues to rise, integrating traditional sustainable practices with modern technology can offer a balanced and efficient approach to waste management, ensuring a cleaner and greener future.

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## 4.2 DRAWBACKS OF THE EXISTING SYSTEM

- Traditional waste segregation methods, while effective in low-waste societies, have several limitations that make them unsuitable for handling modern waste volumes.
- These drawbacks include inefficiency, health risks, environmental pollution, and lack of scalability, which have led to the need for more advanced waste management solutions.
- One of the major issues with traditional methods is inefficiency and inconsistency. In older times, waste segregation was primarily done at the household or community level, where individuals sorted waste based on biodegradable (wet) and non-biodegradable (dry) categories.
- However, there was no standardized system, and people often disposed of waste incorrectly, leading to contamination. Additionally, many communities lacked a proper collection system, resulting in waste being dumped in open areas or mixed together, making recycling difficult.
- Another significant drawback is health hazards for waste handlers. In traditional systems, waste segregation was largely manual, exposing workers to diseases, toxic fumes, and physical injuries. Informal waste pickers, who played a crucial role in salvaging recyclable materials, often worked without protective gear, increasing their risk of infections and accidents.
- Handling hazardous waste like medical or electronic waste was particularly dangerous, as people were unaware of proper disposal methods. Environmental pollution was also a major issue with traditional waste segregation methods.
- Open dumping and burning of waste were common practices, leading to air, soil, and water pollution. Burning plastic and other non- biodegradable materials released toxic gases, contributing to respiratory diseases and climate change. Similarly, improper landfill management led to leachate contamination, where harmful chemicals from waste seeped into the ground and polluted water sources.

## 4.3 PROPOSED SYSTEM

The Automated waste segregation system is designed to overcome the inefficiencies of traditional and existing waste sorting methods by using sensors and microcontroller-based automation. This system provides an efficient, cost-effective, and scalable solution to segregate waste into different categories (wet, dry, and metallic) with minimal human intervention. The core of the system is an Arduino Uno, which serves as the microcontroller responsible for processing sensor data and controlling motor movements. The system integrates multiple sensors to classify waste accurately. An IR sensor detects non-metallic dry waste, an inductive proximity sensor identifies metallic waste, and a raindrop sensor module differentiates wet waste. Once detected, a stepper motor, controlled by a motor driver module (L298N/L293D), rotates to direct the waste into the appropriate bin. This automation eliminates the need for manual sorting, significantly improving accuracy and reducing labor costs. For real-time feedback, a 1-watt LED indicator provides a visual status of system operation, while an optional buzzer alerts users when waste is detected. The entire system is powered by a 9V/12V adapter or battery, ensuring low energy consumption and making it suitable for use in households, schools, and small waste collection centers. The waste sorting mechanism is housed within a structured bin and frame, ensuring organized waste collection with minimal risk of contamination. This proposed system effectively addresses the limitations of traditional and existing waste segregation methods by integrating automation, accuracy, and cost-efficiency. It represents a practical step toward smart waste management, helping reduce landfill waste, improve recycling, and promote environmental sustainability.

## 4.4 ADVANTAGES OF THE PROPOSED SYSTEM

- The proposed automated waste segregation system offers several advantages over traditional and existing methods, making waste management more efficient, cost-effective, and environmentally friendly. integrating sensors and automation, the system eliminates the need for manual sorting, which is often slow, inaccurate, and hazardous to human health.
- Instead of relying on human intervention, the system uses IR sensors, inductive proximity sensors, and a raindrop sensor module to detect and classify dry, wet, and metallic waste, ensuring precise segregation. One of the key benefits of the system is that it reduces human contact with waste, minimizing the risk of infections, toxic exposure, and injuries.
- This is especially important for waste pickers and sanitation workers who often handle hazardous materials without proper protective gear. Additionally, the system operates autonomously, requiring minimal supervision and reducing labor costs associated with waste management.
- Another major advantage is the system's cost-effectiveness. Built using low-cost components such as the Arduino Uno, stepper motors, and standard sensors, it provides an affordable alternative to expensive industrial waste sorting machines.
- The system is also energy-efficient, as it runs on a 9V/12V power supply or battery, making it suitable for household, small business, and community applications without increasing electricity consumption.
- The efficiency of recycling is significantly improved with this system since waste is segregated at the source, reducing contamination and making recyclable materials more usable. This helps recycling plants process waste more effectively, reducing landfill dependency and promoting a circular economy.
- The real-time monitoring system with LED indicators and an optional buzzer provides users with immediate feedback, ensuring that the sorting process is functioning correctly.

