Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ELECTRICAL ENGINEERING
DEPARTMENT OF ENERGY AND POWER ELECTRONICS

Project (MSET695J) on,

Wireless Charging for Laptop Applications

by

Vallabh Bhat ***Reg No: 24MPE0015***

Pritee Girase ***Reg No: 24MPE0017***

Vijayakrishna ***Reg No: 24MPE0018***

Guide

Dr. Arun N

CONTENTS

- Introduction
- Objectives
- Literature Review
- Summary of Literature Review
- Block Diagram
- Overview of Work
- Work Done So Far
- Conclusion
- Challenges and Modifications
- References

INTRODUCTION

- ✓ With the growing demand for power solutions, wireless charging for laptops is emerging as a game-changing technology. Traditional wired charging limits mobility and durability.
- ✓ The wireless charging market is projected to reach $25 billion by 2030, with a CAGR of 24%.
- ✓ Laptop adoption of wireless charging is still in early stages, with companies like Dell and Lenovo exploring built-in solutions.
- ✓ Qi2 standard, backed by the Wireless Power Consortium (WPC), is driving standardization for laptops and other devices. Which demands power transfer efficiency of around 90-95%.

INTRODUCTION

Challenges & Solutions

- ✓ *Power Delivery Limitations:* Currently, there are no wireless chargers available for laptops in the market. Existing wired chargers provide varying power levels roughly around 30-100W. Solution: Optimized coil design.
- ✓ *Distance Constraints:* Most systems are expected to work within 5-10 cm. Solution: Resonant coupling & active alignment technologies.
- ✓ *Heat & Efficiency Losses:* Power transfer can generate excess heat. Solution: Adaptive frequency tuning & advanced cooling techniques.

OBJECTIVES

- ✓ Develop a wireless power transfer (WPT) system optimized for laptop charging using inductive coupling.
- ✓ Achieve high power transfer efficiency (~90-95%) while minimizing losses and heat generation.
- ✓ Ensure sufficient power output (≥60W) to support modern laptop charging requirements.
- ✓ Optimize coil design to allow efficient charging within a range of 5-10 cm and tolerate misalignment.
- ✓ Develop a lightweight and user-friendly charging pad with minimal space requirements.

LITERATURE REVIEW

Paper	Paper Title	Technique Used	Summary of Abstract and Conclusion	Technology Used (includes hardware)	Targeted End Application
[1]	Analysis of Wireless Charging System for Low Power Appliances	Inductive power transfer, focusing on coil design, misalignment effects, and system efficiency through simulations in MATLAB	The paper analyzes the performance of a wireless mobile charging system for low-power appliances using electromagnetic induction, with simulations	The hardware used includes transmitter and receiver coils an oscillator, resonant circuit, rectifier, smoothing capacitor, and voltage regulator	Cell Phones, Wearables, medical devices, and other low-power electronics, providing efficient and cable-free charging solutions.
[2]	Simulation analysis of mobile phone wireless charging system coupling coil	Electromagnetic field simulations, and inductance calculations to optimize and compare coil	This paper reviews the development of high-power wireless power transfer systems and future advancements.	The hardware tools used in this paper include paper analysis of different coil structures for wireless charging systems.	Mobile phones, consumer electronics, and energy-efficient wireless power transfer systems.

LITERATURE REVIEW (contd..)

Paper	Paper Title	Technique Used	Summary of Abstract and Conclusion	Technology Used (includes hardware)	Targeted End Application
[3]	Wireless Charging Technologies: Fundamentals, Standards, and Network Applications	Magnetic resonance, inductive coupling, and optimization of coil design to enhance the efficiency	A comprehensive overview of wireless charging techniques, standards, network applications, challenges.	Devices for power transfer and deployment: These include both the equipment used to send and receive the wireless power	Target end applications for wireless charging devices include portable electronics, electric vehicles, IoT devices
[4]	A Small-scale Inductive Wireless Power Transmission Prototype for Charging Electric Vehicles	Inductive coupling, implemented through a Class D inverter to generate high-frequency voltage.	Inductive wireless power transmission EV charging, with effective high-power transmission	Class-D inverter, inductive coupling coils, compensation capacitors.	Targeted end applications include fixed battery charging systems.

LITERATURE REVIEW (contd..)

Paper	Paper Title	Technique Used	Summary of Abstract and	Technology Used (includes hardware)	Targeted End Application
[5]	Wireless Mobile Charger	electromagnetic induction for wireless power transfer, involving magnetic coupling between transmitter and receiver coils to charge mobile devices	The paper explores the development and benefits of wireless charging using microwave power and electromagnetic principles for efficient, wire-free device charging.	Transmitter and receiver coils, an AC to DC converter (rectifier), an oscillator tank circuit, and a current amplifier.	Microwave-powered wireless charging allows mobile devices to charge automatically in various locations, eliminating physical chargers and enhancing convenience.
[6]	On Wireless Charging for Mobile Sensors	Trajectory planning, mobility prediction, and charging efficiency based on sensor. .	This paper tackles wireless charging for mobile sensors with trajectory planning.	The system uses mobile sensors with charging capabilities, a mobile charger, and WPT systems.	IoT devices, wildlife tracking, and border security, where mobile sensors require efficient wireless charging.

LITERATURE REVIEW (contd..)

