EEN1010 Report
Converter for Wireless charging of drones

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ABSTRACT

The limitations of current drone designs are primarily related to their power and flight time. The need for recharging and the dependence on human involvement during charging significantly limit their autonomy. To overcome these limitations, the use of wireless chargers for drones is proposed. Wireless charging would allow for faster charging times, the ability to use the device while charging, and the removal of heavy batteries, thus reducing weight. Additionally, wireless charging offers adjustable charging alignment, secure connections, and terrain resistance, which are all advantages for drone usage.

CONTENTS

1) INTRODUCTION
   a) Dual Active Bridge Converter
   b) Components
   c) Pulse Generator
   d) Mosfet
   e) Mutual Inductance
   f) Voltage Measurement & Display

2) PULSE GENERATOR

3) SERIES -SERIES COUPLING
   a) Different Methods of Wireless Charging
   b) Series - series resonance inductive coupling
   c) Calculations

4) CONVERTER FOR WIRELESS CHARGING OF DRONE
   a) Requirements
   b) Circuit designing

5) TEST RESULTS

6) CONCLUSION

7) REFERENCES

INTRODUCTION

Dual Active Bridge Converter

A dual active bridge converter is a kind of DC-DC converter that transforms a high-voltage DC input into a lower-voltage DC output using two active bridges.

Components

A dual active bridge converter utilizes the following components:

1) Pulse Generator
2) Mosfet
3) Mutual Inductance

4) Voltage Measurement & Display

Pulse Generator

A pulse generator is an electronic device used to generate electrical pulses of varying frequencies and shapes. These pulses are used in a variety of applications, including in testing electronic circuits, controlling motors, and driving LEDs.

Image Source: https://www.indiamart.com/proddetail/pulse-generator-20-mhz-pg-20-17927502948.html

Mosfet

A MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) is a type of transistor used in electronic circuits to control the flow of current. It is a three-terminal device that works on the principle of a field effect, where an electric field applied to a semiconducting material controls the flow of current through the device.MOSFETs are widely used in electronics due to their high input impedance, low output impedance, and high switching speed. They can be used in a variety of applications, including amplifiers, switches, and power regulators.

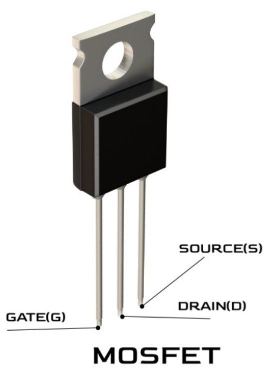
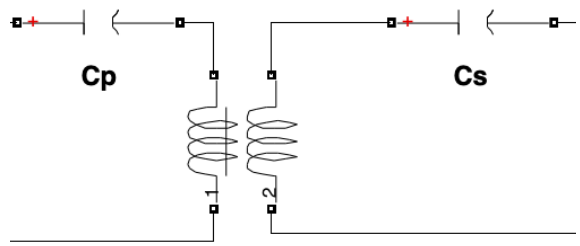


Image Source: https://www.lesics.com/how-does-a-mosfet-work.html

Mutual Inductance

The mutual inductance coupling in RDAB converters refers to the use of two resonant tanks, each with its own inductor and capacitor, coupled by a shared inductor. The shared inductor, also known as the transformer, provides galvanic isolation between the input and output of the converter while also facilitating energy transfer between the two resonant tanks.Mutual inductance coupling is commonly used in RDAB converters to achieve high efficiency power conversion with a wide input voltage range.



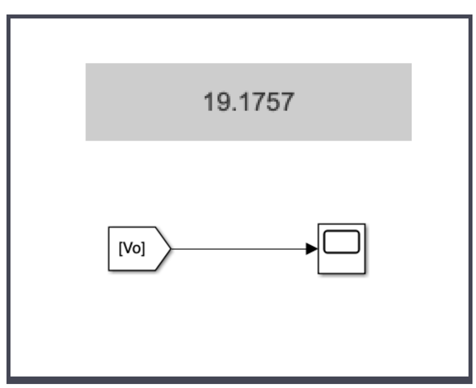
Voltage Measurement & Display

Voltage measurement and display can be done using various blocks and scopes.

