DE-41 (EE) AFTAB NASEER, ZEESHAN ALI

SMART ROAD WITH WIRELESS POWER TRANSFER CAPABAILITIES FOR EV’s

COLLEGE OF
ELECTRICAL AND MECHANICAL ENGINEERING
NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY
RAWALPINDI
2023

ENGINEERING COLLEGE OF ELECTRICAL AND MECHANICAL

DE-41 EE
PROJECT REPORT

SMART ROAD WITH WIRELESS POWER TRANSFER CAPABAILITIES FOR EVs

Submitted to the Department of Electrical Engineering
in partial fulfillment of the requirements
for the degree of
Bachelor of Engineering
in
Electrical
2023

Submitted By:

AFTAB NASEER
ZEESHAN ALI

بسم الله الرحمن الرحيم

Certificate of approval

This is to certify that our final year project titled "**Smart Road with Wireless Power Transfer Capabilities for EVs**" has been successfully done by **ASC AFTAB NASEER** and **ASC ZEESHAN ALI** completed under the guidance and supervision of Assistant Professor **Dr. Taosif Iqbal**.

This project is being submitted to the **Department of Electrical Engineering** at the College of Electrical and Mechanical Engineering Campus, National University of Sciences and Technology, Pakistan, in partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering.

Students:

i) Aftab Naseer

NUST ID: 00000325270

Signature: ___________________________

ii) Zeeshan Ali

NUST ID: 00000325283

Signature: ___________________________

Project Supervisor:

Assist Prof Dr. Taosif Iqbal

Signature: ___________________________

COPYRIGHT STATEMENT

DECLARATION

We hereby declare that the content presented in this Project Thesis is original and has not been submitted in support of any other degree or qualification, either at this educational institution or elsewhere. We acknowledge that any form of plagiarism will result in full responsibility and may lead to disciplinary action, including the potential revocation of our degree, depending on the gravity of the offense.

i) Aftab Naseer

Signature: __________________________

ii) Zeeshan Ali

Signature: __________________________

ACKNOWLEDGMENTS

We would like to begin by expressing our sincere gratitude to Allah Ta'ala for granting us the wisdom and courage to comprehend and overcome the challenges encountered during this endeavor. Alongside our collective efforts, the guidance and support of numerous individuals have played a vital role in the success of this project.

We extend our heartfelt appreciation to our supervisor, Dr. Usman Ali, whose exceptional assistance, encouragement, and guidance were instrumental in our achievements. His unwavering support propelled us forward and helped us navigate through the project with confidence.

Furthermore, we are indebted to our beloved parents, whose unwavering support and patience have been indispensable on our journey. They have consistently been our pillars of strength, providing us with the encouragement and assistance we needed.

Lastly, we would like to express our gratitude to the Electrical Engineering Department for their continuous support throughout our academic endeavors. We are grateful to the instructors and support staff who have tirelessly provided us with invaluable resources and guidance, enabling us to excel in our chosen field.

We acknowledge the contributions of all those who have played a part in our success and extend our heartfelt thanks to each one of them.

ABSTRACT

The current state of battery technology for electric vehicles falls short in terms of energy density advancements, creating a need for a solution that eliminates battery dependency. Our project proposes a simple and scalable design that extracts energy directly from the road, offering infinite range for electric vehicles. This innovative technology, currently under development in Switzerland, utilizes resonated electromagnetic induction to transmit electrical energy to the vehicle. By addressing the challenges of heavy batteries, high carbon footprint, and time inefficiency, our solution aims to revolutionize electric vehicle power and enable widespread adoption.

Implementing this solution requires collaboration among industry experts, policymakers, and researchers. With their support, we strive to overcome the limitations of current battery technology and contribute to a sustainable transportation ecosystem. Our ultimate goal is to provide a practical, efficient, and scalable solution that revolutionizes electric vehicle power, making clean and efficient transportation accessible to all. By harnessing the power of road-based energy extraction, we aim to pave the way for a future where high-power electric vehicles are seamlessly integrated into everyday life.

SUSTAINABLE DEVELOPMENT GOALS

SDG 7 - Affordable and Clean Energy: The project significantly contributes to SDG 7 by enabling affordable and clean energy solutions. Through the integration of wireless power transfer technology into roads, electric vehicles (EVs) can be conveniently and wirelessly charged, reducing reliance on fossil fuels and promoting sustainable energy practices.

SDG 9 - Industry, Innovation, and Infrastructure: The project aligns with SDG 9 by fostering innovation, resilient infrastructure, and sustainable industrialization. By implementing a smart road with wireless power transfer capabilities for EVs, it paves the way for advanced transportation infrastructure, offering efficient charging solutions and contributing to the development of smart and sustainable cities.

SDG 13 - Climate Action: The project plays a vital role in addressing SDG 13 by actively combating climate change. Through the promotion of electric mobility and the use of renewable energy sources, it significantly reduces carbon dioxide emissions and air pollution associated with traditional transportation. The wireless charging enabled by the smart road infrastructure further accelerates the adoption of clean energy for transportation, fostering a more sustainable and low-carbon future.

Table of Contents

LIST OF FIGURES

LIST OF ABBREVIATIONS

The common abbreviations used in our project and used while writing this thesis are:

EV	Electric Vehicle
RF	Radio Frequency
WPT	Wireless Power Transfer
Q factor	Quality Factor
ZVS	Zero Voltage Switching
LCR	Inductance, Capacitance, and Resistance
MPPT	Maximum Power Point Tracking
PWM	Pulse Width Modulation
DC	Direct Current
AC	Alternating Current
GHz	Gigahertz
kHz	Kilohertz
PCB	Printed Circuit Board
MCU	Microcontroller Unit
RFID	Radio Frequency Identification
EMF	Electromagnetic Field
OTA	Over-The-Air
P2P	Point-to-Point
BMS:	Battery Management System
SOC	State of Charge
EMI	Electromagnetic Interference
PCB	Printed Circuit Board
IGBT	Insulated Gate Bipolar Transistor
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
Li-ion	Lithium-ion
SOC	System on Chip
API	Application Programming Interface
GUI	Graphical User Interface
kWh	Kilowatt-hour
OCP	Overcurrent Protection
OVP	Overvoltage Protection

LIST OF SYMBOLS

P	Power
V	Voltage
I	Current
R	Resistance
L	Inductance
C	Capacitance
f	Frequency
η	Efficiency
Q	Q factor
ω	Angular frequency
W	Watt
A	Ampere
Ω	Ohm
H	Henry
F	Farad
kHz	Kilohertz
mm	Millimeter
cm	Centimeter
m	Meter
μ	Micro (Prefix)
Φ	Magnetic flux
D	Diameter
N	Number of turns
d	Distance
AC	Alternating Current
DC	Direct Current
Δ	Delta (Change)
t	Time
E	Electric field strength
B	Magnetic field strength
ε	Permittivity
μ	Permeability

f_res	Resonant frequency
Z	Impedance
LCR	Inductance, Capacitance, and Resistance
mH	Millihenry
uF	Microfarad
S	Siemens (Unit of Conductance)
ε_0	Vacuum permittivity
μ_0	Vacuum permeability
ε_r	Relative permittivity (Dielectric constant)
μ_r	Relative permeability

CHAPTER 01-INTRODUCTION

The introduction chapter lays the foundation for the thesis by providing an overview of the research topic and its significance in the context of sustainable transportation. It highlights the limitations of traditional EV charging methods and introduces the concept of smart roads as a potential solution. Additionally, the chapter outlines the research objectives, presents the research questions that will be addressed, and discusses the scope and limitations of the study.

1.1 Project overview:

The project focuses on the development and implementation of a smart road infrastructure with wireless power transfer capabilities for electric vehicles (EVs). The objective is to design a system that enables efficient and convenient charging of EVs while they are in motion, thereby addressing the limitations of traditional charging methods.

Smart road technology aims to provide a seamless charging experience for EV owners by eliminating the need for frequent stops at charging stations. Instead, the EVs will receive power wirelessly through the road infrastructure, allowing for continuous charging while on the move. This feature not only reduces charging time but also extends the driving range of EVs, making them more practical and appealing to a wider range of users.

The project will involve several key components, including the design of the wireless power transfer system, the integration of charging infrastructure into the road network, and the development of communication protocols for effective vehicle-to-infrastructure interaction. Additionally, the project will explore the implementation of intelligent systems for monitoring and managing the charging process, ensuring optimal efficiency and reliability.

The research will encompass theoretical analysis, system design, simulation studies, and possibly experimental validation to evaluate the performance and feasibility of the proposed smart road technology. Factors such as power transmission efficiency, safety, cost-effectiveness, and scalability will be considered during the project.

The goal of this project is to contribute to the advancement of sustainable transportation by offering an innovative solution that enhances the convenience and practicality of EV charging. By developing a reliable and efficient smart road infrastructure, the project aims to facilitate the wider adoption of EVs and promote a cleaner and greener future in the realm of transportation.

1.2 Problem Statement:

The increasing adoption of electric vehicles (EVs) presents a significant challenge in terms of developing efficient and convenient charging infrastructure. Traditional plug-in charging stations have limitations such as limited availability, long charging times, and the need for physical connections, which can hinder the widespread adoption and practicality of EVs.

To overcome these limitations, there is a need for innovative solutions that can provide continuous and convenient charging for EVs while they are in motion. The existing approach of smart roads with wireless power transfer capabilities for EVs has emerged as a potential solution. However, there are several key challenges and research gaps that need to be addressed in order to fully realize the benefits of this technology.

Firstly, the development of an efficient and reliable wireless power transfer system that can deliver power to EVs while they are in motion poses technical challenges related to power transmission efficiency, safety, and scalability. Ensuring a high level of efficiency and safety in wirelessly transferring power to moving vehicles is critical for the practical implementation of smart roads.

Secondly, the integration of wireless charging infrastructure into the existing road network requires careful planning and design considerations. The implementation of a robust communication system and effective vehicle-to-infrastructure interaction protocols is necessary to facilitate seamless charging and management of EVs on smart roads.

Lastly, there is a need to evaluate the economic viability and feasibility of implementing smart roads with wireless power transfer capabilities on a larger scale. Assessing the cost-effectiveness, environmental impact, and potential regulatory and policy implications is crucial for the successful deployment and adoption of this technology.

1.3 Approach

The project, "Smart Road with Wireless Power Transfer Capabilities for Electric Vehicles (EVs)," focuses on the design of a road infrastructure that enables wireless power transfer to EVs from the road while they are in motion. This innovative approach involves a series of steps to achieve its goal, including:

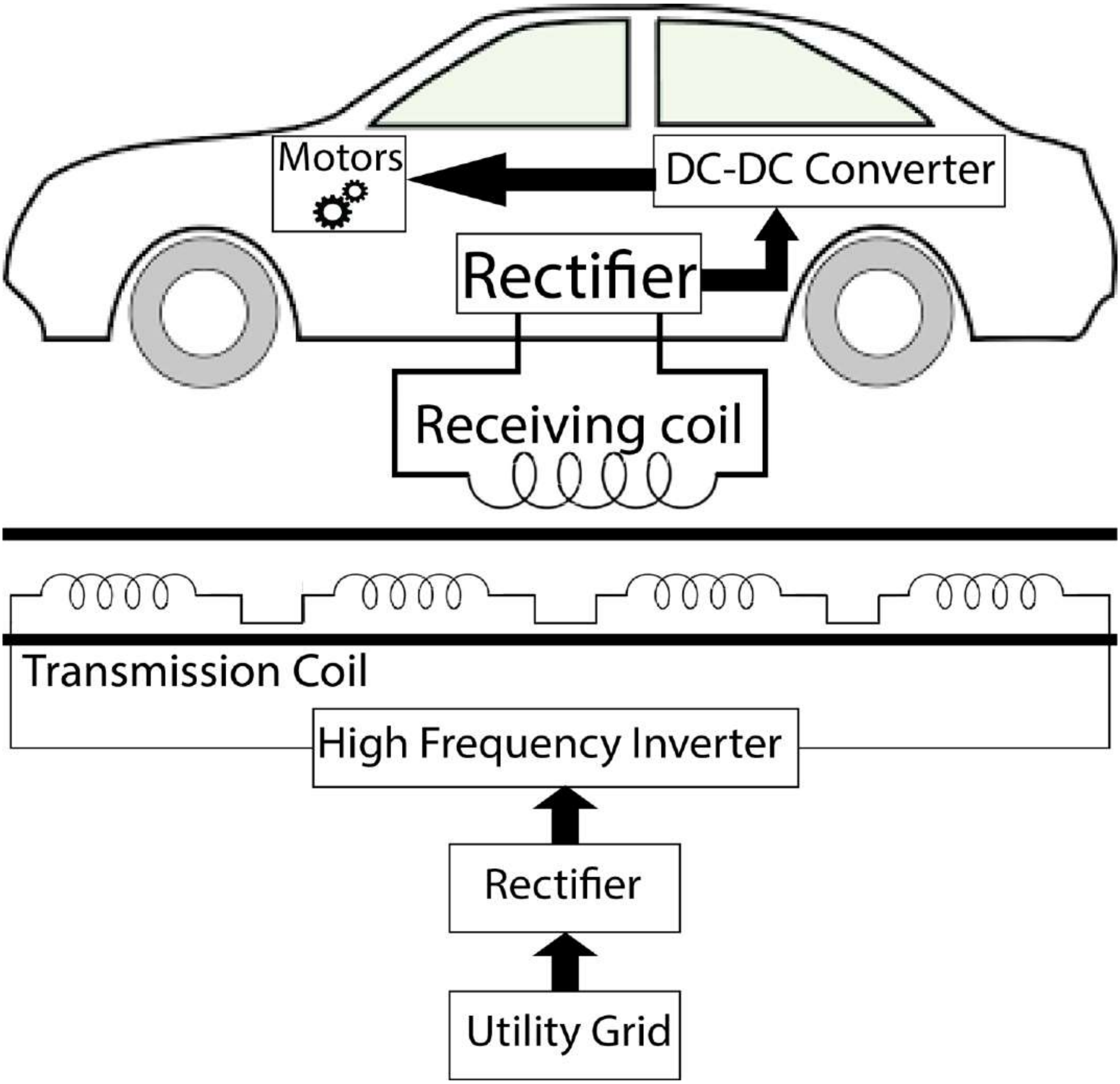


Figure 1

1.3.1 Load Calculations

Load calculations are an essential aspect of the project aimed at designing a smart road with wireless power transfer capabilities for electric vehicles (EVs). These calculations are necessary for a variety of reasons. Firstly, they are crucial in the system design phase. By accurately estimating the power requirements of EVs utilizing the smart road infrastructure, the system can be designed to efficiently handle the expected load. This includes determining the power capacity needed for the wireless power transfer system and designing the infrastructure accordingly.

Furthermore, load calculations are vital for optimizing power transmission efficiency. Accurate load calculations enable the design of systems that minimize power losses during wireless power transfer. By ensuring that the system is appropriately sized to handle the estimated load, energy wastage can be reduced, leading to improved overall system performance.

Safety considerations are also an important factor in load calculations. By accurately estimating the load, the smart road infrastructure can be designed to operate within safe parameters. Overloading the system can lead to potential hazards such as overheating, electrical failures, or damage to the infrastructure. Proper load calculations help ensure that the system operates safely and reliably.

Lastly, load calculations contribute to optimizing the charging efficiency of EVs.By accurately determining the load, the wireless power transfer system can provide the necessary power to the EVs at an appropriate rate. This helps minimize charging times and maximize the overall efficiency of the charging process, making it more convenient for EV owners.

In summary, load calculations are critical for designing our project. They aid in system design, optimize power transmission efficiency, ensure safety, and improve the charging efficiency of EVs. By accurately estimating the load, the smart road can be designed to meet the power demands of EVs effectively and efficiently.

1.3.2 Efficiency and Frequency Target:

Efficiency is crucial in our project as it directly impacts the effectiveness of power transfer from the road infrastructure to the EVs. Achieving high efficiency ensures that a maximum amount of power is transmitted to the EVs, minimizing energy losses during the wireless charging process. This is particularly important for optimizing the overall energy consumption and promoting sustainability in EV charging.By setting and meeting efficiency targets, we can design the wireless power transfer system to operate efficiently, maximizing power transmission while minimizing wasted energy.

Frequency targets are also relevant to our project as they determine the specific frequency at which power is transmitted wirelessly. The selection of an appropriate frequency is essential to ensure efficient and reliable power transfer. The chosen frequency should be compatible with the wireless power transfer technology employed in the smart road infrastructure. It should provide a balance between efficient power transmission and minimal interference with other electronic systems. By setting and adhering to frequency targets, we can design the system to operate within the desired frequency range, ensuring effective and safe power transfer to EVs.

Overall, efficiency and frequency targets are important in our project as they directly impact the performance, effectiveness, and sustainability of the smart road with wireless power transfer capabilities. Meeting these targets allows us to design a system that maximizes power transmission efficiency, minimizes energy losses, and ensures reliable charging of EVs.

1.3.3 Transmitter coil design

In the project aimed at designing a smart road with wireless power transfer capabilities for electric vehicles (EVs), the transmitter design holds great importance. Initially, we began with the spiral coil design as it is commonly used in wireless power transfer systems due to its simplicity and ease of implementation. However, during the development process, we encountered limitations with this design that prompted us to explore alternative options. One major challenge we faced was the decrease in efficiency when the car moved from one coil to another due to the centered magnetic coupling.

To address this issue, we shifted our focus to the rectangular coil design for the transmitter. The rectangular design offers advantages such as improved magnetic coupling and higher power transfer efficiency compared to the spiral coil design. It aimed to enhance the overall performance and reliability of the wireless power transfer system. However, we also encountered a challenge with power leakage through the sides and edges of the rectangular design through magnetic field, which significantly reduced our output and efficiency.

To overcome these challenges, we further refined the transmitter design and introduced the crisp crossing design. This improved design involves arranging the rectangular coils in a specific pattern that optimizes magnetic coupling and power transfer efficiency. The crisp crossing design resulted in enhanced power transmission capabilities, ensuring a more effective and reliable charging process for EVs on the smart road.

Through the transition from the initial spiral coil design to the rectangular design and the subsequent incorporation of the crisp crossing design, we have made significant advancements in the performance of the transmitter. These design iterations have enabled us to achieve higher efficiency, improved power transfer, and enhanced overall system reliability. The transmitter design plays a pivotal role in ensuring efficient wireless power transfer from the road infrastructure to EVs, thereby contributing to the successful implementation of the smart road project.

1.3.4 Receiver coil design

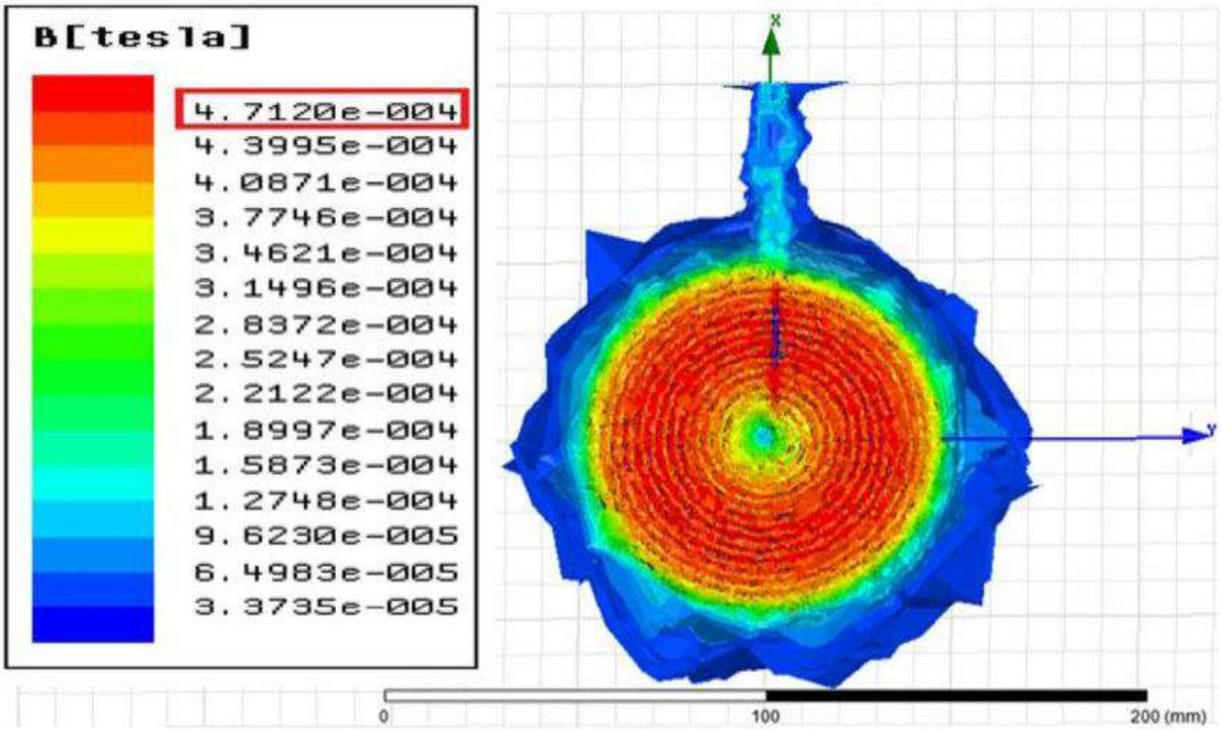


Figure 2

For the receiver coil located on the car in our project of designing a smart road with wireless power transfer capabilities for electric vehicles (EVs), we have opted for a circular design. The circular design offers certain advantages that align well with the requirements of our system.