# CHAPTER 5

# 5. SYSTEM DESIGN

## 5.1 USE CASE DIAGRAM

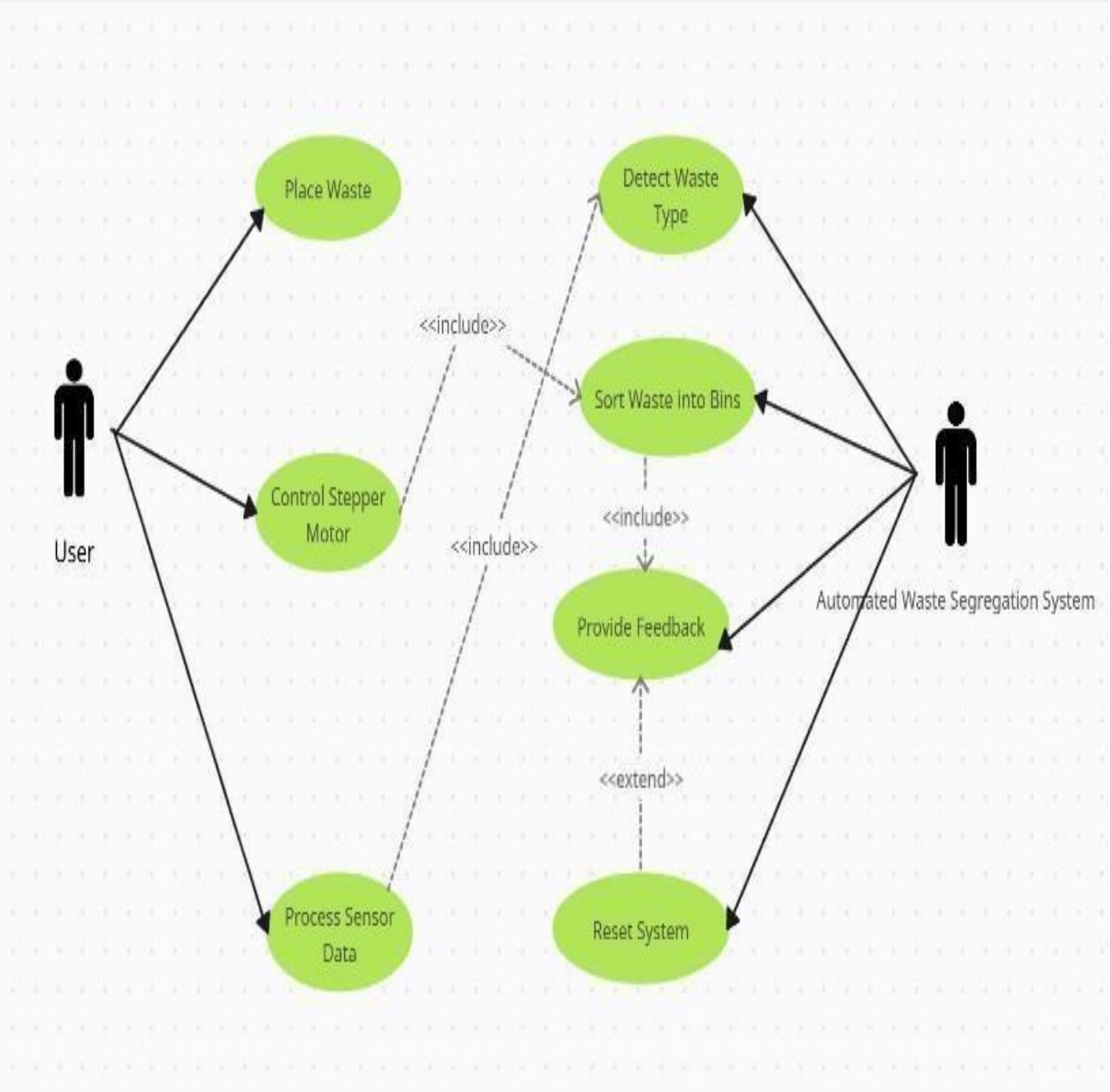



**Figure.1 Use case of Automatic waste segregation system**

## 5.2 CLASS DIAGRAM

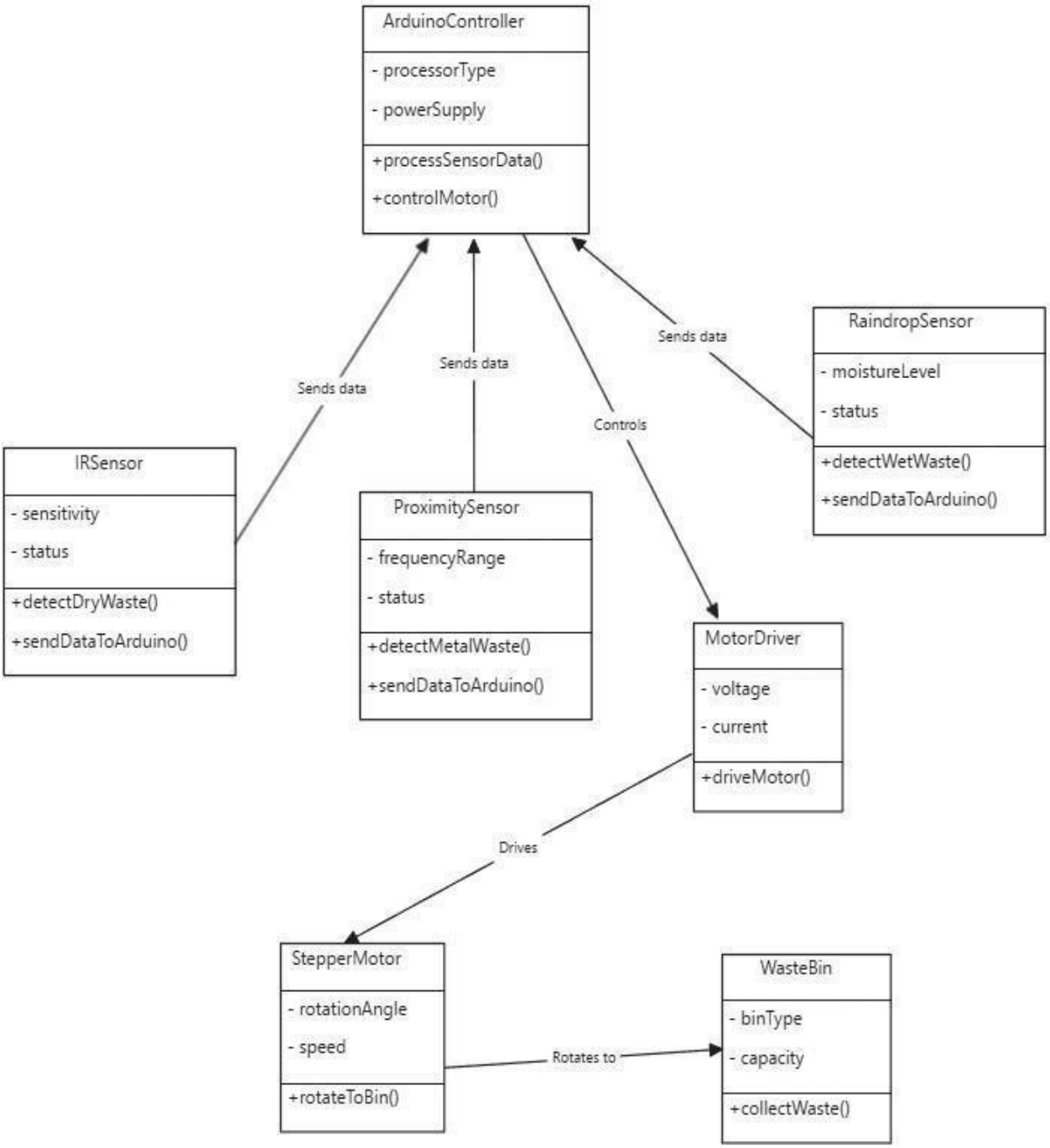



**Figure.2 Class Diagram of Automatic waste segregation system**

## 5.3 SEQUENCE DIAGRAM

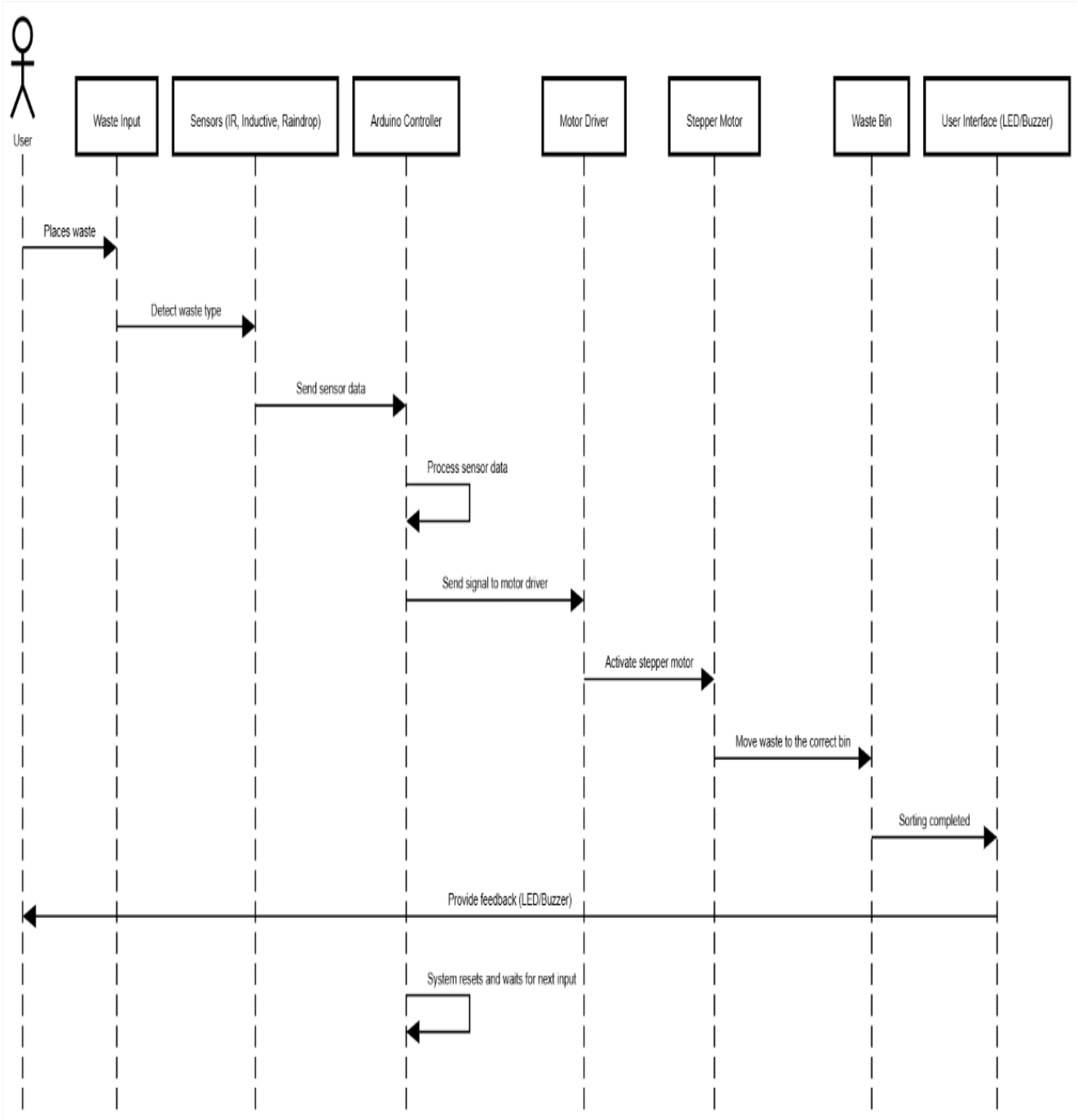



**Figure.3 Sequence diagram of Automatic waste segregation system**

## 5.4 FLOWCHART DIAGRAM

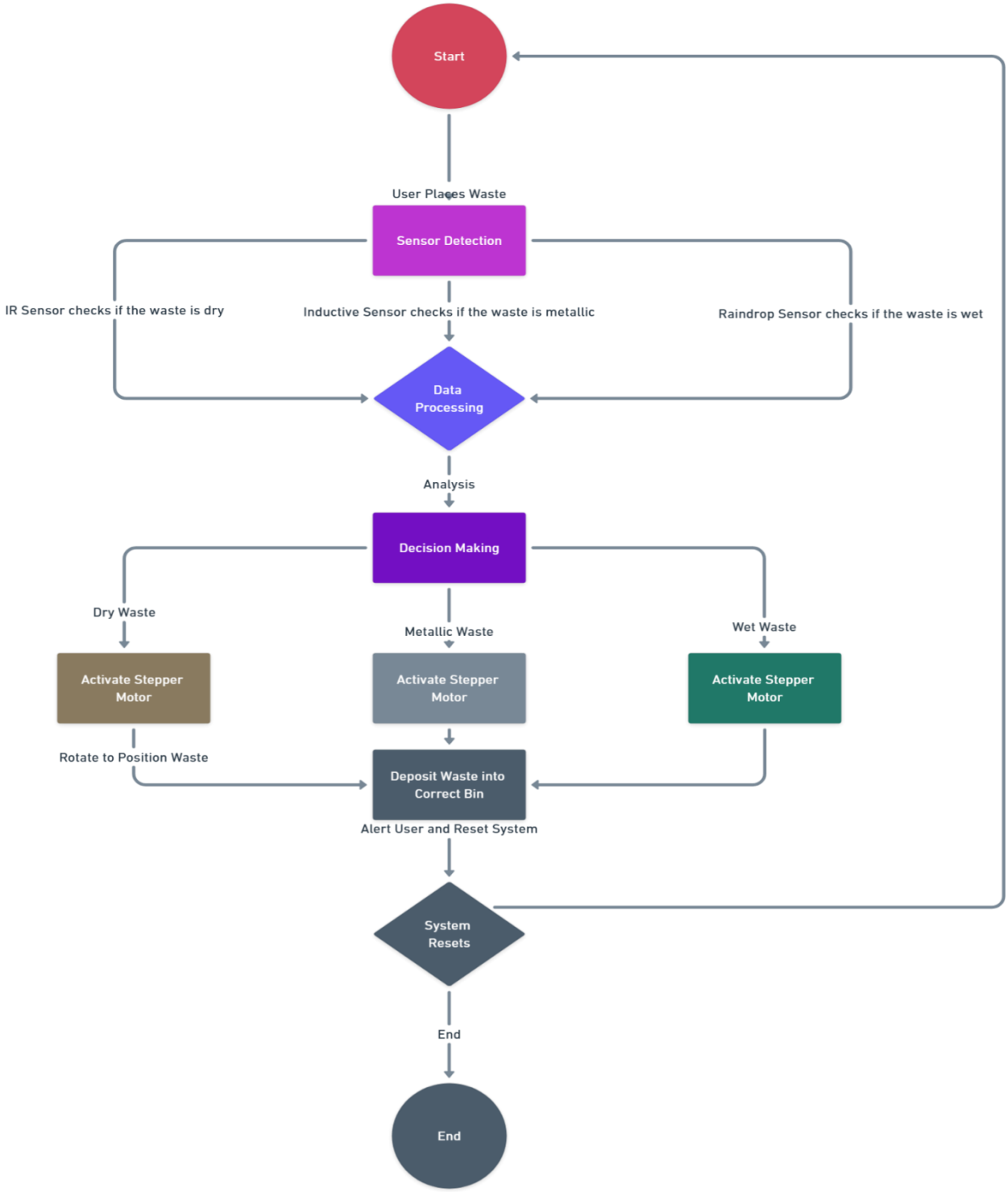



**Figure.4 Flow chart of Automatic waste segregation system**

## 5.5 SIMULATION DIAGRAM

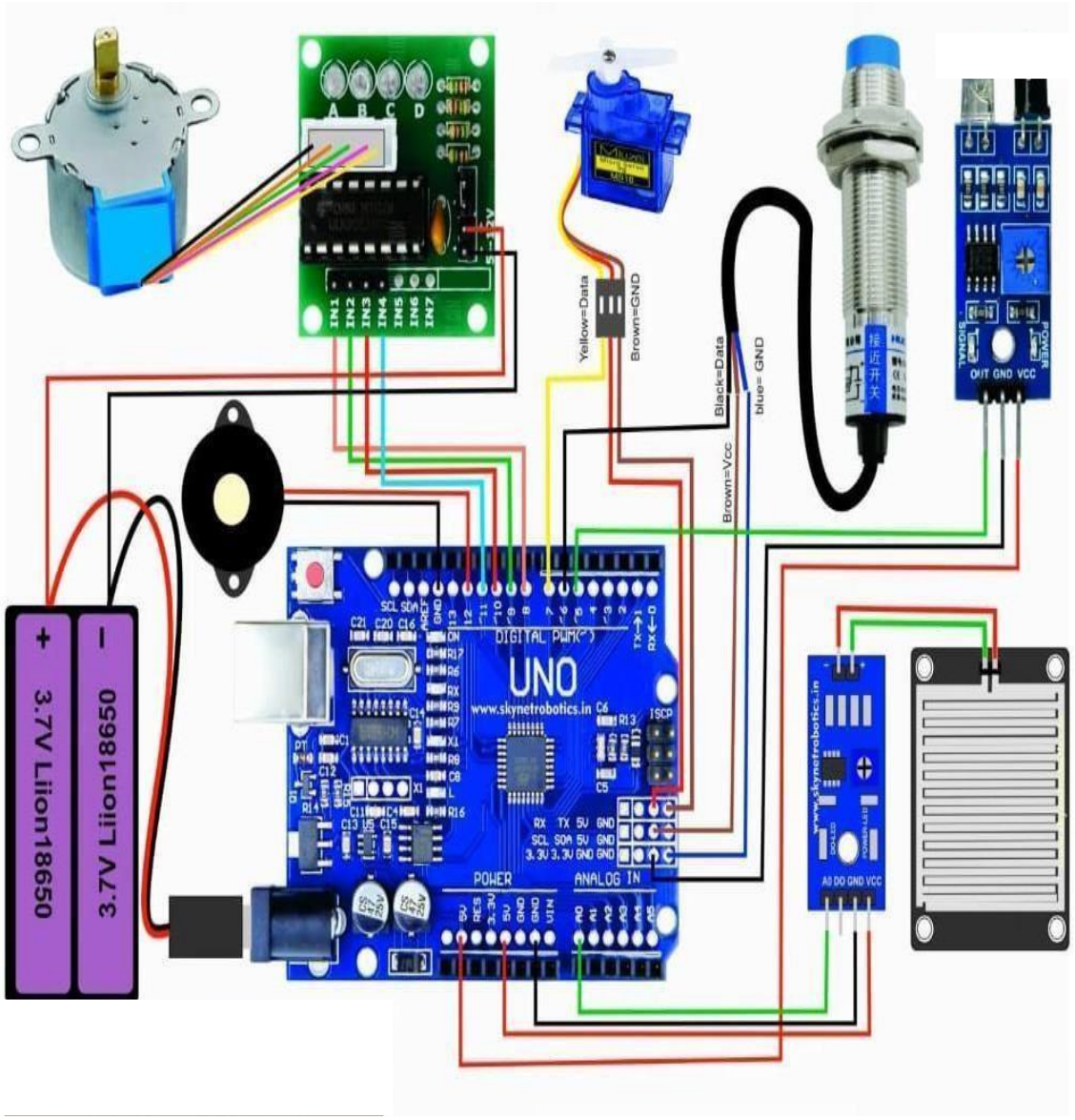



**Figure.5 Simulation diagram for Automatic waste segregation system**

## 5.6 CIRCUIT DIAGRAM

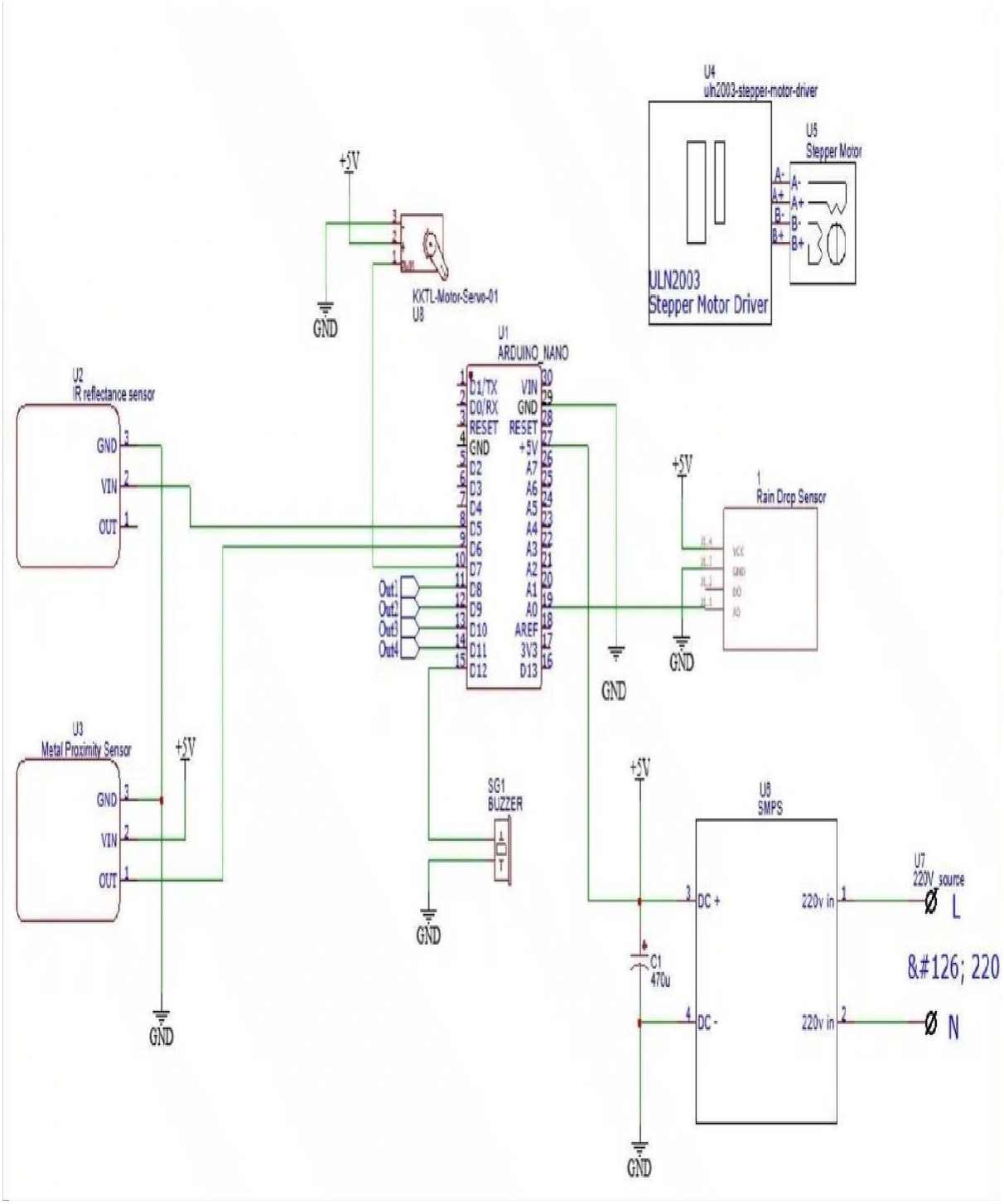



**Figure.6 Circuit diagram for Automatic waste segregation system**

## 5.7 ACTIVITY DIAGRAM

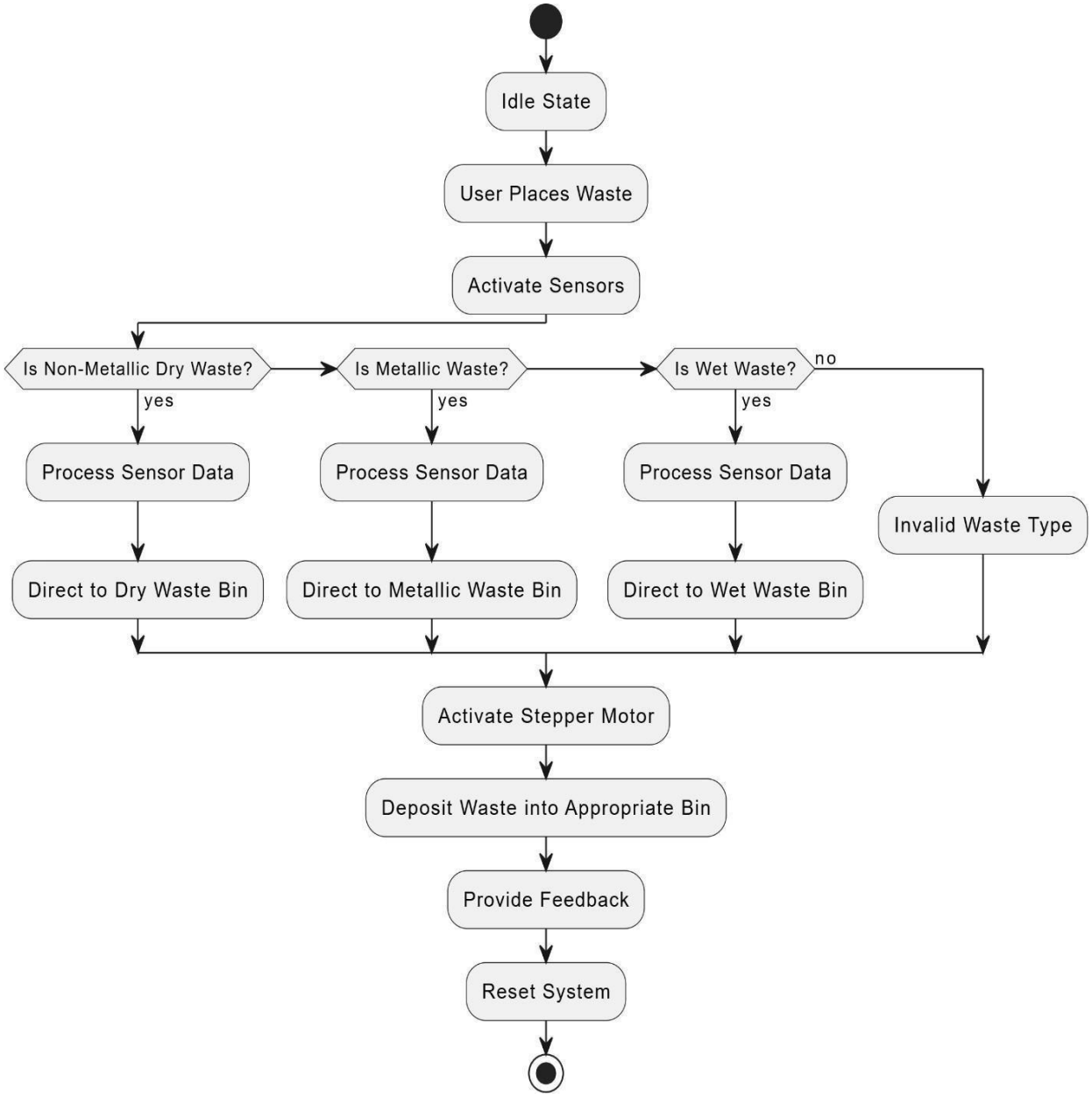



**Figure .7 Activity diagram of Automatic waste segregation**

## 5.8 BLOCK DIAGRAM

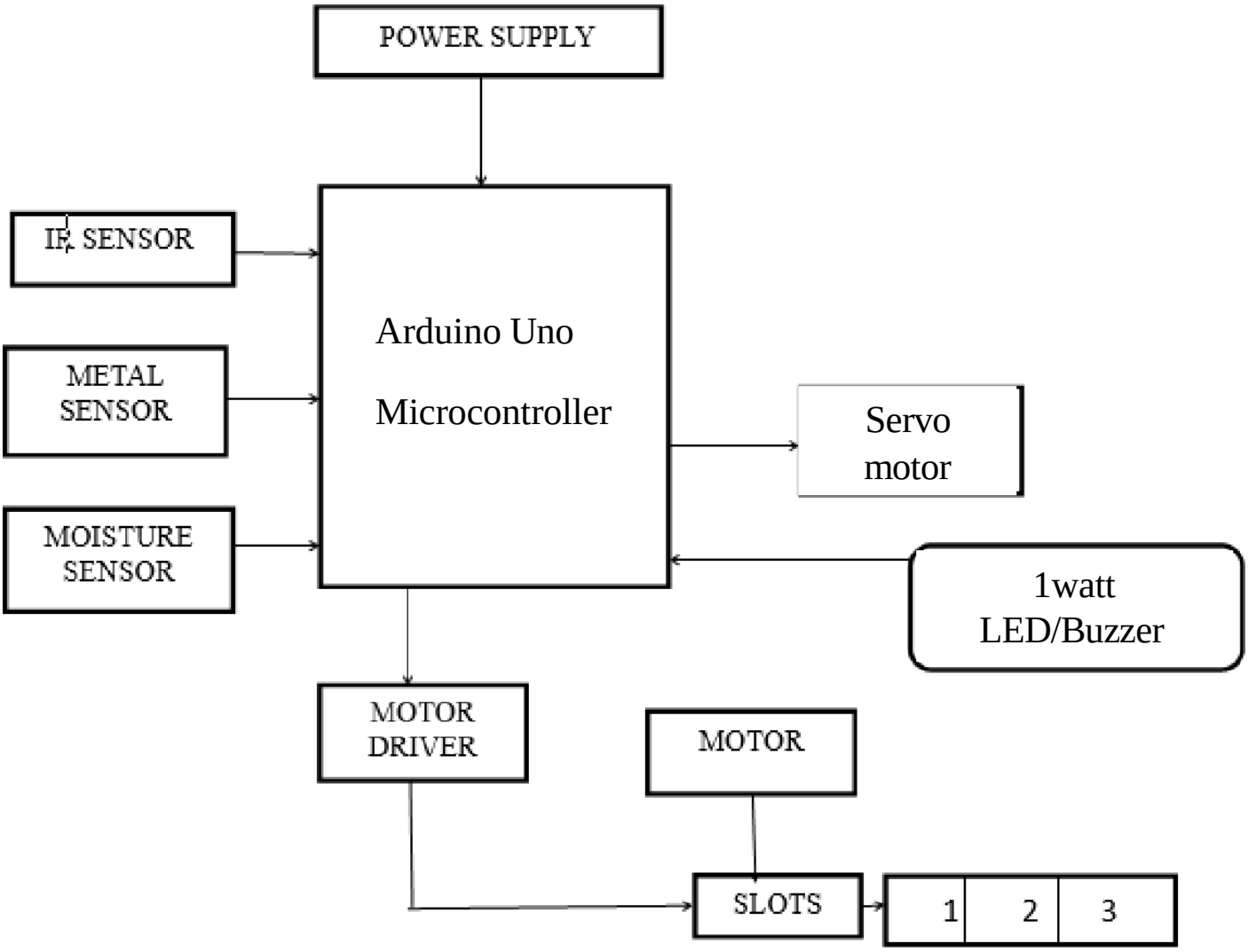



**Figure .8 Block diagram of Automatic waste segregation**

# CHAPTER 6

# 6. SYSTEM IMPLEMENTATION

## 6.1 MODULES DESCRIPTION

## ARDUINO IDE

Arduino is an open-source electronics platform that combines hardware and software to enable the development of interactive digital systems. It is designed to be simple, flexible, and accessible, making it a popular choice for hobbyists, students, and professionals in fields like automation, robotics, and IoT (Internet of Things). The hardware consists of microcontroller-based boards such as Arduino Uno, Mega, and Nano, which have digital and analog input/output pins, allowing them to read data from sensors and control various actuators like motors, LEDs, and displays. The Arduino IDE (Integrated Development Environment) provides a user-friendly platform to write, compile, and upload code in a C-based language. It includes a vast collection of libraries that simplify complex operations, such as sensor data processing, wireless communication, and motor control. Additionally, Arduino supports PWM (Pulse Width Modulation) for precise motor control and SPI protocols for sensor communication, and serial communication for real-time data transfer. One of Arduino's biggest strengths is its scalability and adaptability. It can be used for simple projects like LED blinking and temperature sensing, as well as advanced applications like AI-powered automation, industrial control, and real-time monitoring systems. In an IoT-based smart home system, for example, Arduino can connect to monitor temperature, humidity, and security systems remotely. Similarly, in a renewable energy project, Arduino can control servo motors in a windmill to optimize energy generation based on wind speed data. Its open-source nature, strong community support, and extensive documentation, Arduino remains a powerful tool for rapid prototyping and innovation. Its affordability, flexibility, and ease of use have made it an industry standard in embedded systems, automation, and intelligent control applications.

## ARDUINO UNO

The Arduino Uno is a popularly used open-source micro-controller board that runs on ATmega 328P micro-controller. This board is developed by Arduino.cc which is an Italy based hardware company. This board contains a set of digital and analog I/O data pins that are used to interface this board with other electronic components. Arduino Uno consists of 14 digital pins and 6 analog pins. This board can be programmed with the help of Arduino IDE (Integrated Development Environment) that supports embedded C, its back-end is constructed using JAVA. Uno consists of an USB port through which the code can be uploaded on to the board. This post can also be used to power the board by connecting it to a laptop, PC, etc. Along with a USB port, it also has a DC input power jack. An external battery of 9V can also be used to power Arduino board.

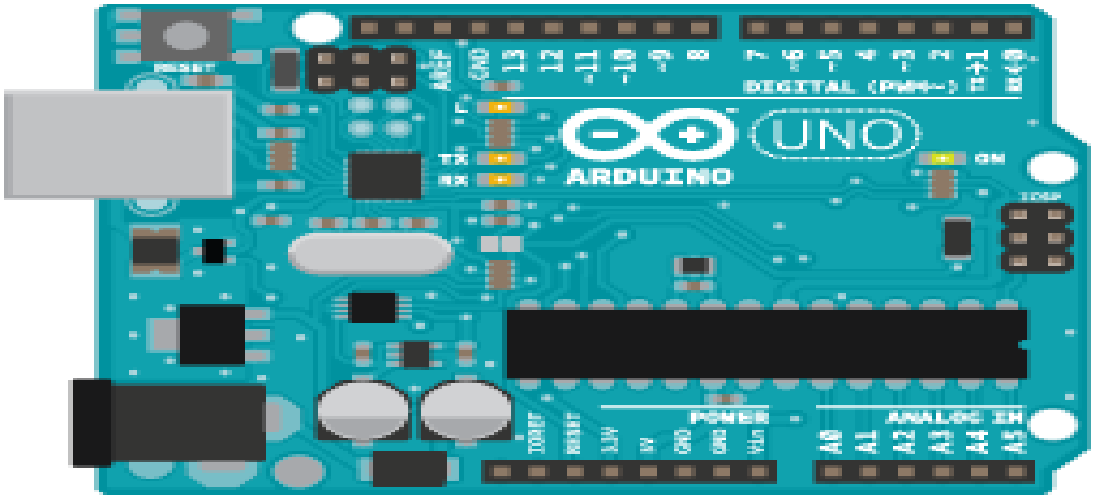
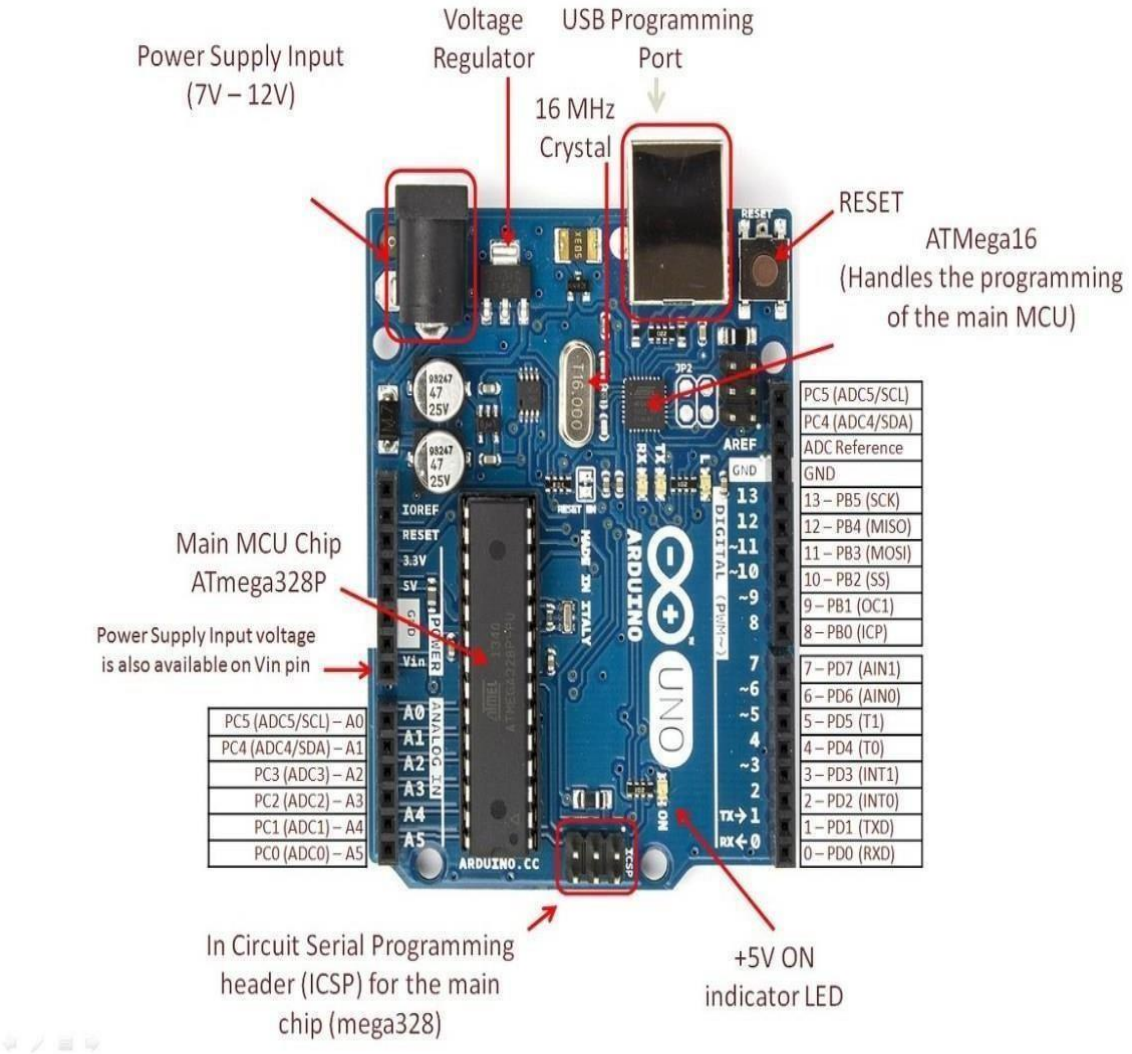



