Circuit Simulation Project

https://esim.fossee.in/circuit-simulation-project

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Title of the circuit: Two switch DC to DC buck-boost converter

Theory:

Non-Inverting Buck-Boost Converter with Manual Control:

This converter employs an NPN transistor (usually used as a switching element) and operates in non-inverting mode. It means that the output voltage remains in the same polarity as the input voltage. The converter can step up (boost) or step down (buck) the input voltage based on the manual control of the switching element.

NPN Transistor Switching: The NPN transistor serves as the switching element in the converter. When the transistor is on, current flows from the input source to the output load. When it's off, the current ceases.

Non-Inverting Operation: In the non-inverting mode, the output voltage is of the same polarity as the input voltage. So, if the input voltage is increased, the output voltage increases as well, and vice versa.

Manual Control: Unlike feedback-controlled converters, which adjust the switching based on the output voltage, this converter relies on manual control. This could involve manually opening or closing the switch to achieve the desired output voltage. However, manual control might not be as precise or efficient as closed-loop control systems.

Open Loop Operation: Since there's no feedback mechanism to regulate the output voltage, the converter operates in an open-loop configuration. This means that the output voltage depends solely on the manual adjustment of the switching element. While this simplicity may be advantageous in some scenarios, it could lead to less accurate voltage regulation.

Overall, this type of converter can be useful in applications where manual control suffices, or where simplicity and cost-effectiveness are priorities.

- Simplicity: Easy to implement and operate due to manual control.
- Cost-Effective: Minimal components result in lower production costs.
- Versatility: Flexible voltage output suits various applications with manual adjustment.

Applications:

- Portable chargers for outdoor activities.
- Emergency backup power sources.
- Low-cost voltage regulators for small-scale electronics.

1. Modes of Operation:

A. Buck Mode
B. Boost Mode

Circuit Diagram:

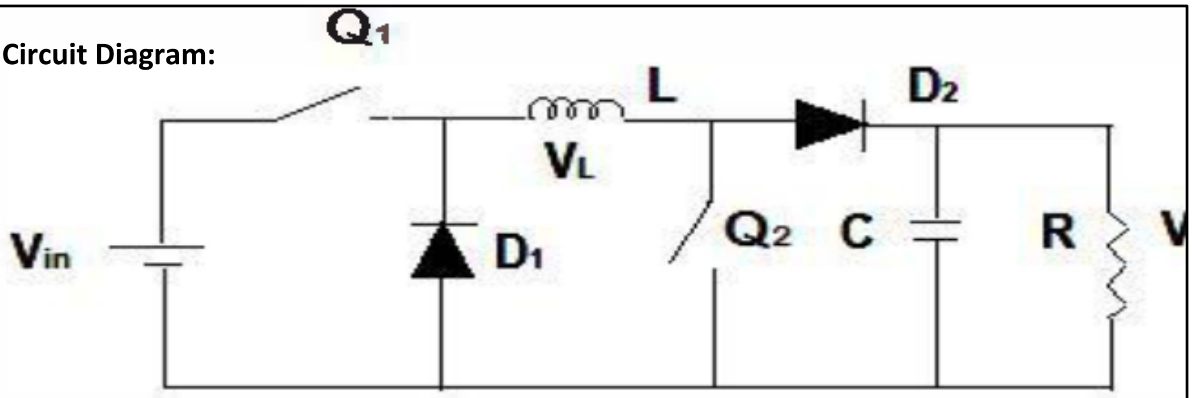

Figure 1: Two switch DC to DC buck-boost converter

A. In buck mode, Q2 switch is controlled to be always OFF, and output voltage is regulated by controlling Q1 Switch as in a typical buck converter.

B. By keeping Q1 switch always ON, D1 is reverse biased and stays OFF, and the two-switch buck-boost converter then operates in boost mode.

2. E-sim Schematic Diagram:

The circuit schematic of Design of Non-inverting Two Switch DC to DC Buck Boost Converter in **eSim** is as shown below:

