LINE FOLLOWING ROBOT

MICROCONTROLLERS AND INTERFACING PROJECT REPORT

Submitted by

GOKULRAJ B	**927623BEC058**
GOPINATH M	**927623BEC060**
BALASUBRAMANIYAN S	**927623BEC301**
DARSAN SANJAI S R	**927623BEC302**

BACHELOR OF ENGINEERING

in

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

M.KUMARASAMY COLLEGE OF ENGINEERING

(Autonomous)

KARUR – 639 113

MAY 2025

M.KUMARASAMY COLLEGE OF ENGINEERING, KARUR

BONAFIDE CERTIFICATE

Certified that this report **"LINE FOLLOWING ROBOT"** is the Bonafide work of **"GOKUL RAJ B (927623BEC058), GOPINATH M (927623BEC060), BALASUBRAMANIYAN S (927623BEC301), DARSHANSANJAI R (927623BEC302)**" who carried out the project work under my supervision in the academic year 2024 - 2025 **EVEN.**

SIGNATURE

Dr.A.KAVITHA, B.E., M.E., Ph.D.,

HEAD OF THE DEPARTMENT,

Professor,

Department of Electronics and

Communication Engineering,

M.Kumarasamy College of Engineering,

Thalavapalayam,

Karur-639113.

SIGNATURE

Dr.E.DINESH B.E., M.E., Ph.D.,

SUPERVISOR,

Assistant Professor,

Department of Electronics and

Communication Engineering,

M.Kumarasamy College of Engineering,

Thalavapalayam,

Karur-639113.

This report has been submitted for the **ECB1223 – Microcontrollers and Interfacing** viva-voce Examination held at M. Kumarasamy College of Engineering, Karur on _____.

INTERNAL EXAMINER

INSTITUTION VISION AND MISSION

Vision
To emerge as a leader among the top institutions in the field of technical education.

Mission

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry and professional associations

DEPARTMENT VISION, MISSION, PEO, PO AND PSO

Vision

To empower the Electronics and Communication Engineering students with emerging technologies, professionalism, innovative research and social responsibility.

Mission

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

Program Educational Objectives

PEO1: **Core Competence:** Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

PEO2: **Professionalism:** Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

PEO3: **Lifelong Learning:** Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

Program Outcomes

PO 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

PSO2: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

Abstract	Matching with POs,PSOs
This project demonstrates a line-following robot using Arduino, designed to follow a predefined path using IR sensors and a motor driver. It emphasizes cost-effectiveness and simplicity for applications in automation.	**PO1, PO2, PO3, PO4, PO5, PO6, PO7, PO8, PO9, PO10, PO11, PO12,PSO1, PSO2**

ACKNOWLEDGEMENT

ABSTRACT

This project focuses on the design and implementation of an Arduino-based line-following robot, an autonomous system engineered to trace a predefined path using infrared (IR) sensors and a motor driver module (L298N). The primary objective is to create a cost-effective, beginner-friendly robotic solution capable of navigating controlled environments with minimal human intervention. Line-following robots have widespread applicability in industrial automation, logistics, and healthcare for tasks such as material handling, guided transport, and delivery systems.

The proposed system employs IR sensors to differentiate between black and white surfaces, enabling the robot to stay on track by constantly analyzing sensor data. The Arduino Uno microcontroller serves as the core processing unit, executing a simple control algorithm to drive the motors in response to real-time input. The L298N motor driver facilitates bidirectional control of the DC motors, allowing for precise steering and maneuvering. Unlike existing solutions that rely on complex and expensive image processing systems, this project emphasizes simplicity and accessibility without compromising on performance. It is tailored for educational and prototyping purposes, providing a strong foundation for enhancements such as obstacle avoidance, speed regulation, and wireless control. This robot serves as a practical demonstration of microcontroller interfacing, sensor integration, and embedded system design. It also underscores the importance of automation in improving efficiency, reducing error rates, and enhancing safety in dynamic operational environments.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACRONYM		ABBREVIATION
IR	-	Infrared
LED	-	Light Emitting Diode
USB	-	Universal Serial Bus
L298N	-	Model number of the motor driver

CHAPTER 1

INTRODUCTION

In recent years, the demand for automation and intelligent systems has grown significantly across various industries. Tasks such as material transportation, inventory movement, and in-house delivery, particularly in warehouses, hospitals, and manufacturing plants, often require repetitive navigation along fixed paths. Automating such processes can enhance efficiency, reduce labor costs, and minimize human error.

