iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: VI Month of publication: June 2026

DOI: https://doi.org/10.22214/ijraset.2026.83751

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Wireless Solid Waste Collector with Conveyor Mechanism

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I. INTRODUCTION

Urban cleanliness plays a vital role in shaping the public image and overall health standards of any country. Clean streets not only reflect the civic responsibility of a community but also contribute significantly to reducing health hazards caused by accumulated waste. However, maintaining street cleanliness remains a persistent challenge, particularly in densely populated cities where the task requires substantial manpower, time, and financial resources. Traditional methods of manual sweeping or the operation of street-cleaning vehicles demand considerable labor and contribute to high operational costs. In fact, municipal corporations often allocate 30 to 50 percent of their solid waste management budgets solely to street cleaning operations.

With the advancement of automation and smart city technologies, there is a growing interest in developing autonomous solutions to address these challenges. Robotic street cleaning offers a promising alternative by reducing human involvement, lowering costs, and increasing operational efficiency. This project focuses on the development of an autonomous street-cleaning robot equipped with long-range wireless communication using LoRa technology and powered by solar energy. The robot is designed to operate efficiently in urban environments, offering remote control and monitoring capabilities, while promoting sustainable and eco-friendly street maintenance practices.

II. LITERATURE SURVEY

Folianto, F., Low, Y. S., & Yeoh, W. S., "Smartbin: Smart Waste Management System," IEEE TENSYMP*, 2015.*

The author proposed an IoT-based smart waste management system called Smartbin. The system used ultrasonic sensors to detect garbage fill levels and transmitted data through wireless communication networks. The objective was to optimize waste collection schedules and reduce operational cost. The research demonstrated that real-time monitoring significantly reduces unnecessary vehicle trips. It also improved cleanliness in urban areas by preventing overflow conditions. The authors highlighted the importance of integrating cloud platforms for centralized monitoring. Their work laid the foundation for sensor-based smart garbage systems. However, the study did not include renewable energy integration. Vehicle electrification was also not considered. This creates scope for combining IoT with solar-powered EV systems.

Pujari, T. et al., "Solar Powered Smart Dustbin," *International Journal of Engineering Research & Technology (IJERT)*, 2024.

The author presented a smart dustbin powered by a solar panel. The system used ultrasonic sensors and GSM modules to monitor garbage levels. Solar panels were installed to power the electronics, reducing dependency on grid electricity. Alerts were sent to municipal authorities when bins reached threshold levels. The study focused on sustainability and renewable energy integration. It demonstrated reduced energy consumption compared to conventional systems. The solar charging system improved reliability in remote locations. However, the research was limited to stationary smart bins. No integration with electric garbage vehicles was discussed. This indicates the need for a combined EV-based collection system.

Longhi, S. et al., "Solid Waste Management Architecture using Wireless Sensor Networks," *IEEE Sensors Journal*, 2012.

This research proposed wireless sensor network architecture for monitoring waste bins. Sensors collected fill-level data and transmitted it to a control center. The system implemented route optimization algorithms to reduce fuel consumption. The results showed improved collection efficiency and reduced operational cost. The study emphasized smart city applications. Data analytics was used to predict waste accumulation patterns. However, the vehicle used in the system was diesel-powered. Renewable energy integration was not addressed. Thus, combining EV technology with such intelligent routing would enhance environmental benefits.

Taefi, T. et al., "Comparative Analysis of Electric and Diesel Trucks in Urban Logistics," *Transportation Research Journal*, 2016.

This study compared electric trucks with diesel trucks for urban services. Results showed reduced greenhouse gas emissions and lower maintenance costs for EVs. Electric vehicles were found suitable for short-distance municipal operations. The research highlighted lower noise pollution benefits. Battery efficiency and charging infrastructure were analyzed. However, solar integration

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was not considered. The focus was mainly on logistics and delivery vehicles. Applying this concept to garbage collection vehicles presents a sustainable opportunity. Integration with smart monitoring can further enhance efficiency.

Md. Hannan et al., "Solar-Powered Waste Compactor System," *Renewable Energy Journal*, 2018.

Author proposed a solar-powered compaction bin system. Photovoltaic panels powered an internal compactor to increase bin capacity. This reduced collection frequency by up to 50%. The study demonstrated reduced vehicle trips and fuel savings. The system was environmentally friendly and suitable for urban areas. However, it focused only on bin-side improvements. No EV-based transport system was included. The integration of solar EV with compaction systems could further improve sustainability. The study supports the use of renewable energy in waste management.

Anitha, A., "Garbage Monitoring System using IoT," *International Journal of Pure and Applied Mathematics*, 2017.

This work presents a GSM-based garbage monitoring system. Ultrasonic sensors detected garbage levels. Data was transmitted to authorities through SMS alerts. The system minimized manual inspection of bins. It improved urban sanitation management. However, it lacked energy optimization strategies. Renewable energy was not incorporated. Transportation system design was also not discussed. The integration of EV and solar systems can overcome these limitations.

Krishnan, R., "Permanent Magnet Synchronous and Brushless DC Motor Drives," *CRC Press*, 2010.

Author explained about the operation and efficiency of BLDC motors. BLDC motors are widely used in electric vehicles due to high efficiency and low maintenance. The book detailed torque-speed characteristics and controller design. It demonstrated energy-saving potential in EV applications. The study supports the selection of BLDC motors for garbage EV design. However, waste management application was not specifically addressed. Integrating BLDC-based EV with smart garbage systems is a novel application.

A. Problem Identification

The increasing generation of solid waste due to rapid urbanization, population growth, and industrial activities has become a major environmental challenge. Waste materials such as plastic bottles, paper, cans, and packaging waste often accumulate in public areas, parks, roadsides, and drainage channels. Improper waste collection and disposal not only degrade the environment but also lead to health hazards, unpleasant surroundings, and blockage of drainage systems.

Conventional waste collection methods primarily rely on manual labor, which is time-consuming, labor-intensive, and exposes workers to harmful and unhygienic conditions. In many cases, waste is collected using simple tools that require direct human contact with contaminated materials. This increases the risk of injuries, infections, and occupational health problems. Furthermore, manual collection methods are often inefficient in inaccessible or hazardous locations where waste accumulation is significant.

To overcome these limitations, there is a need for an automated and efficient waste collection system that minimizes human intervention while improving collection efficiency. The proposed Wireless Solid Waste Collector with Conveyor Mechanism addresses this problem by integrating wireless control technology with a conveyor-based waste collection mechanism. The system enables remote operation, safe waste handling, and efficient transportation of collected waste, thereby contributing to cleaner surroundings and improved waste management practices.

B. Objectives Of The Project

The main objective of the Wireless Solid Waste Collector with Conveyor Mechanism is to develop an efficient and automated system for collecting solid waste while minimizing human effort and direct contact with waste materials. The project aims to utilize wireless communication technology to enable remote operation of the waste collector, thereby improving the safety and convenience of waste management activities. The system incorporates a conveyor belt mechanism to collect and transfer waste into a storage container, ensuring continuous and efficient waste handling.

Furthermore, the project seeks to improve cleanliness in public areas, industrial premises, parks, and drainage channels by providing a cost-effective and environmentally friendly waste collection solution. It also aims to enhance waste collection efficiency, reduce operational time, and support sustainable waste management practices. The developed prototype serves as a foundation for future advancements in smart and automated waste management systems for modern urban environments.

1) Design of Electric Vehicle (EV) .
2) Design of automatic garbage collection System with the help of sensors and intelligent controller.
3) To design and develop a wireless-controlled solid waste collection system for efficient waste management.
4) To reduce human effort and direct contact with waste materials during the collection process.
5) To integrate a conveyor belt mechanism for continuous collection and transportation of solid waste into a storage container.

