Basic Boost Converter — Step-Up DC–DC Conversion

This paper is part of the Power Electronics Learning Portfolio, a self-study documentation series.

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Abstract

This paper explains the basic operation of a Boost Converter, a DC–DC converter used to step up voltage efficiently.
Using PSIM simulation, a 25 V input is converted to 50 V output under open-loop PWM control.
The purpose is to understand how switching, inductance, and capacitance values affect the transient response, ripple, and output stability.

Introduction

A Boost Converter is one of the essential DC–DC converter topologies that steps up a lower DC voltage to a higher level.
It operates by storing energy in an inductor during the switch ON period and releasing it through the diode to the output during the OFF period.
In this experiment, a Boost Converter circuit was simulated in PSIM to observe the effect of duty ratio, inductance, and capacitance on output voltage and startup behavior.

Basic Principle

Operating Modes

When the switch is ON:
The inductor stores energy from the source, and the diode is reverse-biased, isolating the load.

$$V_L = V_{in}$$

When the switch is OFF:
The inductor's stored energy is released through the diode to the load, adding to the input voltage.

$$V_L = V_{in} - V_{out}$$

The average output voltage is given by:

$$V_{out} = \frac{V_{in}}{1 - D}$$

Example: For $V_{in} = 25V$and $D = 0.5$, $V_{out} \approx 50V$.

Circuit Parameters

PARAMETER	SYMBOL	VALUE	DESCRIPTION
INPUT VOLTAGE	(Vin)	25 V	Supply voltage
LOAD RESISTANCE	(R)	5Ω	Represents load
INDUCTOR	(L)	1mH	Controls current ripple
CAPACITOR	(C)	100μF	Smooths output voltage
SWITCHING FREQUENCY	(fs)	5 kHz	Determines ripple and loss
DUTY CYCLE	(D)	0.5	Target ratio for 2× boost

The parameters were selected to balance visible transient response with stable operation and moderate ripple for waveform observation.

Simulation Results

The PSIM simulation circuit is shown in Figure 1, and the output voltage/current waveforms in Figure 2.

- Average output voltage stabilized around 50 V.
- Initial overshoot occurred, peaking around 58 V