1.1 Objective

The primary objective of this project is to design and develop a low-cost, Arduino-based line-following robot capable of autonomously navigating a predefined path using infrared (IR) sensors.

- To build a low-cost, Arduino-based line-following robot.
- To use IR sensors for detecting and following a predefined path.
- To control robot movement using an L298N motor driver and DC motors.

1.2 Problem Statement

Existing material transport systems have several limitations:

- Manual handling of goods in environments like warehouses, hospitals, and factories leads to human errors and inefficiencies.
- Continuous human supervision increases labor costs and reduces overall productivity.
- Advanced automated systems are often expensive, complex, and inaccessible for educational or small-scale applications.

1.3 Scope of the Project

This project focuses on developing an Arduino-based line-following robot for autonomous navigation. The system will:

- Detect and follow a predefined path using IR sensors for real-time line tracking.

- Use an Arduino microcontroller and motor driver to control movement based on sensor input.

- Be tested in a controlled environment to evaluate its accuracy, reliability, and potential for applications in material transport and automation.

- Serve as a foundational model for enhancements like obstacle detection, wireless control, and integration with IoT for smart automation systems.

1.4 Significance

The proposed line-following robot addresses key challenges in automated material handling and navigation. By using IR sensors and microcontroller-based control, it:

- Automates movement along predefined paths, reducing human effort and operational errors.

- Provides a low-cost, efficient alternative to complex industrial robots, making automation accessible for educational and small-scale applications.

- Serves as a practical introduction to embedded systems and robotics, promoting hands-on learning and innovation.

CHAPTER 2
LITERATURE SURVEY

2.1 Overview of Existing Line-Following Robots

- Line-following robots have been developed for decades to automate repetitive navigation tasks. Traditional robots used basic analog sensors and hardcoded logic, which offered limited adaptability.

- With technological advancements, modern systems include microcontroller-based solutions, advanced algorithms, and even camera-based vision systems. These robots are deployed in areas like automated factories, delivery systems in hospitals, and guided warehouse logistics.

2.2 Prior Research and Technological Background

Academic and industrial research has explored various approaches:

- **Analog Line Followers**: Use op-amps and comparators; low-cost but lack flexibility.

- **Microcontroller-based Systems**: Use Arduino, Raspberry Pi, etc., enabling programmability and sensor fusion.

- **Image Processing-based Robots**: Offer high precision using OpenCV and machine learning but are expensive and complex.

2.3 Limitations of Existing Systems

- **Cost-Prohibitive**: Advanced systems require expensive cameras and processors.

- **Complex Setup**: Vision-based systems need calibration and controlled lighting conditions.

- **Inaccessibility**: Not feasible for students and small-scale applications due to cost and complexity.
- **Limited Educational Value**: Many systems are too advanced for beginners, lacking step-by-step learning potential.

2.4 Research Gaps

There's a need for a robot:

- That is low-cost and easy to assemble.
- Uses simple sensors (IR) and widely available microcontrollers (Arduino)
- Is suitable for learning embedded systems and automation basics
- Has potential for modular upgrades like obstacle detection, IoT, and wireless control

CHAPTER 3
EXISTING SYSTEM

3.1 Manual or Semi-Automated Navigation

In many industries, materials are still transported manually or using guided vehicles that need human oversight. These systems:

- Are prone to human error.
- Increase operational cost due to labor dependency
- Offer low precision in repeated navigation

3.2 High-End Robotic Systems

Some companies use autonomous robots with LiDAR or cameras for navigation. These include:

- Automated Guided Vehicles (AGVs).
- Autonomous Mobile Robots (AMRs)