III. BLOCK DAIGRAM

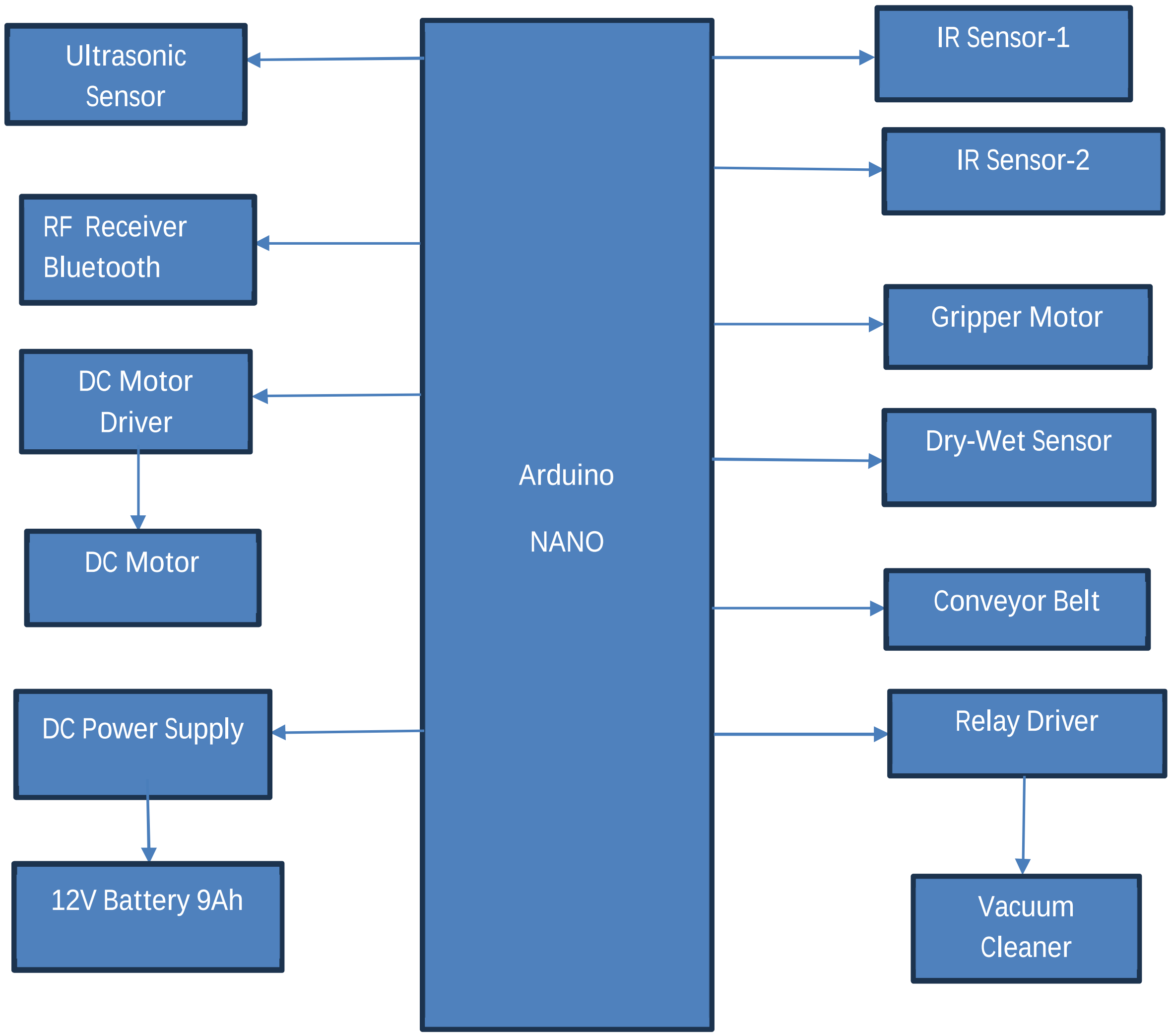

Fig 3.1 Block diagram of proposed model

A. Components Description

1) Solar Panel

A solar panel is a device that converts sunlight into electrical energy using the photovoltaic (PV) effect. It consists of multiple solar cells made from semiconductor materials such as silicon. When sunlight falls on the surface of these cells, it excites the electrons and generates direct current (DC) electricity. This electrical energy can be used directly or stored in batteries for later use.

In the Smart Garbage Collection System using Solar Powered Electric Vehicle, the solar panel plays an important role in supplying renewable energy to the system. The panel absorbs sunlight and converts it into electrical power, which is then used to charge the battery of the electric vehicle. The stored energy is used to operate various components such as the motor, sensors, microcontroller, and garbage collection mechanism.

The use of a solar panel makes the system environment-friendly and energy efficient, as it reduces the dependency on conventional power sources. It also helps in lowering operational costs and reducing carbon emissions. Solar panels are widely used in applications such as solar vehicles, street lighting, water pumping systems, and smart city projects due to their reliability and sustainability.

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Fig 3.1.1 Solar Panel

2) Battery

The battery is an essential power supply component in the Wireless Solid Waste Collector with Conveyor Mechanism, providing the required electrical energy to operate all electronic and mechanical components of the system.

It supplies power to the Arduino Nano, motor driver, DC motors, wireless communication module, and other connected circuits. A rechargeable battery is preferred in this project because it provides continuous operation, reduces maintenance cost, and supports an eco-friendly design.

The battery stores electrical energy in chemical form and converts it into electrical energy whenever the system requires power. The voltage provided by the battery is regulated and distributed to different components according to their operating requirements. Since the project involves mobile operation, the battery enables the waste collector to move freely without the need for a fixed power connection, improving the portability and efficiency of the system.

In this project, the battery powers the DC motors used for vehicle movement and conveyor belt operation. It also ensures stable operation of the control circuit by providing a reliable power source to the Arduino Nano and wireless modules. The selection of battery capacity depends on the power consumption of motors and electronic components, as well as the required operating time of the waste collector.

Specifications (Example):

Type: Rechargeable Lithium-ion battery

Output Voltage: 7.4V / 12V (as per system requirement)

Capacity: Selected based on load requirement

Rechargeable and portable

Provides continuous power supply

Fig 3.1.2 Battery

The battery is a crucial component of the Wireless Solid Waste Collector with Conveyor Mechanism because it acts as the primary source of energy for all system operations. Without the battery, the waste collector would not be able to move, collect waste, or perform wireless control functions.

It ensures uninterrupted operation of the motors, conveyor belt, sensors, and control unit, allowing the system to function efficiently in areas where a direct power supply is unavailable. The battery also enhances the mobility and flexibility of the collector, enabling it to cover larger areas and perform waste collection tasks effectively. Its reliable power delivery is essential for maintaining the overall performance and productivity of the system.

3) Arduino Nano

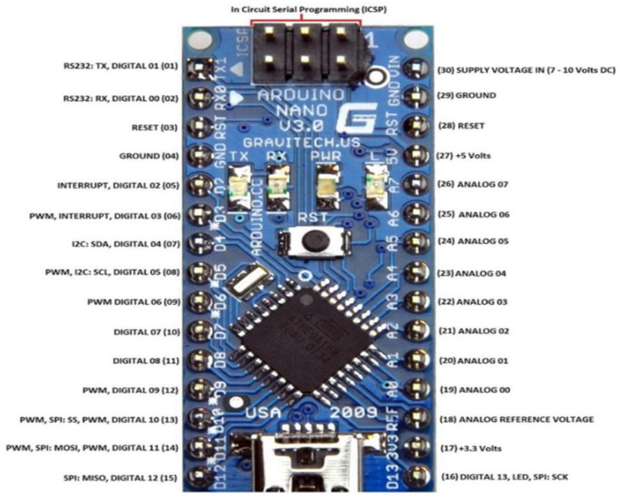

Fig: 3.1.3

The Arduino Nano is a compact and powerful microcontroller board based on the ATmega328P microcontroller. It serves as the brain of the Wireless Solid Waste Collector with Conveyor Mechanism by controlling and coordinating all system operations.

The board processes wireless control signals received from the transmitter and generates appropriate output signals to operate the motor driver and other connected components. Due to its small size, lightweight design, and low power consumption, the Arduino Nano is widely used in robotics, automation, and embedded control applications.

