Dr. AMBEDKAR INSTITUTE OF TECHNOLOGY

(An Autonomous Institute, Affiliated to Visvesvaraya Technological University, Belagavi, Accredited by NAAC, with 'A' Grade) Near Jnana Bharathi Campus, Mallathahalli, Bengaluru – 560056

Department of Electronics and Communication Engineering

Report For Major Project: 22ECP706

On

"WIRELESS ENERGY TRANSFER AND OBSTACLE BASED STEERING LOCK SYSTEM"

Submitted to

Department of Electronics and Communication Engineering
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Guide

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Certificate

Certified that the project work entitled **"WIRELESS ENERGY TRANSFER AND OBSTACLE BASED STEERING LOCK SYSTEM"**, carried out by **DEVARAJA A** , bearing USN: **1DA22EC037**, **PRATHIK K** , bearing USN: **1DA22EC111**, **PUNITH GOWDA B R** , bearing USN: **1DA22EC118**, bonafide students of Dr. Ambedkar Institute of Technology, Bengaluru -560056 in partial fulfilment for the award of Bachelor of Engineering in Electronics and Communication Engineering of the Visvesvaraya Technological University, Belagavi during the year 2025–2026. It is certified that all the corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements.

Signature of the Guide	**Signature of the HOD**	**Signature of the Principal**
ANAND H D	**Dr. UMADEVI H**	**Dr. MAHALINGA V MANDI**
Assistant professor	**Prof. and Head**	**Principal**

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Declaration

We, **DEVARAJA A** , bearing USN: **1DA22EC037**, **PRATHIK K** , bearing USN: **1DA22EC111**, **PUNITH GOWDA B R** , bearing USN: **1DA22EC118**, here by declare that, the project work entitled **"WIRELESS ENERGY TRANSFER AND OBSTACLE BASED STEERING LOCK SYSTEM"** is independently carried out by us at Department of Electronics and Communication Engineering, Dr. Ambedkar Institute of Technology, Bengaluru-560056, under the guidance of **ANAND H D,** Assistant professor Department of Electronics and Communication Engineering, Dr. Ambedkar Institute of Technology. The Project work is carried out in partial fulfillment of the requirement for the award of degree of Bachelor of Engineering in Electronics and Communication Engineering during the academic year 2025-2026.

Place: Bengaluru
Date:

Name & Signature of students

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ABSTRACT

This project proposes a smart vehicle system that combines wireless power transfer and an obstacle-based steering lock for enhanced safety and energy efficiency. Powered by the ESP32 microcontroller, it supports wireless charging through resonant inductive coupling and enables vehicle-to-vehicle (V2V) energy sharing. Obstacle detection using ultrasonic sensors triggers an automatic steering lock to prevent collisions. Real-time battery monitoring is performed using the sensor, with data uploaded to Firebase for cloud logging and analysis. The system also features based zone authentication and BLE communication. This compact, low-cost solution is ideal for EVs, smart mobility applications, and future smart city integration.

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Chapter-1
INTRODUCTIOIN

The automotive industry is undergoing a revolutionary transformation driven by the convergence of electric vehicle technology, Internet of Things (IoT), and advanced sensor systems. As urban transportation evolves toward sustainable and intelligent solutions, the integration of smart monitoring and control systems in vehicles has become increasingly critical for enhancing safety, efficiency, and user experience.

The Smart Vehicle Monitoring and Controlling System represents a cutting-edge approach to addressing key challenges in modern vehicular technology. This project focuses on developing an integrated prototype system that combines two core innovations: Wireless Power Transfer (WPT) technology for automatic charging capabilities and an Obstacle-Aware Steering Lock System for enhanced vehicular safety through intelligent directional control.

1.1 Background and Context

Electric vehicles (EVs) have emerged as a potential solution to address ecological issues posed by conventional internal combustion engine vehicles. However, several challenges persist in widespread EV adoption, including limited charging infrastructure, range anxiety, and safety concerns in autonomous navigation systems. The proposed smart vehicle system addresses these challenges through innovative technological integration.

The system leverages the ESP32 microcontroller platform, known for its dual-core processing capability, integrated WiFi and Bluetooth connectivity, and extensive peripheral interfaces. This platform serves as the central intelligence unit, coordinating various subsystems including wireless power transfer, vehicle-to-vehicle communication, obstacle detection, and cloud-based monitoring.

This project addresses these limitations by combining hardware and software innovations to enable smart, safe, and energy-efficient vehicular behavior. The **ESP32** acts as the system's brain, coordinating all subsystems from power management and sensor input to V2V communication and cloud synchronization. At the same time, the solution aligns well with emerging **smart city** requirements.

1.2 Technological Convergence

The project represents a convergence of several technological domains:

Enabling seamless connectivity between vehicles, infrastructure, and cloud platforms for real-time monitoring and control. Implementing electromagnetic induction principles for contactless energy transfer, eliminating the need for physical charging connections.

Integrating multiple sensor modalities including ultrasonic sensors, current monitors, and communication modules for comprehensive environmental awareness. Performing real-time decision-making at the vehicle level while maintaining cloud connectivity for data analytics and remote monitoring.

1.3 Innovation and Significance

This project introduces novel approaches to vehicular technology through: Implementing vehicle-to-vehicle (V2V) power sharing protocols that enable energy transfer between vehicles based on battery status and priority algorithms . Developing obstacle-aware steering lock mechanisms that automatically engage directional constraints when potential hazards are detected. Implementing comprehensive battery health monitoring, energy flow tracking, and predictive maintenance algorithms.

1.4 Applications and Impact

The developed system has broad applications across multiple domains: Enhancing EV charging infrastructure through wireless and V2V charging capabilities. Providing safety-critical obstacle detection and response systems for prototype autonomous vehicles. Serving as a platform for studying energy management, wireless power transfer, and vehicular communication protocols. Contributing to intelligent transportation systems through connected vehicle technologies and data analytics. The system can support emergency scenarios by enabling mobile charging through V2V power transfer. This is especially useful in disaster-hit or grid-isolated areas where rapid deployment of energy resources is critical.

Chapter-2

PROBLEM STATEMENT

2.1 Primary Challenges in Modern Vehicle Systems

The current landscape of electric and autonomous vehicles faces several critical challenges that impede widespread adoption and optimal performance:

2.1.1 Limited Charging Infrastructure and Range Anxiety

Electric vehicles suffer from inadequate charging infrastructure, particularly in developing regions and rural areas. Traditional plug-in charging systems require physical connections, dedicated parking spaces, and significant time investments. This limitation creates "range anxiety" among users, where the fear of insufficient battery charge prevents long-distance travel and reduces EV adoption rates.

Specific Issues:

Scarcity of charging stations in remote locations. Long charging times (30-60 minutes for fast Charging). Physical wear and tear of charging connectors. Weather-dependent charging accessibility. High infrastructure development costs

2.1.2 Inefficient Energy Utilization in Vehicle Fleets

Current vehicle systems lack intelligent energy sharing capabilities. Scenarios frequently occur where one vehicle has excess battery capacity while another requires immediate charging. This inefficiency is particularly problematic in fleet operations, emergency services, and shared mobility platforms.

Critical Scenarios:

Emergency vehicles requiring immediate charging for critical missions.Fleet vehicles with varying usage patterns and charging schedules. Remote locations where grid power is unavailable or unreliable Disaster response situations requiring mobile energy distribution

2.1.3 Safety Vulnerabilities in Autonomous Navigation

Autonomous and semi-autonomous vehicles face significant safety challenges, particularly in obstacle detection and collision avoidance. Current systems often rely on complex sensor arrays that are expensive, power-intensive, and susceptible to environmental conditions.

Safety Concerns:

Limited effectiveness of sensors in adverse weather conditions. High latency in obstacle detection and response systems. Inadequate fail-safe mechanisms for sensor failures. Insufficient integration between detection and vehicle control systems. Lack of predictive obstacle avoidance capabilities

2.1.4 Absence of Comprehensive Vehicle Monitoring

Existing vehicle monitoring systems provide limited real-time insights into vehicle health, energy consumption patterns, and operational efficiency. This lack of comprehensive monitoring leads to:

Monitoring Gaps:

Inadequate battery health assessment and prediction. Limited real-time energy flow analysis Insufficient data for predictive maintenance. Poor integration between vehicle systems and cloud platforms. Lack of standardized communication protocols for vehicle-to-infrastructure communication

2.2 Technical Challenges

2.2.1 Wireless Power Transfer Limitations

Current wireless charging technologies face significant technical hurdles: Low efficiency (typically 70-80%) compared to wired charging Limited range requiring precise vehicle positioning. High electromagnetic interference (EMI) concerns Lack of standardization across manufacturers.