Voltage measurement block: Voltage Measurement block can be used to measure voltage in a circuit.

Scope block: The "Scope" block in Simulink can be used to display voltage over time. This block can be connected to a voltage measurement block or other signals in the model to display the voltage waveform in real-time.

Display block: Simulink has a "Display" block that can be used to display the voltage value in a digital format.

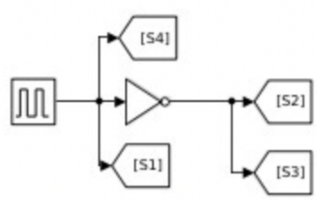


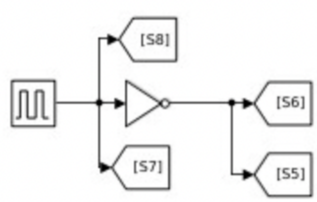
PULSE GENERATOR

The pulse generator used for a resonant dual active bridge converter typically involves a resonant gate drive circuit, which generates the pulse signals at the resonant frequency of the converter.

The resonant gate drive circuit includes a resonant tank circuit consisting of an inductor and a capacitor, which is driven by a gate driver circuit. The gate driver circuit provides the necessary voltage and current to switch the MOSFETs in the converter on and off.

With careful designing and tuning, the resonant circuit operates at the desired frequency and provides the necessary voltage and current to switch the MOSFETs in the converter efficiently.





SERIES -SERIES COUPLING

Different Methods of Wireless Charging

1. Inductive coupling

Inductive coupling is a wireless charging method that uses an electromagnetic field to transfer energy between two objects. It works by using a coil of wire in the charging pad to generate a magnetic field, which is picked up by a coil of wire in the device being charged, converting it back into electrical energy to charge the device's battery.

2. Capacitive coupling

Capacitive coupling is a wireless charging method that uses an electric field to transfer energy between two objects. It works by using two parallel plates, one in the charging pad and one in the device being charged, which creates an electric field that charges the device's battery.

3. Electrodynamic Wireless Power Transfer

Electrodynamic wireless power transfer is a wireless charging method that uses magnetic fields to transfer energy between two objects. It works by using an oscillating magnetic field to induce an electrical current in a receiving coil, which can be used to charge a device's battery.

4. Magneto-dynamic coupling

Magneto-dynamic coupling is a wireless power transfer method that uses magnetostrictive materials to convert a magnetic field into mechanical vibrations, which are then converted into electrical energy to charge a device's battery. This method can be used over longer distances than inductive coupling, but requires specialized materials and is less efficient.

5. Zenneck Wave Transmission

Zenneck wave transmission is a method of wireless communication that uses a specific type of electromagnetic wave, called a surface wave, to transmit signals over long distances along the surface of the Earth or sea. It is named after German physicist Jonathan Zenneck, who first proposed the concept in the early 1900s.

Series - series resonance inductive coupling

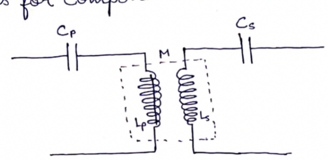
Series-series resonance inductive coupling is a method of wireless power transfer that uses two inductive coils, one in the transmitter and one in the receiver, that are tuned to the same resonant frequency. The coils are connected in series with capacitors, forming an LC circuit that resonates at the desired frequency.

When the transmitter coil is driven with an AC current at the resonant frequency, it generates a magnetic field that induces an AC voltage in the receiver coil. The receiver coil is also connected to a rectifier and filter circuit, which converts the AC voltage into a DC voltage that can be used to charge a battery or power a device.

This method of wireless power transfer has some advantages over other methods, including higher efficiency, longer range, and reduced electromagnetic interference. However, it requires precise tuning of the resonant frequency and can be sensitive to changes in the distance between the coils.

