ZAS ROBOTICS

BUILD THE FUTURE

Navigational Robotics Series

Robot Car-1 (Sensors)

Documentation (V1.0)

Contents

1. Robot Car-1 (Sensors)- Product Overview & Hardware Documentation.

The ZAS Robotics Navigational Robot Car-1 (Sensors Edition) is a fully-featured educational robotics platform designed to teach students real-world concepts in autonomous navigation, embedded systems, motor control, and sensor-based decision making.
It is built using the Kit-1 Motion Control Board, dual DC gear motors, an ultrasonic distance sensor, an IR sensor array, and a servo-mounted scanning system that allows the robot to intelligently sense and respond to its environment.

At its core, Robot Car-1 uses an Arduino-based control board (mounted on the rear side) that reads sensor inputs and drives the motors through the TB6612 motor driver. The front-facing sensor system combines ultrasonic ranging and infrared detection, enabling the robot to perform:

- Obstacle avoidance
- Pit / edge detection
- Wall following
- Line and path behaviour
- Left-right environmental scanning
- Autonomous decision-making

By integrating hardware + coding + navigation algorithms, Robot Car-1 forms a strong foundation in reactive robotics, making it ideal for students learning how intelligent robots perceive and interact with their surroundings.

This kit is perfectly suited for:

- Schools & STEM education programs
- Engineering and polytechnic colleges
- Robotics and AI labs
- Maker spaces & innovation hubs
- Robotics clubs and competitions
- Self-learning robotics enthusiasts

Robot Car-1 (Sensors Edition) is an entry-level yet powerful platform that brings real autonomous robotics concepts into the hands of learners—simple enough for beginners, yet capable enough for advanced experimentation.

