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Analytical Modelling and Simulation of a Class-E π2b Resonant Inverter for Inductive Wireless Power Transfer

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ABSTRACT

High-efficiency power conversion is critical for Wireless Inductive Power Transfer (IPT) systems, especially at high operating frequencies where switching losses, impedance sensitivity, and load variations strongly affect overall performance. Conventional Class-E inverters typically exhibit efficiency degradation when operating outside their optimum load conditions due to impedance mismatch and the consequent loss of soft-switching. To address these limitations, this study investigates the design and performance analysis of a Class-E π2b resonant transmitter, a topology chosen for its capability to sustain zero voltage switching (ZVS) under appropriately matched conditions. The Class-E π2b transmitter is analytically designed for a 16 W power specification using standard Class-E design equations, and its performance is examined through detailed circuit-level simulations in PSIM. The resonant transmitter is evaluated under two operational scenarios: (i) direct operation without an impedance-matching network, and (ii) operation incorporating a π2b impedance-matching network. This comparative approach enables a controlled assessment of how impedance matching influences efficiency, switching behaviour, and output stability. Simulation results show that the Class-E π2b inverter operating without impedance matching achieves approximately 74% efficiency, primarily due to load-dependent mismatch and partial loss of soft-switching. In contrast, when integrated with a π2b matching network, the transmitter preserves ideal ZVS switching characteristics and delivers stable 16 W at 6.78 MHz ISM (Industrial, Scientific, and Medical) band, achieving a significantly improved overall efficiency of 98.2% when driving a 22 Ω load. These findings demonstrate that the Class-E π2b topology, when complemented with an appropriate impedance-matching network, provides a robust and highly efficient solution for high-frequency inductive wireless power transfer applications.

Index Terms - Class-E inverter, wireless power transfer, impedance matching, load variation, resonant converter, PSIM simulation

INTRODUCTION

Wireless Power Transfer (WPT) systems offer significant advantages in convenience, flexibility, and reliability by enabling the transfer of electrical energy without physical connectors. These systems have gained widespread adoption in applications ranging from consumer electronics to electric vehicle charging and industrial automation. Among the various WPT techniques, resonant inductive coupling remains the most widely utilized due to its ability to achieve efficient mid-range power transfer. In this method, energy is conveyed through an oscillating magnetic field between transmitter and receiver coils that are tuned to the same resonant frequency, thereby enhancing coupling efficiency and reducing power loss.

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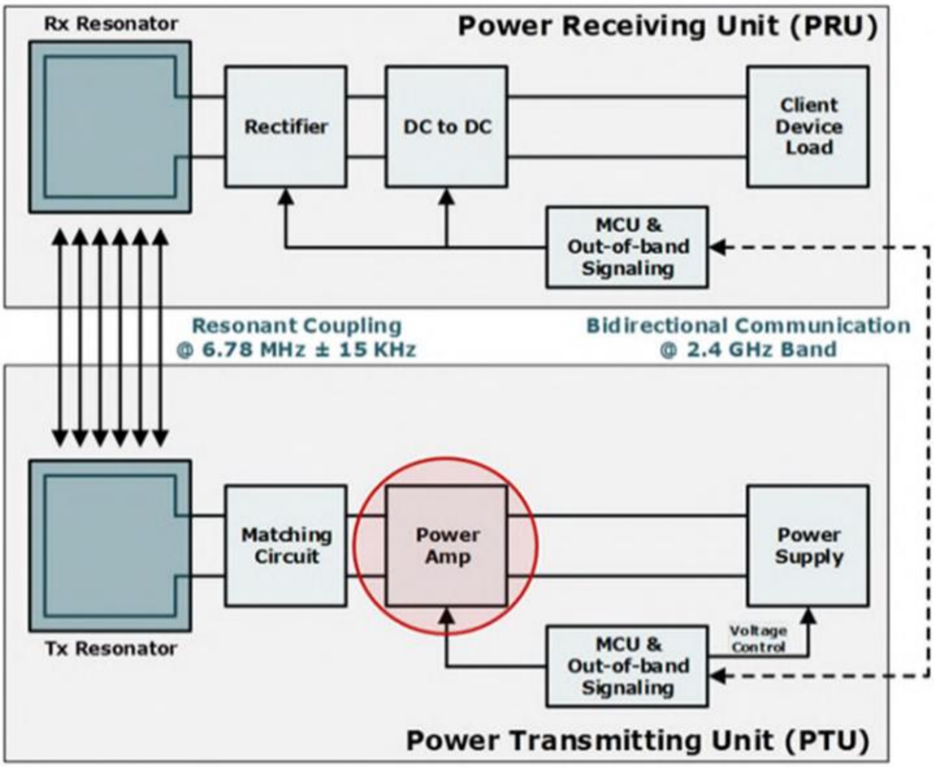
In recent years, WPT systems have attracted interest due to their ability to transmit energy over a distance safely and efficiently. Figure 1 presents an overview of a wireless charging system, comprising two principal sections: the Power Transmitting Unit (PTU) and the Power Receiving Unit (PRU). The PTU is responsible for generating and transmitting electromagnetic energy through a resonant coupling link operating at 6.78 MHz ± 15 kHz, while the PRU receives, rectifies, and regulates this power to supply energy to the connected load. The energy transfer process relies on resonant inductive coupling between the transmitting and receiving resonators, ensuring efficient mid-range power transmission. Additionally, a bidirectional communication channel at 2.4 GHz facilitates control, feedback, and power management between both units, thereby maintaining system stability and reliability.

In the PTU, the power amplifier serves as the critical stage responsible for converting the DC input into a high-frequency AC signal that excites the transmitting resonator. To maximize the power transfer efficiency, an impedance matching network is employed between the amplifier and the resonator to minimize reflection losses.

This research focuses on the design and simulation of the power amplifier and impedance matching network for the PTU. Specifically, the power amplifier to be designed is a Class-E resonant inverter, which is renowned for its high efficiency, soft-switching characteristics, and suitability for wireless power transmission systems.

