Remote Access Control E-Vehicle

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Publication Date: 2025/03/20

Abstract: This paper presents the design of an electrically powered autonomous vehicle for campus and airport shuttle applications. It features a modular ladder-frame chassis for optimal weight distribution and an advanced autopilot system utilizing LiDAR, ultrasonic sensors, and cameras for real-time mapping and obstacle detection. A Central Control Unit (CCU) integrates sensor inputs with adaptive cruise control and lane-keeping systems for safe operation. The vehicle also includes safety redundancy via CAN protocols, Electronic Stability Control (ESC), Regenerative Braking, and an optimized Battery Management System (BMS) for enhanced energy efficiency and performance. Simulations and tests indicate strong potential for urban transportation applications

How to Cite: Gaurav Dhatbale; Harsh Khinwasara; Manvendra Padgalwar; Akash Barote; Vishwashri Kulkarni (2025). Remote Access Control E-Vehicle. *International Journal of Innovative Science and Research Technology*, 10(3), 431-439. https://doi.org/10.38124/ijisrt/25mar304

I. INTRODUCTION

The rapid advancement of electric vehicles (EVs) has industry by reshaped the automotive providing environmentally friendly alternatives to traditional internal combustion engines. As electric propulsion technology evolves, there is growing interest in expanding the functionality of EVs through innovative control systems that enhance accessibility and convenience. This paper presents the design and development of an electric vehicle chassis optimized for Mobile Access Control (MAC), where the vehicle can be operated remotely through platforms such as gaming controllers. Unlike conventional EVs, this design focuses on enabling long-distance remote access, allowing users to control and monitor the vehicle from distant locations. The novelty of this work lies in integrating the mechanical design of the chassis with the electronic systems necessary for remote operation. The vehicle is equipped with a suite of sensors, including LiDAR, cameras, and ultrasonic sensors, which provide real-time data for environmental perception and obstacle detection. These sensors are processed by a Central Control Unit (CCU), which interprets input from remote control interfaces and ensures accurate and responsive vehicle control. In addition, radar-based Adaptive Cruise Control (ACC) and an Automated Lane-Keeping System (ALKS) further enhance the vehicle's ability to maintain safe operation in dynamic environments. Unlike autonomous systems that focus on full self-driving capabilities, this design emphasizes remote operability and user control, offering a unique blend of automation and human oversight. The drive-by-wire technology, which replaces traditional mechanical linkages with electronic controls, facilitates precise communication between the remote access systems and the vehicle's braking, steering,

and acceleration functions. This paper provides a comprehensive approach to chassis design, balancing the physical and electronic requirements for a Mobile Access Control Electric Vehicle, offering a scalable and adaptable platform that can evolve with future advancements in remote vehicle operation, while prioritizing safety, performance, and energy efficiency.

II. MECHANICAL STRUCTURE

A. Chassis and its Properties

The chassis is the framework that supports the loadbearing components of a vehicle, providing structural integrity and acting as a skeleton upon which various systems like the suspension, drivetrain, and body are mounted. In the context of autonomous electric vehicles, such as airport shuttles, the chassis plays a crucial role not only in maintaining the vehicle's structural strength but also in optimizing the distribution of weight, ensuring passenger safety, and accommodating essential components like the battery and motor. Selecting the appropriate chassis design is critical to the performance, safety, and efficiency of the vehicle. The following properties must be considered when designing or choosing a chassis:

➤ Torsional Stiffness: -

Torsional stiffness is one of the most important properties of a chassis. It measures the chassis' resistance to twisting forces that occur when one corner of the vehicle experiences a different load compared to the others. High torsional stiffness is crucial for maintaining structural integrity during cornering, preventing excessive flex, and ensuring that the vehicle's handling remains stable. A chassis

ISSN No:-2456-2165

lacking in torsional stiffness can negatively affect suspension performance and lead to safety concerns, such as rollovers.

