Switched Mode DC-DC Power Converters (Basic Topologies)

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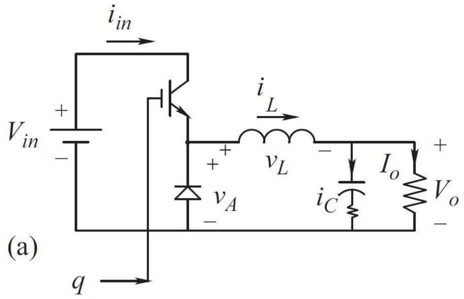
CIRCUIT DIAGRAM and CALCULATIONS:

Design Problems to be solved:

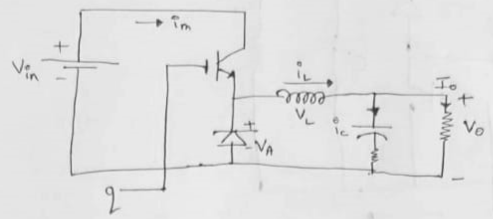
Design a Buck converter for converting a variable input DC in the range 36-72 Volts, to get a regulated output at 12V and 1A maximum. The switching frequency can be set at 50kHz. The maximum peak current ripple can be permissible up-to 10%. The maximum output voltage permissible ripple is 2%. Estimate the value of Inductor and the output filter capacitor. Find out the Duty cycle range for the input variation at 100% load. Verify the results by Computer simulation. Assume ideal switch and continuous conduction mode.



BUCK CONVERTER

→Theoretical solution

Buck Converter:-



Given:- $V_{in\,(min)} = 36V$ $V_{in\,(max)} = 72V$

$V_o = 12V$, $I_o = 1A$, $f_s = 50kHz$

$\Delta V_{out} = 2\%\ V_{out} = 0.02 \times 12 = 0.24V$

$\Delta I_L = 10\%\ I_o = 0.1A$

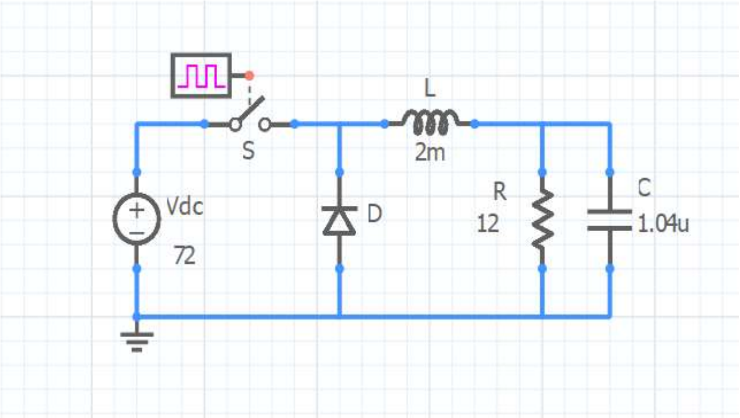
$$\text{Duty Cycle} = D_{min} = \frac{V_{out}}{V_{in}} = \frac{12}{72} = 0.167$$

$$L = \frac{V_{out}\,(V_{in(max)} - V_{out})}{\Delta I_L \times f_s \times V_{in\,(max)}} = \frac{12 \times (72-12)}{0.1 \times 72 \times 5 \times 10^{4}} = 2mH$$