Calculations

Calculations for components :



Assuming the required values for dual active bridge convertor,

Input dc voltage, $V_{dc} = 48\,V$

Required output voltage, $V_o = 20\,V$

Output power, $P_o = 48\,W$

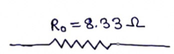
Resonant frequency, $f_r = 50\,kHz$

Quality factor, $Q = 1.75$

Coupling coefficient, $k = 0.7$

- Output Resistance

$$R_o = \frac{V_o^2}{P_o} = \frac{20^2}{48} = 8.33\,\Omega$$



$$\boxed{R_o = 8.33\,\Omega}$$

- Output current

$$I_o = \frac{P_o}{V_o} = \frac{48}{20} = 2.4\,A$$

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For the secondary side,

Secondary inductance is given by

$L_s = 45.22\,\mu H$

$$L_s = \frac{Q R_o}{\omega_r}$$
$$= \frac{1.75 \times 8.33}{2 \times \pi \times 50 \times 10^3}$$
$$= 4.522 \times 10^{-5}\ H$$
$$\boxed{L_s = 45.22\ \mu H}$$

Secondary conductance,

$C_s = 0.192\,\mu F$

$$C_s = \frac{1}{\omega_r^2 L_s}$$
$$= \frac{1}{(2 \times \pi \times 50 \times 10^3)^2 \times 4.522 \times 10^{-5}}$$
$$= 1.92 \times 10^{-7}\ F$$
$$\boxed{C_s = 0.192\ \mu F}$$

- Mutual inductance

$$M = \frac{8 \cdot V_{dc} \cdot V_o}{\pi^2 \omega_r \cdot P_o}$$
$$= \frac{8 \times 48 \times 20}{\pi^2 \times (2 \times \pi \times 50 \times 10^3) \times 48}$$
$$= 5.04 \times 10^{-5}\ H$$
$$\boxed{M = 50.4\ \mu H}$$

For the primary side,

$L_p = 113.3\,\mu H$

We know, $M = K\sqrt{L_s L_p}$

$$M^2 = k^2 L_s L_p$$

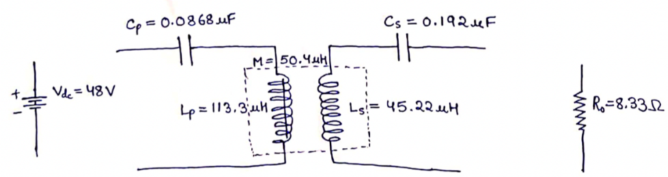
Primary inductance is given by

$$L_p = \frac{M^2}{k^2 L_s}$$
$$= \frac{(5.04 \times 10^{-5})^2}{(0.7)^2 \times 4.522 \times 10^{-5}}$$
$$= 1.133 \times 10^{-4}\ H$$
$$\boxed{L_p = 113.3\ \mu H}$$

Primary conductance,

$C_p = 0.0868\,\mu F$

$$C_p = \frac{1}{\omega_r^2 L_p}$$
$$= \frac{1}{(2 \times \pi \times 50 \times 10^3)^2 \times 1.133 \times 10^{-4}}$$
$$= 8.68 \times 10^{-8}\ F$$
$$\boxed{C_p = 0.0868\ \mu F}$$



Circuit Diagram

CONVERTER FOR WIRELESS CHARGING OF DRONE

Requirements

Parameters	**Value**
Input DC voltage	48 volts
Required output voltage	20 volts
Required Output power	48 W
Resonant frequency	50 KHz
Quality factor	1.75
Coupling coefficient	0.7