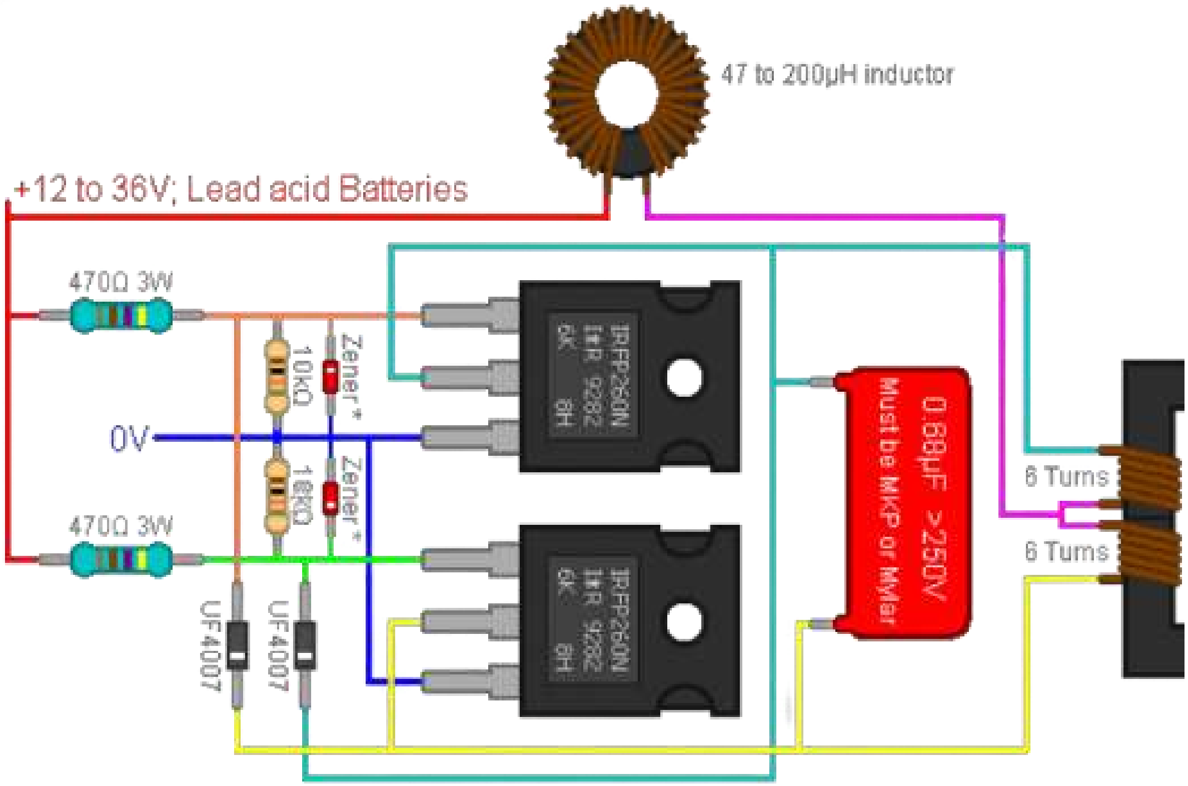
One notable advantage of the circular receiver coil design is its concentrated magnetic field at the center. This characteristic complements the uniformly distributed electromagnetic field of the transmitter along the track. As a result, maximum power transfer can be achieved throughout the entire track. The circular design allows for efficient coupling with the electromagnetic field generated by the transmitter, ensuring optimal power reception by the receiver coil.

By using a circular receiver coil design, we can take advantage of the centralized magnetic field to maximize power transfer efficiency. This design choice enables effective energy harvesting from the smart road infrastructure, allowing the EVs to receive the required power for charging while moving along the track.

Overall, the circular design for the receiver coil provides a practical solution for efficient power transfer in our project. Its ability to capture the concentrated magnetic field generated by the transmitter ensures consistent and effective power reception, contributing to the seamless wireless charging of EVs throughout the smart road.

1.3.5 Driver Circuit

The driver circuit used in our project is a Zero Voltage Switching (ZVS) driver circuit. The ZVS (Zero Voltage Switching) driver circuit is designed to minimize switching losses and improve the overall efficiency of power electronic systems. It achieves this by ensuring that the voltage across the power switches is zero or close to zero during the switching transitions. The CAD circuit diagram of the ZVS Driver is shown below.



* Zener diodes are 12, 15 or 18V

Figure 3

The detailed working process of the ZVS driver circuit:

Initial State: The ZVS driver circuit starts in the off state, with the power switches (typically MOSFETs or IGBTs) turned off. The voltage across the switches is zero, and no current flows through them.

Switch-On Phase: When the control signal triggers the switch-on operation, the ZVS driver circuit rapidly increases the gate voltage of the power switches. This initiates the turn-on process of the switches. As the voltage across the switches is initially zero, the turn-on occurs with minimal switching losses.

Resonant Tank Operation: The ZVS driver circuit is often utilized in resonant converter topologies, which consist of inductors and capacitors forming a resonant tank circuit. During the switch-on phase, the resonant tank circuit absorbs energy from the input source and stores it in the magnetic and electric fields of the inductors and capacitors.

Resonant Oscillation: As energy is stored in the resonant tank circuit, an oscillation process begins. The current flows through the inductors, charging the capacitors and creating a resonant waveform. The resonant frequency is determined by the values of the inductors and capacitors.

Switch-Off Phase: The control signal triggers the switch-off operation of the power switches in the ZVS driver circuit. This is timed to occur when the voltage across the switches approaches zero. By turning off the switches at this moment, the ZVS driver circuit ensures zero voltage switching. This reduces switching losses and prevents excessive stress on the switches.

Energy Transfer: During the switch-off phase, the energy stored in the resonant tank circuit is transferred to the output load. The resonant oscillation allows for efficient energy transfer without significant losses. This energy transfer process is repeated in each switching cycle.

The ZVS Driver can be implemented on the circuit shown.

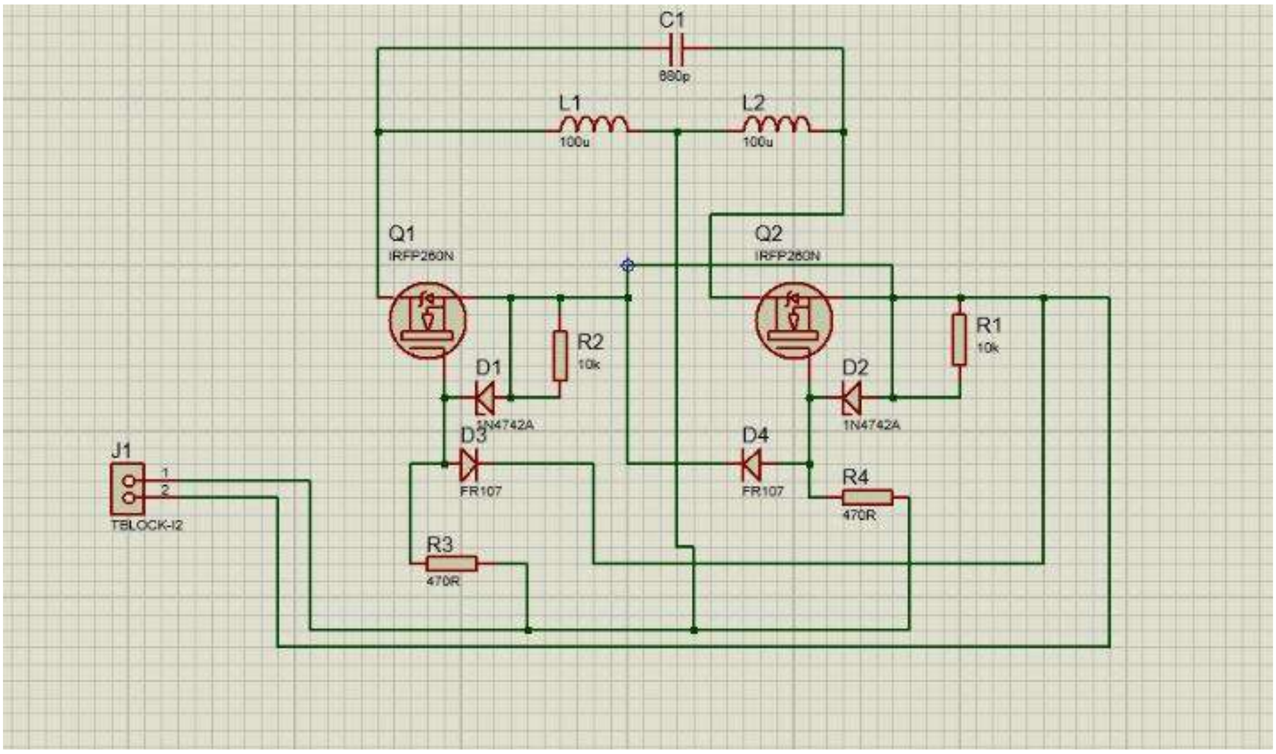


Figure 4

By achieving zero voltage switching, the ZVS driver circuit minimizes the power losses associated with switching transitions. It reduces switching losses, heat generation, and stress on the power switches. This results in improved overall efficiency and reliable operation of power electronic systems.

In summary, the ZVS driver circuit enables efficient power transfer by ensuring zero voltage switching during the transitions of the power switches. Through the resonant tank circuit, it facilitates energy storage, oscillation, and transfer, leading to improved efficiency and reduced losses in power electronic systems.

1.3.6 Power Supply

In our project of designing a smart road with wireless power transfer capabilities for electric vehicles, the power supply is selected based on the specific requirements of the output load. We have chosen a power supply that takes a 220V AC input and provides a regulated DC output of 24V/15A to power our input or transmission side circuit. This ensures that the circuit receives a stable and sufficient power supply for efficient operation.

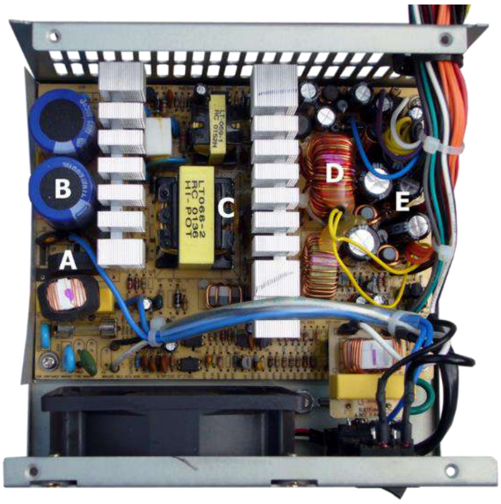


Figure 5

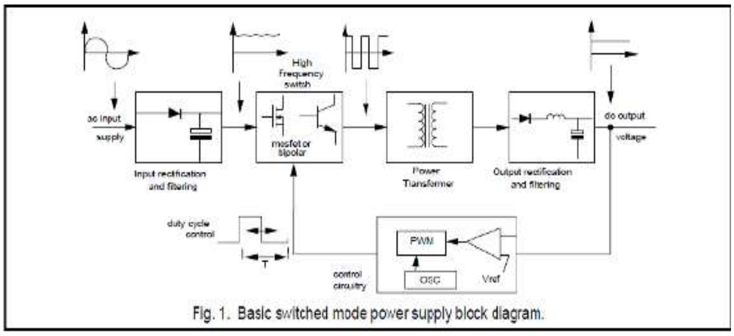


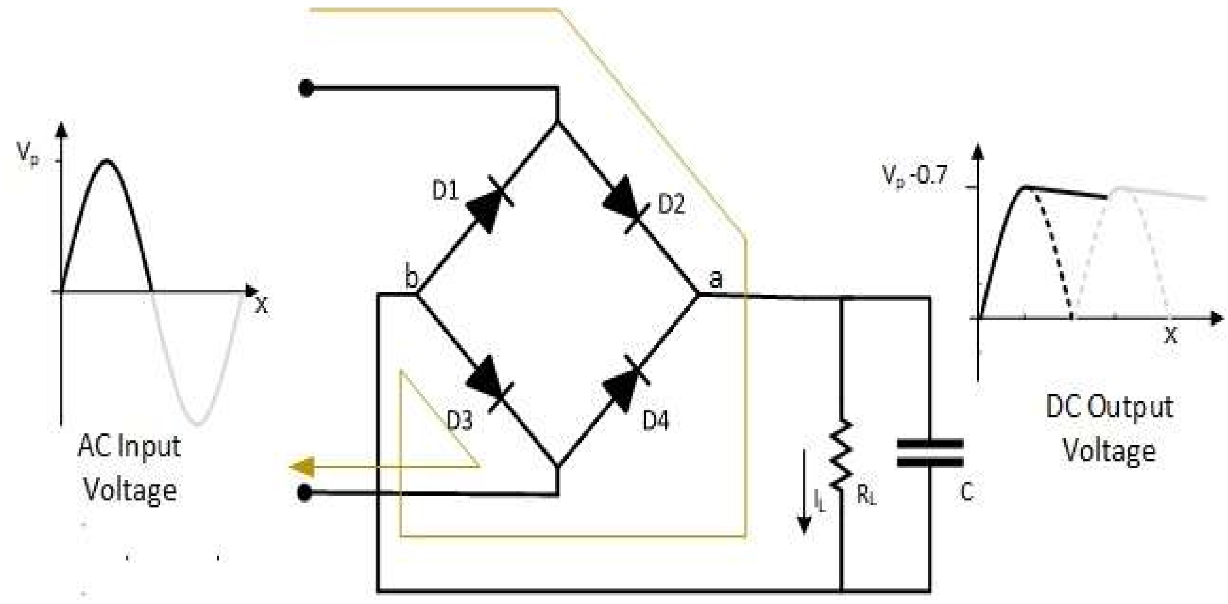
Figure 6

(a)Power Supply (PCB) (b)Power Supply (Circuit)

By tailoring the power supply to the needs of the output load, we optimize the performance and reliability of the wireless power transfer system. The selected power supply ensures compatibility and facilitates seamless power transfer to electric vehicles while they are in motion on the smart road.

1.3.7 High Frequency AC to DC Converter

In our wireless power transfer system, we employ a full bridge rectifier consisting of four high-frequency diodes, such as the UF4007 diodes. This configuration allows us to convert the incoming AC voltage to a pulsating DC voltage. Additionally, we incorporate a capacitor in parallel with the load to smoothen out any ripples in the rectified output.



Current Flow in Fullwave Bridge Rectifier during positive half cycle

Figure 7

The operation of the full bridge rectifier is straightforward. During the positive half-cycle of the AC input, two diodes conduct, enabling current flow through the load and into the output capacitor. Similarly, during the negative half-cycle, the other two diodes conduct, allowing current to flow in the opposite direction. This rectification process effectively converts the AC voltage to a pulsating DC voltage. The output capacitor further helps in reducing any ripples, ensuring a relatively stable DC voltage for the receiving circuit components to utilize.

1.3.8 Buck Converter

To adapt the high DC voltage obtained from the rectification process to a safe operating range for the vehicle components, we integrated a Buck converter, which is a type of DC-to-DC converter. This converter efficiently reduces the voltage by utilizing a switching transistor, inductor, diode, and capacitor.

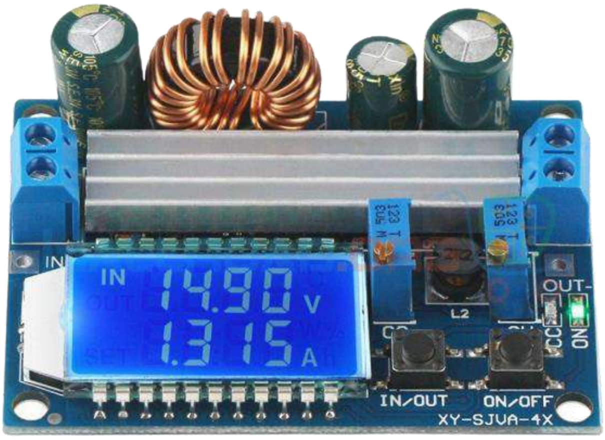


Figure 8

The Buck converter operates through pulse-width modulation (PWM), where the switching transistor alternates between ON and OFF states. During the ON state, energy is stored in the inductor, and when the transistor switches off, the energy is transferred to the output through the diode and capacitor, resulting in a lower DC voltage.

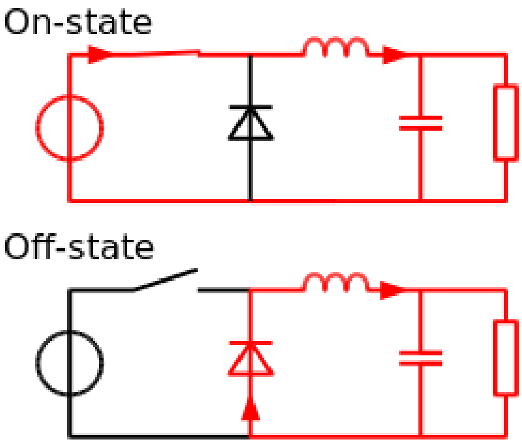


Figure 9

By implementing the Buck converter, we ensure that the DC voltage is regulated and lowered to the specified range required for the safe operation of the vehicle components. This enables reliable performance while preventing any potential damage or malfunctions caused by excessive voltage levels.

1.4 Objectives

Our project objectives can be summarized as follows:

Maximizing power transfer efficiency: Our primary objective is to optimize the power transfer efficiency in the wireless power transfer system. By employing advanced technologies and design strategies, we aim to achieve a high level of efficiency in transmitting electrical power from the road infrastructure to electric vehicles. This will ensure effective and timely charging without significant energy losses.

Ensuring safety and reliability: Another key objective is to prioritize the safety and reliability of the wireless power transfer system. We will implement stringent safety measures and robust quality control protocols to mitigate any potential risks or malfunctions. Ensuring the system's reliability is essential to establish user trust and confidence in the technology.

Showcasing feasibility and benefits: We aim to conduct comprehensive testing and analysis to demonstrate the feasibility and advantages of wireless power transfer for electric vehicles. Through rigorous evaluation and comparative studies, we will highlight the benefits of our system, such as convenience, uninterrupted charging during vehicle movement, and reduced reliance on physical connections or frequent stops.

Developing a system for on-the-move charging: Our main focus is on designing a system that allows electric vehicles to charge wirelessly while in motion. By eliminating the need for physical connections or frequent stops, we aim to provide a seamless charging experience for electric vehicle owners, enhancing their convenience and promoting wider adoption of electric vehicles.

By achieving these objectives, we aim to contribute to the advancement of wireless power transfer technology and its integration into the current infrastructure.

1.5 Specifications

Specifications for the project of designing a smart road with wireless power transfer capabilities for electric vehicles:

Power Transfer Efficiency: The wireless power transfer system should achieve a minimum power transfer efficiency of 70% to ensure effective charging and minimize energy losses during the transmission process.

Charging Range: The system should support a practical charging range, allowing electric vehicles to receive power wirelessly while in motion within a specified distance, such as up to 200 meters, to enable seamless charging during travel.

Power Transfer Capacity: The system should be capable of delivering sufficient power to charge a wide range of electric vehicles, from small passenger cars to larger commercial vehicles, with power transfer capacities ranging from 5 KW to 30 KW or higher. But since this is just a model demonstration so we are targeting 1000 times less power target that is 5 W to 30W.

Safety and Reliability: The system must comply with relevant safety standards and regulations to ensure the safety of users and prevent any electrical hazards. It should include features such as insulation monitoring, fault detection, and protection mechanisms to ensure reliable and secure operation.

Cost-Effectiveness: The system should be cost-effective, considering both the initial installation costs and long-term operational expenses. It should aim to provide an economically viable solution for wireless charging infrastructure deployment.

1.6 Deliverables

The deliverables for the project of designing a smart road with wireless power transfer capabilities for electric vehicles include:

System Design and Documentation: A comprehensive documentation package outlining the system design, including architectural diagrams, electrical schematics, component specifications, and system integration guidelines. This documentation will serve as a reference for future installations and system expansions.

Prototype

. of Wireless Power Transfer System: A fully functional prototype demonstrating the wireless power transfer capabilities for electric vehicles. The prototype will include the transmitter infrastructure embedded within the road, receiver components installed on the electric vehicle, and the necessary control and communication modules for seamless power transfer.

Car Prototype Design: Designing a car prototype specifically tailored to work seamlessly with the wireless power transfer system. This design will encompass the integration of receiving coils, power management systems, and communication modules into the vehicle's structure, ensuring optimal compatibility and functionality with the designed project.

1.7 Thesis Design

This thesis is structured as follows:

Chapter 1: Introduction

This chapter offers a summary of the project, including its goals and problem description. It also provides a quick overview of the concept and components we will be using in our project.

Chapter 2: Background and Literature Review

The literature on wireless power transfer and the driver circuit used in the circuit is provided in this chapter. This chapter will also provide history about electromagnetism, wireless power transfer, different concepts like impedance matching, electrostatic losses etc.

Chapter 3: Design & Implementation

This chapter discusses the system's overall design, including the hardware and software components. It addresses design concerns such as system architecture, block diagrams, and component functioning.

Chapter 4: Results Analysis

This chapter assesses the system's performance using several measures such as efficiency, amount of power transferred, losses in different components, magnetic resonance and impedance matching etc.

Chapter 5: Future Projects

This chapter describes possible future work that might be done to improve the system. It addresses potential enhancements to the hardware and software components, as well as potential new functionality.

Chapter 6: Conclusion:

This chapter outlines the project's research activity and emphasizes the main accomplishments of the project.

Appendices: This section provides some basic information regarding the system design, symbols and abbreviations used, list of formulas etc.

CHAPTER 02-BACKGROUND & LITERATURE REVIEW

The popularity of electric vehicles has surged dramatically in recent years, but the need for charging infrastructure and the time required for charging remains a significant limitation. To address this challenge, researchers are exploring innovative solutions, such as utilizing the road itself as a source of charging. This involves the implementation of wireless power transfer technology, where the magnetic field generated by coils embedded in the road transfers power to a receiver coil in the vehicle, enabling wireless charging while the vehicle is in motion.

By harnessing the power of magnetic fields, this approach eliminates the need for traditional charging stations and offers the potential for continuous charging while driving. The energy received by the vehicle's receiver coil is then utilized to operate the electric vehicle, providing a convenient and efficient charging solution. This research endeavors to revolutionize the charging experience for electric vehicle owners, making it more seamless and reducing dependence on stationary charging infrastructure.

2.1 Background

This chapter serves as an introduction to the various concepts utilized in the project. It primarily focuses on the fundamental principles associated with wireless power transfer, including the generation of Electromagnetic induction through the coils, magnetic resonance phenomena, impedance matching techniques, and the design considerations for both transmitters and receivers. Additionally, it explores the driver circuitry required for efficient power transfer, the design aspects of the electric vehicle and its components, and related literature in the field.

The purpose of this chapter is to provide a comprehensive overview of the hardware and software components involved in the project, while also presenting a survey of existing research in the field. By covering these topics concisely, the chapter aims to support and advance the project's objectives. It aims to familiarize the reader with the key concepts and technologies that form the foundation of wireless power transfer, laying the groundwork for the subsequent chapters that delve deeper into the project's implementation and findings.

2.2 Introduction to Electromagnetic Induction

Electromagnetic induction is a fundamental concept in physics that plays a crucial role in wireless power transfer, which is at the heart of our project. It is the process by which a changing magnetic field induces an electric current in a conductor. Understanding electromagnetic induction is essential for comprehending the underlying principles and operation of the wireless power transfer system we aim to develop.

