Autonomous Mobile Robot Challenge

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Embedded Systems Final Design Project, Fall 2025

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Introduction and Project Overview

This project details the design and implementation of an autonomous mobile robot tasked with navigating a complex multi-zone course. The mission profile includes high-speed line following, low-light tunnel detection, obstacle avoidance, and precision parking. The system is built on a standalone embedded circuit board using the PIC16F877A microcontroller. As a team, we dedicated countless hours to making this project victorious through problem-solving, debugging, trial-and-error, and efficient time-management skills.

To demonstrate low-level mastery, the firmware was written in Embedded C without built-in drivers. All timing, PWM, and sensor logic were implemented using raw register manipulation (Masking) and hardware interrupts.

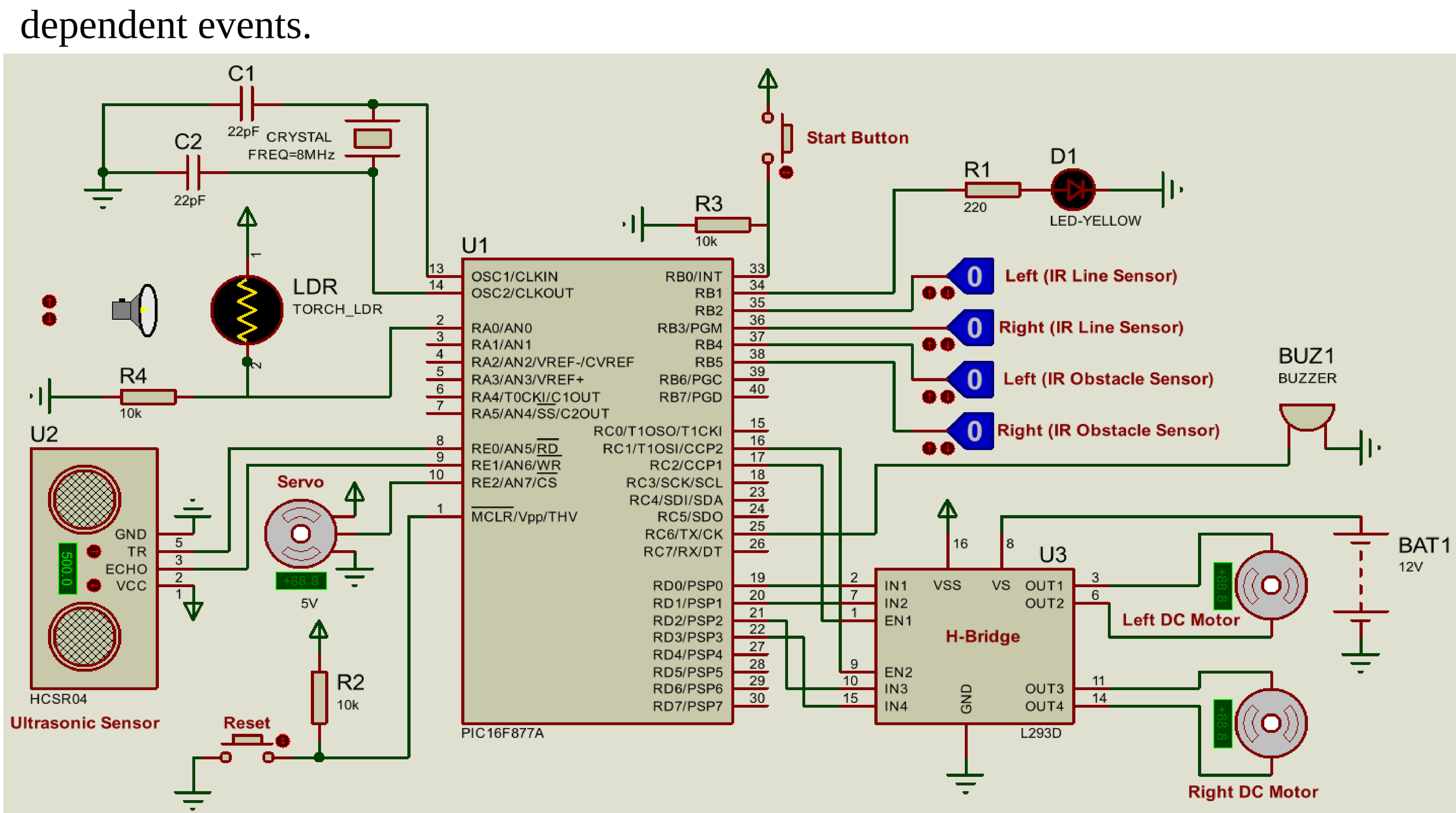
Design and System Architecture:

Embedded Control & Sensor Fusion: The robot is powered by a robust, standalone PIC16F877A embedded circuit, designed to process environmental data in real-time.

