

Automation and IOT Based Vertical Car Parking System

Andhale Prafulla Eknath¹, Bodke Kalyani Madhukar², Ugale Poonam Dilip³, Vishwase Arti Sunil⁴,
Prof. S. S. Hadpe⁵

¹²³⁴Student, Department of Electrical Engineering, Matoshri College of Engineering & Research Center,
Nashik, Maharashtra, India

⁵Guide, Department of Electrical Engineering, Matoshri College of Engineering & Research Center,
Nashik, Maharashtra, India

Email: [prafullaandhale711@gmail.com] | Savitribai Phule Pune University, Pune

Abstract — The rapid increase in the number of vehicles has created a severe shortage of parking space in urban areas, where conventional surface and multi-storey parking consume large amounts of land and are inefficient in space utilization. This paper presents the design, fabrication and testing of an Automation and IoT Based Vertical Car Parking System — a prototype that uses electromechanical, electronic and IoT-based components to automate the parking and retrieval of vehicles across two floors. The system is built around an ESP32 microcontroller and uses NEMA 17 stepper motors driven by DRV8825 drivers for vertical lift movement via a TR8×2 lead screw, while a DC geared motor with an L298N driver rotates the parking platform. Six HC-SR04 ultrasonic sensors detect slot occupancy, an MFRC522 RFID module with six dedicated cards handles user authentication, and a 16×2 LCD with red/green LED indicators provides on-site feedback. SPDT limit switches serve as a safety cut-off, and the Blynk IoT platform enables real-time remote monitoring of all six slots. Twelve functional test cases were executed, all of which passed, and the prototype achieved 100% slot-detection accuracy with average parking and retrieval times of 18–26 seconds. The results demonstrate that a low-cost, IoT-enabled vertical parking prototype can be realised using readily available microcontroller and electromechanical components, with the working principle scalable to full-size automated parking structures.

Keywords — Vertical Parking, ESP32, RFID, Stepper Motor, Lead Screw, Ultrasonic Sensor, Blynk IoT, Automation.

1. INTRODUCTION

The exponential growth in the number of vehicles in urban areas over the past two decades has led to an acute shortage of parking spaces. Conventional surface-level parking lots consume large amounts of valuable land, and even multi-storey conventional car parks require ramps, wide lanes and significant structural investment while still being limited in capacity. Automated Parking Systems (APS) offer an efficient alternative: vertical parking structures stack vehicles in a lift-based mechanism, storing up to four times as many vehicles in the same footprint as conventional parking. In the Indian context, where urban land prices are high and parking space is critically limited, such systems hold strong promise for residential complexes, shopping malls, hospitals and offices.

Manual parking is time-consuming, prone to human error, and requires attendants, while drivers often waste time and fuel searching for empty slots due to the lack of real-time occupancy information. These issues motivate the present work, which aims to:

- Design and fabricate a working two-floor, six-slot vertical car parking prototype;
- Implement RFID-based authentication for slot assignment and retrieval;
- Achieve precise vertical movement via a lead-screw and stepper-motor assembly, and horizontal slot alignment via a DC geared motor;

- Provide real-time occupancy monitoring using ultrasonic sensors, an LCD and LED indicators;
- Develop IoT-based remote monitoring using the Blynk platform on ESP32 Wi-Fi; and
- Implement limit-switch based safety cut-off to protect the mechanical structure.

The scope of the present work is limited to the design, fabrication and testing of a small-scale prototype that demonstrates the working concept using miniature model vehicles; full-scale civil construction and payment-gateway integration are identified as directions for future work rather than part of the present scope.

2. LITERATURE REVIEW

A review of existing work on automated and IoT-enabled parking systems was carried out to identify the present research gap. Singh et al. proposed a PLC and RFID based multi-level parking system using conveyor belts and vertical lifts, reporting up to 60% reduction in parking time but noting high implementation cost and mechanical complexity. Patil and Shinde presented an IoT-based smart parking system using NodeMCU (ESP8266) and ultrasonic sensors with a Blynk-based mobile dashboard, but without any vertical mechanical movement. Joshi et al. built an Arduino and servo-motor based automatic parking prototype with RFID-based slot identification, limited to a single horizontal level. Verma and Agarwal demonstrated a vertical carousel parking system using NEMA 17 stepper motors and a TR8×2 lead screw, achieving positional accuracy within ± 1 mm but without RFID or IoT integration. Kulkarni and Deshmukh validated MFRC522-based RFID authentication with one card per slot for reliable slot-user mapping, while Rao and Krishnamurthy confirmed that the Blynk IoT platform with ESP32 provides stable real-time monitoring at 300–500 ms latency.