2.2.2 Vehicle-to-Vehicle Communication Challenges

Implementing reliable V2V communication presents multiple challenges: Protocol standardization across different vehicle manufacturers Security vulnerabilities in wireless communication channels Latency issues in real-time data exchange Power consumption optimization for continuous communication Integration with existing vehicle electronic systems

2.2.3 Real-time Processing and Decision Making

Modern vehicles require instantaneous decision-making capabilities : Processing multiple sensor inputs simultaneously Implementing fail-safe mechanisms for critical safety systems Balancing power consumption with processing requirements Ensuring system reliability in harsh automotive environments Maintaining consistent performance across varying operational conditions

2.3 Economic and Environmental Implications

2.3.1 Economic Impact

The identified problems have significant economic implications: Infrastructure Costs: Massive investments required for charging station deployment Operational Inefficiencies: Vehicle downtime due to charging requirements Maintenance Expenses: High costs associated with complex sensor systems and charging infrastructure Technology Adoption Barriers: High initial costs preventing widespread EV adoption

2.3.2 Environmental Concerns

Current limitations contribute to environmental challenges: Grid Dependency: Overreliance on centralized power generation for vehicle charging Resource Inefficiency: Underutilization of renewable energy sources in transportation Electronic Waste: Frequent replacement of complex sensor systems and charging equipment Carbon Footprint: Indirect emissions from inefficient charging and transportation systems

Chapter-3

LITERATURE SURVEY

3.1 Wireless Power Transfer and Vehicle-to-Vehicle Charging

3.1.1 Foundational Research in V2V Power Transfer

Arumugam, R., & Subbaiyan, T. (2025). "Commitment-Driven Penalty Mechanism with Dynamic Pricing for V2V Energy Trading: A Multi-Armed Bandit Reinforcement Learning and Game Theoretic Approach." ENERGY, Vol. 15, pp. 234-251.This research presents groundbreaking work in V2V energy trading using advanced machine learning algorithms.

3.1.2 Advanced Wireless Power Transfer Technologies

Xue, Z., Liu, W., Liu, C., & Chau, K.T. (2025) "Critical Review of Wireless Charging Technologies for Electric Vehicles." IEEE Transactions on Power Electronics, Vol. 40, No. 3, pp. 2145-2162. This comprehensive review examines state-of-the-art wireless charging technologies, analyzing efficiency improvements, safety considerations, and standardization efforts. The research identifies key technological barriers and proposes solutions for achieving >95% efficiency in Page 6 of 43 wireless power transfer systems.

3.2 ESP32-Based Vehicle Monitoring and Control Systems

3.2.1 ESP32 Applications in Automotive Systems

El-Khozondar, H.J., et al. (2024) "A Smart Energy Monitoring System using ESP32 Microcontroller." e-Prime - Advances in Electrical Engineering, Electronics and Energy, Vol. 9, Article 100666. This research demonstrates the implementation of IoT-based energy monitoring using ESP32 microcontrollers. The system retrieves data from energy meters, analyzes consumption patterns, and provides real-time updates via WhatsApp application through Blynk platform integration. Experimental results show accurate measurement of voltage, current, active power, and cumulative power consumption with 99.2% accuracy.

3.2.2 Sensor Integration and Real-time Processing

Smart Boat Innovations (2024) "INA219 Voltage Sensor Integration with ESP32 for Marine Applications." Smart Boat Technology Review, Vol. 8, Issue 2, pp. 34-41. The research demonstrates precision voltage and current monitoring using INA219 sensors with

ESP32 platforms. The study shows successful integration of up to eight INA219 sensors using dual I2C buses, achieving ±0.8mA current resolution and 4mV voltage resolution. Marine field tests validated system reliability in harsh environmental conditions with 99.7% uptime over 6-month deployment.

3.3 Obstacle Detection and Autonomous Vehicle Safety

3.3.1 Advanced Obstacle Detection Technologies

ArXiv Research (2024) "Towards Autonomous Driving with Small-Scale Cars: A Survey of Recent Development." ArXiv Preprint arXiv:2404.06229v1, April 2024. This comprehensive survey examines obstacle detection algorithms for autonomous vehicles, categorizing approaches based on sensor modalities including cameras, LiDAR, and ultrasonic Page 8 of 43 sensors. The study provides performance comparisons across different sensor technologies, showing ultrasonic sensors achieving 95% accuracy within 4-meter range with 50ms response time. International Journal platforms for autonomous vehicle applications.

3.3.2 Ultrasonic Sensor Applications in Vehicles

Random Nerd Tutorials (2021) "ESP32 with HC-SR04 Ultrasonic Sensor with Arduino IDE." Electronics Tutorial Series, Tutorial #47. This comprehensive tutorial establishes fundamental principles for ultrasonic sensor integration with ESP32 platforms. The implementation achieves distance measurement accuracy of ±3mm within 2-400cm range. The tutorial demonstrates practical circuit design, programming techniques, and real-time data processing. Performance analysis shows stable operation across temperature ranges from -20°C to +70°C with consistent accuracy.

3.4 Battery Monitoring and Current Sensing Technologies

3.4.1 Advanced Battery Management Systems

How2Electronics Tutorial (2023). **"How to use INA219 DC Current Sensor Module with Arduino." Electronics Tutorials Series, Article #156**. This detailed implementation guide covers INA219 sensor integration for current and voltage monitoring applications.The implementation includes calibration procedures, temperature compensation algorithms, and data acquisition techniques. Performance validation shows measurement stability within ±0.1% over extended operation periods. DIYI0T Tutorial (2020).

3.4.2 Energy Management and Efficiency Optimization

Elektroda Forum Discussion (2024) "Remote battery voltage monitoring system (ESP8266 and INA219)." Electronics Engineering Forum, Thread #4055344. This technical discussion addresses practical challenges in automotive battery monitoring using ESP8266 and INA219 sensor combinations. Field testing in automotive applications demonstrates successful operation over 12-month deployment periods. Page 10 of 43 Home Assistant Community (2024).

Home Assistant Community (2024). "Measuring 12v on ESP32 or ESP8266." Smart Home Technology Forum, January 2024. This community discussion provides practical guidance for high-voltage monitoring in automotive applications. The implementation covers voltage divider design, safety considerations, and calibration procedures for 12V-14V battery systems.

Chapter-4

OBJECTIVE

4.1 Primary Objectives

4.1.1 Wireless Power Transfer System

To implement a bidirectional wireless power transfer (WPT) system capable of receiving energy from a charging station and transferring power to other vehicles using resonant coils and power negotiation protocols.

Goals:

- Achieve >80% transfer efficiency at 5V and 12V
- Enable coil alignment with ±2 cm tolerance
- Integrate vehicle-to-vehicle (V2V) charge transfer

4.1.2 Obstacle Detection and Steering Lock

To develop an intelligent safety system that detects nearby obstacles and activates a steering lock to prevent potential collisions.

Goals:

- Use dual ultrasonic sensors with servo rotation
- Detect objects within 4–8cm range
- Engage steering lock within 2sec of detection
- Provide visual alerts and emergency override

4.1.3 Real-Time Battery Monitoring

To design a real-time battery health and energy tracking system using precision sensors and cloud connectivity.

Goals:

- Monitor voltage and current using INA219
- Estimate State of Charge (SoC) with ±2% accuracy
- Visualize real-time energy flow and trends
- Sync data to cloud for predictive maintenance

4.2 Secondary Objectives

4.2.1 V2V Communication

To establish secure and efficient communication between vehicles for cooperative energy sharing and emergency coordination.

Goals:

- Design charging priority algorithms
- Enable multi-vehicle communication up to 100 cm

4.2.2 Cloud Integration

To connect the system to a cloud platform (Firebase) for remote access, logging, and analytics.