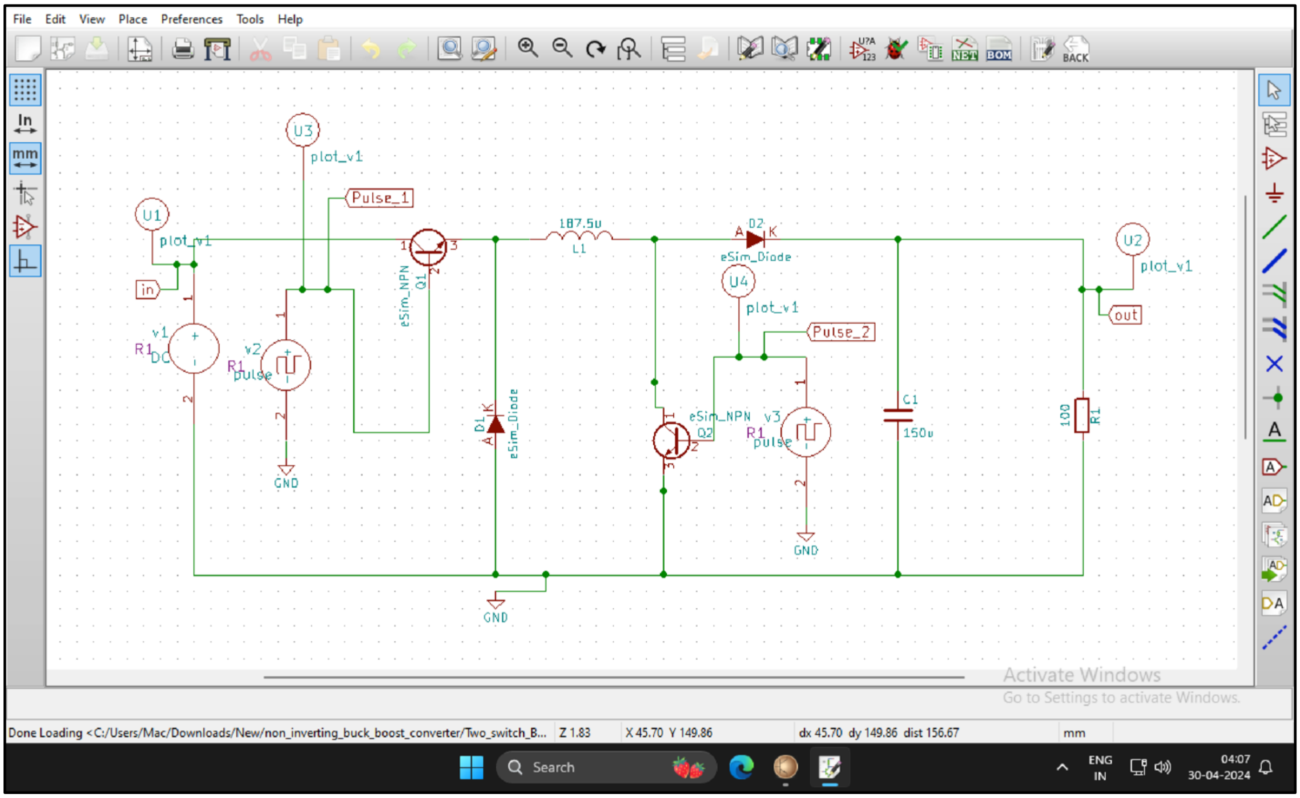

Figure 2: Circuit Schematic of Two Switch DC to DC Buck Boost Converter

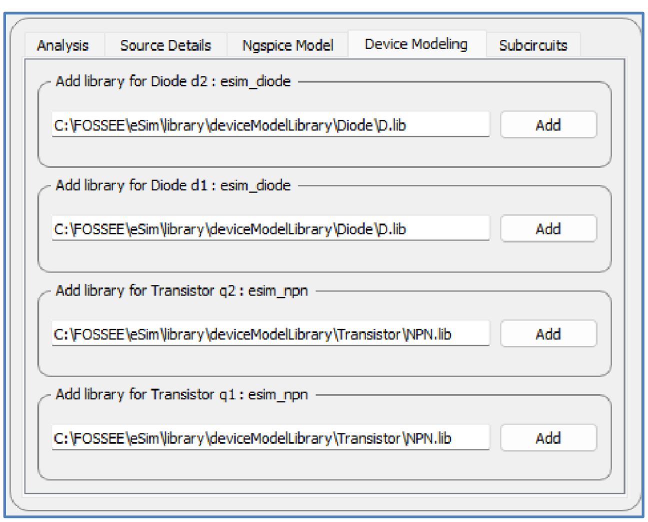

Figure 3 : Device Modeling (Libraries)

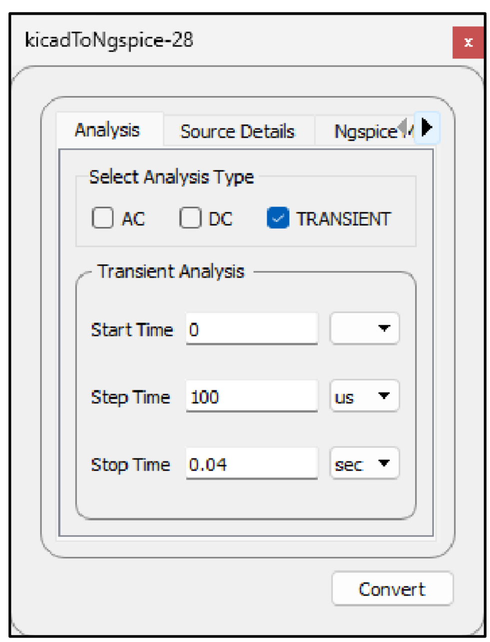

Figure 4: Analysis Parameters (Kicad to Ngspice)