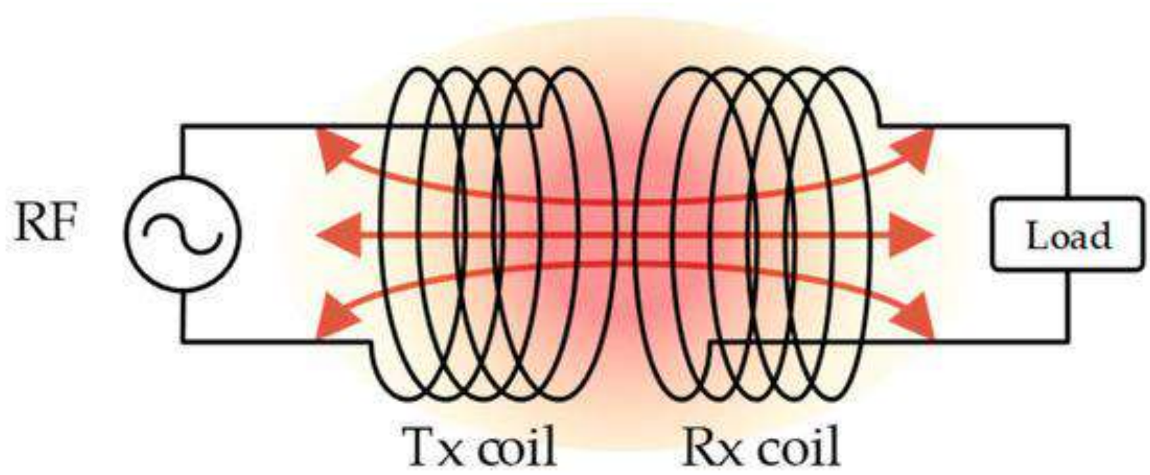


Figure 10

In our project, electromagnetic induction is employed to transfer power wirelessly from the road infrastructure to the electric vehicle. The road infrastructure incorporates coils that generate a varying magnetic field. As the electric vehicle equipped with a receiving coil moves over the road, the changing magnetic field induces an electric current in the receiving coil. This induced current is then used to charge the vehicle's battery or power its electrical components.

The phenomenon of electromagnetic induction relies on Faraday's law and Lenz's law. Faraday's law states that a change in the magnetic field through a loop of wire induces an electromotive force (EMF) and subsequently an electric current. Lenz's law, on the other hand, describes the direction of the induced current, which opposes the change in the magnetic field that produced it.

By harnessing electromagnetic induction, our project aims to create a wireless power transfer system that can efficiently and effectively charge electric vehicles while they are in motion. This technology offers a convenient and eco-friendly solution to address the limitations of traditional charging stations and reduce the need for frequent stops for charging. Understanding the principles of electromagnetic induction enables us to design and optimize the wireless power transfer system, ensuring the reliable and efficient transfer of power from the road to the electric vehicle.

2.2.1 Impedance Matching

Impedance matching is a critical concept in our project's wireless power transfer system. It refers to the process of optimizing the electrical impedance of the transmitter and receiver circuits to maximize power transfer efficiency. Impedance matching ensures that the impedance of the source (transmitter) matches the impedance of the load (receiver), allowing for efficient power transfer without significant reflections or losses.

The literature review on impedance matching explores prior studies and research focused on achieving optimal impedance matching in wireless power transfer systems. The review examines different impedance matching techniques, such as passive matching networks, resonant matching, and adaptive matching algorithms. It investigates the significance of impedance matching in maximizing power transfer efficiency and minimizing signal reflection. By analyzing the existing literature, our project aims to gain insights into the challenges and advancements in impedance matching strategies and leverage this knowledge to design an efficient and reliable wireless power transfer system with improved power transfer capabilities for electric vehicles on the smart road.

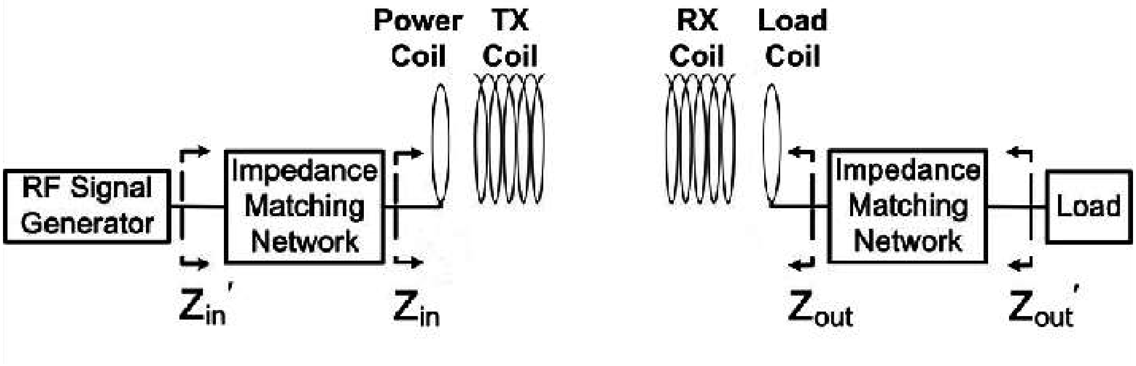


Figure 11

In our project, impedance matching is crucial to achieve effective power transfer from the road infrastructure to the electric vehicle. The transmitter circuit, which includes the coils embedded in the road, should have an impedance that matches the impedance of the receiver circuit in the vehicle. This matching minimizes the reflections and maximizes the power transfer efficiency.

Impedance matching is typically achieved by using impedance matching networks or components such as capacitors, inductors, and transformers. These components are carefully selected and configured to ensure the impedance of the transmitter and receiver circuits are appropriately matched. The matching network helps to eliminate impedance mismatches, reducing power losses, and optimizing the power transfer efficiency.

By employing impedance matching techniques, our project aims to ensure efficient power transfer from the road infrastructure to the electric vehicle. Proper impedance matching minimizes power losses, reduces reflected power, and maximizes the power delivered to the receiver, thus enhancing the charging capabilities and overall performance of the wireless power transfer system. The design and implementation of an effective impedance matching network are essential for achieving high power transfer efficiency and reliable operation of the wireless charging system in our project.

2.2.2 Electrostatic loss compensation

Electrostatic loss compensation is a technique used to mitigate power losses caused by electrostatic effects in wireless power transfer systems. When electrical energy is transmitted wirelessly, electrostatic interactions between the transmitter and receiver can result in losses due to electric field leakage and capacitance effects. These losses can reduce the overall efficiency of the power transfer system.

The literature review on electrostatic loss compensation examines prior studies and research related to mitigating electrostatic losses in wireless power transfer systems. The review explores various techniques and approaches proposed to minimize these losses, such as using compensation circuits, shielding, and optimized coil designs. By analyzing the existing literature, our project aims to understand the challenges associated with electrostatic losses and identify effective methods to compensate for them. This review serves as a valuable resource to enhance our knowledge and guide the development of strategies to improve the overall efficiency and power transfer capabilities of the wireless power transfer system for electric vehicles on the smart road.

In our project, minimizing electrostatic losses is crucial to enhance the power transfer efficiency of the wireless charging system. One approach to compensate for electrostatic losses is to implement appropriate compensation techniques. This can involve the use of compensation networks or components that help counteract the effects of electrostatic interactions.

To minimize electrostatic losses, our project employs various strategies. First, we carefully design the physical layout and geometry of the transmitter and receiver coils to minimize electrostatic coupling and maximize magnetic coupling. This reduces the extent of electrostatic interactions and their associated losses. Additionally, we implement shielding and insulation measures to minimize electric field leakage and stray capacitance.

Furthermore, the use of impedance matching techniques, as mentioned earlier, also contributes to minimizing electrostatic losses. Proper impedance matching helps optimize the power transfer efficiency, reducing the impact of electrostatic effects on the overall system performance.

By addressing and compensating for electrostatic losses, our project aims to maximize the efficiency and effectiveness of the wireless power transfer system. This enables more efficient charging of electric vehicles and reduces energy losses, ensuring that a higher percentage of the transmitted power is effectively utilized for charging purposes.

2.2.3 Frequency adaptation

Frequency adaptation in our project refers to the ability to dynamically adjust the operating frequency of the wireless power transfer system based on the specific requirements and conditions. It involves modifying the frequency of the electromagnetic field generated by the transmitter to optimize power transfer efficiency and address potential challenges or variations in the environment.

The frequency adaptation capability plays a crucial role in maximizing power transfer efficiency in our project. By adjusting the operating frequency, we can overcome certain limitations and enhance the overall performance of the wireless power transfer system. Here are some key benefits and implementations of frequency adaptation in our project:

Resonance optimization: Frequency adaptation allows us to achieve resonance between the transmitter and receiver coils. Resonance occurs when the natural frequencies of the coils match, leading to maximum power transfer efficiency. By adapting the frequency, we can ensure resonance is achieved even in the presence of varying load conditions or environmental factors.

Mitigating interference: In a wireless charging environment, there may be other electromagnetic devices or sources that can cause interference. Frequency adaptation helps us select a frequency that minimizes interference and maximizes the signal-to-noise ratio, resulting in more reliable and efficient power transfer.

Environmental considerations: Different environmental conditions, such as changes in temperature or humidity, can affect the performance of the wireless power transfer system. Frequency adaptation allows us to dynamically adjust the operating frequency to compensate for these variations and maintain optimal power transfer efficiency.

In our project, we implement frequency adaptation by incorporating a feedback mechanism and control system. The system continuously monitors the operating conditions and adjusts the frequency accordingly to optimize power transfer efficiency. This may involve utilizing sensors, such as temperature sensors or load sensors, to gather real-time data and make appropriate frequency adjustments.

By employing frequency adaptation, we ensure that our wireless power transfer system adapts to the changing conditions and delivers efficient and reliable charging for electric vehicles. It enhances the overall performance and robustness of the system, allowing for seamless and effective power transfer in various operating scenarios.

2.2.4 Q Factor

The Q factor, also known as the quality factor, is a parameter that characterizes the efficiency and selectivity of a resonant circuit. In the context of our project on wireless power transfer, the Q factor plays a crucial role in determining the performance and effectiveness of the transmitter and receiver coils.

The literature review on the Q factor provides insights into previous studies and research focused on the Q factor optimization in wireless power transfer systems. The review examines the significance of the Q factor in determining system efficiency and power transfer capabilities. It investigates various factors that impact the Q factor, such as coil design, parasitic elements, and tuning techniques. By analyzing the previous literature, our project aims to build upon existing knowledge and identify strategies to improve the Q factor, thereby enhancing the overall performance and efficiency of the wireless power transfer system for electric vehicles on the smart road.

The Q factor is calculated by dividing the resonant frequency of the circuit by the bandwidth. Mathematically, it is expressed as:

Q = (Resonant Frequency) / (Bandwidth)

The Q factor indicates how "selective" the resonant circuit is in terms of transmitting power at its resonant frequency while rejecting frequencies outside the bandwidth. A higher Q factor indicates a more selective and efficient circuit.

In our project, the Q factor is essential for several reasons:

Power transfer efficiency: A higher Q factor corresponds to lower power losses in the resonant circuit. This means that a higher percentage of the transmitted power is effectively transferred to the receiver, resulting in increased charging efficiency for electric vehicles.

Resonance optimization: The Q factor helps in achieving optimal resonance between the transmitter and receiver coils. Resonance occurs when the natural frequencies of the coils match, leading to maximum power transfer efficiency. By designing the coils with an appropriate Q factor, we can ensure efficient resonance and enhance power transfer capabilities.

Bandwidth control: The Q factor determines the bandwidth of the resonant circuit. A narrower bandwidth allows for more selective power transfer, reducing the likelihood of interference from external sources. This helps in maintaining a stable and reliable wireless charging process.

To calculate the Q factor, we need to determine the resonant frequency of the circuit and measure the bandwidth. The resonant frequency is determined by the physical characteristics of the coils, such as their inductance and capacitance. The bandwidth is the range of frequencies around the resonant frequency over which the circuit exhibits acceptable power transfer efficiency.

In our project, optimizing the Q factor involves designing the transmitter and receiver coils with appropriate parameters to achieve the desired resonant frequency and bandwidth. This ensures efficient power transfer and minimizes power losses, resulting in effective and reliable wireless charging for electric vehicles.

The Q factor is necessary for our project as it determines the power transfer efficiency, resonance characteristics, and bandwidth control of the wireless power transfer system. By designing the coils with an optimal Q factor, we can enhance the charging performance, improve system reliability, and achieve efficient power transfer from the road infrastructure to electric vehicles.

2.3 Transmitter inductance

Inductance is a fundamental property of an electrical component, particularly an inductor, that describes its ability to store energy in a magnetic field when a current flows through it. It is represented by the symbol "L" and is measured in Henries (H). Inductance arises from the self-induced electromotive force (EMF) generated by the changing magnetic field surrounding a conductor.

The literature review on transmitter inductance focuses on previous studies and research regarding the inductance of the transmitter coil in wireless power transfer systems. It explores various coil designs, materials, and geometries used to optimize the inductance value. The review investigates how inductance impacts the efficiency, power transfer capabilities, and overall performance of the wireless power transfer system. By examining the literature on transmitter inductance, our project aims to gain insights into design considerations, techniques, and challenges associated with achieving the desired inductance value. This review provides valuable knowledge that guides our efforts in designing an efficient and reliable transmitter coil with the appropriate inductance for effective power transfer to electric vehicles on the smart road.

In our project on wireless power transfer, inductance plays a significant role, especially in the design and operation of the transmitter coil. The transmitter coil, also known as the primary coil, is responsible for generating the magnetic field that transfers power to the receiver coil in the electric vehicle.

It is essential to consider in our project for the following reasons:

Power transfer efficiency: The impedance matching between the transmitter and receiver coils is crucial to maximize power transfer efficiency. When the impedance of the transmitter closely matches that of the receiver, it allows for efficient power transfer and minimizes power losses.

Resonance optimization: Inductance plays a key role in achieving resonance between the transmitter and receiver coils. Resonance occurs when the natural frequencies of the coils align, resulting in maximum power transfer efficiency. By carefully designing the inductance of the transmitter coil, we can achieve optimal resonance and enhance the power transfer capabilities.

Voltage and current control: The inductance of the transmitter coil influences the voltage and current characteristics of the power transfer system. By controlling the inductance, we can regulate the voltage and current levels to ensure safe and reliable charging of the electric vehicle.

Considering the transmitter impedance helps us achieve efficient power transfer, maintain system stability, and ensure compatibility between the transmitter and receiver components. By designing the transmitter coil with the appropriate inductance and impedance, we can optimize the power transfer efficiency, minimize losses, and provide effective wireless charging for electric vehicles.

Inductance plays a vital role in our project as it determines the characteristics of the transmitter coil and influences the impedance matching, resonance, and voltage/current control in the wireless power transfer system. By considering the transmitter impedance and designing the coil with the appropriate inductance, we can enhance power transfer efficiency, ensure reliable charging, and achieve effective wireless power transfer for electric vehicles.

2.4 Transmitter efficiency curve

The transmitter efficiency curve is a graphical representation that shows the relationship between the efficiency of the wireless power transmitter and the load impedance. It helps us understand how the efficiency of the transmitter varies with different load conditions and allows us to determine the optimal operating point for maximum power transfer.

The literature review on the transmitter efficiency curve examines previous studies focused on optimizing the efficiency of wireless power transfer systems. It explores the relationship between input power and output power, considering factors such as coil design, resonant frequency, and load impedance. By analyzing the literature on transmitter efficiency curves, our project aims to understand the key parameters influencing efficiency and identify strategies to enhance the overall performance of the wireless power transfer system. The review serves as a valuable resource for gaining insights into existing knowledge and advancements in transmitter efficiency, informing our efforts to achieve maximum power transfer and improve the charging capabilities of electric vehicles on the smart road.

In our project, the transmitter efficiency curve is useful for several reasons:

- The curve helps us identify the load impedance that results in the highest efficiency. By operating at this point, we can maximize the power transfer from the transmitter to the receiver, ensuring effective charging of electric vehicles.
- The transmitter efficiency curve guides us in achieving impedance matching between the transmitter and receiver. Impedance matching ensures that the load impedance seen by the transmitter is equal to the internal impedance of the transmitter, resulting in minimal reflections and maximum power transfer efficiency.
- By analyzing the transmitter efficiency curve, we can assess the performance of our wireless power transfer system under different load conditions. This information allows us to optimize the design parameters and operating conditions to enhance overall system efficiency and reliability.
- To obtain a good transmitter efficiency curve, we typically perform a series of measurements and calculations. Here are the general steps:
- Set up the transmitter and receiver system with the desired coil design and circuit components.
- Vary the load impedance connected to the receiver and measure the corresponding power transfer efficiency.
- Repeat the measurement for different load impedance values, covering a range of values.
- Plot the measured efficiency values on a graph, with load impedance on the x-axis and efficiency on the y-axis.
- Analyze the curve to identify the peak efficiency point, which represents the optimal load impedance for maximum power transfer.

To obtain a good curve, it is important to ensure accurate measurements, minimize any external factors that may affect efficiency (such as interference), and repeat the measurements multiple times for reliability.

By obtaining a well-defined transmitter efficiency curve, we can effectively optimize the power transfer efficiency, identify the optimal load impedance, and enhance the performance of our wireless power transfer system in charging electric vehicles.

2.5 Maximum power point tracking (MPPT)

Maximum Power Point Tracking (MPPT) is a technique used to optimize the power output of a photovoltaic (PV) system by continuously tracking and operating at the maximum power point of the PV module. The objective is to extract the maximum available power from the PV source under varying environmental conditions, such as changes in sunlight intensity and temperature.

In the context of our project on wireless power transfer for electric vehicles, MPPT plays a crucial role in maximizing power transfer efficiency from the transmitter to the receiver. While MPPT is commonly used in solar PV systems, its principles can be adapted and applied to optimize the power transfer in wireless charging systems.

The literature review on Maximum Power Point Tracking (MPPT) focuses on optimizing power output in the wireless power transfer system for electric vehicles. It encompasses various studies and algorithms used to maximize energy harvesting from photovoltaic (PV) modules under changing environmental conditions. The review evaluates MPPT techniques such as Perturb and Observe (P&O), Incremental Conductance (IncCond), and intelligent optimization methods. By determining the MPPT point through load checking, our project aims to ensure efficient power generation and effective charging of electric vehicles, enhancing the overall performance and reliability of the wireless power transfer system. The review provides insights into the state-of-the-art in MPPT techniques, aiding in the selection and implementation of the most suitable algorithm for our project's specific requirements.

In our project, we aim to implement an MPPT algorithm specifically designed for wireless power transfer. This algorithm will monitor the power transfer efficiency, track the optimal operating point, and adjust the system parameters to ensure maximum power transfer between the transmitter and receiver. By continuously adapting to changing conditions, such as variations in coil coupling and load impedance, the MPPT algorithm will optimize the power transfer efficiency and enhance the charging capabilities of electric vehicles.

To achieve MPPT in our project, we will employ a combination of measurement techniques and control algorithms. This will involve monitoring parameters such as voltage, current, and power at both the transmitter and receiver sides. By comparing these measurements with the desired power transfer efficiency, the MPPT algorithm will dynamically adjust the system parameters, such as coil resonance frequency or transmitter power level, to maintain operation at the maximum power point. Through iterative adjustments and feedback control, we will continuously track and optimize the power transfer efficiency to achieve efficient and reliable wireless charging for electric vehicles.

Overall, incorporating MPPT techniques in our project will enable us to adaptively control and optimize the power transfer process, enhance system efficiency, and ensure effective charging of electric vehicles using wireless power transfer technology.

2.6 Load impedance Balancing

Load impedance balancing refers to the process of achieving an optimal match between the load impedance of the receiver and the internal impedance of the transmitter in a wireless power transfer system. It is an essential aspect of maximizing power transfer efficiency and ensuring effective charging of electric vehicles.

Literature review on load impedance balancing provides valuable insights into various techniques and strategies employed to achieve impedance matching in wireless power transfer systems. These studies explore methods such as resonant impedance matching, adaptive impedance matching, and impedance compensation techniques. The review helps in understanding the advantages, limitations, and performance characteristics of these methods in different scenarios.

In our project, load impedance balancing is critical for efficient power transfer from the transmitter to the receiver. By achieving impedance matching, we can minimize power losses due to reflections and maximize the power transfer efficiency. This ensures effective charging of electric vehicles and reduces energy wastage.

To achieve load impedance balancing in our project, we will employ several approaches. Firstly, we will design and optimize the transmitter and receiver coils to have compatible impedance characteristics. This involves selecting suitable coil geometries, dimensions, and materials to achieve resonance and minimize impedance mismatches.

Additionally, we will incorporate impedance matching circuits or networks in the transmitter and receiver circuits. These circuits will be designed to match the load impedance with the internal impedance of the transmitter, reducing reflections and maximizing power transfer efficiency. Techniques such as L-section matching networks, matching capacitors, and inductors can be employed to achieve the desired impedance matching.

Furthermore, we will utilize feedback control mechanisms and monitoring techniques to continuously assess and adjust the load impedance to maintain optimal matching conditions. This may involve measuring parameters such as voltage, current, and power at both the transmitter and receiver sides and employing control algorithms to dynamically adjust the load impedance.

By implementing load impedance balancing techniques in our project, we can ensure efficient power transfer, minimize energy losses, and optimize the charging capabilities of electric vehicles. This will contribute to the overall performance and reliability of our wireless power transfer system, enabling effective and convenient charging solutions for electric vehicle users.

CHAPTER 03-DESIGN & IMPLEMENTATION

In the chapter, we will delve into the detailed process of designing our project, focusing on both the hardware and software aspects. We will outline the design considerations and decisions taken to develop an effective and efficient wireless power transfer system for electric vehicles on the smart road. The hardware part will encompass the design and selection of components, such as the transmitter and receiver coils, power supply, driver circuits, and impedance matching networks. Additionally, we will discuss the software part, which includes the control algorithms, communication protocols, and system integration. Furthermore, we will explore the implementation phase, describing the step-by-step process of assembling and integrating the hardware components, coding, and programming the software functionalities, and conducting thorough testing and validation. Through this chapter, we aim to provide a comprehensive overview of the design and implementation process, highlighting the key considerations and approaches that have been taken to develop a successful wireless power transfer system for electric vehicles.