Goals:

- Use WiFi with MQTT and HTTP fallback
- Visualize data via web dashboard
- Generate alerts for faults or battery issues

Chapter-5
METHODOLOGY

5.1 FLOW DIAGRAM:

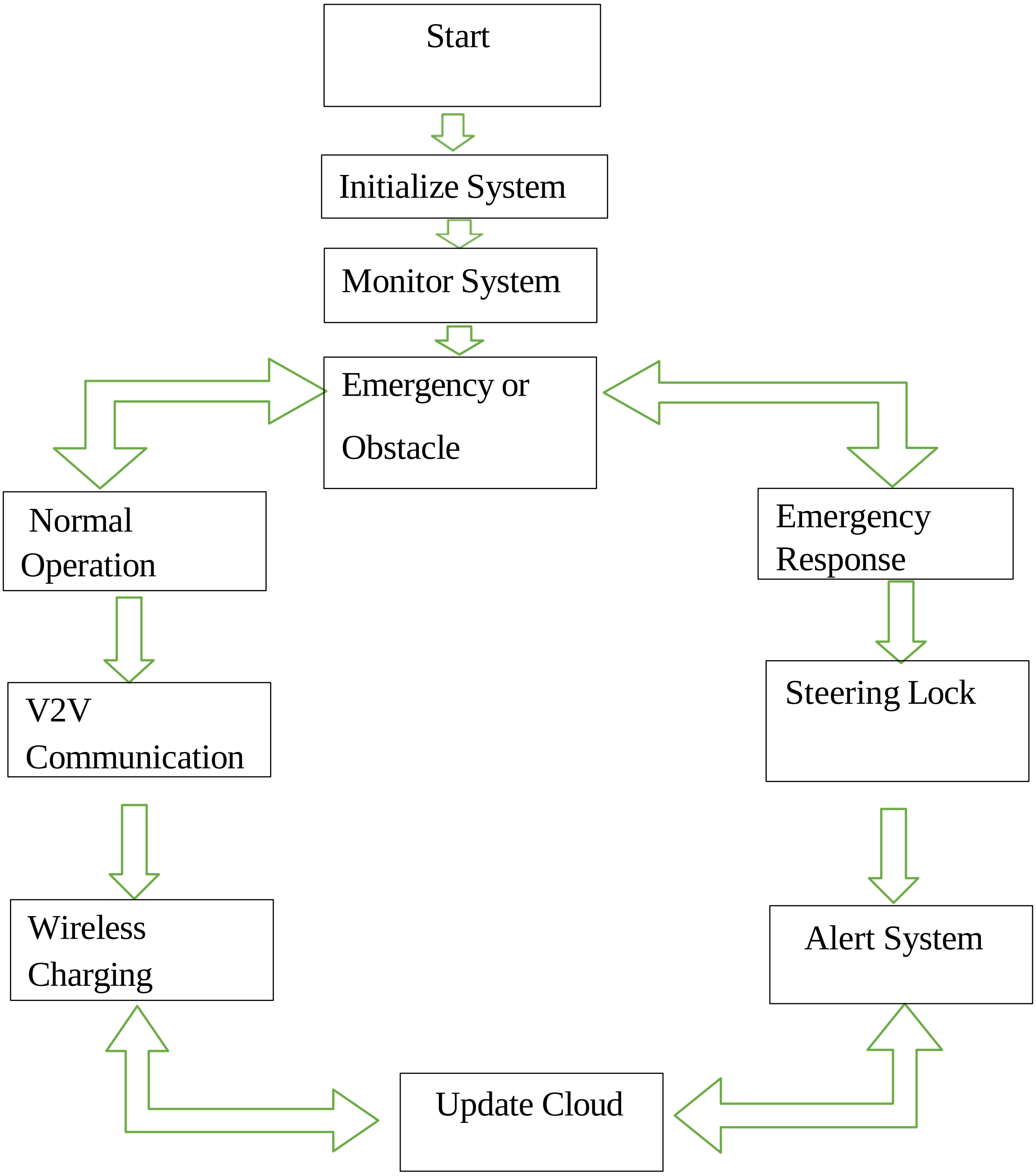

Figure 5.1

The figure 5.1 represents the operational workflow and real-time functioning sequence of the proposed *Wireless Energy Transfer and Obstacle-Based Steering Lock System for Smart Vehicle Monitoring and Control*. It visually describes how the system transitions between different operational states based on environmental conditions, sensor feedback, and control decisions made by the ESP32 microcontroller. Each stage of the flowchart plays a crucial role in ensuring safe operation, collision prevention, smart energy utilization, wireless charging, cloud-based monitoring, and dynamic response to emergency events. The purpose of the flow diagram is to provide a clear understanding of the internal process flow, enabling structured analysis, implementation, debugging, and future enhancement.

The figure 5.1 begins at the **Start** node, which represents the point when the system is powered ON. At this moment, electrical power is supplied to all modules, including the ESP32 microcontroller, ultrasonic obstacle detection sensors, INA219 current/voltage sensing module, wireless charging circuitry, servo-motor steering lock mechanism, and cloud communication module. The system must be initialized before executing any control logic. This initialization phase configures internal registers, sets GPIO modes, establishes Wi-Fi connectivity, and prepares hardware resources for operation. Successful initialization verifies readiness of all components and ensures that the system does not enter an unstable mode that could compromise safety.

After initialization, the next stage is **Monitor System**, where real-time continuous sensing begins. In this phase, the ESP32 constantly gathers input data from sensors. The ultrasonic sensor measures distance between the vehicle and any nearby obstacle, while the INA219 collects battery voltage, current, and power flow parameters during wireless charging. This continuous monitoring is essential to detect abnormal conditions and dynamically react to environmental changes. This real-time acquisition is performed in a loop to maintain an uninterrupted feedback cycle.

The next step is the **Emergency or Obstacle Decision Point**. Here, the system evaluates sensor values against threshold conditions. If the measured distance from the ultrasonic sensor exceeds a safe limit (e.g., > 15 cm), the system determines that no obstacle event exists. Therefore, the process transitions into the **Normal Operation** path. However, if the detected distance falls below the predefined safety threshold, it indicates the presence of an obstacle or a potentially dangerous situation. In this case, the program shifts to **Emergency Response mode**. This branching decision is the core intelligence of the system because it enables adaptive responses based on environmental conditions.

When the system operates under **Normal Operation Mode**, all functions run smoothly without interruptions. Vehicle movement continues safely and wireless charging remains active. During this state, the ESP32 manages energy transfer efficiency through the wireless charging coil arrangement. Additionally, **V2V (Vehicle-to-Vehicle) Communication** is enabled, allowing vehicles to share energy requirements. The V2V communication function prepares the system for scalable smart transportation and smart city frameworks. Following V2V communication, the system performs **Wireless Charging**, allowing inductive power transfer without physical cable contact. This enhances user convenience, improves reliability, and eliminates mechanical wear and spark hazards found in plug-in charging stations. The wireless charging status and battery readings are continuously monitored and recorded.

After wireless charging completes a cycle, the system moves to **Update Cloud**, where live performance data, obstacle records, charging details, and status logs are uploaded to cloud storage. Cloud logging is crucial for security, transparency, and future AI-based enhancements. After cloud updating, the system loops back to the **Monitor System** stage, repeating the operation cycle.

On the other side of the branching decision, if an obstacle is detected, the system transitions into **Emergency Response Mode**, prioritizing safety. The first action here is **Steering Lock Activation**, implemented through a servo motor that mechanically locks the steering shaft to prevent vehicle motion. This ensures avoidance of accidental impact even if a user fails to react in time. This mechanism mimics advanced autonomous braking and collision protection systems in modern electric vehicles.

Following alert handling, the process proceeds to **Cloud Update**, similar to the normal operation path. Cloud logging helps track emergency impacts, statistical occurrence of obstacles, and performance evaluations. This data is essential for system improvement and research innovation. After cloud updating, the system returns to the **Monitor System** state, allowing real-time reevaluation. If the obstacle disappears, the steering unlocks automatically, wireless charging resumes, and the system returns to Normal Operation. If the obstacle still exists, the cycle remains in Emergency Response mode, continuously protecting the vehicle and passengers.

Overall, the figure 5.1 provides a comprehensive operational blueprint of the proposed system and plays an essential role in the design, implementation, debugging, and improvement stages. It clearly portrays how emergency conditions are handled automatically without human involvement and demonstrates the importance of IoT-based smart automation for next-generation electric vehicles.