A. Buck Mode:

I. Analysis:

To use the given circuit in Buck Mode following settings should be used.
Condition: Q1 = (Range: 0-100% duty Cycle) & Q2 = OFF (Where Q1 & Q2 are switches)

1. **Pulse_v2 = (0 10 0 1n 1n 7u 10u)**
2. **Pulse_v3 = (0 0 0 1n 1n 7u 10u)**

Also, we can Say that, to run the circuit in Buck Mode we have to turn Pulse_v3 = OFF (which is 2nd Pulse).
for turning it off, We kept Pulse Value = 0 in (Pulse_v3)

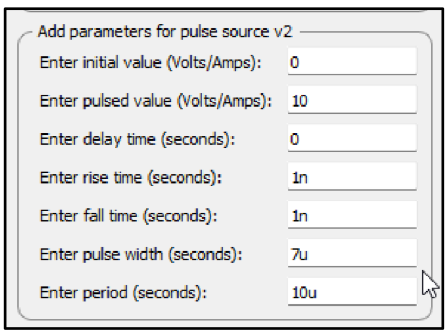

Figure 6: Parameters for Pulse_v2

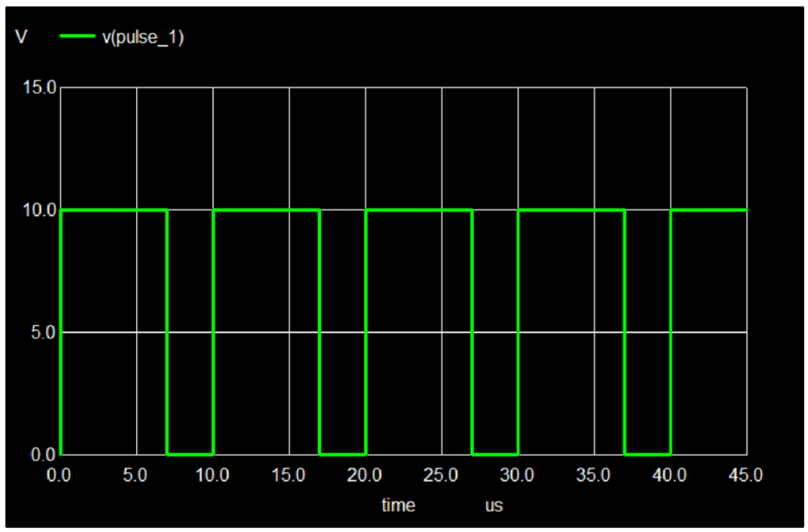

Figure 5: Ngspice Input Source Pulse_v2 (1st Pulse = Pulse_1)

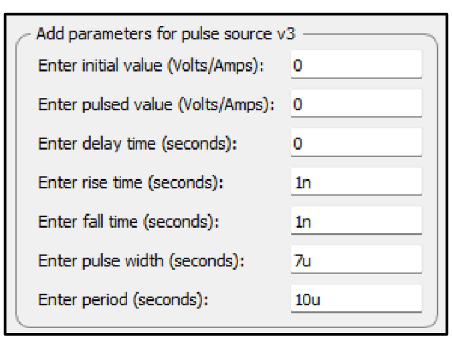

Figure 7: Parameters for Pulse_v3

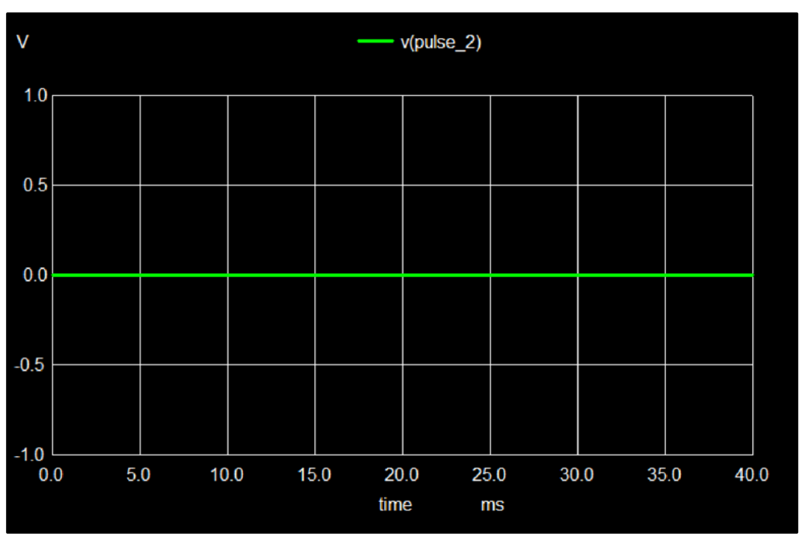

Figure 8: Ngspice Input Source Pulse_v3 (2nd Pulse = Pulse_2)

As, Pulse_v2 has above Parameters (figure 5)
We get results.