3.1 Design Structure

In our operation, we are utilizing a Switched-Mode Power Supply (SMPS) to convert the mains power supply voltage from 220 volts to 24 volts. An SMPS is a sophisticated electronic circuitry that efficiently regulates and transforms electrical power to match the specific requirements of our equipment.

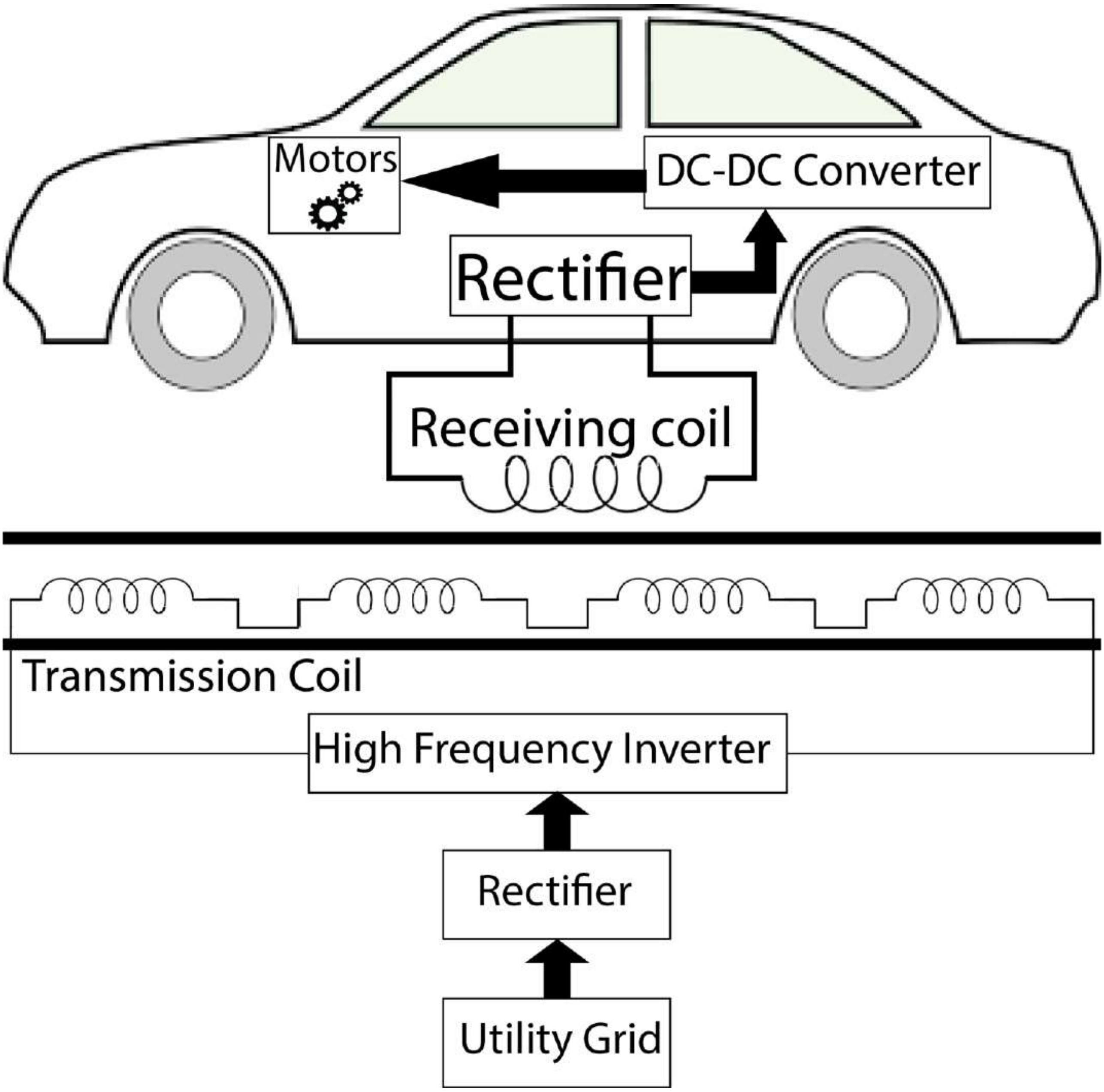


Figure 1

The SMPS operates by rapidly switching the input voltage on and off at a high frequency. This switching action allows for efficient voltage conversion and regulation. The process involves several key stages:

Rectification: The AC voltage from the mains power supply is initially converted into a pulsating DC voltage using a rectifier circuit. This rectified voltage is still relatively high and requires further processing.

Filtering: The pulsating DC voltage is then fed into a smoothing capacitor, which filters out the high-frequency ripples and provides a more stable DC voltage. This smoothed DC voltage serves as the input for the subsequent stages.

Power Conversion: The filtered DC voltage is fed into a high frequency switching circuit, typically implemented using a power transistor or MOSFET. This switching element rapidly turns the voltage on and off at a high frequency, typically in the range of tens or hundreds of kilohertz.

Transformation: The switched voltage is then fed into a transformer, which consists of primary and secondary windings. The switching action induces a magnetic field in the transformer, which allows for voltage transformation and isolation. The secondary winding provides the desired output voltage level of 24 volts.

Rectification and Filtering (Output): The 24-volt AC output from the transformer is rectified once again to convert it into a stable DC voltage. Like the earlier stage, a smoothing capacitor is used to filter out any remaining ripples, providing a clean and regulated DC output.

Voltage Regulation: To ensure a constant and stable 24-volt output, the SMPS employs a feedback control mechanism. This feedback circuit continuously monitors the output voltage and adjusts the switching action of the power transistor, accordingly, maintaining the desired voltage level despite variations in input voltage or load conditions.

The SMPS, with its efficient and precise voltage conversion capabilities, allows us to effectively step down the mains power supply from 220 volts to 24 volts. This lower voltage level is then used to power and operate our equipment and systems reliably and safely.

In addition to the SMPS, we are utilizing a Zero Voltage Switching (ZVS) driver in our operation. The ZVS driver is a specialized circuit that enhances the efficiency and performance of our power supply system.

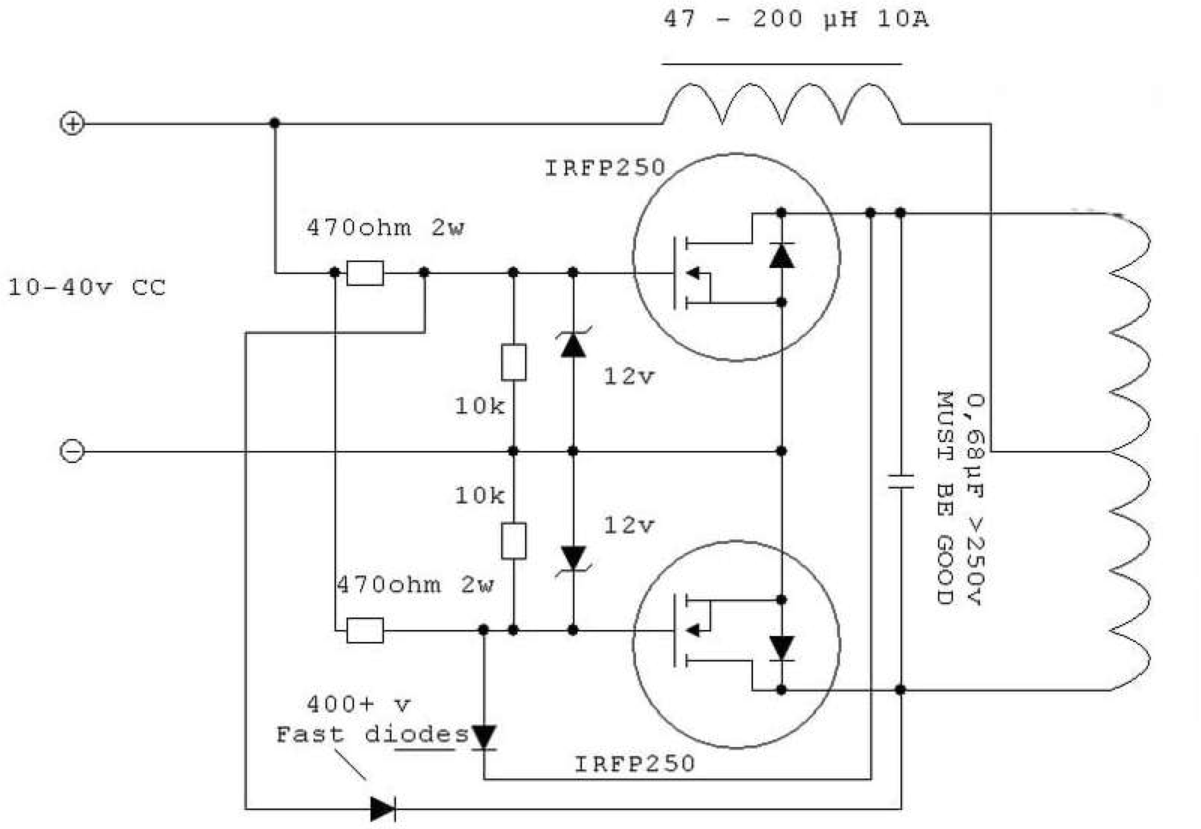


Figure 12

The ZVS driver works by controlling the switching action of the power transistors in the SMPS at specific points in the AC voltage waveform, known as zero crossings. During these zero crossings, the voltage across the power transistors is minimal, allowing for a smooth and efficient switching process. By synchronizing the switching action with the zero crossings, the ZVS driver minimizes power losses and reduces stress on the power transistors, resulting in improved efficiency and reliability.

The ZVS driver achieves its zero-voltage switching capability through the use of resonant circuits. These resonant circuits, typically consisting of inductors and capacitors, are carefully designed to create an oscillating voltage waveform that aligns with the zero crossings of the AC input voltage. When the power transistors switch on or off, the resonant circuit ensures that the voltage across the transistors is close to zero, minimizing switching losses.

By incorporating the ZVS driver into our power supply system, we can achieve several advantages. Firstly, it significantly reduces switching losses, which translates to higher efficiency and lower heat generation. This efficiency improvement leads to energy savings and a longer lifespan for the power transistors.

Furthermore, the ZVS driver helps to reduce electromagnetic interference (EMI) generated by the switching operation. The smooth switching at zero voltage crossings reduces high-frequency noise emissions, ensuring compliance with electromagnetic compatibility (EMC) regulations.

The ZVS driver also plays a crucial role in enhancing the overall reliability of the power supply system. By minimizing stress on the power transistors, it reduces the likelihood of component failure and extends their operational lifespan. This increased reliability results in improved system uptime and reduced maintenance requirements.

In our operation, we have implemented a rectangular transmitter design following the ZVS driver circuit. This design consists of a rectangular-shaped coil or an array of coils that efficiently transmit power from the power source to the receiver coil in the vehicle. The rectangular transmitter design offers several advantages for wireless power transfer.

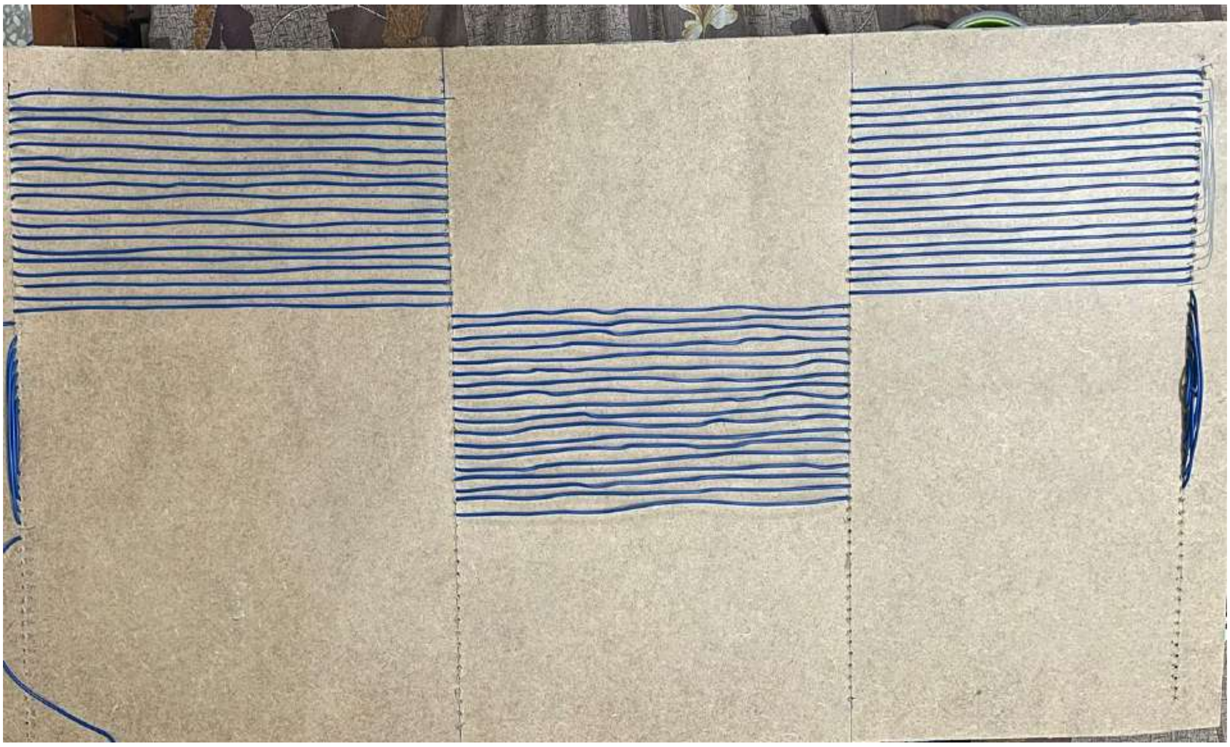


Figure 13

One key advantage is the increased effective coupling area between the transmitter and receiver coils. The rectangular shape allows for a larger surface area, enhancing the efficiency of power transfer. This larger coupling area improves alignment tolerance, enabling the vehicle to receive power wirelessly even if it is not perfectly positioned over the transmitter. The design also facilitates efficient power transfer over longer distances. The geometry of the rectangular coil array helps concentrate the magnetic field within the desired region, minimizing losses and extending the range of effective power transmission. This extended range allows for convenient charging options, as electric vehicles can receive power wirelessly even when parked at a short distance from the transmitter.

By incorporating the rectangular transmitter design into our wireless charging system, we can ensure efficient and reliable power transfer for electric vehicles. The increased coupling area and extended range contribute to improved alignment tolerance and convenient charging capabilities, making wireless charging from the road infrastructure a practical and accessible solution.

The larger surface area of the rectangular receiver allows for improved power capture efficiency. With a greater surface area to interact with the magnetic field generated by the transmitter, the receiver can capture a higher amount of energy during the wireless charging process. This efficient power capture translates into reduced charging times and increased charging effectiveness, ensuring that electric vehicles can quickly and effectively replenish their battery power.

Moreover, the rectangular receiver design enhances alignment tolerance, providing flexibility in the positioning of the vehicle during charging. The design compensates for slight misalignments or variations in vehicle placement, allowing for reliable power transfer even if the vehicle is not perfectly aligned with the charging station. This feature adds convenience and ease of use for electric vehicle owners, as they do not have to worry about precise alignment and can confidently park their vehicles in the charging area.

By incorporating the rectangular receiver design, our wireless charging system optimizes power capture efficiency and enhances the overall user experience. With its larger surface area and improved alignment tolerance, this design ensures efficient and reliable charging for electric vehicles, making wireless charging from the road infrastructure a practical and user-friendly solution.

Following the rectangular receiver design in our wireless charging system, we have incorporated a high-frequency rectifier using FR107 diodes and a capacitor. This rectification stage plays a crucial role in converting the alternating current (AC) induced in the receiver coil into a direct current (DC) that can be stored and utilized by the vehicle's battery.

The FR107 diodes are specifically chosen for their fast-switching characteristics, allowing them to efficiently rectify the high-frequency AC signal generated by the receiver coil. These diodes ensure minimal power losses during the rectification process, maximizing the conversion efficiency and overall charging performance.

In conjunction with the diodes, a capacitor is employed to smoothen the rectified output and filter out any remaining AC ripples or noise. The capacitor acts as a reservoir, storing the rectified DC voltage and providing a stable and continuous power supply to the vehicle's battery or charging system.

By integrating the high-frequency rectifier stage into our wireless charging system, we ensure a reliable and efficient conversion of the AC signal induced in the receiver coil to a usable DC voltage. This rectification process, facilitated by FR107 diodes and a capacitor, enables effective energy storage and utilization, contributing to a seamless and reliable charging experience for electric vehicles.

After the rectification stage in our wireless charging system, we have implemented a buck-boost converter to achieve maximum power transfer efficiency. The buck-boost converter is a DC-DC power conversion circuit that regulates the voltage level to match the specific requirements of the vehicle's battery or charging system.

The buck-boost converter operates by adjusting the duty cycle of a switching element, typically a power transistor or MOSFET, to step up or step down the DC voltage. This control mechanism allows the converter to efficiently regulate the voltage regardless of whether the input voltage is higher or lower than the desired output voltage.

By utilizing a buck-boost converter, we can optimize the power transfer to ensure maximum efficiency. If the rectified voltage is lower than the required voltage for charging the vehicle's battery, the converter steps up the voltage to the appropriate level. Conversely, if the rectified voltage is higher than the desired voltage, the converter steps it down to prevent overcharging.

The buck-boost converter also provides benefits in terms of power factor correction and voltage stabilization. It helps to improve power factor, ensuring a more balanced and efficient utilization of electrical power from the grid. Additionally, the converter helps to maintain a stable output voltage, compensating for variations in input voltage or load conditions, and providing a reliable and consistent power supply to the vehicle's charging system.

Incorporating the buck-boost converter into our wireless charging system enables us to achieve maximum power transfer efficiency and effectively regulate the voltage for optimal charging performance. This contributes to faster and more efficient charging of electric vehicles, enhancing the overall usability and convenience of wireless charging technology.

After the buck-boost converter in our wireless charging system, we connect the main load to utilize the converted and regulated DC power. The main load refers to the electrical components or systems that require power to operate within the electric vehicle.

The connected main load could include various components, such as the vehicle's traction motor, onboard electronics, lighting systems, and auxiliary power systems. These loads consume the converted DC power to perform their respective functions and ensure the smooth operation of the electric vehicle.

The buck-boost converter plays a crucial role in ensuring that the voltage supplied to the main load is at the appropriate level for its optimal operation. By regulating and adjusting the voltage as required, the converter ensures that the connected load receives a stable and consistent power supply, maximizing the efficiency and performance of the vehicle's electrical systems.

Additionally, the buck-boost converter provides important protection features for the main load. It helps to prevent voltage fluctuations and spikes, ensuring that the connected load receives a clean and reliable power supply. The converter also incorporates safety measures to safeguard against overvoltage, overcurrent, and other potential electrical hazards, protecting both the load and the overall system.

By connecting the main load to the output of the buck-boost converter, our wireless charging system enables the efficient operation of various electrical components and systems within the electric vehicle. The converter ensures the provision of stable voltage and offers protective features to maintain the integrity and reliability of the load, contributing to the overall performance and safety of the vehicle.

3.2 Hardware Selection

We have selected following components for our hardware implementation.

3.2.1 Power Transmitter and Power receiver

In both the transmitter and receiver of our wireless charging system, we utilize Litz wire as a crucial component. Litz wire is a specialized type of wire consisting of multiple individually insulated strands woven together. This unique construction offers several advantages for efficient power transfer and minimization of losses.

Litz wire is specifically designed to reduce the skin effect and proximity effect that occur at high frequencies. The skin effect refers to the tendency of alternating current to concentrate near the surface of a conductor, resulting in increased resistance and power loss. The proximity effect, on the other hand, occurs when adjacent conductors induce currents in each other, leading to further power losses.

By using Litz wire in our transmitter and receiver coils, we mitigate these effects. The individual insulated strands of the wire distribute the current more evenly throughout the cross-section of the conductor, minimizing the skin and proximity effects. This helps to reduce power losses and enhance the overall efficiency of the wireless power transfer process.

Additionally, Litz wire offers improved flexibility and mechanical strength compared to solid-core wires. The weaving of multiple strands provides greater flexibility, making it easier to shape and arrange the wire according to the design requirements of the coils. The enhanced mechanical strength ensures durability and longevity, allowing for reliable performance in demanding applications such as wireless charging.

In summary, the use of Litz wire in both the transmitter and receiver of our wireless charging system helps to minimize power losses, improve efficiency, and enhance the mechanical robustness of the coils. This ensures optimal power transfer and reliability in our wireless charging setup, contributing to a more efficient and effective charging experience for electric vehicles.

3.2.2 ZVS Driver

The ZVS (Zero Voltage Switching) driver circuit in our wireless charging system utilizes several specific components to achieve its operation effectively. These components play essential roles in enabling zero voltage switching and ensuring optimal performance.

IRFP260N MOSFETs: The IRFP260N MOSFETs are chosen as the primary switching devices in the ZVS driver circuit. These MOSFETs are known for their high power handling capability, fast switching speed, and low on-resistance. They enable efficient power switching and help achieve zero voltage switching, reducing power losses and improving overall circuit efficiency.

FR107 Diodes: The FR107 diodes are used as rectifier diodes in the ZVS driver circuit. These fast recovery diodes have low forward voltage drop and fast switching characteristics, making them suitable for high-frequency applications. They are responsible for converting the alternating current generated by the resonant tank circuit into a direct current, enabling efficient power transfer.

IN4148 Zener Diodes: The IN4148 Zener diodes are employed as voltage regulation components in the ZVS driver circuit. These diodes provide a stable reference voltage and protect the circuit against voltage spikes or transients. They help maintain proper voltage levels and ensure reliable and stable operation of the ZVS driver.

10k and 470 Ohm Resistors: The 10k and 470 Ohm resistors are used for current limiting and voltage division purposes in the ZVS driver circuit. They help control the flow of current and protect the circuit from excessive current levels. Additionally, they assist in voltage division, ensuring appropriate voltage levels for different components in the circuit.

Heat Sinks: Heat sinks are essential components in the ZVS driver circuit to dissipate heat generated by the MOSFETs during operation. They provide efficient heat dissipation and prevent the MOSFETs from overheating, ensuring their optimal performance and prolonging their lifespan.

100µH Inductors and 0.6µF Capacitor: The 100µH inductors and 0.6µF capacitor are part of the resonant tank circuit in the ZVS driver. The inductors store energy in their magnetic fields, while the capacitor stores electrical energy. Together, they create a resonant circuit that enables zero voltage switching and promotes efficient power transfer.