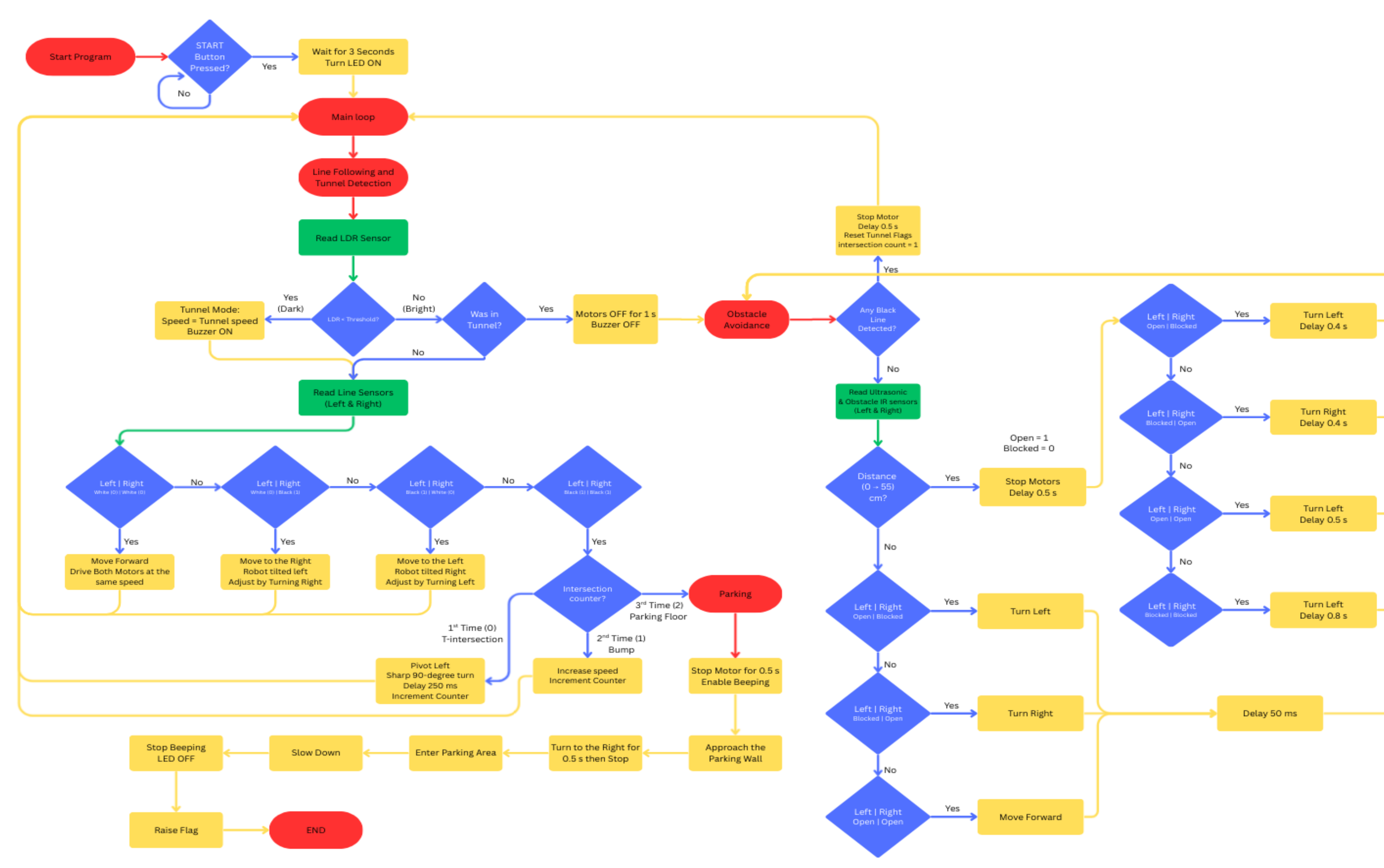
Finite State Machine (FSM): We implemented a dynamic control architecture that allows the robot to seamlessly switch behaviors, transitioning instantly from high-speed line following to precision maneuvering when obstacles or parking zones are detected.