**Figure 9 Arduino Uno Microcontroller**

### GENERAL PIN FUNCTIONS

1. LED- Arduino Uno contains an onboard built-in LED that is connected to digital pin 13. When this pin is HIGH, the LED glows.
2. IN- When powering the Arduino using an external power supply, this pin has to be used.
3. 5V- This pin supplies the board a regulated voltage of 5V via the voltage regulator. Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.
4. GND- Arduino Uno consists of 3 ground pins.

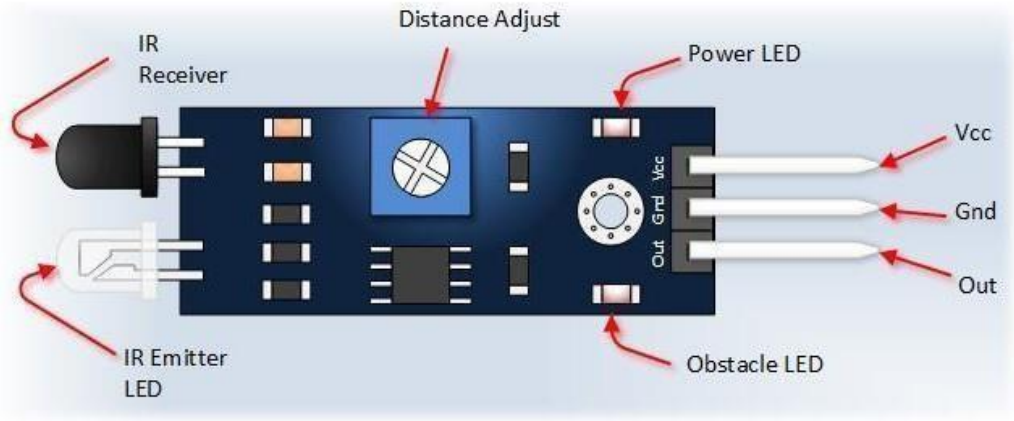



**. Figure 10. Arduino Uno Microcontroller PIN Diagram**

Communication -The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pin 0 (RX) and 1 (TX). ATmega16U2 on the board channels this serial communication over USB and appears as virtual com port to software on the computer. The advantages of Arduino over 8051 or any micro-controller in the 8051 family is countless. Arduino contains inbuilt ADC and DAC which is not the case with 8051. Programming Arduino is simpler because it can be programmed using an IDE that supports C programming, on the other hand, 8051 has to be programmed using assembly language programming

## IR SENSOR

IR sensor is one of the most commonly used sensors in the field of electronics, it has a large number of applications at the domestic as well as at the industrial level. IR module is a sensor module that consists of both IR transmitter and a receiver. Operating voltage of this module is 5 volts and the obstacle detection range is 5 cm that can be increased by 15 cms. An IR sensor can detect the heat of an object as well any motion in the surrounding. The functioning of an IR module is pretty straightforward. As the module contains both transmitter and receiver. When powered, IR transmitter starts to transmit continuous IR waves, if an obstacle is placed in the path of the waves, they get reflected back from the obstacle and are received by the receiver.



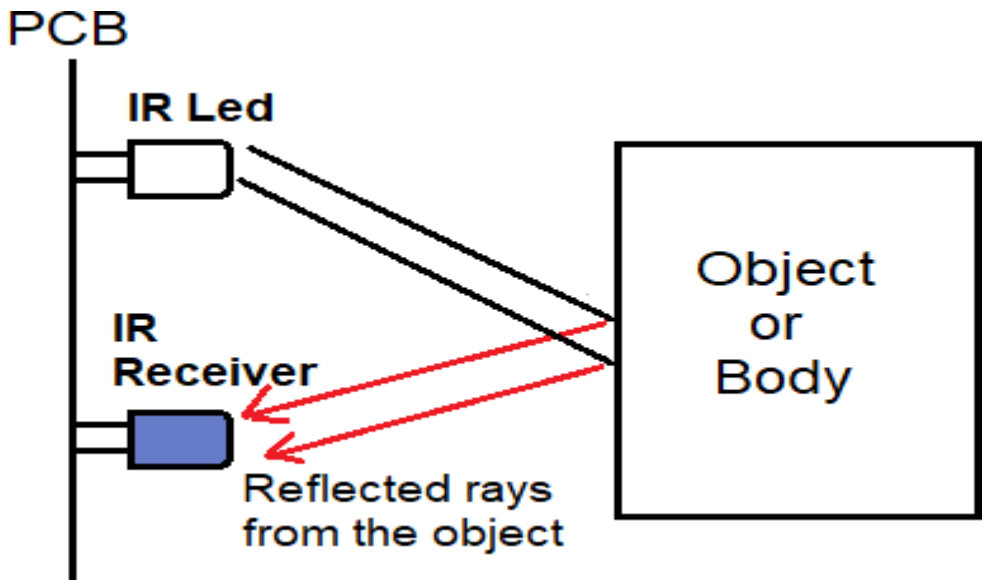




**Figure11. IR Sensor module description**

**TECHNICAL SPECIFICATIONS**

1. Operating Voltage: 5V
2. Minimum Distance: 2-5 CMS
3. Maximum Distance: 10-15 CMS

**CIRCUIT DESCRIPTION**

The circuit of an infrared sensor contains the following components-

1. LM358 IC two IR transmitter and receiver pair.
2. Resistors in the kilo ohms range
3. Variable resistors
4. Light emitting diode

When the IR receiver does not receive a signal, the potential at the inverting input goes higher than that non-inverting input of the comparator IC (LM339). Thus, the output of the comparator goes low, but the LED does not glow. When the IR receiver module receives signal to the potential at the inverting input goes low. Thus, the output of the comparator (LM 339) goes high and the LED starts glowing. Resistor R1 (100), R2 (10k) and R3 (330) are used to ensure that minimum 10 mA current passes through the IR LED Devices like Photodiode and normal LEDs respectively. Resistor VR2 is used to adjust the output terminals. Resistor VR1is used to set the sensitivity of the circuit Diagram.

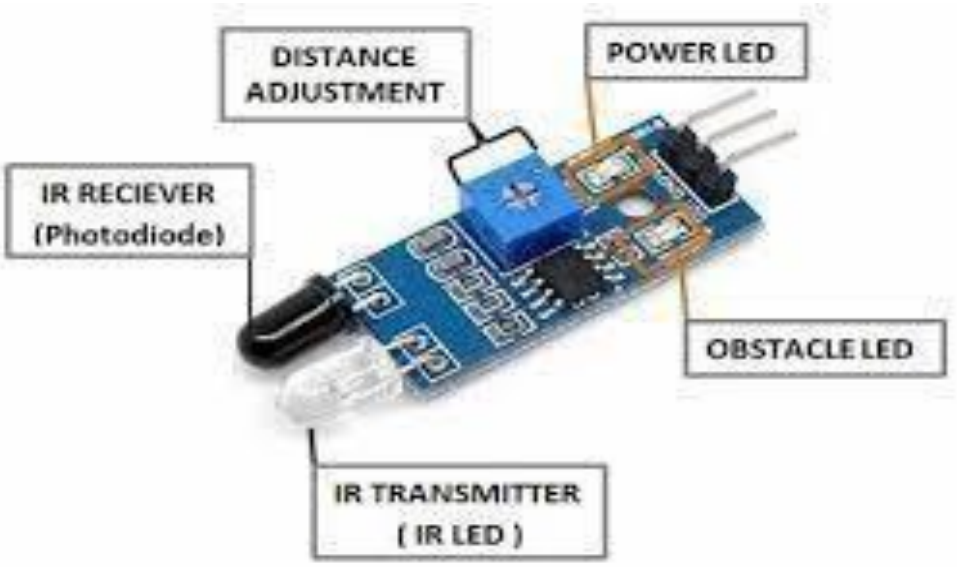



**Figure 12. IR Sensor circuit description**

## PROXIMITY SENSOR

An Inductive Proximity Sensor is a non-contact electronic proximity sensor used for the detection of metals. Sensing range of this sensor completely depends upon the metal being detected. Their working principle is based on a coil and an oscillator that generates an electromagnetic field in the surrounding of the sensing range. Presence of any metallic substance in the sensing range causes dampening of oscillation amplitude. Rise and fall of amplitudes is detected by a threshold circuit that causes a corresponding change in the output of the sensor. If a metal contains some percentage of ferrous, the sensing range is longer, while non-ferrous metals like copper reduce the sensing range by 60 percent. There are two possible outputs of this sensor, hence it is also called inductive proximity switch. Common applications of inductive sensors include metal detectors, traffic lights, etc and a plethora of industrial automated processes.