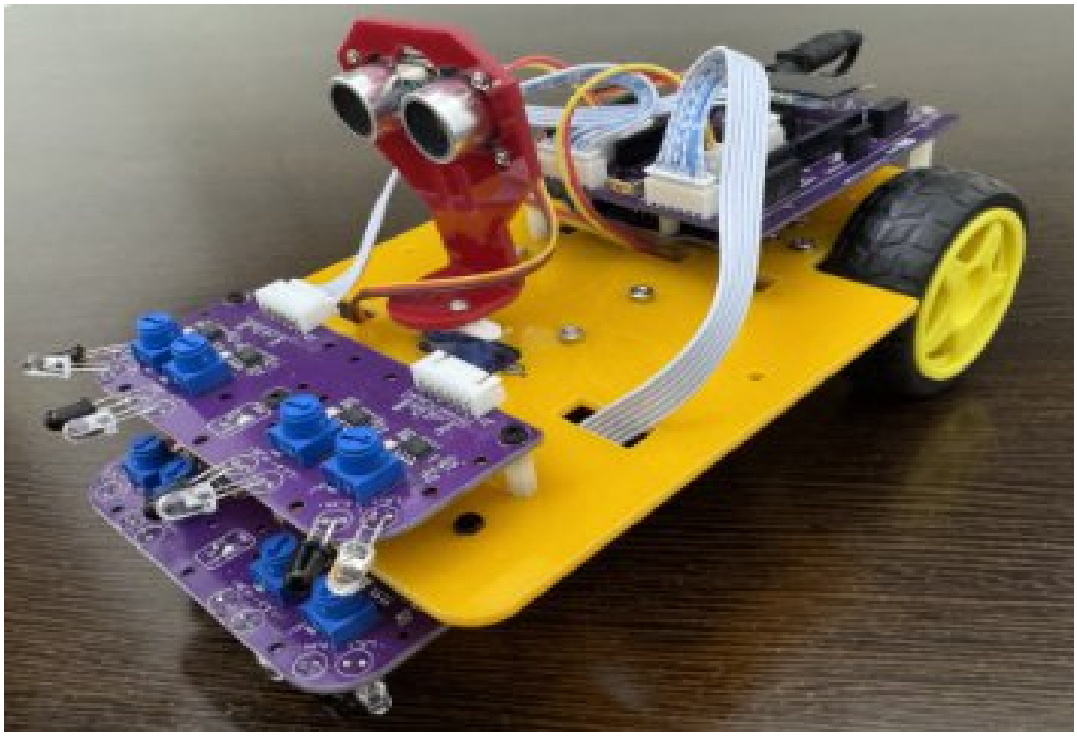

Figure 1. Robot Car-1 (Sensors edition) - Navigational Robotics Series

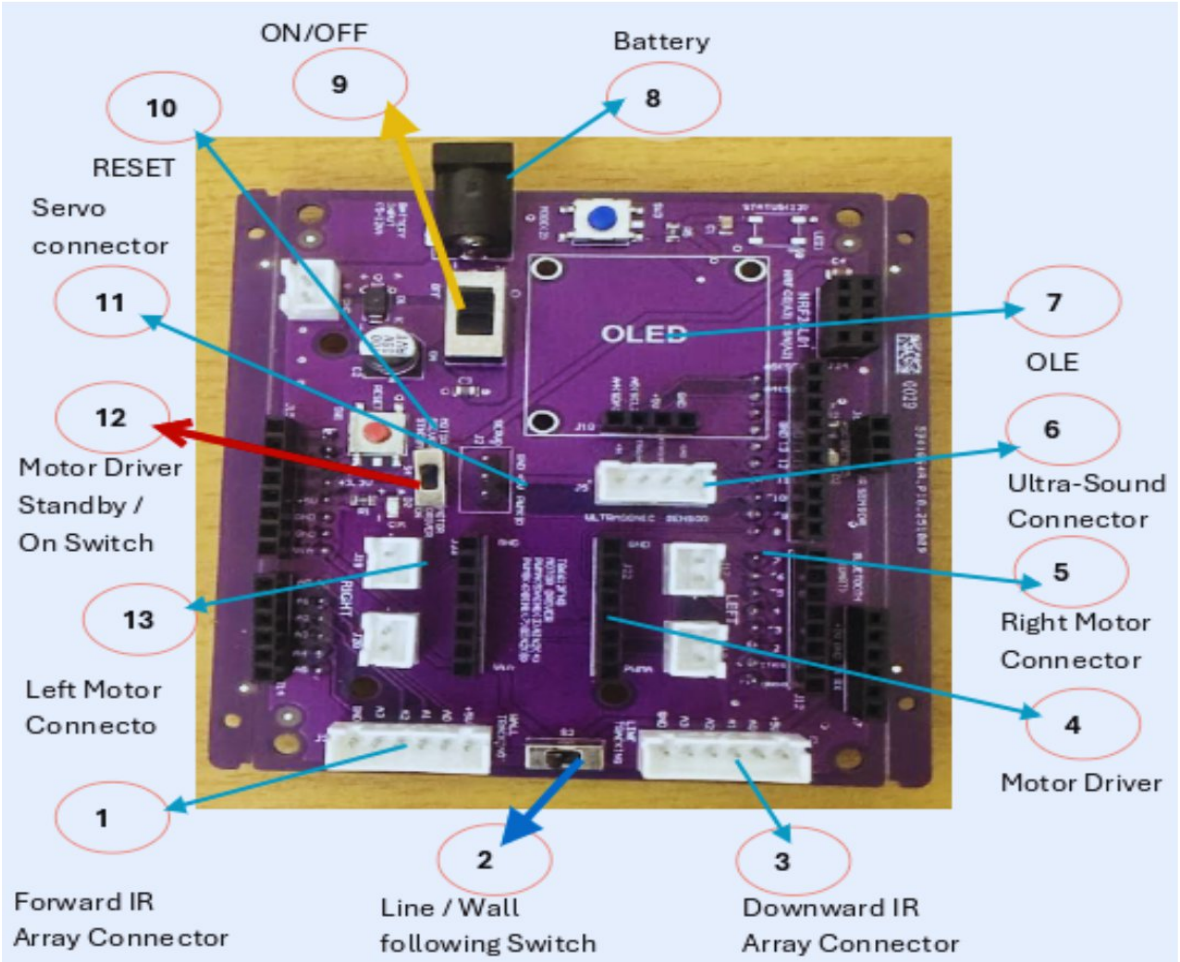

Figure 2. Robot Car-1 (Sensors edition) – Block Diagram

Component Description Table

SI No.	Component Name	Description	Function
1	**Forward IR Array Connector**	White connector for front-facing IR sensors	Connects the forward-facing IR sensor array for obstacle detection and navigation
2	**Line/Wall Following Switch**	Toggle switch for mode selection	Switches between line-following mode and wall-following mode
3	**Downward IR Array Connector**	White connector for downward sensors	**Critical for Pit Avoidance** - Connects 4 downward-facing IR sensors to detect edges and pits
4	**Motor Driver**	Motor control circuitry	Controls power and direction for both left and right motors
5	**Right Motor Connector**	White connector for right motor	Provides power and control signals to the right DC motor
6	**Ultra-Sonic Connector**	White connector for ultrasonic sensor	Connects HC-SR04 or similar ultrasonic sensor for distance measurement
7	**OLED**	Display module connector	Connects OLED display for showing sensor values, mode, and status information
8	**Battery Connector**	Black power connector	Main power input from 7.4V Li-ion battery pack
9	**ON/OFF Switch**	Power switch	Master power control for the entire robot
10	**RESET**	Reset button	Resets the microcontroller to restart the program
11	**Servo Connector**	3-pin connector for servo motor	Connects servo motor for pan-tilt mechanisms or gripper control
12	**Motor Driver Standby/On Switch**	Toggle switch for motor driver	Enables or disables the motor driver (safety feature during programming)
13	**Left Motor Connector**	White connector for left motor	Provides power and control signals to the left DC motor

2. Hardware System Architecture