Fig. 1. Wireless Charging Overview



In summary, this paper offers three key contributions. First, it presents the complete design, analytical formulation, and performance evaluation of a Class-E π2b resonant transmitter, including detailed calculations of total conduction loss, switching loss, and gate-drive loss to establish an accurate efficiency profile. Second, the study provides a comprehensive comparison between theoretical predictions and PSIM simulation results to validate the accuracy of the proposed design under practical operating conditions. Third, the paper includes a Professional Engineering Discussion that contextualizes the design within regulatory, sustainability, and ethical engineering considerations, thereby demonstrating the relevance of the proposed transmitter for high-frequency inductive wireless power transfer applications.

CLASS-E π2b TOPOLOGY

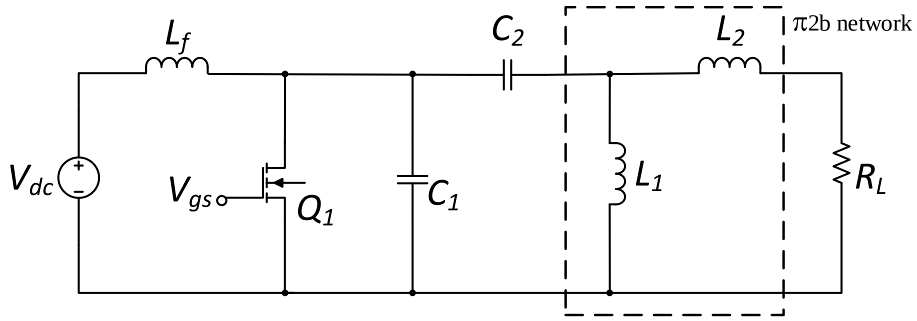
Figure 2 illustrates the proposed wireless power transmitter based on the Class E π2b topology, which integrates a conventional Class E resonant inverter with a π2b impedance matching network. As shown in Figure 2(a), the overall circuit consists of the primary Class E stage that includes the DC supply, radio frequency choke (L_f), switching device (Q_1), shunt capacitor (C_1), and series resonant capacitor (C_2). This section is followed by the π2b matching network formed by inductors (L_1) and (L_2).

Class E inverters operate as switching mode power amplifiers and are well known for their simplicity, requiring only a single active switch, typically a MOSFET, and for achieving high efficiency at radio frequency operation. When properly designed, the inverter satisfies the zero voltage switching (ZVS) condition, ensuring that the switch turns on at zero drain voltage. This minimizes switching losses and enables high frequency and high efficiency operation.

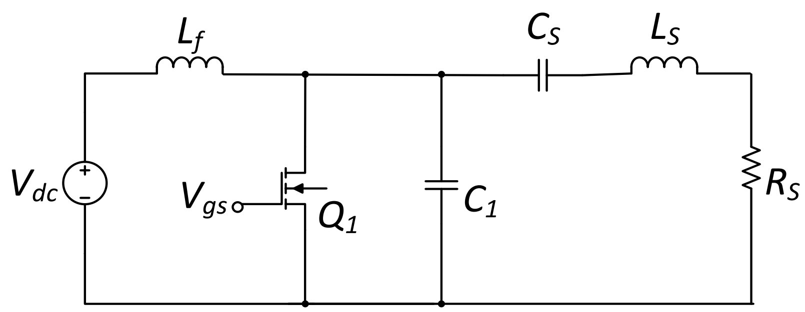
The π2b impedance matching network provides a downward impedance transformation between the output of the Class E inverter and the load. This network employs a tapped inductor configuration that consists of L_1 and L_2, where L_1 also functions as the transmitter and receiver coil for inductive power transfer. The equivalent representation of this matching network is shown in Figure 2(b), where the network is expressed in terms of the equivalent series resistance (R_s), series capacitor (C_s), and inductor (L_s). These parameters can be analytically derived to achieve optimal Class E operation at a duty ratio of D = 0.5.

In summary, the proposed design combines the advantages of the Class E resonant inverter with the impedance transforming capability of the π2b network. This configuration enables efficient power transfer to the inductive coil while maintaining soft switching and minimizing losses.

Fig. 2. Circuit of Class E π2b impedance matching



(a)



(b)

Waveforms illustrating a load-independent Class-E inverter with a duty ratio of 0.5 are presented in Figure 3. The switch is in an on-off state, and upon switching off, the inductor and resonant filter current flows through the shunt capacitor and generates the switch voltage V_{ds} [2]. The ZVS condition is satisfied again upon activation of the switch and voltage measurement :

$$v_{ds}(\pi) = 0 \qquad (1)$$

This condition avoids power losses during switching, permitting the inverter to maintain an efficient performance, even at higher frequency ranges.