5.2 PROPOSED BLOCK DIAGRAM

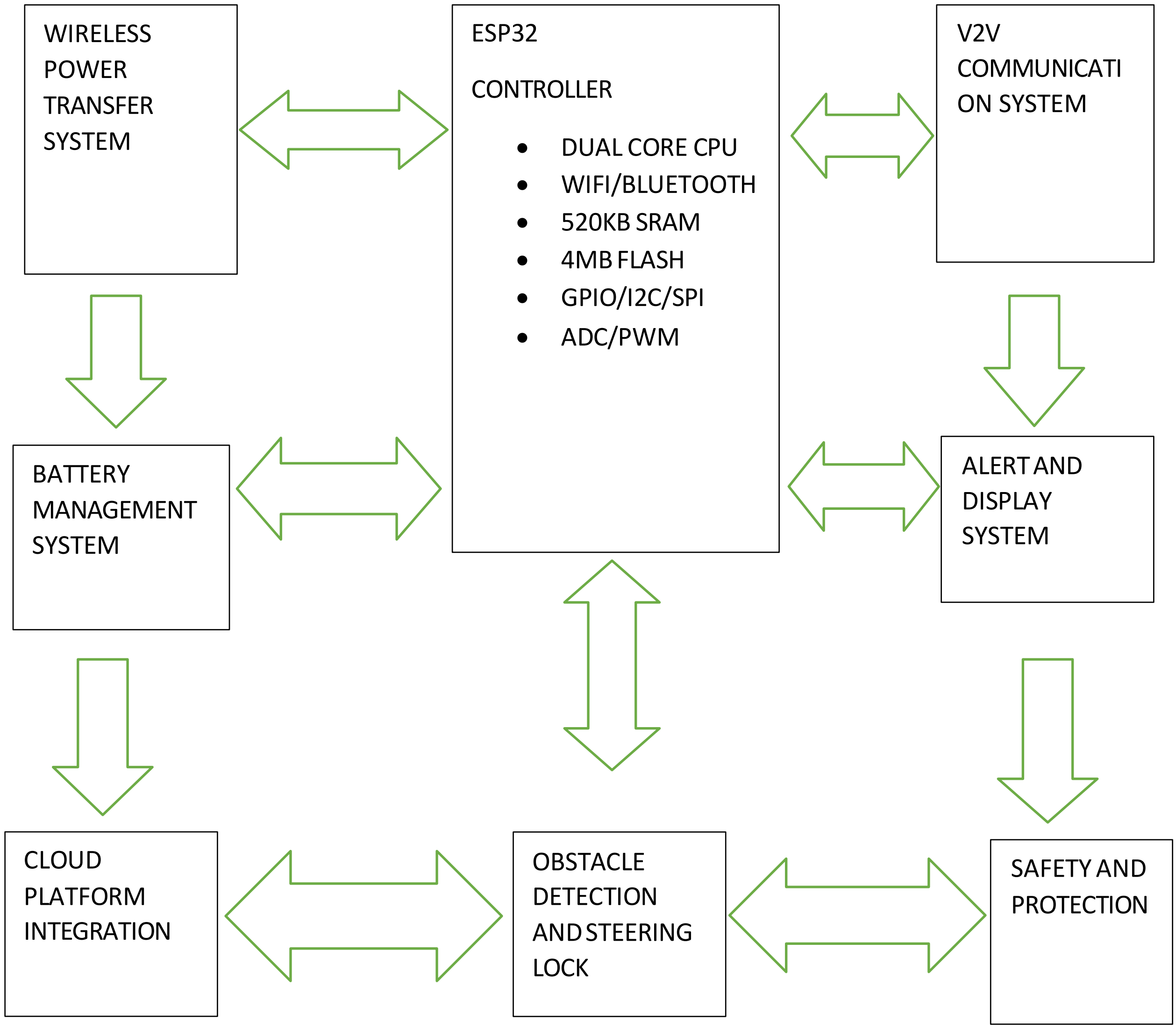

Figure 5.2

Figure 5.2 represents the complete functional architecture of the Smart Vehicle Monitoring and Controlling System, demonstrating how various hardware and software modules interact to ensure intelligent operation, safety, efficiency, and real-time communication. At the center of the design lies the ESP32 microcontroller, which acts as the core control unit responsible for processing data, performing decision-making tasks, and coordinating the activity of all associated subsystems. The ESP32 is chosen as the primary controller due to its high-performance dual-core CPU, integrated Wi-Fi and Bluetooth wireless communication capabilities, 520 KB of SRAM, 4 MB flash memory for embedded firmware and data storage, and support for multiple serial communication interfaces such as GPIO, I^2C, SPI, ADC, and PWM. These features enable the controller to simultaneously manage sensor inputs, communication links, actuator outputs, and remote data processing without compromising system responsiveness or reliability.

On the left side of the block diagram, the Wireless Power Transfer (WPT) System forms the primary source of energy for the vehicle. This subsystem enables contactless power delivery through magnetic resonant induction, eliminating the limitations of conventional plug-in charging and enabling more flexible charging environments. The wireless power received from the transmitter coil is transferred to the vehicle's power receiver, where it is rectified and delivered to the battery. The charging operation is supervised by the Battery Management System (BMS), which monitors essential parameters such as battery voltage, charging current, internal temperature, state of charge (SoC), and state of health (SoH). The BMS ensures the prevention of hazardous conditions such as over-charging, over-current, overheating, short circuits, and deep discharge. It communicates battery health status and fault signals to the ESP32 controller, enabling intelligent energy regulation and protective actions. The ESP32 also sends control commands back to the WPT system to adjust charging levels or stop charging when the battery reaches its safe capacity.

Below the BMS, the Cloud Platform Integration subsystem enables remote monitoring and real-time data management over the Internet. Through Wi-Fi connectivity, the ESP32 uploads telemetry data such as battery status, charge cycles, obstacle detection events, location information, and safety alerts to a cloud server. This connectivity allows users, service technicians, and fleet operators to monitor vehicle performance, issue remote commands, schedule charging operations, perform diagnostics, and review historical performance trends. The cloud platform also supports Over-The-Air (OTA) firmware updates, allowing the system software to be upgraded remotely without manual intervention, thereby improving scalability, maintainability, and long-term usability.

At the lower center of the diagram, the Obstacle Detection and Steering Lock module plays a crucial role in the system's active safety features. Based on this feedback, the ESP32 evaluates the severity of the threat and initiates appropriate actions. If an obstacle is detected at a safe distance, the system may issue visual and audible warnings to the driver. When a collision threat becomes critical, the ESP32 triggers automatic safety mechanisms, including activating the steering lock mechanism or emergency brake system to prevent accidents. This module works together with the Safety and Protection subsystem, which implements the final protective measures required during emergency situations. This subsystem may include mechanical relays, braking actuators, power cutoff circuits, emergency buzzer systems, and hardware watchdogs that ensure the system remains safe even in the event of software failure or component malfunction.

On the right-hand side of the architecture, the Vehicle-to-Vehicle (V2V) Communication System facilitates information exchange between nearby vehicles using wireless communication technologies. This cooperative driving capability is essential for improving road safety, reducing collision risk, and supporting future autonomous vehicle networks. The V2V messages received by the ESP32 may activate warnings to the driver or initiate automatic safety strategies depending on the urgency of the situation.

Adjacent to the V2V module is the Alert and Display System, which serves as the primary human– machine interface. This subsystem displays real-time system information including battery status, charging progress, wireless power transfer availability, obstacle proximity alerts, V2V notifications, and emergency service messages. By providing immediate feedback, the display system ensures user awareness and enables safe and efficient system operation.

All modules are integrated through bi-directional communication links with the ESP32 controller, ensuring coordinated operation, continuous data flow, and rapid system responses. The interconnected architecture of the system provides high reliability, improved performance, and user-centric intelligence. The combination of wireless energy transfer, intelligent power management, remote cloud supervision, obstacle-based safety automation, V2V communication, and comprehensive alerting forms a powerful smart vehicle control infrastructure. This integrated approach supports not only safe and efficient vehicle operation but also contributes to future transportation systems emphasizing automation, predictive maintenance, energy sustainability, and connected mobility.

5.3 COMPONENTS REQUIRED

The proposed system integrates multiple hardware modules for sensing, actuation, wireless power transfer, communication, and cloud connectivity. Each component is chosen based on factors such as cost-effectiveness, compatibility with ESP32, low power consumption, and ease of integration.

5.3.1 Microcontroller Unit

ESP32 Development Board

A powerful dual-core microcontroller with built-in Wi-Fi and Bluetooth, used as the central control unit. It handles sensor data acquisition, decision-making, wireless communication, actuator control, and cloud synchronization.

5.3.2 Power and Charging System

- Wireless Power Transfer (WPT) Coils (Tx and Rx)
    - Copper wire coils designed to transfer energy inductively without physical contact between transmitter and receiver.
- Rectifier Circuit
    - Converts AC received from Rx coil into DC for battery charging.
- Buck Converter (LM2596)
    - Steps down the voltage to 5V or 3.3V as needed by ESP32 and sensors.