In this project, the Arduino Nano continuously monitors the input commands from the wireless communication module and executes the required actions such as moving the waste collector forward, backward, left, or right, and operating the conveyor mechanism for waste collection. The microcontroller contains built-in memory for storing the program code and data required for system operation. It also provides multiple digital and analog input/output pins that allow easy interfacing with sensors, motor drivers, wireless modules, and other peripheral devices.

The Arduino Nano operates at a clock frequency of 16 MHz, enabling fast execution of instructions and real-time control of the system.

Specifications:

Microcontroller: ATmega328P

Operating Voltage: 5V

Recommended Input Voltage: 7–12V

Digital I/O Pins: 14

Analog Input Pins: 8

Flash Memory: 32 KB

SRAM: 2 KB

EEPROM: 1 KB

Clock Speed: 16 MHz

Communication Interfaces: UART, SPI, I2C

Dimensions: 45 mm × 18 mm

Weight: Approximately 7 g

Function in the Project:

Acts as the central control unit.
Receives wireless commands from the transmitter.
Controls the movement of the waste collector vehicle.
Operates the conveyor belt mechanism.
Interfaces with motor drivers and other electronic modules.
Ensures coordinated and efficient system operation.

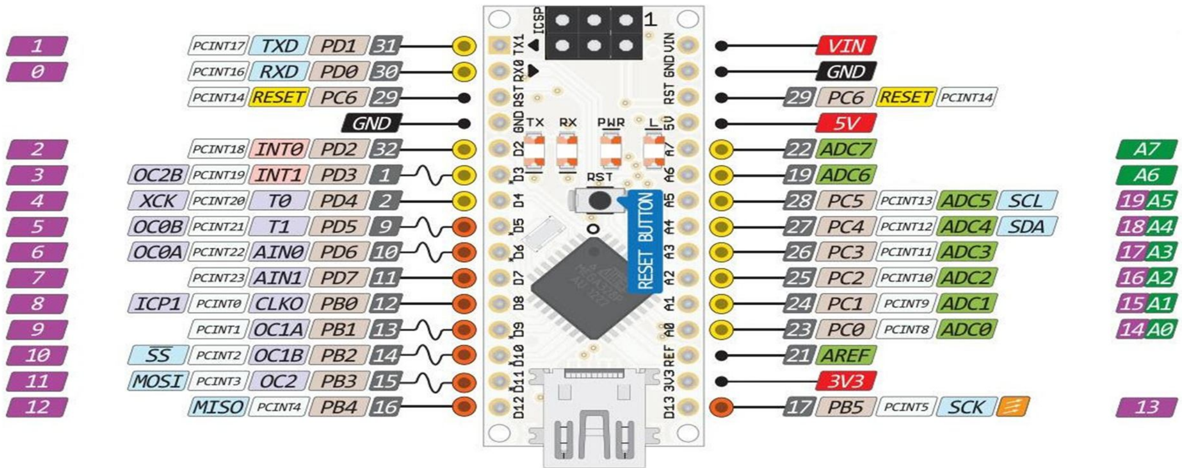

Fig 3.1.4 Arduino UNO

It supports various communication protocols such as UART, SPI, and I2C, making it compatible with a wide range of electronic modules. The board can be programmed using the Arduino IDE, which simplifies software development and debugging. Its reliability, ease of programming, affordability, and versatility make it an ideal choice for controlling the Wireless Solid Waste Collector with Conveyor Mechanism.

4) Ultrasonic Sensor

The Ultrasonic Sensor is a distance-measuring device used in the Wireless Solid Waste Collector with Conveyor Mechanism for obstacle detection and monitoring the surrounding environment. It works by transmitting high-frequency ultrasonic sound waves and measuring the time taken for the reflected waves (echoes) to return after hitting an object. Based on this time interval, the sensor calculates the distance between the sensor and the obstacle.

In this project, the ultrasonic sensor helps improve the safety and efficiency of the waste collector by detecting objects in its path. When an obstacle is detected within a specified distance, the sensor sends information to the Arduino Nano, which can take appropriate action such as stopping the vehicle, changing its direction, or alerting the operator. This prevents collisions and ensures smooth operation of the waste collection system.

The sensor consists of a transmitter and a receiver. The transmitter emits ultrasonic waves, while the receiver captures the reflected waves. The Arduino Nano processes the received data and determines the distance to nearby objects. Ultrasonic sensors are widely used in robotic and automation applications because they provide accurate, non-contact distance measurement and are unaffected by lighting conditions.

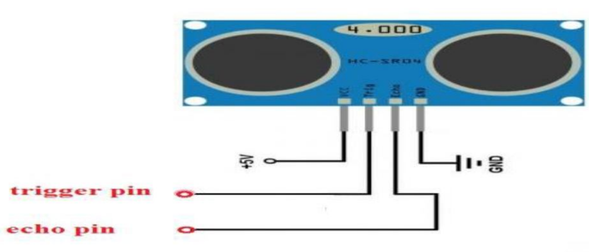

Fig 3.1.5 Ultrasonic Sensor

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The ultrasonic sensor is used to monitor the waste level and detect objects in the wireless solid waste collector. It provides real-time distance measurements to the microcontroller, enabling automatic conveyor belt control, overflow prevention, and wireless notification when the waste bin reaches its maximum capacity.

5) Vacuum Cleaner

The vacuum cleaner is one of the main waste collection components used in the Wireless Solid Waste Collector with Conveyor Mechanism.

It creates suction by generating a pressure difference between the inside and outside of the vacuum unit. This suction force enables the system to collect light weight waste materials such as dust, paper pieces, plastic wrappers, dry leaves, and other small debris from the ground surface.

In this project, the vacuum cleaner is integrated with the waste collection mechanism to improve the efficiency of cleaning operations. When the collector moves over a waste-covered area, the vacuum unit draws the waste through an inlet and transfers it into a collection chamber or storage container. This reduces manual effort and ensures cleaner surroundings. The vacuum cleaner works simultaneously with the conveyor mechanism, allowing collected waste to be transported and stored effectively.

The vacuum cleaner consists of an electric motor, fan, suction inlet, and dust collection chamber. The motor drives the fan, which creates airflow and generates the required suction pressure. The collected waste is separated from the airflow and stored in the waste container for later disposal. Due to its compact size and efficient operation, the vacuum cleaner is suitable for mobile waste collection systems.

The use of a vacuum cleaner enhances the overall performance of the Wireless Solid Waste Collector by enabling quick and hygienic waste collection while minimizing human contact with waste materials. The components of vacuum cleaner are Dc motor, Fan, Filter, Dust collecting Chamber, Suction pipe.

High speed DC motor of nearly 12000RPM is being used. Since it has high speed at no load, this motor is light in weight and has balanced torque to weight ratio at high speed. High speed motor is used to make centrifugal force for suction and collect the dustbin dust chamber.

Fig. 3.1.6 Vacuum Cleaner

Specifications (Typical Mini Vacuum Cleaner):
Operating Voltage: 12V DC
Power Rating: 30–60 W
Suction Type: Motor-driven vacuum suction
Compact and lightweight design
Low power consumption
Suitable for dry waste collection

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6) DC Motor

DC motorsare configured in many types and sizes, including brush less, servo and gear motor types. A motor consists of a rotor and a permanent magnetic field stator. The magnetic field is maintained using either permanent magnets or electromagnetic windings. DCmotors are most commonly used in variable speed and torque.

Motion and controls cover a wide range of components that in some way are used to generate and/or control motion. Areas within this category include bearings and bushings, clutches and brakes, controls and drives, drive components, encoders and resolves, Integrated motion control, limit switches, linear actuators, linear and rotary motion components, linear position sensing,motors (both AC and DC motors), orientation position sensing, pneumatics and pneumatic components, positioning stages, slides and guides, power transmission (mechanical), seals, sliprings, solenoids, springs.

Motors are the devices that provide the actual speed and torque in a drive system. This family includes AC motor types (single and multiphase motors, universal, servo motors, induction, synchronous, and gear motor) and DC motors (brush less, servo motor, and gear motor) as well as linear, stepper and air motors, and motor contactors and starters.