Paper	Paper Title	Technique Used	Summary of Abstract and	Technology Used (includes hardware)	Targeted End Application
[7]	Design of High-Power Static Wireless Power Transfer via Magnetic Induction: An Overview	Algorithms for power management, compensation network tuning, fault detection, and communication protocols.	This paper provides an overview of high-power static wireless power transfer (WPT) systems via magnetic induction, discussing key prototypes, power elevation techniques, coil design.	High-power static WPT systems includes coils (e.g., bipolar, circular, square), compensation networks.	Electric vehicles, rail transit, buses, ferries, industrial equipment, and automated charging stations.
[8]	An LLC-Based Planar Wireless Power Transfer System for Multiple Devices	The technique involves Control algorithms for variable frequency adjustment, impedance matching.	This paper presents a universal wireless power transfer (WPT) system using an LLC resonant circuit and parallel-connected transmitting coils.	Coils, LLC resonant circuits, DC-DC converters, sensors, and controllers.	charging portable devices like smartphones, tablets, and wearables.

LITERATURE REVIEW (contd..)

Paper	Paper Title	Technique Used	Summary of Abstract	Technology Used (includes hardware)	Targeted End Application
[9]	Design and Analysis of Four-Layer MOD Coil Array with Printed Spiral Detection Coils for Wireless Power Transfer	For the system design and simulation is HFSS (High-Frequency Structure Simulator) for the coil array configuration	Solution for future transportation as they can be powered directly from the road without relying on large, heavy batteries. The paper presents a four-layer MOD coil array for detecting metal objects in WPTS, improving safety and efficiency.	The hardware used in the system includes a four-layer printed spiral MOD coil, a 1 MHz sine wave source, an oscilloscope, and a function generator.	Roadway-powered electric vehicles (RPEVs), which include various forms of electric transportation such as buses, cars, trains, and trucks

SUMMARY OF LITERATURE REVIEW

- ✓ WPT has been widely studied for applications ranging from low-power devices to high-power charging.
- ✓ Research highlights the feasibility of inductive coupling for efficient energy transfer and advancements in coil design and power efficiency [1][2].
- ✓ Studies on wireless charging standards, high-power static WPT, and resonant circuits provide insights into improving system performance [3][7][8].
- ✓ Innovations in static charging and safety mechanisms further contribute to the evolution of WPT technology [9][10], laying a foundation for its application in wireless laptop charging.

BLOCK DIAGRAM

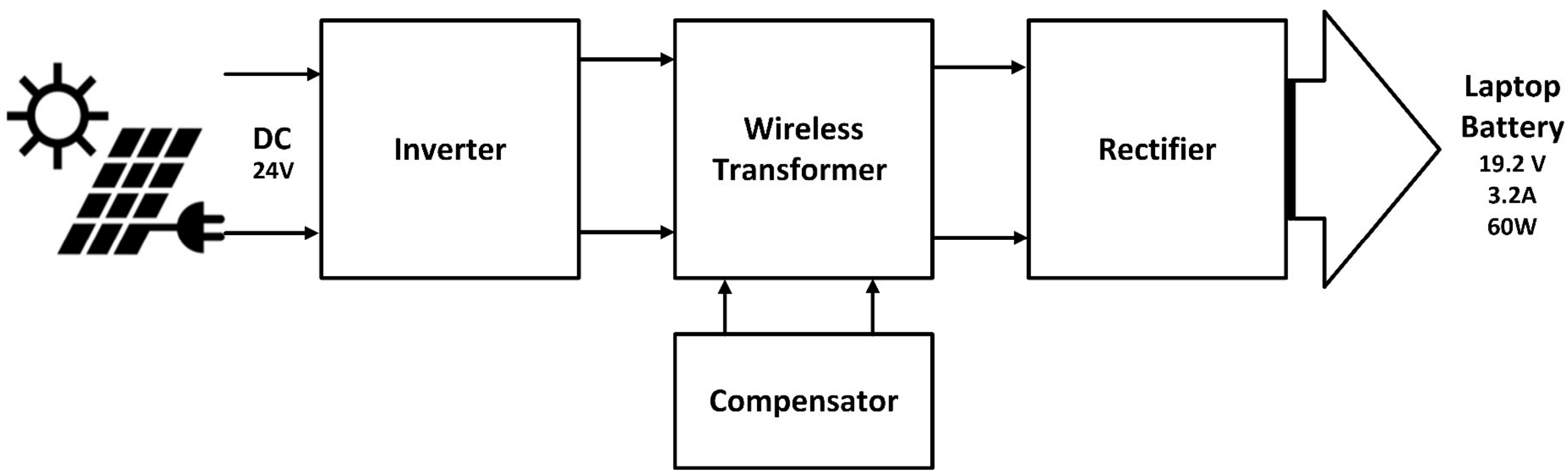

Figure 1. Renewable Energy Powered WPT Block Diagram

OVERVIEW OF WORK

- We began by reviewing existing Wireless Power Transfer (WPT) technologies and comparing various compensation topologies to determine the most efficient solution for laptop charging.
- Based on our analysis, we selected the Series-Series (SS) compensation topology for its optimal performance.
- A simulation model was developed to validate system performance, ensuring stable voltage and current delivery.
- After achieving promising results in simulation, we have now moved towards hardware implementation, where real-world testing and further optimizations will be conducted.