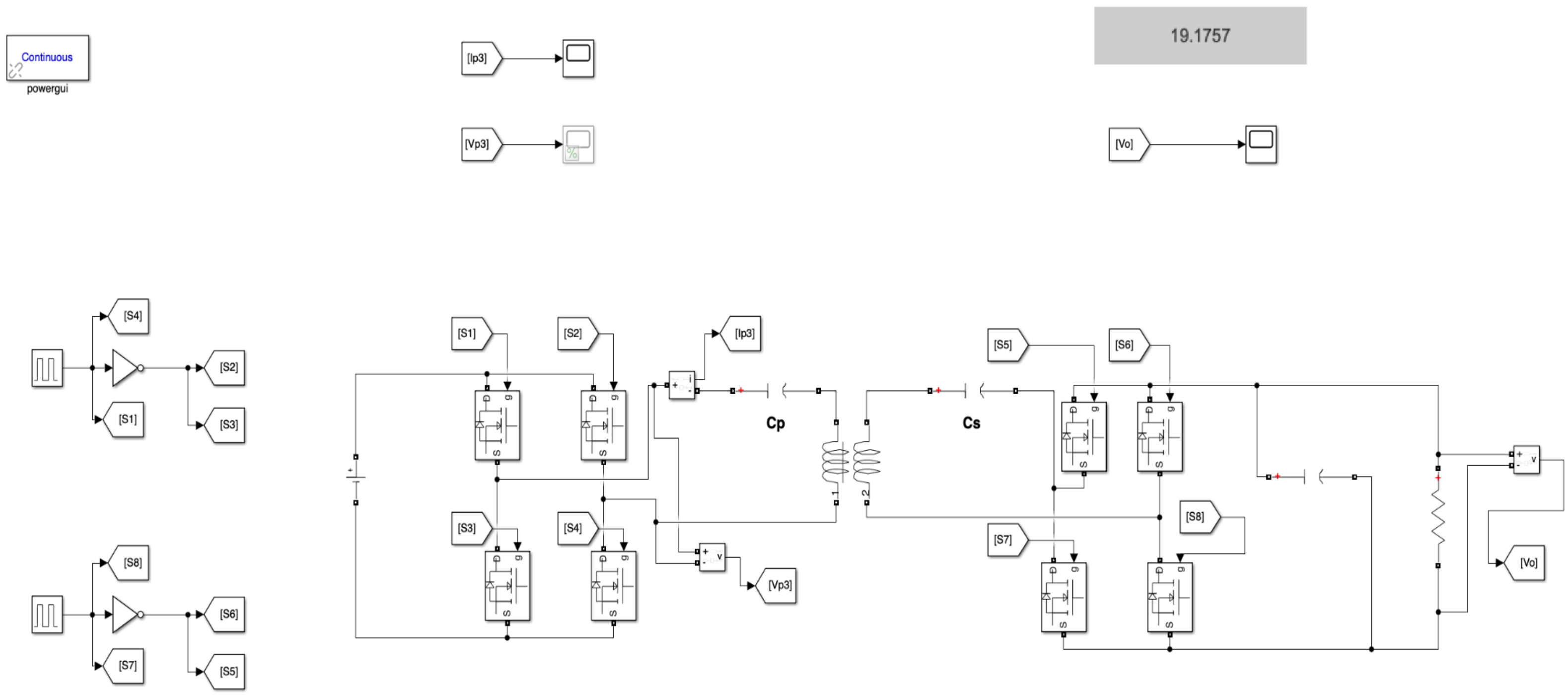
Circuit designing

We have defined the specifications of the dual active bridge converter, including input voltage, output voltage, output power, and switching frequency. These specifications will determine the required component values and overall performance of the converter.

Then we calculated the values of the components based on the specifications and the desired performance. This involves using equations and calculations to determine the appropriate component values for the specific design.

To build the circuit ,we have used Simulink software in Matlab to model the dual active bridge converter with mutual inductance in series-series coupling. .First of all , we have added PowerGUI block.PowerGUI is a graphical user interface for Simulink that allows users to model and simulate power systems. It provides a range of pre-built blocks and models for power electronics, electric drives, and renewable energy systems, and allows us to customize and create our own models as well.

Having entered the values of parameters, we run the simulation and analyze the results. This can include observing the voltage waveforms and the efficiency of the converter. The simulation results will provide insight into the performance of the converter and identify any potential issues or areas for improvement.