The ZAS Robotics Navigational Robot Car-1 (Sensors Edition) is engineered with a structured, classroom-friendly modular architecture. The complete system is organized into three primary hardware layers: **Base Chassis**, **Front Sensor Module**, and the **Creative Controller Board with Arduino Integration**. This layered design makes the robot easy to assemble, easy to troubleshoot, and ideal for STEM classrooms, training labs, and competitions.

- ### Base Chassis (3-Wheel Drive System)

The mechanical foundation of Car-1 is a stable **3-wheel drive platform**, designed for smooth navigation and accurate sensor performance.

Key Features

Two DC Gear Motors (Left & Right)

provides forward, reverse, turning, and left/right pivot motions

Front Caster Wheel

Acts as the third support point, enabling free rotation and stability across multiple indoor surfaces.

Rear-Mounted Battery Pack

Ensures proper weight balance and prevents front-side tilting.

Central Servo Mount

A dedicated bracket securely holds the servo that rotates the ultrasonic sensor for directional scanning.

- ### Front Sensor Module (IR + Ultrasonic System)

The front module is the robot's "eyes," enabling intelligent decision-making based on live sensor feedback.

IR Sensor Array (Downward Facing)

- Mounted at the front bottom edge
- Adjustable sensitivity (using onboard potentiometers)
- Used for:
- Pit detection
- Edge detection
- Line tracking
- Close-range obstacle detection on the ground

Forward IR Obstacle Sensors

- Detect front-facing obstacles and walls
- Trigger braking and direction correction logic

Ultrasonic Sensor with Servo Rotation

- Mounted on a **servo bracket** for 180° sweeping
- Measures distance using Trigger & Echo
- Used for:
- Object avoidance
- Wall following
- Path planning decisions
- Scanning left–center–right before turning

- # Creative Controller Board (Car-1) + Arduino Integration

The Car-1 Creative Controller Board is a custom-designed PCB engineered to simplify wiring, improve durability, and enable fast classroom deployment.