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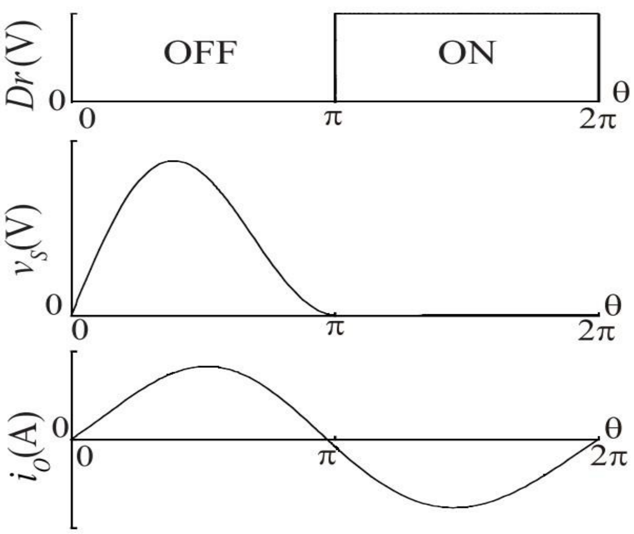
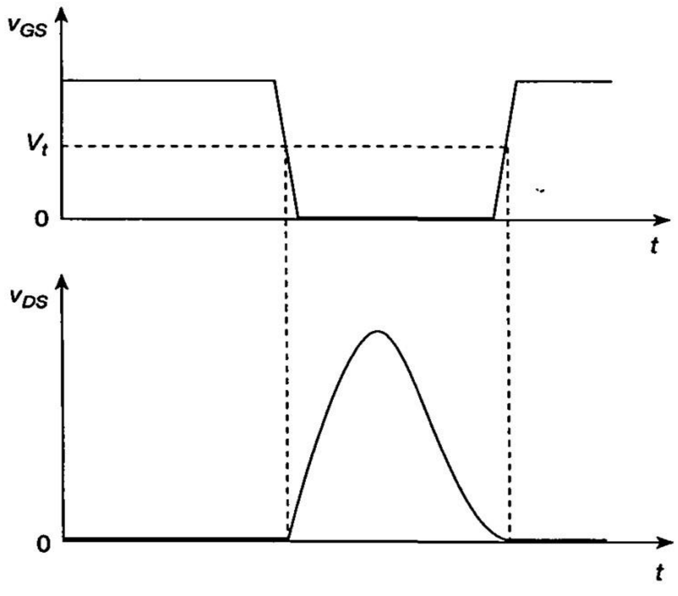
Fig. 3. Waveforms of the load-independent [2]



In addition, Figure 4 depicts the voltage and current waveforms of the Class-E inverter and the corresponding Z_{VS} and Z_{DS} operation. When the switch turns off, the resonant network practically ensures the drain-to-source voltage is relaxed to zero before the next switching period. This softswitching characteristic eliminates losses and improves the inverter efficiency, making it appropriate for high frequency wireless power transfers [3].

Fig. 4. Waveforms of V_{GS} and V_{DS} in a Class-E inverter [3]



Proposed System

This section presents the design of the proposed system, beginning with the analytical design calculations of the Class-E resonant inverter under two operating conditions, namely without impedance matching and with the inclusion of an impedance matching network. The subsequent circuit performance evaluation analyses the inverter's efficiency and provides a detailed assessment of total conduction loss, switching loss, and gate drive loss in order to evaluate the overall performance of the Class E π2b transmitter circuit.

Design Of Class-E Resonant Inverter

The design procedure is based on the specifications provided in Table 1. These parameters serve as the foundational reference for developing each circuit configuration, with the quality factor and duty cycle assigned practical values to facilitate accurate modelling and optimal Class E inverter performance.

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Table I Design Specifications for Class-E Resonant Inverter

DC Input voltage, V_{dc}	12V
Output power, P_o	16W
Frequency, f	6.78MHz
Duty Cycle, D	0.5
Quality Factor, Q	10

The Class-E design equations enable the calculation of the load resistance as shown in the following equation (2) is derived from the relationship between DC input voltage and the effective load.

$$R_s = \frac{8}{\pi^2+4}\left(\frac{V_{dc}^2}{P_o}\right) = 5.19\ \Omega \qquad (2)$$

The optimum Class-E design equation enables the calculation of the shunt capacitance as shown in the following equation (3).

$$C_1 = \frac{8}{\pi(\pi^2+4)}\left(\frac{1}{2\pi f R_s}\right) = 6.83\ \text{nF} \qquad (3)$$

Using equation (4), the series capacitor is sized based on a quality factor of Q = 10.

$$C_s = \frac{1}{2\pi f R_s\left(Q_L + \frac{\pi(\pi^2+4)}{16}\right)} = 8.51\ \text{nF} \qquad (4)$$

The Class-E design equations and the resonant inductor relation enable the calculation of the series inductor and is shown in the following equation (5).

$$L_f = 2(\frac{\pi^2+1}{4})\left(\frac{R_s}{f}\right) = 5.21\ \mu\text{H} \qquad (5)$$

In equation (6), the resonant load inductor is calculated.

$$L_s = \frac{Q_L R_s}{2\pi f} = 1.22\ \mu\text{H} \qquad (6)$$

The specifications given make it possible to design a Class-E resonant inverter that works at 6.78 MHz and achieves the conditions of ZVS. The inverter provides high efficiency gated performance.

Table II Calculated Values for Class-E Components

Component	**Calculated Value**
Load Resistance, Rs	5.19Ω
Shunt Capacitor, C_1	6.83 nF
Series Capacitor, Cs	8.51 nF
Resonant Inductor, L_f	5.21µH
RF Choke Inductor, Ls	1.22µH

Circuit Performance Evaluation

This section analyzes the performance of the Class-E resonant inverter circuit with respect to its input power, output power, and efficiency. Regarding the efficiency measurement, the calculation incorporates assumed design values and parameters for determining conduction loss (P_r), switching loss (P_{tf}), and gate-drive loss (P_g).

To validate the performance of the resonant inverter, power was calculated using the DC input and the AC output currents. For the final answer, the equal symbol is used to depict the ideal situation under which all calculations were performed.

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$$I_{dc} = \frac{P_o}{V_{dc}} = 1.33 \text{ A} \qquad (7)$$

$$V_{o(rms)} = \sqrt{P_o R} = 9.11 \text{ V} \qquad (8)$$

$$I_{o(rms)} = \frac{V_{o(rms)}}{R} = 1.76 \text{ A} \qquad (9)$$

For Class-E inverter design, $V_{ds(max)}$ and $I_{d(max)}$ can calculated as:

$$V_{ds(max)} = 3.562V_{dc} = 42.75 \text{ V} \qquad (10)$$

$$I_{d(max)} = \left(\frac{\sqrt{\pi^2+4}}{2} + 1\right) I_{dc} = 3.81 \text{ A} \qquad (11)$$

Next, input and output power were calculated :

$$P_{in} = V_{dc} \times I_{dc} = 16 \text{ W} \qquad (12)$$

$$P_o = V_{o(rms)} \times I_{o(rms)} = 16.0 \text{ W} \qquad (13)$$

Under ideal conditions, the Class-E inverter is able to obtain an efficiency of 98.86% at a 5.19 Ω load. Once the load is increased to 22 Ω, the efficiency drops to 74%, even without considering power loss. This is due to the fact that the inverter is designed for a specific load impedance. When the load resistance is altered without proper impedance matching, the inverter experiences a degree of mismatch of the active and reactive power. This causes the inverter to lose the softswitching mode and permits excessive switching, resulting in reduced efficiency.

