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Design of Buck Converter for Low Power Application: A Comparative Study for Selecting the Semiconductor Devices

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Abstract: *This paper presents a detailed analysis of semiconductor device selection for a buck converter, emphasizing the optimization of MOSFETs and diodes to enhance performance and efficiency. The study evaluates three MOSFETs (IRFZ44N, IRFZ46N, and Si4410DY) in combination with three diodes (MBRS340, MBR745, and B550C) to assess their influence on converter efficiency, voltage ripple, and output stability. Comprehensive calculations for passive components, including inductors and capacitors, are performed to ensure an optimal design for stepping down a 12V input to a 5V output with a 2A load. Simulations using LTspice provide insights into component behavior under varying conditions, enabling a comparison of performance metrics for different MOSFET-diode pairings. Additionally, the study includes a PCB layout design for the optimized buck converter, facilitating practical validation of the simulation results. The results highlight the best pairing based on voltage ripple, efficiency, and output stability. This study offers valuable guidelines for selecting semiconductor devices in buck converter designs, striking a balance between performance and cost-effectiveness.*

Keywords: Semiconductor Device, Efficiency, Voltage Ripple, Optimization Design

1. INTRODUCTION

The buck converter is a widely utilized DC-DC converter that efficiently steps down voltage levels for various applications, including consumer electronics, industrial systems, and renewable energy systems. Its performance is significantly influenced by the selection of semiconductor devices, particularly the MOSFET and the diode. Optimal component selection is crucial for achieving high efficiency, stable operation, and minimal thermal losses.

Several studies have examined the performance of buck converters with different semiconductor devices. For instance, a study by S. S. S. R. Depuru et al. [1] investigated the impact of various MOSFET-diode pairings on the efficiency and thermal performance of a buck converter, highlighting the trade-offs between cost and efficiency. MOSFETs, being the primary switching elements in converters, determine the efficiency and thermal behavior due to their conduction and switching losses. Research in [2] emphasizes that MOSFETs with lower ON-State resistance $R_{DS(on)}$and gate charge are preferred for high-frequency applications. On the other hand, M. H. Rashid [3] highlighted the influence of diode characteristics on voltage ripple and power dissipation, demonstrating that Schottky diodes outperform standard diodes in high-frequency converters.

Additionally, passive components, including inductors and capacitors, play a critical role in maintaining voltage stability and current ripple. The design of these components must align with the desired specifications of the converter, such as output voltage ripple and peak inductor current ripple. Detailed design considerations for selecting inductors and capacitors to achieve

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optimal performance in high-frequency converters are well-documented [4].

In this study, the focus is on designing a buck converter with a load current of 2A, an input voltage of 12V, and an output voltage of 5V. The design aims to maintain stringent performance criteria, including a voltage ripple of 0.5% and an inductor current ripple of 5%. Using LTspice, the performance of three MOSFETs (IRFZ44N, IRFZ46N, and Si4410DY) and three diodes (MBRS340, MBR745, and B550C) is evaluated through simulation. The results are analyzed to determine the optimal MOSFET-diode pairing, providing practical insights for improving the efficiency and stability of buck converter designs.

2. ANALYSIS OF BUCK CONVERTER

2.1 Principle of Operation

The buck or step-down converter is a type of DC-DC power converter that converts its DC input voltage to another DC voltage that is lower than the input voltage value while maintaining high efficiency [5]. It is widely used in applications like power supplies for electronics, battery chargers, and voltage regulation systems.

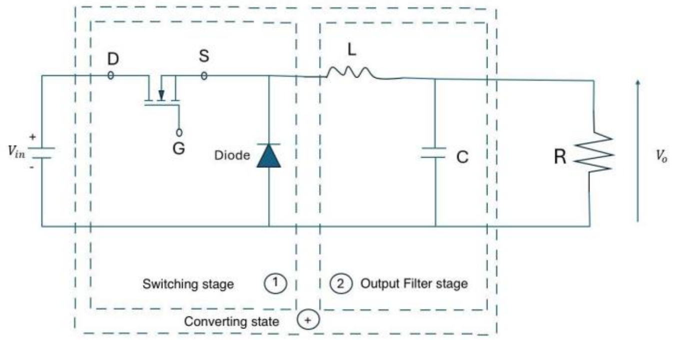


Fig. 1. Buck converter topology

The buck converter from source to load is divided into two stages: the switching stage and the output filter stage. Together, they make up the "converting state," as shown in Fig 1, which governs the transition of energy from the input to the output.