Front-Side Features

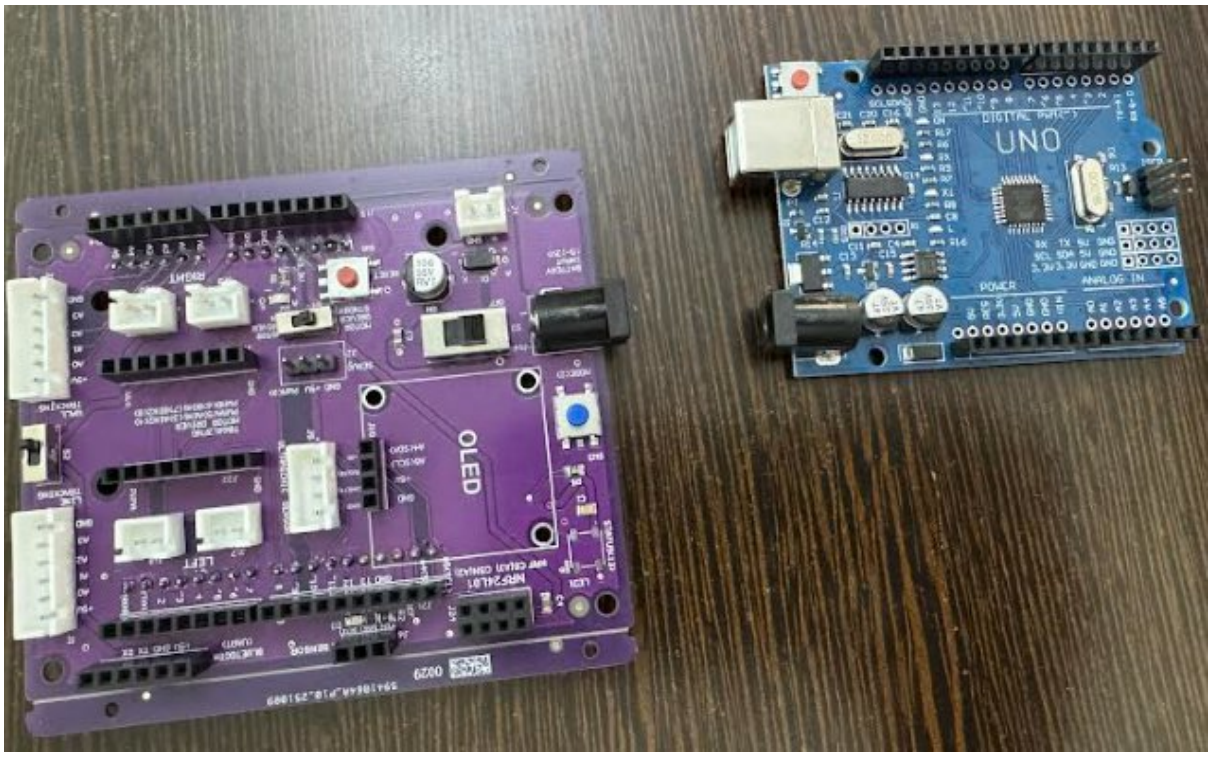

Figure 4. Robot Car-1 (Sensors edition) - Front-Side View of car-1 Sensor creative board and Arduino

Plug-and-play JST connectors for:

- IR sensor boards (4 downward + 2 forward)
- Ultrasonic sensor module
- TB6612 motor driver interface
- OLED display
- Buttons/switches
- **Onboard diagnostic LEDs**
- **Protected power rails and regulated 5V output**
- **Clearly labeled pins** for error-free connections

Back-Side Engineering

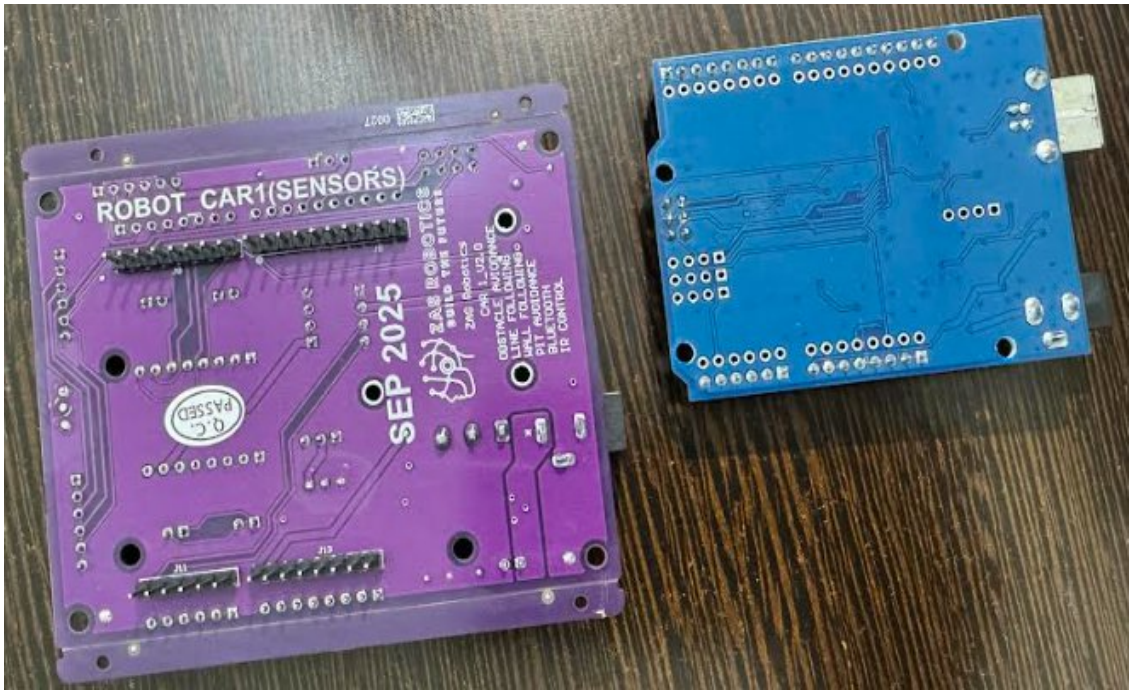

Figure 5. Robot Car-1 (Sensors edition) - Back-Side View of car-1 Sensor creative board and Arduino

- Clean signal routing to minimize noise in sensor readings
- Reinforced motor current traces

Arduino Board Mounted on the Controller Board

The Arduino Uno is mounted directly on top of the Creative Controller Board, transforming the assembly into a **single unified controller system**.