**Figure 13. Proximitysensor for metal detection**

.

**TECHNICAL SPECIFICATIONS**

1. Operating Voltage: 5V
2. Sensing Range (In case of ferrous waste): 5-3 CMS
3. Sensing Range (Absence of ferrous waste): 1-1.5 CMS

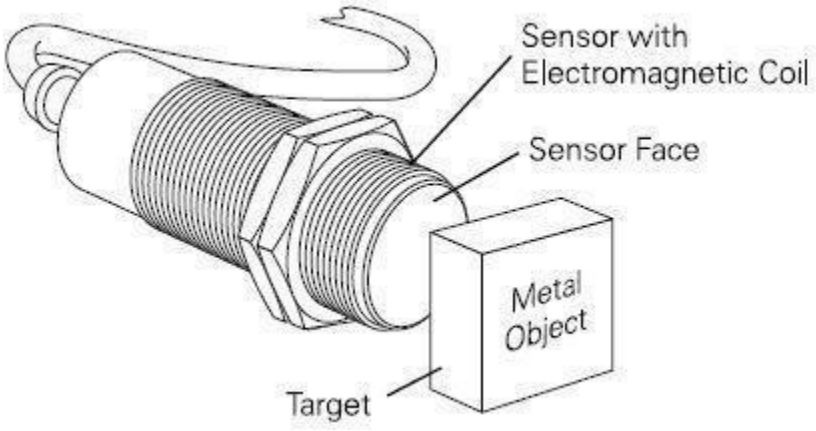



**Figure14. Proximity sensor technical description**

**INDUCTIVE PROXIMITY SENSOR RANGE**

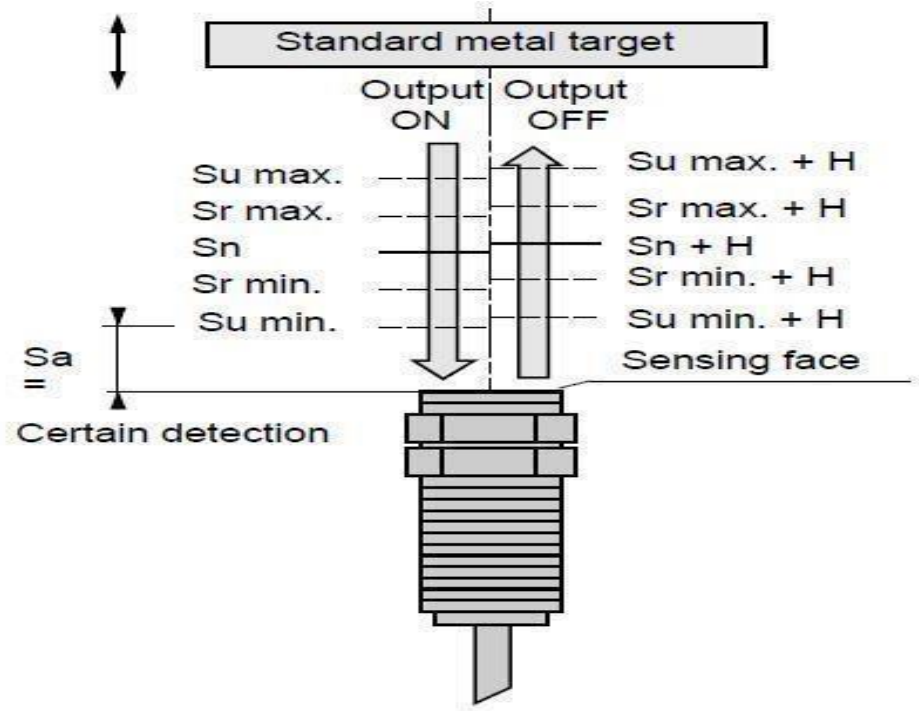



**Figure 15. Inductive Proximity Sensor Range**

1. The capacitive proximity sensors, inductive proximity sensors have a narrower sensing range.
2. However, they can detect objects within a range of 1mm to 60mm. Special purpose sensors can also be designed to have an increased sensing distance.

3. In this diagram, we can identify some of the parameters that are used to define the characteristics of the sensor. **Sn** is the nominal sensing distance. This is the distance that the sensor is designed to operate. This range does not take any variations into account.

4. **Sr** is the real sensing distance. This distance is defined at the rated voltage and the rated ambient temperature. **Su** is the usable sensing distance. Su defines the region where it is between 90% and 110% of the real sensing distance.

5. The most important parameter is **Sa**, the assured operating distance. This is between 0% and 81% of the nominal sensing distance, and the sensor is guaranteed to detect any detectable object within this region.

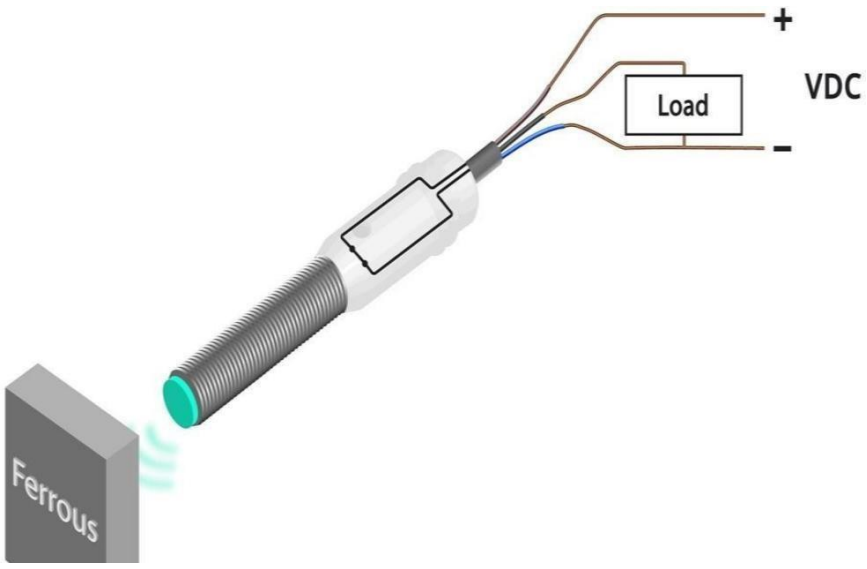



**Figure 16. Inductive Proximity Sensor of Circuit diagram**

## RAIN SENSOR MODULE

The rain sensor module is an easy tool for rain detection. It can be used as a switch when raindrop falls through the raining board and also for measuring rainfall intensity. The module features, a rain board and the control board that is separate for more convenience, power indicator LED and an adjustable sensitivity though a potentiometer. The analog output is used in detection of drops in the amount of rainfall. Connected to 5V power supply, the LED will turn on when induction board has no rain drop, and DO output is high. When dropping a little amount water, DO output is low, the switch indicator will turn on. Brush off the water droplets, and when restored to the initial state, outputs high level.


**Figure 17. Rain Sensor Module**

### TECHNICAL SPECIFICATION

1. Adopts high quality RF-04 double sided material.
2. 5cm x 4cm nickel plate
3. Anti-oxidation, anti-conductivity, with long use time
4. Comparator output – Clean output waveform is good, with driving ability over 15mA
5. Potentiometer-adjustable sensitivity
6. Working voltage: 5V
7. Uses a wide voltage range LM393 comparator
8. Output format: Digital binary and Analog Output AO
9. Bolt holes for easy installation
10. Small PCB size: 3.2cm x 1.4cm

1. The Raindrops Detection sensor module is used for rain detection. It is also for measuring rainfall intensity. Rain sensor can be used for all kinds of weather monitoring and translated into output signals and AO.
2. Raindrops Detection Sensor Module Rain Weather Module for Arduino, etc. Rain sensor can be used to monitor a variety of weather conditions and turned into several fixed output signal and Analog output.
3. It includes a printed circuit board (control board) that "collects" the raindrops. As raindrops are collected on the circuit board, they create paths of parallel resistance that are measured via the op-amp.
4. The lower the resistance (or the more water), the lower the voltage output. Conversely, the less water, the greater the output voltage on the analog pin. A completely dry board, for example, will cause the module to output 5V.
5. The module includes a rain board and a control board that is separate for more convenience. It has a power indicator LED and an adjustable sensitivity through a potentiometer. The module is based on the LM393 op-amp

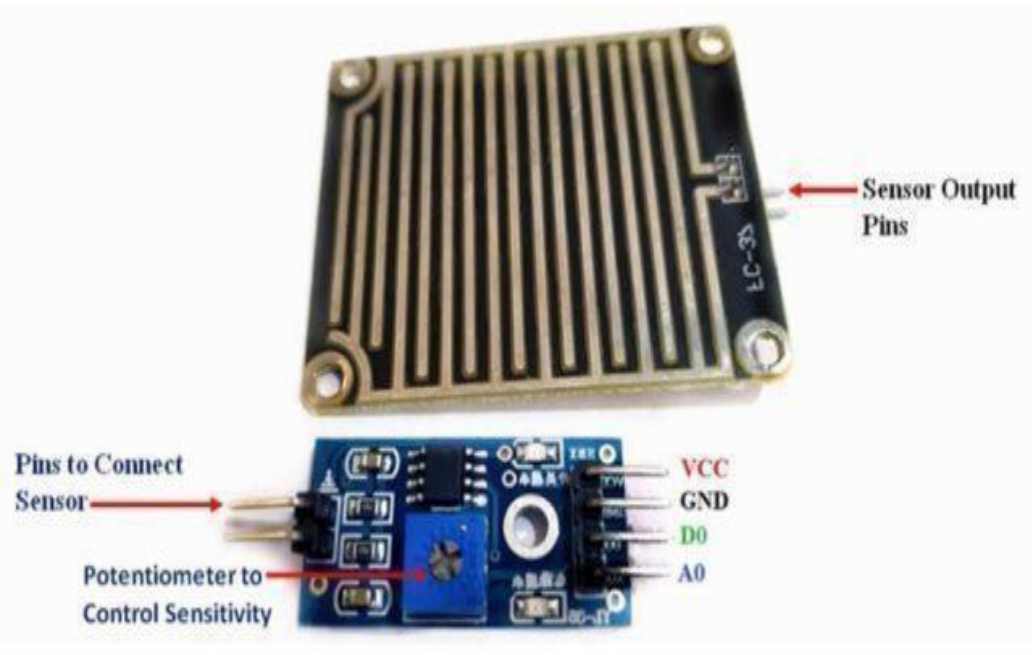



**Figure 18. Rain Sensor pin description**

## STEPPER MOTOR

A stepper motor controller can be used to activate the drive transistors in the right order, and this ease of operation makes unipolar motors popular with hobbyists; they are probably the cheapest way to get precise angular movements. For the experimenter, the windings can be identified by touching the terminal wires together in PM motors. If the terminals of a coil are connected, the shaft becomes harder to turn. One way to distinguish the center tap (common wire) from a coil-end wire is by measuring the resistance. Resistance between common wire and coil-end wire is always half of the resistance between coil-end wires. This is because there is twice the length of coil between the ends and only half from center (common wire) to the end. A quick way to determine if the stepper motor is working is to short circuit every two pairs and try turning the shaft. Whenever a higher-than-normal resistance is felt, it indicates that the circuit to the particular winding is closed and that the phase is working.

**Figure 19. DC 5V Stepper motor 28BYJ-48**

Stepper motors, due to their unique design, can be controlled to a high degree of accuracy without any feedback mechanisms. The shaft of a stepper, mounted with a series of magnets, is controlled by a series of electromagnetic coils that are charged positively and negatively in a specific sequence, precisely moving it forward or backward in small steps. There are two types of steppers, Unipolar and Bipolars, and it is very important to know which type you are working with. For each of the motors, there is a different circuit. The example code will control both kinds of motors. See the unipolar and bipolar motor schematics for information on how to wire up your motor. The stepper is controlled by with digital pins 8, 9, 10, and 11 for either unipolar or bipolar motors.

## STEPPER DRIVER CIRCUIT

Stepper motor performance is strongly dependent on the driver circuit. Torque curves may be extended to greater speeds if the stator poles can be reversed more quickly, the limiting factor being a combination of the winding inductance. To overcome the inductance and switch the windings quickly, one must increase the drive voltage. This leads further to the necessity of limiting the current that these high voltages may otherwise induce. An additional limitation, often comparable to the effects of inductance, is the back-EMF of the motor. As the motor's rotor turns, a sinusoidal voltage is generated proportional to the speed (step rate). This AC voltage is subtracted from the voltage waveform available to induce a change in the current.

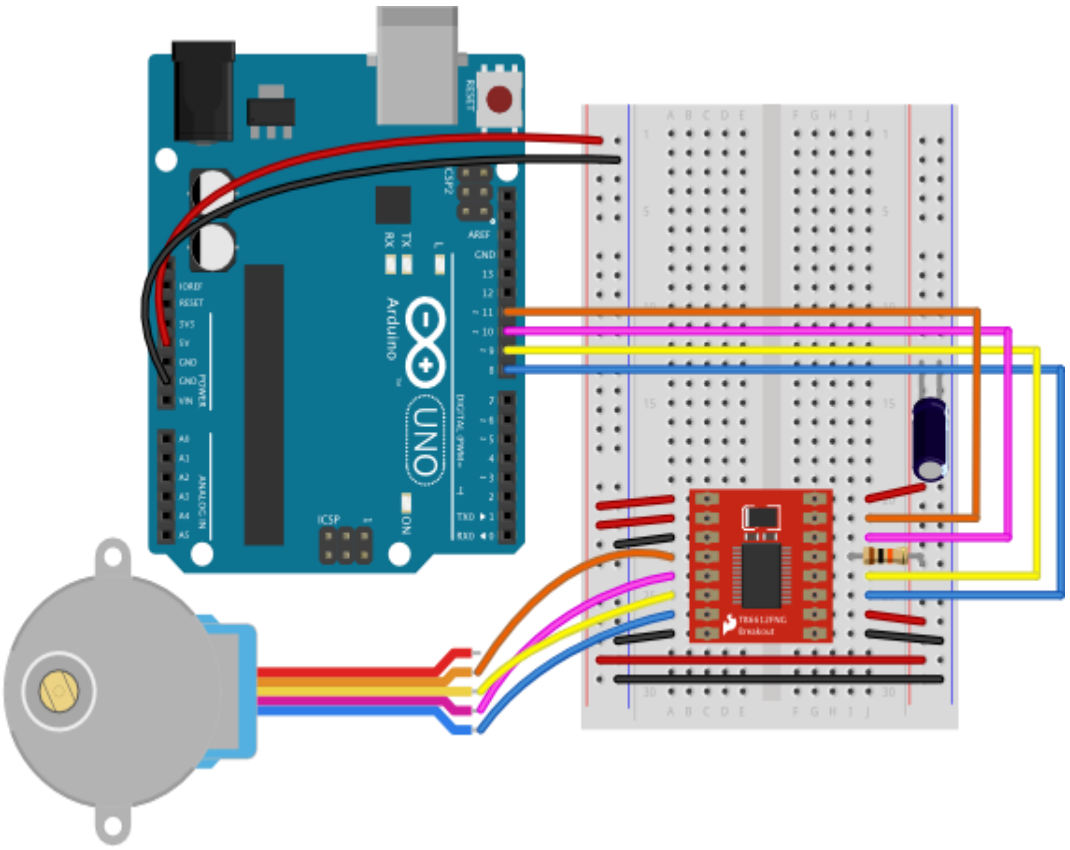



**Figure 20. Stepper motor connects with stepper driver of simulation**

## STEPPER MOTOR CONTROL

The motor coils need to be energized, in a specific sequence, to generate the magnetic field with which the rotor is going to align. Several devices are used to supply the necessary voltage to the coils, and thus allow the motor to function properly. Starting from the devices that are closer to the motor.

- A transistor bridge is the device physically controlling the electrical connection of the motor coils. Transistors can be seen as electrically controlled interrupters, which, when closed allow the connection of a coil to the electrical supply and thus the flow of current in the coil. One transistor bridge is needed for each motor phase.
- A pre-driver is a device that controls the activation of the transistors, providing the required voltage and current, it is in turn controlled by an MCU.
- An MCU is a microcontroller unit, which is usually programmed by the motor user and generates specific signals for the pre-driver to obtain the desired motor behavior.