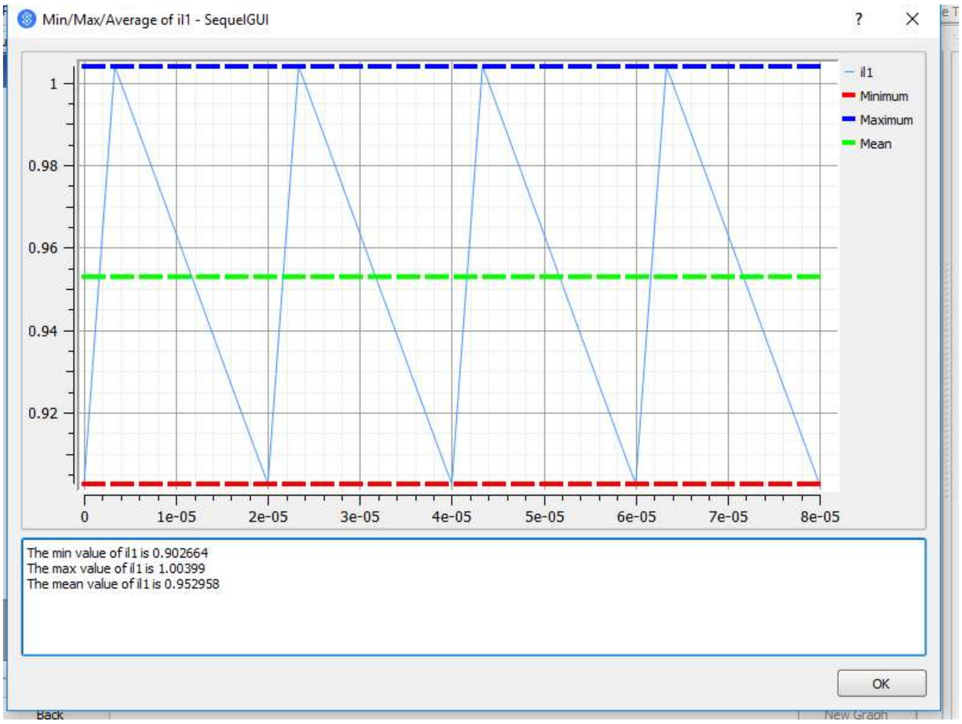
$$C = \frac{\Delta I_L}{8 \times f_s \times \Delta V_{out}} = \frac{0.1}{8 \times 5 \times 10^4 \times 0.24} = 1.042\,\mu F$$