➢ Bending Resistance: -

Chassis design must also account for resistance to vertical and lateral bending. Vertical bending typically occurs when the vehicle's weight, passengers, or cargo create forces that cause the chassis to sag in the middle. Lateral bending is experienced during cornering when side forces act on the vehicle. Both types of bending can lead to structural fatigue if not properly accounted for. A well-designed chassis should minimize these bending stresses to ensure a longer service life.

➤ Load Distribution: -

In electric vehicles, particularly those using a skateboard chassis, the load distribution is vital to ensure proper weight balance. The placement of heavy components, such as batteries and motors, must be carefully planned to lower the vehicle's center of gravity and improve stability. A well-balanced load distribution also contributes to better handling, reduced energy consumption, and an extended range.

➤ Material Selection: -

The choice of materials plays a significant role in chassis performance. Common materials used include Advanced High Strength Steel (AHSS), aluminum, magnesium, and composites like carbon fiber-reinforced plastic (CFRP). Each material offers different trade-offs in terms of strength, weight, cost, and recyclability. For example, AHSS provides excellent strength and torsional stiffness, but at a higher weight compared to aluminum, which is lighter but less rigid. CFRP offers the best strengthto-weight ratio but is more expensive and difficult to recycle.

> Durability and Corrosion Resistance: -

A chassis must be designed to withstand the wear and tear of daily use, including exposure to environmental factors like moisture and corrosive agents. Materials like aluminum and galvanized steel offer better corrosion resistance, extending the chassis' lifespan. This is especially important for vehicles operating in harsh or wet environments, such as airport shuttles that may be exposed to weather extremes and pollutants.

> Crashworthiness and Safety: -

Safety is a key concern in chassis design. The chassis must absorb impact forces during a collision to protect passengers. This is usually achieved by incorporating crumple zones and using materials with high energyabsorbing properties, such as AHSS. Additionally, the structural integrity of the chassis must remain intact to prevent excessive deformation in the event of a crash.

Manufacturability and Cost Efficiency: -

While performance characteristics are paramount, the chassis must also be manufacturable at scale. The design should allow for cost-effective production processes, such as welding or extrusion, and it should minimize material waste. Highly specialized materials or complex shapes can drive up production costs, making it essential to strike a balance between performance and manufacturability.

https://doi.org/10.38124/ijisrt/25mar304

Sustainability and Environmental Impact:

In modern vehicle design, sustainability plays a critical role. The chassis should be designed with recyclable materials to reduce environmental impact. Life Cycle Analysis (LCA) is commonly used to assess the sustainability of different material choices, from raw material extraction to the end-of-life phase. For instance, while materials like CFRP and magnesium offer superior weight reduction, they tend to have higher greenhouse gas (GHG) emissions during manufacturing compared to more traditional metals like steel and aluminum.

B. Types of Chassis

In the field of vehicle engineering, the chassis serves as the backbone of any vehicle, providing structural integrity, load-bearing capacity, and housing various critical components such as the powertrain, suspension, and electric motors. Several types of chassis are used in the automotive industry, each with distinct design characteristics and applications. The appropriate selection of a chassis type depends on factors such as the vehicle's intended use, structural demands, manufacturing constraints, and overall performance requirements.

> Backbone Chassis

The backbone chassis consists of a strong tubular backbone running along the vehicle's length, connecting the front and rear suspension systems. This chassis is primarily used in sports cars and heavy vehicles that need high torsional stiffness. However, it lacks side impact protection and is not suitable for larger vehicles or mass production.

- Advantages: Strong torsional rigidity, good for sports cars and heavy-duty applications.
- Disadvantages: Lacks side impact resistance, expensive, and not easily mass-produced.

➤ Monocoque Chassis

The monocoque chassis is a one-piece structure that integrates the vehicle's frame with its body. This design is most commonly found in passenger cars and is highly efficient for mass production. The monocoque chassis provides good crash protection, as the entire body absorbs and distributes impact forces. However, it is less suitable for larger, heavier vehicles.