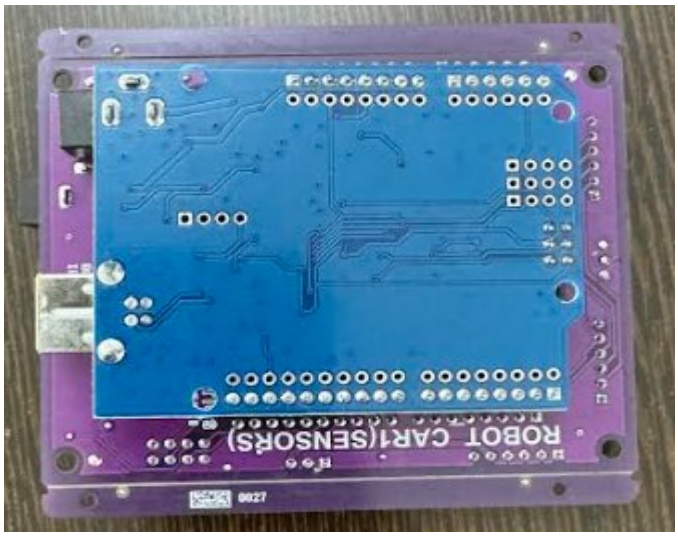

Figure 6. Robot Car-1 (Sensors edition) - Mounted car-1 Sensor creative board and Arduino

Advantages

- No jumper wires required
- All signals (motor, sensors, power) routed internally
- Fast debugging — modules connect independently
- Ideal for beginner and intermediate learners
- strong and durable for repeated classroom use

This professional mounting system provides a clean, robust hardware stack that mirrors real-world robotics architecture.

3. Component List & Function

The robot's behaviour is achieved through coordinated interaction of sensing, actuation, and control modules.
Each component plays a specific role in perception, movement, or processing, as described in the table below.

Component / Module	Purpose / Role
Arduino Board	Core microcontroller responsible for reading sensors and controlling motor actions
TB6612 Motor Driver	Drives the left and right DC motors using PWM for speed control and direction signals
2× DC Gear Motors	Provide all motion, including forward

	movement, reverse, turning, and rotation
Ultrasonic Sensor (HC-SR04)	Measures distance using trigger/echo pulses; used for front obstacle detection
IR Sensor Array (4 sensors)	Detects floor edges, pits, line markings, and close-range objects
Servo Motor	Rotates the ultrasonic sensor for left/center/right environmental scanning
OLED Display	Shows debug information, distance readings, and current navigation mode
Battery Pack	Supplies power to motors, sensors, and the microcontroller

4. IR Sensor Theory for Robot Car-1 (Downward & Forward Sensing)

The Robot Car-1 uses two types of IR sensing arrangements—**downward-facing IR sensors** and **forward-facing IR sensors**—each serving a different purpose in autonomous navigation.