By incorporating components such as IRFP260N MOSFETs, FR107 diodes, IN4148 Zener diodes, resistors, heat sinks, inductors, and capacitors, our ZVS driver circuit facilitates efficient and controlled switching operations. These components work together to achieve zero voltage switching, minimize power losses, and enhance the overall performance of the wireless charging system.

3.3 Model car

We have designed the car for our project in the following way:

3.3.1 Material for car.

We chose to design our model car using acrylic sheets due to their versatility, durability, and ease of customization. Acrylic sheets offer a lightweight yet robust construction material that allows us to create sleek and precise components for our vehicle. With acrylic sheets, we have the flexibility to cut, shape, and bend them to match our desired design and dimensions.

Figure 14

The transparency of acrylic sheets also provides aesthetic appeal, allowing us to showcase the inner workings of our model car. Additionally, acrylic is resistant to impact and UV radiation, ensuring that our vehicle remains resilient and maintains its visual appeal over time.

Furthermore, working with acrylic sheets is relatively straightforward. We can use various techniques such as laser cutting, drilling, and heat bending to fabricate precise parts for our model car. The smooth surface finish of acrylic also facilitates painting, adhesive bonding, or adding decals to achieve the desired aesthetics.

Overall, by utilizing acrylic sheets as the primary material for our model car, we can achieve a balance between structural integrity, design flexibility, and visual appeal. This choice allows us to create a visually striking and functional vehicle that showcases our creativity and engineering prowess.

Type of Board for programming and execution.

Using an Arduino as the basic processor for your model RC car is a popular choice due to its versatility and ease of use. The Arduino platform provides a user-friendly development environment and a wide range of compatible modules and libraries that can be utilized to enhance the functionality of your RC car.

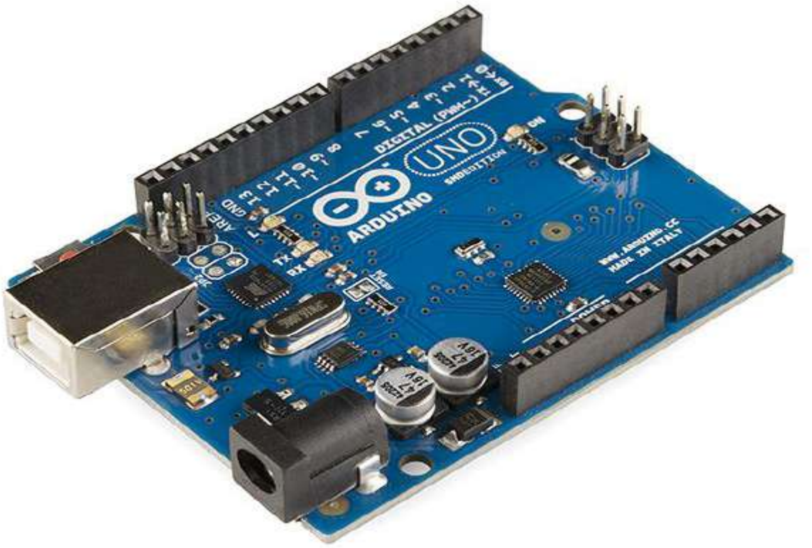


Figure 15

Here are some key considerations for incorporating Arduino into your project:

Control and Communication: The Arduino can be used to control various aspects of your model car, such as motor speed, steering, and other auxiliary functions. Utilize PWM (Pulse Width Modulation) pins to control the motor speed and servo motor libraries to control steering. Additionally, you can establish wireless communication between the Arduino and the receiver module to receive commands from the transmitter and enable remote control functionality.

Sensor Integration: Arduino boards have analog and digital input pins that can be used to connect and interface with various sensors. Consider incorporating sensors such as proximity sensors, gyroscopes, or accelerometers to enable features like obstacle detection, collision avoidance, or stability control. The Arduino can read sensor data, process it, and make decisions based on the input received.

Data Logging and Telemetry: Arduino boards can be equipped with additional modules, such as SD card readers or wireless transceivers, to enable data logging and telemetry capabilities. You can log various parameters, such as speed, battery voltage, or sensor readings, to analyze and monitor the performance of your model car. Telemetry allows you to transmit real-time data to a remote device for monitoring and analysis purposes.

Customization and Expansion: Arduino boards offer numerous input and output pins, making it easy to connect additional components and expand the functionality of your model car. Consider adding features like LED indicators, sound modules, or even Bluetooth connectivity for controlling your car using a smartphone or a custom mobile app.

Programming and Debugging: Utilize the Arduino IDE (Integrated Development Environment) to write and upload code to your Arduino board. The IDE provides a simple programming language based on C/C++, making it accessible for beginners and experienced programmers alike. Leverage the built-in debugging tools and serial communication capabilities to monitor and troubleshoot your code during development.

By integrating Arduino into your model RC car, you can harness its flexibility and extensive ecosystem of libraries and modules to enhance the control, functionality, and customization of your project. The Arduino platform provides a solid foundation for developing a versatile and interactive model car that aligns with your specific requirements and objectives.

3.3.2 Type of Signal transmitter

In our model car setup designed to run on a track, we have incorporated the Fly Sky FSi6X transmitter and FSi6B receiver as essential components. The Fly Sky FSi6X transmitter serves as the controller, allowing for wireless control and communication with the model car, while the FSi6B receiver receives the signals transmitted by the transmitter and translates them into actions for the car.

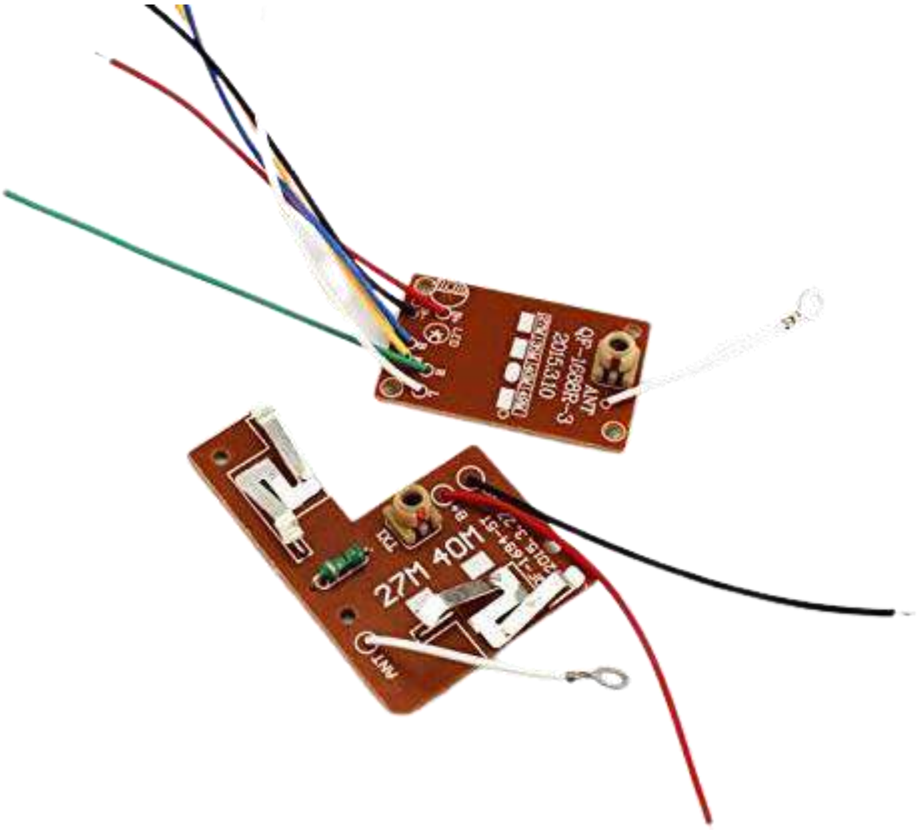


Figure 16

The Fly Sky FSi6X transmitter is specifically designed for RC (remote control) applications and offers six channels of control. With its ergonomic design and user-friendly interface, the FSi6X transmitter provides a comfortable grip and intuitive controls, enabling precise and responsive operation of the model car on the track.

The FSi6B receiver is responsible for receiving the signals transmitted by the FSi6X transmitter and relaying them to the model car's control system. It ensures reliable and accurate signal reception, allowing for precise control and maneuvering of the car during races or track runs. The receiver's compact size and compatibility with the transmitter make it an ideal choice for model car enthusiasts.

By incorporating the Fly Sky FSi6X transmitter and FSi6B receiver into our model car setup, we can enjoy wireless control and enhanced maneuverability on the track. The reliable signal transmission and reception provided by these components ensure responsive control, allowing for an immersive and enjoyable model car racing experience.

3.3.3 Type of motor driver

Using the L298N motor driver for your model RC car is a great choice for controlling the motors effectively. The L298N is a popular dual H-bridge motor driver module that allows bidirectional control of two DC motors or a single stepper motor.

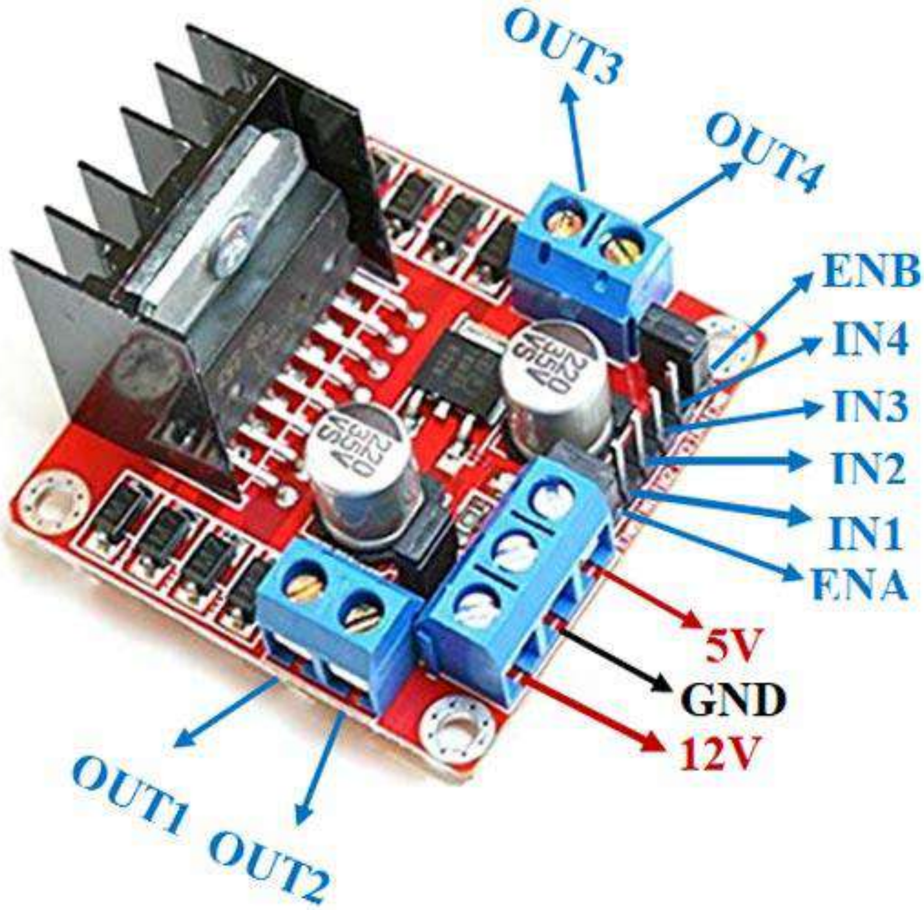


Figure 17

Here are some key considerations when integrating the L298N motor driver into your project:

Motor Connections: Connect the motors of your model car to the outputs of the L298N motor driver. Ensure proper polarity and wiring, and make sure the motor specifications (voltage, current, etc.) are within the operating range of the L298N module.

Power Supply: Provide an appropriate power supply to the L298N module. This power supply should be capable of delivering the required voltage and current for the motors. Be cautious not to exceed the maximum voltage and current limits specified by the L298N module.

Control Signals: Utilize the digital output pins of the Arduino to provide control signals to the L298N module. Connect the appropriate pins of the L298N module to the corresponding pins of the Arduino, following the pinout diagram provided by the manufacturer. Use PWM pins for speed control if necessary.

Direction and Speed Control: The L298N module allows you to control the direction and speed of the motors. By setting the appropriate logic levels on the control pins of the L298N, you can control the motor rotation direction (forward or reverse). Adjust the pulse width modulation (PWM) signals to control the motor speed.

External Protection: Consider adding external protection components like diodes across the motor terminals to prevent voltage spikes and reverse current when the motors are switched off. These protection measures help safeguard the L298N module and other components from potential damage.

Testing and Calibration: Test your motor control setup to ensure proper functionality. Start with simple motor control commands and gradually implement more complex maneuvers. Calibrate the motor speeds and control algorithms to achieve smooth and responsive operation.

3.4 Software

In our project, we will be utilizing several software tools to aid in the development and design process. These software tools include Proteus, KiCAD, and Coil64.

3.4.1 Proteus

Proteus is a popular electronic design automation software that allows us to simulate and test our circuit designs. With Proteus, we can create virtual prototypes of our circuits, including the various components, and analyze their behavior in a simulated environment. This enables us to identify and resolve any potential issues or errors before implementing the circuit in the physical model. Proteus provides a comprehensive set of simulation capabilities, including interactive debugging, waveform analysis, and virtual testing, which greatly streamline the development process and improve overall efficiency.

3.4.2 KiCAD

KiCad is a powerful open-source electronic design automation (EDA) software suite that provides a comprehensive set of tools for designing printed circuit boards (PCBs). With its intuitive interface, extensive functionality, and active user community, KiCad has become a popular choice among electronics enthusiasts, hobbyists, and professional designers alike.

One of the key advantages of KiCad is its cross-platform compatibility, allowing users to work seamlessly on Windows, macOS, and Linux operating systems. This flexibility enables collaborative design projects and promotes accessibility across different platforms. Additionally, being an open-source software, KiCad is continually updated and improved by a dedicated community of developers, ensuring a stable and feature-rich environment for PCB design.

KiCad offers a wide range of features to support the complete design process. Its schematic editor allows users to create and modify electronic circuit schematics, with extensive symbol libraries and intuitive drawing tools. The integrated component editor facilitates customization and management of component libraries, making it easy to add, modify, or import components as per project requirements.

The PCB layout editor in KiCad provides a powerful and flexible environment for designing the physical layout of the circuit board. It supports features such as multi-layer routing, automatic and manual placement, design rule checking, and 3D visualization. The interactive routing tools allow for precise trace routing and efficient use of available space on the board.

KiCad also includes a comprehensive suite of tools for generating manufacturing-ready outputs. It supports the generation of Gerber files, drill files, bill of materials (BOM), and 3D models for collaboration with manufacturers or fabrication houses. The integrated electrical rule checking (ERC) and design rule checking (DRC) features help ensure the integrity and compliance of the design.

Furthermore, KiCad's ecosystem extends beyond the core software itself. It provides a platform for users to share and access community-contributed libraries, footprints, and 3D models, facilitating collaboration and accelerating the design process. Additionally, KiCad offers seamless integration with other open-source tools and utilities, expanding its capabilities even further.

In summary, KiCad is a feature-rich and user-friendly EDA software suite that empowers electronics designers to bring their ideas to life. Its comprehensive set of tools, cross-platform compatibility, and active community support make it a go-to choice for PCB design projects of all scales. Whether you're a hobbyist, student, or professional, KiCad offers a robust and flexible platform to unleash your creativity and turn your electronic designs into reality.

3.4.3 COIL 64

Coil64 is a specialized software tool designed for the analysis and design of electromagnetic coils. It offers a comprehensive set of features and capabilities that make it a valuable tool for engineers, researchers, and designers working in various fields such as electronics, power systems, and electrical engineering.

One of the notable features of Coil64 is its ability to accurately analyze and simulate the behavior of electromagnetic coils. With its advanced algorithms and numerical methods, the software can calculate important parameters such as inductance, resistance, and capacitance of the coils, enabling users to understand and optimize the performance of their coil designs. This information is crucial for applications where precise coil characteristics are required, such as in transformers, motors, antennas, and wireless power transfer systems.

Coil64 provides a user-friendly interface that allows users to define the coil geometry, material properties, and operating conditions. The software supports various coil configurations, including solenoidal, toroidal, and planar geometries. It also allows for the inclusion of core materials and accounts for their magnetic properties in the analysis. This flexibility enables users to model and simulate a wide range of coil designs tailored to their specific application requirements.

Another key feature of Coil64 is its ability to generate visual representations of the coil's magnetic field distribution. This feature is particularly useful for understanding the behavior of the coil and identifying potential areas of improvement. The software provides 2D and 3D visualization tools, allowing users to visualize the magnetic field lines, flux density, and other related parameters. These visualizations help in the analysis and optimization of coil designs, ensuring that the magnetic field is properly controlled and utilized for the desired application.

In addition to analysis and simulation capabilities, Coil64 also offers design optimization tools. Users can define design constraints and objectives, and the software can automatically search for optimal coil configurations that meet the specified criteria. This feature streamlines the design process, saving time and effort by assisting users in finding the best coil design for their specific application needs.

Furthermore, Coil64 supports the export of simulation results and coil designs in various formats, facilitating seamless integration with other software tools and workflows. This interoperability allows users to incorporate the coil designs into larger system simulations or transfer data to manufacturing processes.

3.5 RC Car Model

As part of our project, we are undertaking the exciting task of building our own RC (Remote Control) car from scratch. This endeavor allows us to gain hands-on experience in designing and constructing a functional vehicle tailored to our specific requirements. By building our own RC car, we have the opportunity to explore various aspects of the project, from selecting the chassis and motor systems to integrating the control electronics and implementing advanced features. This hands-on approach not only enhances our technical skills but also offers a deeper understanding of the intricacies involved in creating a fully operational RC car.

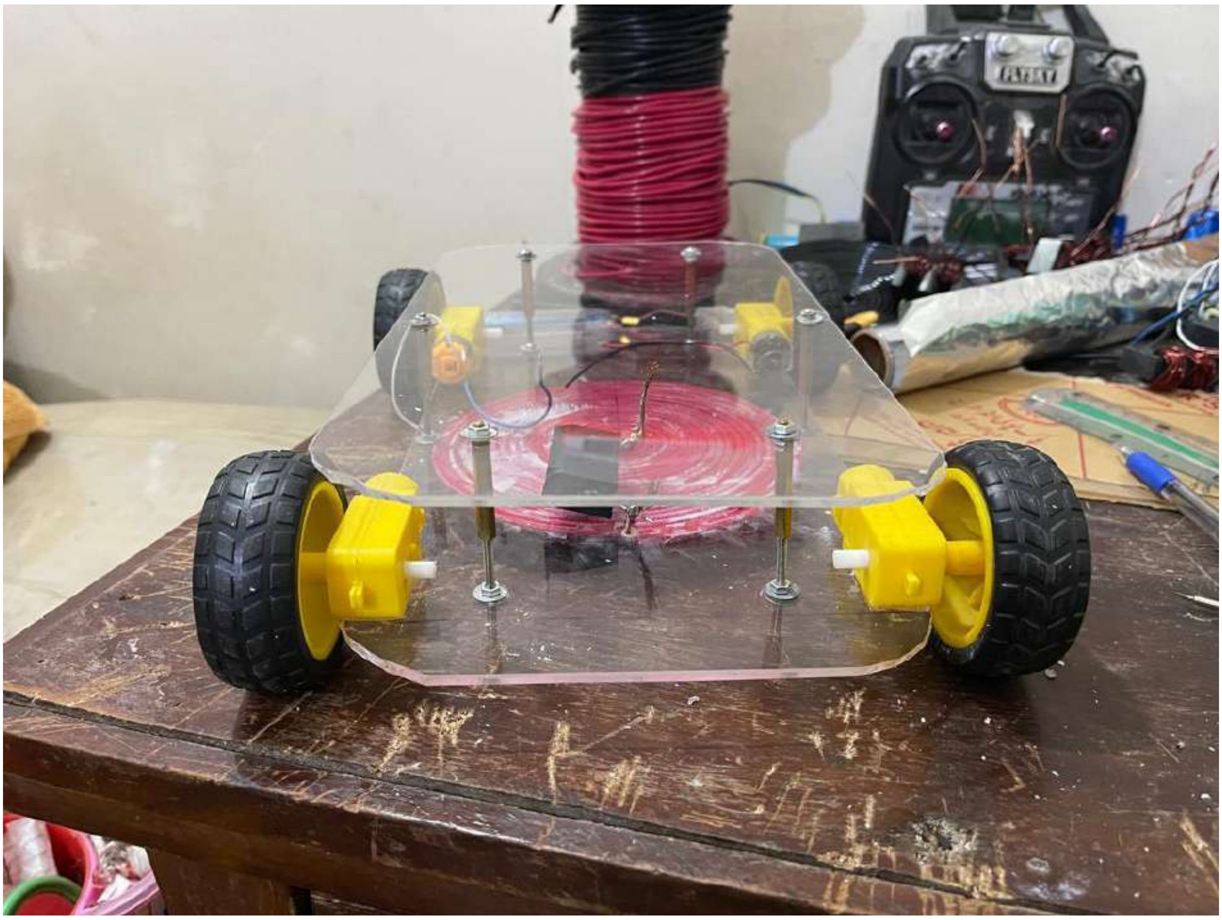


Figure 18

Building our own RC car also opens up possibilities for customization and innovation. We have the freedom to experiment with different components, materials, and design concepts, enabling us to create a unique and personalized vehicle. Through the construction process, we can tackle challenges and solve problems, fostering a sense of creativity and resourcefulness. Furthermore, by taking ownership of the entire build process, we can ensure that the final product meets our specific requirements and performance expectations. Overall, building our own RC car is a rewarding and fulfilling endeavor that allows us to explore our passion for engineering and showcase our ingenuity in creating a functional and impressive model vehicle.

3.5.1 Module Firmware

To update the firmware of the Fly-Sky transmitter, follow these steps:

First, ensure that you have the necessary firmware update file compatible with your specific FlySky transmitter model. Visit the official FlySky website or other reliable sources to download the latest firmware version. Connect your transmitter to a computer using a USB cable, making sure it is powered on and in programming mode.

Figure 19

Next, open the firmware update tool or software provided by FlySky or a third-party firmware update utility compatible with your transmitter. Launch the software on your computer and select the appropriate firmware file you downloaded earlier.