- Advantages: Lightweight, fuel-efficient, excellent crash protection, cost-effective for mass production.
- Disadvantages: Less robust for heavy vehicles, challenging to repair after a major crash, limited flexibility in design.

➢ Sub Frame Chassis

The subframe chassis is a hybrid design where separate subframes are attached to the main body. These subframes can be used to support the engine, suspension, and other components, reducing noise and vibration. The subframe is

Volume 10, Issue 3, March – 2025

International Journal of Innovative Science and Research Technology

https://doi.org/10.38124/ijisrt/25mar304

often used in conjunction with monocoque designs for sports cars and compact vehicles.

- Advantages: Reduces noise and vibration, enhances torsional rigidity and allows modular design.
- Disadvantages: More expensive than simple monocoque, not suitable for heavy-duty applications.

Skateboard Chassis

ISSN No:-2456-2165

The skateboard chassis is a relatively new platform used primarily for electric vehicles (EVs). It features a flat battery pack at the base with electric motors mounted at either end. The "skateboard" structure allows great flexibility in vehicle design, making it easy to swap out different bodies on the same platform.

- Advantages: Flexibility for EVs, centralized battery placement for optimal weight distribution, low center of gravity.
- Disadvantages: Requires a flat, non-modular design, not as robust for off-road or heavy-duty vehicles, costly to produce.

> Ladder (Frame) Chassis

The ladder chassis is one of the oldest and simplest designs, consisting of two longitudinal beams (or rails) connected by several cross-members. This traditional chassis is often used in trucks, buses, and off-road vehicles because of its strength and ability to handle heavy loads. The ladder chassis is typically more robust and can withstand higher torsional and bending stresses, making it ideal for heavy-duty applications.

• Advantages: High load-bearing capacity, durable, easy to repair, excellent for heavy-duty and off-road applications.

Why Ladder Chassis is best suitable for Our EV The ladder chassis remains an optimal choice for applications requiring high durability, load-bearing capacity, and ease of maintenance, particularly in autonomous, heavyduty vehicles like airport shuttles. Key reasons for advocating the ladder chassis include:



Fig 1 Ladder Chassis

Structural Integrity: The ladder chassis offers superior torsional rigidity and resistance to bending, making it ideal for vehicles that experience high loads, such as shuttles transporting passengers and luggage. This high level of rigidity helps maintain vehicle stability and ensures that the chassis can withstand various stresses during operation, including lateral and vertical bending.

Load-Bearing Capacity: Due to its simple but strong construction, the ladder chassis can easily support heavy loads without compromising performance. This makes it suitable for buses, trucks, and utility vehicles that require robust frames to handle significant gross vehicle weights (GVW).

Durability and Longevity: The ladder chassis is highly durable and can withstand the stresses of long-term use in challenging environments. Its sturdy construction ensures it performs well in off-road and uneven terrains, which is essential for airport shuttles that may have to endure varying surfaces.

Ease of Maintenance and Repair: One of the primary benefits of the ladder chassis is its ease of maintenance. If damage occurs, individual components such as the crossmembers or side rails can be replaced or repaired without needing to dismantle the entire frame. This reduces downtime and maintenance costs, an essential factor for fleet vehicles like shuttles.

Modularity: The ladder chassis is modular, meaning different vehicle bodies can be mounted on the same base. This flexibility allows manufacturers to produce multiple vehicle variants on the same basic structure, improving efficiency and reducing costs.

Cost-Effective Production: Though heavier than monocoque designs, the ladder chassis is simpler and cheaper to produce. Its straightforward construction allows for costeffective manufacturing processes, making it an attractive option for vehicles that prioritize robustness and costefficiency over weight savings.