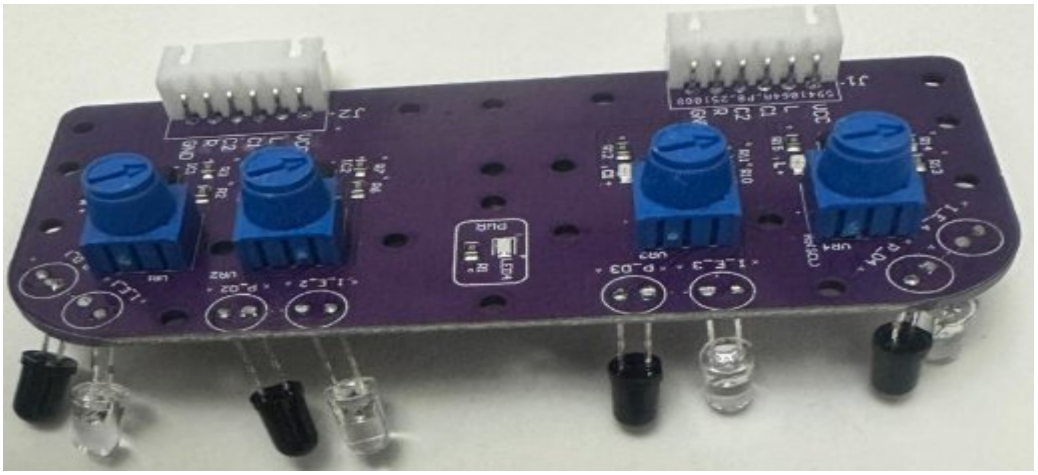

Figure 7. Robot Car-1 (Sensors edition) - downward-facing IR sensors

Downward-Facing IR Sensors (Pit / Edge Detection)

(Based on first attachment)

These sensors are mounted at the bottom side of the robot and are designed to detect changes in floor surface, such as:

- Pits / gaps
- Edges of a table
- Stairs or drop-offs
- Black lines or dark regions

How it Works

IR modules emit infrared light toward the ground.
The amount of reflected IR light depends on the surface:

- Light/white surface → High reflection → Sensor ON
- Dark/black surface → Low reflection → Sensor OFF
- No ground below (pit) → No reflection → Sensor OFF

This allows the robot to:

- Stop before falling off an edge
- Avoid pits and unsafe zones
- Stay on the designated path
- Detect floor markings

Key Advantage

Downward IR sensing provides fast-response safety—essential for preventing the robot from falling or crossing boundaries.

Forward-Facing IR Sensors (Short-Range Obstacle Detection)

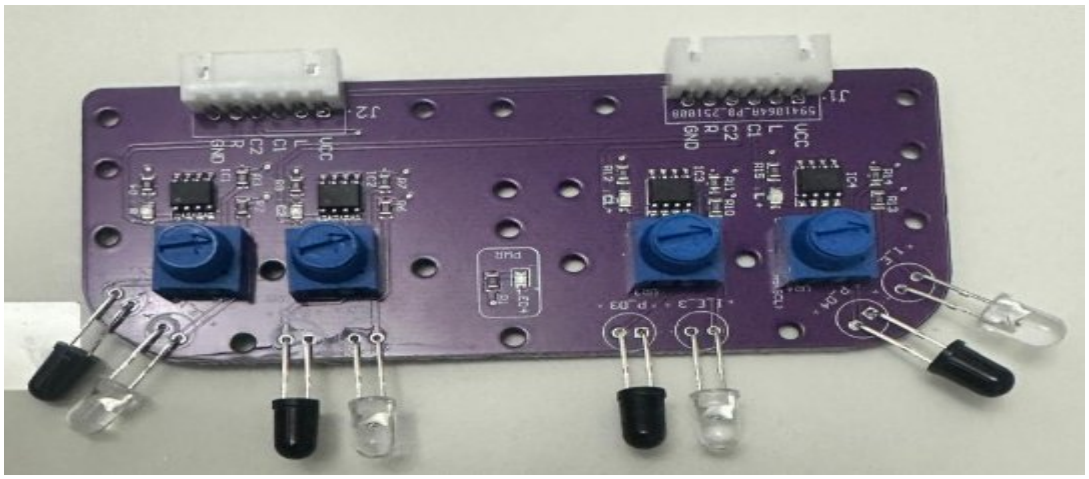

Figure 8. Robot Car-1 (Sensors edition) - upward-facing IR sensors

These sensors face forward and detect **nearby obstacles**, such as:

- Walls
- Furniture
- Objects placed in front of the robot
- Narrow gaps and corners

How it Works

Forward IR sensors project IR light outward.
When the IR light hits a nearby object, it reflects back to the receiver.

- **Object close → Strong reflection → Sensor ON**
- **Object far → Weak/no reflection → Sensor OFF**

Forward IR sensors are ideal for:

- Detecting obstacles before collision
- Edge-based wall following
- Short-range object avoidance
- Supporting ultrasonic sensor in decision making

Why Use Forward IR With Ultrasonic?

Ultrasound handles **distance measurement**, but IR sensors excel at detecting:

- Very short-range obstacles
- Thin objects
- Fast changes in proximity

Together, they provide **dual-layer safety** and more accurate navigation.