WORK DONE SO FAR

➢ <u>Comparison of Topologies</u> :

- Compensation networks are essential in WPT systems to enhance efficiency, regulate power flow, and maintain stable operation.
- The most used topologies are,

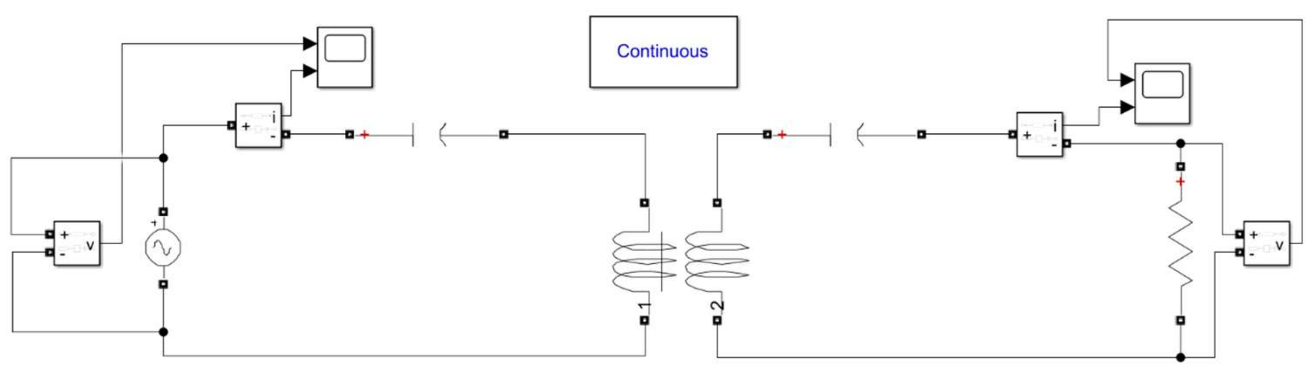

Figure 2. SS Compensation

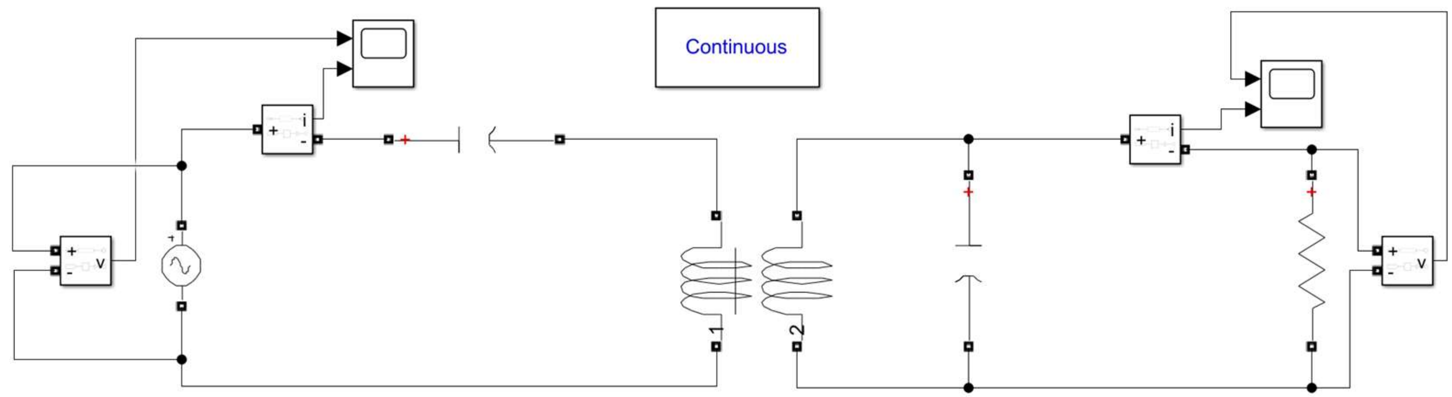

Figure 3. SP Compensation

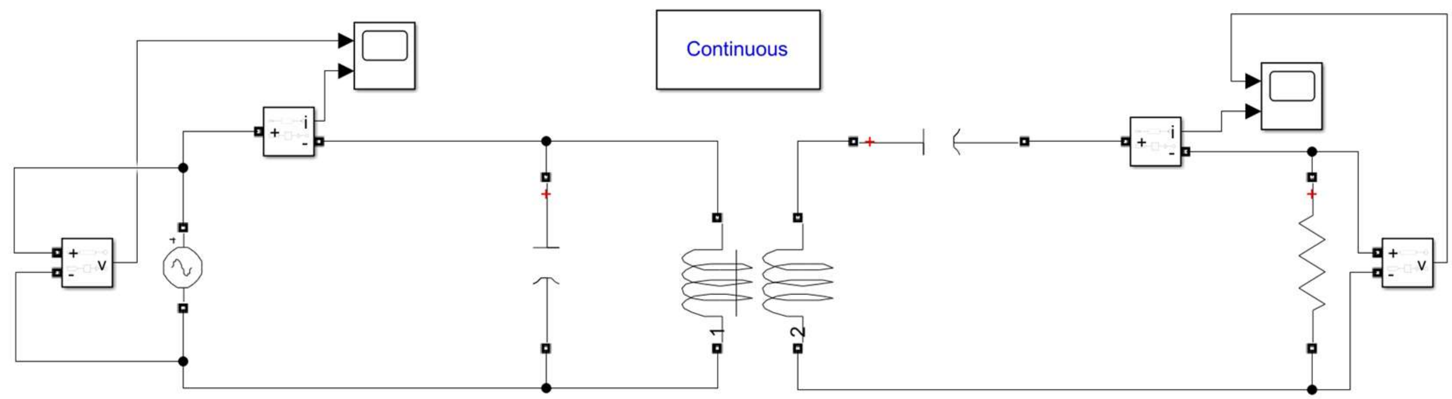

Figure 4. PS Compensation

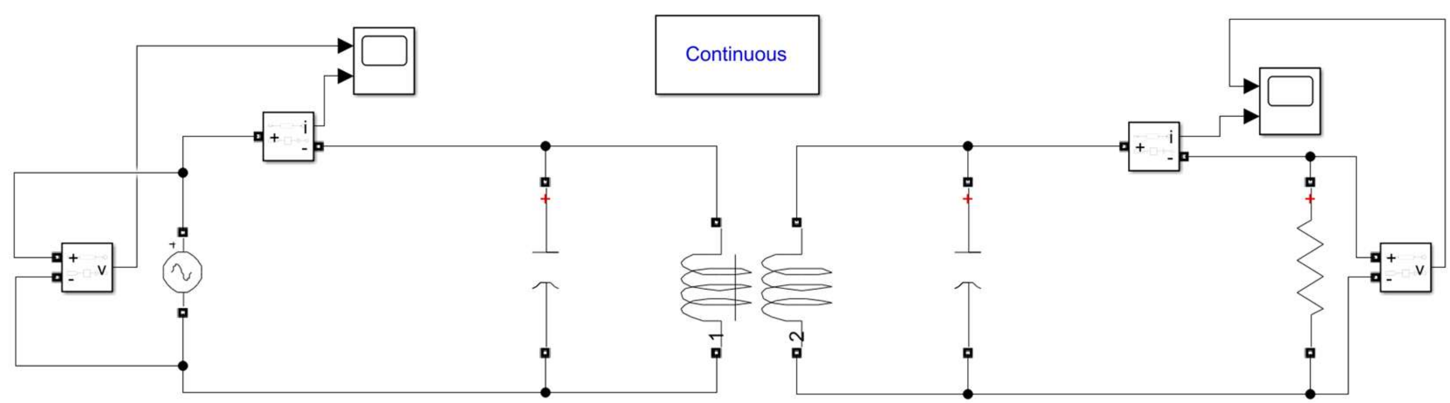

Figure 5. PP Compensation

WORK DONE SO FAR

➢ Comparison of Different Topologies :

Topology	Rated Power	Resonant Frequency	Air Gap	Efficiency
SS	2kW	20kHz	15cm	82%
SPS	2kW	100kHz	14cm	75%
SS	5kW	50kHz	20cm	95%
PP + Sensor	400W	20kHz	10cm	76%
SP + LCL	300W	100kHz	15cm	81%
SP	120W	8.7kHz	10cm	75%
SS	3kW	60kHz	2.8cm	85%
LCL	5kW	20kHz	25cm	90%
SS	300W	10kHz	3cm	80%
SS	400W	31.5kHz	3.5cm	75%

- Existing work achieved 95% efficiency at a 20cm separation, but this is not directly comparable as it may be for higher power applications or different operating conditions.
- Only 76% efficiency was achieved for the same at full load due to a reduced air gap and energy conservation constraints.

WORK DONE SO FAR

➢ Mathematical Modelling

- We shall initially consider the coil parameters as;

Number of turns of coil (N) = 11

Coil diameter or the radius of circular loop (d) = 7.2cm = 0.072m

Hence, we have radius of loop (R) = 3.6cm = 0.036m

Wire radius (Litz Wire) (r) = 0.04mm = 0.0004m

- Having these values with us, we considered R_1 and R_2. Adding these values will lead to Mutual Resistance (R_m).