The switching stage is responsible for controlling the flow of energy from the input source. It consists of a switch (typically a MOSFET) and a diode. It is used to stabilize the required output voltage by continuously turn ON/OFF of switching device.

The output filter stage is designed to smooth the pulsed energy coming from the switching stage, providing a steady voltage to the load. It consists of an inductor (L) and a capacitor (C). Together, the inductor and capacitor form a low-pass filter that eliminates the high-frequency switching components, delivering a clean DC output to the load.

The buck converter consists of two operation modes, which are continuous conduction mode (CCM) and discontinuous conduction mode (DCM). The key to the analysis for determining the output V_o is to examine the inductor current and inductor voltage first for the switch closed (CCM). The average inductor voltage is zero (as seen in Fig. 2a). Moreover, as illustrated in Fig. 2c, the net change in capacitor current over one period must be zero for steady-state operation.

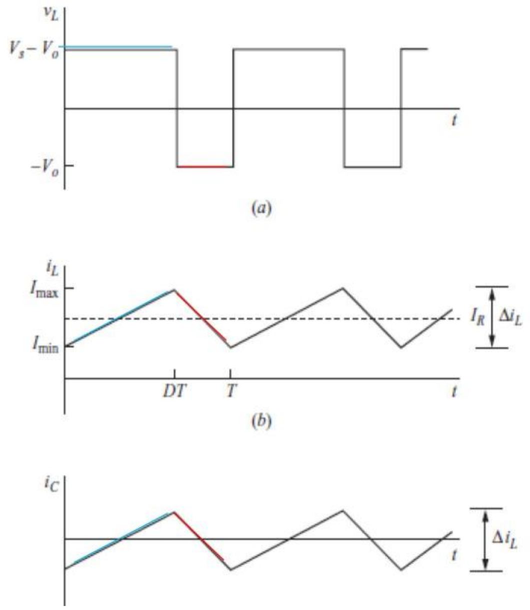


Fig. 2. The graph of inductor voltage, current, and capacitor current, when operating in CCM.

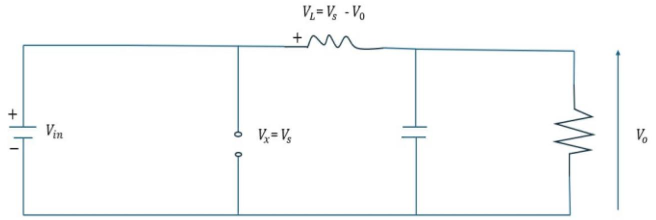


Fig. 3. Equivalent circuit of the buck converter for Switch-ON operation

Switch-ON Operation: As shown in Fig. 1, a diode is in a reverse-biased (OFF-State) during the turn-ON interval of the main MOSFET. Fig. 3 demonstrates an equivalent circuit of the buck converter during switch-ON operation of the MOSFET. By applying Kirchhoff's Voltage Law (KVL), the voltage across the inductor can be derived as follows:

$$v_L = V_{in} - V_o = L\frac{di_L}{dt} \tag{2.1}$$

$$\frac{di_L}{dt} = \frac{V_{in} - V_o}{L}, \tag{2.2}$$

From equation (2.1), the inductor current ripple can be obtained as presented from equations (2.2) to (2.4). Because of buck converter is used to step down the voltage, the term ($V_{in} - V_o$) is always positive, which leads to a rising current, from minimum to maximum (Fig. 2), during turn-ON interval. As a result, the inductor voltage is positive, the inductor stores the energy for being used in the next turn-OFF operation.