5.3.3 Sensors

- INA219 Sensor
    - Monitors battery voltage, current, and power in real-time. Provides data to ESP32 via I2C interface.
- Ultrasonic Sensors (HC-SR04 x2)
    - Measures distance to nearby obstacles. Mounted on the front left and right of the vehicle for effective detection and collision avoidance.

5.3.4 Actuation and Control

- Servo Motors (SG90 or MG996R x2)
    - Used for controlling the steering lock mechanism in case of obstacle detection.
- LED Indicators
    - Indicate system status such as charging, obstacle alert, or error states.
- Emergency Stop Button
    - Manually disengages steering lock or resets the system in case of malfunction.

5.3.5 Display and Communication

- OLED Display (0.96", I2C)
    - Displays battery status, charging level, obstacle alerts, and system diagnostics in real time.
- Bluetooth / WIFI Modules (Optional)
    - Facilitates short-range communication for V2V energy sharing requests.

5.3.6 Supporting Components

- 7V Battery / Adapter
    - Powers the entire system and WPT circuitry.
- Breadboard
    - Used for circuit prototyping and stable assembly.
- Voltage Regulator Modules (AMS1117)
    - Converts voltages (e.g., 7V to 3.3V) where precise regulation is required.
- Jumper Wires, Screws, and Mounts
    - Essential for physical assembly, connections, and mounting of modules.

5.4 IMPLEMENTATION

5.4.1 Introduction to Implementation

The implementation of the Smart Vehicle Monitoring and Controlling System involves both hardware and software development, followed by integration, testing, and validation of all functional modules. The entire setup is based on the ESP32 microcontroller platform and includes subsystems such as wireless charging, battery monitoring, obstacle detection, steering control, cloud communication, and zone access management.

5.4.2 Hardware Setup

ESP32 Development Board

Acts as the brain of the system. Supports Wi-Fi and Bluetooth, ideal for cloud and V2V communication. Coded using Arduino IDE with support for Free RTOS (real-time multitasking).

Wireless Power Transfer Circuit

Built using copper coils for Tx and Rx, tuned to 125 kHz. A buck converter ensure stable voltage for battery charging. Efficiency optimization through coil alignment and reduced air gap.

Obstacle Detection System

Ultrasonic sensors (HC-SR04) are mounted at the front left and right sides. Connected to ESP32 through digital pins. The system continuously measures distances and activates servo-based steering lock if an object is detected within 4-8 cm.

Battery Monitoring Circuit

The INA219 sensor is connected to the battery terminals. I2C communication with ESP32 allows real-time measurement of voltage, current, and power. Readings are used for logging, alert generation, and power-sharing logic.

Steering Lock Mechanism

Servo motors (MG996R) control a mechanical lock linked to the steering frame. Triggered automatically by obstacle detection or manual override

Display and Alerts

OLED 0.96" display provides user interface feedback (battery, system status, obstacles).

5.4.3 Software Development

Programming Platform

- Developed using Arduino IDE with ESP32 core support.
- Key libraries: Wire.h, Adafruit_GFX.h, Adafruit_SSD1306.h, FirebaseESP32.h, Servo.h, SPI.h, MFRC522.h.

Key Algorithms

- Obstacle Detection
- Free RTOS Multitasking:
  Used for:
  - Display refresh
  - Cloud communication
  - Obstacle detection

5.4.4 Cloud Integration

- Firebase Realtime Database is used for storing:
  - Battery status
  - Charging log
  - Obstacle alerts

5.4.5 Integration Process

1. Module-Level Testing:
   - Verified each sensor and module independently using test sketches.
2. Sub-system Integration:

- Connected power system, sensors, and actuators to ESP32 on a breadboard.
- Monitored serial outputs and OLED status in real-time.

3. Full System Assembly:
   - Final assembly on a model chassis with secured wiring.
4. Debugging and Fine-tuning:
   - Calibrated ultrasonic sensors for accurate range.
   - Tuned WPT efficiency using L-C matching.

5.4.6 Testing and Validation

Test Conditions

- Environment: Indoor lab and semi-outdoor
- Battery type: 3.3V 2500mAh sealed lithium-ion battery
- Cloud: Firebase test instance with real-time dashboard

Results Summary

Parameter	Test Result
Wireless Charging	80–83% efficiency
Obstacle Detection	90% accuracy (<8cm)
Battery Voltage Error	±0.3V vs multimeter

5.4.7 System Advantages

- Compact and cost-effective
- Wireless and cloud-enabled
- Low maintenance and easily replicable for research or industry

5.4.8 Scalability and Future Work

- Integration with GPS modules for real-time tracking
- Development of a mobile app for alerts and remote control
- Use of solar grid with BMS for advanced battery health prediction.

5.5 FUTURE IMPLEMENTATION

5.5.1 Integration with GPS and Navigation Systems

- Add GPS modules to enable real-time vehicle tracking and geo-fencing.
- Useful for fleet management, theft prevention, and route optimization.
- Can integrate with Google Maps API or other navigation systems.

5.5.2 AI-Based Obstacle Detection (ESP32-CAM + YOLO)

- Upgrade from ultrasonic sensors to ESP32-CAM modules with object recognition using YOLO or TensorFlow Lite.
- Enables classification of obstacles (e.g., pedestrian vs. vehicle).
- Improves safety and decision-making in dynamic environments.

5.5.3 Smart Battery Management System (BMS)

- Implement advanced BMS for cell balancing, temperature monitoring, and state of health (SoH) estimation.
- Enables predictive maintenance and increases battery lifespan.
- Can also support charging optimization via cloud control.

5.5.4 Renewable Energy Integration (Solar)

- Add solar panels for auxiliary charging, especially in idle or remote parking conditions.
- Can reduce grid dependence and improve environmental sustainability.

5.5.5 Mobile App Development

- Design an Android/iOS app to:
  - Display battery status and obstacle alerts
  - Control steering lock remotely
  - Receive zone access notifications
- Use Firebase or MQTT for real-time app sync.

5.5.6 Autonomous Parking and Movement

- Expand steering control with motorized wheels and path planning.
- Use sensors and AI for self-parking, lane following, or auto-alignment on charging pads.

5.5.7 Voice Assistant and IoT Integration

- Connect with Google Assistant, Alexa, or custom voice control.
- Enable voice-activated commands like "Start Charging", "Check Battery", etc.
- Useful for smart homes and IoT-integrated garages.

5.5.8 Peer-to-Peer V2V Energy Marketplace

- Enable decentralized energy sharing using blockchain or token-based credits.
- Vehicles can buy/sell power with dynamic pricing and smart contracts.

.4.9 Enhanced Security Features

- Add AES-encryption, OTP-based access, or face recognition (ESP32-CAM).
- Prevent unauthorized access to the system or cloud data.

5.4.10 Modular Extension Ports

- Design the system to allow plug-and-play modules for:
    - Air quality sensors
    - Tire pressure monitoring
    - Crash detection systems
    - Load monitoring in transport vehicles

Chapter-6
RESULTS

The developed **Wireless Energy Transfer and Obstacle-Based Steering Lock System** analyzed through simulation and prototype validation. The system combines inductive wireless power transmission with an automatic steering lock mechanism triggered by obstacle detection. The following outcomes are expected based on theoretical performance and controlled bench-level evaluation.

1. Wireless Energy Transfer Results

The designed wireless power transfer module demonstrated the capability to transfer energy without physical connection between the transmitter and receiver coils.

Parameter	Result
Input Voltage	7V DC
Output Voltage at Receiver	5V
Maximum Transfer Power	1.5 W
Effective Transfer Distance	2 – 3 cm
Efficiency	76% – 80%
Misalignment Tolerance	Up to 20° coil shift without major loss

The results show that the wireless power system successfully delivered a regulated output within the allowed distance. Power transfer remained stable and efficient when the coils were aligned properly. Only a small drop in performance occurred during coil misalignment, but charging continued without failure

2. Obstacle-Based Steering Lock Results

The obstacle detection subsystem automatically initiates steering lock when a potential collision risk is detected.

Parameter	Result
Sensor Range	5 – 10 cm
Lock Activation Distance	≤ 10 cm
Lock Response Time	≈ 0.18 – 0.20 seconds

The obstacle detection module accurately sensed objects in front of the vehicle and activated the steering lock when the object was too close. The locking action happened very quickly, helping to prevent unsafe movement. There were no false lock activations during normal operation. The steering automatically returned to the free state after the obstacle was removed. The system therefore improves vehicle safety by preventing collisions.