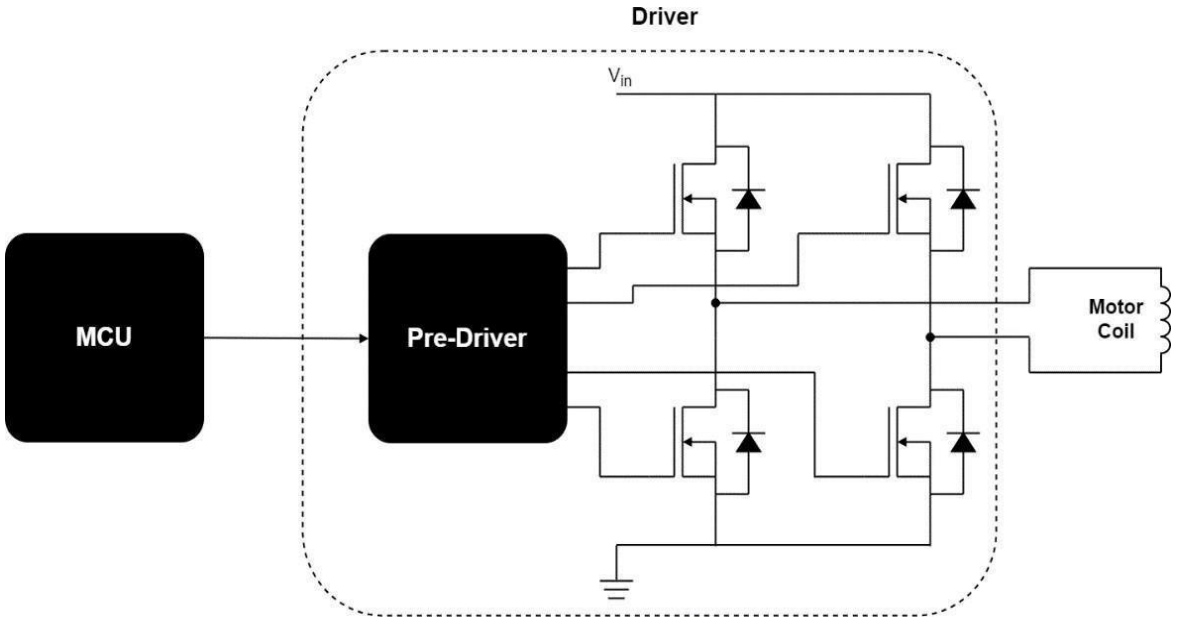



**Figure 21. Stepper motor control of Node MCU**

## SERVO MOTOR

A servo motor is a special kind of electric motor designed to enable precise and accurate movement. It is commonly used in applications such as robots or machines. A servo motor is like a smart motor because it can control its position, speed, and power. This motor works with a sensor that tells it where it is, and a controller makes sure it moves the way we want it to. People use these motors a lot in big machines, especially in places like factories where we need things to move very accurately and smoothly. This article discusses servo motors, and their importance in various fields such as robotics and manufacturing, explaining how they work, how they're built, and where they are commonly used.

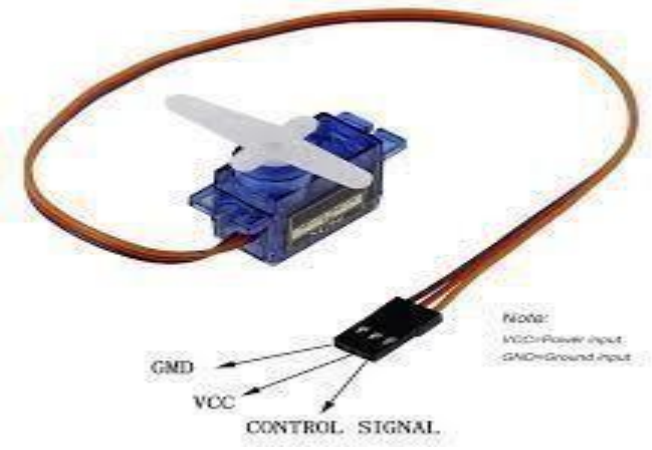



**Figure 22. SG-90 Micro Servomotor of pins**

Servo motors are like powerful little engines with a high torque-to-inertia ratio, meaning they can generate a lot of twisting force relative to their size and weight. This makes them perfect for tasks that need quick acceleration, deceleration, and precise movements. They come in various sizes and power levels to suit different jobs and can be powered by either AC or DC voltage. What's good is that we can control their speed and force using special signals called pulse width modulation (PWM). Some servo motors have extra features like built-in controllers and communication interfaces, which makes them adaptable and easy to integrate into complex systems.

## 6.2 PROJECT OVERVIEW

**IMPLEMENTATION OF AUTOMATIC WASTE SEGREGATOR SYSTEM**

**STEP 1: GATHER COMPONENTS**

The first step is to gather all the necessary hardware components required for building the automated waste segregation system. These include an Arduino Uno as the main controller, various sensors for detecting different types of waste, a stepper motor for sorting, and a buzzer for user feedback. Ensuring the correct components are used is critical for the successful functioning of the system. Additionally, a motor driver is required to control the stepper motor efficiently, and proper wiring and power management should be planned to avoid any electrical issues. Double-checking connections before proceeding to the next step can prevent potential failures in later stages.

| |
|---|
| Arduino Uno |
| IR Sensor |
| Inductive Proximity Sensor |
| Raindrop Sensor Module |
| Cheap Stepper Motor |
| Stepper Motor Driver |
| Motor Driver Module (L298N/L293D) |
| 1-Watt LED |
| Buzzer (Optional) |
| Power Supply (9V/12V Adapter or Battery) |
| Jumper Wires |
| Waste Sorting Mechanism (Bins & Frame) |

**STEP 2: CONNECT THE SENSORS**

In this step, all the sensors are properly connected to the Arduino. The Metal Detector Sensor is wired to digital pin 2 to detect metallic waste. The IR Sensor is attached to digital pin 3 for detecting plastic, while the Moisture Sensor is linked to the analog pin A0 to determine if waste is biodegradable. Proper sensor calibration is necessary to improve detection accuracy. Ensuring the sensors are correctly positioned enhances detection efficiency. Additionally, using shielding techniques can prevent interference from external signals, improving overall system reliability. Regular maintenance and periodic recalibration of sensors help maintain long-term accuracy and performance.

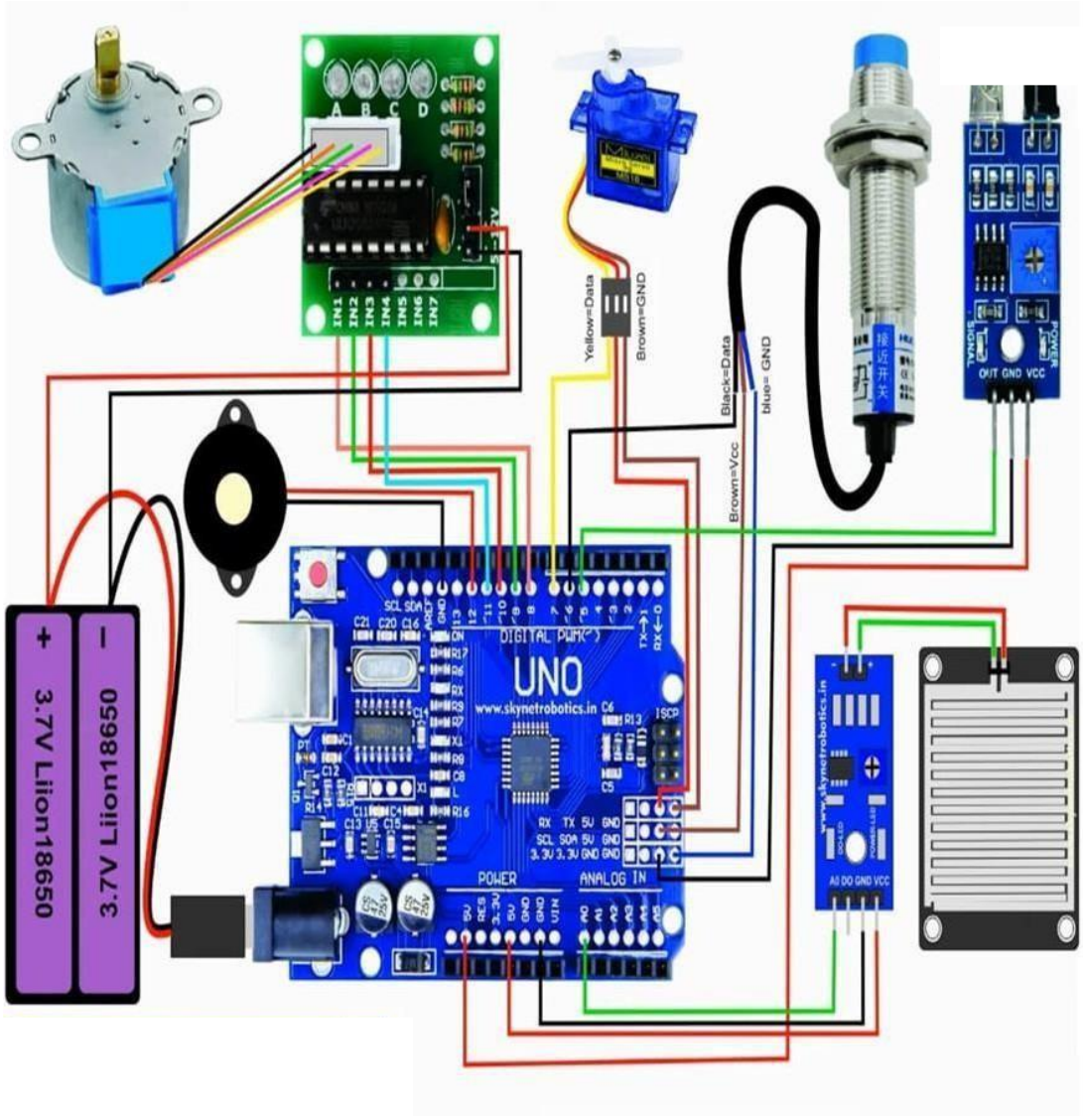



**Figure23. Configurationof Connectinga sensor to Node**

## STEP 3: CONNECT THE STEPPER MOTOR

The stepper motor plays a crucial role in sorting waste. It is connected to digital pins on the Arduino via a motor driver module. Based on the sensor readings, the Arduino will send signals to the stepper motor, instructing it to move to a specific angle that directs the waste to the correct bin. Testing the motor's movement is essential to ensure it responds accurately to commands. To enhance efficiency, the motor speed can be adjusted according to the weight of the waste, reducing sorting time. Additionally, adding a feedback mechanism using limit switches or encoders can help track the motor's position, ensuring precise movements and minimizing errors. Proper lubrication and maintenance of the motor gears will also improve its durability and operational reliability.

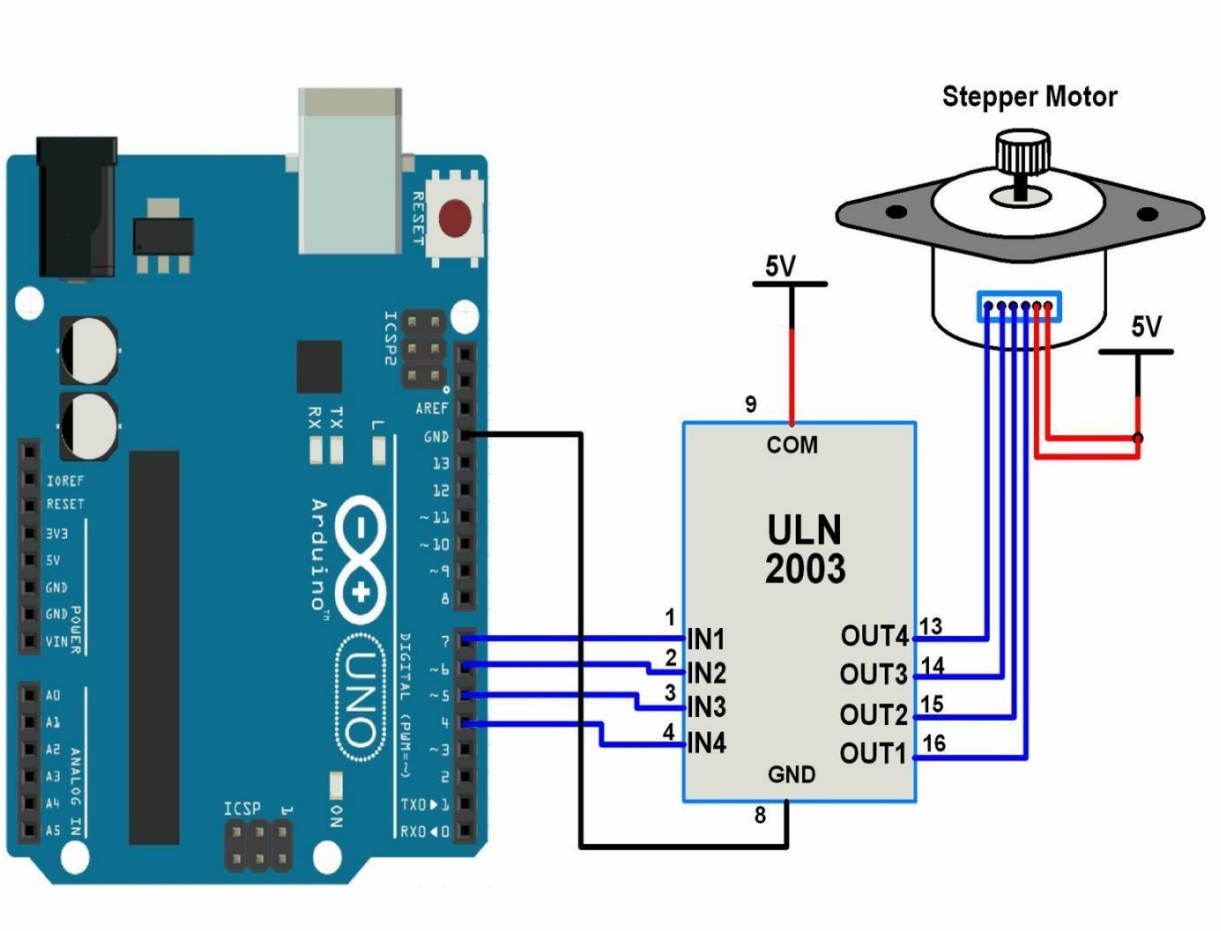



**Figure 24. Connecta Servo Motor MCUand Steppermotor to thestepper driver**

## STEP 4: ADD USER FEEDBACK COMPONENTS

To make the system interactive, a buzzer is connected to digital pin 4 to produce an alert sound whenever waste is detected. This step ensures that users are aware of the waste segregation process in real-time. Additionally, an LED indicator can be added to provide visual feedback, signalling different colors based on waste type. This enhances user experience by offering both auditory and visual notifications.

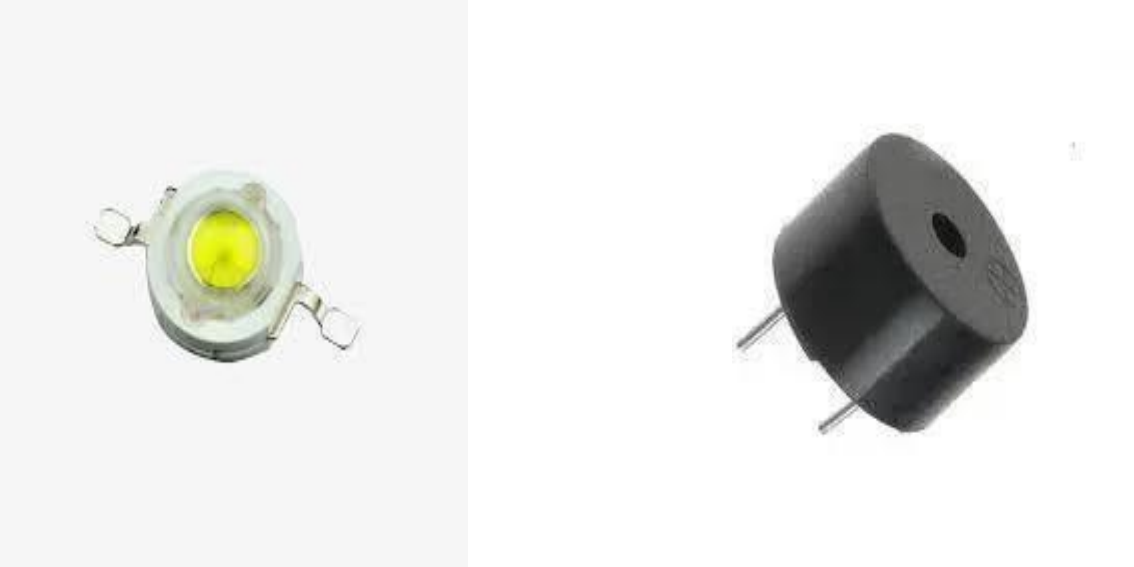


**Figure 25. User feedback of 1 watt LED and Mini Buzzer**

**1W LED Uses**

- Indicates system status (e.g., sorting in progress, standby mode).
- Provides feedback when waste is successfully categorized.
- Alerts users in case of errors or system malfunctions.

