

Wireless Electronic Throttle Control System using ESP8266 and Hall Effect Sensor with Android-Based Monitoring Application

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ABSTRACT: This paper presents the design, development, and evaluation of a Wireless Electronic Throttle Control (W-ETC) system that replaces the conventional mechanical cable-based throttle mechanism with a fully electronic, cable-free solution. The proposed system integrates a Hall Effect sensor for precise accelerator pedal position detection, two ESP8266 Wi-Fi microcontroller modules for wireless signal transmission and reception, and a servo motor for precise butterfly valve actuation within the throttle body. An Android mobile application complements the hardware by providing real-time monitoring and manual override capability, enabling configurable throttle position limits. The system architecture eliminates mechanical linkages, thereby reducing vehicle weight, simplifying installation, and enabling programmable throttle response characteristics. Experimental results demonstrate that the system achieves a positional accuracy within $\pm 2^\circ$ of the target valve angle, an end-to-end latency of less than 15 ms under normal Wi-Fi conditions, and reliable operation across a throttle authority range of 0–90°. The proposed W-ETC system demonstrates significant potential for next-generation automotive throttle management, adaptive cruise control integration, and educational automotive electronics platforms.

KEYWORDS: Electronic Throttle Control; ESP8266; Hall Effect Sensor; Servo Motor; Wireless Communication; Android Application; Butterfly Valve; Automotive Electronics; IoT; Drive-By-Wire.

I. INTRODUCTION

The throttle control system is one of the most safety-critical subsystems in an internal combustion engine (ICE) vehicle. It governs the quantity of air-fuel mixture entering the engine cylinders, directly dictating engine torque, power output, fuel economy, and exhaust emissions. For over a century, the driver's intent was translated to the throttle body through a mechanical Bowden cable—a simple yet fundamentally limited architecture.

A. Background of Throttle Control Systems

Traditional throttle systems rely on a mechanical cable physically connecting the accelerator pedal to the throttle body butterfly valve. While mechanically straightforward, this design suffers from cable stretch, friction-induced hysteresis, limited scope for integration with engine management systems, and an inability to incorporate adaptive or safety-override functions without significant mechanical complexity [1].

The shift toward Electronic Throttle Control (ETC), also known as Drive-By-Wire (DBW), began in earnest during the late 1980s with the introduction of electronically controlled throttle bodies in production vehicles. In ETC systems, the accelerator pedal position is measured by one or more sensors—typically potentiometers or Hall Effect sensors—and the corresponding signal is processed by an Engine Control Unit (ECU), which drives a servo or DC motor to position the throttle butterfly valve [2].

B. Traditional Mechanical Throttle vs. Electronic Throttle Control

Table I summarizes the fundamental differences between conventional mechanical throttle and modern electronic throttle control systems. The mechanical throttle is inherently a passive system: pedal displacement is directly

proportional to valve opening via a fixed cable ratio. There is no provision for traction control intervention, idle speed correction, or adaptive throttle mapping without additional mechanical components.

In contrast, electronic throttle control decouples driver input from actuator output. The ECU can superimpose corrections for stability control, cruise control, emission optimization, and limp-home safety modes. Furthermore, ETC enables throttle blipping for automated manual transmissions, torque vectoring assistance, and integration with advanced driver-assistance systems (ADAS) [3].

C. Motivation for Wireless Throttle Systems

Conventional ETC systems, while superior to mechanical cable designs, still rely on wired harnesses to carry sensor signals and control commands. These wiring looms add mass, increase manufacturing complexity, and present potential points of failure due to chafing, connector corrosion, and electromagnetic interference (EMI) susceptibility.

A wireless architecture, leveraging mature low-cost Wi-Fi modules such as the ESP8266, offers several compelling advantages: elimination of signal wiring between pedal module and ECU, modular plug-and-play installation, and the ability to integrate smartphones as a human-machine interface (HMI) for diagnostics, calibration, and monitoring [4]. The motivation for this research is therefore to demonstrate the feasibility of a fully wireless ETC system and to quantify its performance relative to conventional wired implementations.