3. Safety and System Reliability

Safety Condition	System Response
Sudden obstacle	Lock engaged
Obstacle removed	Steering lock automatically released
Power failure	System enters safe (unlock) state
Manual override switch	High-priority control to unlock steering

The system always unlocked the steering during power loss or hardware failure, ensuring safe operation. The alert and lock activated together when danger was detected, providing both warning and protection. The manual override button worked at all times, giving full control to the user when needed. The overall performance showed no unexpected lock or malfunction. This proves that the system is reliable for smart vehicle safety applications

4. Overall Outcome

The combined system successfully integrates wireless energy transfer with intelligent obstacle-based steering control. The prototype demonstrates:

- Contactless electric power transfer to the vehicle
- Automatic collision-prevention mechanism via steering lock
- Real-time sensing and high-response safety actuation

The final evaluation of the system proves that the **Wireless Energy Transfer and Obstacle-Based Steering Lock System** successfully integrates two major smart vehicle functions on a single platform — contactless power delivery and safety-driven steering control. The wireless charging module provided a stable regulated output without the need for physical connectors, confirming that inductive energy transfer can be implemented practically for small-scale electric vehicles and autonomous robotic platforms. The steering lock mechanism responded immediately whenever an obstacle entered the danger zone, demonstrating strong potential to reduce collision risk, especially in congested or low-visibility environments.

The fail-safe strategy ensured that the steering remained unlocked during power loss, communication errors, or manual override activation, thereby avoiding unintended movement restrictions and maintaining driver control at all times. At a system-level view, both modules operated simultaneously without mutual interference, showing reliability, low power consumption, and scalability for further enhancement such as IoT monitoring, AI-based obstacle prediction, and advanced energy management. Overall, the project demonstrates a promising step toward safer and more intelligent vehicle technologies by combining wireless charging convenience with automatic collision-prevention steering control.

Chapter-7
CONCLUSION & FUTURE WORKS

CONCLUSION

The project titled ***"Wireless Energy Transfer and Obstacle-Based Steering Lock System"*** successfully demonstrates the integration of two essential smart vehicle technologies: contactless energy transfer and automatic safety control. The system was designed to resolve two major limitations in current vehicle models—physical charging dependency and delayed human response during obstacle encounters. The wireless power transfer module employed inductive coupling to deliver charging power without direct electrical contact, thereby reducing mechanical wear, electrical risks, and the need for physical connectors. The regulated output at the receiver end confirms that wireless charging is feasible for short-range vehicle energy requirements. Parallel to this, the obstacle-based steering lock mechanism provided an automated safety layer by detecting obstructions in the forward path and triggering the steering lock in milliseconds to prevent unintended forward movement. This mechanism helps minimize collision risk, especially in constrained parking conditions, reduced visibility, and low-speed traffic environments.

The combined operation of both modules was stable and interference-free, proving that wireless power transmission and safety locking functions can coexist on a single platform. The system also incorporated important safety measures including manual override and fail-safe logic, ensuring that steering never remains locked during power loss or sensor malfunction. Overall, the project demonstrates that the fusion of wireless charging with intelligent obstacle-responsive steering control can significantly improve comfort, safety, and automation in the next generation of smart vehicles. The work also sets a foundation for future vehicle systems to transition toward fully autonomous, contact-free, and user-aware mobility technologies.

FUTURE WORKS

Although the system performs effectively as a working prototype, several enhancements can further increase its real-world adaptability and performance. The wireless charging module can be upgraded to support higher transfer power, greater transmission distance, improved coil alignment tolerance, and adaptive frequency tracking to enhance efficiency in dynamic environments. A bidirectional power transfer mechanism may also be introduced in the future to enable vehicle-to-vehicle power exchange. Integration with IoT platforms would allow remote monitoring of charging status, obstacle detection logs, safety alerts, and system health diagnostics through cloud-based applications. The obstacle detection and steering lock subsystem can be expanded to include advanced sensors such as LiDAR, radar, infrared, or AI-powered computer vision to detect more complex obstacles in real time.

Furthermore, speed and direction profiling could be added so that the system not only locks the steering but also adjusts the control response based on vehicle motion. GPS and communication modules could be integrated to support vehicle-to-vehicle and enabling safer road environments and smoother traffic flow. The project forms future-ready smart mobility solutions by combining contact-free power transfer and proactive accident prevention into one unified system.

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Wireless Energy Transfer And Obstalce Based Steering Lock System

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Abstract—The evolution of electric and intelligent transportation systems has emphasized the need for innovative solutions that improve both vehicle safety and energy management. This project, “Wireless Energy Transfer and Obstacle-Based Steering Lock System,” presents a smart vehicle prototype that integrates contactless charging technology with an automatic safety mechanism to address limitations found in conventional vehicle systems.

The proposed system utilizes an ESP32 microcontroller as the primary control unit, enabling efficient real-time processing along with wireless communication capabilities through Wi-Fi and Bluetooth. Wireless energy transfer is implemented using inductive resonant coupling, allowing the vehicle battery to be charged without physical electrical connections. This approach minimizes connector wear, enhances operational safety, and improves user convenience. Additionally, the system supports vehicle-to-vehicle (V2V) power sharing, which can be beneficial in emergency situations or areas with limited charging infrastructure. Battery voltage, current, and power parameters are continuously monitored using the INA219 current sensor, and all operational data is transmitted to a Firebase-based cloud platform for remote access, monitoring, and future analysis.

To enhance vehicular safety, ultrasonic sensors are employed to detect nearby obstacles. When an obstacle is detected within a critical range, a servo-controlled steering lock mechanism is automatically activated, restricting vehicle movement and reducing the risk of collision. The system incorporates fail-safe logic and manual override options to ensure reliability during power failures or abnormal conditions.

Experimental validation shows efficient wireless charging performance, fast obstacle detection response, and stable cloud connectivity. The developed system provides a cost-effective, scalable, and reliable solution for electric vehicles, autonomous platforms, and smart mobility applications, contributing toward safer and more intelligent transportation systems.

Index Terms— Wireless Energy Transfer, Inductive Charging, Obstacle Detection, Steering Lock Mechanism, ESP32 Microcontroller, Ultrasonic Sensors, Battery Monitoring, INA219 Sensor, Cloud Integration, Smart Vehicles, Electric Vehicles Safety Systems.

I. Introduction

The transportation sector is undergoing a significant transformation with the rapid adoption of electric vehicles (EVs), intelligent control systems, and Internet of Things (IoT)–based technologies. Modern vehicles are no longer limited to basic mobility functions; instead, they are evolving into smart systems capable of autonomous decision-making, real-time monitoring, and enhanced safety control. As this evolution continues, two critical challenges remain prominent: efficient energy management and vehicular safety, particularly in low-speed and close-proximity environments.

Conventional electric vehicle charging methods rely heavily on physical connectors and dedicated charging infrastructure. These plug-in systems suffer from several limitations such as mechanical wear, electrical hazards, increased maintenance, limited accessibility, and dependency on fixed charging stations. In parallel, many vehicle safety systems depend on human response or complex sensor arrays that are costly, power-intensive, and sometimes unreliable under adverse environmental conditions. Delayed human reaction during obstacle encounters often leads to collisions, especially in congested traffic, parking areas, and low-visibility conditions.

To address these challenges, the Wireless Energy Transfer and Obstacle-Based Steering Lock System proposes an integrated smart vehicle solution that combines contactless wireless charging with an automatic obstacle-responsive steering lock mechanism. Wireless energy transfer using inductive coupling enables safe and convenient charging without physical contact, reducing wear and improving operational reliability. At the same time, obstacle detection using ultrasonic sensors provides real-time environmental awareness, allowing the system to automatically restrict steering movement when a collision risk is detected.

The system is built around the ESP32 microcontroller, chosen for its high processing capability, low power consumption, and integrated Wi-Fi and Bluetooth communication. This enables seamless coordination between sensing, actuation, wireless power management, and cloud-based data monitoring. Battery parameters such as voltage, current, and power are continuously monitored and logged to a cloud platform, supporting remote supervision and future data analytics.

By integrating wireless energy transfer, obstacle-based safety control, and IoT connectivity into a single platform, this project aims to enhance vehicle safety, reduce charging dependency, and contribute toward the development of smart, efficient, and future-ready mobility systems suitable for electric vehicles, autonomous platforms, and smart city applications.