Table 1: Summary of Literature Review

Ref.	Key Contribution	Limitation	Improvement in Present Work
[1]	PLC-based multi-level parking	High cost, complex setup	Low-cost ESP32-based solution
[2]	IoT-based slot monitoring	No vertical movement	Vertical lift + RFID added
[3]	RFID + Arduino parking	Single level only	Multi-floor, lead-screw lift
[4]	Lead-screw vertical movement	No IoT / RFID	IoT + RFID integrated
[5]	RFID authentication	No real-time IoT	Blynk IoT added
[6]	Blynk IoT monitoring	Monitoring only	Full automated parking

While individual aspects such as RFID authentication, IoT monitoring and lead-screw based vertical movement have each been studied independently, an integrated low-cost prototype combining all of these features was found to be limited in the existing literature. The present work addresses this gap by integrating an ESP32 controller with RFID authentication, ultrasonic slot sensing, a stepper-driven lift, a DC-motor rotational platform, Blynk IoT monitoring, limit-switch safety and LED indication within a single cohesive system.

3. SYSTEM ARCHITECTURE AND DESIGN

3.1 System Overview

The proposed system simulates a two-floor vertical parking structure with three slots per floor (six slots total), arranged at 120° angular separation. A central vertical lift, driven by two lead-screw assemblies, carries a model vehicle to the required floor, while a rotating platform on each floor aligns the correct slot with the lift. Operation is initiated by swiping an RFID card assigned to the desired slot. The ESP32 microcontroller forms the central processing unit, reading inputs from the RFID reader, six ultrasonic sensors and two limit switches, and driving the stepper motors, DC motor, LCD, LED indicators, buzzer and the Blynk cloud link, as shown in Fig. 1.

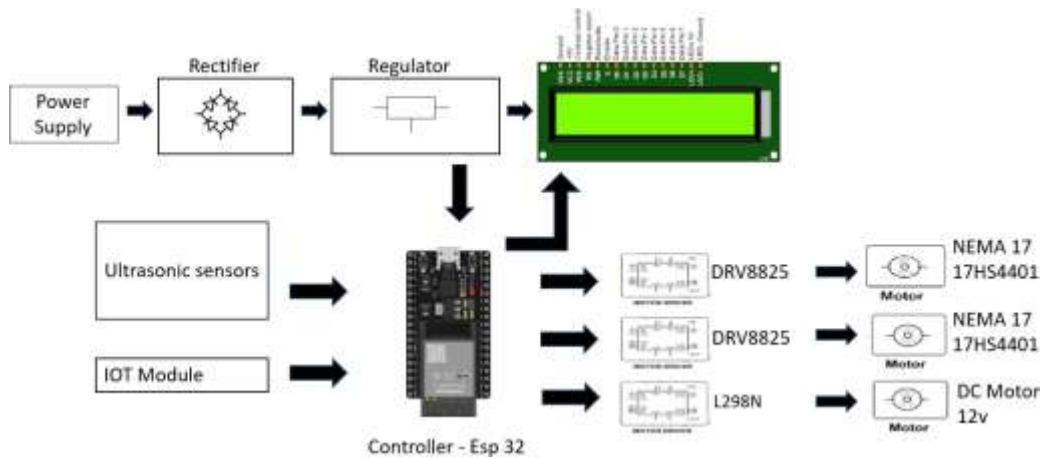


Fig. 1: Block Diagram of the Automation and IoT Based Vertical Car Parking System

3.2 System Specifications

Parameter	Specification
Controller	ESP32 (dual-core, 240 MHz, Wi-Fi + BLE)
Floors / Slots	2 floors × 3 slots = 6 slots total
Vertical travel	600 mm (TR8×2 lead screw)
Vertical drive	2 × NEMA 17 stepper motor (DRV8825 driver)
Horizontal drive	DC geared motor, 12 V, 30 RPM (L298N driver)
Slot detection	7 × HC-SR04 ultrasonic sensors
Authentication	MFRC522 RFID (13.56 MHz), 6 cards
Display / Indication	16×2 LCD; 6 red + 6 green LEDs
Safety	2 × SPDT limit switch
IoT platform	Blynk (over ESP32 Wi-Fi)
Power supply	230 V AC → 12 V DC (SMPS); 5 V / 3.3 V via LM2596