- We have considered **Coupling Co-efficient** $(\mathbf{k}) = \mathbf{0.33}$. This depicts tightly coupled scenario with maximum variations of up to ~7cm.
- The standard equation for Self Inductance ($L_1 and\ L_2$) both across primary and secondary is give by,

$$\boldsymbol{L = \mu_o N^2 R \left[\ln\left(\frac{8R}{r}\right) - 2\right]} \qquad (1)$$

WORK DONE SO FAR

➢ Mathematical Modelling (contd..)

- Were,

  μ_o is permeability of free space give by $\mu_o = 4\pi \times 10^{-7}$ H/m

- Using this equation (1), we calculate the equivalent Self Inductance ($L_1 and\ L_2$) values by considering the drop R_1 and R_2 respectively across each.
- Now that we have these values with us, we compute Mutual Inductance (L_m) given by the equation,

$$\boldsymbol{L_m = k\sqrt{L_1 L_2}} \tag{2}$$

- This leads us to the Resonant Frequency (f_r) which is given by the equation,

$$\boldsymbol{f_r = \frac{1}{2\pi \times \sqrt{LC}}} \tag{3}$$

- On substituting the values of L and C, where C values are considered based on train and error basis. We get the f_r value at $178.16KHz$.
- This leads us to get our peak output voltage at approx. $200KHz$.

WORK DONE SO FAR

➢<u>Components Selection Considering Non-Idealities</u> :

Power MOSFET: Infineon-IPD025N06N

Electrical characteristics:

SI.no	Parameter	Value	Unit
1	Vds	60	V
2	Id	90	A
3	Rd(on)max	2.5	mΩ

Dynamic characteristics:

SI.no	Parameter	Value	Unit
1	Tdon	16	ns
2	Tr	20	ns
3	Tdoff	34	ns
4	Tf	12	ns

WORK DONE SO FAR

➢Components Selection:

Power Diode: ST microelectronics-STPS5L40

Electrical characteristics:

SI.no	Parameter	Value	Unit
1	Vf	0.44	V
2	Rd(on)	1	mΩ
3	If(AV)	5 (@125˚C)	A
4	Vrrm	40 (@125˚C)	V
5	Tj(max)	150	˚C