With the firmware update tool running, follow the on-screen instructions to initiate the update process. This typically involves pressing a specific button combination on your transmitter to put it into firmware update mode.

Once the transmitter is in firmware update mode, the update tool will begin transferring the new firmware to the transmitter. It is crucial to keep the transmitter connected to the computer throughout the update process and avoid interrupting the connection or powering off the transmitter.

Wait for the update process to complete. The update tool will indicate the progress, and once it finishes, you will receive a notification confirming the successful firmware update. At this point, you can safely disconnect the transmitter from the computer.

After the firmware update, it is essential to perform a thorough functional check of the transmitter to ensure it is operating correctly. Test all the controls, switches, and settings to verify their functionality and responsiveness.

By following this complete procedure for updating the firmware of your FlySky transmitter, you can benefit from the latest features, improvements, and bug fixes provided by the firmware update. Always refer to the manufacturer's documentation and guidelines specific to your FlySky transmitter model to ensure a successful and trouble-free firmware update process.

3.5.2 Receiver Coding

In our model car, we have a dedicated receiver that plays a crucial role in receiving signals from the transmitter and translating them into appropriate actions. The receiver acts as the communication link between the transmitter and the car's control system. When the transmitter sends out control signals, the receiver captures them through its antenna and processes the incoming data. It decodes the signals and sends corresponding instructions to the car's onboard control unit, which then translates those instructions into specific actions such as controlling the motor speed or steering direction. This seamless interaction between the transmitter and receiver allows for real-time and accurate control over the model car, enabling us to navigate it with precision and responsiveness.

3.5.2.1 Arduino

The coding aspect of our RC car project will be carried out using the Arduino software, a versatile and user-friendly platform for programming microcontrollers. Arduino provides a robust and accessible development environment that simplifies the process of writing code for our vehicle's control system. With its extensive library support and intuitive programming language based on C/C++, Arduino empowers us to implement various functionalities and control mechanisms for our RC car.

Using the Arduino software, we can define and configure the behavior of different components and sensors, such as motor drivers, steering mechanisms, and remote control interfaces. By writing code in the Arduino IDE (Integrated Development Environment), we can easily set up communication protocols, establish sensor readings, and design logic for decision-making algorithms. Arduino's flexibility allows us to create custom control sequences.

The code we write for our RC car is:

```
#include <VirtualWire.h>
```

```
#define THROTTLE_PIN A0
#define STEERING_PIN A1

void setup() {
  vw_set_rx_pin(2);     // Set the receiver pin
  vw_set_ptt_inverted(true);  // Required for FlySky receiver
  vw_setup(2000);       // Set the data rate in bits per second (baud rate)
  vw_rx_start();        // Start the receiver
}

void loop() {
  // Read throttle and steering values
  int throttleValue = analogRead(THROTTLE_PIN);
  int steeringValue = analogRead(STEERING_PIN);

  // Map the analog input values to the desired output range
  int mappedThrottle = map(throttleValue, 0, 1023, 1000, 2000);
  int mappedSteering = map(steeringValue, 0, 1023, 1000, 2000);

  // Create a message buffer to store the mapped values
  char message[10];
  sprintf(message, "%d,%d", mappedThrottle, mappedSteering);

  // Send the message via the transmitter
  vw_send((uint8_t *)message, strlen(message));
  vw_wait_tx();  // Wait until the message is sent

  delay(20);  // Add a small delay between transmissions
}
```

Explanation:

The code work in the following manners.

1. The code begins by including the necessary library, **VirtualWire**, which provides

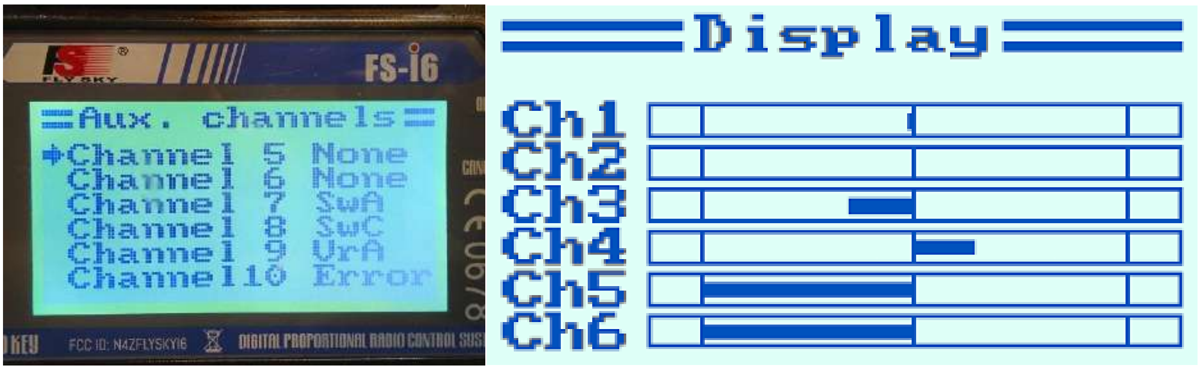
communication capabilities for wireless transmission.

2. The **THROTTLE_PIN** and **STEERING_PIN** constants are defined, representing the analog input pins connected to the throttle and steering inputs of the RC car, respectively.
3. In the **setup()** function, the receiver pin is set using **vw_set_rx_pin()**, the PTT (Push To Talk) inverted mode is enabled with **vw_set_ptt_inverted()**, and the data rate is set to 2000 bits per second using **vw_setup()**. Finally, **vw_rx_start()** starts the receiver.
4. The main logic is in the **loop()** function, which executes repeatedly.
5. The throttle and steering values are read from the analog pins using **analogRead()**.
6. The **map()** function is used to convert the analog input values (ranging from 0 to 1023) to the desired output range (1000 to 2000). This mapping allows the transmitter to send appropriate control signals to the receiver for throttle and steering control.
7. A message buffer **message** is created to store the mapped throttle and steering values.
8. The **sprintf()** function is used to format the mapped values as a string message in the **message** buffer.
9. The **vw_send()** function transmits the message via the FlySky transmitter using the VirtualWire library. The **strlen()** function is used to determine the length of the message.
10. The **vw_wait_tx()** function is called to wait until the message is sent before proceeding to the next iteration.
11. A small delay of 20 milliseconds is added using **delay()** between each transmission to ensure smooth operation and avoid overwhelming the system.

With this code, the Arduino reads the throttle and steering inputs, maps them to the desired output range, and transmits the values via the FlySky transmitter. The transmitted values can then be received by the FlySky receiver connected to the RC car, allowing it to respond accordingly and control the motors for throttle and steering functions.

3.5.2.2 Transmitter synchronization

We calibrated the Fly Sky transmitter, specifically the FS-i6X model, to ensure precise and accurate control over our RC car. By carefully adjusting the control stick endpoints, trim settings, and center positions, we established a reliable and responsive connection between the transmitter and receiver. This calibration process allowed us to fine-tune the control inputs, ensuring that the throttle, steering, and auxiliary channels are properly aligned with the desired movements and functionalities of our RC car. With a properly calibrated Fly Sky transmitter, we can confidently navigate our model car with ease, enjoying smooth and proportional control. The calibration step has played a crucial role in optimizing the performance of our RC car, enhancing our overall experience and allowing us to explore the full capabilities of this exciting project.



Aux. channels

Channel 5 None
Channel 6 None
Channel 7 SwA
Channel 8 SwC
Channel 9 VrA
Channel10 Error

Figure 20

We began the calibration process of our Fly Sky FS-i6X transmitter by powering it on and ensuring that the batteries were fully charged. With the transmitter powered on, we moved all control sticks to their center positions to establish neutral calibration. Next, we checked the trim settings and made sure they were centered or at their default positions. This step ensured that the trim adjustments were properly calibrated for accurate control input. We then connected the receiver to our RC car according to the manufacturer's instructions, ensuring secure and aligned connections. After powering on the model car, we verified signal reception between the transmitter and receiver, confirming that they were communicating effectively. With the receiver receiving signals, we proceeded to test each control on the transmitter, including the throttle, steering, and any auxiliary channels, to ensure their functionality aligned with the intended movements and features of the RC car. Throughout the process, we made adjustments as necessary to achieve precise and proportional control. By following this comprehensive calibration procedure, we have successfully established a reliable and accurate control system for our RC car, enhancing our overall driving experience

CHAPTER 04-CALCULATIONS & RESULT ANALYSIS

This chapter will provide a comprehensive evaluation of the results obtained from the practical implementation of our wireless power transfer system. The discussion will highlight the achievements, challenges, and future possibilities for enhancing the performance, efficiency, and safety of the system. The results obtained will serve as valuable insights for further research, development, and real-world implementation of wireless power transfer technology.

4.1 Transmitter coil Dimensions

The important information for our wireless power transfer project includes the length of the track, which is 1.2m, and the width of the track, which is 20cm. These dimensions define the physical layout of the track where our wireless power transfer system will be implemented.

Additionally, we have the number of turns in the transmitter coil, which is 18, and the turn spacing, which is 1cm. These details are crucial for determining the characteristics of the transmitter coil, such as its inductance and Q factor.

The length and width of the track play a significant role in determining the overall size and layout of the wireless power transfer system. The number of turns and turn spacing of the transmitter coil directly impact its inductance and other electrical properties. These parameters affect the efficiency and performance of the wireless power transfer system.

By considering this given data, we can proceed with calculations and simulations to optimize the design and performance of our wireless power transfer system. The provided dimensions and coil parameters serve as a foundation for further analysis and experimentation to achieve efficient and reliable power transfer.

4.1.1 Transmitter coil Resistance calculations

The use of litz wire in our wireless power transfer system introduces the challenge of accurately determining its resistance, especially at higher frequencies. The limitations of the LCR (inductance-capacitance-resistance) meter at 10kHz prevent us from directly measuring the resistance at our operating frequency of 32.5kHz. However, we can make use of the available data within the LCR meter’s frequency range to estimate the resistance at 32.5kHz.

Based on the measurements we obtained, the transmitter coil resistance at 0Hz is 1 ohm, at 1kHz is 1.1 ohm, and at 10kHz is 2 ohms. We observe that as the frequency increases, the resistance also tends to increase.

To estimate the transmitter coil resistance at 32.5kHz, we can interpolate or extrapolate from the available data points. By analyzing the trend in resistance as the frequency increases, we can deduce that the resistance at 32.5kHz would be higher than the measured value at 10kHz. In this case, the estimated resistance at 32.5kHz is found to be approximately 7.27 ohms.

It is important to note that this estimation is based on the assumption that the resistance of the litz wire follows a consistent pattern with frequency.

4.1.2 Transmitter coil Inductance Calculations

Using the given data, we can calculate the transmitter coil inductance and the Q factor associated with it. The length of the track is 1.2m, and the width is 20cm. We also know the number of turns, which is 18, and the turn spacing, which is 1cm.

To calculate the transmitter coil inductance, we can use the formula for the inductance of a solenoid coil:

$$L = (\mu_0 * N^2 * A) / l$$

Where: L is the inductance of the coil, μ_0 is the permeability of free space (constant), N is the number of turns in the coil, A is the cross-sectional area of the coil, and l is the length of the coil.

Given that the width of the track is the same as the cross-sectional area of the coil, we can substitute the values into the formula:

$$L = (\mu_0 * N^2 * A) / l$$

Substitute the values into the formula:

$$L = (\mu_0 * 18^2 * 0.2) / 1.2$$

Calculate the value:

$$L=52uH$$

4.1.3 Transmitter coil Q Factor Calculations

To calculate the Q factor of the transmitter coil using the given data, we need to determine the coil’s inductance and resistance.

Given data:

Length of track (l): 1.2m

Width of track (w): 20cm

Number of turns (N): 18

Turn spacing (s): 1cm

First, we calculate the effective length of the coil (Leff):

$$Leff = l + (N-1) * s$$

Substitute the values:

$$Leff = 1.2m + (18-1) * 0.01m$$

$$Leff = 1.2m + 0.17m$$

$$Leff = 1.37m$$

Next, we calculate the inductance (L) of the transmitter coil:

$$L = (\mu_0 * N^2 * A) / Leff$$

Where:

μ_0 is the permeability of free space ($4\pi * 10$^-7 H/m)

N is the number of turns

A is the cross-sectional area of the coil.

Since the width of the track is given as 20cm, we convert it to meters:

$$w = 20cm = 0.2m$$

The cross-sectional area of the coil (A) is then calculated as:

$$A = w * Leff$$

$$A = 0.2m * 1.37m$$

$$A = 0.274m^2$$

Now we can calculate the inductance (L):

$$L = (4\pi * 10\text{\^{}-7}\ H/m * 18^2 * 0.274m^2) / 1.37m$$

$$L = (4\pi * 10\text{\^{}-7}\ H * 18^2 * 0.274) / 1.37$$

$$L = 52uH$$

Finally, we can calculate the Q factor:

$$Q = \omega * L / R$$

Where: ω is the angular frequency (2π * frequency) R is the resistance of the transmitter coil at 32.5kHz (7.27 ohm, as previously calculated)

Using the operating frequency of 32.5kHz:

$$\omega = 2\pi * 32.5kHz$$

$$\omega = 2\pi * 32{,}500$$

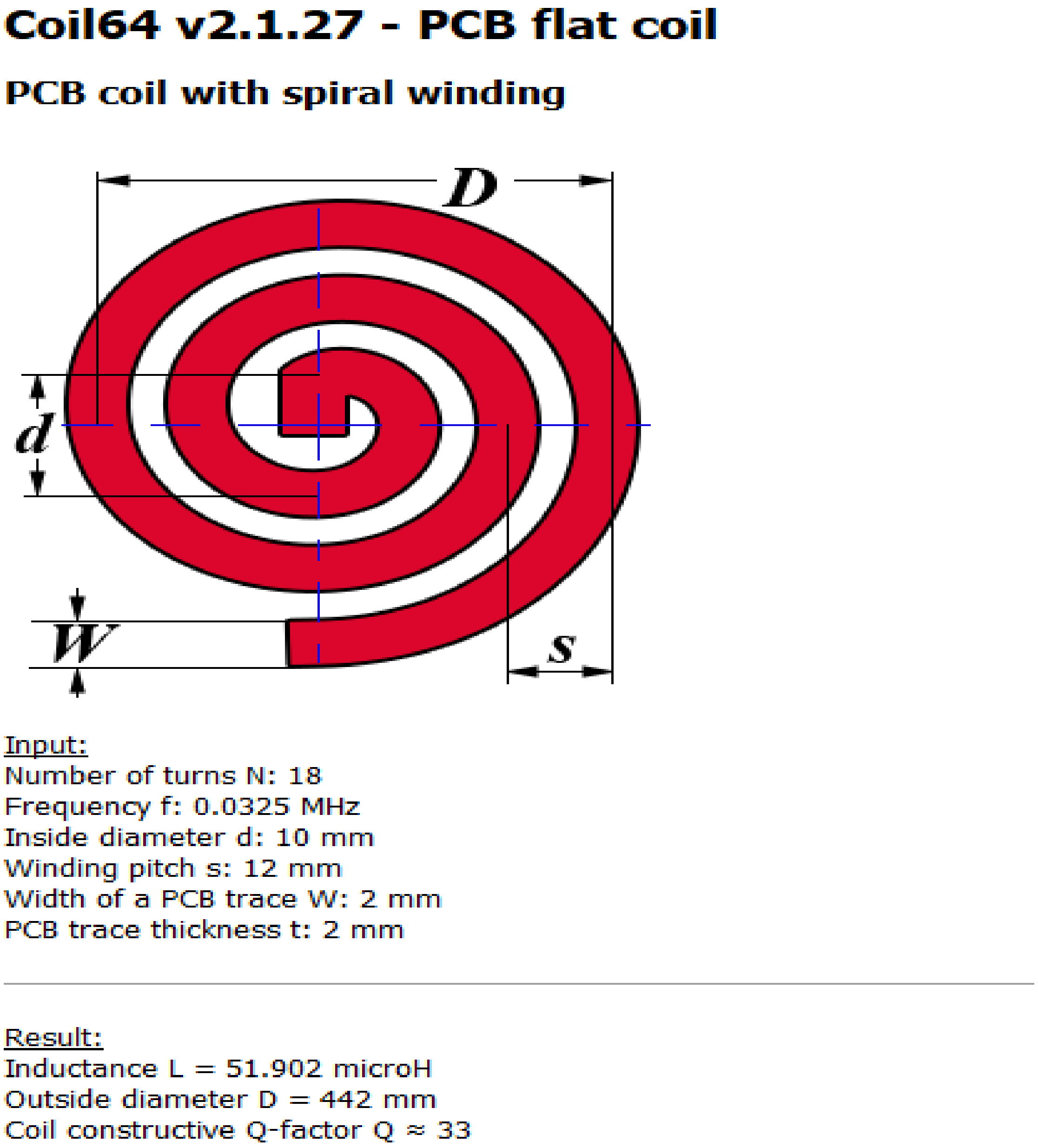
$$Q = (2\pi * 32{,}500 * 52u) / 7.27\ Q \approx 33$$

Therefore, the Q factor of the transmitter coil is approximately 33.

4.1.4 Transmitter coil calculations (Using the Coil64 software)

Coil 64 is a powerful software tool used for calculating the inductance and Q factor of coil systems. By inputting parameters such as the number of turns, length of the coil, turn spacing, operating frequency, and inside diameter, the software automatically generates precise values. This eliminates the need for manual calculations and streamlines the coil design process. With its user-friendly interface and accurate results, Coil 64 enables engineers and researchers to efficiently analyze and optimize coil systems for various applications, saving time and ensuring optimal performance.

The result for our transmitting coil is shown below.



Coil64 v2.1.27 - PCB flat coil

PCB coil with spiral winding

Input:
Number of turns N: 18
Frequency f: 0.0325 MHz
Inside diameter d: 10 mm
Winding pitch s: 12 mm
Width of a PCB trace W: 2 mm
PCB trace thickness t: 2 mm

Result:
Inductance L = 51.902 microH
Outside diameter D = 442 mm
Coil constructive Q-factor Q ≈ 33

Figure 21

4.2 Receiver Coil Dimensions

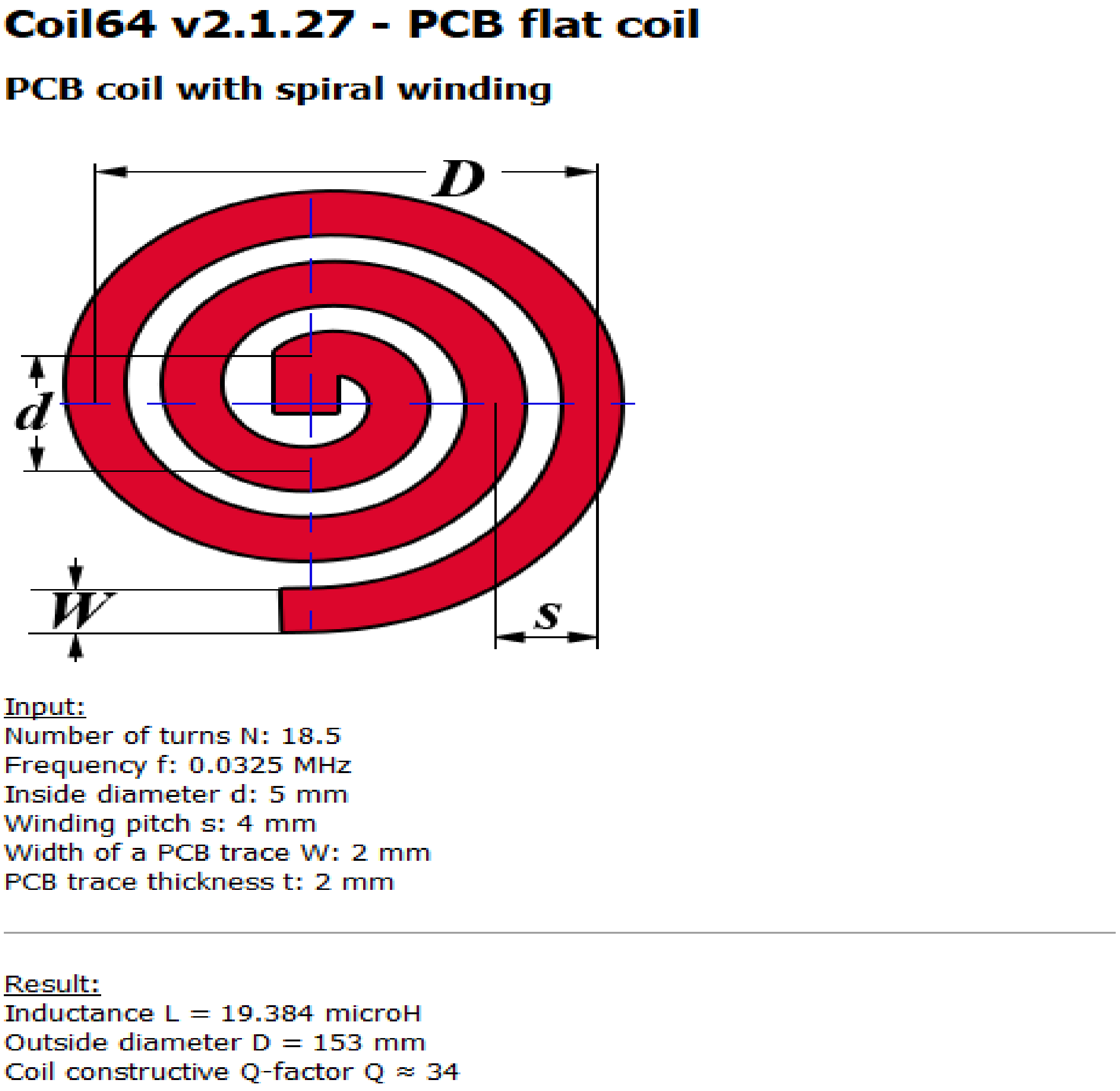
The receiver coil data provided includes the diameter, width of the track, number of turns, and turn spacing. The diameter of the coil is measured to be 14 cm, which represents the overall size of the coil. The width of the track, specified as 2 mm, refers to the width of the conducting material used to create the coil.

The number of turns in the receiver coil is stated as 18, indicating the total count of wire loops present in the coil structure. Each turn is evenly spaced, with a turn spacing of 2 mm. This spacing determines the distance between adjacent turns of the coil.

These parameters are essential in calculating the inductance and Q factor of the receiver coil. By accurately measuring and specifying these values, we can determine the performance characteristics and efficiency of the receiver coil in the wireless power transfer system.