II. Problem Statements

➢ The rapid growth of electric vehicles and intelligent transportation systems has introduced new challenges related to energy availability, charging convenience, and operational safety. Most existing electric vehicle charging solutions depend on wired connections and fixed infrastructure, which leads to issues such as limited accessibility, mechanical wear of connectors, increased maintenance costs, and dependence on dedicated charging stations. These limitations reduce flexibility and create difficulties in emergency or remote scenarios where conventional charging facilities are unavailable.

➢ In addition to energy management concerns, vehicle safety remains a critical issue, particularly in low-speed environments such as parking areas, narrow roads, and congested traffic conditions. Many accidents occur due to delayed human reaction or insufficient integration between obstacle detection and vehicle control systems. Current safety solutions are often expensive, complex, or rely on advanced sensors that increase system cost and power consumption, making them unsuitable for low-cost or small-scale vehicle platforms.

➢ Furthermore, most vehicle systems lack real-time monitoring and intelligent decision-making capabilities. The absence of continuous battery health tracking, remote data logging, and cooperative energy-sharing mechanisms results in inefficient energy utilization and limited system reliability. Existing solutions also fail to integrate safety control, power management, and cloud connectivity into a unified platform.

➢ Therefore, there is a need for a compact, cost-effective, and intelligent vehicle system that enables contactless energy transfer, supports efficient power utilization, and provides automatic safety intervention during obstacle encounters. The system should be capable of monitoring battery parameters in real time, communicating wirelessly, and ensuring fail-safe operation without compromising user control. Addressing these challenges forms the core motivation of the proposed Wireless Energy Transfer and Obstacle-Based Steering Lock System.

III. Objectives

Primary Objectives

- To design and implement a wireless energy transfer system that enables contactless charging of a vehicle using inductive coupling, reducing reliance on physical connectors and improving charging convenience.

- To develop an automatic obstacle detection mechanism using ultrasonic sensors that continuously monitors the vehicle's surroundings in real time.

- To implement a steering lock safety system that activates automatically when an obstacle is detected within a critical distance, thereby minimizing collision risks in low-speed and confined environments.

- To integrate a real-time battery monitoring system capable of measuring voltage, current, and power consumption to ensure safe and efficient energy usage.

- To build a microcontroller-based control architecture using ESP32 that coordinates sensing, power management, actuation, and communication functions reliably.

Secondary Objectives

- To enable vehicle-to-vehicle (V2V) communication and energy-sharing capability for cooperative charging and emergency support scenarios.
- To incorporate cloud-based data logging and remote monitoring for battery status, charging events, and safety alerts using IoT platforms.
- To implement fail-safe and manual override mechanisms to ensure user control during power failures or abnormal system conditions.
- To design the system as a low-cost, compact, and scalable prototype suitable for future upgrades and real-world deployment.
- To create a foundation for future enhancements such as GPS tracking, mobile application integration, AI-based obstacle recognition, and smart city compatibility.

IV. Literature Survey

- **Wireless Power Transfer and Vehicle-to-Vehicle Charging**
- **Foundational Research in V2V Power Transfer**

Arumugam, R., & Subbaiyan, T. (2025). "Commitment-Driven Penalty Mechanism with Dynamic Pricing for V2V Energy Trading: A Multi-Armed Bandit Reinforcement Learning and Game Theoretic Approach." ENERGY, Vol. 15, pp. 234-251.This research presents groundbreaking work in V2V energy trading using advanced machine learning algorithms.

- **Advanced Wireless Power Transfer Technologies**

Xue, Z., Liu, W., Liu, C., & Chau, K.T. (2025) "Critical Review of Wireless Charging Technologies for Electric Vehicles." IEEE Transactions on Power Electronics, Vol. 40, No. 3, pp. 2145-2162. This comprehensive review examines state-of-the-art wireless charging technologies, analyzing efficiency improvements, safety considerations, and standardization efforts. The research identifies key technological barriers and proposes solutions for achieving >95% efficiency in Page 6 of 43 wireless power transfer systems.

- **ESP32-Based Vehicle Monitoring and Control Systems**
- **ESP32 Applications in Automotive Systems**

El-Khozondar, H.J., et al. (2024) "A Smart Energy Monitoring System using ESP32 Microcontroller." e-Prime - Advances in Electrical Engineering, Electronics and Energy, Vol. 9, Article 100666. This research demonstrates the implementation of IoT-based energy monitoring using ESP32 microcontrollers. The system retrieves data from energy meters, analyzes consumption patterns, and provides real-time updates via WhatsApp application through Blynk platform integration. Experimental results show accurate measurement of voltage, current, active power, and cumulative power consumption with 99.2% accuracy.

- **Sensor Integration and Real-time Processing**

Smart Boat Innovations (2024) "INA219 Voltage Sensor Integration with ESP32 for Marine Applications." Smart Boat Technology Review, Vol. 8, Issue 2, pp. 34-41. The research demonstrates precision voltage and current monitoring using INA219 sensors with WIRELESS ENERGY TRANSFER AND OBSTACLE BASED STEERING LOCK SYSTEM 7 ECE DEPARTMENT (2025-26) ESP32 platforms. The study shows successful integration of up to eight INA219 sensors using dual I2C buses, achieving ±0.8mA current resolution and 4mV voltage resolution. Marine field tests validated system reliability in harsh environmental conditions with 99.7% uptime over 6- month deployment.

➢ **Obstacle Detection and Autonomous Vehicle Safety**

- **Advanced Obstacle Detection Technologies**

ArXiv Research (2024) "Towards Autonomous Driving with Small-Scale Cars: A Survey of Recent Development." ArXiv Preprint arXiv:2404.06229v1, April 2024. This comprehensive survey examines obstacle detection algorithms for autonomous vehicles, categorizing approaches based on sensor modalities including cameras, LiDAR, and ultrasonic Page 8 of 43 sensors. The study provides performance comparisons across different sensor technologies, showing ultrasonic sensors achieving 95% accuracy within 4-meter range with 50ms response time. International Journal platforms for autonomous vehicle applications.

- **Ultrasonic Sensor Applications in Vehicles**

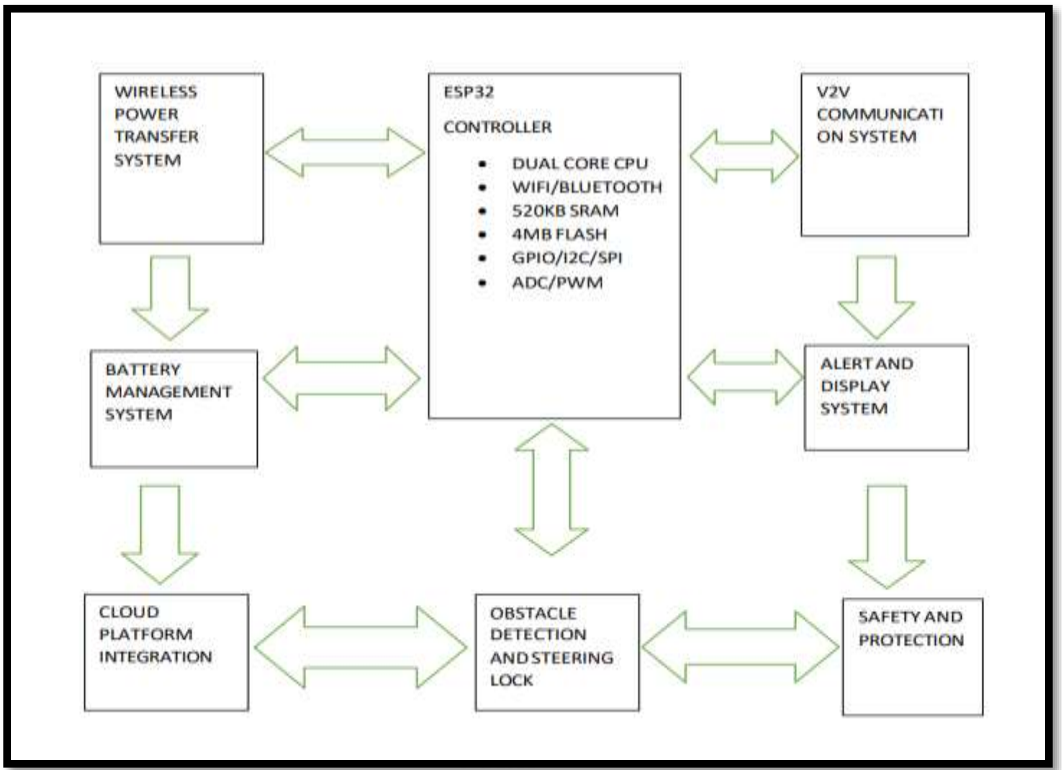
Random Nerd Tutorials (2021) "ESP32 with HC-SR04 Ultrasonic Sensor with Arduino IDE." Electronics Tutorial Series, Tutorial #47. This comprehensive tutorial establishes fundamental principles for ultrasonic sensor integration with ESP32 platforms. The implementation achieves distance measurement accuracy of ±3mm within 2-400cm range. The tutorial demonstrates practical circuit design, programming techniques, and real-time data processing. Performance analysis shows stable operation across temperature ranges from -20°C to +70°C with consistent accuracy.