∴ Duty Ratio: 70%

∴ Output Voltage ≈ 5.5V (Buck)

ii. NgSpice Plots:

a. Input wave
b. Output Wave

a. Input Voltage: 12V DC

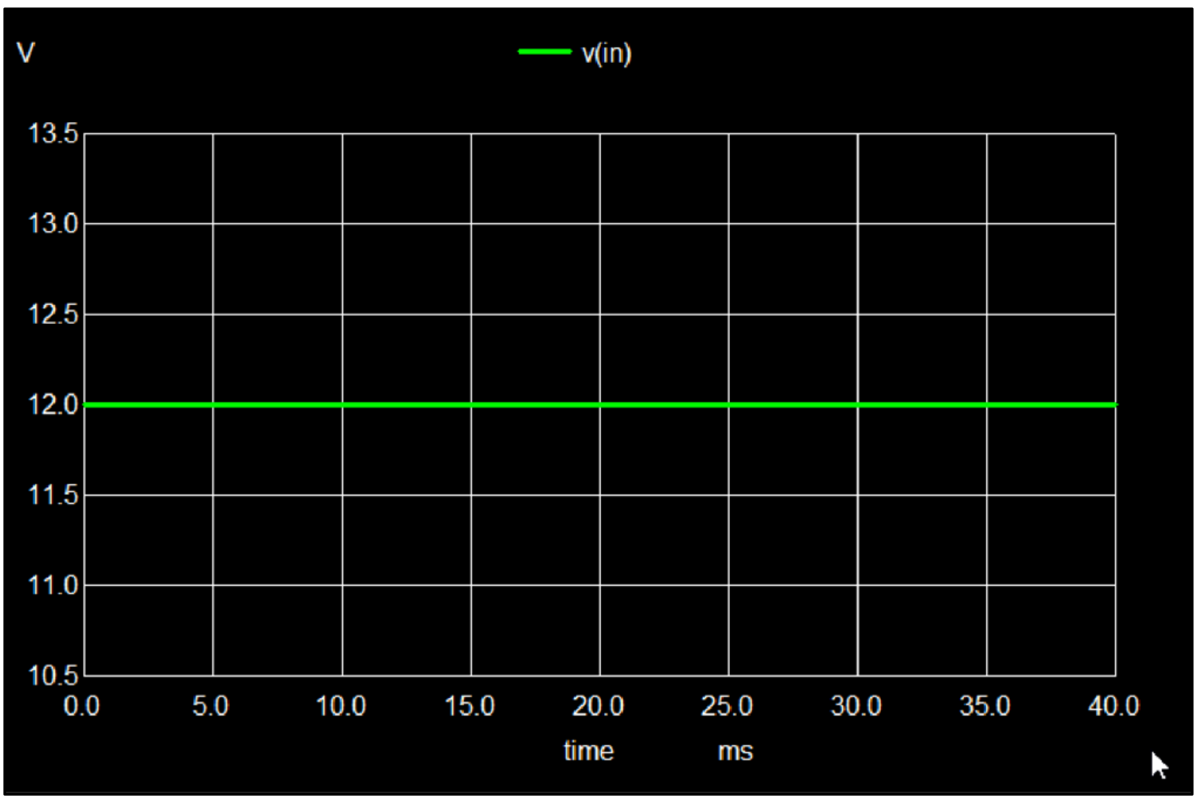

Figure 9: Ngspice Input Voltage Plot

b. Output Voltage: ≈ 5.5V (Buck)