WORK DONE SO FAR

- Simulation results

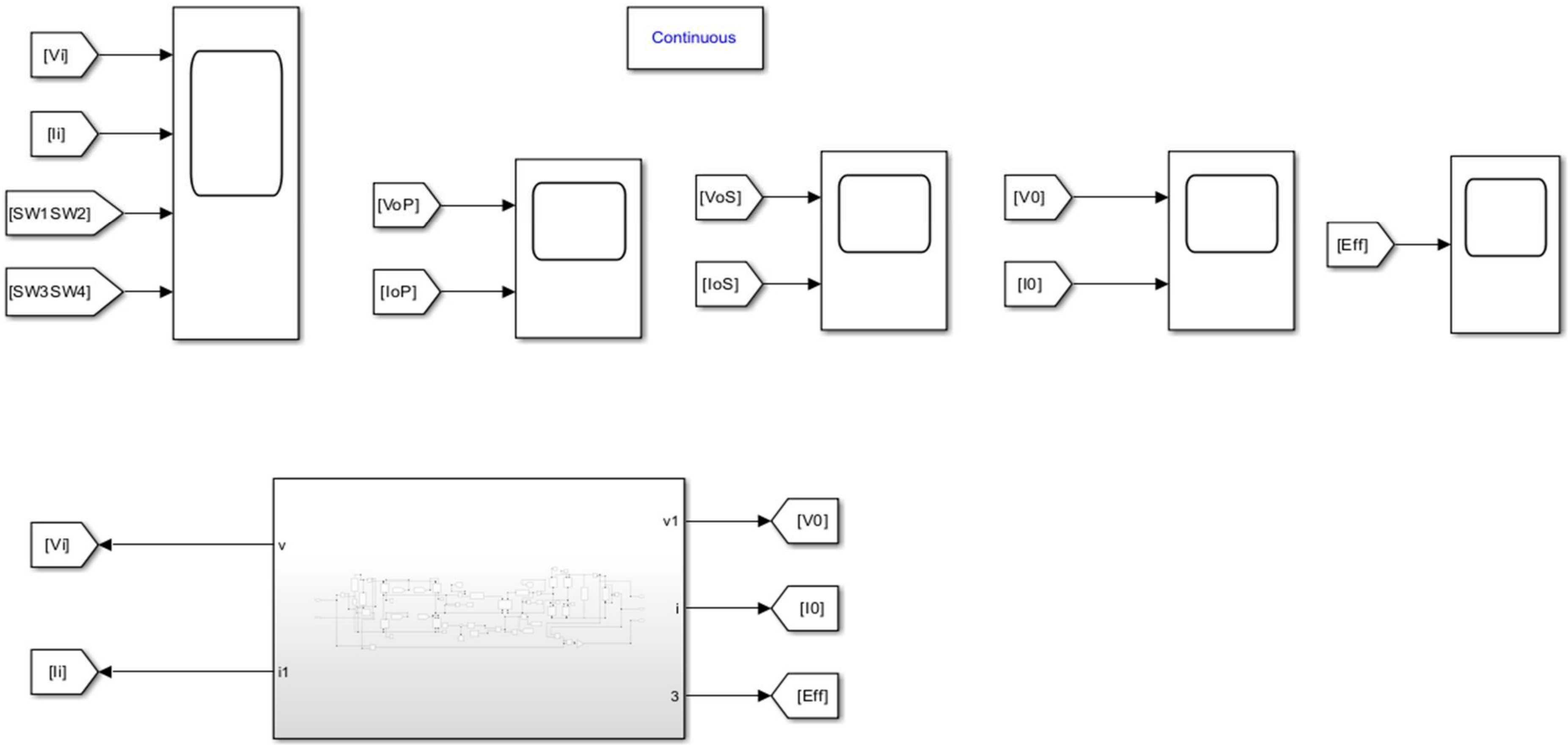

Figure 6. MATLAB-Simulink closed loop model for laptop wireless charging

WORK DONE SO FAR

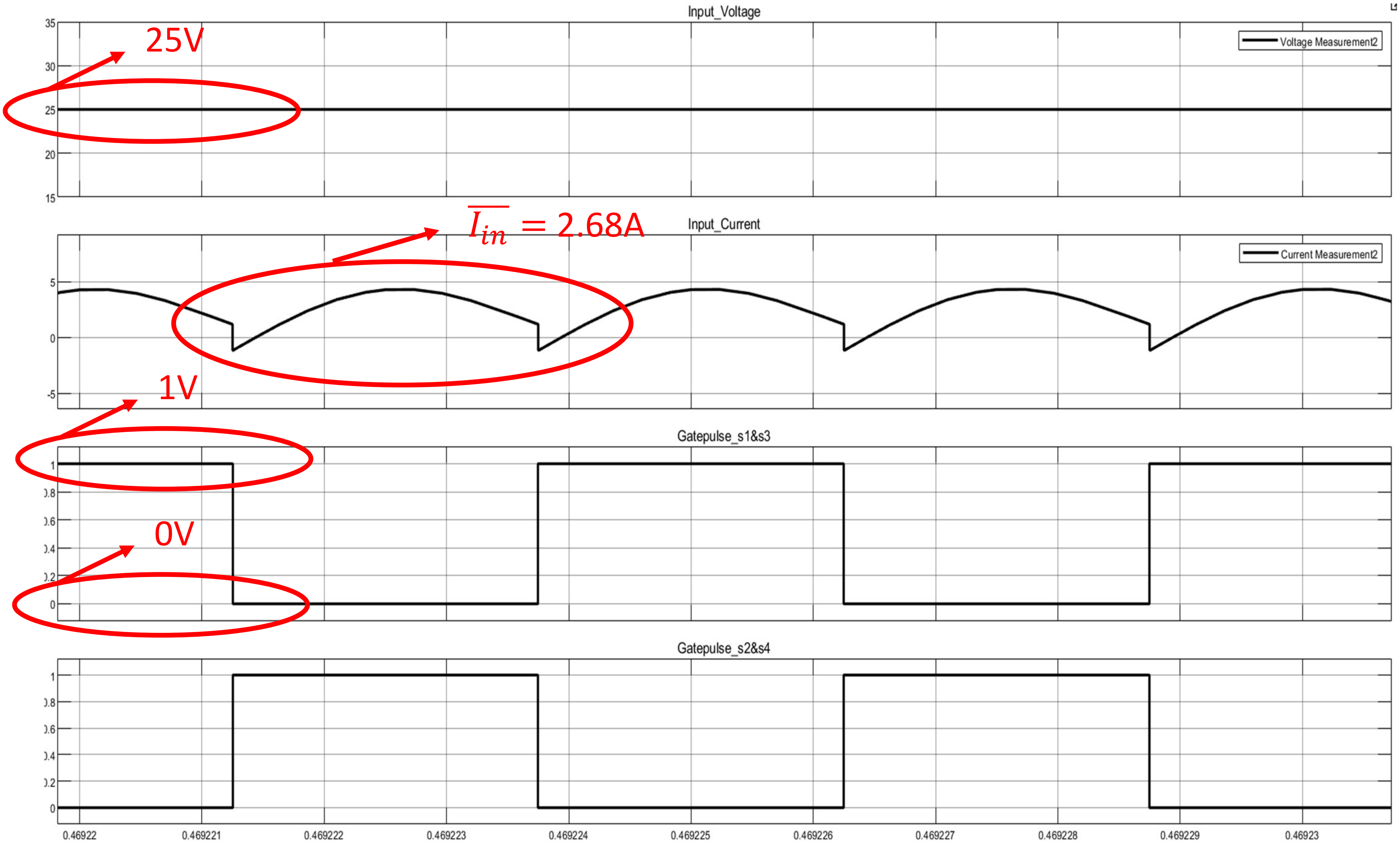

Figure 7. Waveform of input voltage, input current and switch gate pulse for S1,S2,S3 and S4