Under real conditions, the MOSFET, inductors, and capacitors incur additional conduction loss, which includes power dissipation in the form of heat. The total conduction loss can be expressed as:

$$Pr = PrDS + PrLF + PrC1 + PrL + PrC \qquad (14)$$

Next, the drain-source loss of the MOSFET is determined based on its on-state resistance.

$$I_{rms} = I_{dc}\sqrt{\frac{\pi^2+28}{4}} = 2.05 \text{ A} \qquad (15)$$

$$P_{rDS} = R_{DS(on)} I_{rms}^2 = 2.10 \text{ W} \qquad (16)$$

Following this, the loss associated with the choke inductor is calculated:

$$P_{rLF} = R_{LF} I_{dc}^2 = 0.177 \text{ W} \qquad (17)$$

Subsequently, the capacitor C_1 loss is computed:

$$I_{C1(rms)} = I_{dc}\sqrt{\frac{\pi^2-4}{4}} = 0.81 \text{ A} \qquad (18)$$

$$P_{rC1} = r_{C1} I_{C1(rms)}^2 = 0.0328 \text{ W} \qquad (19)$$

Next, the loss in the load-side inductor is evaluated:

$$I_m = I_{dc}\sqrt{\frac{\pi^2+4}{4}} = 2.48 \text{ A} \qquad (20)$$

$$P_{rL} = \frac{R_L I_m^2}{2} = 1.54 \text{ W} \qquad (21)$$

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Finally, the loss in the resonant capacitor is expressed as:

$$P_{rC} = \frac{r_C I_m^2}{2} = 0.154 \text{ W} \quad (22)$$

The total conduction loss is obtained by summing the individual component losses:

$$P_r = 4.00 \text{ W} \quad (23)$$

The switching loss (P_{tf}) is calculated using the transistor transition time and operating frequency:

$$t_f = \frac{0.05}{f} = 7.37 \text{ ns} \quad (24)$$

$$\omega t_f = 2\pi f t_f = 0.314 \text{ rad} \quad (25)$$

$$P_{tf} = \frac{(\omega t_f)^2 P_o}{12} = 0.132 \text{ W} \quad (26)$$

Next, the gate-drive loss (P_g) is obtained based on the switching frequency, gate voltage, and gate charge:

$$P_g = f V_{gs} Q_g = 1.46 \text{ W} \quad (27)$$

The total power loss of the Class-E inverter is expressed as:

$$P_{loss} = P_r + P_{tf} + P_g = 5.59 \text{ W} \quad (28)$$

Finally, the efficiency of the circuit can be calculated as:

$$\eta = \frac{P_o}{P_o + P_{loss}} \times 100\% = 74.1\% \quad (29)$$

In this situation, the Class-E resonant inverter has an overall efficiency of 74.1% and total power losses of 5.6 W. These observations indicate that the efficiency reduction of the circuit is predominantly due to practical conduction, switching, and gate-drive losses. This observation aligns well with theoretical operational behavior in practical Class-E inverter systems.

Class-E Including Impedance Matching

In order to focus on attaining maximum power to a 22 Ω load at 6.78 MHz, a π2b load matching network is placed in-between the Class-E resonant inverter and the load. Given the effective source resistance of 5.19 Ω and with a quality factor assumption of 10, 4.778 can be calculated for the intermediate key term k.

$$k = \sqrt{\frac{R_s(Q_L^2 + 1)}{R_L} - 1} = 4.778 \quad (30)$$

For the load side series inductor, L_2 was calculated.

$$X_{L2} = R_L k = 105.11\ \Omega \quad (31)$$

$$L_2 = \frac{X_{L2}}{2\pi f} = 2.47\ \mu\text{H} \quad (32)$$

For the source side series inductor, L_1 was calculated.

$$X_{L1} = \frac{R_s(Q_L^2 + 1)}{Q_L - k} = 100.38\ \Omega \quad (33)$$

$$L_1 = \frac{X_{L1}}{2\pi f} = 2.36\ \mu\text{H} \quad (34)$$

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Table III Calculation for Class-E With Impedance Matching

Component	Calculated Value
Source-side Inductor, L_1	2.36µH
Loas-side Inductor, L_2	2.47µH

Circuit Performance Evaluation (With Impedance Matching)

The simulation waveform and the respective measured input values of 11.79 V and 1.21 A provided an input power of 17.04 W. $P_{in} = V_{dc} \times I_{dc} = 17.04$ W (35)

With a measured RMS output voltage of 19.187 V, the output power produced was 16.73 W.

$$P_o = \frac{V_o^2}{R} = 16.73 \text{ W} \qquad (36)$$

The overall efficiency of the matched Class-E inverter was calculated to be 98.2%.

$$\eta = \frac{P_o}{P_{in}} \times 100\% = 98.2\% \qquad (37)$$

Given the inclusion of the impedance-matching network, the efficiency values and results post-simulation are demonstrably high. The circuit without impedance matching achieved roughly 74% efficiency. Relative to this, the impedancematching design confirms power transfer as fundamentally perfect, ensuring loss minimization and efficient transformation between the resonant inverter and the load. This confirms the π2b matching network improves overall circuit performance and maintains high efficiency under the stated conditions.