**Buzzer Uses**

- Generates an audio alert when incorrect waste is placed in the system.
- Notifies users when the bin is full or requires maintenance.
- Provides different tones to indicate successful sorting or faults**.**

## STEP 5: UPLOAD THE ARDUINO CODE

The Arduino code is written and uploaded to the microcontroller using the Arduino IDE. The code enables the system to read sensor inputs, determine the type of waste, and activate the stepper motor accordingly. Debugging and testing the code at this stage is important to resolve any errors before full deployment. The logic is refined by adjusting sensor threshold values and motor rotation angles for accurate waste placement. Multiple test cases are conducted with various waste materials to ensure consistent performance. Additionally, logging data from the serial monitor helps identify potential issues and improve system efficiency over time.

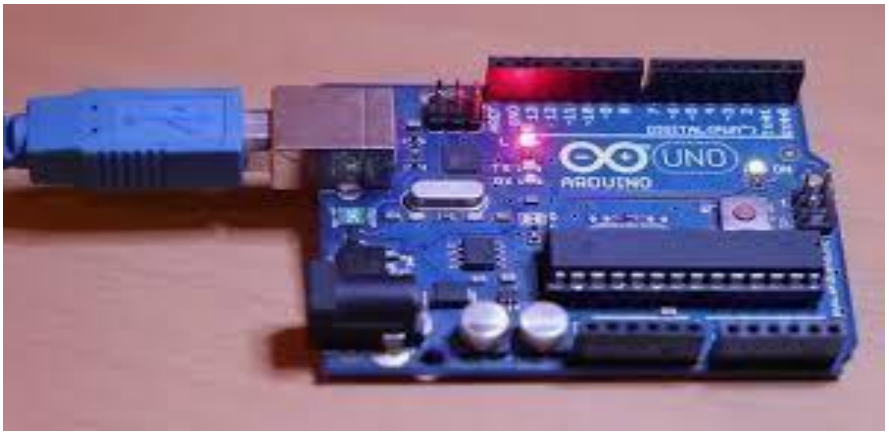



**Figure26. Microcontroller ATmega328pto connect forcode upload**

- **Arduino IDE:** Make sure you have the Arduino IDE installed and open.
- **Arduino Board:** Connect your Arduino board to your computer using a USB cable.
- **Board Package:** Ensure the necessary board package is installed in the IDE for your specific board.
- **Sketch:** Have a sketch (your Arduino code) ready in the Arduino IDE

## CONNECT ARDUINO TO COMPUTER

- Use a USB cable to connect your **Arduino Uno** (or compatible board) to your computer.
- Open the Arduino IDE and navigate to **Tools > Port** to select the correct COM port for your board.

**Figure 27. Arduino Uno USB (A to B) Connector**

## SELECT THE CORRECT BOARD

- In the Arduino IDE, go to **Tools > Board** and select **Arduino Uno** (or your specific board model).

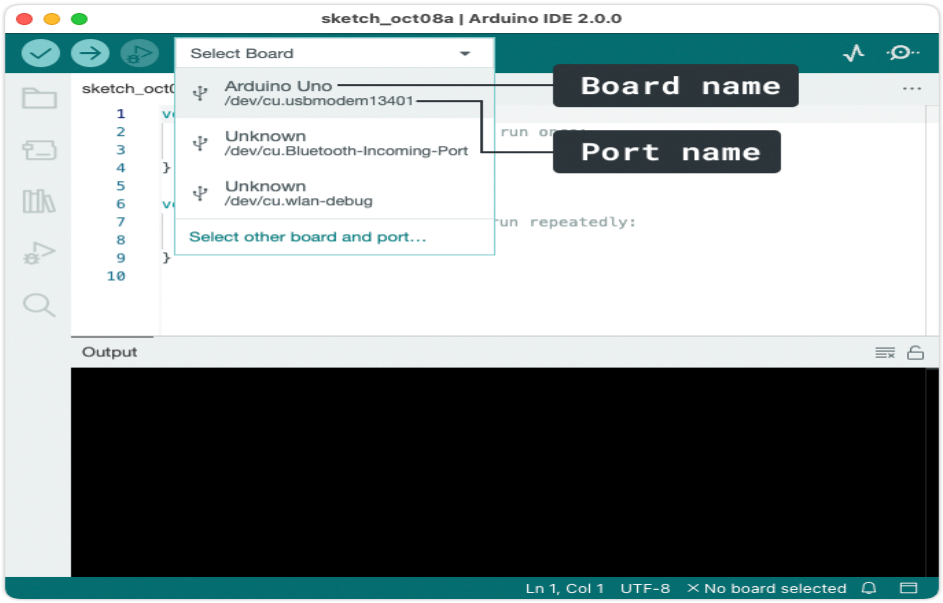



**Figure 28. Opena Arduino IDE to Select right Boardand port**

## VERIFY THE CODE

- Click the **Checkmark ( ✓ ) icon** at the top-left of the IDE to compile the code.
- Ensure there are no syntax errors. If there are errors, debug them before proceeding.

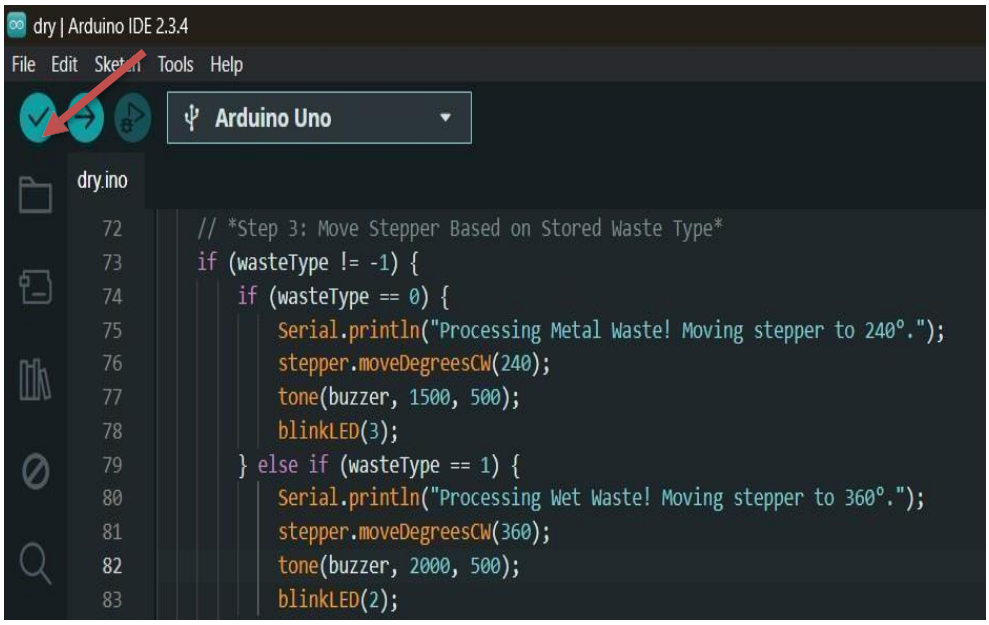



**Figure 29. Arduino IDE to verify the checkmark**

## UPLOAD THE CODE

- Click the **Upload (→) button** in the Arduino IDE to transfer the code to the board.
- Wait for the upload to complete; you should see a "Done Uploading" message in the IDE.

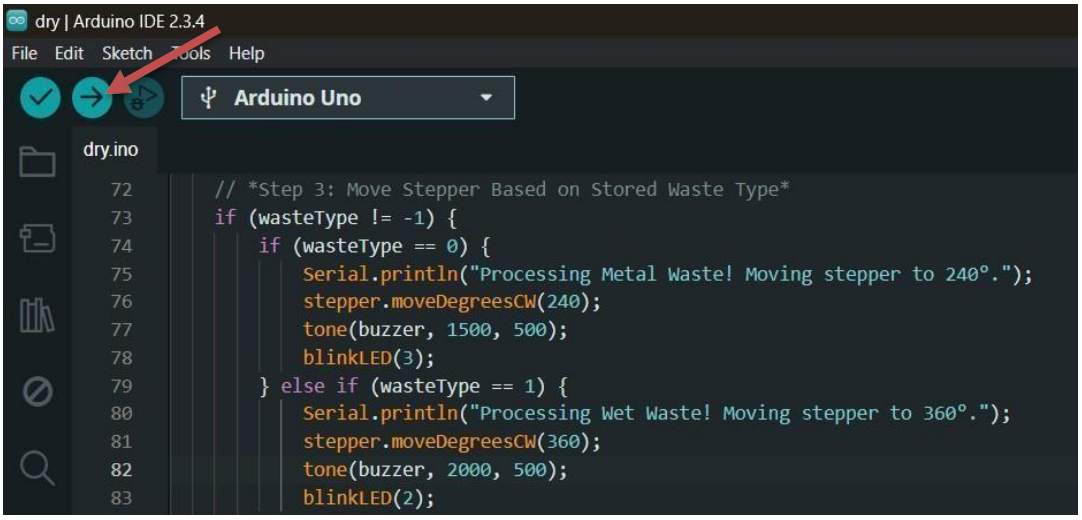



**Figure 30. Arduino IDE Right Arrow click it and uploadcode**

**MONITOR SERIAL OUTPUT**

- Open the **Serial Monitor** (Tools > Serial Monito r) to view real-time output from the Arduino.
- This is useful for debugging and checking sensor values.


**Figure 31. Output Screen of Arduino IDE Serial Monitor**

**TEST THE HARDWARE**

- Ensure the sensors detect waste correctly.
- Verify that the stepper motor moves waste into the right bin.
- Check if the buzzer and LED indicators function as expected.

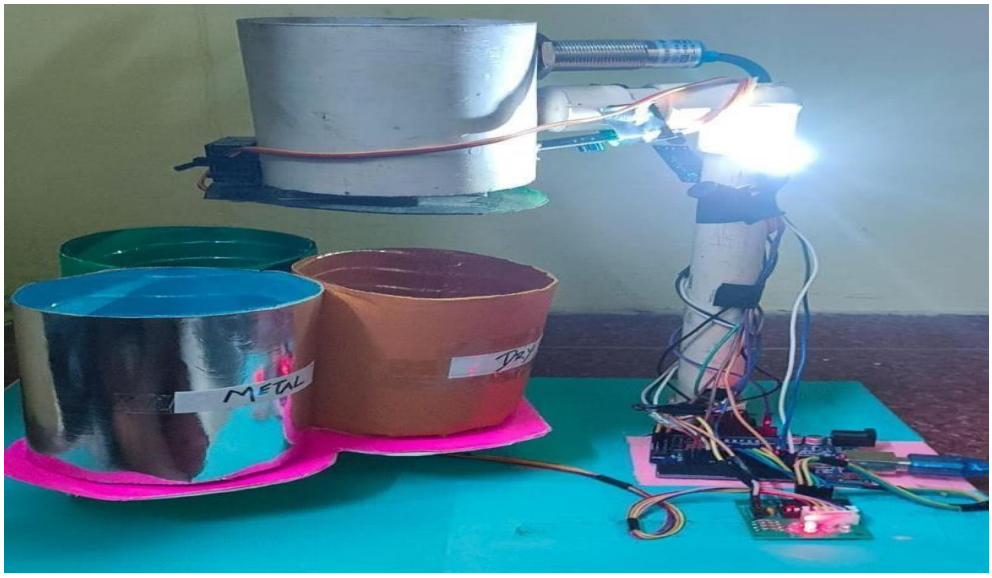



**Figure 32. Check the hardware components work properly**

## STEP 6: TEST THE SYSTEM

Once the hardware is assembled and the code is uploaded, the system needs to be tested. Different waste materials are manually placed near the sensors to observe if they detect them correctly. The stepper motor's movement is monitored to ensure waste is placed in the right bins. The buzzer is checked to confirm it provides accurate user feedback. Additionally, system responses are logged through the serial monitor for further analysis. If any issues are encountered, debugging is done to fine-tune the system, including adjusting sensor sensitivity, recalibrating motor movements, and refining the waste detection algorithm for better accuracy.

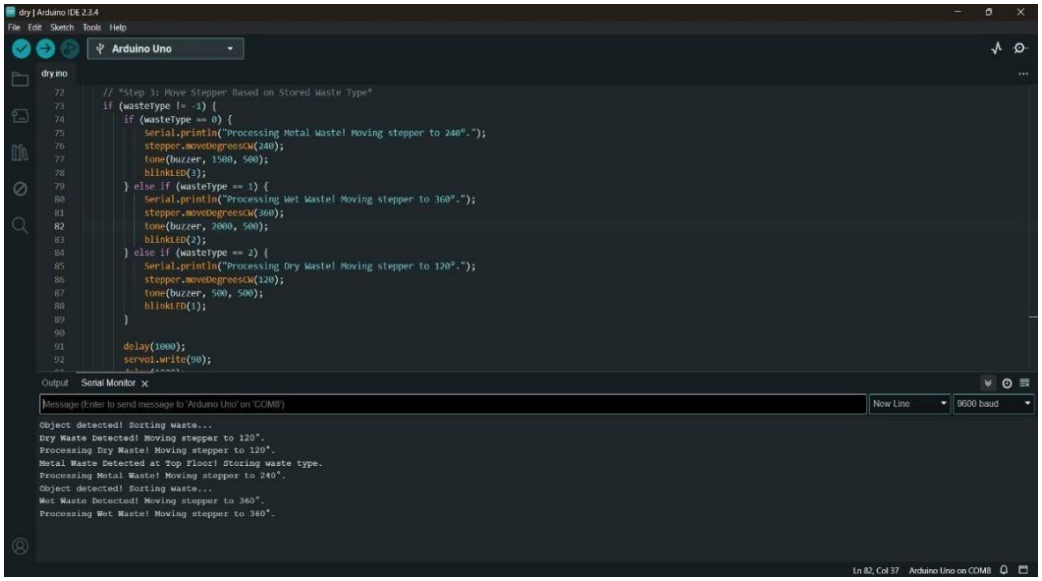



**Figure 33. Final Output Screen of Arduino IDE**

## 6.3 TESTING AND DEBUGGING

### TESTING PROCESS

Testing and debugging are essential steps in ensuring the proper functionality of an automatic waste segregation system built using Arduino Uno. This section will guide you through various testing methods, identify common issues, and provide troubleshooting strategies to resolve these problems effectively.

### COMPONENT FUNCTIONAL TESTS

- **IR Sensor**

  Test the IR sensor by placing an object in front of it. Check if the Arduino identifies this presence through serial output. Use a multimeter to verify voltage levels if no response occurs.

- **Inductive Proximity Sensor**

  Verify metal detection by waving a metal object near the sensor. Ensure the sensor outputs the expected signal.

- **Stepper Motor**

  Use a simple program to run the motor without any sorting conditions. This isolates issues within the motor's connection or code.

### INTEGRATION TESTS

- Combine all components based on your circuit setup. Check for serial feedback for each sensor response to ensure they work cooperatively to trigger the sorting process.
- Monitor the communication between sensors and the Arduino using the Serial Monitor within the Arduino IDE to catch any discrepancies in input readings.
- Observe serial feedback for sensor responses to ensure seamless interaction.
- Confirm that each component properly triggers the sorting mechanism.

### STRESS TESTING

- Simulate high-frequency waste detection by placing multiple objects in front of the sensors to determine the system's capacity and response time under workload.
- Test the system’s capacity by running it continuously over an extended period.
- Analyze response time and make necessary optimizations.

## COMMON ISSUES AND THEIR SOLUTIONS

| Issue | Potential Cause | Solution |
|---|---|---|
| No detection from IR Sensor | Incorrect wiring or sensor malfunction | Check connections and test with a different power supply |
| Inductive Proximity Sensor not responding | Interference from nearby devices | Move the sensor away from interference sources |
| Stepper motor does not turn | Inadequate power supply or misconfiguration of motor driver | Ensure the driver is properly linked and sufficient current is supplied |
| Sensors provide erratic signals | Floating or lose ground connections | Establish a common ground connection between all components |
| Incorrect material sorting | Faulty logic in code, such as wrong threshold values | Debug the sorting logic through Serial outputs to verify behavior |

### ADDITIONAL DEBUGGING STEPS

- Check Connection: Often, issues stem from improper wiring. Use a breadboard and verify each connection visually.
- Use or Add Debugging Outputs: Adding more Serial. Print statements in various sections of your code helps to see exactly where things might be going wrong.
- Update Libraries: Ensure all libraries you are using are up to date, as there may have been fixes for bugs in newer versions.
- Testing each component and systematically debugging potential issues, you can enhance the reliability and performance of your automatic waste segregation system.