Multi-Sensor Integration: The design successfully fuses data from 7 distinct inputs, including Ultrasonic distance ranging, LDR light sensing, IR arrays, and a Start pushbutton, to create a complete analysis of the robot's surroundings.

Interrupt-Driven Timing: To ensure responsiveness, the system utilizes hardware interrupts for critical tasks, such as PWM motor speed regulation and keeping a precise track of time-dependent events.



Electrical Design on Proteus



Flowchart Diagram of the Logic

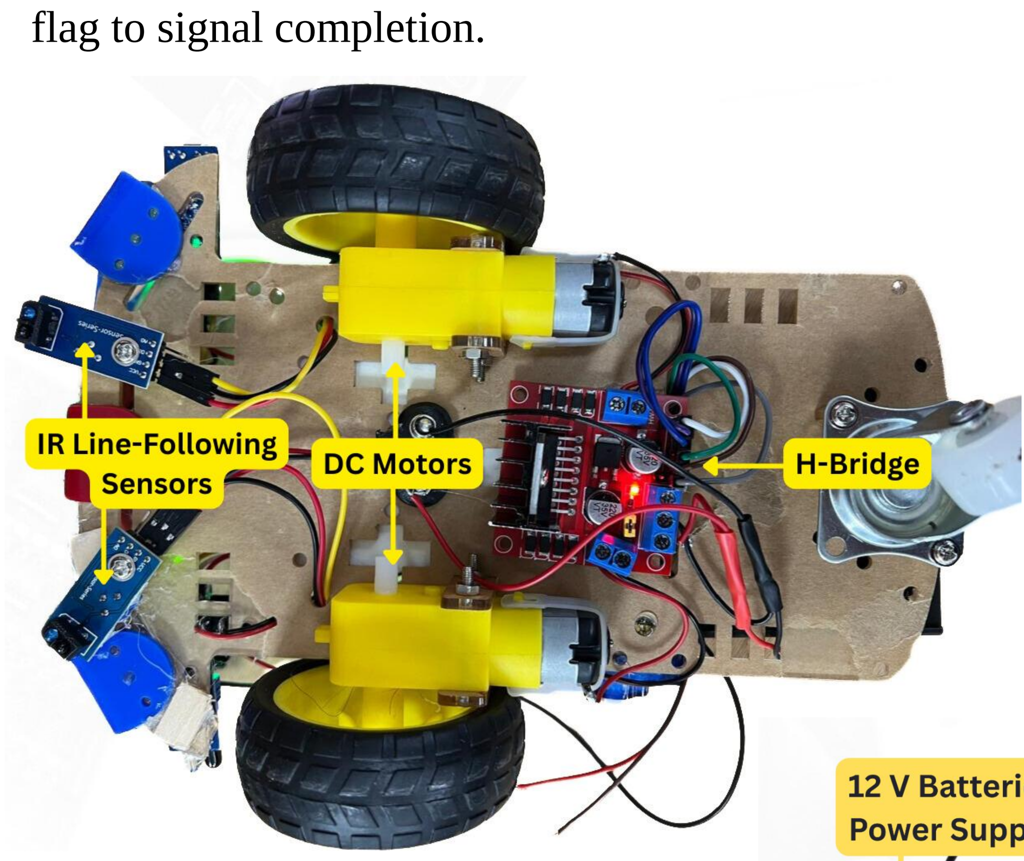
Results and Operational Achievements:

Mission Success & Adaptive Logic: The final prototype successfully navigated the complete multi-zone course, demonstrating intelligent adaptability in complex scenarios.