The resistance of the litz wire will be same since the operating frequency and length and properties of the wire are same. Thus, the wire will have the same resistance at 32.5kHz as that of transmitting coil, which is 7.27 ohms.

The result we obtained for inductance and Q factor by the given information using the software is shown.



Coil64 v2.1.27 - PCB flat coil

PCB coil with spiral winding

Input:
Number of turns N: 18.5
Frequency f: 0.0325 MHz
Inside diameter d: 5 mm
Winding pitch s: 4 mm
Width of a PCB trace W: 2 mm
PCB trace thickness t: 2 mm

Result:
Inductance L = 19.384 microH
Outside diameter D = 153 mm
Coil constructive Q-factor Q ≈ 34

Figure 22

4.3 Skin Depth Calculation of Litz Wire

The skin depth is a characteristic of conductive materials and refers to the depth at which the current density is reduced to approximately 37% (1/e) of its value at the surface. It is a measure of how deeply the current penetrates into a conductor.

The skin depth is determined by the frequency of the current passing through the conductor and the electrical properties of the material. It is given by the formula:

$$\delta = \sqrt{(2 / (\pi * \mu * \sigma * f))}$$

Where:

- δ is the skin depth
- ρ is the resistivity of the material (for copper, $\rho = 1.68$ x 10^-8 Ω*m)
- f is the frequency of operation (32.5 kHz in this case)
- μ is the permeability of the material (for copper, $\mu = \mu_0 = 4\pi$ x 10^-7 H/m)

Using the given data, we can calculate the skin depth as follows:

$$\text{Skin Depth } (\delta) = \sqrt{((1.68 \text{ x } 10\text{^-}8\ \Omega*\text{m}) / (\pi * 32.5 \text{ x } 10\text{^}3 \text{ Hz} * 4\pi \text{ x } 10\text{^-}7 \text{ H/m}))}$$

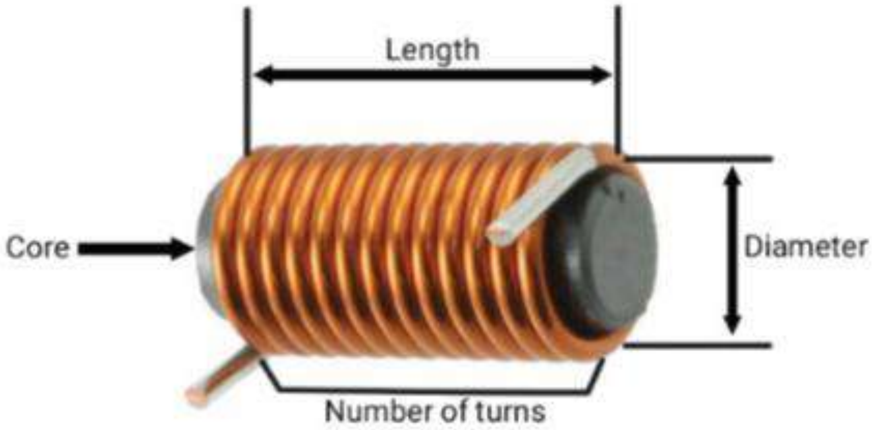
Simplifying the equation, we get:

$$\text{Skin Depth } (\delta) \approx 0.015 \text{ m or } 15 \text{ mm}$$

Therefore, the skin depth of the copper wire at a frequency of 32.5 kHz is approximately 15 mm. This indicates that the current tends to penetrate up to a depth of 15 mm into the copper wire.

4.4 Inductance of inductor

The inductance of an inductor is a measure of its ability to store energy in the form of a magnetic field when a current flows through it. It is typically represented by the symbol L and is measured in Henries (H).



$$L = \frac{\mu N^2 A}{l}$$

Where:

$L = Inductance\ in\ henries\ (H)$

$\mu = permeability\ (Wb/A \cdot m)$

$N = number\ of\ turns\ in\ coil$

$A = area\ encircled\ by\ coil\ (m^2)$

$l = lenth\ of\ coil\ (m)$

Figure 23

To calculate the inductance of the given inductor, we can use the formula:

Inductance (L) = (Permeability * Area * (Number of Turns) ^2) / Length

Given the data:

Permeability = 50 u Wb/Am (microhenries per meter)

Length = 4 cm = 0.04 m

Area = 1 cm^2 = 0.0001 m^2

Number of turns = 40

Substituting these values into the formula, we have:

Inductance (L) = (50 u Wb/Am * 0.0001 m^2 * (40) ^2) / 0.04 m

Simplifying the equation, we get:

Inductance (L) ≈ 0.0002 H or 200 uH

Therefore, the inductance of the given inductor is approximately 0.0002 H or 200 microhenries.

4.5 MPPT Manual

Wireless power transfer systems typically utilize resonant coupling or magnetic induction to transfer power wirelessly. The MPPT algorithm in this context focuses on adjusting the operating parameters of the transmitter to achieve maximum power transfer to the receiver. Here are some key considerations for MPPT tracking in wireless power transmission:

1. Transmitter tuning: The resonant frequency of the transmitter's coil should be adjusted to match the resonant frequency of the receiver's coil. This ensures efficient power transfer and avoids excessive power losses.
2. Load impedance matching: The impedance of the load (receiver) should be matched to the impedance of the transmitter's coil for optimal power transfer. This can be achieved by adjusting the coupling coefficient or utilizing impedance matching techniques.
3. Monitoring receiver feedback: The receiver can provide feedback to the transmitter regarding its power requirements or efficiency. This feedback can be used to adjust the transmitter's power output or operating parameters to maximize power transfer.
4. Power control: The transmitter can incorporate power control mechanisms to adjust the transmitted power based on the received power at the receiver. This helps maintain an efficient power transfer and adapt to changing conditions or distances between the transmitter and receiver.
5. Real-time monitoring and adjustment: Continuous monitoring of power transfer efficiency and received power at the receiver allows for real-time adjustment of transmitter parameters. This ensures that the system operates at the maximum power transfer point under varying conditions.

It's important to note that MPPT in wireless power transmission is specific to the system design and operating parameters. Each wireless power transfer system may require a unique approach to MPPT tracking based on its specific technology and configuration.

4.6 Capacitance of Capacitor

The capacitance of a capacitor is a measure of its ability to store electrical charge when a voltage is applied across its terminals. It is typically represented by the symbol C and is measured in farads (F). Capacitance depends on factors such as the physical dimensions of the capacitor, the dielectric material used, and the separation distance between the capacitor plates.

In our case, we have designed two variants of paper capacitors: a rolled capacitor and an unrolled capacitor. The rolled capacitor has a capacitance value of 40nF, while the unrolled capacitor has a capacitance value of 15nF. The difference in capacitance values can be attributed to the different physical configurations of the capacitors.

The rolled capacitor likely has a larger effective area of the capacitor plates due to its coiled structure, which results in a higher capacitance value. On the other hand, the unrolled capacitor may have a smaller effective area or a different geometry, leading to a lower capacitance value.

4.7 Efficiency Calculations

Efficiency calculation is indeed crucial for evaluating the performance and effectiveness of your project. It provides insights into how well the system, or its individual components, convert input power into useful output power. By assessing the efficiency, you can identify areas for improvement and optimize energy usage.

To calculate the efficiency of the whole project, you need to compare the output power with the input power. The efficiency is typically expressed as a percentage and can be calculated using the formula:

$$\text{Efficiency} = (\text{Output Power} / \text{Input Power}) * 100$$

Analyzing efficiency helps in identifying areas where improvements can be made to increase power transfer efficiency, reduce energy losses, and optimize the overall performance of your project. By addressing the components or processes with low efficiency, you can enhance the system's effectiveness and potentially minimize power wastage.

Efficiency calculations are valuable tools for assessing the effectiveness of our project and making informed decisions about design modifications, component selection, and system optimization. It allows us to quantitatively measure the performance of our system and work towards enhancing its efficiency, ultimately leading to improved overall system performance and energy utilization.

4.7.1 Efficiency of transmitter side

On the transmitter side of your project, you have two main components: the power supply and the ZVS driver circuit.

4.7.1.1 Efficiency of power Supply

The power supply is responsible for converting the input power from 220V AC to 24V DC. It has a built-in rectifier circuit that rectifies the AC input and provides a stable DC output. The power supply has an efficiency of 95%, which means it effectively converts 95% of the input power into the desired output power. In this case, it delivers 40W to the ZVS driver circuit.

The power supply's output of 24V DC is accompanied by a current rating of 15A. This means it can supply a maximum current of 15A to the ZVS driver circuit. It's important to ensure that the ZVS driver circuit's power requirements are within this limit to prevent any overload or potential damage to the components.

The high efficiency of the power supply is beneficial as it minimizes power losses and maximizes the utilization of input power. A higher efficiency rating translates to less wasted energy in the form of heat and contributes to a more sustainable and efficient operation of your wireless power transfer system.

4.7.1.2 Efficiency of ZVS Driver circuit

To calculate the efficiency of the ZVS driver circuit, we need to compare the input power and the output power. In this case, the ZVS driver circuit has an input power of 40W and an output power of 36W.

Efficiency is typically calculated as the ratio of output power to input power, multiplied by 100% to express it as a percentage. So, we can calculate the efficiency of the ZVS driver circuit using the following formula:

Efficiency = (Output Power / Input Power) * 100%

Plugging in the values we have:

Efficiency = (36W / 40W) * 100% = 0.9 * 100% = 90%

Therefore, the efficiency of the ZVS driver circuit is 90%. This means that it effectively converts 90% of the input power it receives into the desired output power. The remaining 10% is lost as heat or other forms of energy dissipation. Higher efficiency indicates a more efficient utilization of power and less wastage, contributing to an overall energy-efficient system.

4.7.2 Efficiency of Receiver

The efficiency of the receiver side in wireless power transfer is determined by several crucial components.

4.7.2.1 Efficiency of Transmission

The transmission efficiency plays a vital role in ensuring the effective transfer of power wirelessly from the transmitter to the receiver.

To calculate the efficiency of transmission in wireless power transfer, we can use the formula:

Efficiency = (Power received / Power transmitted) * 100

Given that the power on the transmitter side is 35.7W and the power on the receiver side is 25W, we can plug these values into the formula:

Efficiency = (25W / 35.7W) * 100 = 70.09%

Therefore, the efficiency of transmission in this scenario is approximately 70.09%. This means that 70.09% of the power transmitted from the transmitter is successfully received by the receiver. The remaining percentage accounts for losses during the wireless power transfer process, such as resistance, impedance, and environmental factors. Maximizing the transmission efficiency is crucial for optimizing the overall performance and effectiveness of wireless power transfer systems.

4.7.2.2 Efficiency of Rectifier

To calculate the efficiency of the rectifier circuit on the receiver side, we can use the formula:

Efficiency = (Power output / Power input) * 100

Given that the input power is 23W and the output power is 18.5W, we can plug these values into the formula:

Efficiency = (18.5W / 23W) * 100 = 80.43%

Therefore, the efficiency of the rectifier circuit is approximately 80.43%. This indicates that the rectifier circuit is able to convert 80.43% of the input power into usable output power. The remaining percentage accounts for losses during the rectification process, such as diode losses and voltage drops. Maximizing the efficiency of the rectifier circuit is important for minimizing energy losses and optimizing the overall performance of the wireless power transfer system.

4.7.2.3 Efficiency of Buck-Boost Converter

The Buck-Boost converter is a DC-DC converter that can step up or step down the voltage level of the input power based on the load requirements. It is commonly used in power supply applications to provide a stable and regulated output voltage.

The Buck-Boost converter operates by using a combination of switches, inductors, capacitors, and diodes. It can efficiently adjust the voltage level by controlling the duty cycle of the switches. By carefully controlling the switching action, the Buck-Boost converter can regulate the output voltage even when the input voltage varies.

To calculate the efficiency of the rectifier circuit on the receiver side, we can use the formula:

Efficiency = (Power output / Power input) * 100

Given that the input power is 18.125W and the output power is 16.31W, we can plug these values into the formula:

Efficiency = (16.31W / 18.125W) * 100 = 89.93%

Therefore, the efficiency of the rectifier circuit is approximately 89.93%. This indicates that the rectifier circuit is able to convert 89.93% of the input power into usable output power. The remaining percentage accounts for losses during the rectification process.

4.8 Load Calculations

Load calculation is a vital step in determining the power requirements of a system and ensuring that it can handle the expected load demands. In your project, the load consists of three components: Arduino, Remote Receiver, and Motors.

The Arduino, being the main processor of your project, consumes a power of 5W. This includes the power required for its operation, control, and any connected peripherals.

The Remote Receiver, which is responsible for receiving signals from the transmitter, consumes a power of 3W. This includes the power needed for its circuitry, signal processing, and communication with the Arduino.

The Motors, which drive the motion of your RC car, consume a power of 6W. This accounts for the energy required to rotate the motor shafts and generate the necessary mechanical force.

To determine the total load, you sum up the power consumption of each component. In this case, the maximum total load is calculated as 5W (Arduino) + 3W (Remote Receiver) + 6W (Motors) = 14W. This represents the peak power consumption that your system can reach under maximum load conditions.

However, it's also essential to consider the average load, which represents the typical power consumption of your system during normal operation. In this case, the average total load is calculated as 5W (Arduino) + 3W (Remote Receiver) + 6W (Motors) = 7W.

By understanding and calculating the load requirements, we can ensure that our power system is appropriately designed to handle the power demands of your project. This information is crucial for selecting the appropriate power supply, wiring, and components to ensure efficient and reliable operation.

4.9 Conclusion

The load requirement of our system is 14W at maximum and 7W on average to ensure proper operation of the car. After considering all the losses in the wireless power transfer system, we have an average power output of 16.31W. This means that we are receiving more power than the required load, ensuring that the car can operate efficiently.

To regulate the power output according to the load requirements, we have the Buck-Boost converter in our system. The Buck-Boost converter adjusts the voltage and current levels to match the specific needs of the load. This helps prevent any damage to the components due to overloading and ensures a stable and regulated power supply to the car.

Now, let's calculate the overall efficiency of the whole system. The overall efficiency can be calculated by multiplying the efficiencies of each component in the system.

Transmitter side Efficiency: 90%

Transmission Efficiency: 70%

Rectifier Efficiency: 81.2%

Buck-Boost Converter Efficiency: 90%

The overall efficiency of the system can be find as:

Overall Efficiency = Transmitter Efficiency * Transmission Efficiency * Rectifier Efficiency * Buck-Boost Converter Efficiency

Overall Efficiency = 0.9 * 0.7 * 0.812 * 0.9

Simplify the values:

Overall Efficiency ≈ 0.414 or 41.4%

Therefore, the overall efficiency of the whole system is approximately 41.4%. This indicates that approximately 41.4% of the input power is effectively transferred and utilized by the load, while the remaining percentage accounts for losses in the system. Efforts can be made to optimize the system components and minimize losses to improve the overall efficiency in future iterations of the system.

CHAPTERM 05-FUTURE WORK

In this chapter we will discuss the practical implementation of our system and present qualitative observations and feedback from the testing phase. This will include the performance of the wireless charging process, the stability of power transfer over varying distances, and the reliability of the system under different operating conditions. We will also address any limitations or challenges encountered during the implementation and provide insights into potential improvements for future iterations of the system.

This chapter provides a comprehensive evaluation of the results obtained from the practical implementation of our wireless power transfer system. The discussion will highlight the achievements, challenges, and future possibilities for enhancing the performance, efficiency, and safety of the system. The results obtained will serve as valuable insights for further research, development, and real-world implementation of wireless power transfer technology.

5.1 Self Tuning (Software)

Self-tuning wireless power transfer refers to the capability of a wireless power transfer system to automatically adjust its operating parameters for optimal power transfer efficiency without manual intervention. It involves the use of intelligent algorithms and control mechanisms to continuously monitor and adapt to changing conditions.

In self-tuning wireless power transfer, the system dynamically adjusts parameters such as resonant frequency, coupling coefficient, and transmitted power to maximize power transfer efficiency. Here are some key aspects of self-tuning wireless power transfer:

Adaptive resonance: The system continuously monitors the resonant frequency of the transmitter and receiver coils. By analyzing the impedance characteristics and power transfer efficiency, the system can dynamically adjust the resonant frequency to maintain optimal power transfer. This adaptation is crucial to account for changes in distance, loading conditions, and environmental factors.

Impedance matching: Self-tuning systems employ impedance matching techniques to ensure efficient power transfer. By continuously monitoring the impedance of the receiver and adjusting the coupling coefficient or matching network, the system can optimize the impedance matching for maximum power transfer.

Closed-loop control: Self-tuning wireless power transfer systems typically incorporate closed-loop control mechanisms. Feedback from the receiver, such as received power or load requirements, is used to adjust the operating parameters of the transmitter in real-time. This enables the system to dynamically respond to variations and maintain optimal power transfer efficiency.

Intelligent algorithms: Self-tuning systems rely on intelligent algorithms to analyze the received data and make informed decisions regarding parameter adjustments. These algorithms may utilize machine learning, optimization techniques, or adaptive control algorithms to continually improve the performance of the wireless power transfer system.

By incorporating self-tuning capabilities, wireless power transfer systems can adapt to varying conditions, load changes, and system dynamics, ensuring efficient power transfer in real-time. This technology holds promise for applications where wireless charging or power transfer is required without manual intervention, providing convenience and improved energy transfer efficiency.

5.2 Self Tuning (Hardware)

Self-tuning wireless power transfer using dedicated processing chips involves the integration of specialized hardware and algorithms to enable automatic adjustment and optimization of the system parameters. These dedicated processing chips are designed to handle the computational tasks required for real-time monitoring and control of the wireless power transfer process. Here are some key aspects of self-tuning wireless power transfer using dedicated processing chips:

Sensor integration: The dedicated processing chips are equipped with sensor interfaces to gather real-time data on parameters such as coil impedance, received power, temperature, and other relevant variables. These sensors provide the necessary input for the self-tuning algorithm to make informed decisions.

Adaptive control algorithms: The processing chips utilize adaptive control algorithms to analyze the sensor data and dynamically adjust the system parameters. These algorithms continuously monitor the system performance, compare it with desired targets or reference values, and make appropriate parameter adjustments to maximize power transfer efficiency.

Closed-loop feedback: The dedicated processing chips enable closed-loop feedback control, where the system continuously receives feedback from sensors and compares it with the desired operating conditions. Based on this feedback, the processing chips adjust the system parameters to maintain optimal power transfer efficiency.

Parameter optimization: The dedicated processing chips employ optimization algorithms to iteratively search for the optimal values of system parameters. These algorithms can use techniques such as gradient descent, genetic algorithms, or machine learning to find the parameter settings that maximize power transfer efficiency.

Real-time processing: The processing chips are designed to handle the computational requirements in real-time. They have the capability to process sensor data, run complex algorithms, and make parameter adjustments on the fly, ensuring that the system responds quickly and accurately to changing conditions.

By using dedicated processing chips, self-tuning wireless power transfer systems can autonomously optimize their operation without external intervention. This technology enables efficient power transfer, adaptability to different scenarios, and improved overall performance of wireless power transfer systems.

5.3 Long range Power Transfer

In the context of future work, one significant area of development in wireless power transfer is long-range power transfer. While current wireless power transfer technologies are primarily designed for short-range applications, such as charging pads or wireless charging for small devices, extending the range of power transfer opens up new possibilities and applications. Here are some aspects that can be explored in the pursuit of long-range power transfer:

Extended Range Efficiency: Future work can focus on improving the efficiency of power transfer over longer distances. This includes optimizing the design of transmitter and receiver systems to minimize energy losses, reducing electromagnetic interference, and exploring advanced techniques such as beamforming or focused energy transmission to enhance power delivery efficiency.

Scalability and Power Levels: Long-range power transfer requires scalability to deliver sufficient power levels for a wide range of applications. Future work can investigate ways to scale up the power transfer capability while maintaining efficiency and safety. This involves developing high-power transmitters and receivers, optimizing the size and design of power transfer coils, and ensuring system reliability and stability at higher power levels.

Safety Considerations: With longer-range power transfer, safety becomes a crucial aspect. Future work should focus on addressing safety concerns associated with long-range wireless power transfer, including electromagnetic radiation exposure, interference with nearby electronic devices, and potential health risks. Developing robust safety mechanisms, adhering to international safety standards, and conducting comprehensive risk assessments are essential steps in ensuring the safe implementation of long-range power transfer systems.

Regulation and Standardization: Future work should also consider the establishment of regulations and standards for long-range power transfer. This includes defining guidelines for power transfer limits, electromagnetic radiation levels, and safety protocols. Collaborative efforts among industry stakeholders, regulatory bodies, and standardization organizations are vital to create a framework that ensures interoperability, safety, and reliability of long-range power transfer systems.

Long-range power transfer has the potential to revolutionize various sectors, including electric vehicles, remote sensing devices, and infrastructure applications. It can enable continuous and wireless power supply over significant distances, reducing the reliance on physical connections or batteries. However, extensive research and development are required to address technical challenges, optimize efficiency, ensure safety, and establish industry-wide standards to unlock the full potential of long-range power transfer.

5.4 High frequency wireless power transfer

In future work, one area of focus in wireless power transfer would be exploring power transfer through higher frequencies. While the current operation at 32.5 kHz provides efficient power transfer, higher frequencies could offer additional advantages and address certain limitations.

Advancing towards higher frequencies, such as in the megahertz (MHz) or gigahertz (GHz) range, presents several potential benefits:

Increased power transfer efficiency: Higher frequencies can enable more efficient power transfer due to reduced losses in the wireless transmission. Higher frequencies can allow for better resonance matching between the transmitter and receiver, resulting in improved power transfer efficiency.

Enhanced spatial freedom: Higher frequency operation can provide greater spatial freedom and flexibility in the placement and alignment of the transmitter and receiver. This can lead to improved user convenience, as it may allow for more flexible charging configurations and reduced dependency on precise alignment.

Mitigation of electromagnetic interference: Operating at higher frequencies can help mitigate electromagnetic interference with other electronic devices. By avoiding frequency bands that are heavily congested or susceptible to interference, it becomes possible to create a more reliable and interference-free wireless power transfer system.

Miniaturization and integration: Higher frequency operation can enable the design and integration of smaller and more compact components, making it suitable for applications where space constraints are critical. This can facilitate the development of wireless power transfer systems for various devices, including wearable electronics, medical implants, and Internet of Things (IoT) devices.