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. As you are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

Let's start by looking at a simple 2-pole DCelectric motor (here red represents a magnet or winding with a "North" polarization, while green represents a magnet or winding with a "South" polarization).

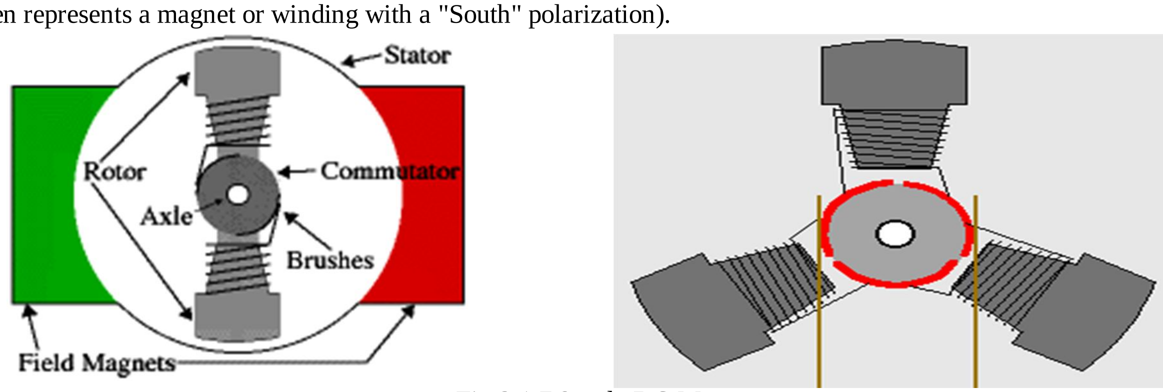

Fig 3.1.7 2-pole DC Motor

Every DC motor has six basic parts -- axle, rotor (a.k.a., armature), stator, commutator, field magnet(s), and brushes. In most common DC motors (and all that Beamers will see), the external magnetic field is produced by high-strength permanent magnets[1]. The stator is the stationary part of the motor -- this includes the motor casing, as well as two or more permanent magnet pole pieces. The rotor (together with the axle and attached commutator) rotates with respect to the stator. The rotor consists of windings (generally on a core), the windings being electrically connected to the commutator. The above diagram shows a common motor layout with the rotor inside the stator (field) magnets.

The geometry of the brushes, commutator contacts, and rotor windings are such that when power is applied, the polarities of the energized winding and the stator magnet(s) are misaligned, and the rotor will rotate until it is almost aligned with the stator's field magnets. As the rotor reaches alignment, the brushes move to the next commutator contacts, and energize the next winding. Given our example two-pole motor, the rotation reverses the direction of current through the rotor winding, leading to a "flip" of the rotor's magnetic field, and driving it to continue rotating.

In real life, though, DC motors will always have more than two poles (three is a very common number). In particular, this avoids "dead spots" in the commutator. You can imagine how with our example two-pole motor, if the rotor is exactly at the middle of its rotation (perfectly aligned with the field magnets), it will get "stuck" there. Meanwhile, with a two-pole motor, there is a moment where the commutator shorts out the power supply (i.e., both brushes touch both commutator contacts simultaneously). This would be bad for the power supply, waste energy, and damage motor components as well. Yet another disadvantage of such a simple motor is that it would exhibit a high amount of torque" ripple" (the amount of torque it could produce is cyclic with the position of the rotor).

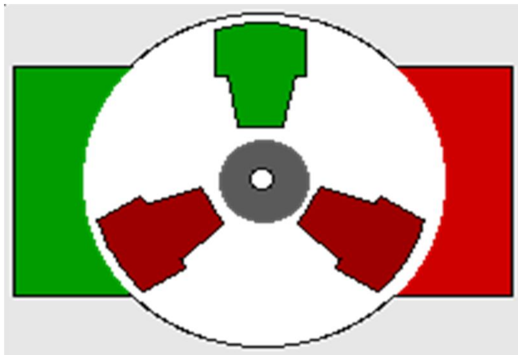

Fig 3.1.8 Pole design Motor

In three pole design motor one pole is fully energized at a time (but two others are "partially" energized). As each brush transitions from one commutator contact to the next, one coil's field will rapidly collapse, as the next coil's field will rapidly charge up.

PWM technique

A pulse width modulator (PWM) is a device that may be used as an efficient light dimmer or DC motor speed controller. A PWM works by making a square wave with a variable on-to-off ratio; the average on time may be varied from 0 to 100 percent. In this manner, a variable amount of power is transferred to the load. The main advantage of a PWM circuit over a resistive power controller is the efficiency, at a 50% level, the PWM will use about 50% of full power, almost all of which is transferred to the load, a resistive controller at 50% load power would consume about 71% of full power, 50% of the power goes to the load and the other 21% is wasted heating the series resistor. Load efficiency is almost always a critical factor in solar powered and other alternative energy systems. One additional advantage of pulse width modulation is that the pulses reach the full supply voltage and will produce more torque in a motor by being able to overcome the internal motor resistances more easily. Finally, in a PWM circuits, common small potentiometers may be used to control a wide variety of loads whereas large and expensive high power variable resistors are needed for resistive controllers. As shown in fig 4.7 Pulse width modulation consists of three signals, which are modulated by a square wave. The duty cycle or high time is proportional to the amplitude of the square wave. The effective average voltage over one cycle is the duty cycle times the peak-to-peak voltage. Thus, the average voltage follows a square wave. In fact, this method depends on the motor inductance to integrate out the PWM frequency.

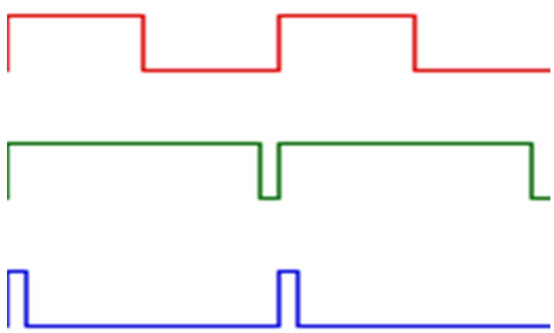

Fig 3.1.9 PWM Signal

A very simply off line motor drive can be built using a TRIAC and a control IC. This circuit can control the speed of a universal motor. A universal motor is a series wound DC motor. The circuit uses phase angle control to vary the effective motor voltage.

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7) L293D IC (DC MOTOR DRIVER)

Fig 3.1.10: L293D Driver IC

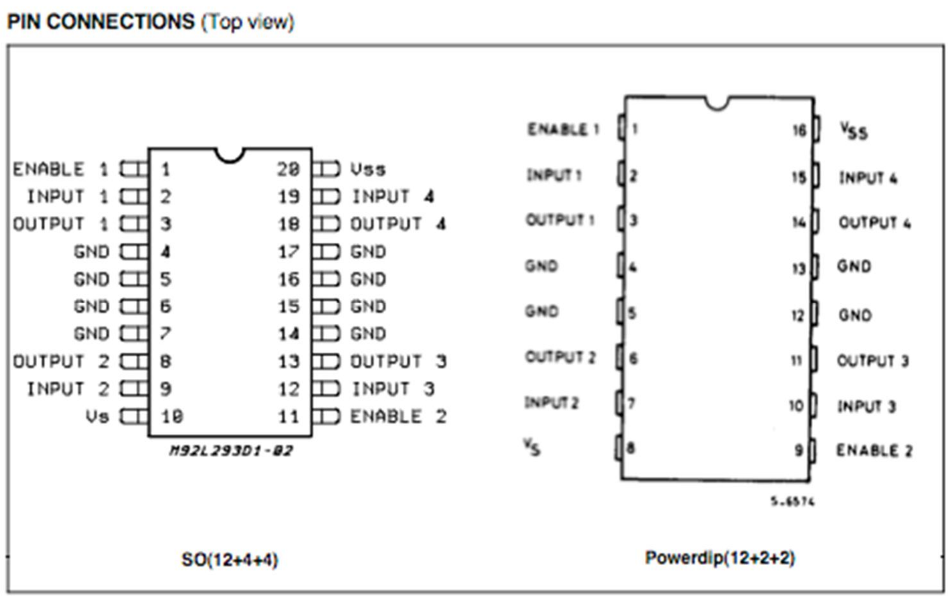

Fig 3.1.11 Pin Connection of L293D driver IC

The L293 and L293D are quadruple high-current half-H drivers. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications. All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN.