WORK DONE SO FAR

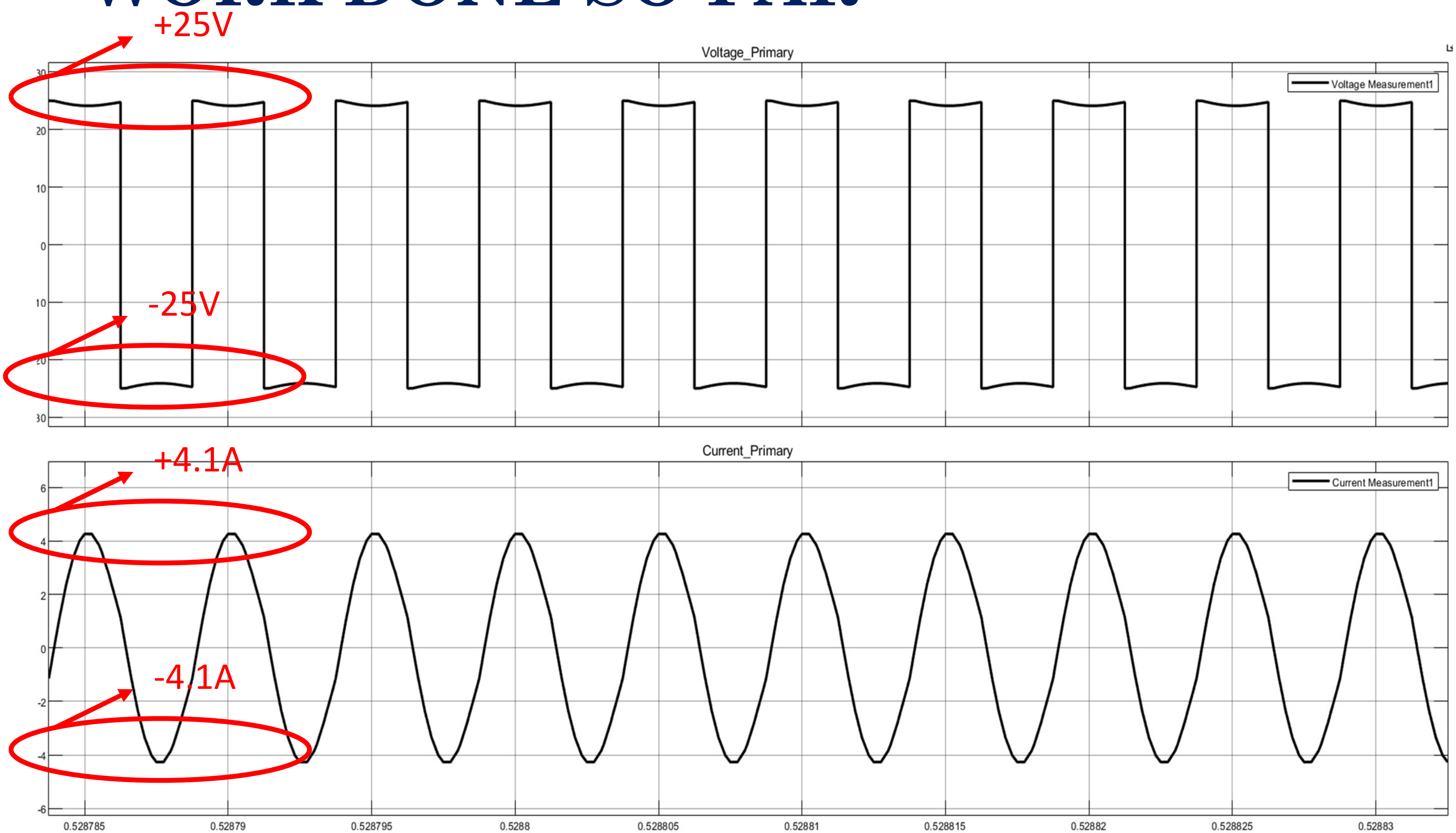

Figure 8. Waveform of primary voltage and primary current

WORK DONE SO FAR

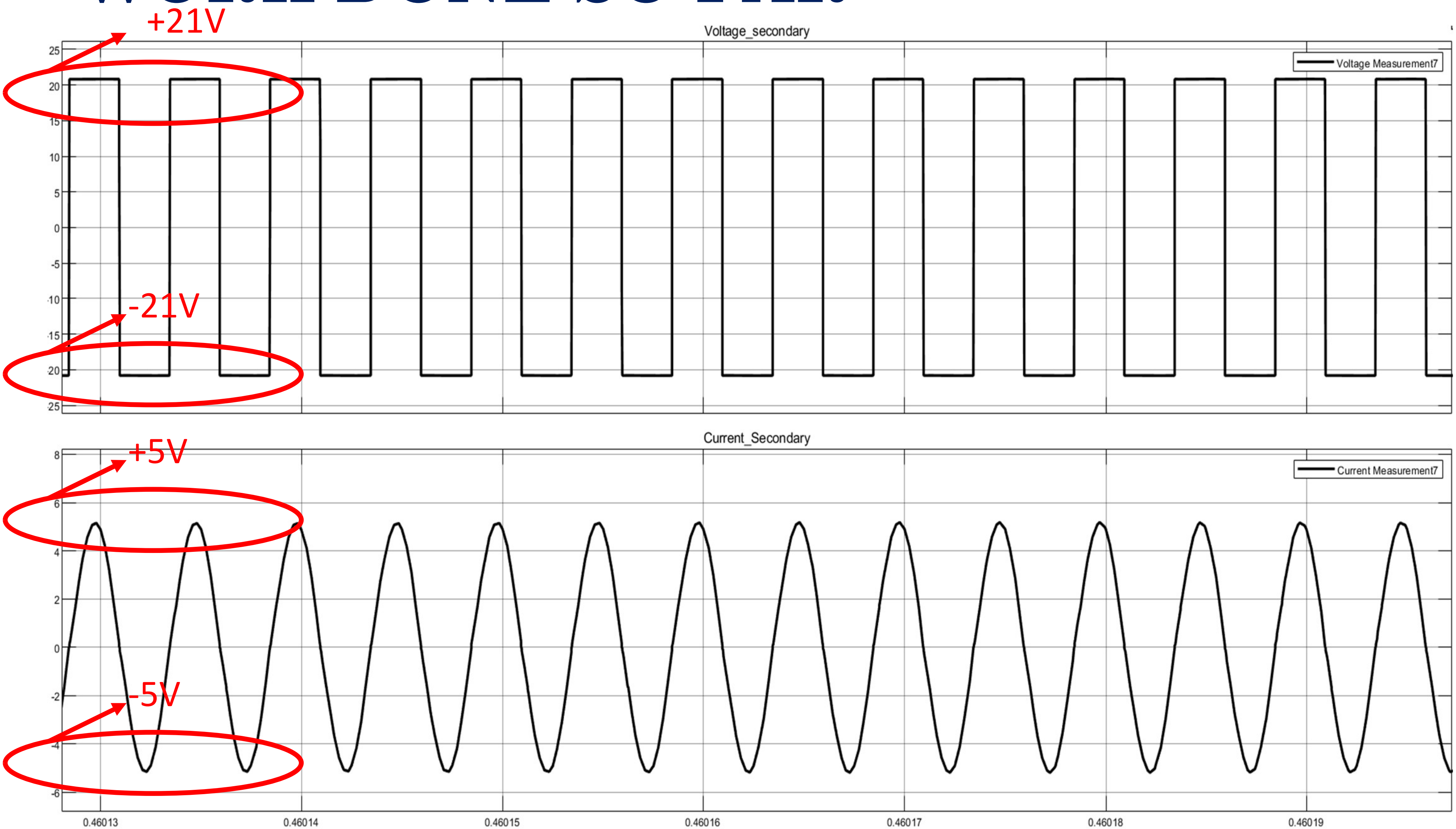

Figure 9. Waveform of secondary voltage and secondary current

WORK DONE SO FAR

Figure 10. Waveform of output voltage and output current

WORK DONE SO FAR

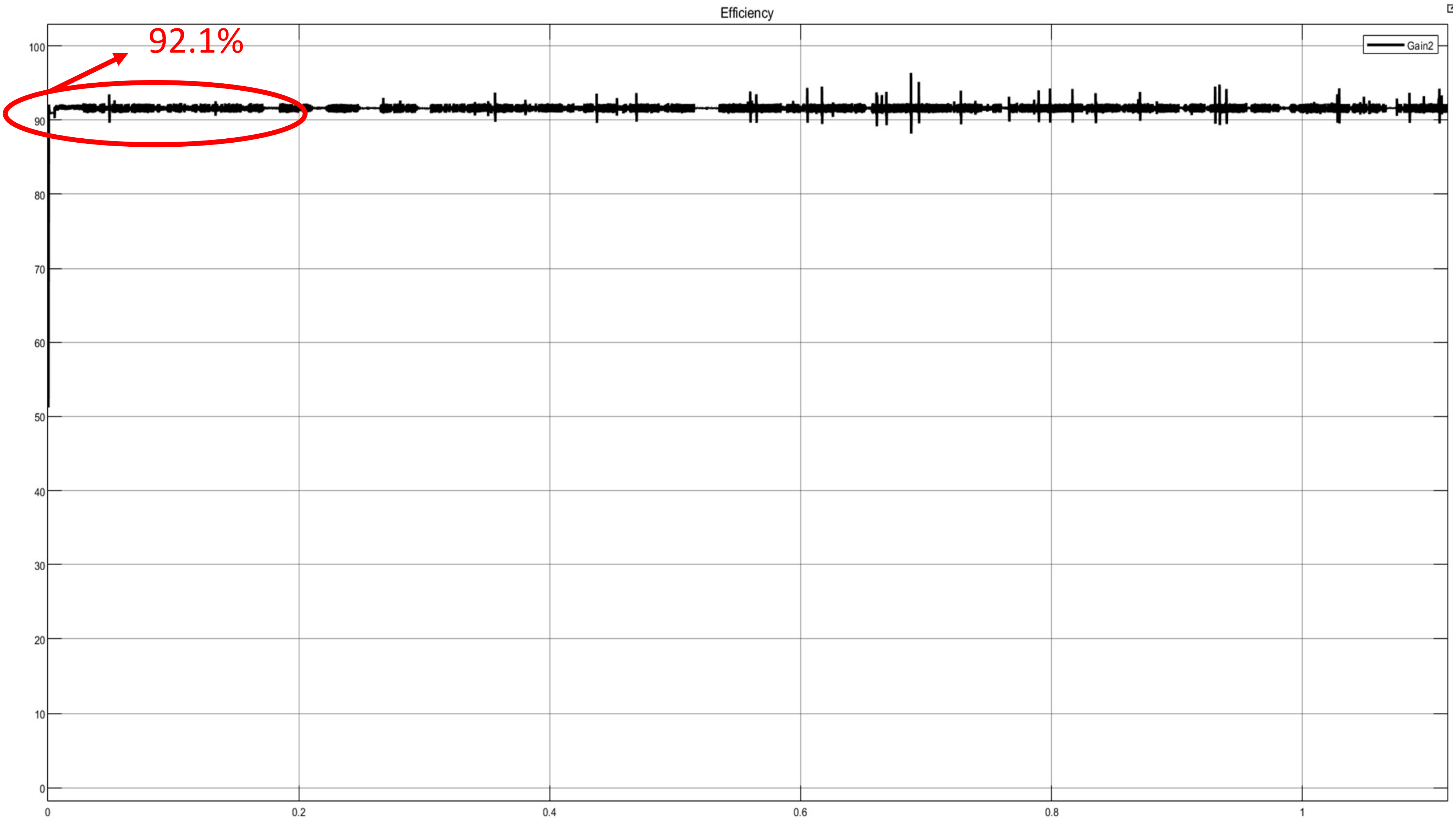

Figure 11. Waveform of efficiency

WORK DONE SO FAR

➢Comparative Results:

The following are our results for different topologies,

Topology	Vin	Iin	Vout	Iout	Pout	Efficiency
SS	25V	1.15A	19.2V	3.2A	60W	92%
SP	25V	0.149A	4.168V	0.694A	3W	77%
PS	25V	1.5112A	6.64V	1.106A	7W	19.45%
PP	25V	0.8A	1.11V	0.18A	0.2W	1.03%

CONCLUSION

- ✓ Wireless charging for laptops presents a convenient and efficient alternative to traditional wired charging, addressing issues like cable wear and mobility constraints. We have successfully simulated a wireless power transfer system with a 60W power rating, 19.2V output, and 3.2A current, and we are now preparing for hardware implementation.
- ✓ By optimizing coil design, improving power transfer efficiency, and integrating advanced materials like Silicon Carbide (SiC) switches, the system can achieve higher efficiency, extended range, and better thermal management.