However, they:

- Require complex environments (RFIDs, barcodes, visual markers)
- Demand high technical skill to operate and maintain
- Are not scalable for educational or hobbyist use

3.3 Drawbacks Identified

- Lack of affordable alternatives for learning and prototyping
- Over-engineered for simple navigation tasks
- Limited hands-on opportunity for students in embedded design

CHAPTER 4
PROPOSED SYSTEM

The proposed architecture of the line-following robot is designed with a focus on cost-effectiveness, modularity, and ease of implementation for educational and prototype automation applications. The architecture integrates essential electronic components including sensors, a microcontroller, a motor driver, and actuators in a coordinated system to ensure precise line tracking.

The robot uses infrared (IR) sensors to detect a black line on a white surface. These sensors provide binary signals to an Arduino Uno microcontroller based on surface reflectivity. The Arduino processes the inputs using a control algorithm and generates commands to steer the robot accordingly.

The L298N motor driver is used to control the direction and speed of two DC motors based on Arduino's output. These motors are connected to the wheels of the robot, providing mobility and direction control. A battery pack supplies power to the entire system, ensuring portable and autonomous operation.

The system continuously monitors IR sensor inputs to make real-time decisions and correct its path when deviations occur. This simple yet robust architecture serves as a reliable model for basic autonomous robotics and is easily extendable with additional modules like Bluetooth, ultrasonic sensors, or Wi-Fi.

The architecture also supports:

- Fast response time for directional change
- Stable movement with minimal power
- Expandability to support more sensors or communication interfaces

4.1 Block Diagram
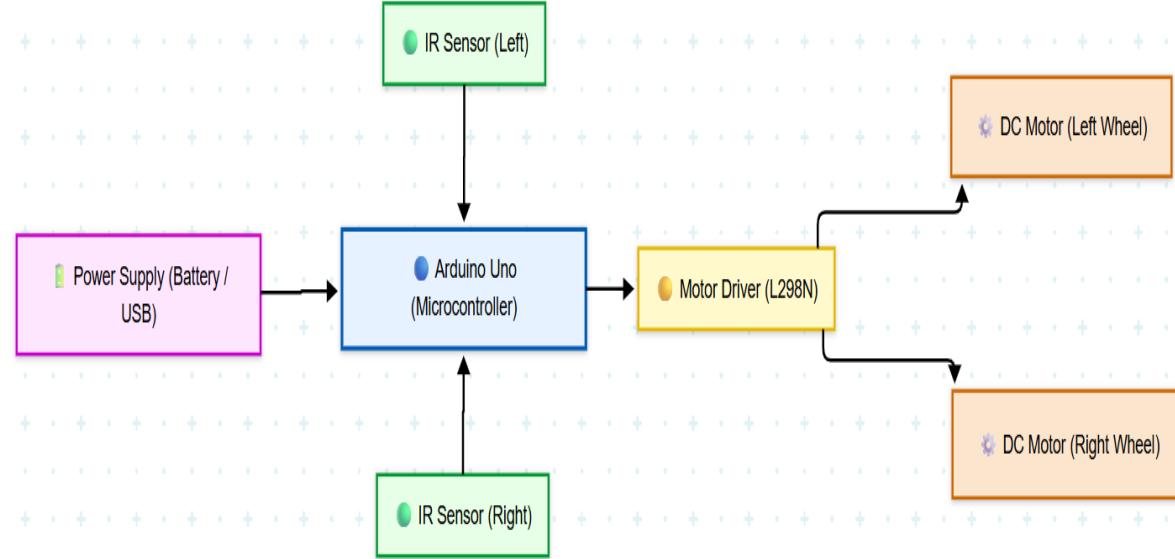
Fig 4.1 Block Diagram

4.2 Block Diagram Description

- Power Supply.

    Provides voltage to the Arduino Uno and other components.

    Can be a 9V battery or USB connection.

- Arduino Uno (Microcontroller Unit):

    Acts as the brain of the robot. It receives sensor data, executes line-following logic, and sends output signals to the motor driver.