Table 2: System Specifications Summary

3.3 Mechanical Structure

The mechanical assembly is built on a 70 cm diameter wooden base that supports the lead-screw columns, drive motors and a 20 cm diameter lift platform positioned 6 cm above the base. Two 60 cm diameter acrylic floors, each carrying three slots at 120° spacing, are mounted at 29 cm and 44.5 cm above the base respectively. Six ball bearings (2 cm OD) guide the lead-screw assembly for smooth, low-friction vertical travel, and red/green LEDs together with one ultrasonic sensor are fitted at every slot for local occupancy indication.

4. HARDWARE AND CIRCUIT DESIGN

4.1 Major Components

Component	Qty	Role	Key Rating
ESP32 Dev. Board	1	Central controller, Wi-Fi/Blynk link	240 MHz, 34 GPIO, 3.3 V
DRV8825 Driver	2	Microstepping drive for lift motors	Up to 2.5 A/phase, 1/8 microstep
L298N Driver	1	Drives platform rotation DC motor	Dual H-bridge, 2 A/ch
NEMA 17 (17HS4401)	2	Vertical lift actuation via lead	1.8° step, 40 N·cm holding

		screw	torque
DC Geared Motor	1	Rotates floor platform by 120° steps	12 V, 30 RPM
HC-SR04	7	Slot occupancy / intake detection	2 cm–4 m range, 40 kHz
MFRC522 RFID	1	User authentication (6 cards)	13.56 MHz, SPI, 5 cm range
Component	Qty	Role	Key Rating
LCD 16×2	1	Local status display	Parallel/I2C interface
SPDT Limit Switch	2	Over-travel safety cut-off	Top and bottom of lift travel
LM2596 Buck Converter	2	Step-down 12 V → 5 V / 3.3 V	Up to 3 A, 92% efficiency
SMPS	1	Mains power conversion	230 V AC → 12 V DC
LEDs / Buzzer	12 / 1	Slot status & fault indication	Red/Green via 220 Ω, active buzzer

Table 3: Major Hardware Components

4.2 Circuit and Power Distribution

The ESP32 interfaces with the MFRC522 over SPI, drives the two DRV8825 stepper drivers and the L298N motor driver through dedicated GPIOs, and reads the seven HC-SR04 sensors and two limit switches as digital inputs, as shown in the schematic of Fig. 2. The 230 V AC mains supply is converted to a regulated 12 V DC rail by the SMPS, which directly powers the stepper and DC motor drivers. Two LM2596 buck converters step this down further to 5 V for the sensors, LCD and L298N logic supply, and to a 3.3 V logic rail for the ESP32 and RFID module (Fig. 3), with 100 μF decoupling capacitors used across each rail to suppress switching noise from the motor drivers.