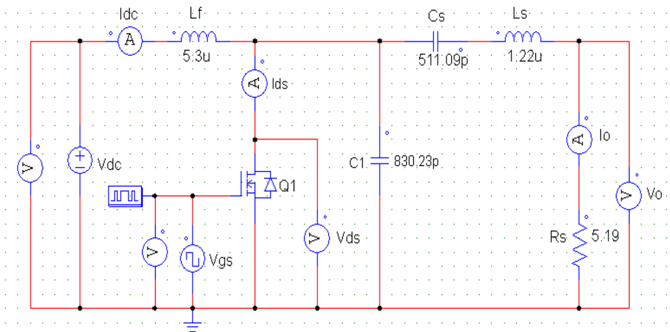
Simulation Result

This section discusses the simulations conducted on the Class-E resonant inverter design. The main aim of the simulations was to study the inverter switching performance and to analyze the voltage and current waveform interactions, including the performance of the inverter during the specified operating conditions. The performance of the inverter was evaluated in both configurations in PSIM and the results were validated.

Simulation Without Impedance Matching

This section the Class-E resonant inverter without impedance matching is discussed. The PSIM simulated circuit of the Class-E resonant inverter design without impedance matching is shown in Figure 5 and the corresponding component values. This circuit was configured for analyzing input and output waveforms and for evaluating the switching performance and resonant operations of the inverter. The simulation was conducted to analyze the overall efficiency of the inverter while also verifying the operation of soft-switching.

Fig. 5. Class -E Resonant Inverter Circuit Schematic



From Figure 6 the input voltage is nearly constant at 12 V and the input current is averaged at 1.4 A. The slightly sinusoidal nature of the current injection suggests the power draw is in fact smooth at 6.78 MHz.The output waveforms V_o and I_o in Figure 7 are in phase and sinusoidal with RMS values of V_o is 9.26 V and I_o is 1.78 A, which indicates that power is being stably delivered to the load.

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Fig. 6. Input Voltage and Current

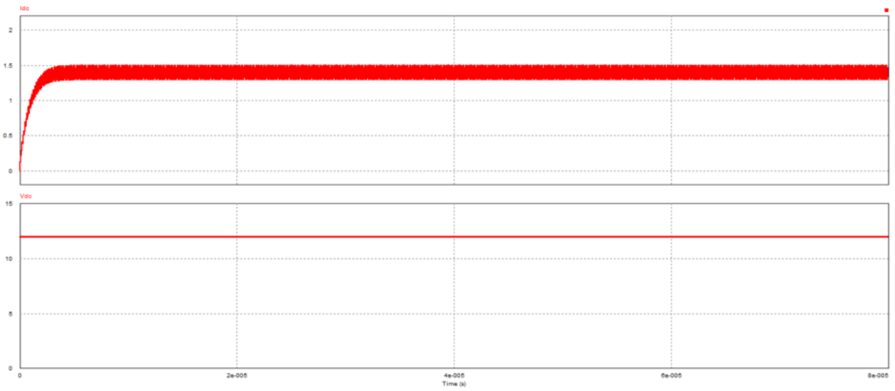
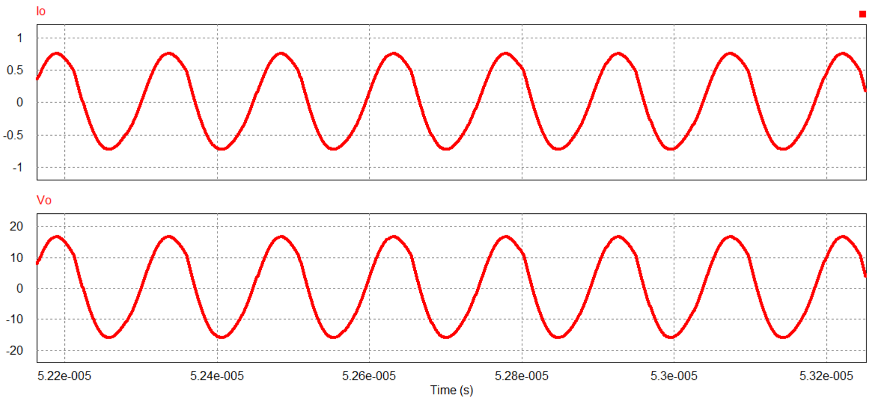
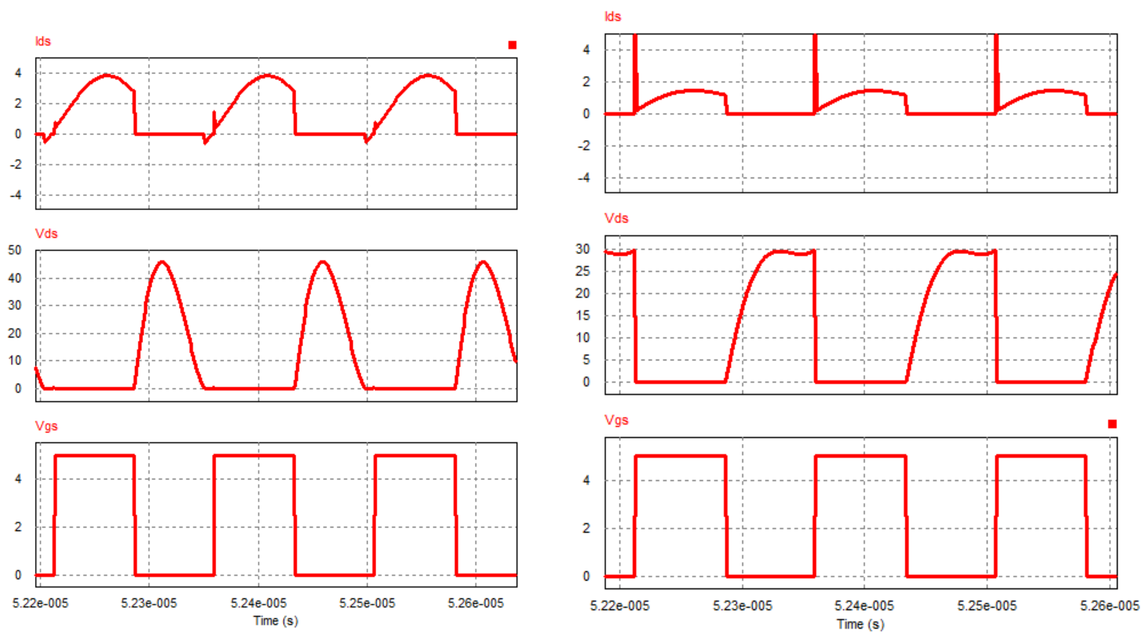