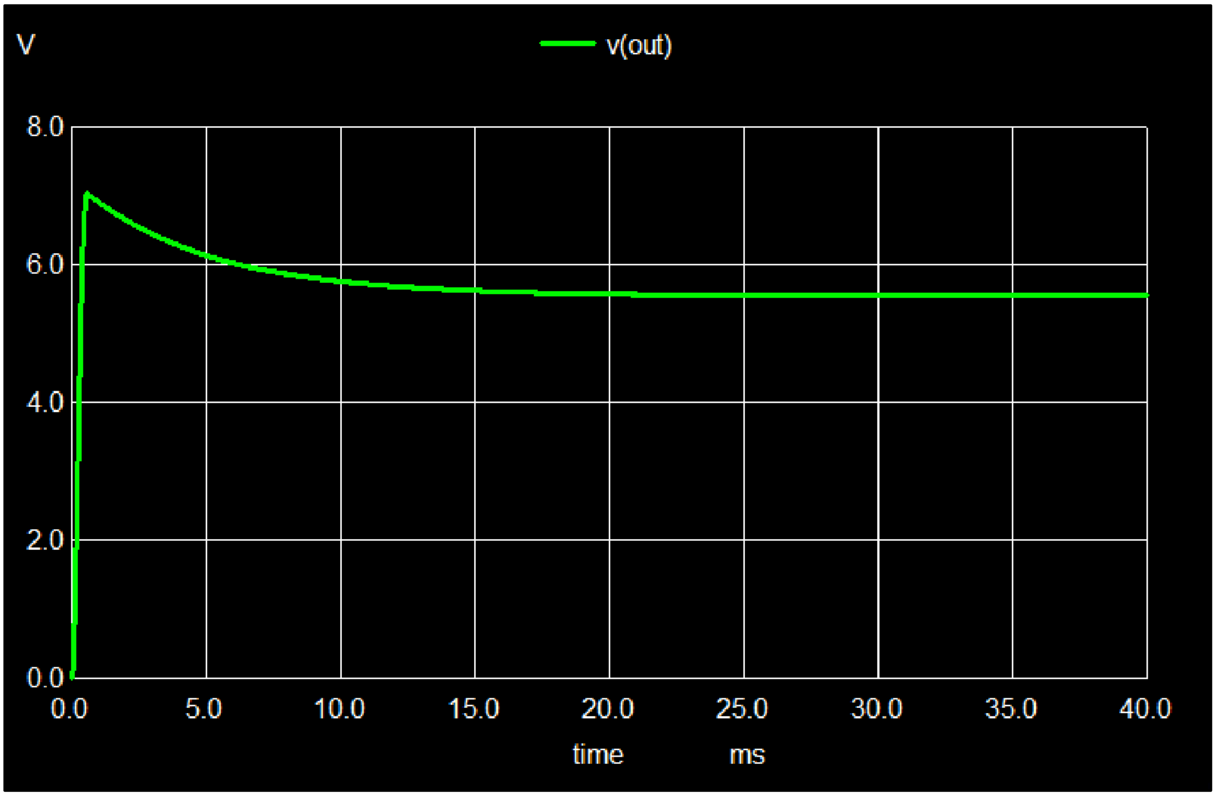

Figure 10: Ngspice Output Voltage Plot

Steady State Voltage:

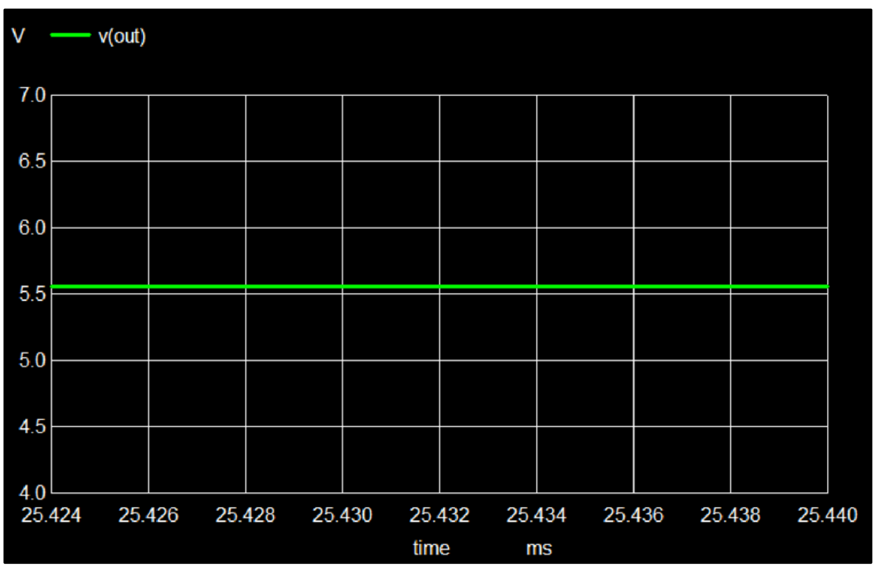

Figure 11: (Zoomed) Ngspice Output Voltage Plot

B. Boost Mode:

I. Analysis:

To use the given circuit in Buck Mode following settings should be used.
Condition: S1 = ON (100% Duty Cycle) & S2 = (Range: 0-100% duty Cycle)

1. **Pulse_v2 = (0 10 0 1n 1n 10u 10u)**
2. **Pulse_v3 = (0 10 0 1n 1n 7u 10u)**

Also, we can say that, to run the circuit in Boost Mode we have to turn Pulse_v3 = ON for turning it ON, We kept Pulse Value = 10 in (Pulse_v3)
And for current flow though the circuit. Turn ON 1st Switch by Pulse_v2.