When an enable input is high, the associated drivers are enabled and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications. On the L293, external high-speed output clamp diodes should be used for inductive transient Suppression. A VCC1 terminal, separate from VCC2, is provided for the logic inputs to minimize device power dissipation. The L293and L293D are characterized for operation from 0°C to 70°C.

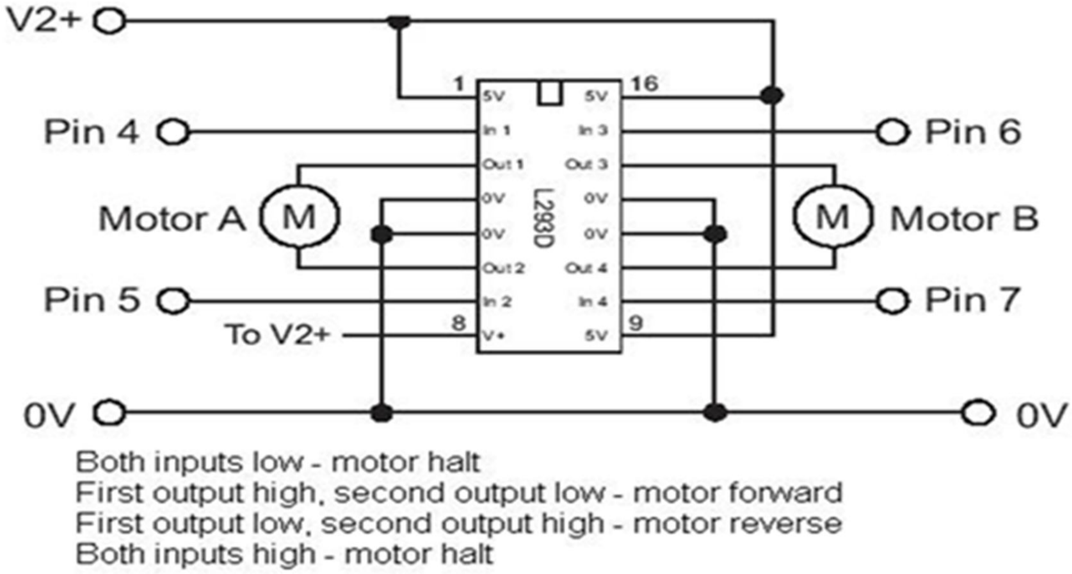

Fig 3.1.12 H Bridge

8) Dry and Wet Sensor

A dry and wet sensor (moisture sensor) is used in waste segregation systems to automatically identify whether the waste is wet or dry based on its moisture content. The sensor consists of two metal probes that come in contact with the waste material. When wet waste such as food scraps, vegetable peels, or organic matter touches the probes, the moisture present in the waste allows electric current to pass easily between the probes, resulting in low electrical resistance. In contrast, dry waste like paper, plastic, or metal contains very little moisture, so the electrical resistance between the probes becomes high, and very little current flows. The sensor converts this change in conductivity into an electrical signal and sends it to a microcontroller such as Arduino. The microcontroller compares the received signal with a preset threshold value and determines whether the waste is wet or dry. Based on this decision, a motor or mechanical sorting mechanism is activated to direct the waste into the appropriate bin, either a wet waste bin for biodegradable waste or a dry waste bin for recyclable materials. This automatic detection and sorting process helps improve waste management efficiency, reduces manual labor, and supports environmentally friendly recycling systems.

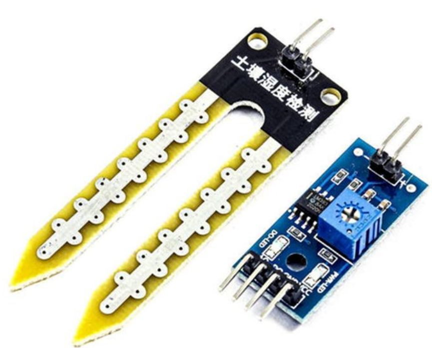

Fig.3.1.13 Dry Wet Sensor

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9) Relay Driver

A Relay Driver Module is an electronic interface circuit used to control high-voltage or high-current devices using a low-power signal from a microcontroller such as Arduino, PIC, or other controllers. Since microcontrollers opera2te at low voltages (typically 3.3V or 5V) and cannot directly drive high-power loads like motors, pumps, or lights, the relay driver module acts as a switching device between the controller and the load.

The module typically contains a relay, transistor driver circuit, diode for protection, and sometimes an optocoupler for isolation. When the microcontroller sends a control signal to the module, the transistor inside the relay driver amplifies the signal and energizes the relay coil. This causes the relay contacts to switch, allowing the connected high-power device to turn ON or OFF safely without damaging the microcontroller.

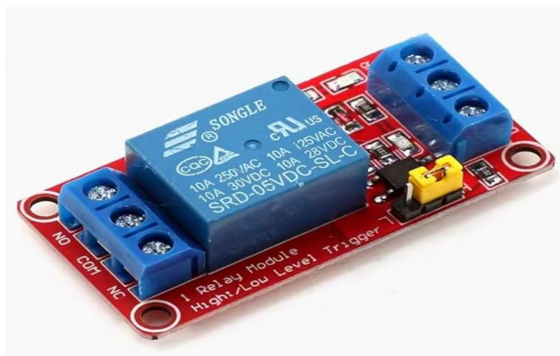


Fig .3.1.14 Relay

10) Wheels

The wheels are important mechanical components of the Wireless Solid Waste Collector with Conveyor Mechanism, providing mobility and support to the entire system. They enable the waste collector to move smoothly in different directions and transport the collected waste from one location to another. The wheels are mounted on the chassis and are connected to DC motors, which provide the necessary rotational motion for movement.

In this project, the wheels play a crucial role in ensuring efficient navigation of the waste collector. When the Arduino Nano sends control signals to the motor driver, the DC motors rotate the wheels, allowing the vehicle to move forward, backward, left, or right according to the wireless commands received from the operator. The wheels help the system cover larger areas with minimal effort and improve the overall effectiveness of the waste collection process.

The wheels are designed to provide good traction and stability on different surfaces such as roads, pavements, and indoor floors.

Their lightweight yet durable construction helps maintain balance and reduces the load on the motors. Proper wheel selection is essential for achieving smooth movement, better control, and reliable operation of the waste collector.

Fig .3.1.15 Relay

The use of wheels makes the system portable, flexible, and capable of reaching areas that may be difficult to clean manually. They contribute significantly to the mobility, efficiency, and performance of the Wireless Solid Waste Collector.

11) Conveyor Belt

The conveyor belt is a key mechanical component of the Wireless Solid Waste Collector with Conveyor Mechanism, used for collecting and transporting waste from the ground into the storage container. It consists of a continuous belt driven by a DC motor and supported by rollers. The conveyor belt moves in a continuous loop, allowing waste materials to be lifted and transferred efficiently without manual intervention.

In this project, the conveyor belt is positioned at the front of the waste collector. As the system moves forward, the rotating belt picks up solid waste such as paper, plastic wrappers, leaves, and other lightweight debris from the ground surface. The collected waste is then carried upward by the belt and deposited into a waste collection bin. This automated mechanism significantly reduces human effort and improves the efficiency of the waste collection process.

The conveyor belt is driven by a motor controlled by the Arduino Nano through a motor driver circuit. When a command is received, the motor rotates the belt at a suitable speed to ensure smooth and continuous waste transfer. The belt material is selected to provide adequate grip and durability while handling different types of waste. The conveyor mechanism ensures that waste is collected quickly and transported without spillage.