$$R = \frac{V_o}{I_o} = \frac{12}{1} = 12\Omega$$

→Simulated circuit with graphs

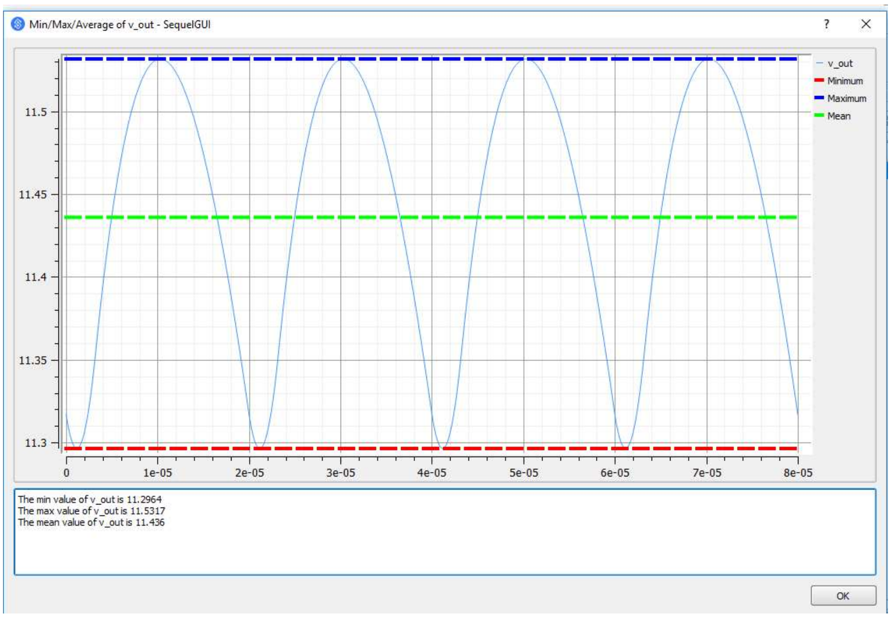


- Output Ripple Current



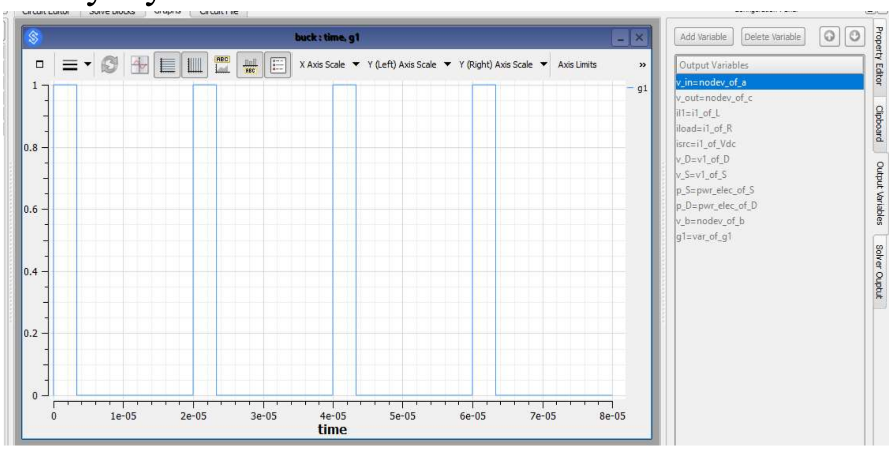
Imax-Imin = 1.00399-0.902664= 0.1A

- Output peak to peak Voltage Ripple



The difference between max and min value is 0.24

- Duty Cycle of the Wave

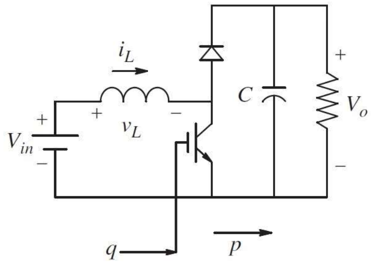


$$D = 3.28e{-}06/2e{-}05 = 0.164 \approx 0.167$$

Comparison of Values

Component	Calculated	Simulated
Current Ripple	0.1 A	0.101 A
Voltage Ripple	0.24 V	0.2353 V
Duty Cycle	0.167	0.164

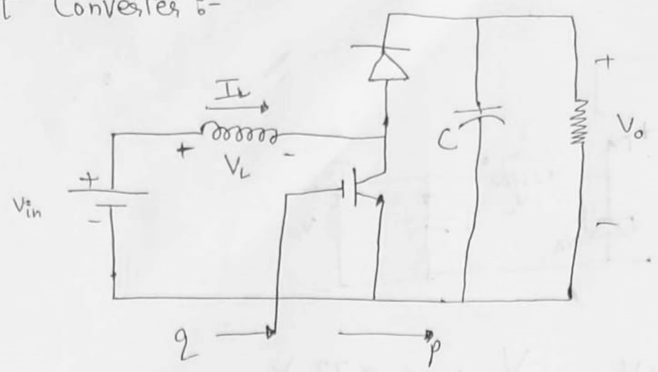
Design a Boost converter for converting a variable input DC in the range 5 Volts, to get a regulated outputat 12V at 3A maximum. The switching frequency can be set at 50kHz. The maximum peak current ripple canbe permissible up-to 10%. The maximum output voltage permissible ripple is 2%. Estimate the value of Inductor and the output filter capacitor. Find out the Duty cycle range for the load variation from 10% to 100%.Verify the results by Computer simulation. Assume ideal switch and continuous conduction mode.



BOOST CONVERTER

→Theoretical solution

Boost Converter :-



Given :- $V_{in} = 5V$, $V_{out} = 12V$, $I_o = 3A$, $f_s = 50\,kHz$

$$D = 1 - \frac{V_{in}}{V_{out}} = \frac{1-5}{12} = \frac{7}{12} = 0.583$$

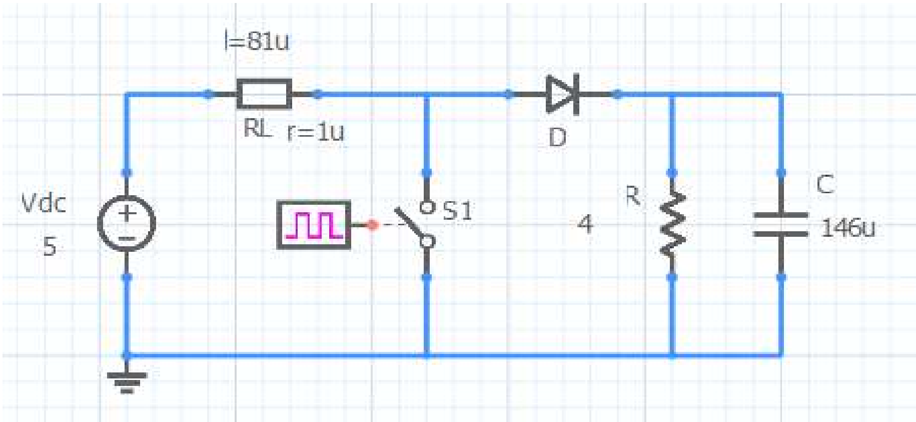
$$\Delta I_L = 10\%\ I_o \times \frac{V_{out}}{V_{in}} = \frac{0.1 \times 3 \times 12}{5} = 0.72A$$

$$L = \frac{V_{in}(V_{out} - V_{in})}{\Delta I_L \times f_s \times V_{out}} = \frac{5(12-5)}{0.72 \times 5 \times 10^4 \times 12} = 81\,\mu H$$