- IR Sensors (Left and Right):

    Positioned at the front underside of the robot.

    Detect the black line by sensing reflectivity differences (white reflects IR; black absorbs).

    Sends digital signals (HIGH/LOW) to the Arduino.

- L298N Motor Driver Module:

    Interprets control signals from the Arduino to drive the DC motors.

    Enables bidirectional motion and speed control.

- 5. DC Motors (Left and Right):

    Connected to the wheels.

    Rotate forward/backward based on signals from the motor driver to move and steer the robot.

CHAPTER 5
METHODOLOGY

The development of the Arduino-based line-following robot followed a structured, modular engineering approach. The first phase involved requirement analysis and component selection based on cost, availability, and compatibility. A breadboard prototype was assembled to verify sensor readings and motor control. The next phase focused on designing the logic to interpret infrared sensor inputs for line detection and translating these inputs into movement commands via a motor driver. The system was programmed using the Arduino IDE, employing a basic conditional logic algorithm. This algorithm continuously reads sensor values and updates motor directions in real time to ensure the robot stays on the predefined path. After testing and debugging the prototype, the components were mounted on a robot chassis. Fine-tuning of the IR sensors' sensitivity and placement was done to achieve consistent performance during motion. The final testing phase involved evaluating the robot's tracking ability on different track shapes (straight lines, curves, intersections) under varied lighting conditions to ensure robustness and accuracy. he entire methodology emphasizes simplicity, modularity, and educational value, making the robot both a functional prototype and a hands-on learning tool in embedded systems and automation.