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_{in} - V_o}{L} \qquad (2.3)$$

$$(\Delta i_L)_{ON} = \left(\frac{V_{in} - V_o}{L}\right) DT \qquad (2.4)$$

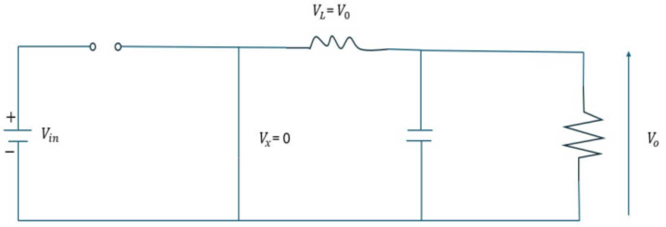


Fig. 4. Equivalent circuit of the buck converter for Switch-OFF operation

Switch-OFF Operation: When the switch is open, the diode becomes forward-biased to carry the inductor current. Fig. 4 shows the equivalent circuit of the buck converter during switch-OFF interval. According to KVL, the voltage across the inductor when the switch is open is:

$$v_L = -V_o = L\frac{di_L}{dt} \qquad (2.5)$$

Rearranging

$$\frac{di_L}{dt} = \frac{-V_o}{L}\ , \quad \text{Switch OFF} \qquad (2.6)$$

The derivative of current in the inductor is a negative constant, and the current decreases linearly as shown in Fig. 2b. The change in inductor current when the switch is open is:

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{-V_o}{L} \qquad (2.7)$$

$$(\Delta i_L)_{OFF} = -\left(\frac{V_o}{L}\right)(1-D)T \qquad (2.8)$$

Steady-state operation requires that the inductor current at the end of the switching cycle be the same as that at the beginning, meaning that the net change in inductor current over one period is zero.

$$(\Delta i_L)_{ON} + (\Delta i_L)_{OFF} = 0 \qquad (2.9)$$

Using eq. (2.4) and (2.8),

Solving for Vo,

$$V_o = V_{in}D \qquad (2.10)$$

From [6], the equations to express the required inductance and capacitance in terms of specified peak-to-peak inductor current and voltage ripple are given below:

$$L = \frac{V_s - V_o}{\Delta i_L f} \times D \qquad (2.11)$$

$$C = \frac{1-D}{8L\left(\frac{\Delta V_o}{V_o}\right) f^2} \qquad (2.12)$$

Efficiency for buck converter is given below equation

$$\eta = \frac{P_o}{P_{in}} \times 100 \qquad (2.13)$$

Input and output power

$$P_{in} = V_{in}.I_{in} \qquad (2.14)$$

Or

$$P_{in} = P_o + P_{loss,\ total} \qquad (2.15)$$

$$P_o = V_o I_o \qquad (2.16)$$

2.2 Devices' Sizing

In buck converters, proper sizing and selection of devices such as switches, diodes, inductors, and capacitors are crucial for achieving optimal performance, efficiency, and reliability. The key considerations include power handling capacity, thermal performance, switching speed, and electrical characteristics like voltage and current ratings.

The Specification of the buck converter for this application are detailed in Table 1:

Table 1: Specification for Design Buck converter

The load current, Io	2A
Input voltage, Vin	12V
Output voltage, Vo	5V
ΔVo	0.5% of Vo
ΔiL	5% of Io (peak)
Duty Circle	0.416
Switching Frequency	100kHz

2.2.1 Selection of MOSFET

MOSFETs must handle peak currents and voltages while minimizing switching and conduction losses.
Based on the specification of the application, the MOSFET must:

- Handle the input voltage $V_{DS} \geq V_{in}$, so choose a MOSFET with a voltage rating of at least 20V. A 30V or 40V MOSFET is safer.
- Conduct the peak inductor current ($I_{peak} = I_o + \frac{\Delta I_L}{2} = 2 + 0.05 = 2.05A$). Choose a MOSFET rated for at least 4A.
- Have a low $R_{DS(on)}$ to minimize conduction losses.

- Switch efficiently at the desired switching frequency.