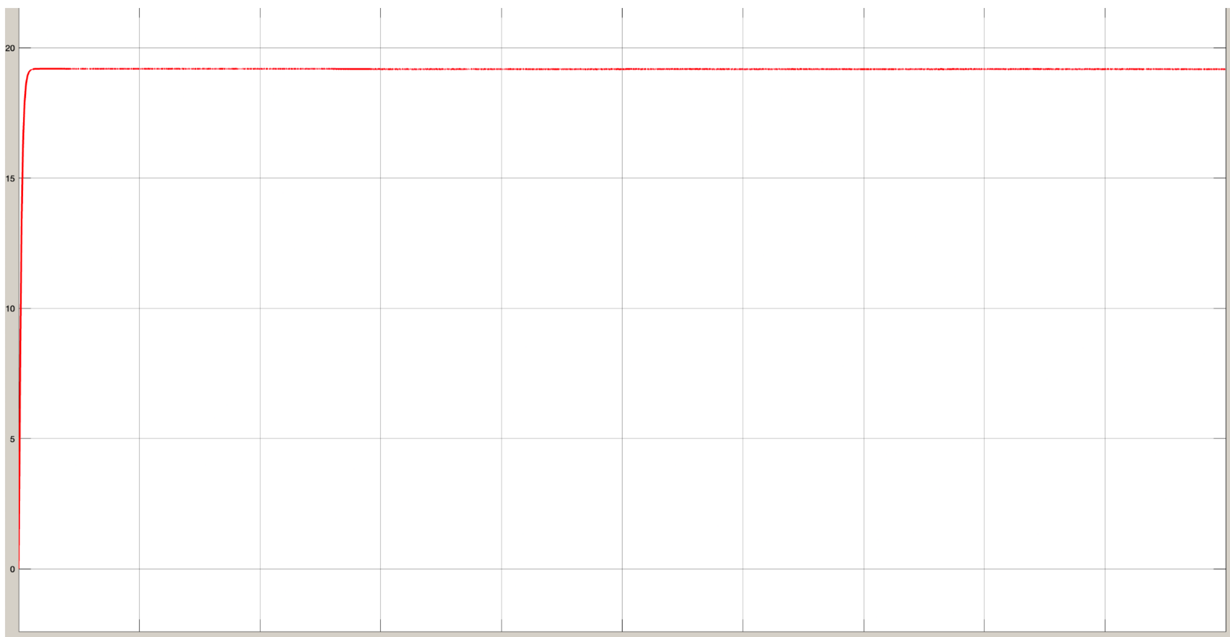


Circuit of Resonance DAB converter in Simulink

The RDAB converter uses a resonant tank in the DC-DC stage to achieve soft switching and reduce switching losses. The resonant tank helps to reduce the voltage and current stress on the switches, thus improving the overall efficiency of the converter.

TEST RESULT

Using the circuit made in Simulink, we have measured the voltage across the load resistor (having resistance as 8.33 Ω) which comes out to be 19.1757 V, close to the desired output value with an error of 4.12 %.The use of resonant components reduces the stress on the switching devices, leading to improved reliability and longer lifespan.



Graph of Output Voltage vs time

CONCLUSION

In this project we analyzed the usefulness of Resonant Dual Active Bridge Converter. We aimed at building a wireless charger and were successful in doing so with an output voltage of 19.1757 V.

The converter, designed to efficiently transfer power wirelessly to the drone's battery, has demonstrated a close match between the obtained output voltage (19.1757 V) and the desired output voltage (20 V). This indicates that the converter is effective in transferring power to the drone, providing a more convenient and practical solution for its power needs.

The converter can operate over a range of distances, which is particularly useful for charging drones in flight or inaccessible areas. Furthermore, the resonant nature of the converter means that it is less sensitive to changes in distance, allowing for a more reliable charging process.

Overall, the successful design and simulation of the resonant dual active bridge converter is a significant step forward in the development of wireless charging technology for drones. Further research and development in this area will undoubtedly lead to more advanced and efficient wireless charging solutions.

REFERENCES

1) https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6165867

2) https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7309830

3) https://www.ti.com/lit/ug/tidueg2c/tidueg2c.pdf?ts=1682187635798&ref_url=https%253A%252F%252F www.google.com%252F

4) https://www.tutorialspoint.com/power_electronics/power_electronics_types_of_inverters.htm

5) https://www.youtube.com/watch?v=A78yP8oApqk (power electronics)

6) https://theses.lib.polyu.edu.hk/handle/200/9798