Sensor Type	Purpose	Advantage
Downward IR (Pit Sensors)	Detect pits, edges, floor color changes	Prevents falling, essential safety
Forward IR (Obstacle Sensors)	Detect close objects & obstacles	Fast response, detects thin objects
Ultrasonic Sensor	Measures distance & avoids obstacles	Long-range precision scanning

5. Ultrasonic Scanner & 3-Wheel Drive Theory

The Navigational Robot Car-1 uses a combination of **servo-based ultrasonic scanning** and a **two-motor, three-wheel drive system** to achieve smooth autonomous movement and intelligent obstacle avoidance. Each mechanical component contributes to stable navigation and accurate environmental sensing.

Figure 9. Robot Car-1 (Sensors edition) - ultrasonic mount

Ultrasonic Sensor Mounted on a Servo (Environmental Scanning)

The ultrasonic sensor (HC-SR04) is mounted on a **rotating servo platform** that allows the robot to perform **left–center–right scanning** instead of sensing only in front.

How It Works

- The servo rotates the ultrasonic sensor in small steps (e.g., 0°, 45°, 90°, 135°, 180°).
- At each angle, the ultrasonic module measures distance.
- The robot builds a simple "map" of nearby obstacles.

Based on the shortest and farthest distances, the robot decides:

- whether to turn left or right
- whether to move forward
- or whether to stop and scan again

Advantages

- Much smarter than fixed ultrasonic sensors
- Detects open paths more accurately
- Helps navigate narrow passages
- Enables advanced modes like **wall following** and **path decision making**

6.Two Rear Wheels (Drive Wheels)

The robot uses **two large rear wheels**, each connected to a **DC gear motor**, forming a **differential drive system**.

Figure 10. Robot Car-1 (Sensors edition) - Rear Wheels

How It Works

- Both motors forward → robot moves straight
- Left motor only → robot turns right
- Right motor only → robot turns left
- Motors in opposite directions → robot rotates in place

Advantages

- Excellent turning capability
- Simple motor control using PWM + direction signals
- Smooth forward and curved path navigation
- Suitable for obstacle avoidance & line/path following

7. Front Caster Wheel (Support Wheel)

The front of the robot uses a **metal ball caster wheel**, also called a free-rolling support wheel.

Figure 11. Robot Car-1 (Sensors edition) – Front caster Wheel

Purpose

- Supports the robot's weight at the front
- Allows friction-free movement in any direction
- Follows the steering generated by the rear wheels
- Ensures stability during rotation and turns

Advantages

- Zero steering mechanism needed
- Low friction on most surfaces
- Smooth motion even on curves

8. Dual DC Motors (Main Power for Movement)

The robot is powered by **two TT DC gear motors** with ~130 RPM speed.

Figure 12. Robot Car-1 (Sensors edition) – Dual DC motor for rear left and right wheels

These motors provide all the motion:

- Forward movement
- Reverse movement
- Turning left / right
- Rotating on the spot

The motors are controlled using the **TB6612 motor driver**, which provides:

- High-efficiency PWM speed control
- Reliable direction control
- Enough current to drive both motors simultaneously

9. Motor Driver Pin Configuration (TB6612 + Motors)

Left Motor

- A-IN1 → Arduino Nano Pin **3**
- A-IN2 → Arduino Nano Pin **4**
- PWMA → Arduino Nano Pin **5**

Right Motor

- B-IN1 → Arduino Nano Pin **8**
- B-IN2 → Arduino Nano Pin **7**
- PWMB → Arduino Nano Pin **6**

Motor Specifications

- TT Motor (Yellow Gear Motor)
- **Speed:** 130 RPM
- **Operating Voltage:** 6V

11. Robot Operating Modes & Algorithms

Robot Car-1 supports multiple autonomous navigation behaviours:

Obstacle Avoidance

- Infrared Obstacle Avoidance (short-range)
- Ultrasonic Obstacle Avoidance (front distance scanning)

Line / Pit / Edge Behaviour

- Pit avoidance
- Edge detection
- Line interaction

Wall Following

- External Wall Following – Left
- External Wall Following – Right
- Internal Wall Following – Left
- Internal Wall Following – Right

Additional Modes

- IR Remote Control (optional)
- Bluetooth App Control (optional)
- Servo-based directional scanning

- Basic Motor Movement (Forward / Backward / Turns)

Purpose / Learning Outcome

Students learn DC motor control using an H-bridge motor driver and PWM speed regulation.

Working Principle

Each motor is controlled by two direction pins and one speed (PWM) pin.
Changing HIGH/LOW combinations determines forward, reverse, left, or right movement.