Chassis Type	Torsional Rigidity	Weight	Cost	Suitability for Heavy Vehicles	Crashworthiness	Repairability
Backbone	High	Medium	High	Medium	Low	Low
Monocoque	Medium	Low	Low	Low	High	Low
Subframe	Medium- High	Medium	Medium	Medium	Medium	Medium
Skateboard	Medium	Low	High	Medium	Medium	Low
Ladder	High	High	Medium	High	Medium	High

Table 1 Comparison of Chassis

While modern chassis designs such as the skateboard and monocoque chassis offer advantages for specific applications like electric passenger cars, the ladder chassis remains the superior option for autonomous airport shuttles and other heavy-duty vehicles. Its strength, load-bearing capacity, and ease of maintenance make it an ideal choice for vehicles that operate under demanding conditions and require long-lasting durability. By combining these attributes with modern materials like Advanced High Strength Steel (AHSS), the ladder chassis can continue to serve as a benchmark for high-performance vehicle design in robust applications.

C. Steering Mechanism

In automotive engineering, the steering mechanism is a critical component that directly impacts vehicle control and driver safety. Various types of steering mechanisms have been developed over time, each with its own advantages and applications.

Different types of Steering Mechanism are given.

Mechanical Steering Mechanism

A mechanical steering mechanism is the most basic type of steering system, where no external power assistance is provided. In this system, the driver relies solely on physical effort to turn the steering wheel, with the motion being directly transmitted to the vehicle's wheels through a series of mechanical linkages. Key components of the system include the steering column, pitman arm, tie rods, and steering rack, all of which work together to transfer the driver's input to the wheels. Since there is no power assistance, steering, particularly at low speeds or when stationary, requires significant force from the driver. This type of steering was common in early vehicles and is still used in some heavy-duty off-road vehicles where simplicity and durability are prioritized. However, due to the high physical effort required, mechanical steering has largely been replaced by powerassisted systems in modern vehicles.

Hydraulic Power Steering (HPS)

Hydraulic power steering (HPS) was a widely used system in the past, providing power assistance to the driver through the use of hydraulic fluid. In this system, a power steering pump, which is driven by the vehicle's engine, pressurizes the hydraulic fluid to assist in turning the wheels, significantly reducing the effort required by the driver, particularly at low speeds or when manoeuvring heavy vehicles. While HPS improves ease of steering, especially in larger vehicles such as SUVs and trucks, the hydraulic assist can sometimes diminish the natural road feel, making the feedback to the driver less precise. Despite this, the system still offers some level of feedback. HPS was especially popular from the 1950s through the early 2000s and was commonly found in larger and heavier vehicles where reducing steering effort was a major advantage. Today, it has largely been replaced by more efficient electric power steering systems.

Electric Power Steering (EPS)

Electric Power Steering (EPS) is a modern steering system that uses an electric motor to assist the driver, offering significant advancements over traditional hydraulic systems. Instead of relying on a hydraulic pump, EPS utilizes sensors to detect the driver's steering input, and a computercontrolled electric motor provides the necessary assistance. This design improves fuel efficiency as power is only consumed when steering input is required, unlike hydraulic systems that continuously run the pump. EPS offers precise control, with the ability to adjust steering assistance based on speed, providing lighter steering at low speeds for easier maneuverability and heavier steering at high speeds for better stability. Additionally, the system has lower maintenance costs, as it eliminates the need for hydraulic fluid and pumps. EPS is highly adaptable, making it ideal for integration with advanced driver-assistance systems (ADAS) such as lanekeeping assist and autonomous driving features. It is now commonly used in modern cars, light trucks, and some commercial vehicles.

Rack and Pinion Steering

Rack and pinion steering is a widely used mechanical steering mechanism, known for its simplicity and direct response. In this system, when the driver turns the steering wheel, it rotates a pinion gear that meshes with a toothed rack. The linear movement of the rack then turns the wheels left or right, providing precise control. This design offers a straightforward and efficient way to steer, making it highly responsive to driver input. Although it can function as a purely mechanical system, it is often paired with power-assist systems, such as hydraulic power steering (HPS) or electric power steering (EPS), to reduce the effort required to turn the wheel, especially at low speeds. Rack and pinion steering is widely applied in modern vehicles, ranging from small

ISSN No:-2456-2165

passenger cars to trucks, because of its reliability, accuracy, and compatibility with both hydraulic and electric assistance for enhanced performance.