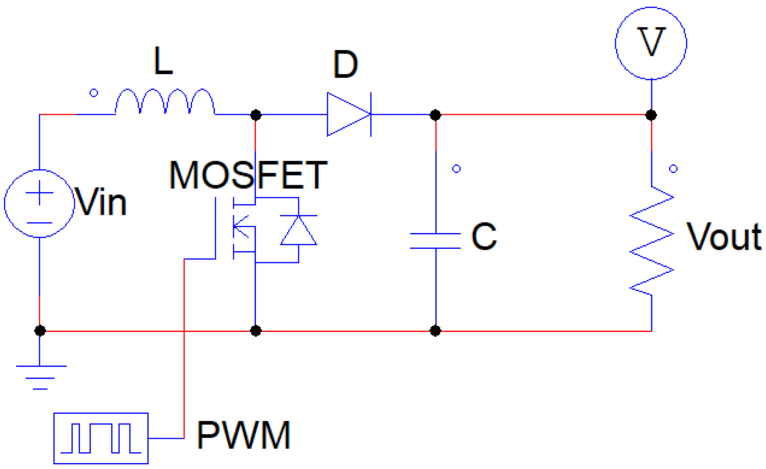

Figure 1

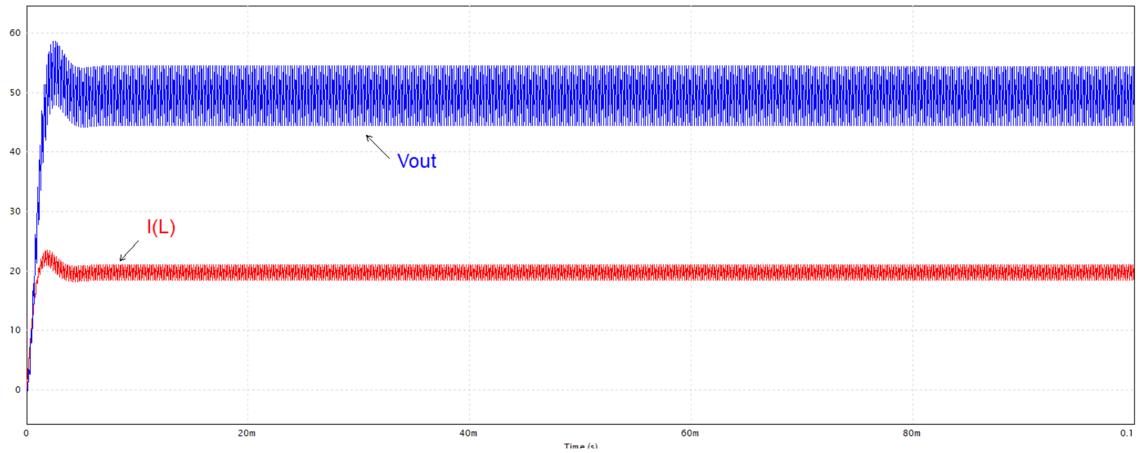

Figure 2

Discussion

In the simulation, the startup overshoot was mainly influenced by the inductor (L) and capacitor (C) combination.
At $L = 1$ mHand $C = 100\ \mu$F, the output voltage initially rose rapidly but showed a noticeable overshoot before stabilizing near 50 V.
To improve damping and reduce the transient peak, the switching frequency was increased from 5 kHz to 20 kHz, the inductor was enlarged to 5 mH, and the capacitor was increased to 200 μF.

Under these new parameters, the converter exhibited a fully stable startup with no overshoot and a smooth exponential rise to steady-state as shown below in Figure 3.
The higher switching frequency reduced inductor current ripple, the larger inductance slowed the current ramp for better energy control, and the larger capacitor effectively absorbed transient energy, minimizing voltage fluctuation.

This combination created a critically damped response, demonstrating that stability in a Boost Converter can be greatly improved by optimizing switching frequency and energy storage components rather than simply lowering capacitance.

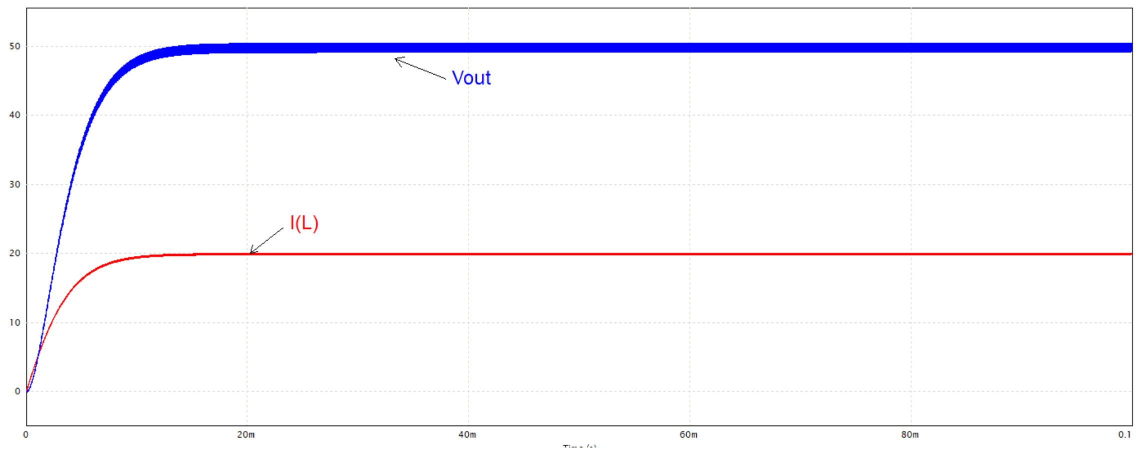

Figure 3

Conclusion

Through PSIM simulation, the Boost Converter's ability to step up voltage was successfully demonstrated.
Starting from $V_{in} = 25$ V, the circuit achieved approximately $V_{out} = 50$ V, confirming the theoretical gain relationship $V_{out} = \frac{V_{in}}{1-D}$.

At lower switching frequency (5 kHz) and smaller components ($L = 1\text{mH}, C = 100\ \mu\text{F}$), the circuit exhibited noticeable overshoot at startup due to high inductor current ripple and weak damping.
By increasing the frequency to 20 kHz, the inductance to 5 mH, and the capacitance to 200 µF, the converter achieved a stable, overshoot-free, and well-damped response.

These results confirm that increasing switching frequency and energy storage components (L and C) significantly enhances transient stability by reducing both current and voltage ripple.
For practical implementation, this highlights the importance of selecting parameters that balance dynamic response, efficiency, and component stress.
Future work may include adding closed-loop voltage feedback or soft-start control to achieve consistent behavior under varying loads and input voltages.