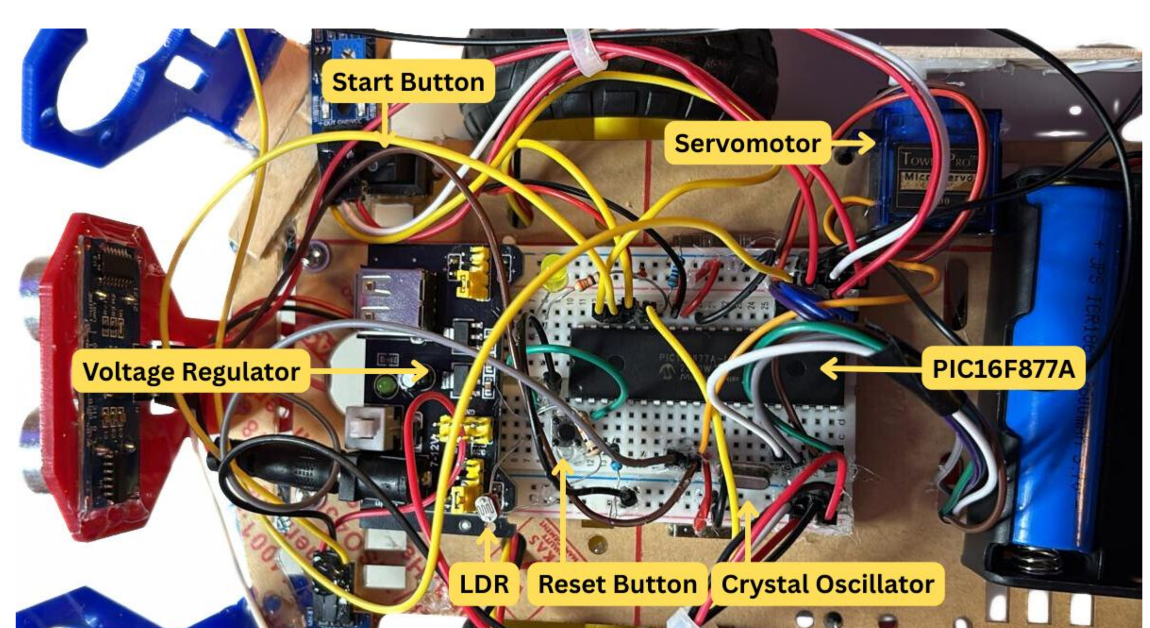
Smart Intersection, Bump, and Parking Detection: A key innovation was the development of the "Intersection count" algorithm. The system successfully detects the T-intersection, the 30° Incline, and the parking ground and distinguishes them from each other to take the correct corresponding course of action.

Tunnel Response: The analog light-sensing circuit provides rapid response times, instantly detecting dim environments to activate the buzzer and increasing speed to minimize time spent in the tunnel zone.

Precision Parking: The robot executes a highly accurate end-of-mission routine, using ultrasonic feedback to approach the wall, perform a sharp 90° turn to the right, and raise the servo flag to signal completion.