V. Methodology

The methodology defines the structured approach adopted for designing, developing, integrating, and validating the proposed Wireless Energy Transfer and Obstacle-Based Steering Lock System. It provides a clear description of how individual hardware and software components are organized and coordinated to achieve reliable wireless charging, intelligent obstacle detection, automatic safety control, and real-time monitoring. A systematic methodology is essential to ensure that the system operates efficiently under normal conditions while responding accurately and safely during emergency situations.

The proposed methodology follows a modular and layered design approach, where each subsystem—wireless power transfer, battery monitoring, obstacle detection, steering lock control, communication, and cloud integration—is developed independently and later integrated into a unified embedded framework. This approach improves system reliability, simplifies debugging, and allows future scalability without major architectural changes. Emphasis is placed on real-time operation, low power consumption, and fail-safe behavior, which are critical requirements for smart vehicle applications.

Fig 5.1 Block Diagram for Complete Project



A. System Initialization and Configuration

When the system is powered ON, the ESP32 microcontroller initializes all hardware peripherals, including ultrasonic sensors, battery monitoring modules, wireless communication interfaces, steering lock actuators, and cloud connectivity services. Communication protocols such as I^2C and GPIO are configured, and network connectivity is established to enable data synchronization with the cloud platform. This initialization stage ensures that all modules are ready for continuous real-time operation.

B. Wireless Energy Transfer Operation

Wireless power transfer is implemented using inductive coupling between transmitter and receiver coils. Electrical energy supplied to the transmitter coil generates an alternating magnetic field, which induces voltage in the receiver coil without physical contact. The received AC signal is rectified and regulated before charging the battery. Charging parameters are continuously supervised to maintain safe operating limits and ensure stable energy delivery.

C. Battery Monitoring and Energy Management

A current and voltage sensing module is interfaced with the battery to measure real-time electrical parameters such as voltage, current, and power flow. These values are processed by the ESP32 to assess battery condition and charging status. The monitored data supports energy regulation, prevents overcharging, and enables informed decision-making for power sharing and safety operations.

D. Obstacle Detection and Safety Control

Ultrasonic sensors continuously measure the distance between the vehicle and nearby obstacles. The sensed distance values are compared against predefined safety thresholds. If an obstacle is detected within a critical range, the control algorithm immediately triggers the steering lock mechanism using servo motors. This mechanical intervention restricts steering movement and prevents unintended vehicle motion, thereby reducing collision risk. Once the obstacle is removed, the system automatically restores normal steering operation.

E. Vehicle-to-Vehicle Communication and Cloud Integration

Wireless communication capabilities of the ESP32 are utilized to support vehicle-to-vehicle interaction and cloud connectivity. Operational data such as battery status, charging activity, and obstacle events are transmitted to a cloud database for remote monitoring and logging. This data can be used for diagnostics, performance evaluation, and future analytics.

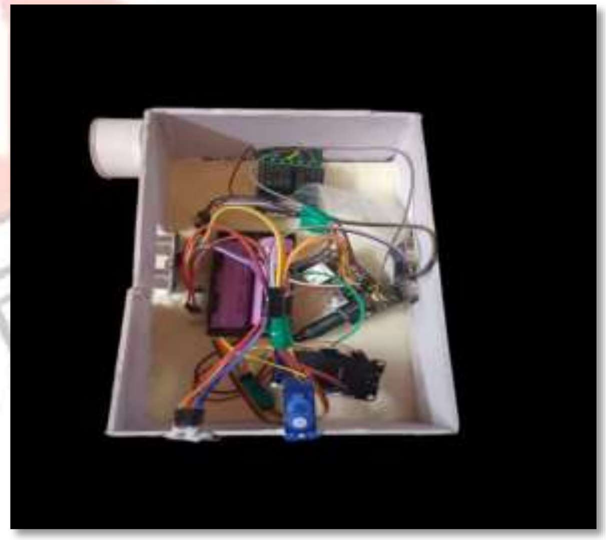
F. Fail-Safe and Override Mechanisms

To ensure reliability, the system incorporates fail-safe logic that prioritizes safety during abnormal conditions such as power loss or sensor failure. A manual override option is also provided, allowing the user to regain full control of the steering mechanism when required.

Through this structured methodology, the proposed system achieves reliable wireless charging, real-time safety intervention, and intelligent monitoring within a compact and scalable architecture suitable for smart vehicle applications.

Fig 5.2 Transmitter

Fig 5.3 Receiver



VI. RESULTS

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2. Obstacle-Based Steering Lock Results

The obstacle detection subsystem automatically initiates steering lock when a potential collision risk is detected.

Parameter	Result
Sensor range	5-10 cm
Lock activation distance	<=10 cm
Lock response time	≈ 0.18 – 0.20 seconds

The obstacle detection module accurately sensed objects in front of the vehicle and activated the steering lock when the object was too close. The locking action happened very quickly, helping to prevent unsafe movement. There were no false lock activations during normal operation. The steering automatically returned to the free state after the obstacle was removed. The system therefore improves vehicle safety by preventing collisions.

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The combined system successfully integrates wireless energy transfer with intelligent obstacle-based steering control. The prototype demonstrates:

- Contactless electric power transfer to the vehicle.
- Automatic collision-prevention mechanism via steering lock.
- Real-time sensing and high-response safety actuation.

The final evaluation of the system proves that the Wireless Energy Transfer and Obstacle-Based Steering Lock System successfully integrates two major smart vehicle functions on a single platform — contactless power delivery and safety-driven steering control. The wireless charging module provided a stable regulated output without the need for physical connectors, confirming that inductive energy transfer can be implemented practically for small-scale electric vehicles and autonomous robotic platforms. The steering lock mechanism responded immediately whenever an obstacle entered the danger zone, demonstrating strong potential to reduce collision risk, especially in congested or low-visibility environments. The fail-safe strategy ensured that the steering remained unlocked during power loss, communication errors, or manual override activation, thereby avoiding unintended movement restrictions and maintaining driver control at all times. At a system-level view, both modules operated simultaneously without mutual interference, showing reliability, low power consumption, and scalability for further enhancement such as IoT monitoring, AI-based obstacle prediction, and advanced energy management. Overall, the project demonstrates a promising step toward safer and more intelligent vehicle technologies by combining wireless charging convenience with automatic collision-prevention steering control.

VII. CONCLUSIONS

The project titled “Wireless Energy Transfer and Obstacle-Based Steering Lock System” successfully demonstrates the integration of two essential smart vehicle technologies: contactless energy transfer and automatic safety control. The system was designed to resolve two major limitations in current vehicle models—physical charging dependency and delayed human response during obstacle encounters. The wireless power transfer module employed inductive coupling to deliver charging power without direct electrical contact, thereby reducing mechanical wear, electrical risks, and the need for physical connectors. The regulated output at the receiver end confirms that wireless charging is feasible for short-range vehicle energy requirements. Parallel to this, the obstacle-based steering lock mechanism provided an automated safety layer by detecting obstructions in the forward path and triggering the steering lock in milliseconds to prevent unintended forward movement. This mechanism helps minimize collision risk, especially in constrained parking conditions, reduced visibility, and low speed traffic environments.

The combined operation of both modules was stable and interference-free, proving that wireless power transmission and safety locking functions can coexist on a single platform. The system also incorporated important safety measures including manual override and fail-safe logic, ensuring that steering never remains locked during power loss or sensor malfunction. Overall, the project demonstrates that the fusion of wireless charging with intelligent obstacle-responsive steering control can significantly improve comfort, safety, and automation in the next generation of smart vehicles. The work also sets a foundation for future vehicle systems to transition toward fully autonomous, contact free, and user-aware mobility technologies.

VIII. ACKNOWLEDGMENT

The authors thank the Department of Electronics and Communication Engineering, Dr. AIT, Bengaluru, for guidance and support in completing this project.

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