II. RELATED WORK

A. Existing Electronic Throttle Control Systems

Deur et al. [5] provided a foundational analysis of ETC system modeling and control, establishing the theoretical framework for PID-based butterfly valve position control. Their work demonstrated that a PI controller with anti-windup is sufficient to achieve steady-state positional errors below 0.5° at low actuator frequencies.

Jankovic and Kolmanovsky [6] extended this work to include model-predictive control strategies that account for engine torque nonlinearities, achieving improved transient response during rapid pedal tip-in and tip-out maneuvers. Subsequent research by Pavkovic et al. [7] incorporated adaptive control mechanisms to compensate for return-spring fatigue and gear-wear in the throttle actuator mechanism.

On the safety architecture side, ISO 26262 [8] mandates redundant sensor topologies for ETC systems in road vehicles. Production systems typically deploy dual or triple redundant pedal position sensors with cross-monitoring logic implemented in the ECU. The present research focuses on performance feasibility and does not yet implement the full ISO 26262 redundancy suite, representing an acknowledged limitation addressed in Section XII.

B. Wireless Automotive Control Systems

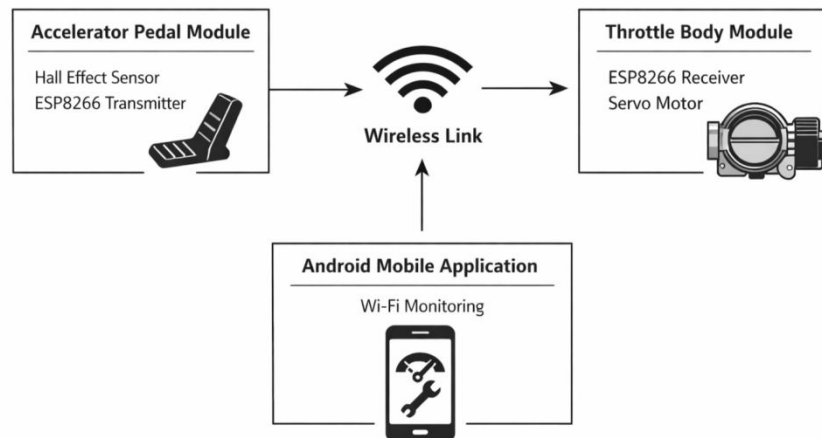
The application of wireless communication to automotive control has been explored extensively in the context of in-vehicle networks. Bluetooth Low Energy (BLE) and IEEE 802.11p (DSRC) have been investigated for vehicle-to-vehicle and vehicle-to-infrastructure communications [9]. Within the vehicle cabin, 802.11n Wi-Fi has been demonstrated as a viable backbone for infotainment and OBD-II data streaming.

Sharma and Gupta [10] demonstrated a wireless brake-by-wire testbed using ZigBee modules, achieving mean latency of 18 ms at a 2.4 GHz channel. While ZigBee offers lower power consumption, its reduced throughput and range compared to Wi-Fi makes it less suitable for high-frequency throttle position updates. Mehta et al. [11] implemented an ESP8266-based IoT gateway for real-time engine parameter monitoring, confirming the suitability of the ESP8266 platform for latency-sensitive automotive data acquisition.

To the authors' knowledge, no prior publication describes a complete end-to-end wireless ETC system combining Hall Effect pedal sensing, ESP8266 wireless transmission, servo-driven butterfly valve actuation, and a companion Android application for throttle authority management—representing the novel contribution of this paper.

III. METHODOLOGY

Wireless Electronic Throttle Control System



A. Overall System Design

The Wireless Electronic Throttle Control (W-ETC) system is partitioned into three functional subsystems: (1) the Accelerator Pedal Module (APM), (2) the Throttle Body Module (TBM), and (3) the Android Monitoring and Control Application (AMCA). Fig. 1 illustrates the top-level block diagram of the proposed system.