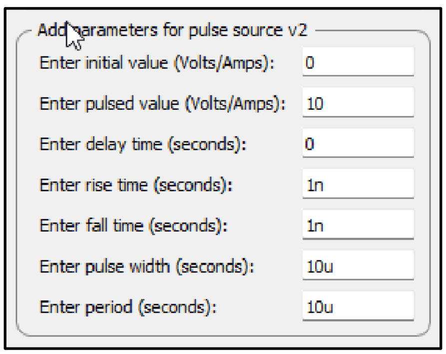

Figure 12: Parameters for Pulse_v2

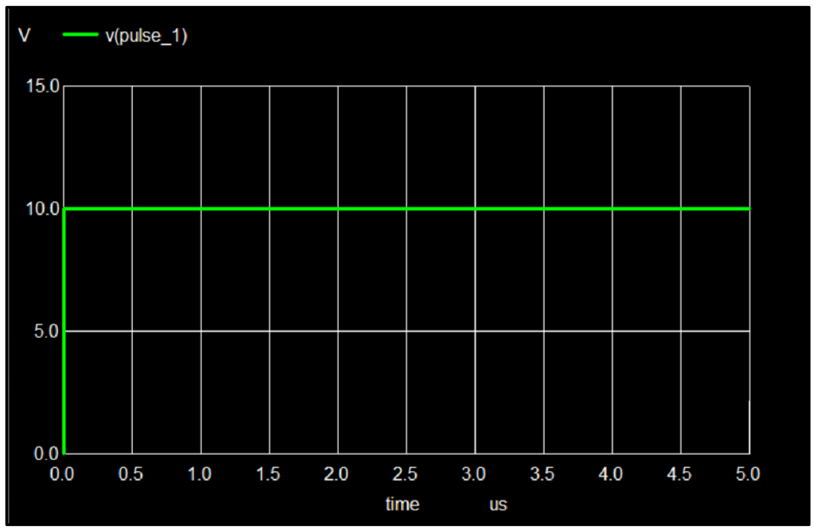

Figure 13: Ngspice Input Source Pulse_v2 (1st Pulse = Pulse_1)

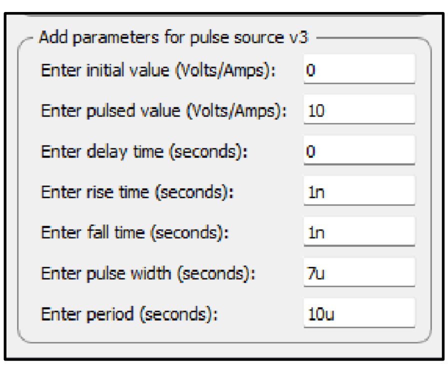

Figure 15: Parameters for Pulse_v3

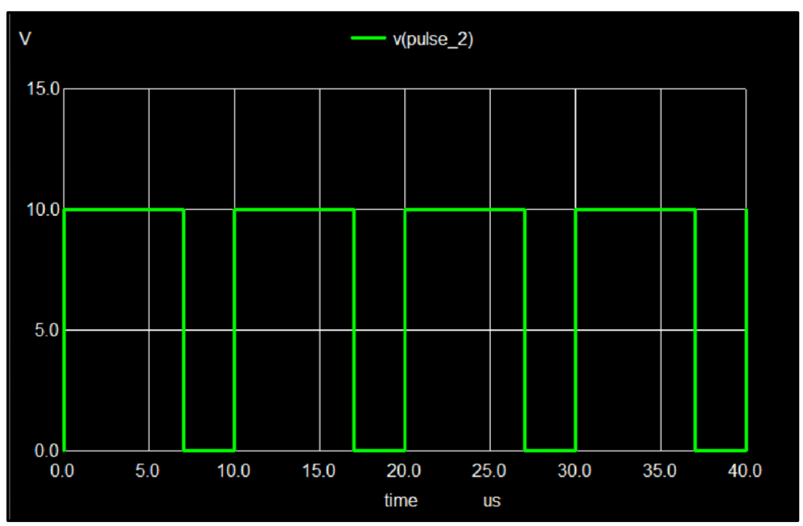

Figure 14: Ngspice Input Source Pulse_v3 (2nd Pulse = Pulse_2)

As, Pulse_v3 has above Parameters (figure 14)
We get results.