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# CHAPTER 7

# 7. ARDIUNO SCRIPT

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## 7.1 SCRIPT IMPLEMENTATION

```
#include <Servo.h>
#include <CheapStepper.h>
#define ir 5
#define proxi 3
#define raindrop 4
#define buzzer 12
#define led 13
Servo servo1;
CheapStepper stepper(8, 9, 10, 11);
int wasteType = -1;  // -1: No waste, 0: Metal, 1: Wet, 2: Dry
void setup() {
 Serial.begin(9600);
 pinMode(proxi, INPUT_PULLUP);
 pinMode(ir, INPUT);
 pinMode(raindrop, INPUT);
 pinMode(buzzer, OUTPUT);
 pinMode(led, OUTPUT);
 servo1.attach(7);
 servo1.write(0);
 stepper.setRpm(17);
 delay(1000);
}
void blinkLED(int times) {
 for (int i = 0; i < times; i++) {
 digitalWrite(led, HIGH);
 delay(300);
 digitalWrite(led, LOW);
 delay(300);
          }
      }
```

```
 void loop() {
 int rain = digitalRead(raindrop);
 int object = digitalRead(ir);
 // *Step 1: Detect Metal Waste at Top Floor (Proximity Sensor)*
 if (wasteType == -1) { // Only detect if no waste is stored
 int metal = 0;
 for (int i = 0; i < 5; i++) {
 metal += digitalRead(proxi);
 delay(50);
  }
 metal = (metal >= 3) ? 0 : 1; // If detected at least 3 times, consider metal
if (metal == 0) {
Serial.println("Metal Waste Detected at Top Floor! Storing waste type.");
wasteType = 0; // Store waste as metal
            }
        }
// *Step 2: Detect Object at Bottom Floor (IR Sensor)*
if (object == 0 && wasteType == -1) { // Only check if no metal detected
Serial.println("Object detected! Sorting waste...");
tone(buzzer, 1000, 500);
delay(500);
// *Step 2.1: Check for Wet Waste*
if (rain == 0) {
Serial.println("Wet Waste Detected! Moving stepper to 360°.")
 wasteType = 1; // Store waste as wet
 } else {
 Serial.println("Dry Waste Detected! Moving stepper to 120°.");
 wasteType = 2; // Store waste as dry
            }
        }
 // *Step 3: Move Stepper Based on Stored Waste Type*
if (wasteType != -1) {
if (wasteType == 0) {
Serial.println("Processing Metal Waste! Moving stepper to 240°.");
stepper.moveDegreesCW(240);
```

```
 tone(buzzer, 15A00, 500);
 blinkLED(3);
 } else if (wasteType == 1) {
 Serial.println("Processing Wet Waste! Moving stepper to 360°.");
 stepper.moveDegreesCW(360);
 tone(buzzer, 2000, 500);
blinkLED(2);
} else if (wasteType == 2) {
Serial.println("Processing Dry Waste! Moving stepper to 120°.");
stepper.moveDegreesCW(120);
tone(buzzer, 500, 500);
blinkLED(1);
 }
 delay(1000);
 servo1.write(90);
 delay(1000);
 servo1.write(0);
 stepper.moveDegreesCCW((wasteType == 0) ? 240 : (wasteType == 1) ? 360 : 120);
 noTone(buzzer);
 wasteType = -1; // Reset for the next waste item
        }
    }
```

## 7.2 CODE DESCRIPTION

The Automated Waste Segregation System code is structured to ensure efficient waste detection and sorting through sensor-based decision-making. The Arduino code for the Automated Waste Segregation System is designed to detect and classify dry, wet, and metallic waste using IR, inductive, and raindrop sensors. The system processes sensor data through the Arduino Uno, which then controls a stepper motor via a motor driver module to direct waste into the appropriate bin. The code also provides real-time user feedback using an LED and a buzzer. At the beginning of the program, the sensor pins, LED, buzzer, and stepper motor are initialized in the setup () function. The loop () function continuously reads data from the IR sensor (for dry waste), inductive sensor (for metallic waste), and raindrop sensor (for wet waste). If metallic waste is detected, the Arduino sends a signal to rotate the stepper motor to Bin 1. If wet waste is detected, it moves to Bin 2, and for dry waste, it moves to Bin 3. The stepper motor is responsible for directing waste into the correct bin. The motor driver (L298N or L293D) enables the Arduino to control motor movement, ensuring accurate positioning. After sorting, the system activates the LED and buzzer to notify the user that waste has been processed. Once sensor readings are obtained, the Arduino Uno processes the data and determines the type of waste, sending appropriate commands to the motor driver module to move the stepper motor accordingly. The moveToBin () function moves the stepper motor to different positions based on the detected waste type, ensuring accurate sorting. Once the waste is deposited into the correct bin, the system resets and waits for the next waste input. This system ensures efficient waste management, reduces human effort, and minimizes health risks by automating the segregation process. The code structure is modular, making it easy to expand with additional sensors or integrate IoT for real-time monitoring.

# CHAPTER 8

# 8. CONCLUSION

The Automated Waste Segregation System is a significant step toward efficient and sustainable waste management. By utilizing sensors and Arduino-based automation, the system accurately classifies dry, wet, metallic, and plastic waste, reducing human effort and errors in manual sorting. The integration of IR sensors, inductive proximity sensors, and raindrop sensors ensures precise waste detection, while the stepper motor and motor driver automate the sorting process, directing waste into the correct bins. This approach not only improves recycling efficiency but also helps in reducing landfill waste and environmental pollution. One of the biggest advantages of this system is its cost-effectiveness and scalability. It can be implemented in households, schools, offices, and industries, making waste segregation more accessible and organized. Additionally, the system minimizes health risks for waste workers by reducing direct contact with hazardous waste materials. The LED indicators and buzzer provide real-time feedback, ensuring smooth operation and user interaction. Moving forward, the system has the potential for further enhancement through artificial intelligence (AI) and machine learning (ML). AI-powered image recognition systems can be integrated to identify a wider range of waste types, improving sorting accuracy. IoT-based real-time monitoring can allow remote tracking of waste levels, sending notifications when bins are full and optimizing collection schedules. Furthermore, plastic detection using near-infrared (NIR) sensors or AI algorithms can enable better recycling of plastic waste, contributing to a more sustainable approach. The future of waste management depends on smart, automated, and energy-efficient systems that can adapt to growing waste disposal challenges. The incorporation of solar power, robotic arms for advanced sorting, and smart data analytics can make the next generation of waste segregation fully autonomous. By integrating these technologies, this system has the potential to revolutionize waste disposal practices, ensuring a cleaner environment and a sustainable future for upcoming generations.

## 8.1 FUTURE ENHANCEMENT

- Automated Waste Segregation System will focus on making the system smarter, more efficient, and adaptable to next-generation waste management needs. One major advancement would be the integration of AI and machine learning to enable real-time waste identification and classification.
- Another improvement would be automatic bin full detection, using ultrasonic sensors to alert users when a bin reaches capacity. This would help prevent overfilled waste bins and improve disposal efficiency. Expanding the system to classify additional waste types such as glass, hazardous waste, and organic materials could further enhance its functionality.
- Detecting plastic waste using near- infrared (NIR) sensors or AI-based image recognition would be a significant enhancement, as plastic segregation is crucial for recycling.
- The system could differentiate between biodegradable and non-biodegradable plastics, ensuring proper disposal and promoting sustainable recycling practices. High-resolution cameras and image processing algorithms, the system could recognize a wide range of waste materials, including different types of plastics, glass, and hazardous waste. This would significantly improve recycling efficiency by ensuring proper segregation at the source.
- Sensor fusion technology combining infrared, inductive, and optical sensors could enhance accuracy in detecting plastic waste, organic waste, and recyclables. This would allow waste management authorities to track waste generation patterns, predict waste accumulation rates, and optimize collection schedules using AI-driven insights. Additionally, smart bins with automatic compression could be introduced to reduce waste volume, minimizing landfill waste.
- Further improvements such as robotic arms for precise waste sorting and solar-powered operation could make the system fully autonomous and energy-efficient. By incorporating these advanced technologies, the next-generation waste segregation system would revolutionize waste disposal and recycling practices, contributing to a cleaner and more sustainable environment.