Fig. 7. Output Voltage and Current



As shown in Fig. 8(a), the V_{ds} waveform drops to nearly zero before the MOSFET turns on, confirming that the inverter achieves proper ZVS soft-switching at the optimal load of 5.19 Ω. The corresponding V_{ds} and V_{gs} waveforms also support the presence of low switching stress and reduced switching loss, resulting in stable operation at 6.78 MHz with an efficiency of about 99.1%. However, when the load resistance increases to 22 Ω, as illustrated in Fig. 8(b), the ZVS condition becomes disrupted, with V_{ds} failing to reach zero at turn-on. This loss of soft-switching introduces higher switching stress and indicates impedance mismatch, which contributes to an efficiency drop to 74%. The following section demonstrates how incorporating a Class-E inverter with an appropriate impedance-matching network effectively restores ZVS and improves overall efficiency.

Fig. 8. Switching Waveforms



(a) 5.19Ω (b) 22Ω

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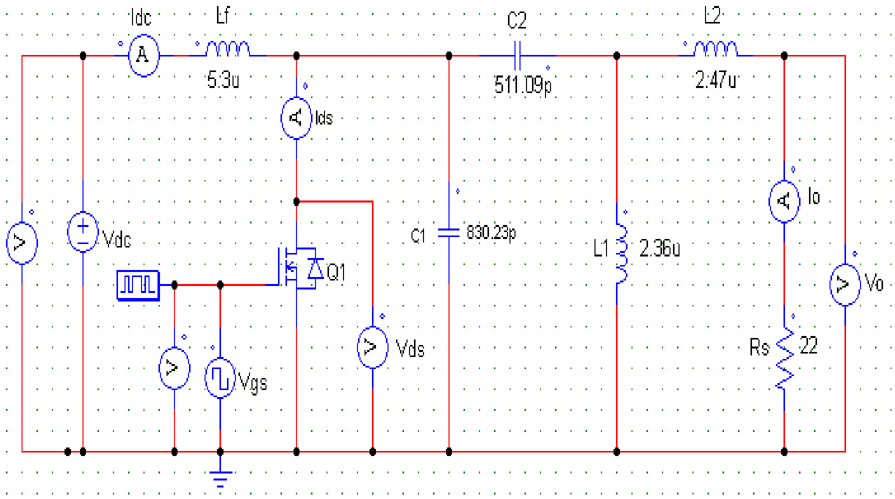
Table IV Comparison Between Theoretical and Simulation

Parameters	Theoretical	Simulation
I_{dc}	1.33A	1.39A
I_O	1.76A	1.78A
V_{dc}	12V	11.99V
V_O	9.11V	9.26V
$V_{ds\,(max)}$	42.74V	44.58.8V
$I_{ds\,(max)}$	3.81A	3.98A
P_{in}	16W	16.67W
P_o	16W	16.52W
η	100%	99.1%

Simulation With Impedance Matching

This section shows the simulation results for the Class E resonant inverter with a π2b impedance-matching network designed for optimal power transfer and loss minimization. Figure 9 depicts the Class E resonant inverter integrated with impedance matching designed in PSIM with the provided element values. The matching network has inductors L_1 is 2.36 µH and L_2 is 2.47 µH connected to a 22 Ω load and facilitating power transfer at 6.78 MHz.

Fig. 9. Circuit with Impedance Matching



As shown in Figure 10, the input voltage remains constant at 12 V and the input current is 1.42 A on average. The waveforms are smooth and stable. Figure 11 shows the output waveforms of V_o and I_o are sinusoidal and in phase at 19.19 V and 8.72 A on the average which indicates that the π2b matching network transfers power to the load efficiently with minimal loss.