The IRFZ44N, IRFZ46N, and Si4410DY are widely used in switching applications. It provides high current capacity and a low on-resistance, which are ideal for reducing losses in this DC-DC converter design. Basic information about each MOSFET is given in Table 2.

Table 2: Specification of MOSFET

MOSFET Model		IRFZ44N	IRFZ46N	Si4410DY
Package	Type	TO-220AB	SOT96-1	TO-220AB
Characteristics	V_{DS}	55V	30V	60V
	Temperature	-55 to 175 ºC	-55 to 175 ºC	-55 to 150 ºC
	$R_{DS\text{-}on}$	28mΩ	16.5mΩ	16.5mΩ
	Charge	67nC	72nC	60nc

2.2.2 Selection of Diode

Diodes (or synchronous rectifiers) should support the converter's current and reverse voltage, with low forward voltage drops to improve efficiency.

For this buck converter, the diode must withstand the reverse voltage (Vin = 12 V), so choose a diode with a voltage rating of at least 20V for a safety margin and the diode must handle the average current (Io = 2 A), so choose a diode with a current rating of 2–3A.

The MBRS340, MBR745, B550C are good choices as they meet the voltage and current requirements while maintaining efficiency with a low forward voltage drop. Schottky diodes like this are commonly used in DC-DC converters. The specification of each diode is given in Table 3.

Table 3. Specification of Diode

Diode Model		MBRS340	MBR745	B550C
Package	Type	Schottky	Schottky	TO-220AB
Characteristics	V_{RRM}	40V	45V	60V
	I	4A	7.5A	5A
	V_d	0.5V	0.75V	0.70V
	$I_{leakage}$	1mA	100μA	0.5mA

2.2.3 Inductor's Calculation

Inductors play a critical role in energy storage and current ripple control, necessitating proper inductance value selection and attention to core saturation limits.

From the above specification, the inductor must be calculated by eq. (2.11) and the result must be chosen $L = 291.2\ \mu H$.

Choose for Standard Values: Inductors are typically available in standard E-series values such as 270 μH, 300 μH, etc.
Recommendations: Choose for the next higher standard value a 300 μH inductor is a practical choice because it ensures the current ripple is slightly lower than designed, which is safer for most applications [7]. Ensure the inductor's current rating exceeds the maximum current of buck converter will handle. This prevents saturation. DCR (DC Resistance): Look for an inductor with low DCR to minimize conduction losses.

2.2.4 Capacitor's Calculation

Capacitors filter voltage ripples and stabilize the output; they require appropriate values and low equivalent series resistance (ESR). The capacitor is calculated by eq. (2.12) and the result is $C = 5.01\ \mu F$.

Choose for Standard Values: Capacitors are available in standard values like 4.7 μF, 5 μF, and 6.8 μF.
Recommendations: Select a 6.8 μF capacitor for better filtering, especially in applications with high output ripple. The capacitor's voltage rating should be at least 1.5–2 times the output voltage of the buck converter [8]. Use a ceramic capacitor (e.g., X7R or X5R dielectric) for low ESR (Equivalent Series Resistance) and better high-frequency performance.

The important simulation parameters are listed in Table 4. These parameters will be used later in designing the buck converter.

Table 4. Buck converter after calculated parameter

Component	**Value**
Switch (MOSFET)	IRFZ44N, IRFZ46N, Si4410DY
Diode	MBRS340, MBR745, B550C
Capacitor	6.8 μF
Inductor	300 μH
Resistance Load	2.5 Ω

2.3 Simulation and Comparison Results

The simulations were conducted to obtain an initial perspective on the characteristics of the proposed buck converter. Several simulations were organized to demonstrate the operation of the proposed design. These simulations were executed using LTSpice software, where the combination of diode and MOSFET was employed to evaluate and optimize the performance of the buck converter. This approach allowed to analyse the output voltage behaviour and efficiency to identify the best configuration for the desired application. The circuit diagram of the proposed buck converter is shown in Fig. 5.

