USER MANUAL

Analog Line Following Robot

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Team Outlaws

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Chapter 1

Introduction

The Analog Line Following Robot is an autonomous mobile robot designed to follow a line, usually represented by a black line on a white surface. Unlike digital robots that rely on microcontrollers and programming, this robot operates using a fully analog electronic control system. The behaviour of the robot is determined purely through electronic circuits, resulting in fast response and high reliability.

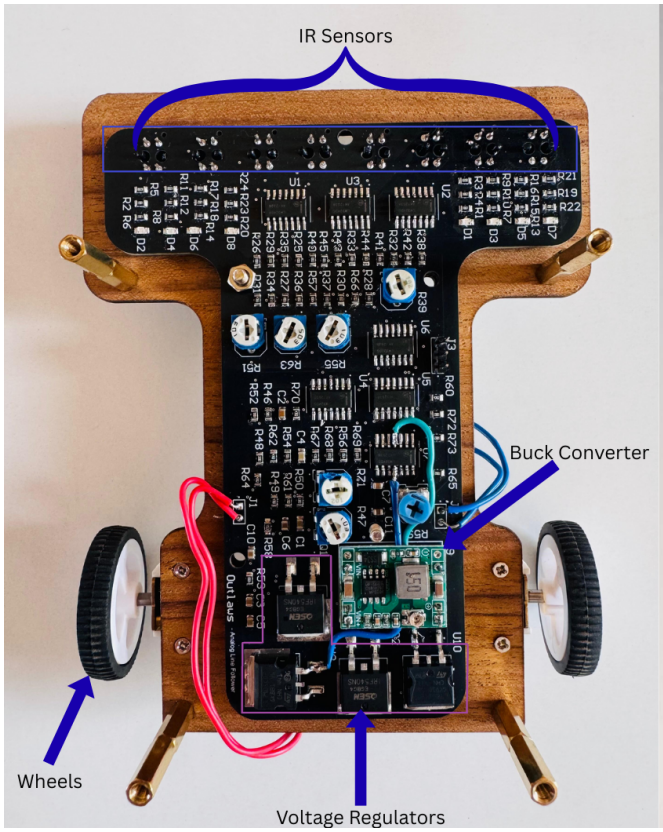
The robot uses an array of infrared (IR) reflective sensors to detect the position of the line beneath it. These sensor outputs pass through buffer circuits, weighted-sum processing blocks, and an analog PID controller consisting of proportional, integral, and derivative components.

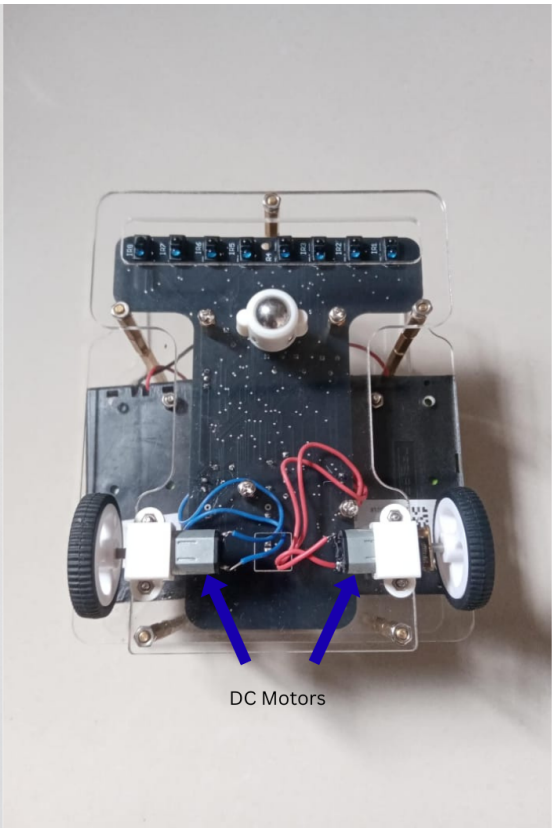
A triangular wave generator and a voltage comparator convert the PID output into PWM signals, which control the motors. This allows the robot to adjust its speed and direction smoothly based on the line position. The system is powered using two rechargeable Li-Ion batteries with appropriate voltage regulation.