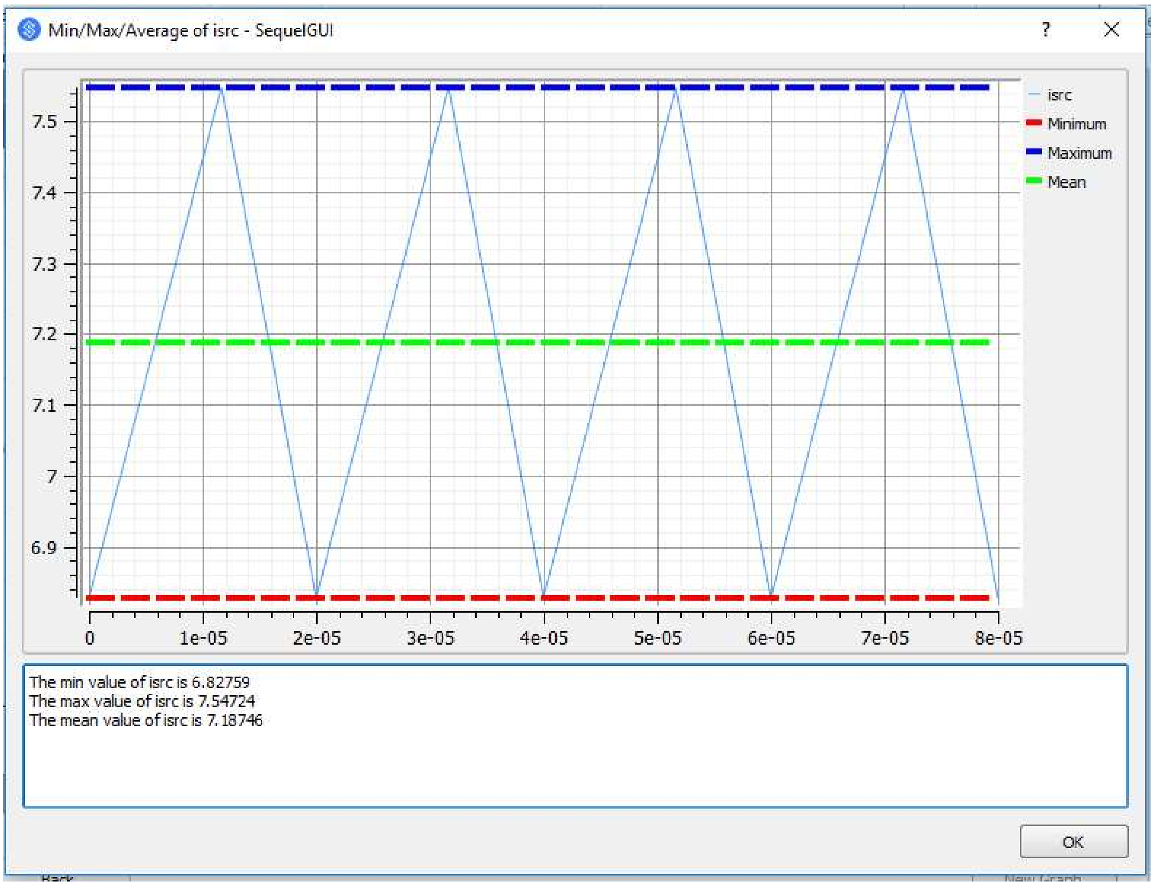
$$C = \frac{I_{out} \times D}{f_s \times \Delta V_{out}} = \frac{3 \times 0.583}{5 \times 10^4 \times 0.24} \approx 146\,\mu F$$