∴ Duty Ratio: 70%

∴ Output Voltage ≈ 30 V (Boost)

ii. NgSpice Plots :

a. Input wave
b. Output Wave

a. Input Voltage: 12V DC

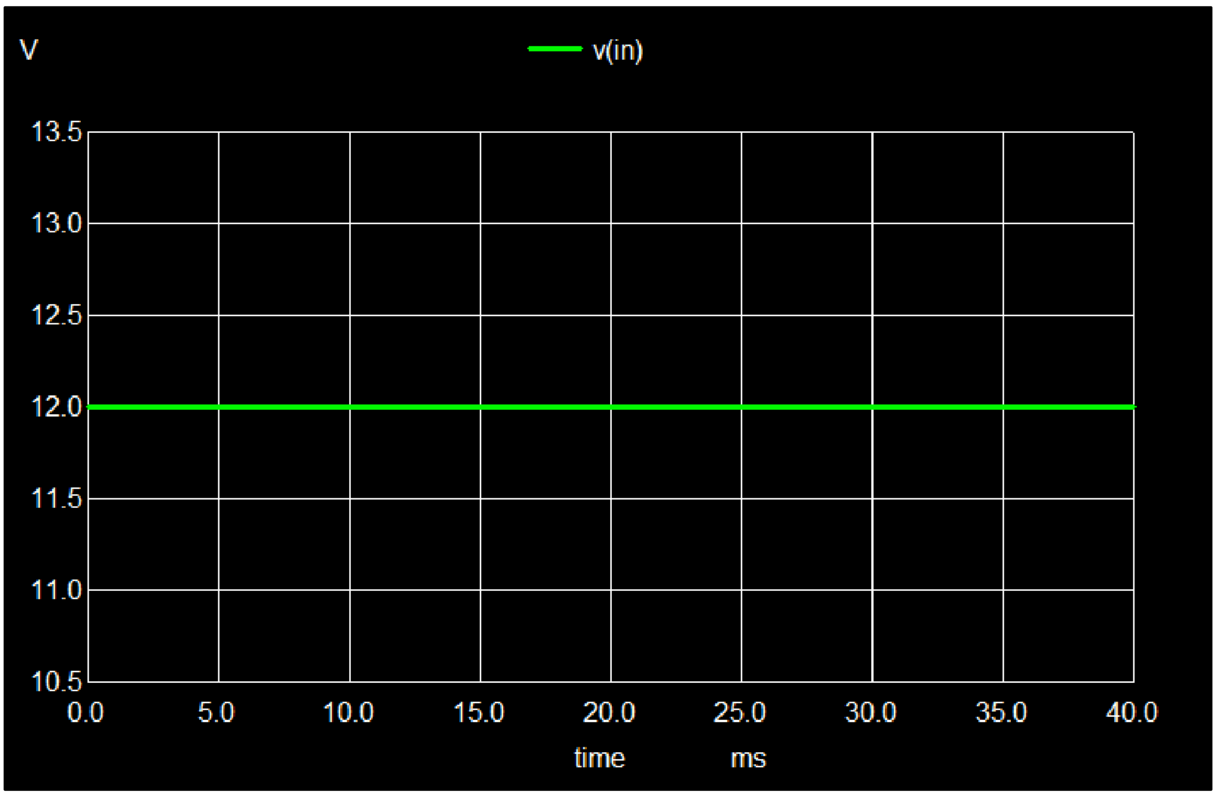

Figure 16: Ngspice Input Voltage Plot

a. Output Voltage: ≈ 30 V (Boost)