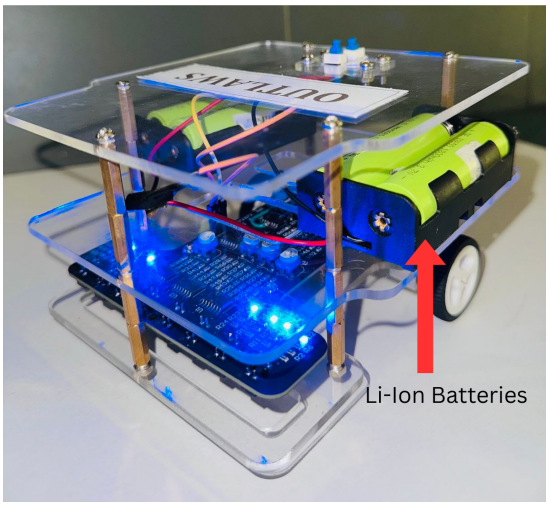
This manual explains the parts of the robot, how to operate it, safety guidelines, maintenance tips, and troubleshooting steps.

Chapter 2

Parts and Specifications







Main Components

- **IR Sensor Array (TCRT5000)** Detects the line using infrared reflection. Includes 8 sensors for higher accuracy.
- **Buffer Amplifiers** Condition and stabilize sensor output signals.
- **Weighted Scaling Adders** Generate left and right weighted sums for line position detection.
- **Analog PID Controller (P, I, D)** Provides smooth correction for line following.
- **Triangular Wave Generator** Generates the reference waveform for PWM creation.
- **Comparator (PWM Generator)** Converts analog PID output into PWM for motor control.
- **Transistor Motor Driver** Drives the motors using MOSFET switching.
- **DC Motors** Provide mechanical movement to the robot.
- **Li-Ion Batteries (4 $\times$ 3.7V)** Provide the main power supply.
- **Voltage Regulators** Generate stable $\pm$5V supply for analog operation.

Chapter 3

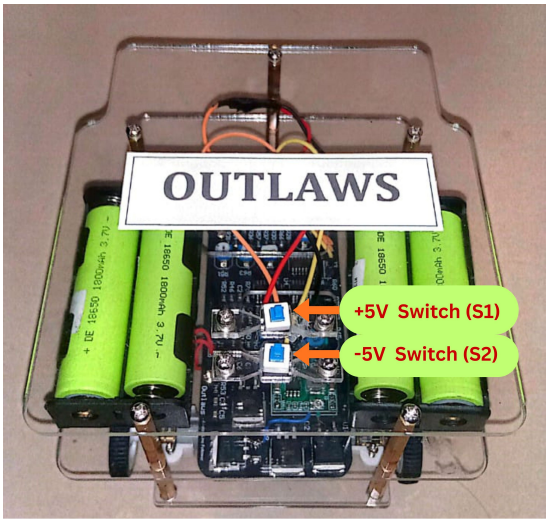
Assembly Overview

This section outlines the physical and electrical integration of the robot's components to ensure reliable analog performance.

- **Sensor Mounting**: Securely mount the IR sensor array (TCRT5000) at the front of the robot chassis. Ensure the sensors are positioned at a consistent height above the surface to maintain accurate infrared reflection.
- **PCB Installation**: Fix the main PCB—containing the buffer circuits, PID controller, and PWM generator—securely onto the chassis. Use standoffs to prevent short-circuiting the underside of the board against the frame.
- **Motor Integration**: Connect the left and right motor driver outputs to their respective DC motors. Ensure the polarity is correct so that a forward signal rotates both wheels in the intended direction.
- **Power Connectivity**: Connect the battery pack to the power input.
  - **Polarity Check**: Double-check the polarity before connecting to avoid damaging the voltage regulators ($\pm 5V$).
  - **Insulation**: Ensure all connectors are firmly attached and properly insulated to prevent electrical shorts.