$$\Delta V_{out} = 2\%\ V_o = 0.02 \times 12 = 0.24V$$

→Simulated circuit with graphs

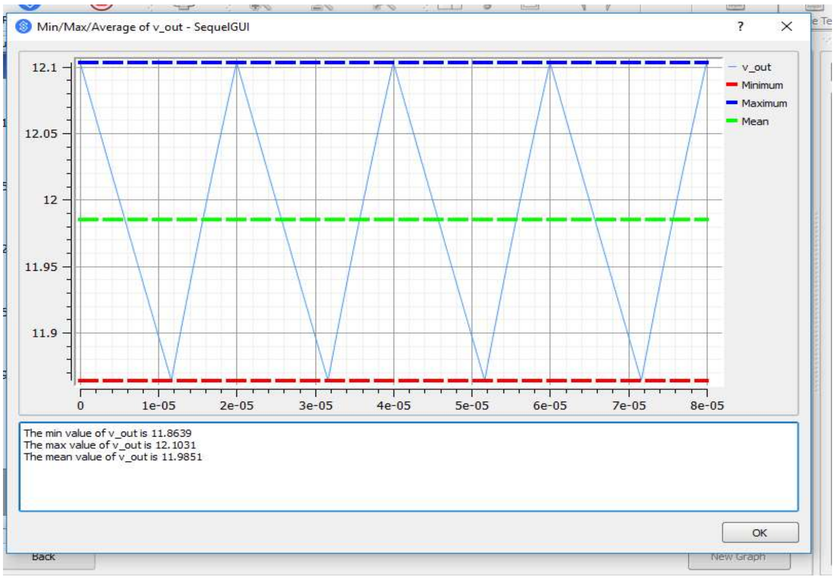


- Output Ripple Current



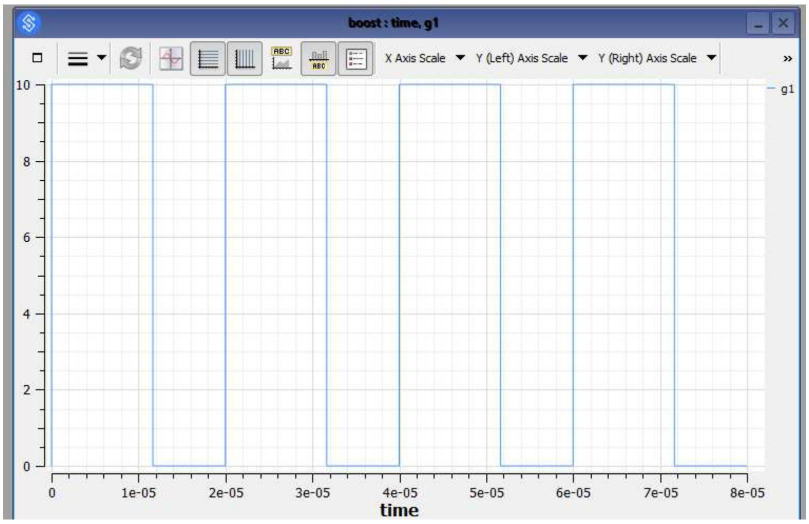
Difference between the min and max is 0.7196 A

- Output peak to peak Voltage Ripple



Difference between the min and max value of the wave is 0.239 V

- Duty Cycle of the Wave



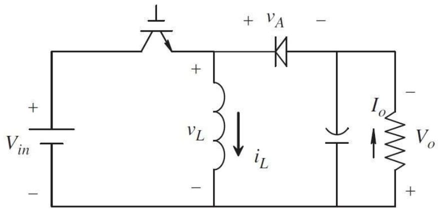
D = Ton/Ts= 1.154e−05/2e−05 = 0.577 ≈ 0.583

Comparison of Values

Component	Calculated	Simulated
Current Ripple	0.72 A	0.7196 A
Voltage Ripple	0.24 V	0.239 V
Duty Cycle	0.583	0.577

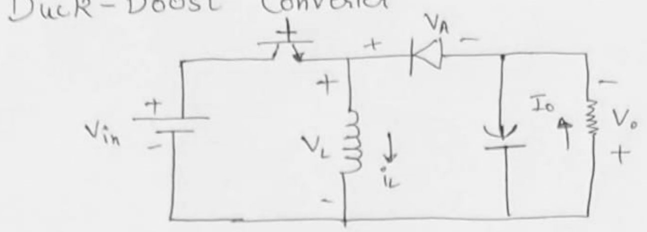
Design a Buck-Boost converter for converting a variable input DC in the range 36-72 Volts, to get a regulated output at 48V at 2A maximum. The switching frequency can be set at 100kHz. The maximum peak current ripple can be permissible up-to 10%. The maximum output voltage permissible ripple is 2%. Estimate the value of Inductor and the output filter capacitor. Find out the Duty cycle range for the supply voltage variation at 50% load. Verify the results by Computer simulation. Assume ideal switch and continuous conduction mode.