➢ Four-Wheel Steering (4WS)

Four-wheel steering systems enhance vehicle maneuverability and stability by allowing the rear wheels to turn in coordination with the front wheels. At low speeds, the rear wheels typically turn in the opposite direction to the front wheels, which effectively reduces the vehicle's turning radius, making tight turns easier and improving overall maneuverability in urban environments. Conversely, at higher speeds, the rear wheels turn in the same direction as the front wheels, which increases stability and handling by providing better alignment during lane changes and highspeed cornering. This dual-functionality makes four-wheel steering particularly beneficial in high-performance sports cars, luxury sedans, and some heavy trucks, where both agility and stability are crucial for an enhanced driving experience. By optimizing the relationship between the front and rear wheels, four-wheel steering systems significantly improve the overall dynamics of the vehicle, making it more responsive and enjoyable to drive

Steer-by-Wire

Steer-by-wire systems represent a cutting-edge advancement in steering technology, eliminating the traditional mechanical connection between the steering wheel and the wheels. Instead of relying on physical linkages, this system uses electronic controls and actuators to process the driver's input, enabling highly customizable and precise steering responses. This innovation allows for minimal effort from the driver, as the system can be tuned to provide varying levels of resistance and feedback based on driving conditions or personal preferences. Additionally, steer-by-wire systems facilitate enhanced integration with automated driving technologies and adaptive control features, paving the way for more advanced vehicle dynamics. By removing mechanical components, these systems also have the potential to reduce vehicle weight, contributing to improved efficiency and performance. Currently, steer-by-wire technology is

emerging in concept vehicles and select high-end electric cars, aligning with the industry's shift towards greater automation and the future of autonomous driving.

https://doi.org/10.38124/ijisrt/25mar304

Why Rack and Pinion with Electric Power Steering over other Steering Mechanism

The integration of a rack and pinion steering system with electric power steering (EPS) stands out as the superior choice for modern automated electric vehicles (EVs). This combination offers a unique blend of precision, efficiency, and adaptability that other steering mechanisms cannot match. The direct mechanical connection of the rack and pinion design ensures a responsive steering feel, while the electric power assistance significantly reduces the physical effort required from the driver, enhancing overall comfort and control. Moreover, EPS allows for customizable steering feedback and integration with advanced driver-assistance systems, which are crucial for the functionality of automated driving. Additionally, this setup contributes to weight reduction by eliminating bulky hydraulic components, thus improving vehicle efficiency. As the automotive industry moves toward greater automation and electrification, the rack and pinion with electric power steering configuration emerges as a forward-thinking solution that aligns perfectly with the demands of modern EV design and performance.



Fig 2 Rack and Pinion Steering



Fig 3 Hydraulic Assisted Power Steering



Fig 4 Electric Assisted Power Steering



Fig 5 Wheel Steering System

https://doi.org/10.38124/ijisrt/25mar304

Table 2 Com	parison, Ad	vantages and	Disadvantages	of	different	Chassis
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Steering	Key Features	Advantages	Disadvantages	Application	
Mechanism					
Rack and Pinion	Direct mechanical	Responsive and precise	- Initial cost can be	Common in modern	
with EPS	connection,	Minimal driver effort	higher	EVs, passenger cars,	
	Electric motor assistance,	-Integrates easily with	- Requires electronic	luxury vehicles	
	Customizable feedback	ADAS	components		
Mechanical	Direct mechanical	-Simple and reliable	- High effort required,	Early vehicles, heavy-	
Steering	connection	- Low cost	especially at low speeds	duty off-road vehicles	
			- Limited feedback		
Hydraulic	Engine-driven hydraulic	Significant reduction in	- Heavier system	Vehicles from the	
Power Steering	pump	steering effort	- Maintenance for	1950s to early 2000s,	
(HPS)	Power assistance	-Good feedback	hydraulic fluid	larger vehicles	

III. SYSTEM DESIGN

A. Hardware Components

The following components were selected and integrated to meet the specific requirements of the project:

➢ Raspberry Pi 3B:

The Raspberry Pi 3B serves as the central processing unit (CPU) of the system. It receives input signals from the remote control or mobile application and processes them to generate control signals. With its quad-core ARM Cortex-A53 CPU, the Raspberry Pi 3B provides sufficient computing power to handle real-time data processing, communication with the Arduino, and control signal generation. It also supports wireless connectivity, enabling the use of a mobile app for remote control.