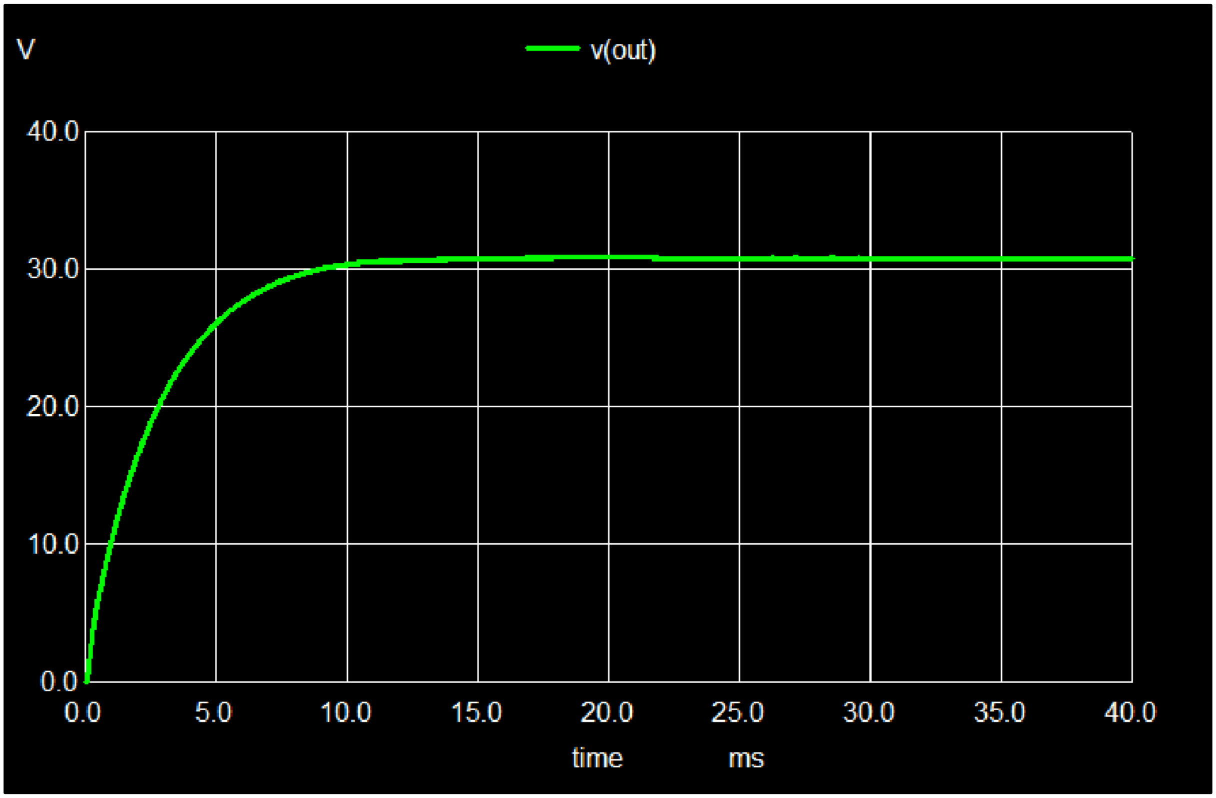

Figure 17: Ngspice Output Voltage Plot

- Steady State Voltage:

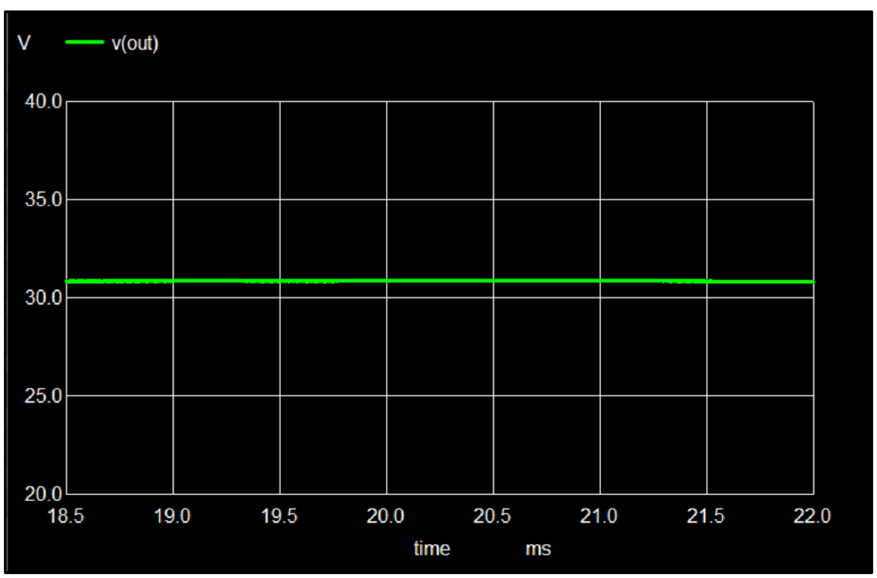

Figure 18: (Zoomed) Ngspice Output Voltage Plot

Results:

Buck: V IN = 12V, V Out ≈ 5.5V

Boost: V IN = 12V, V out ≈ 30V

Conclusion: The Buck Boost circuit is successfully simulated in eSim (software). We get both Buck & Boost Output from single Circuit by switching the Switch Q1 & Switch Q2.

References:

1. **Page No. 22 (Analog Applications Journal (Industrial)) Texas Instruments | AAJ 3Q 2014 https://www.ti.com/lit/an/slyt584/slyt584.pdf?ts=1714395492744&ref_url=https%253A%252F%252Fwww.google.com%252F**

2. **https://www.electronicproducts.com/what-every-engineer-should-know-about-buck-boost-converters/**

3. **Chandran and L. R. Chandran, "Performance analysis of Two Switch Buck Boost Converter fed DC motor," 2015 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Melmaruvathur, India, 2015, pp. 0099-0103, doi: 10.1109/ICCPEIC.2015.7259448. keywords: {Inductors;Switches;Vehicles;Pulse width modulation;Two Switch Buck Boost Converter;Three Point Starter},**

4. **E. Schaltz, P. O. Rasmussen and A. Khaligh, "Non-inverting buck-boost converter for fuel cell applications,"** ***2008 34th Annual Conference of IEEE Industrial Electronics***, **Orlando, FL, USA, 2008, pp. 855-860, doi: 10.1109/IECON.2008.4758065.**