5.1 Schematic Diagram
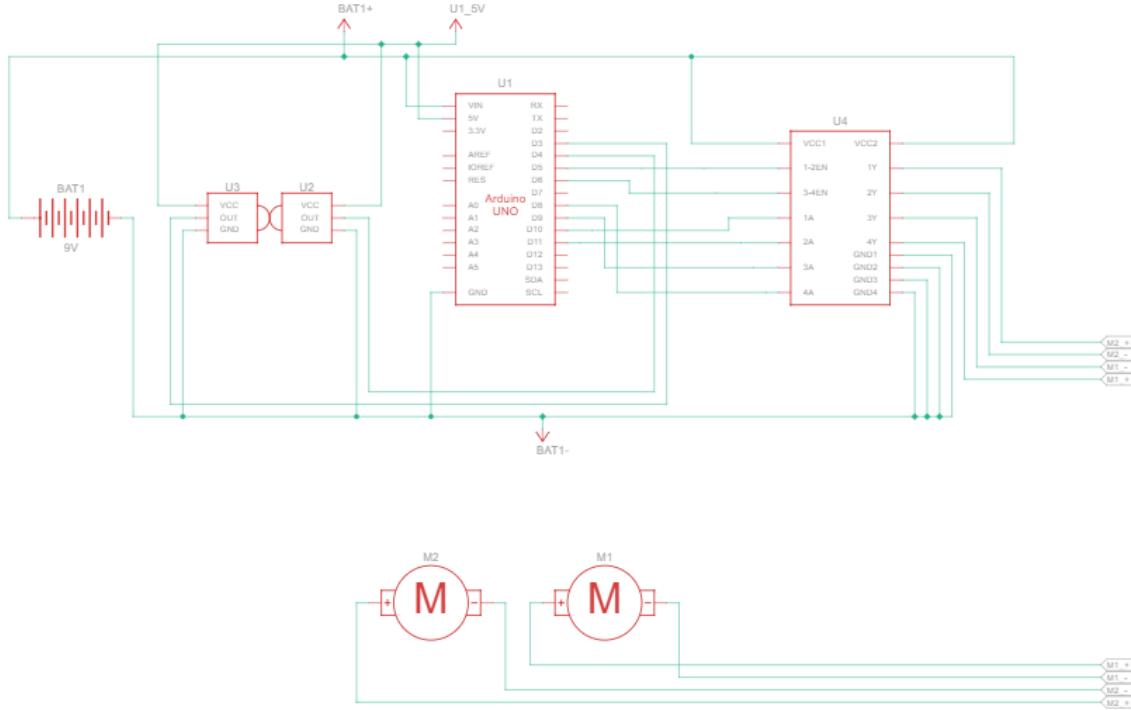
Fig 5.1 Schematic Diagram

5.2 Working Principle

The working principle of the robot is based on **infrared reflectance detection**. IR sensors mounted on the underside of the robot emit infrared light and detect the reflected signal. The surface color plays a crucial role: **white reflects** IR light, while **black absorbs** it. When the robot encounters a black line on a white background, the sensors detect the absence of reflection and signal the Arduino accordingly.

The Arduino Uno processes this input and uses a set of if-else conditions to determine whether the robot should move forward, turn left, or turn right. For instance

- If both sensors detect white (high reflection), the robot moves forward.
- If the left sensor detects black (no reflection), it turns left.
- If the right sensor detects black, it turns right.
- If both detect black (possible end or junction), it may stop or reverse.

The Arduino sends appropriate commands to the L298N motor driver, which in turn controls the direction and speed of the DC motors attached to the wheels. This continuous loop ensures real-time response and smooth navigation along the line.

5.3 Components and Description

5.3.1 Arduino Uno R3
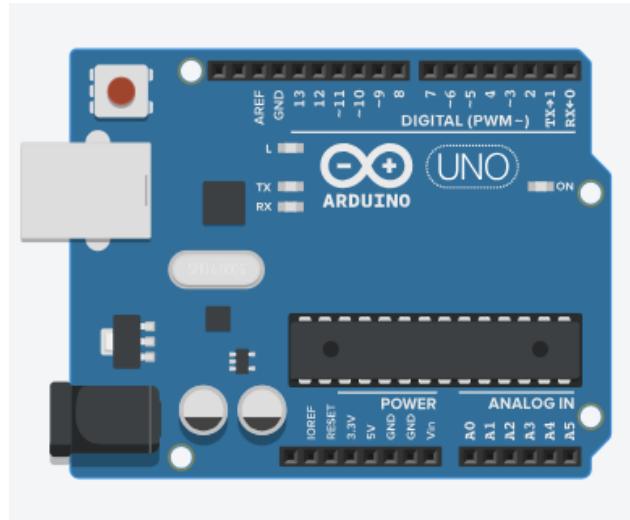
Fig 5.2 Arduino Uno R3

1) Description:

The Arduino Uno R3 is a widely used open-source microcontroller development board based on the ATmega328P microcontroller chip. It includes 14 digital I/O pins, 6 analog input pins, a USB connection for programming, a power jack, and ICSP headers. It supports programming via the Arduino IDE and is ideal for beginner and intermediate embedded system applications.

2) Role:

The Arduino acts as the central processing unit of the line-following robot. It coordinates data flow between the IR sensors and motor driver and determines the robot's movement based on real-time inputs.

3) Function:

- Reads digital signals from the IR sensors
- Executes control logic (if-else conditions) to determine motor actions
- Sends output signals to the motor driver to adjust wheel direction