➤ Key Features:

- Quad-core ARM Cortex-A53 1.2GHz
- 1GB RAM
- 40 GPIO pins for hardware interfacing
- Integrated 802.11n wireless LAN
- Bluetooth 4.1

Role in the Project:

The Raspberry Pi processes remote control inputs, manages serial communication with the Arduino, and performs decision-making tasks for vehicle operation.

> Arduino UNO:

The Arduino UNO is used as the secondary controller to manage the motor driver and relays. It receives commands from the Raspberry Pi via serial communication and converts these into PWM signals that control the motor's speed and steering. The Arduino also interfaces with the relays, enabling forward and reverse motion, and controls additional vehicle functions such as the horn.



Fig 7 Arduino Uno Board

- ➤ Key Features:
- ATmega328P microcontroller
- 14 digital input/output pins (6 PWM)
- 6 analog input pins
- Serial communication capability with the Raspberry Pi
- *Role in the Project:*

The Arduino receives commands from the Raspberry Pi and sends control signals to the motor driver and relays to manage the vehicle's speed, direction, and other functions.

Cytron 10A Motor Driver:

The Cytron 10A motor driver is responsible for controlling the steering motor of the vehicle. It receives PWM signals from the Arduino, which regulate the voltage supplied to the motor, thereby controlling its speed and direction. The motor driver is crucial for ensuring smooth and precise steering, which is essential for vehicle maneuverability.



Fig 8 Cytron 10amp Motor Driver

- > Key Features:
- Supports up to 10A continuous current
- Dual H-Bridge for controlling two DC motors
- PWM frequency up to 20 kHz for smooth motor control

Role in the Project: The motor driver adjusts the speed and direction of the steering motor based on PWM signals from the Arduino, allowing for precise control of the vehicle's steering system.

Rack and Pinion System with Angle Sensor:

The vehicle's steering is based on a rack and pinion system, which is a widely used mechanism in automotive steering. An angle sensor is mounted on the rack and pinion to provide real-time feedback to the Raspberry Pi regarding the steering angle. This feedback allows for accurate control of the steering motor by adjusting the motor's rotation to match the desired angle.



Fig 9 Angle Sensor Placement

- Key Features:
- Real-time feedback on the steering angle
- Interface with Raspberry Pi for closed-loop control
- > Role in the Project:

The angle sensor ensures precise steering control by providing feedback on the position of the steering system, which the Raspberry Pi uses to adjust motor output.

Relays for Motion Control:

Relays are used to control the vehicle's forward and reverse motion, as well as to operate the horn. The relays are activated based on commands from the Arduino, which in turn receives instructions from the Raspberry Pi.

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Fig 10 Relay Module

- ➤ Key Features:
- Electromechanical switches for controlling high-power circuits
- Can handle the vehicle's power requirements for motion control
- > Role in the Project:

Relays manage the vehicle's directional control (forward/reverse) and auxiliary functions (e.g., horn).

Voltage Step-Down Modules:

The vehicle incorporates voltage step-down modules to ensure proper power distribution to the various components. These modules reduce the vehicle's battery voltage to levels suitable for the Raspberry Pi, Arduino, and other low-power components.



Fig 11 Voltage StepUp Module

➤ Key Features:

- Converts input voltage (e.g., 12V) to lower output voltages (e.g., 5V)
- High efficiency to minimize power loss
- Role in the Project: Voltage step-down modules are critical for powering the Raspberry Pi, Arduino, and other electronics safely, without overloading them.