Fig. 10. Input Voltage and Current

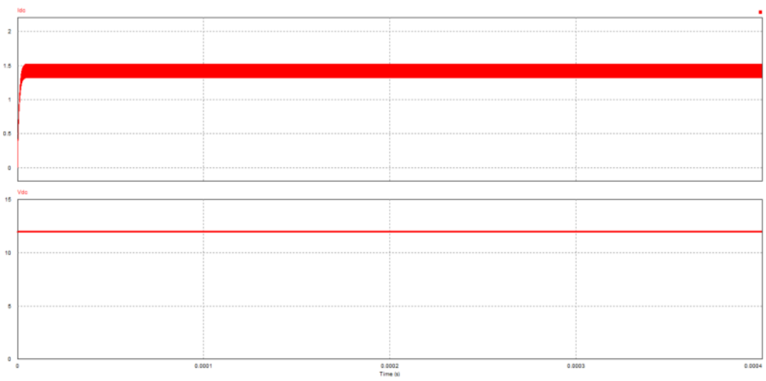


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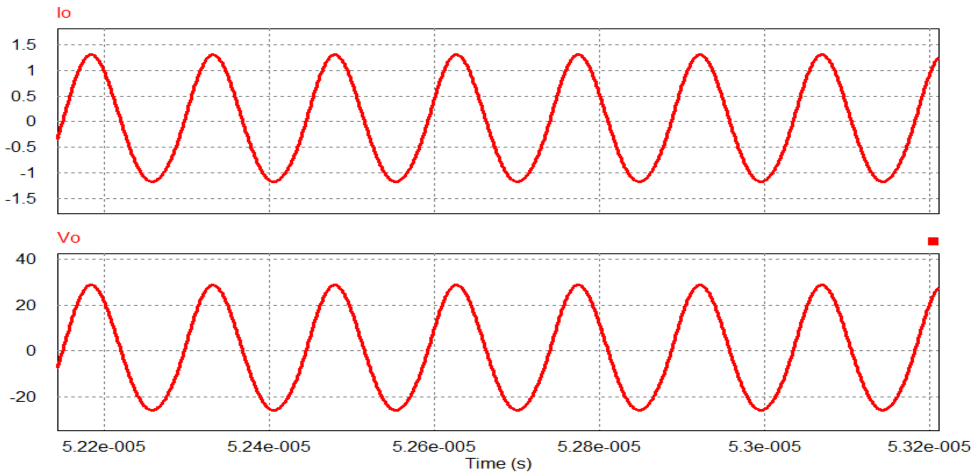
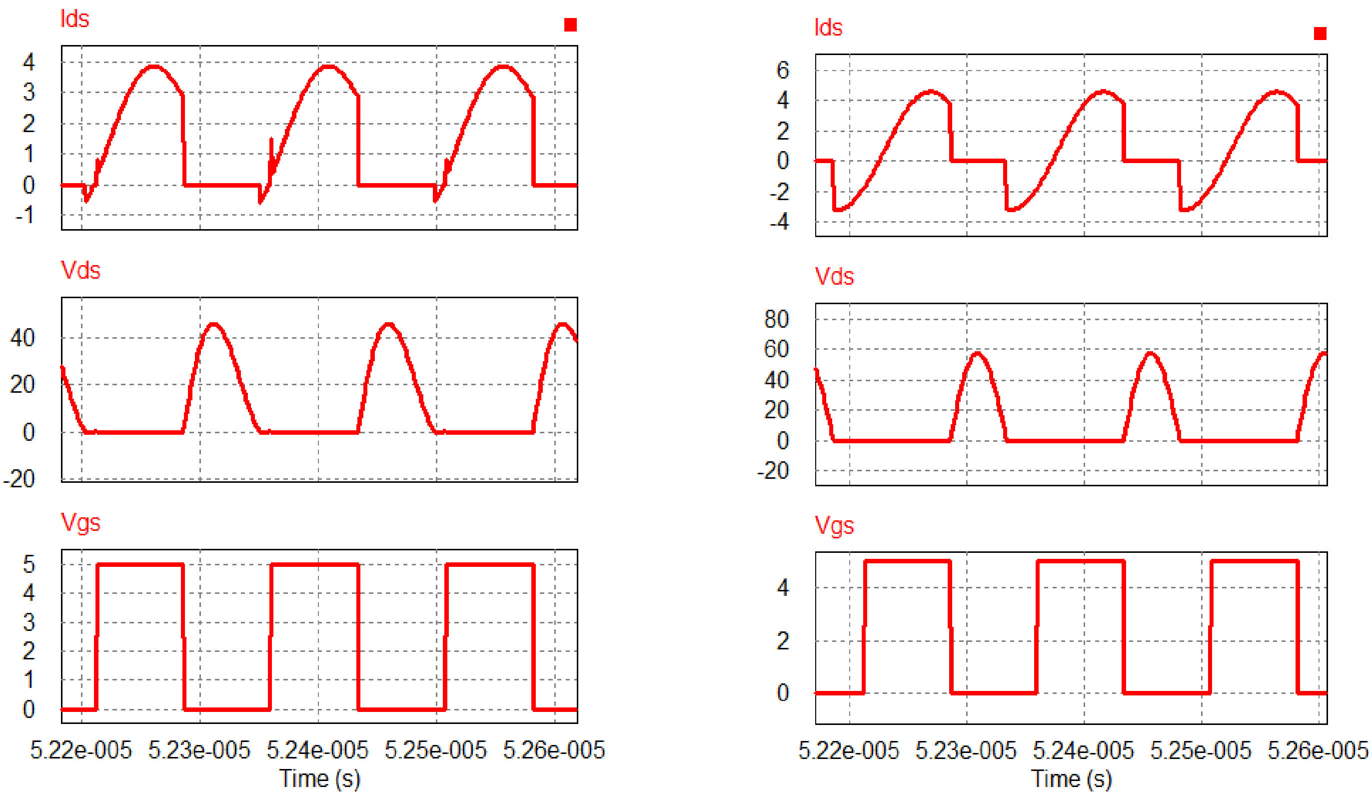
Fig. 11. Output Voltage and Current



As illustrated in Fig. 12, the V_{ds} approaches zero immediately prior to the MOSFET turn-on interval, thereby verifying ZVS. The drain current Ids and gate voltage Vgs waveforms exhibit well-defined and non-overlapping transitions, indicative of reduced switching stress and minimized switching loss. With the incorporation of an impedance-matching network, the Class-E inverter sustains high-efficiency operation at 6.78 MHz, achieving 98.2% efficiency even as the load resistance is varied from 5.19 Ω to 22 Ω. In contrast, the absence of impedance matching results in a degradation of efficiency to 74%, underscoring the critical role of proper impedance matching in maintaining optimal inverter performance under varying load conditions.

Fig. 12. Switching Waveforms



(a) 5.19Ω (b) 22Ω

Table V Comparison Between Theoretical and Simulation

Parameters	Theoretical	Simulation
I_{dc}	1.33A	1.39A
I_O	0.853A	0.872A
V_{dc}	12V	11.79V
V_O	18.76V	19.19V

$V_{ds\,(max)}$	42.74V	45.80V
$I_{ds\,(max)}$	3.5A	3.87A
P_{in}	16W	17.04W
P_o	16W	16.73W
η	100%	98.2%