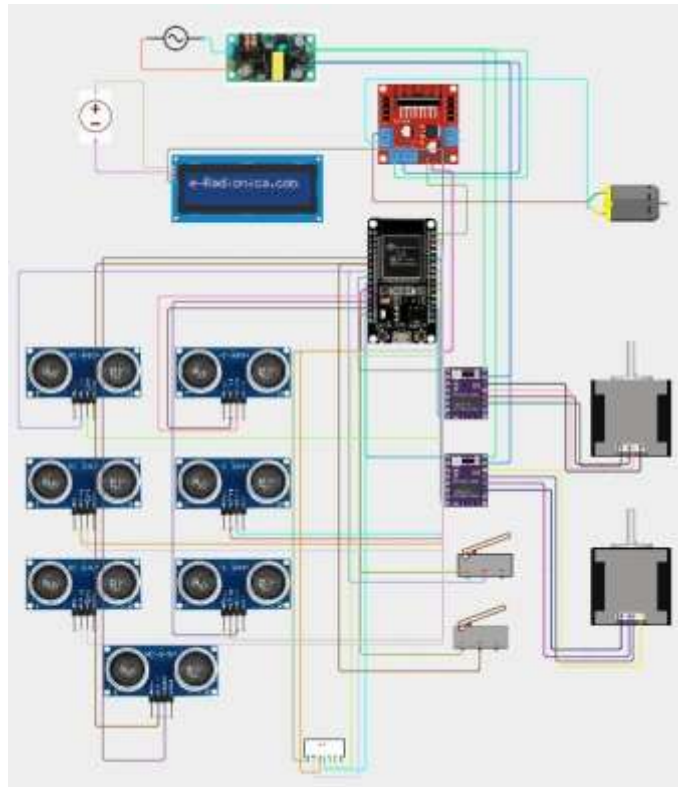


Fig. 2: Overall Circuit Schematic Diagram

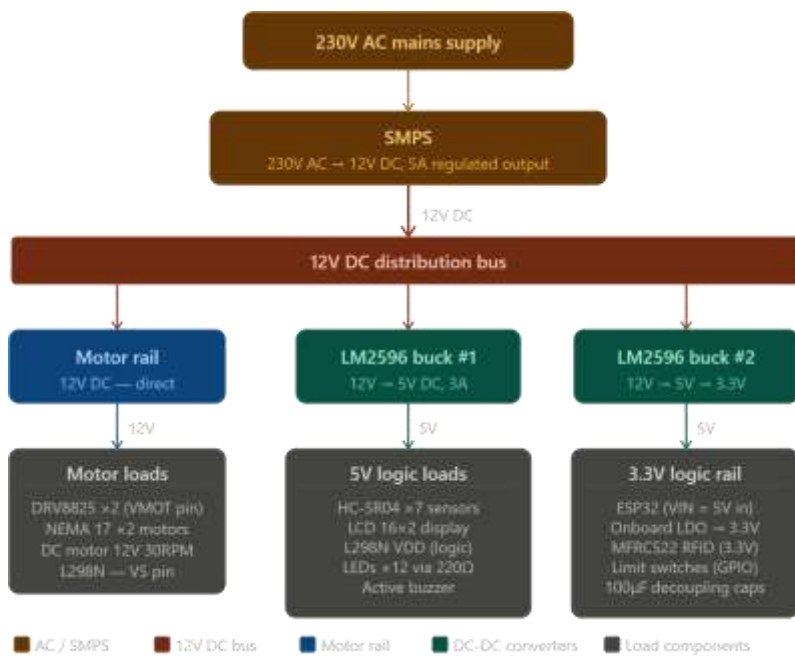


Fig. 3: Power Distribution Architecture

4.3 Software Implementation

Firmware is developed in the Arduino IDE for ESP32 using the MFRC522, LiquidCrystal, AccelStepper and BlynkSimpleEsp32 libraries. The firmware is organised into functional modules: initialization (sets up peripherals, Wi-Fi and Blynk connection, and homes the lift); slot-occupancy sensing (cyclic polling of all six ultrasonic sensors against an 8 cm threshold); RFID card reading (UID lookup against six stored slot mappings); parking/retrieval logic (selects the correct sequence based on sensed slot status); motor control (computes lift steps from the lead-screw pitch and drives platform rotation in 120° increments); limit-switch safety (an interrupt-driven routine that halts all motors and triggers the alarm state); and Blynk updates (pushes slot status to six virtual pins only on state change, to minimise bandwidth).

5. WORKING METHODOLOGY

On power-up, the ESP32 initializes all peripherals, polls the six ultrasonic sensors to establish the initial slot status, connects to Wi-Fi and the Blynk server, homes the lift to ground level, and displays ‘System Ready — Swipe Card’ on the LCD.

For a parking operation, the user places the vehicle at the ground-level intake and swipes the card assigned to an empty slot; the ESP32 verifies the slot is empty via its ultrasonic sensor, rotates the ground platform to align the slot, raises the lift to the correct floor height using the stepper motors, rotates the floor platform to align the target slot, and pushes the vehicle into place. The slot’s ultrasonic sensor then detects occupancy, switching its LED from green to red and updating the corresponding Blynk virtual pin, after which the lift returns to the home position.

Retrieval follows the reverse sequence: the lift rises to the occupied slot, the floor platform aligns the slot above the lift, the vehicle is collected, the slot LED and Blynk indicator revert to green/empty, and the lift descends to deliver the vehicle at the ground exit point.

If the lift mechanically reaches either travel extreme — due to a sensor fault or software error — the corresponding SPDT limit switch triggers an interrupt that immediately disables both stepper drivers and the DC motor driver, switches all six red LEDs on, sounds the buzzer continuously, displays a fault message on the LCD, and pushes a notification to the user’s phone via Blynk; the system remains in this fault state until the

switch is released and the controller is reset. During normal operation, the Blynk dashboard mirrors the live state of all six slots (green = empty, red = occupied) and additionally flags an ‘all slots full’ condition when every sensor reports occupancy.