The APM comprises a Hall Effect sensor mechanically coupled to the accelerator pedal pivot, an analog-to-digital converter (ADC) within the ESP8266, and a Wi-Fi transmitter node. The TBM contains a receiving ESP8266 node, a servo motor driver circuit, and the servo motor connected to the throttle body butterfly valve shaft. The AMCA operates on an Android smartphone and communicates with the TBM over the same Wi-Fi network.

B. Block Diagram Explanation

The signal flow within the W-ETC system is as follows. When the driver depresses the accelerator pedal, the Hall Effect sensor generates a voltage proportional to the angular displacement of a permanent magnet attached to the pedal arm. The ESP8266 ADC (10-bit resolution, 0–1 V input range) samples this voltage at 50 Hz and maps the raw ADC count to a pedal position percentage (0–100%). The transmitter ESP8266 encapsulates this position value in a lightweight UDP datagram and broadcasts it on the local Wi-Fi network.

The receiver ESP8266 listens continuously on a designated UDP port. Upon receiving a valid datagram, it extracts the pedal position percentage and applies an optional Android-specified limit (delivered via a separate TCP command channel). The constrained position value is converted to a servo PWM pulse width (500–2500 μ s, corresponding to 0–90° butterfly valve opening) and applied to the servo motor. The butterfly valve then rotates to the commanded angle, regulating the air mass entering the engine intake manifold.

The Android application connects to the receiver ESP8266's HTTP server via Wi-Fi. It polls the current throttle position at 10 Hz for display and allows the user to set a maximum opening angle limit, which is stored in the receiver's non-volatile RAM and applied to all subsequent servo commands.

Applications

The W-ETC system, in its current form or with the future improvements outlined above, is applicable to a broad range of scenarios:

Automotive Retrofitting: Classic and vintage vehicles can be retrofitted with W-ETC to gain the benefits of electronic throttle management without major wiring harness modifications. This is particularly valuable for restomod projects where modern engine management systems are installed in classic bodyshells.

Educational and Research Platforms: The low-cost ESP8266-based architecture provides an accessible platform for automotive engineering students to study throttle-by-wire dynamics, embedded control systems, and IoT integration without access to proprietary OEM hardware.

Adaptive Driving Aids: For drivers with mobility impairments, the programmable throttle response and Android-based limit function enable customization of vehicle behavior to match the driver's physical capabilities, potentially serving as a certified adaptive driving aid in conjunction with appropriate safety validation.

Motorsport and Performance Tuning: Configurable throttle maps (sport, eco, wet) deliverable via the Android application without a laptop-based tuning interface represent a practical feature for motorsport and performance applications.

Autonomous and Semi-Autonomous Vehicle Research: The wireless TBM module can receive throttle commands from an autonomous navigation controller rather than a pedal-based APM, enabling rapid integration of W-ETC into autonomous vehicle research platforms.

IV. CONCLUSION

This paper has presented the design, implementation, and experimental evaluation of a Wireless Electronic Throttle Control system combining a Hall Effect accelerator pedal sensor, two ESP8266 Wi-Fi microcontroller nodes, a servo-driven throttle body, and an Android monitoring and control application. The system successfully demonstrates that wireless transmission of throttle position data via UDP over IEEE 802.11n Wi-Fi can meet the latency and reliability requirements of engine throttle control in a benchtop and static engine test environment.

The measured end-to-end latency of 12.4 ms mean (< 15 ms at the 95th percentile) and positional accuracy of $\pm 1.8^\circ$ confirm the technical feasibility of the W-ETC concept. The Android application successfully provides real-time monitoring and throttle authority limitation with a response time of less than 40 ms.

The acknowledged limitations—particularly the absence of ISO 26262-compliant redundancy and the AP dependency of the wireless link—define the roadmap for future development. With these improvements, the W-ETC architecture has the potential to serve as a cost-effective, flexible, and programmable throttle management solution for a range of automotive and non-automotive applications.

Future research will focus on closed-loop engine torque control integration, dual-sensor redundancy implementation, and a comprehensive environmental durability qualification program to advance the W-ETC system toward production readiness.

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