The use of a conveyor belt enhances the automation, productivity, and reliability of the Wireless Solid Waste Collector. It enables continuous collection of waste and improves the overall cleanliness and effectiveness of the system.

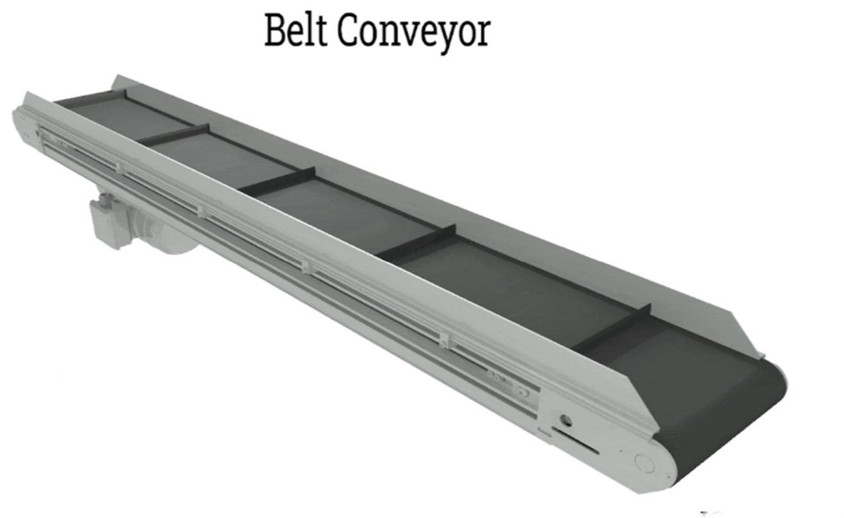


Fig .3.1.16 Relay

Specifications (Typical):
Type: Continuous moving belt conveyor
Material: Rubber, PVC, or Fabric Belt
Drive Mechanism: DC Motor Driven
Lightweight and durable construction
Adjustable speed based on motor specifications
Suitable for handling lightweight solid waste

12) IR Sensor

The Infrared (IR) Sensor is an important sensing component used in the Wireless Solid Waste Collector with Conveyor Mechanism for object detection and automation purposes. It operates by emitting infrared light and detecting the reflected light from nearby objects. When an object comes within the sensor's detection range, the reflected infrared rays are received by the sensor, which then generates a signal that can be processed by the Arduino Nano.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

In this project, the IR sensor is used to detect the presence of waste or objects near the collection mechanism. The sensor helps improve the efficiency of the waste collection process by providing real-time information to the controller. Based on the sensor output, the Arduino Nano can activate or control the conveyor mechanism and other system functions. Since IR sensors provide fast response and reliable detection, they are widely used in robotic and automation applications.

The sensor consists of an infrared transmitter (IR LED) and an infrared receiver (photodiode or phototransistor). When infrared light strikes an object and reflects back to the receiver, the sensor detects the object and sends a corresponding signal. The compact size, low power consumption, and easy interfacing capability make the IR sensor suitable for smart waste collection systems.

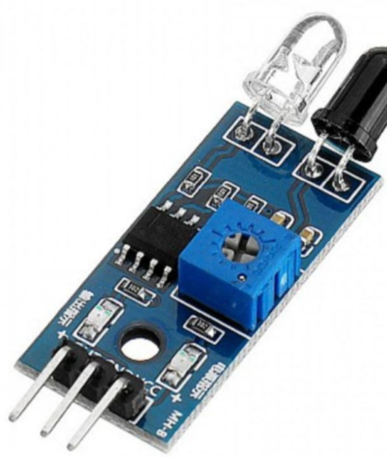


Fig .3.1.17 Relay

Specifications (Typical):
Operating Voltage: 3.3V – 5V DC
Detection Range: 2 cm to 30 cm (depending on model)
Low Power Consumption
Fast Response Time
Digital Output Signal
Compact and Lightweight Design

13) Bluetooth Module

The Bluetooth module is a wireless communication component used in the Wireless Solid Waste Collector with Conveyor Mechanism to establish communication between the user and the waste collection system. It enables the operator to control the movement and operation of the collector remotely using a smartphone or other Bluetooth-enabled device. The module receives wireless commands and transmits them to the Arduino Nano, which processes the commands and controls the corresponding actions of the system.

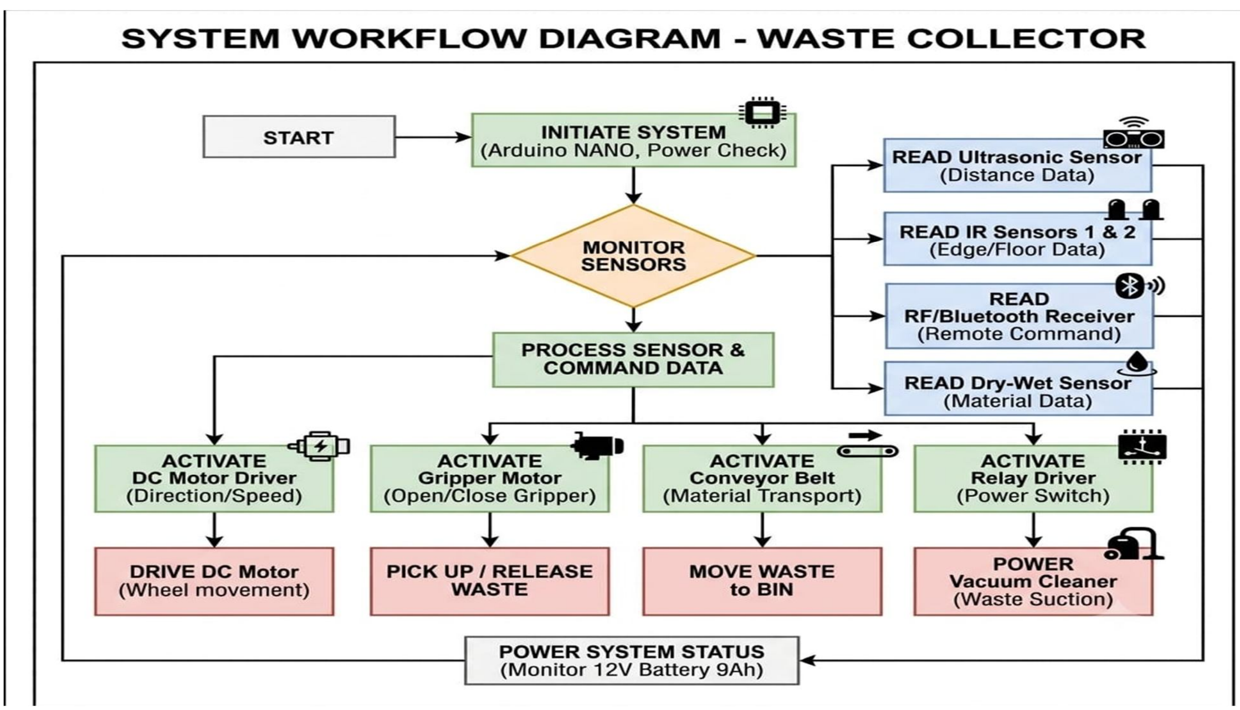
In this project, the Bluetooth module eliminates the need for wired connections, making the system more flexible and convenient to operate. The user can send commands such as forward, backward, left, right, stop, and conveyor belt operation through a mobile application. The module communicates with the Arduino Nano through serial communication (UART), ensuring reliable and real-time data transfer. Its low power consumption, compact size, and ease of interfacing make it suitable for portable and battery-operated applications.

The Bluetooth module provides stable communication within a limited range and allows efficient control of the waste collector without direct physical interaction. This improves user safety, enhances system mobility, and contributes to the automation of the waste collection process. The module plays a vital role in achieving wireless operation and improving the overall functionality of the system.