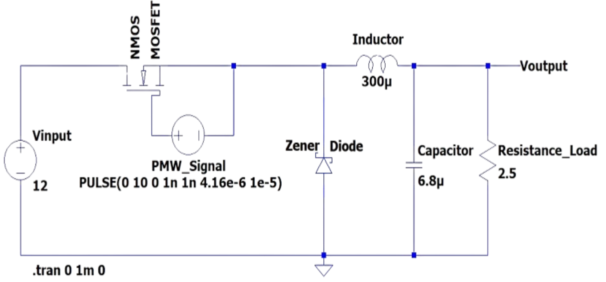


Fig. 5. Buck converter in a spice model.

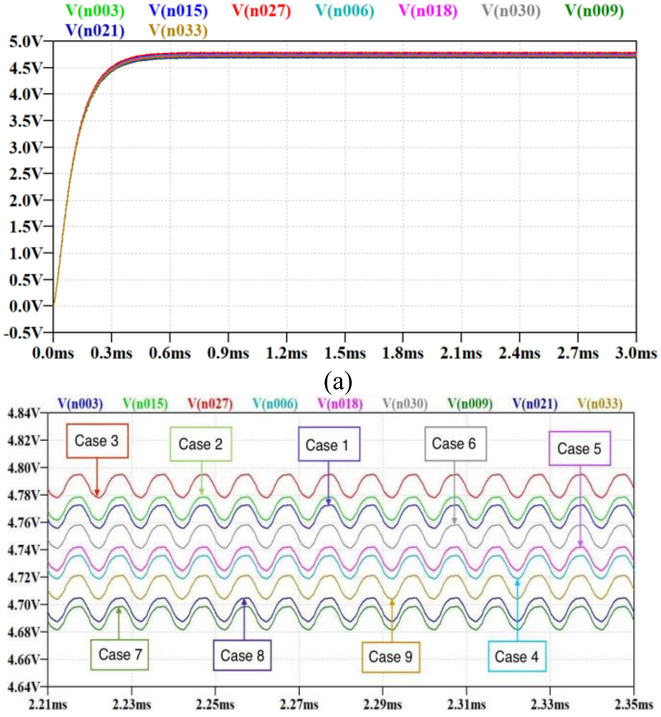
2.3.1 Simulation results with different Semiconductor Devices

The procedure of simulation divides into nine cases as shown in Table 5, which include 9 circuits simulation for analyze the result. The simulation results of the buck converter in LTspice for all case are shown in Fig. 6 (a), (b) respectively. The zoomed-in results demonstrate the buck converter's ability to maintain a low output voltage ripple across all cases. The ripple amplitude is consistent for all MOSFET-diode pairings, indicating effective filtering of switching noise. However, slight variations in ripple phase and amplitude between cases suggest subtle differences in component performance. These variations impact the final component selection when prioritizing efficiency, thermal behavior, or cost. Overall, the results confirm stable operation with minimal ripple as given specification, approximately meeting the design objectives for a 5V output.

Table 5. The combination of diode and MOSFET for each case

Case	**MOSFET**	**DIODE**
1	IRFZ44N	MBRS340
2	IRFZ46N	MBRS340
3	Si4410DY	MBRS340
4	IRFZ44N	MBR745
5	IRFZ46N	MBR745
6	Si4410DY	MBR745
7	IRFZ44N	B550C
8	IRFZ46N	B550C
9	Si4410DY	B550C

On the other hand, the simulation can provide the average value of current and voltage, which are useful for calculating the power and efficiency of each case. The efficiency, input power, and output power are calculated from equations 2.13, 2.14, and 2.16. The result of all cases is shown in Table 6.