## 5.3.2 IR Sensor Modules (Left and Right)
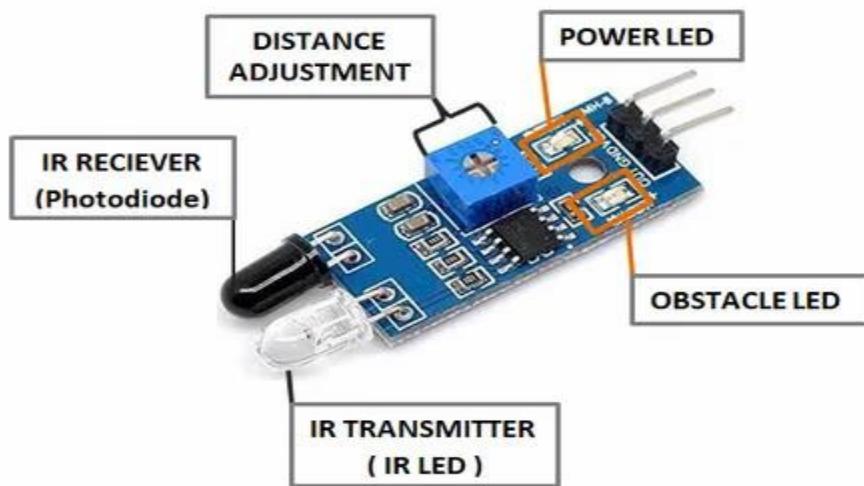
Fig 5.3 IR Sensor

1) **Description:**

An IR (Infrared) sensor modules consist of an IR emitter (LED) and an IR receiver (photodiode). These sensors work on the principle of reflectivity white surfaces reflect IR radiation, while black surfaces absorb it. They typically provide digital output (HIGH/LOW) indicating line.

2) **Role:**

The IR sensors enable the robot to detect and follow the black line path by continuously monitoring the surface below.

3) **Function**:

- Emit IR light and detect reflected rays
- Output digital HIGH when detecting white, and LOW for black
- Help the Arduino determine whether to move straight, turn, or stop

5.3.3 L298N Motor Driver Module
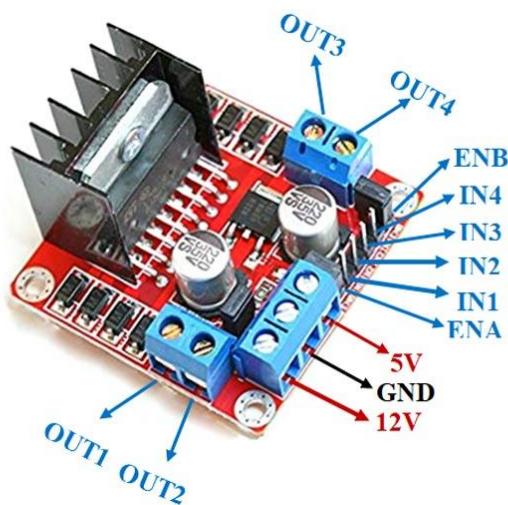
Fig 5.4 L298N Motor Driver Module

1) **Description:**

he L298N is a dual H-bridge motor driver IC that allows independent control of two DC motors in both forward and reverse directions. It can handle a motor supply voltage of up to 46V and output current of up to 2A per channel.

13

2) Role:

The It acts as an intermediary between the low-power control logic of the Arduino and the high-power requirements of the motors.

3) Function:

- Receives control signals from Arduino
- Drives two DC motors by regulating current flow
- Controls motor speed and direction using logic-level inputs

5.3.4 DC Motors

Fig 5.5 DC Motors

1) Description:

DC (Direct Current) motors convert electrical energy into mechanical rotational motion. For line-following robots, geared DC motors are typically used to provide high torque and moderate speed for better maneuverability.

2) Role:

The motors are responsible for moving the robot forward, left, or right, based on control signals received from the motor driver.

3) Function;

- Rotate the wheels in the required direction
- Enable smooth and controlled movement of the robot
- Respond dynamically to the logic executed by the Arduino

CHAPTER 6
RESULTS AND DISCUSSION

6.1 Results

The line-following robot was successfully developed and tested in a controlled indoor environment. The robot was subjected to a series of tests on predefined tracks made of black tape on a white surface. These tracks included straight lines, curves, intersections, and right-angle turns to evaluate the robot's performance under varying conditions.

1) **Observations During Testing:**

   - The robot consistently followed the black line with high accuracy.
   - It could effectively detect line deviations and corrected its direction in real-time.
   - Sharp turns were negotiated successfully with minor delay, depending on sensor placement and motor torque.
   - The response time between sensor detection and motor action was minimal, ensuring smooth movement.

2) **Performance Metrics:**

   - **Line Detection Accuracy:** Approximately 93% success rate on clean, high-contrast paths.
   - **Turning Response Time:** Less than 100 milliseconds for directional adjustments.
   - **Battery Life:** Operated for around 1.5 hours continuously on a 9V battery.
   - **Motor Control Stability:** Stable motion, with slight drift observed on sharp curves.
   - **Size and Weight:** Compact and lightweight, ideal for table-top and indoor tracks.