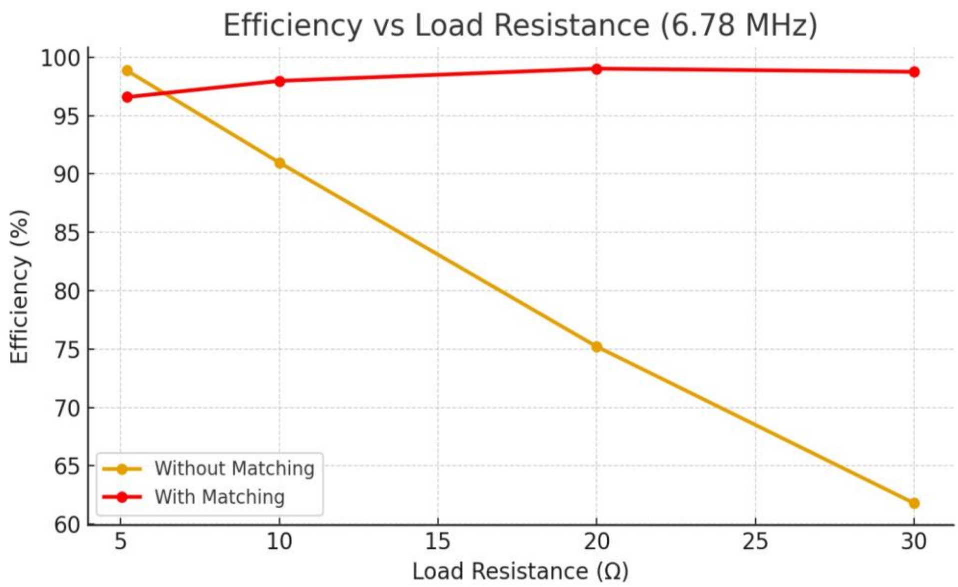
Load Variation And Efficiency Analysis

To evaluate the sensitivity of the inverter to load variations, the Class-E topology was analyzed under four resistive loads: 5 Ω, 10 Ω, 20 Ω, and 30 Ω, selected around the nominal design value of 22 Ω to represent realistic variations encountered in wireless power transfer applications. As shown in Fig. 13, the inverter without impedance matching exhibits a substantial reduction in efficiency when the load deviates from its design point. This degradation is attributed to severe impedance mismatch, which increases switching stress and elevates switching losses. Consequently, the efficiency drops from nearly 98% at 5 Ω to approximately 62% at 30 Ω.

In contrast, the inverter integrated with the π2b impedance-matching network maintains a consistently high efficiency in the 97–99% range across all evaluated load conditions. The matching network presents the inverter with the correct load impedance at 6.78 MHz, thereby minimizing reflection, improving impedance alignment, and ensuring effective power transfer.

Overall, the results in Fig. 13 confirm that the inclusion of the impedance-matching network significantly enhances the robustness of the wireless power transfer system by preserving stable, high-efficiency performance across varying load conditions.

Fig. 13. Efficiency vs. Load Resistance for Class-E Inverter



ANALYSIS AND DISCUSSION

Performance Comparison of Both Circuits

Simulation results indicate improvements in the efficiency of the type-E Class resonant inverter when an impedancematching network is added. The efficiency without matching was 74%. With the impedance-matching network π2b, the efficiency is 98.2%. The matching network facilitates inverter load impedance matching, which permits maximum power transfer 6.78 MHz. Even with the load resistance varying between 5.19 Ω and 22 Ω, the π2b adapts the impedancematching network to optimal performance.

Consequently, an impedance matching Class-E inverter operates with higher output power, more efficient energy use with lower losses, and output waveforms of less ripple. These results illustrate the impedance matching as an integral component to the performance and efficiency of Class-E inverters with regard to appliances incorporating wireless power transfer.

PROFESSIONAL ENGINEERING DISCUSSION

The performance of the Class-E resonant inverter was studied through simulation to ensure that the design meets both technical and professional engineering standards. The inverter functions at 6.78 MHz, which falls within the regulation ISM frequency band hence ensuring no legal liabilities, and communication band disruption. The design also advocates for energy efficient operations by attaining ZVS, which minimizes switching losses and enhances efficiency. These ZVS techniques reduce the generation of heat and conserve energy, making the design more environmentally friendly and sustainable. The incorporation of reliable and enduring components that work safely within the prescribed engineering ethics of voltage and current proved responsible engineering judgment. The design of the system was underpinned by reliable calculations and successfully verified by simulation, thus demonstrating professionalism and technical competency as well as the strong pursue of sustainable engineering. The project also advocates for the improved use of power electronics design, advocating for cleaner and more sustainable power and energy use, which underpins the UN Sustainable Development Goal (SDG) 7, which is Affordable and Clean Energy.

Comparison Between Theoretical and Simulation

Tables IV and V present results comparing simulation and theoretical results for the Class-E resonant inverter, both with and without impedance matching. The results exhibit minimal disparity. In the case of the inverter without matching, the variation is in the range of approximately 2-3%, and for the matched circuit, the difference is under 2%. Such small discrepancies can primarily be attributed to component non-idealities and the switching losses accounted for in the simulation. In conclusion, the results validate the theoretical design and confirm the simulation results.

CONCLUSION

The Class E resonant inverter for WPT operating at 6.78 MHz was successfully designed, modelled, and simulated. Its performance was evaluated under both ideal and practical operating conditions. Under ideal, lossless assumptions, the inverter achieved an efficiency of 98.86% when driving a 5.19 Ω load. When practical non-idealities were introduced, including conduction, switching, and gate drive losses, the efficiency decreased to 74.1%. Further increases in load resistance to 22 Ω resulted in an efficiency of approximately 74%, primarily due to impedance mismatch and the associated loss of soft switching, which increased switching stress and contributed to overall performance degradation. The integration of the π^2b impedance matching network significantly enhanced system performance. With proper impedance matching, the inverter maintained ZVS conditions enabling stable operation at 6.78 MHz and improving efficiency to 98.2%. These results demonstrate that impedance matching is essential for maximizing power transfer efficiency, maintaining soft switching, and minimizing losses in high frequency WPT transmitters. Future work will focus on the hardware development, prototyping, and experimental validation of the proposed Class E π2b resonant inverter to further verify its performance under real-world operating conditions.

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