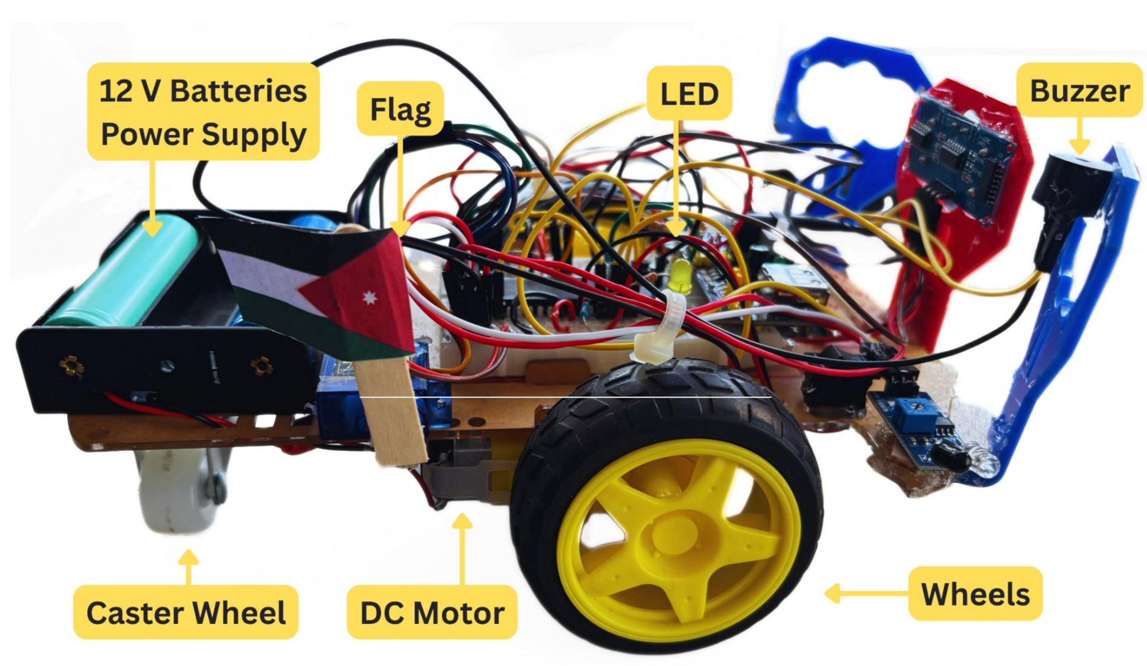


Bottom View

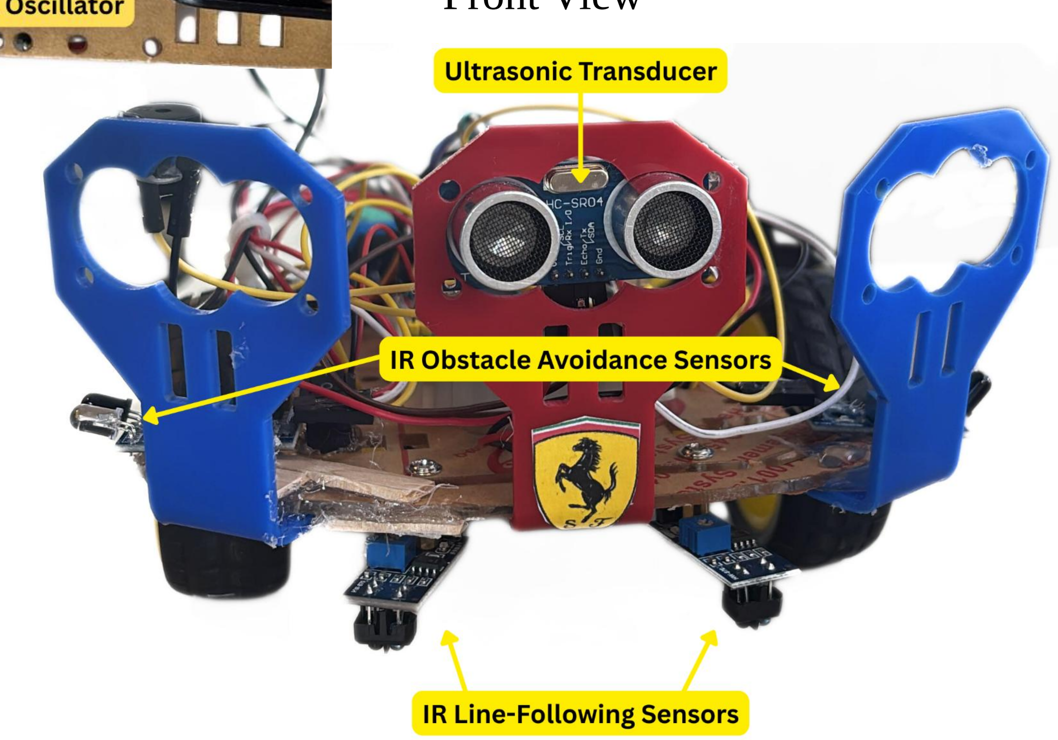


Top View

Side View



Front View



Conclusion, Summary, and Future Work

The project successfully met all physical and operational constraints. By developing drivers from scratch, the team gained deep proficiency in low-level Embedded C, specifically in Finite State Machine (FSM) design, Register Masking, and Manual Interrupt Handling.

The current PCB strategically maps motor enable pins to RC1 (CCP2) and RC2 (CCP1), allowing for a seamless firmware upgrade to hardware-based PWM without circuit redesign. While the Software-PWM (Timer0) works effectively, migrating to Hardware PWM (CCP Modules) in future iterations would free up CPU cycles for more advanced algorithms, such as PID control for smoother line tracking.