6. RESULTS AND DISCUSSION

6.1 Functional Testing

The prototype shown in Fig. 4 was subjected to twelve functional test cases covering initialization, parking and retrieval on both floors, invalid-card handling, full-capacity behaviour, limit-switch safety response (top and bottom), and Blynk status/notification updates. All twelve test cases passed, confirming correct integration of the mechanical, electronic and IoT subsystems.



Fig. 4: Prototype Hardware — Physical Setup

Test	Description and Result	Status
T1	Power-on initialization: sensors polled, Blynk connected, system ready	PASS
T2	Valid card on empty Slot 1 (Floor 1): lift and platform aligned correctly	PASS
T3	Valid card on empty Slot 4 (Floor 2): correct floor height reached	PASS
T4	Valid card on occupied slot: vehicle retrieved and delivered at ground	PASS
T5	Invalid card swipe: ‘Invalid Card’ shown, no motor movement	PASS
T6	All 6 slots full: ‘Parking Full’ displayed, operation blocked	PASS
T7 / T8	Top / bottom limit-switch trigger: all red LEDs + buzzer activated, motors stopped	PASS
T9 / T10	Blynk slot indicator updates on parking / retrieval (<1 s latency)	PASS
T11	Limit-switch fault notification pushed to smartphone via Blynk	PASS
T12	Simultaneous Floor 1 and Floor 2 operations with no inter-floor interference	PASS

Table 4: Test Cases and Results

6.2 Performance Analysis

At an 8 cm detection threshold, all six HC-SR04 sensors achieved 100% slot-detection accuracy, with an average measured distance of about 3.25 cm when a vehicle was present and about 14.35 cm when the slot was empty — a clear margin that avoids false detections. Table 5 summarises the measured parking and retrieval times for representative slots.

Operation	Target Slot	Avg. Time	Remarks
Parking	Slot 1 (Floor 1)	~18 s	Includes lift + rotation
Parking	Slot 4 (Floor 2)	~24 s	Higher floor, longer travel
Retrieval	Slot 1 (Floor 1)	~20 s	Includes lift descent to ground
Retrieval	Slot 4 (Floor 2)	~26 s	Higher floor retrieval
Home return	—	~10 s	Lift returns to ground
Blynk update latency	—	<1 s	Over local Wi-Fi

Table 5: Parking and Retrieval Time Measurement



Fig. 5: Blynk IoT Dashboard — Real-Time Slot Monitoring

6.3 Comparison with Existing Systems

Feature	Manual Parking	Basic Arduino Parking	Present System
Floors	1	1	2
Total slots	1–3	3–4	6
Automation	Manual	Partial	Full
RFID authentication	No	Some	Yes
IoT monitoring	No	No	Yes (Blynk)
Safety limit switch	No	No	Yes
Parking time	Human-dependent	~30 s	~18–26 s

Table 6: Comparison with Existing Systems

The results indicate that the proposed system improves on prior single-feature implementations by combining multi-floor vertical storage, RFID authentication, real-time IoT monitoring and hardware safety interlocks within one cost-effective prototype, while matching or improving on the parking speed reported for simpler Arduino-based systems.

7. CONCLUSION AND FUTURE SCOPE

This work successfully designed, fabricated and tested a working prototype of an Automation and IoT Based Vertical Car Parking System that automates parking and retrieval across two floors and six slots through the integration of stepper-driven vertical lift, DC-motor rotational platforms, RFID authentication, ultrasonic occupancy sensing, limit-switch safety and Blynk-based IoT monitoring. All twelve functional test cases passed, slot detection achieved 100% accuracy, and average parking/retrieval times of 18–26 seconds were recorded — demonstrating that a low-cost, readily reproducible prototype can validate the working principle of a vertical automated parking structure that is, in principle, scalable to full-size deployment.

Future enhancements identified for this work include scaling to a full-size tower using industrial-grade servo motors and PLC control; integrating an automated fee-payment gateway (UPI / RFID wallet); adding a mobile app for remote slot reservation; incorporating CCTV with license-plate recognition for security; powering the control electronics via solar panels; extending the structure to 4–6 floors with 12–18 slots; adding voice announcements; and logging parking events to a cloud database such as Firebase or ThingSpeak for analytics.

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