BUCK-BOOST CONVERTER



→Theoretical solution

Buck-boost Converter



$V_{in(min)} = 36V$, $V_{in(max)} = 42V$, $V_o = 48V$

$I_o = 2A$, $f_s = 100\ KHz$

$$D_{min} = \frac{V_o}{V_o + V_{in(max)}} = \frac{48}{48+72} = 0.4$$

$\Delta V_{out} = 2\%\ V_{out} = 0.02 \times 48 = 0.96V$

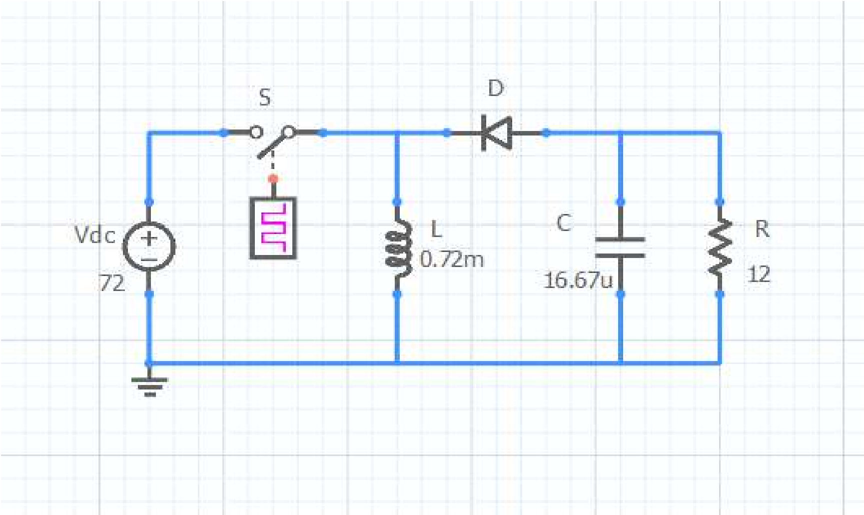
At Half load (50%), Since the voltage stays constant, the current of the load increases

$$\frac{V_o}{I_o} = R$$

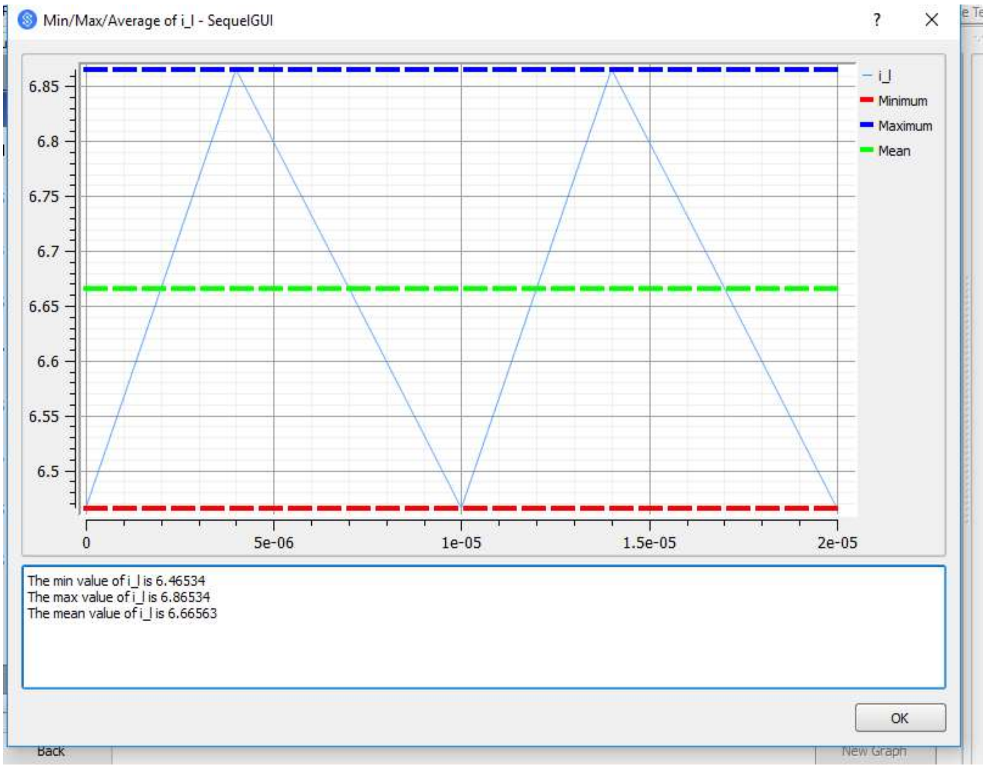
$$I_o \propto \frac{1}{R}$$

$\therefore$ Since R becomes R/2, I_o becomes $2I_o$. Hence new current at half load is 4A.