Fig .3.1.17 Relay

Specifications (HC-05 Bluetooth Module):
Operating Voltage: 3.6V – 6V DC
Communication Protocol: Bluetooth V2.0 + EDR
Frequency Band: 2.4 GHz
Communication Range: Up to 10 meters
Data Transfer Rate: Up to 3 Mbps
Interface: UART (Serial Communication)
Low Power Consumption
Function in the Project:
Enables wireless communication between the user and the system.
Receives control commands from a smartphone or Bluetooth device.
Transmits data to the Arduino Nano for processing.
Allows remote operation of the waste collector.
Eliminates the need for wired control connections.
Improves flexibility, convenience, and automation of the system.

B. Software Implemententaion



C. Component Spciefication

BATTERY	12v, 40Ah
ULTRASONIC SENSOR	COVERAGE 2cm to 400 cm, 5v
DC MOTOR	24v, 20 rpm
DRY AND WET SENSOR	WET ABOVE 60% DRY BELOW 50%

D. Working Principle

The proposed smart garbage collection system operates using a combination ofsolar energy, sensor technology, wireless communication, and automated control**.** The system is designed to collect garbage efficiently while minimizing human effort and reducing environmental pollution.

Initially, the solar panel captures sunlight and converts it into electrical energy through the photovoltaic effect. This electrical energy is used to charge the 12V rechargeable battery**,** which acts as the primary power source for the entire system. The stored energy is supplied through the DC power supply module, which regulates the voltage and distributes power to the Arduino Nano, sensors, motors, and other electronic components.

The Arduino Nano acts as the central controller of the system. It continuously receives input signals from various sensors such as the ultrasonic sensor and dry–wet sensor. Based on these inputs, the Arduino processes the data and sends control signals to actuators like the motor driver, servo motor, and relay module. This enables automatic and intelligent functioning of the garbage collection vehicle.

The ultrasonic sensor is installed near the garbage bin to measure the level of waste inside the bin. It emits ultrasonic waves and detects the reflected signal from the garbage surface. By calculating the distance, the system determines whether the bin is empty, partially filled, or full. When the garbage level reaches a predefined limit, the system can initiate the collection process or notify the operator.

The dry–wet sensor helps in identifying the type of waste present in the garbage. It distinguishes between wet waste and dry waste, which is useful for waste segregation. Proper segregation helps in recycling and better waste management practices.

The Bluetooth or RF receiver module allows wireless communication between the system and a remote controller or smartphone. Through this module, the operator can control the movement of the garbage collection vehicle such as forward, backward, left, and right directions. This feature enables remote operation and easy navigation of the vehicle in different areas.

The DC motors connected to the wheels of the vehicle provide the necessary movement for the garbage collection process. These motors are controlled through the DC motor driver module**,** which receives control signals from the Arduino Nano. The motor driver amplifies these signals to supply sufficient current to the motors for proper operation.

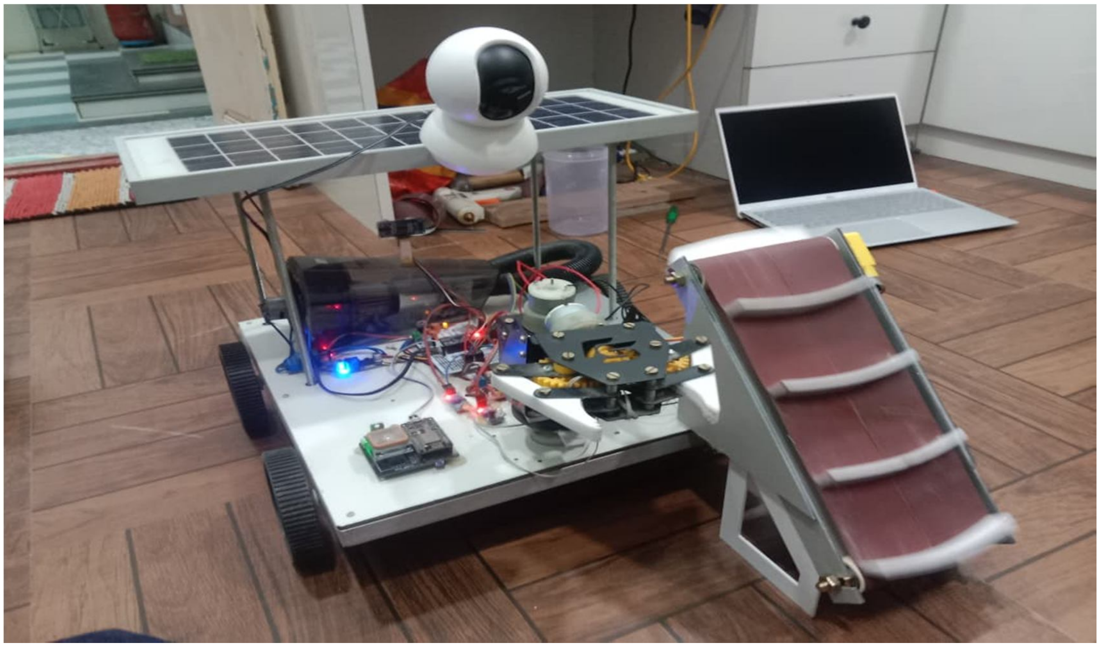
The servo motor is used to control mechanical movements such as opening or closing the garbage collection lid or adjusting the cleaning mechanism. The Arduino sends precise control signals to the servo motor to achieve accurate positioning.

For cleaning and collecting small waste particles, the system uses a vacuum cleaner mechanism**.** The vacuum cleaner is controlled through a relay driver module, which acts as an electronic switch. When the Arduino activates the relay, the vacuum cleaner starts operating and collects dust and small garbage from the ground surface.

Additionally, the ESP32 camera module is used for visual monitoring of the garbage collection process. It captures images or video of the surroundings and can transmit the data wirelessly for remote observation. This helps in monitoring the system operation and ensuring proper waste collection.

Overall, the system works by integrating renewable energy, sensor-based monitoring, wireless communication, and automated control mechanisms. The solar-powered electric vehicle moves to the garbage location, detects waste levels, collects garbage using the vacuum system, and enables smart waste segregation. This approach improves efficiency, reduces manual labor, and supports sustainable waste management in modern smart city environments.

E. Implementation



F. Methodology

The methodology of the Wireless Solid Waste Collector with Conveyor Mechanism involves the design and development of a wireless waste collection system capable of collecting and transporting solid waste with minimal human intervention. Initially, all required components such as the Arduino Nano, Bluetooth module, IR sensor, ultrasonic sensor, motor driver, DC motors, conveyor belt, vacuum cleaner, battery, and wheels are integrated into a compact mobile platform. The Arduino Nano is programmed to control the movement of the vehicle and coordinate the operation of the conveyor mechanism based on commands received through the Bluetooth module.

The user operates the system wirelessly through a smartphone application. The Bluetooth module receives the control commands and sends them to the Arduino Nano. Based on these commands, the Arduino controls the motor driver, which drives the DC motors to move the collector in the desired direction. As the vehicle moves, the IR sensor detects the presence of waste, while the ultrasonic sensor detects obstacles to ensure safe navigation. Once waste is detected, the conveyor belt and vacuum cleaner are activated to collect the waste from the ground surface.

The conveyor belt lifts the collected waste and transfers it into the storage container mounted on the vehicle. The battery supplies power to all electronic and mechanical components throughout the operation. After collection, the waste remains stored in the container until it is disposed of at the designated location. The complete system is tested under different conditions to evaluate its waste collection efficiency, wireless control performance, and obstacle detection capability, ensuring reliable and effective operation.

IV. RESULTS AND DISCUSSION

A. Results

The developed Wireless Solid Waste Collector with Conveyor Mechanism was successfully designed, fabricated, and tested under different operating conditions. The experimental results demonstrated that the system was capable of performing automated waste collection efficiently while being controlled wirelessly by the user. The movement of the collector in forward, backward, left, and right directions was achieved successfully through wireless communication, allowing the operator to control the system from a safe distance. The Arduino Nano functioned effectively as the central controller, coordinating the operation of all system components and ensuring smooth execution of commands. The conveyor belt mechanism operated continuously and efficiently collected waste materials from the ground surface. During testing, the conveyor belt was able to pick up lightweight waste such as paper pieces, plastic wrappers, dry leaves, and small debris and transfer them into the storage container without significant loss of material.

