

Secure Drive-by-Wire Conversion and Autonomous Lane-Keeping Platform (SecureDBW)



Modern autonomous vehicles rely on Drive-by-Wire (DBW) architectures, where steering, throttle, and braking are electronically actuated rather than mechanically controlled. Such architectures provide the foundation for advanced driver assistance systems (ADAS), autonomous driving functions, and software-defined vehicles. In industrial practice, one of the first steps in autonomous vehicle development is converting a conventional vehicle into a software-controllable platform while ensuring safe remote operation, reliable telemetry, and emergency intervention capabilities.

The aim of this project is to convert an existing electric ride-on vehicle or RC vehicle into a secure Drive-by-Wire (DBW) platform capable of autonomous lane following, encrypted remote operation, and real-time telemetry. Students are expected to replicate a real-world engineering workflow by integrating mechanical design, embedded control, computer vision, wireless communication, cybersecurity, and autonomous navigation into a single multidisciplinary test platform.

The design must have the following features:

- The system must include electronically actuated steering, throttle, and independent emergency braking mechanisms to convert the vehicle into a DBW platform without requiring mechanical driver input.
- Manual remote operation must be executed via a physical driving station utilizing analog inputs for steering, acceleration, and braking, requiring students to develop a general physical control interface that mimics the mechanical inputs of a real vehicle.

- An embedded vehicle controller must be developed to translate high-level driving commands into real-time, actuator-level control signals.
- The system must utilize a monocular camera-based perception system to detect lane markings and autonomously maintain lane position using suitable control algorithms.
- A secure RF communication system must be developed to support encrypted manual driving, autonomous mode switching, and emergency stop functionality.
- The system must support bidirectional telemetry to wirelessly transmit critical vehicle information (speed, battery status, motor currents, steering position, and diagnostics) to a ground station in real time.
- Use of personal or laptop computers is not allowed for data acquisition or processing. The system must include an embedded processing unit for all operations other than providing telemetry information on the ground station.

The system must respect the following performance criteria:

- The project must utilize an existing electric ride-on vehicle or large-scale RC vehicle as the base platform.
- The vehicle's speed must be software-limited to a maximum of 1 m/s during autonomous operation.
- The lane-keeping algorithm must maintain lateral tracking errors (measured from the center of the lane) within one quarter of the vehicle width under nominal test conditions, and speed errors within ± 0.1 m/s of the desired speed, relying exclusively on a single forward-facing camera without external positioning systems.
- The encrypted RF communication must operate reliably over a minimum distance of 20 meters in open environments.
- The communication latency introduced by encryption and wireless transmission must remain below 100 ms for control commands.
- Fail-safe mechanisms must ensure the vehicle stops completely within 0.5 seconds upon communication failure, an emergency stop command, or critical system faults.
- The onboard power system must support a minimum of 20 minutes of continuous operation per test session.

Some possible extra features of the system are the following:

- Develop a desktop or web-based graphical ground control station for real-time visualization of telemetry, vehicle trajectory, actuator states, and system diagnostics.
- Develop a lane detection pipeline with a neural network capable of end-to-end autonomous steering.
- Integrate all embedded controllers and actuators using a CAN bus communication network similar to those used in commercial vehicles.
- Extend the platform with waypoint navigation, autonomous parking, or return-to-home capabilities.
- Integrate a Large Language Model (LLM) or Vision-Language Model (VLM) into the autonomous driving stack to perform semantic scene interpretation, explain vehicle

decisions, generate adaptive driving strategies, or assist perception and path-planning algorithms.

- Adopt a modular architecture to facilitate independent development, testing, and future expansion.