→Simulated circuit with graphs

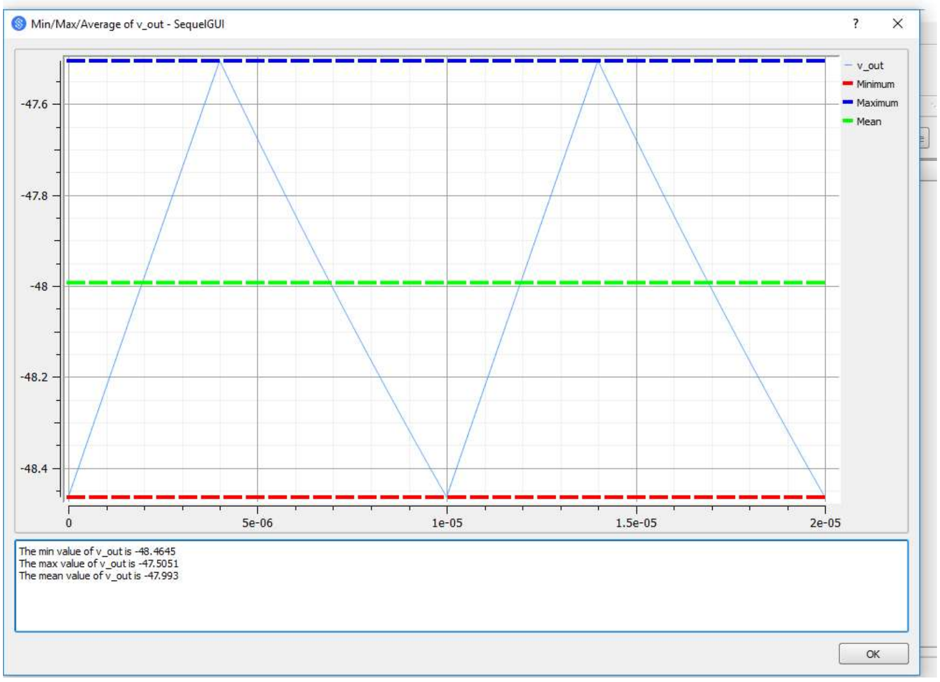


- Output Ripple Current



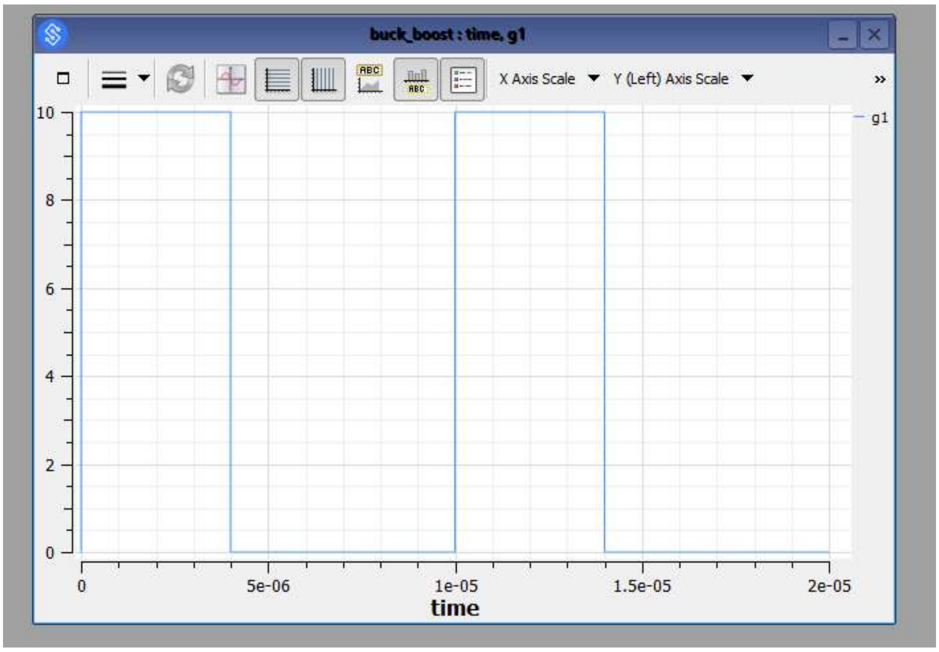
Difference between max and min value is 0.4

- Output peak to peak Voltage Ripple



Difference between the min and max is 0.959 V

- Duty Cycle of the Wave



D = Ton/Ts = 3.967e-06/1e-05 = 0.3967

Comparison of Values

Component	Calculated	Simulated
Current Ripple	0.4 A	0.4 A
Voltage Ripple	0.96 V	0.959 V
Duty Cycle	0.4	0.3967

EXPERIMENT NO: 9 **DATE: 31/07/ 2022**

Switched Mode DC-DC Power Converters (Basic Topologies)

AIM: To Design Switched Mode DC-DC Power Converters (Buck, Boost, Buck-boost) and verify it through simulation.