(b)

Fig. 6. Simulation results of output voltage for all cases: a) Not zoomed for time interval 0 to 3 ms, b) Zoomed in, for time interval 2.21 to 2.35 ms

Table 6: Average value of simulation

Case	Vin (V)	Iin (A)	Pin (W)	Vo (V)	Io (A)	Po (W)	Efficiency (%)
1	12	0.788	9.456	4.7104	1.8842	8.8753	93.8593
2	12	0.79	9.48	4.7165	1.8866	8.8981	93.8623
3	12	0.795	9.54	4.7324	1.893	8.9584	93.9039
4	12	0.782	9.384	4.674	1.8696	8.7385	93.1213
5	12	0.784	9.408	4.6801	1.872	8.7611	93.1244
6	12	0.789	9.468	4.696	1.8784	8.8209	93.1661
7	12	0.757	9.084	4.512	1.8048	8.1432	89.6439
8	12	0.759	9.108	4.5181	1.8073	8.1655	89.6526
9	12	0.764	9.168	4.5332	1.8133	8.2200	89.6602

2.3.2 Simulation Results and Discussions

Table 6 offer valuable insights into the performance of the nine combinations of MOSFETs and diodes in the buck converter. Efficiency, output voltage, output current, and output power were key evaluation metrics. Among these, Cases 1 to 6, using MBRS340 and MBR745 diodes, demonstrated better performance, achieving efficiencies consistently above 93%. In contrast, Cases 7 to 9, which employed the B550C diode, had lower efficiencies, averaging around 89.65%. This highlights the impact of the diode's forward voltage drops and switching characteristics on overall performance.

Case 3, which combines the Si4410DY MOSFET with the MBRS340 diode, stands out as the optimal configuration. It achieves the highest efficiency of 93.9039%, an output power of 8.958 W, and an output voltage of 4.732 V. The superior performance of this pairing can be attributed to the Si4410DY’s low $R_{DS(on)}$ and gate charge, which minimize switching losses, and the MBRS340's lower forward voltage drop of 0.5 V, which reduces conduction losses. Other configurations, such as Cases 2 and 6, also performed well but fell slightly short of Case 3 in terms of output voltage and power.

The performance of diodes and MOSFETs was a critical determinant of the results. The MBRS340 and MBR745 diodes consistently outperformed the B550C, whose higher forward voltage drop (0.7 V) resulted in increased power losses. Similarly, the Si4410DY MOSFET proved to be the most efficient among the three MOSFETs tested, with the IRFZ46N and IRFZ44N also delivering reasonable but lower performance.

The combination of the Si4410DY MOSFET and MBRS340 diode (Case 3) is the most efficient and effective configuration for the buck converter. This pairing delivers optimal output power, voltage stability, and minimized losses, making it the ideal choice for applications requiring a 5 V output from a 12 V input with a 2 A load. The results underscore the importance of selecting components with high efficiency and low switching and conduction losses for DC-DC converter designs.

2.4 PCB design

After selecting the best pair of MOSFET and diode, we start to design PCB for our buck coverter. We use 555 timer circuit to generate 100kHz frequency to controll our MOSFIT. We design the circuit on Kicad software, a well-known software for engineer design.

Calcution the track width: If we specitfy the maxmum current, then the trace widths should be calculate to suit.The maximum current it can handle will we calculated in the formula from IPC 2221:

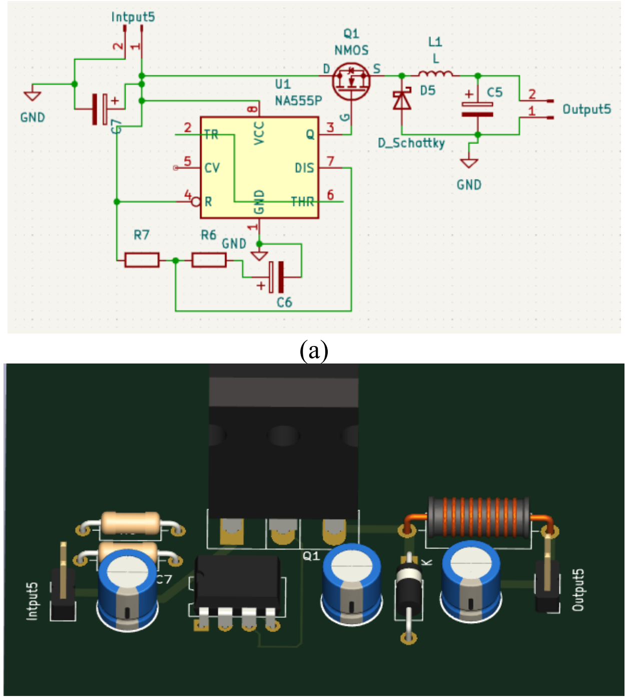
$$I = K \cdot \Delta T^{0.44} \cdot (W \cdot H)^{0.725} \tag{2.17}$$