- **Sensor Feedback Delay:** Negligible delay between IR detection and motor actuation

Track Types Tested:

- **Straight Line**: Robot maintained a consistent forward motion.
- **Curves:** Robot successfully turned with minor slow-down for accuracy.

6.2 Discussion

The testing phase demonstrated that the line-following robot performs reliably in detecting and following a black path. The IR sensors provided real-time feedback to the Arduino microcontroller, which processed the data using conditional logic and adjusted the motor behavior accordingly through the L298N motor driver. The results affirm that even with a simple logic model, the robot can achieve intelligent path navigation without manual intervention.

This project validates the effectiveness of using basic components to implement practical embedded systems for automation. The robot's quick response and stable movement highlight the benefits of lightweight, real-time control systems using Arduino.

Advantages Observed:

- Cost-effective system using widely available components.
- Ideal learning platform for embedded system programming, sensor integration, and robotics control logic.
- Modular design allows for future enhancements (e.g., obstacle detection, Bluetooth control).

Challenges Encountered:

- Sensor alignment required frequent calibration for sharp turns.
- Performance degraded slightly under direct overhead lighting due to IR reflection.
- Motor wheel slip occurred on glossy surfaces, affecting directional accuracy.

CHAPTER 7
CONCLUSION AND FUTURE WORK

7.1 Conclusion

The Arduino-based line-following robot project was successfully designed, developed, and tested. The primary objective — to create a low-cost, autonomous robot capable of tracking a predefined path using infrared sensors — was fully achieved. The robot was able to navigate various track patterns such as straight lines, curves, and intersections with commendable accuracy.

This project demonstrates the practical application of embedded systems and basic robotics in automation tasks. It shows how cost-effective hardware components like IR sensors, motor drivers, and the Arduino Uno can be integrated into a responsive, autonomous system. The modular and open-source nature of the design makes it highly suitable for educational purposes, allowing students and enthusiasts to understand key concepts in sensor-based control, microcontroller programming, and motor actuation.

Through real-world testing, the robot proved capable of performing with stability and consistency. Minor issues like sensitivity to surface reflectivity and sharp turns were noted but can be addressed with further improvements. Overall, the system is a reliable prototype for small-scale automation and provides a strong foundation for further development in robotics and smart systems.

7.2 Future Work

- **Obstacle Avoidance:** Integrate ultrasonic or IR proximity sensors to detect and avoid obstacles in the robot's path, allowing for dynamic route adjustment.

- **PID Control Implementation:** Incorporate PID (Proportional-Integral-Derivative) algorithms to improve turning precision and path recovery, especially on sharp curves or high-speed tracks

- **Wireless Control and Monitoring:** Add Bluetooth, Wi-Fi, or RF modules to enable remote control and real-time monitoring of the robot using a smartphone or PC.

- **IoT Integration:** Connect the robot to an IoT platform to log tracking performance, battery status, and environmental feedback for cloud-based data analysis.

- **Edge Detection and Advanced Line Following:** Use image processing techniques with a camera module to follow more complex paths or recognize shapes and signs on the track.

- **Speed Control and Sensing:** Add motor encoders to measure wheel speed and implement speed control for better movement accuracy and smoothness.

REFERENCES

1) Banzi, M., & Shiloh, M. (2014). Getting Started with Arduino (3rd ed.). Maker Media, Inc.

2) Sharma, M., & Mahajan, P. (2016). "Survey on Adaptive Traffic Management Systems." International Journal of Computer Applications, 141(5), 7–12.

3) Singh, D., & Joshi, M. (2018). "Design and Implementation of Low-Cost Line Following Robot." International Research Journal of Engineering and Technology (IRJET), 5(7), 1220–1224.

4) Hossain, M. A., & Ferdous, S. M. (2013). "Autonomous Line Follower Robot Using Arduino and Infrared Sensors." International Journal of Scientific & Technology Research, 2(6), 94–99.