APPARATUS AND COMPONENTS REQUIRED: Sequel Simulator

THEORY: Write theory related with following questions:

1) What is need of SMPS Vs. linear? State their applications

	Linear Regulated Power Supplies	Switch Mode Power Supplies
Size	50W linear power supply typically 3 x 5 x 5.5"	50W switching power supply typically 3 x 5 x 1"
Weight	50W linear power supply – 4lbs	50W switching power supply – 0.62lbs
Input voltage range	105 – 125 VAC and/or 210 – 250 VAC	90 – 132 VAC or 180 – 264 VAC without PFC 90 – 264 VAC with PFC
Efficiency	Typically 40%-60%	Typically 70%-85%
EMI	Low	High
Leakage	Low	High
Circuit Design	Moderate complexity, can be designed with guides	High complexity, requires specialty knowledge
Load Regulation	0.005% to 0.2%	0.05% to 0.5%
Line Regulation	0.005% to 0.05%	0.05% to 0.2%
Part Count	Low, only requires regulator and I/O filtering	High, requires switcher, snubber, transformer, capacitors, feedback network, etc.

Application :

- You'll most often find switching power supplies used in applications where battery life and temperatures are important, such as:
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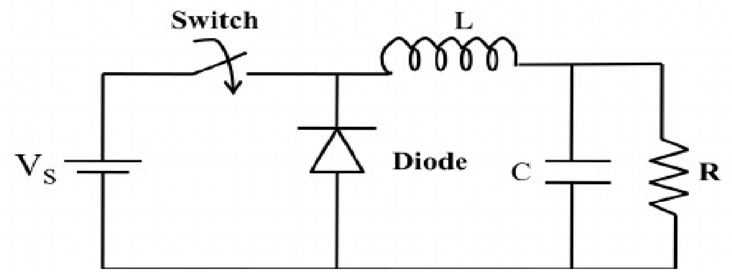
- Electrolysis, waste treatment, or fuel cell applications
- DC motors, slot cars, aviation, and marine applications
- R&D, manufacturing, and testing equipment

- Battery charging for Lithium-Ion batteries used in aviation and vehicles
- Electroplating, anodizing, and electroforming processes

2) What is operating principles of Buck, Boost and Buck-Boost PWM DC-DC Converters?

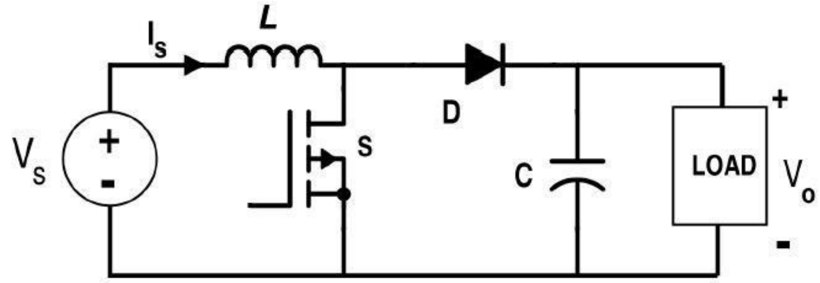
Buck Converter:

The basic operation of the buck converter is the current in an inductor controlled by two switches, that is a transistor is a diode. It reduces the voltage as compared to input voltage.



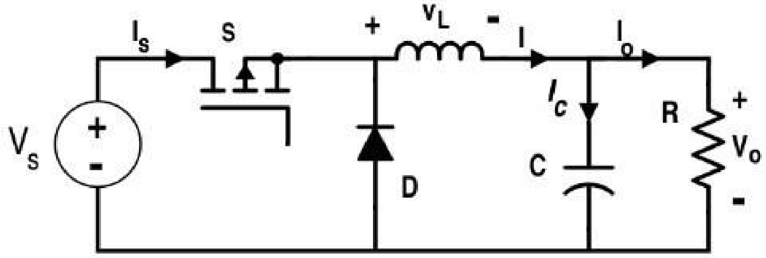
Boost Converter:

The boost converter has a bit different construction than the buck converter, the main difference is that the output voltage is HIGHER than the input voltage.



Buck-Boost Converter:

A buck-boost converter transforms a positive DC voltage at the input to a negative DC voltage at the output. The current through the inductor increases & the diode is in blocking state.



PROCEDURE:

1) Design the Buck, Boost and Buck-boost converter as per the specifications given in the problem statement.

2) Verify the design done in step 1) by simulation.

CONCLUSION:

We have learned about three type of power converter, Buck, Boost & Buck Boost converter and their applications in daily life. We have solved the design questions and verified them through the sequel software