Where:
I is the maximum current is A
ΔT is the temperature rise above ambient in ℃
W is the width in mils
H is the thickness (height) in mils
K is 0.024 for internal traces or 0.048 for external traces

These calculations are valid for currents up to 35A (external) or 17.5A(internal). temperature rise up to 100℃ and widths of up to 400 mils(10mm). For safty reason we calculation the track width with the maximum current 20% to 35% of initail current. In this paper we need the output current 2 A, so the track width must be calculate as describe above. The data of the footprint given in Table 7. Fig. 7 presents the PCB design of the converter.

Table 7: The footprint dimension of our component.

Name	Model	Foot print(mm)
MOSFET	Si4410DY	0.46
Diode	MBRS340	0.77
Inductor	300mH	1.44
Capator	6.8uF	0.46



(a)

(b)

Fig. 7. PCB design result: a) circuit diagram, b) 3D Model of PCB Design of buck converter with 555 timer.

3. CONCLUSIONS

This study thoroughly evaluated the performance of nine combinations of MOSFETs and diodes in a buck converter designed to step down a 12 V input to a 5 V output at a 2 A load. The analysis focused on key performance metrics, including efficiency, output voltage, output current, and output power. Among the tested configurations, the combination of the Si4410DY MOSFET and MBRS340 diode emerged as the most efficient and effective, achieving a peak efficiency of 93.9%, an output voltage of 4.732 V, and an output power of 8.958 W. The findings underscore the critical influence of component characteristics, such as the forward voltage drop of diodes and the $R_{DS(on)}$ and gate charge of MOSFETs, on the overall performance of DC-DC converters. The Si4410DY MOSFET, with its low switching and conduction losses, and the MBRS340 diode, with its minimal forward voltage drop, proved to be the optimal pairing for this application. In contrast, configurations using the B550C diode exhibited reduced efficiency due to higher conduction losses. Additionally, the inclusion of a PCB design for the optimized buck converter enabled practical implementation and validation of the simulation results. This step further emphasized the feasibility of the proposed design and its alignment with real-world applications. make it more easy to understand

This research highlights the importance of strategic component selection in achieving high efficiency and performance in power electronic systems. The insights gained from this study can serve as a valuable reference for future DC-DC converter designs, especially in applications requiring efficient and reliable voltage regulation under varying load conditions.

RFERENCES

[1] S. S. S. R. Depuru, M. S. S. R. Depuru, and S. S. S. R. Depuru, "Design and Simulation of Synchronous Buck Converter in Comparison with Regular Buck Converter," *IJRCS*, vol. 8, no. 2, pp. 1-6, 2018.
[2] B. J. Baliga, *Power Semiconductor Devices*, 2nd ed., Prentice Hall, 2010, pp. 210-212.
[3] M. H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, 4th ed., Pearson, 2014, pp. 345-347.
[4]. J. M. Rivas et al., "Design Considerations for Very High Frequency DC-DC Converters," in *Proc. IEEE Power Electronics Specialists Conf.*, pp. 2287-2293, Jun.2006.
[5] S. N. Manias, *Power Electronics and Motor Drive Systems*. Oxford, UK: Academic Press, 2017, pp. 501.
[6] Daniel Hart, D. W. (2011). Power electronics. New York, NY: McGraw-Hill. , pp. 198–205
[7] Erickson, R. W., & Maksimovic, D. (2001). *Fundamentals* of power electronics (2nd ed.). Springer.
[8] Texas Instruments. (2011). Optimizing capacitor selection for DC/DC converters. Retrieved from https://www.ti.com/lit/an/slta055/slta055.pdf