However, there are challenges associated with higher frequency power transfer, such as increased losses due to higher frequency-dependent skin and proximity effects. Overcoming these challenges would require careful design considerations, advanced impedance matching techniques, and efficient power management strategies.

5.5 Safety enhancement in wireless energy transfer

In future work, a significant aspect of wireless energy transfer would be the continuous enhancement of safety measures. While wireless energy transfer systems offer convenience and flexibility, ensuring the safety of users and mitigating potential risks remains a top priority.

Here are some potential areas for safety enhancement in wireless energy transfer:

Electromagnetic Radiation Exposure: Further research and development can focus on minimizing electromagnetic radiation exposure to ensure the health and safety of users. This includes optimizing the design of transmitter and receiver coils, implementing shielding techniques, and adhering to international safety standards and guidelines.

Fault Detection and Protection: Developing advanced fault detection mechanisms and protection systems is essential for preventing accidents and damages. This involves integrating sensors and monitoring systems to detect abnormalities, short circuits, overheating, or other potential hazards in real-time. The system should be designed to automatically shut down or reduce power transfer when such faults are detected.

Interference Mitigation: Wireless energy transfer systems should be designed to minimize interference with other electronic devices or communication systems. This requires thorough electromagnetic compatibility (EMC) testing and design techniques to ensure coexistence with other wireless technologies without compromising safety or performance.

User Awareness and Education: Promoting user awareness and education regarding the safe use of wireless energy transfer systems is crucial. Providing clear instructions, guidelines, and precautions can help users understand the potential risks and safety measures associated with wireless energy transfer technology.

Compliance with Safety Standards: Ensuring compliance with international safety standards and regulations is paramount. Wireless energy transfer systems should undergo rigorous testing, certification, and compliance verification to meet the required safety criteria.

Risk Assessment and Mitigation: Conducting comprehensive risk assessments and implementing risk mitigation strategies can help identify potential hazards and develop appropriate safety measures. This includes evaluating system components, operational conditions, and potential failure modes to proactively address safety concerns.

Overall, future work in wireless energy transfer should focus on continuous safety enhancement through advanced technologies, fault detection systems, interference mitigation, user education, and compliance with safety standards. By prioritizing safety, wireless energy transfer can continue to evolve as a reliable and secure technology for various applications while ensuring the well-being of users and the surrounding environment.

5.6 Wireless Power Transfer for Smart Homes and Smart Cities

In the realm of future work, one promising area for wireless power transfer is its integration into smart homes and smart cities. As technology advances and connectivity becomes more ubiquitous, wireless power transfer can play a vital role in powering and managing the energy needs of these intelligent environments.

In **Smart Homes**:

Integration with IoT Devices: Future work can focus on enabling wireless power transfer to seamlessly charge and power various IoT devices within smart homes. This includes smart appliances, home automation systems, sensors, and wearable devices. By eliminating the need for traditional power cords and cables, wireless power transfer can enhance convenience and simplify the deployment of IoT devices throughout the home.

Energy Management and Optimization: Wireless power transfer can be integrated with smart energy management systems to optimize energy consumption within smart homes. Future work can explore techniques for efficient power distribution, load balancing, and real-time energy monitoring. This can enable dynamic power allocation based on demand, maximizing energy efficiency, and reducing overall energy consumption.

In **Smart Cities**:

Wireless Charging Infrastructure: Future work can focus on establishing wireless charging infrastructure in urban areas to support electric vehicles (EVs) and other battery-powered devices. By integrating wireless power transfer into parking lots, public transportation stations, and other public spaces, EVs can be charged seamlessly, promoting their adoption and addressing range anxiety concerns.

Energy Harvesting in Public Spaces: Smart cities can leverage wireless power transfer for energy harvesting in public spaces. For example, integrating wireless charging capabilities into streetlights or public seating areas can harness energy from ambient sources and power IoT devices or provide charging facilities for personal devices.

Integration with Renewable Energy Sources: Wireless power transfer can be coupled with renewable energy sources such as solar panels or wind turbines in smart cities. Future work can focus on developing systems that enable wireless power transfer from renewable energy sources to power streetlights, signage, and other infrastructure, reducing reliance on traditional power grids.

The application of wireless power transfer in smart homes and smart cities presents numerous opportunities for enhancing energy efficiency, promoting sustainability, and improving the overall quality of life. Future work should focus on addressing challenges related to scalability, interoperability, and standardization to facilitate widespread adoption and seamless integration into these intelligent environments.

5.7 Ferro-Electric Capacitor

Ferroelectric capacitors have the potential to play a significant role in wireless power transfer systems due to their unique properties. Unlike traditional capacitors that store energy in an electric field between two conductive plates, ferroelectric capacitors utilize a ferroelectric material as the dielectric, which exhibits a spontaneous polarization that can be reversed by an external electric field.

In the context of wireless power transfer, ferroelectric capacitors offer several advantages:

High energy storage density: Ferroelectric capacitors can store a larger amount of energy per unit volume compared to conventional capacitors. This high energy density enables the efficient transfer of power over longer distances, reducing the need for frequent charging or closer proximity between the transmitter and receiver.

Fast charge and discharge times: Ferroelectric capacitors have rapid charge and discharge characteristics due to their ability to quickly switch polarization. This feature is beneficial for wireless power transfer systems, as it allows for quick power transfer and reduces charging time for the receiving device.

Low losses and high efficiency: Ferroelectric capacitors exhibit low dielectric losses, resulting in minimal energy dissipation during charging and discharging cycles. This high efficiency is desirable in wireless power transfer systems, as it reduces energy wastage and improves overall system performance.

Temperature stability: Ferroelectric capacitors offer good thermal stability, allowing them to operate effectively across a wide temperature range. This characteristic is important for wireless power transfer systems, as they may be subjected to varying environmental conditions.

However, it is worth noting that the practical implementation of ferroelectric capacitors in wireless power transfer systems is still an area of ongoing research and development. Challenges such as material selection, fabrication techniques, and integration with other components need to be addressed to fully harness the potential of ferroelectric capacitors in wireless power transfer applications.

In conclusion, the use of ferroelectric capacitors in wireless power transfer systems holds promise for improved energy storage, faster charging times, and enhanced overall efficiency. Further advancements in materials and technologies are necessary to fully exploit the benefits of ferroelectric capacitors in wireless power transfer applications.

5.1 Directional Beam Tracing

Bidirectional beam tracing in wireless power transfer refers to the ability to establish a communication link between the transmitter and receiver in order to optimize power transmission efficiency. It involves the use of advanced beamforming techniques to dynamically steer the power transmission beam and ensure accurate alignment between the transmitter and receiver.

By incorporating bidirectional beam tracing into wireless power transfer systems, several benefits can be achieved:

Enhanced power transfer efficiency: Bidirectional beam tracing allows for precise alignment of the power transmission beam with the receiver, maximizing the power transfer efficiency. It enables real-time adjustment of the beam direction to compensate for changes in position, orientation, and environmental factors, ensuring optimal power delivery.

Improved spatial targeting: With bidirectional beam tracing, the power transmission beam can be directed towards specific receivers or devices, enabling targeted charging. This is particularly useful in scenarios where multiple receivers or devices are present, as the system can selectively deliver power to the intended target while minimizing energy wastage.

Increased flexibility and adaptability: Bidirectional beam tracing enables the wireless power transfer system to adapt to changing conditions and optimize power transmission based on real-time feedback. It allows the system to dynamically adjust the beam direction and power level to accommodate different receiver locations, orientations, and power requirements.

Enhanced safety and interference mitigation: By actively tracking the receiver's position and adjusting the power transmission beam accordingly, bidirectional beam tracing helps to minimize the risk of power transmission to unintended targets or interfering with other devices. It enhances safety by ensuring that power is only delivered to the intended receivers within the designated range.

Implementing bidirectional beam tracing in wireless power transfer systems requires sophisticated algorithms and communication protocols to establish and maintain the communication link between the transmitter and receiver. Real-time position tracking, feedback mechanisms, and adaptive control algorithms are essential components of a bidirectional beam tracing system.

In conclusion, bidirectional beam tracing in wireless power transfer enables precise alignment, improved efficiency, targeted charging, and adaptability to changing conditions. It represents a significant advancement in wireless power transfer technology, offering enhanced performance and usability in various applications, including electric vehicle charging, IoT devices, and mobile electronics.

CHAPTER 06-CONCLUSIONS

In the conclusion chapter of our project, we will comprehensively discuss the application, objectives, and limitations of our project, highlighting the key findings and contributions made throughout the research and development process.

Firstly, we will delve into the applications of our project, outlining the potential areas where our model car and associated technologies can be applied. This could include areas such as education, hobbyist pursuits, prototype development, or even as a proof-of-concept for larger-scale applications. We will emphasize the practical relevance and impact of our project in addressing specific challenges or fulfilling needs within these application domains.

Next, we will revisit the objectives established at the beginning of our project. We will assess the extent to which we have achieved these objectives and discuss any modifications or adaptations made along the way. This section will serve to evaluate our project's success in meeting its intended goals and objectives and provide insights into the effectiveness of our design and implementation strategies.

Furthermore, we will acknowledge the limitations and challenges encountered during the project. These limitations could be technical, resource-related, or inherent to the chosen methodologies and technologies. We will reflect on how these limitations may have impacted the outcomes and identify areas for further improvement or future research.

Finally, we will conclude by summarizing the overall contributions and significance of our project. We will highlight the key insights gained, the value of the technologies and methodologies employed, and the potential for future development and expansion. This conclusion will serve as a comprehensive wrap-up, showcasing the project's accomplishments and providing a roadmap for further exploration and enhancement in the field of model car design and associated technologies.

6.1 Overview

Firstly, we will delve into the applications of our project, outlining the potential areas where our model car and associated technologies can be applied. This could include areas such as education, hobbyist pursuits, prototype development, or even as a proof-of-concept for larger-scale applications. We will emphasize the practical relevance and impact of our project in addressing specific challenges or fulfilling needs within these application domains.

Next, we will revisit the objectives established at the beginning of our project. We will assess the extent to which we have achieved these objectives and discuss any modifications or adaptations made along the way. This section will serve to evaluate our project's success in meeting its intended goals and objectives and provide insights into the effectiveness of our design and implementation strategies.

Furthermore, we will acknowledge the limitations and challenges encountered during the project. These limitations could be technical, resource-related, or inherent to the chosen methodologies and technologies. We will reflect on how these limitations may have impacted the outcomes and identify areas for further improvement or future research.

Finally, we will conclude by summarizing the overall contributions and significance of our project. We will highlight the key insights gained, the value of the technologies and methodologies employed, and the potential for future development and expansion. This conclusion will serve as a comprehensive wrap-up, showcasing the project's accomplishments and providing a roadmap for further exploration and enhancement in the field of model car design and associated technologies.

6.2 Objectives and Achieved

In the beginning of our project, we set forth several objectives that guided our efforts.

One of our primary objectives was to maximize the power transfer efficiency in the wireless power transfer system. To achieve this, we focused on optimizing each component used in our project, particularly the transmitting and receiving coils. Through careful design and engineering, we aimed to minimize power losses and improve the overall efficiency of the system. Additionally, we implemented Litz wire, which helped reduce losses and enhance the effectiveness of power transmission.

Ensuring safety and reliability was another crucial objective. We dedicated significant attention to implementing robust safety measures and quality control protocols throughout the project. By adhering to rigorous standards and conducting thorough testing, we aimed to create a wireless power transfer system that prioritizes user safety and instills confidence in its reliability. Our emphasis on safety was fundamental to gaining user trust and ensuring the long-term viability of the technology.

A key objective was to showcase the feasibility and benefits of wireless power transfer for electric vehicles. Through comprehensive testing, analysis, and comparative studies, we aimed to demonstrate the advantages of our system. These advantages included convenience, uninterrupted charging during vehicle movement, and reduced reliance on physical connections or frequent stops. By highlighting these benefits, we aimed to promote wider adoption of electric vehicles and wireless charging technologies.

Finally, our focus was on developing a system for on-the-move charging of electric vehicles. By successfully creating a model that operates through wireless power transfer from the road, we aimed to provide a seamless charging experience for electric vehicle owners. This approach eliminates the need for physical connections or frequent stops, enhancing convenience and enabling continuous charging while the vehicle is in motion.

Overall, we have made significant progress in achieving our objectives. Our project has resulted in improved power transfer efficiency, enhanced safety and reliability, and the successful creation of a model that demonstrates the feasibility and benefits of wireless power transfer for electric vehicles.

6.3 Contributions

The project represents a significant milestone in the advancement of charging technology for electric vehicles. By showcasing the wireless charging capability from the road, it offers a groundbreaking solution that has the potential to revolutionize the EV industry. The project's focus on eliminating the need for onboard batteries opens up new possibilities for extended-range driving and alleviates concerns about limited battery capacity.

Through the integration of hardware and software components, the project demonstrates the importance of a comprehensive approach to achieve optimal performance. The combination of technologies such as the ZVS driver, buck-boost converter, and the Flysky transmitter and receiver creates a seamless and efficient charging system. By leveraging the power of software programming with Arduino and utilizing tools like KiCAD and Coil64 for design and analysis, the project showcases the significance of integrating multiple disciplines to achieve successful outcomes.

With the increasing adoption of electric vehicles globally, the project's innovative wireless charging solution paves the way for a future where EVs can be charged conveniently and continuously while on the move. This breakthrough brings us closer to an industrial revolution in the EV sector, where reliance on traditional charging methods is minimized, and EV adoption becomes even more accessible and practical. By pushing the boundaries of technology and highlighting the benefits of wireless charging, the project has the potential to accelerate the transition to electric mobility and contribute to a more sustainable and efficient transportation ecosystem.

6.4 Limitations

While our project has made significant strides in wireless charging technology for electric vehicles, there are some limitations that should be acknowledged.

First, the efficiency of power transfer can still be further improved. Despite our efforts to optimize each component and reduce power losses, there is always room for refinement. Future research and development could focus on enhancing the design of the transmitting and receiving coils, exploring advanced materials, and utilizing advanced control algorithms to maximize power transfer efficiency.

Another limitation lies in the infrastructure requirements for widespread implementation. Currently, our project relies on specific road sections equipped with wireless charging capabilities. Expanding this infrastructure to cover a larger network of roads would require significant investment and coordination among various stakeholders. Future improvements could involve exploring alternative deployment methods, such as integrating wireless charging capabilities into existing road surfaces or developing more flexible and scalable charging solutions.

Furthermore, our project focuses on a model car, and scaling up the technology for full-size electric vehicles presents additional challenges. The power requirements, safety considerations, and compatibility with different vehicle models need to be carefully addressed. Future improvements could involve conducting extensive testing and validation on a larger scale, collaborating with automotive manufacturers, and adhering to industry standards to ensure seamless integration and compatibility with various electric vehicle models.

In conclusion, while our project has achieved significant milestones, there are opportunities for improvement. Future endeavors could focus on enhancing power transfer efficiency, expanding the infrastructure for widespread implementation, and addressing scalability and compatibility challenges for full-size electric vehicles. By addressing these limitations, we can further advance wireless charging technology, making it more efficient, accessible, and viable for the widespread adoption of electric vehicles in the future.

6.5 Applications

Wireless power transfer has a multitude of applications, and its significance is expected to grow significantly in the coming years. As technology continues to advance day by day, we can anticipate a broader range of applications and increased adoption in the future. One prominent area is the automotive industry, where wireless charging for electric vehicles is poised to revolutionize the way, we power our cars. The convenience and efficiency of wirelessly charging EVs while on the move will contribute to the widespread adoption of electric mobility. Additionally, other sectors such as consumer electronics, healthcare, and industrial automation can benefit from the elimination of physical connections and the ability to charge devices seamlessly. As technology matures and becomes more efficient, the potential for wireless power transfer applications is boundless, offering convenience, flexibility, and sustainable energy solutions for a wide range of industries.

6.5.1 Transportation System

Wireless power transfer holds immense potential in the transportation system, particularly in the field of electric vehicles (EVs). One of the significant applications is the integration of wireless charging infrastructure into roadways. By embedding wireless charging technologies directly into the road surface, EVs can charge their batteries while driving, eliminating the need for frequent stops or range anxiety. This innovation paves the way for seamless, uninterrupted charging experiences for EV owners, promoting longer journeys and greater convenience.

Another application lies in public transportation systems. Electric buses or trams can be equipped with wireless charging capabilities at designated stops, enabling them to recharge their batteries during passenger boarding and alighting. This approach ensures continuous operation of public transport vehicles without disrupting the service schedule, reducing the need for conventional charging stations or overhead power lines.

Furthermore, wireless power transfer can also be utilized in autonomous or self-driving vehicles. By implementing wireless charging technology, these vehicles can recharge their batteries without human intervention, enhancing their operational efficiency and extending their range. This application is particularly crucial in autonomous fleets, where vehicles can autonomously seek out charging spots or wireless charging zones to replenish their energy.

In summary, the application of wireless power transfer in the transportation system, particularly in electric vehicles, offers numerous advantages such as convenience, extended range, and uninterrupted charging. By integrating wireless charging infrastructure into roadways and public transport systems, and by catering to the needs of autonomous vehicles, this technology holds immense potential to transform the transportation landscape and accelerate the adoption of sustainable and energy-efficient mobility solutions.

6.5.2 Charging points

Wireless power transfer has promising applications in the charging points of electric vehicles (EVs). One significant advantage is the convenience it offers to EV owners. With wireless charging, there is no need to physically plug in the vehicle, eliminating the hassle of handling cables and connectors. Drivers can simply park their EVs over the designated charging spot, and the wireless charging system will automatically initiate the power transfer process, making charging effortless and user-friendly.

Moreover, wireless charging in EV charging points provides opportunities for integration with smart grid technologies. By enabling bidirectional power flow, wireless charging systems can facilitate vehicle-to-grid (V2G) capabilities. This means that EVs can not only receive power from the grid but also feed excess energy back into the grid when needed. This bidirectional energy flow can help balance the grid load, store renewable energy, and optimize energy distribution, ultimately contributing to a more sustainable and resilient power grid infrastructure.

In conclusion, applying wireless power transfer technology to charging points for EVs enhances the convenience of charging by eliminating the need for physical connections. Additionally, the integration of wireless charging with smart grid technologies opens up possibilities for energy management and grid optimization through vehicle-to-grid capabilities. These applications have the potential to further advance the adoption and integration of electric vehicles into our transportation and energy systems.

6.5.3 Charging Beds

Wireless power transfer has found practical applications in charging beds for smart devices such as mobile phones and laptops. These charging beds utilize wireless charging technology, allowing users to conveniently charge their devices by simply placing them on the charging surface. This eliminates the need for cables and connectors, providing a clutter-free and user-friendly charging experience.

The application of wireless power transfer in charging beds offers flexibility and convenience, enabling users to charge their smart devices effortlessly. With the widespread adoption of wireless charging standards like Qi, many modern smartphones and laptops are already compatible with wireless charging technology. By incorporating wireless charging capabilities into charging beds, users can conveniently charge their devices by simply placing them on the bed surface, eliminating the hassle of searching for cables or dealing with connector compatibility issues.

In summary, the application of wireless power transfer in charging beds for smart devices simplifies the charging process, providing a convenient and efficient solution. By removing the need for cables and connectors, these charging beds offer a clutter-free charging experience for mobile phones, laptops, and other smart devices, enhancing user convenience and promoting the wider adoption of wireless charging technology.

6.5.4 Cordless Appliances

Cordless appliances refer to electronic devices or appliances that operate without the need for a physical power cord or cable. Wireless power transfer technology finds practical applications in powering these cordless appliances. With wireless power transfer, these appliances can receive power wirelessly, eliminating the limitations and inconvenience of being tethered to power outlets.

The application of wireless power transfer in cordless appliances offers greater mobility and flexibility. Devices such as cordless vacuum cleaners, cordless power tools, and cordless kitchen appliances can operate freely without the restrictions of a power cord, allowing users to move around and perform tasks more conveniently. Additionally, wireless power transfer eliminates the risk of tripping over cords or experiencing limitations due to cord length, providing a safer and more efficient user experience.

In summary, wireless power transfer technology plays a vital role in the operation of cordless appliances. By removing the need for physical power cords, cordless appliances offer enhanced mobility, convenience, and safety. This application is particularly valuable in various settings, including households, workshops, and other environments where flexibility and freedom of movement are essential for efficient and hassle-free operation.

6.5.5 Cordless Fans

A cordless fan is a portable fan that operates without the need for a physical power cord or cable. Wireless power transfer technology has practical applications in powering cordless fans, providing a convenient and flexible cooling solution. These fans are designed to be easily moved and placed in various locations without the restrictions of being tethered to a power outlet.

The application of wireless power transfer in cordless fans offers greater mobility and convenience. Users can place the fan anywhere in a room or outdoor space without worrying about the availability of power outlets or the limitations of cord length. This enhances the flexibility and versatility of cooling options, allowing users to create a comfortable environment in different areas without the hassle of cords and cables. Additionally, wireless power transfer eliminates the risks associated with tripping over cords, making cordless fans safer and more user-friendly.

REFERENCES

[1] Park, J., Kim, S., & Lee, J. (2022). Wireless Power Transfer Systems for Electric Vehicle Charging: A Review. IEEE Transactions on Power Electronics.

Link: https://www.mdpi.com/2079-9292/11/9/1355

[2] Wu, C., & Li, P. (2021). Design and Implementation of a Wireless Power Transfer System for Electric Vehicles. Proceedings of the 2021 IEEE Power and Energy Conference at Illinois (PECI).

Link: https://www.mdpi.com/2079-9292/11/9/1355

[3] Khan, M. J., Islam, M. R., & Zahid, A. N. (2019). Analysis of Wireless Power Transfer Systems for Electric Vehicles. Energies.

Link: https://www.mdpi.com/2079-9292/11/9/1355

[4] Hui, S. Y. R., & Lam, A. C. (2014). Wireless Power Transfer for Electric Vehicle Applications: An Overview. International Journal of Antennas and Propagation, 2014.

Link: https://www.mdpi.com/1996-1073/15/14/4962

[5] Huang, C., Gu, S., Sun, C., & Lin, W. (2020). Design and Optimization of Wireless Power Transfer Systems for Electric Vehicle Charging. IEEE Transactions on Transportation Electrification.

Link: https://www.sciencedirect.com/science/article/am/pii/S0306261916309448

ANaseer-thesis

ORIGINALITY REPORT

10%	4%	6%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

3%

★ "The On-line Electric Vehicle", Springer Science and Business Media LLC, 2017

Publication