Logic Summary

- Write PWM to both motors
- Set direction pins for desired motion
- Add delays to observe each action

```
set motor pins as OUTPUT
set speed for both motors

repeat:
   move forward for 2 sec
   move backward for 2 sec
   turn right for 0.5 sec
   turn left for 0.5 sec
   stop for 1.5 sec
```

• Infrared Obstacle Avoidance (2 IR Sensors)

Purpose / Learning Outcome

Students understand digital IR sensing for detecting nearby obstacles.

Working Principle

- IR output = **0** → no obstacle
- IR output = **1** → object detected
- If both sensors detect object → stop

Logic Summary

- Read left IR and right IR
- If both clear → move forward
- If any blocked → stop

```
read leftIR
read rightIR

if both sensors = clear:
   forward
else:
   stop
```

• Line Following (4-Sensor IR Array)

Purpose / Learning Outcome

Students learn following a black line using differential motor control.

Working Principle

- Left sensor detects line → turn left
- Right sensor detects line → turn right
- Both white → forward
- Both black → stop (junction/stop line)

• Pit / Edge Avoidance (Table Edge Detection)

Purpose / Learning Outcome

Robot detects a cliff using downward IR sensors to avoid falling.

Working Principle

- Downward IR sensors detect ground visibility:
- White surface = HIGH
- No reflection at table edge = LOW

```
if all sensors HIGH:
    forward
if center LOW:
    backward → turn left
if left LOW:
    turn right
if right LOW:
    turn left
if many LOW:
    backward → escape turn
```

• Ultrasonic Obstacle Avoidance (Servo Scanning)

Purpose / Learning Outcome

Students learn ultrasonic distance measurement + servo-based scanning.

Working Principle

- Look forward (90°)
- If obstacle within distance → scan left & right
- Choose direction with more free space
- Turn away from obstacle

```
look forward → measure distance
if distance > safe:
  forward
else:
  scan left
  scan right
  choose larger distance
  turn toward free side
```

- # Wall Following

Purpose / Learning Outcome

Robot maintains a side distance using IR sensors to follow a wall.

Working Principle

- Read wall-side IR sensors
- Adjust steering to stay parallel to wall

```
if too close: stop left motor
if too far: stop right motor
if aligned: move forward
```

12. Learning Outcomes for Students

By working with Robot Car-1, students will learn:

- Programming Arduino for motors, sensors, logic flow
- Driving DC motors using **TB6612** with PWM speed control
- Interfacing sensors: ultrasonic distance, IR edge detection
- Implementing servo-based scanning for obstacle direction
- Writing navigation algorithms:
- forward, stop, turn
- avoid edges & pits
- avoid obstacles
- Displaying data on **OLED using I2C**
- Debugging using Serial Monitor
- Integrating hardware + code to build an autonomous robot
- Laying the foundation for:
- reactive robotics
- path decision-making
- sensor fusion
- multi-mode navigation

13. Safety Guidelines

a. **Double-check all power wiring**
   Ensure correct VCC and GND for motors, sensors, OLED, etc.
b. **Use correct voltage input**
   Battery input must be **5V–12V**.
c. **Work on a safe surface**
   Use insulated table (wood/plastic), ensure it is dry.
d. **Do not leave the robot powered unattended.**
e. **Build and test incrementally**
   Power microcontroller first, connect modules step-by-step.
f. **Never leave batteries charging unattended.**
g. **Robot Car-1 is for indoor use only.**
h. **Always use 4-eyes principle**
   (Two students cross-check wiring before powering ON)

14. Additional Mechanical Notes

- Robot Car-1 uses a **3-wheel configuration**.
- **2× powered wheels** (left & right)
- **1× caster wheel** for balancing and turning
- The battery pack is mounted on the **rear side of the chassis** for optimal weight distribution.
- The ultrasonic sensor is mounted on a **servo platform** allowing left-center-right scanning to estimate obstacle direction.
- IR sensors are mounted on a **front purple PCB** with:
- adjustable sensitivity knobs
- plug-and-play connectors
- multiple IR LED+receiver pairs for reliability

15. Summary

The ZAS Robotics Navigational Robot Car-1 (Sensors Edition) is a powerful hands-on learning platform that bridges the gap between beginner robotics and advanced autonomous systems. Its clean modular design, plug-and-play sensor architecture, and real-world navigation modes allow students to build, program, and understand intelligent robots just like professionals. With its versatility and educational depth, this kit is perfectly suited for STEM education, robotics clubs, competitions, and engineering learning labs