Chapter 4

How to Use



1. **Charge Batteries**: Ensure the Li-Ion batteries are fully charged before operation.
2. Place the robot on a white surface with a distinct black line.
3. Turn on the main power switches (S1 and S2).
4. Ensure the IR sensors are aligned exactly above the line.
5. Allow the robot to adjust and move automatically.
6. If deviation occurs, reposition the robot manually and restart.
7. Keep the surface clean for optimal sensor performance.

Chapter 5

Safety Guidelines

Operating an analog robot with high-capacity Li-Ion batteries requires specific safety protocols to prevent hardware damage.

- **Battery Safety**:
  - **Short Circuits**: Do not short circuit the battery terminals, as this can lead to fire or battery failure.
  - **Charging**: Ensure batteries are properly charged using recommended chargers to maintain the cells at safe voltage levels.
- **Electrical Hazards**:
  - Avoid touching exposed wiring while the main power switches (S1 and S2) are in the ON position.
  - Keep the robot and its electronic components away from water or moisture.
- **Operational Precautions**:
  - **Moving Parts**: Avoid placing fingers or loose objects near the moving wheels during operation.
  - **Surface Limitations**: Do not operate the robot on uneven or dark surfaces, as these may interfere with the IR sensors or damage the chassis.

Chapter 6

Troubleshooting

6.1 Preset Adjustments and Functions

This robot uses several adjustable presets (trimmer potentiometers) on the PCB to fine-tune the analog PID control system and PWM generation. These presets allow the user to optimize line-following performance based on surface conditions, line thickness, and robot speed.