B. System Architecture

The system architecture is designed to allow for seamless communication and control between the Raspberry Pi, Arduino, motor driver, and relays.

Volume 10, Issue 3, March – 2025

ISSN No:-2456-2165

- > Signal Flow:
- Inputs from the remote control or mobile app are processed by the Raspberry Pi.
- The Raspberry Pi communicates with the Arduino UNO via serial communication.
- The Arduino converts the data into PWM signals for the motor driver and sends control signals to the relays.

Steering and Motion Control:

Steering control is achieved through the Cytron motor driver, which adjusts the rotation of the steering motor. The vehicle's forward and reverse motion is controlled by activating the appropriate relays, which change the polarity of the motor's power supply.

> Power Management:

The vehicle's battery powers all components, with voltage step-down modules ensuring that the Raspberry Pi, Arduino, and sensors receive the appropriate power levels.

IV. IMPLEMENTATION DETAILS

➤ Steering Control

The steering system is based on a rack and pinion mechanism, which converts the rotational motion of the steering motor into linear motion, turning the vehicle's wheels. The angle sensor mounted on the rack and pinion system provides feedback to the Raspberry Pi, which adjusts the motor's output to achieve the desired steering angle.

• Closed-Loop Feedback System:

The Raspberry Pi uses feedback from the angle sensor to compare the current steering angle with the target angle, adjusting the PWM signal to the motor driver to correct any deviation. This closed-loop system ensures precise steering control, allowing the vehicle to navigate accurately.

Motor Speed and Direction Control

The speed of the vehicle's drive motor is controlled by the Arduino, which sends PWM signals to the motor driver. The PWM signal modulates the voltage applied to the motor, adjusting its speed accordingly. The direction of motion (forward or reverse) is managed by the relays, which switch the polarity of the motor's power supply.

• *PWM Control:*

PWM allows for fine-grained control over the motor's speed by varying the duty cycle of the signal. The Arduino adjusts the duty cycle based on input from the Raspberry Pi, ensuring smooth acceleration and deceleration.

• Relay-Based Direction Control:

Relays are used to reverse the polarity of the motor's power supply, enabling forward or reverse motion. This is achieved by toggling the relays based on the commands sent from the Raspberry Pi through the Arduino.

Power Distribution and Voltage Regulation

The vehicle's electrical system is powered by a main battery, which supplies voltage to all components. However, many components, such as the Raspberry Pi and Arduino, require lower voltage levels. Voltage step-down modules are used to regulate the voltage supplied to these components, ensuring stable and safe operation.

https://doi.org/10.38124/ijisrt/25mar304

• Step-Down Module Efficiency:

The voltage step-down modules operate at high efficiency, minimizing power loss and heat generation while supplying a consistent voltage to the sensitive electronic components.

V. RESULTS

The completed project successfully demonstrates the ability to control an electric vehicle remotely using both a handheld remote control and a mobile app. The system allows for precise control of steering through the integration of the angle sensor and feedback loop, while the vehicle's motion is reliably managed via relays and PWM signals. All components worked together seamlessly, and voltage regulation ensured stable operation throughout testing.

Steering Control: The steering system responded accurately to user inputs, with real-time feedback from the angle sensor allowing for precise adjustments to the steering motor.

Speed and Motion Control: The PWM control of the motor provided smooth acceleration and deceleration, while the relays ensured reliable switching between forward and reverse motion.

System Stability: Power distribution was well-managed through the use of voltage step-down modules, preventing any issues related to overvoltage or power surges.

VI. CONCLUSION

This project successfully demonstrates the design and development of a remote-controlled electric vehicle using Raspberry Pi and Arduino. By integrating various hardware components such as a motor driver, relays, and angle sensors, the system provides precise control over the vehicle's steering and motion. The use of both remote control and mobile app-based operation adds flexibility and convenience, making this solution applicable to a wide range of use cases, from personal transportation to industrial automation.

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