- ✓ Future advancements in high-power transfer, standardization, and smart charging integration will further enhance its practicality, making wireless laptop charging a viable solution for next-generation devices.

CHALLENGES & MODIFICATIONS

- ✓ Thermal management and electromagnetic interference (EMI) are key challenges in wireless charging systems, particularly in high-power applications.
- ✓ Heat generation can affect system efficiency and component lifespan, while EMI can interfere with nearby electronic devices, requiring proper shielding and filtering techniques.
- ✓ As our hardware model is still under development, these challenges have not been fully addressed in the current PPT.
- ✓ However, we anticipate encountering these issues during hardware testing, where we will implement optimization techniques to ensure safe and efficient operation.

REFERENCES

[1] Reddy, B., M.E, A., Students, & Assistant Professor, Dept. of ECE, Sathyabama University, Chennai 600119. (2017). Wireless Mobile charger. In International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE) https://www.technoarete.org/common_abstract/pdf/IJSEM/v4/i12/Ext_10392.pdf.

[2] Analysis of wireless charging system for Low-Power appliances. (2024, July 31). IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/document/10718159.

[3] Simulation analysis of mobile phone wireless charging system coupling coil. (2023, May 26). IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/document/10176840

[4] On wireless charging for mobile sensors. (2024, September 1). IEEE Journals & Magazine | IEEE Xplore. https://ieeexplore.ieee.org/document/10418156.

[5] An LLC-based planar wireless power transfer system for multiple devices. (2014, March 1). IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/document/6803798.

REFERENCES

[6] Design of high-power static wireless power transfer via magnetic induction: An overview. (2021, December 1). CPSS Journals & Magazine | IEEE Xplore. https://ieeexplore.ieee.org/document/9675068.

[7] Wireless Charging Technologies: fundamentals, standards, and network applications. (2016, January 1). IEEE Journals & Magazine | IEEE Xplore. https://ieeexplore.ieee.org/document/7327131

[8] Design and Analysis of Four-Layer MOD Coil Array with Printed Spiral Detection Coils for Wireless Power Transfer. (2023, October 23). IEEE Conference Publication | IEEE Xplore. https://ieeexplore.ieee.org/document/10326346

[9] A. M. U. Dr. Yasser Rafat, "Feasibility study and Implementation of Solar based Static EV Wireless Charging Station in India," India Science, Technology and Innovation Portal, Government of India.

Thank You