6.1.1 Preset Locations

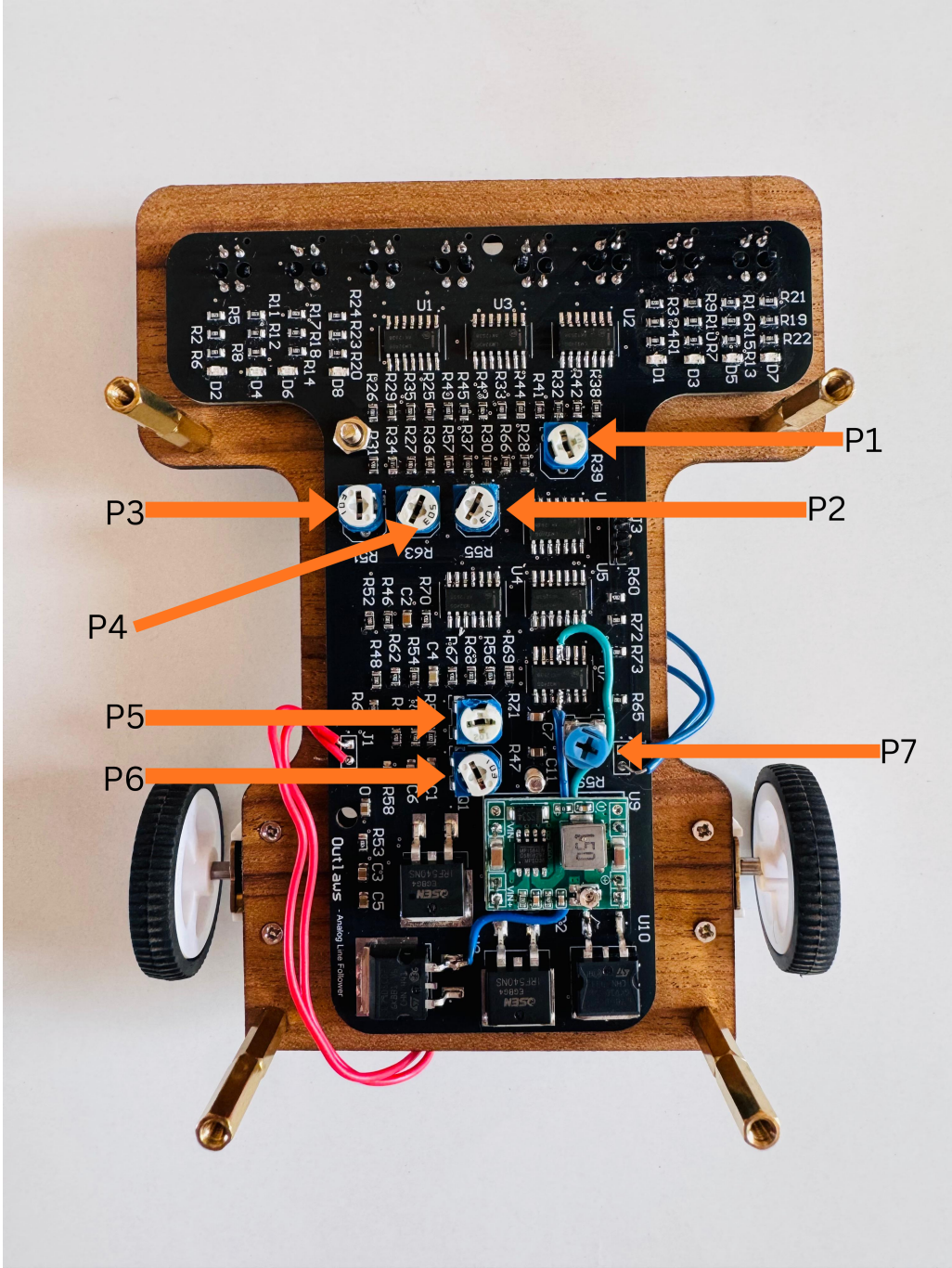


Figure 6.1: PCB layout showing adjustable presets P1–P7

Note: The preset labels P1 to P7 shown in Figure 6.1 correspond to the functions described in Table 6.1.

6.1.2 Preset Functions

Preset	Name	Function Description
P1	Total Error Zero Offset	Adjusts the zero offset of the total error signal. This preset is used to ensure that the error output is zero when the robot is perfectly aligned with the line.
P2	Integral Gain Adjustment	Controls the integral (I) component of the PID controller. Increasing this value helps eliminate steady-state error but excessive adjustment may cause oscillations.
P3	Derivative Gain Adjustment	Adjusts the derivative (D) component of the PID controller. This preset improves response to sudden changes in the line path and reduces overshoot.
P4	PID Output Scaling	Scales the total PID correction signal. This preset determines the overall strength of the control signal sent to the motor driver.
P5	PID Output Zero Offset	Corrects the zero offset of the total PID output. Used to balance the left and right motor speeds when no correction is required.
P6	Proportional Gain Adjustment	Controls the proportional (P) component of the PID controller. Increasing this value improves responsiveness but excessive gain may cause instability.
P7	PWM Frequency Adjustment	Adjusts the frequency of the triangular wave used for PWM generation. This preset affects motor smoothness and audible noise.

Table 6.1: Functions of adjustable presets on the PCB

6.2 Preset Adjustment Guidelines

- Always begin tuning with all presets set to their mid positions.
- Adjust one preset at a time while observing robot behavior.
- Start with P6 (Proportional), then P2 (Integral), and P3 (Derivative).
- Use P1 and P5 only if the robot drifts when perfectly centered.
- Adjust P7 if motors produce excessive noise or jerky motion.

Robot not following the line:

- Check if the IR sensors are clean.
- Ensure the line is thick and dark enough.

- Verify battery voltage is sufficient.

Robot shakes or oscillates:

- Reduce proportional gain (P).
- Check sensor alignment.

Robot moves too slowly:

- Motors may be underpowered—recharge batteries.
- Check motor driver MOSFETs.

Chapter 7

Maintenance and Care

Regular maintenance ensures the analog PID controller remains accurately tuned and the mechanical parts stay efficient.

- **Sensor Optimization**: Clean the IR sensor array after every use using a soft, dry cloth to remove dust that could interfere with line detection.
- **Electrical Upkeep**:
  - **Battery Storage**: Ensure batteries are stored at safe voltage levels when the robot is not in use.
  - **Connection Audit**: Periodically check all wiring and solder joints for signs of wear or loosening.
- **Mechanical Care**:
  - **Friction Management**: Lubricate the motor shafts if any friction or unusual noise is detected during movement.
  - **Traction**: Keep the wheels clean to ensure optimal grip on the white surface.