# APPENDIX

## SCREENSHOTS:


**Figure 34. Three small bins for collect a waste**

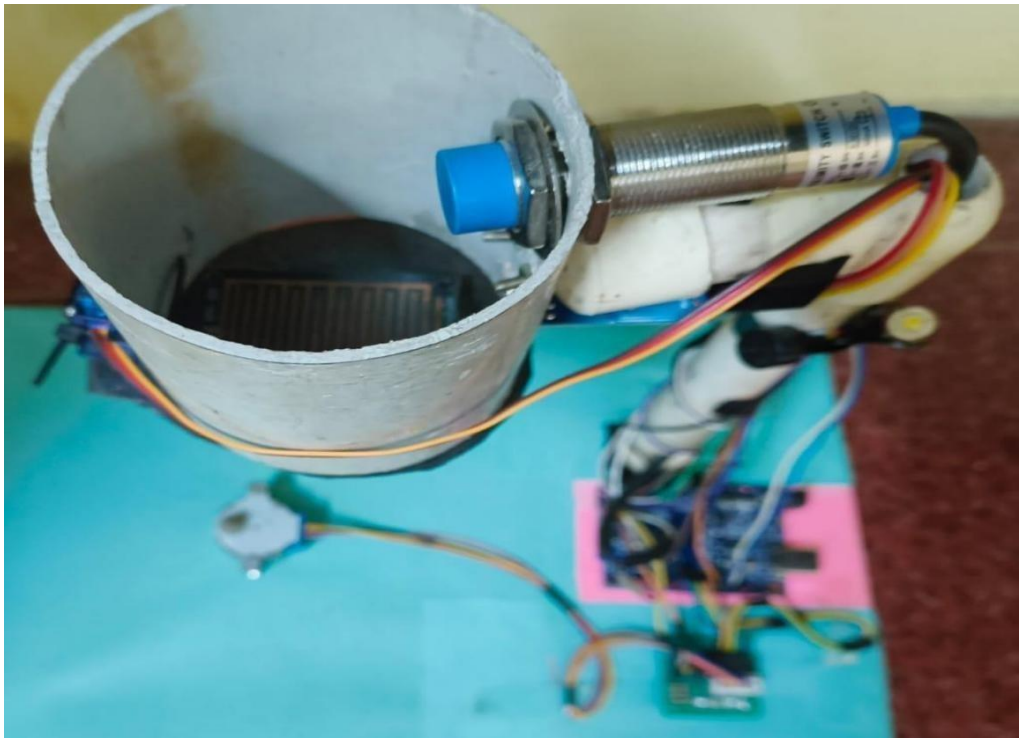

**Figure 35. The waste was detected here to pass the data into stepper driver**

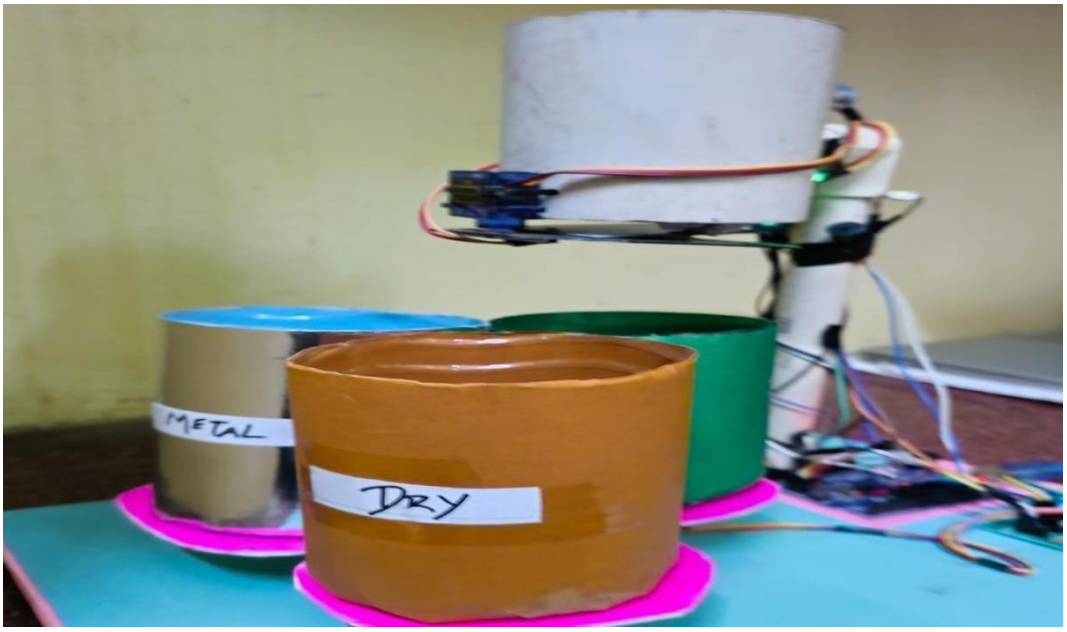


**Figure 36. Idle stage of segregation system**

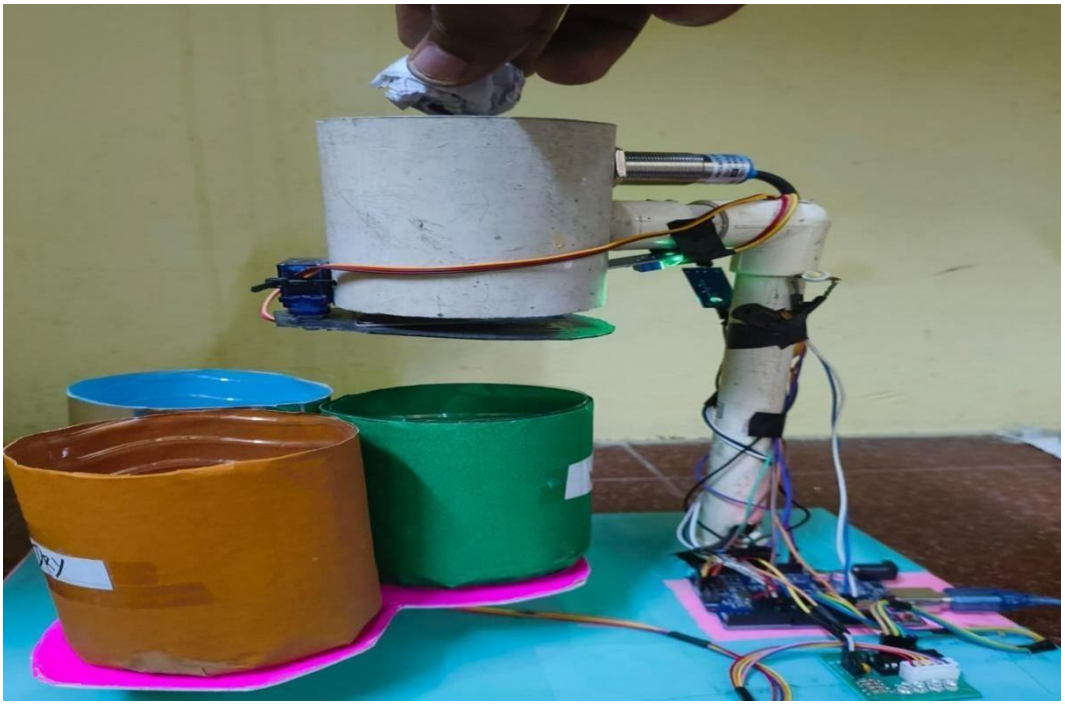

**Figure 37. The dry waste was detected by using ir sensor under bin**

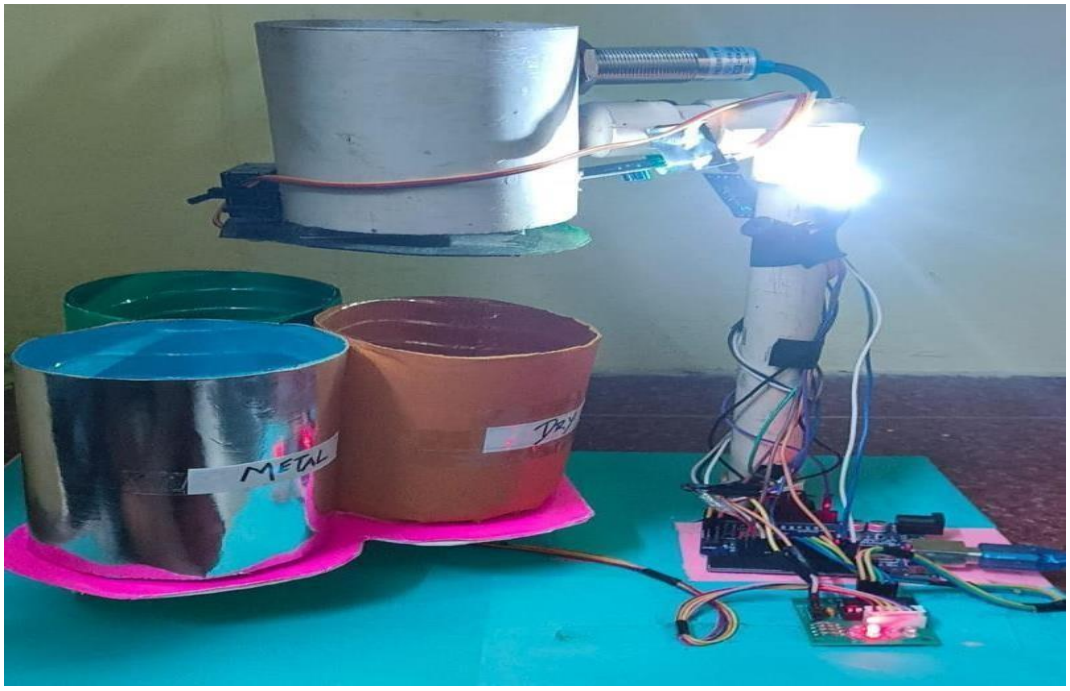


**Figure 38. The bins move into right place to receive a dry waste**

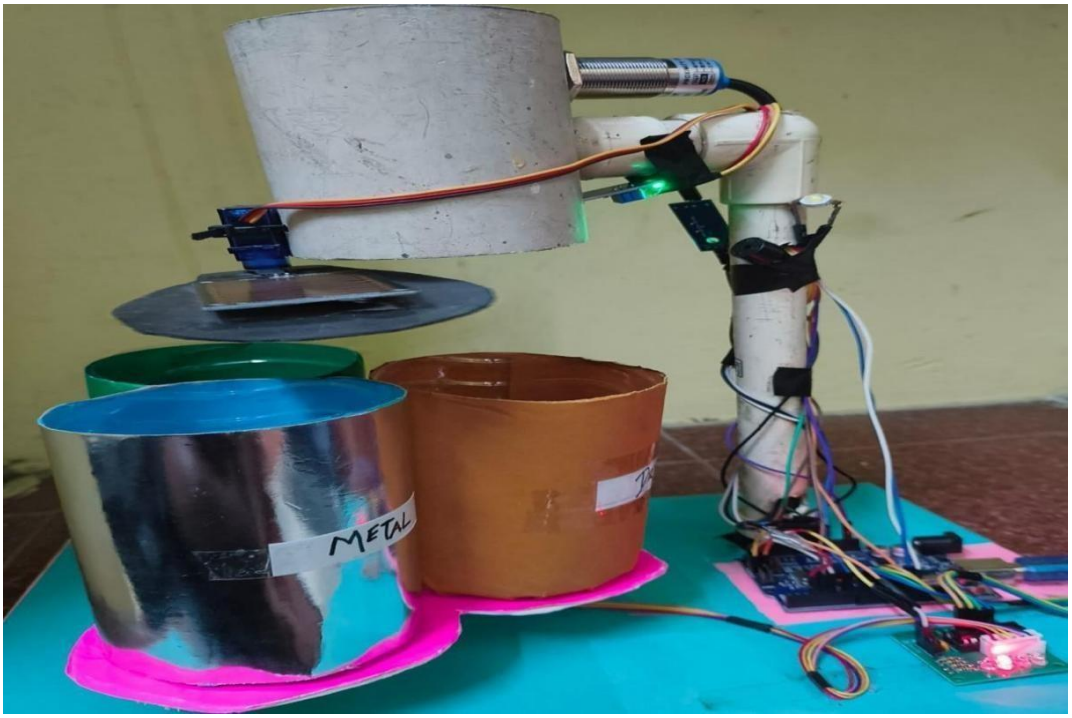


**Figure 39. Once collect the waste it rotates into clockwise direction**


**Figure 40. The metal waste was detected by using proximity sensor**

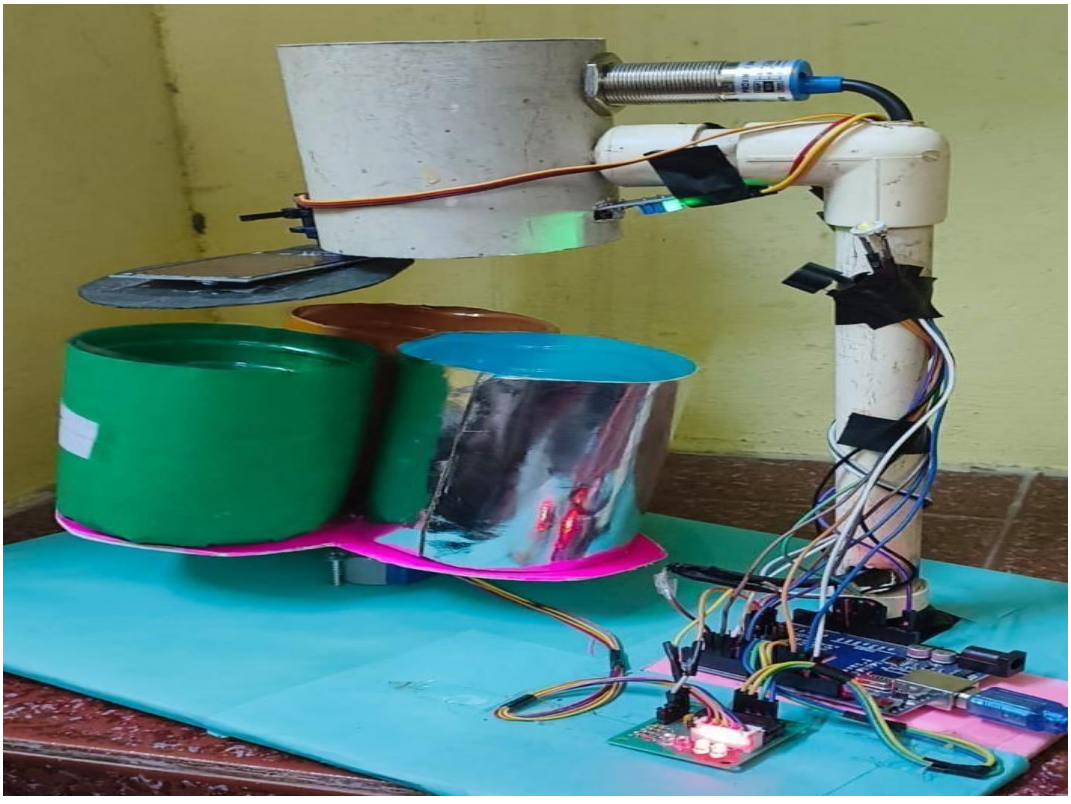

**Figure 41. The bins move into right place to receive a metal waste**

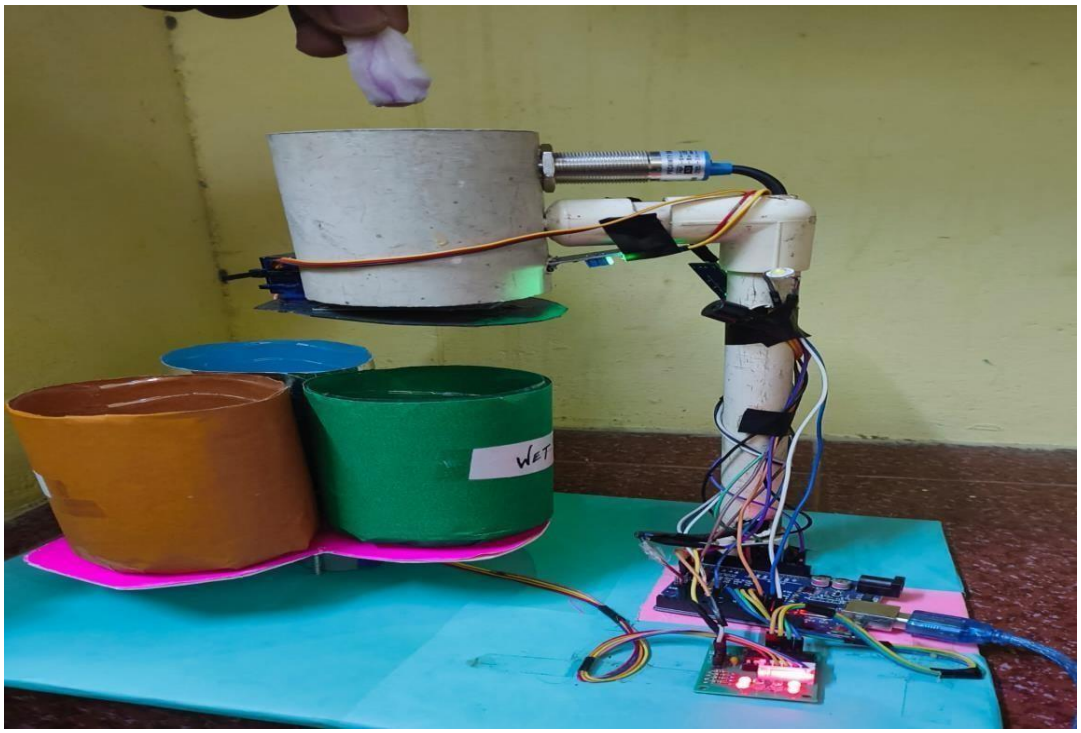


**Figure 42. Put the waste here then the sensor will detect**

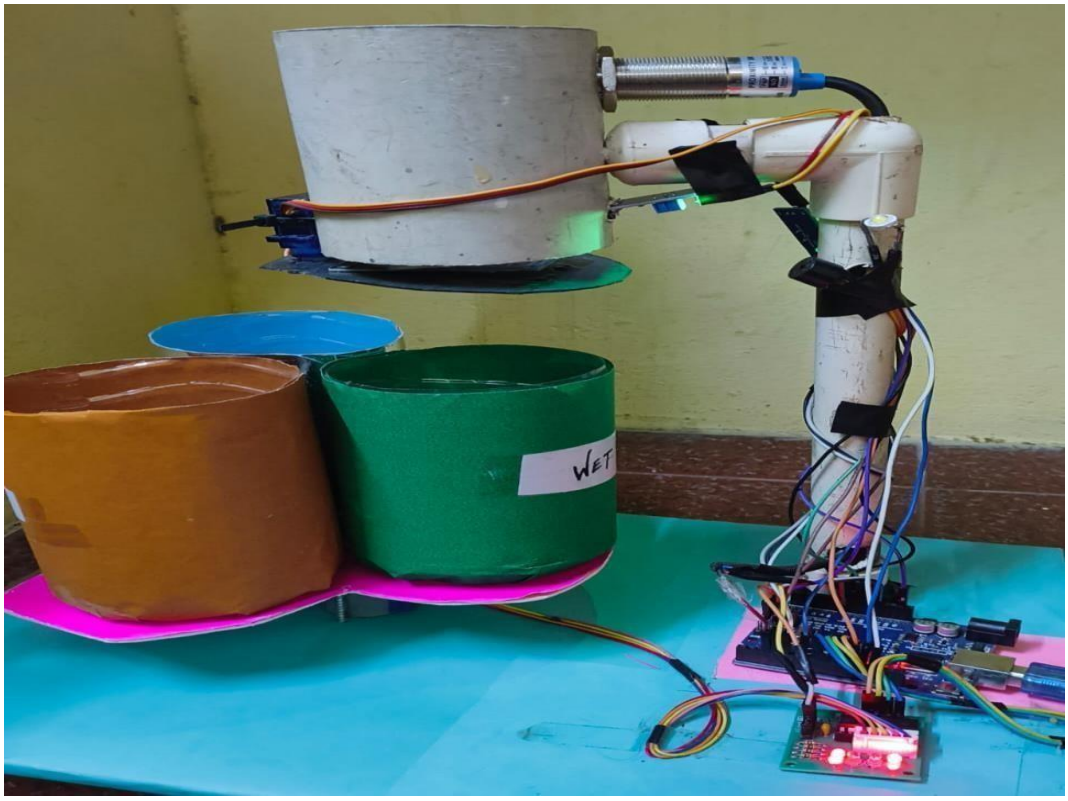


**Figure 43. The wet waste was detected by using raindrop sensor**

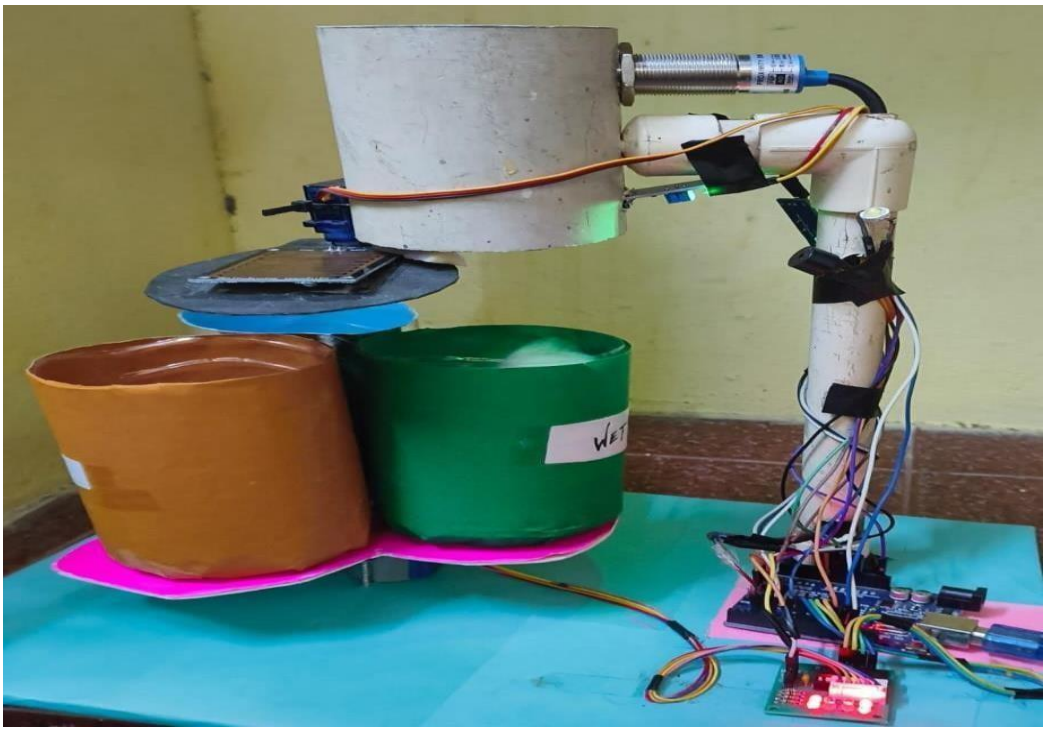


**Figure 44. The bins move into right place to receive a wet waste**

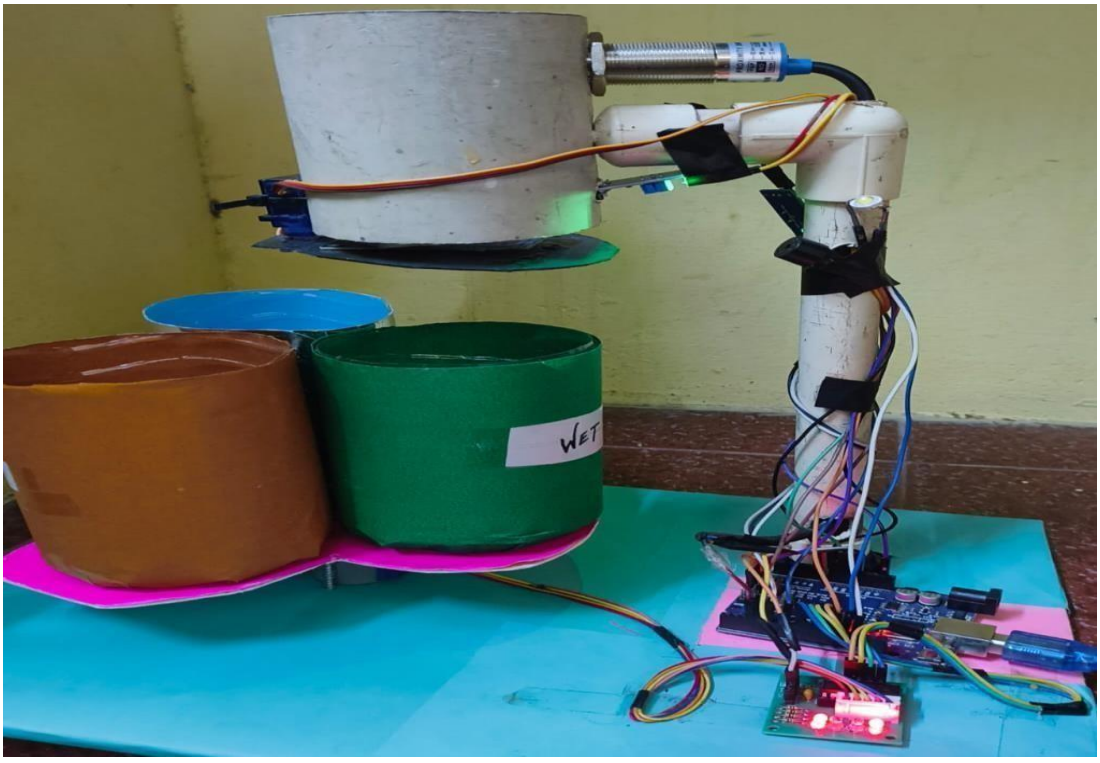


**Figure 45. Once collect the waste it rotates into clockwise direction**

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