The wheels provided stable movement and allowed the collector to navigate across flat surfaces with ease. The battery supplied adequate power to all electronic and mechanical components, enabling uninterrupted operation throughout the testing period. The ultrasonic sensor successfully detected nearby obstacles and provided distance information to the controller, helping to avoid collisions and improving the safety of the system. The integration of the vacuum cleaner further enhanced waste collection efficiency by assisting in the removal of dust and lightweight particles that were difficult to collect using the conveyor belt alone. The wireless control system exhibited reliable performance within the specified operating range, with minimal delay between command transmission and system response. The overall performance analysis indicated that the proposed system effectively reduced manual effort involved in waste collection and improved operational efficiency. The collected waste was transferred and stored successfully, demonstrating the practicality of the conveyor-based collection approach. The system performed best when handling lightweight and dry waste materials and showed satisfactory results in small-scale waste management applications. The testing results confirmed that the combination of wireless control, conveyor mechanism, ultrasonic sensing, and automated mobility can provide an effective solution for modern waste collection. Therefore, the developed prototype successfully achieved its intended objectives and demonstrated the feasibility of implementing an automated wireless waste collection system for maintaining cleaner and more hygienic environments.

B. Discussion

The developed Wireless Solid Waste Collector with Conveyor Mechanism successfully achieved its objective of automated waste collection. The wireless control system, conveyor belt, and vacuum cleaner worked effectively to collect and transfer waste with minimal human effort. The ultrasonic sensor improved operational safety by detecting obstacles, while the battery-powered design provided mobility and flexibility. The system demonstrated good performance for collecting lightweight waste materials and proved to be a practical, cost-effective solution for small-scale solid waste management applications.

V. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

A. Advantages

- Reduces manual effort required for waste collection.
- Improves cleanliness and hygiene in areas.
- Wireless operation allows remote control of the system.
- Conveyor mechanism enables efficient collection and transfer of waste.
- Minimizes direct human contact with waste materials.

B. Disadvantages

- Battery may drain fast, due to heavy motor load.
- Collection efficiency can be affected by wet or sticky waste.

C. Applications

Applications of Wireless Solid Waste Collector with Conveyor Mechanism

- Indoor cleaning of large buildings and halls.
- Collection of lightweight solid waste materials.
- Automated cleaning in places.
- Environmental sanitation and hygiene maintenance.
- Remote-controlled waste collection operations.
- Reduction of manual waste handling and labor.
- Cleaning of school and college corridors.
- Indoor cleaning of hospitals and healthcare facilities.

VI. CONCLUSION

The proposed solar-powered electric garbage collection vehicle provides an efficient and eco-friendly solution for modern waste management. The system uses a robotic arm to collect waste and place it into the vehicle, reducing manual labor and improving safety for sanitation workers. A dry and wet waste segregation mechanism automatically separates different types of waste for easier recycling and processing.

For handling large quantities of garbage from streets**,** aconveyor mechanismis used to quickly transfer waste into the storage unit of the vehicle. Additionally, a vacuum cleaner system helps collect small particles such as dust, paper pieces, and fine waste from roadsides. Overall, this integrated system improves the efficiency of garbage collection, promotes proper waste segregation, and supports cleaner and more sustainable urban environments.

VII. FUTURE SCOPE

The Wireless Solid Waste Collector with Conveyor Mechanism can be further enhanced by incorporating advanced technologies to improve its efficiency and functionality. Future versions of the system can include GPS and IoT integration for real-time tracking and monitoring, allowing waste collection activities to be managed remotely. The system can also be equipped with AI-based waste detection and segregation techniques to automatically identify and separate different types of waste materials such as plastic, paper, and metal.

In addition, the waste collector can be upgraded with solar-powered charging systems, larger waste storage capacity, and autonomous navigation features to reduce human intervention. Advanced sensors and machine vision systems can be incorporated to improve obstacle detection and route planning.

These improvements would make the system more suitable for large-scale applications in smart cities, industrial areas, and public infrastructure, contributing to efficient and sustainable waste management.

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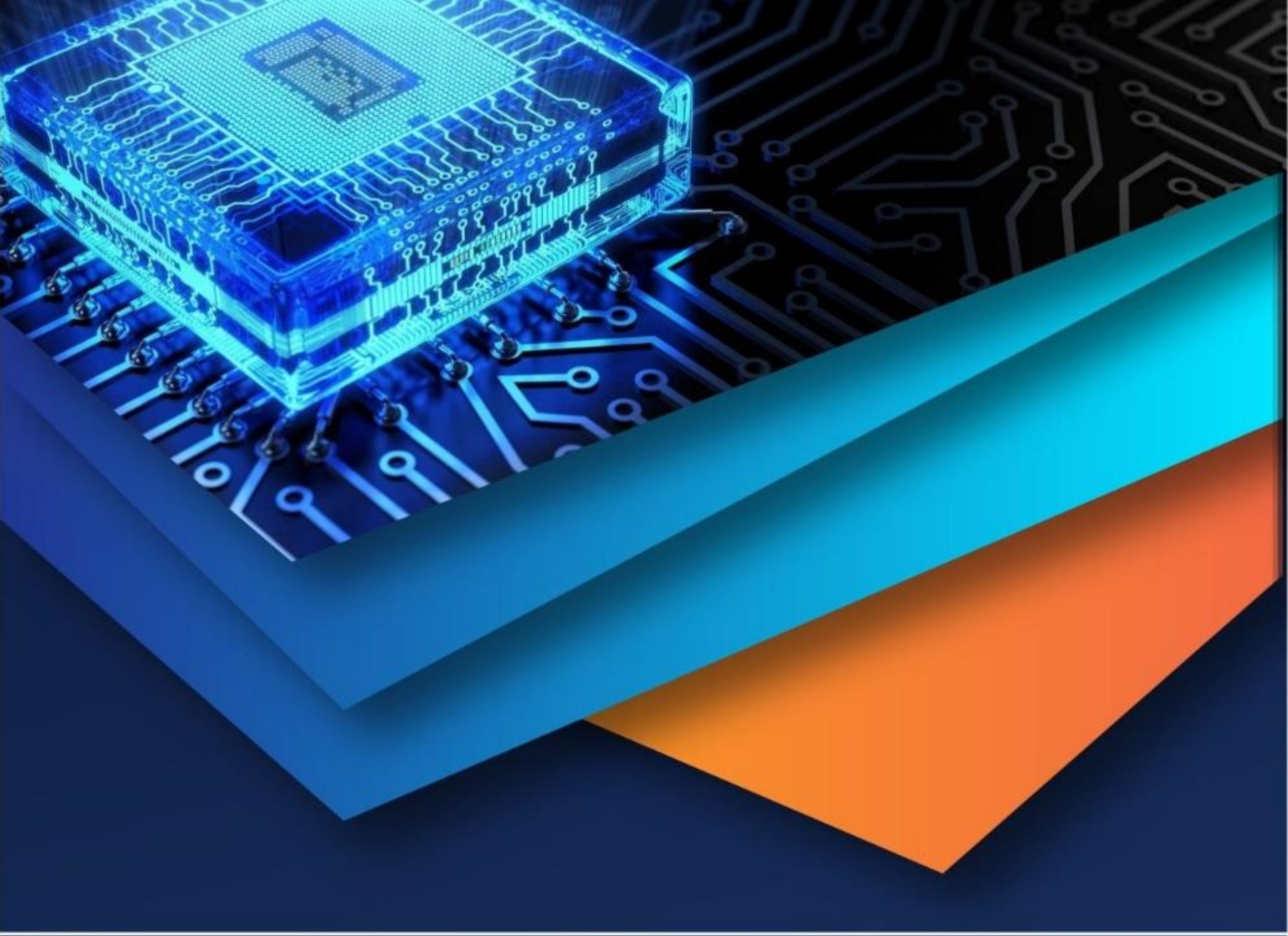

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