ASSIGNMENT 3 - REPORT

Power Electronics and Applications

ELEC3204

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Assignment 3 – Report

Boost Converter Designing

Specifications of Circuit

Table 1: Parameters for Converter Circuit

Symbol	Description	Value
P_{norm}	Nominal Power Rating	$48W$
V_{in}	Nominal Input Voltage	$12V$
V_o	Nominal Output Voltage	$48V$
f_{sw}	Switching Frequency	$100kHz$
ΔI_L	Nominal Peak-to-Peak ripple of Inductor Current	$1A$
ΔV_o	Nominal Peak-to-Peak ripple of Capacitor Voltage	$0.5V$

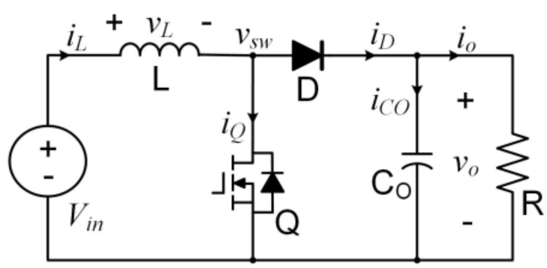

Figure 1: Boost Converter Design

Steady-State Analysis

1. The following section of the report will focus on the conceptual design of the boost converter and the steady-state analysis of the response.
   a. Assuming the CCM, the following denotes the computation of the on-state duty ration D_{ON}:

$$\frac{48}{12} = \frac{1}{1 - D_{ON}} \rightarrow 48(1 - D_{ON}) = 12 \rightarrow D_{ON} = 0.75$$

$$\therefore D_{ON} = 75\%$$

   b. Computation of the on-state time T_{ON} or T_{UP} is:

$$0.75 = \frac{T_{ON}}{T_{sw}} \rightarrow T_{sw} = \frac{1}{f_{sw}} = 0.00001 = 10 \times 10^{-6} = 10\mu s$$

$$0.75 = \frac{T_{ON}}{1 \times 10^{-5}} \rightarrow T_{ON} = 7.5 \times 10^{-6} = 7.5\mu s$$

c. Based on the converter specification, the derived inductance of the boost converter L is as follows:

$$L = \frac{V_{IN}}{\Delta I_L} T_{ON} \rightarrow L = \frac{12}{1}(7.5 \times 10^{-6}) \rightarrow L = 90\mu H$$

d. Based on the converter specification, the derived capacitance C_o is:

$$I_{RMS} = \frac{\Delta I}{2\sqrt{3}} = \frac{1}{2\sqrt{3}} = 0.289A\ (\,correct\ to\ 3\ significant\ figures)$$

$$C_O = \frac{I_{RMS} T_{ON}}{\Delta V_O} = \frac{(0.289)(7.5 \times 10^{-6})}{0.5} = 4.3\mu F$$

e. Evaluation of the design and the condition of BCM regarding the levels of the output current and load resistance are as follows:

$$AVG(i_L) = \frac{\Delta I_L}{2} = \frac{1}{2} = 0.5A$$

$$I_o = AVG(i_D) = AVG(i_L) \times (1 - D_{ON}) \rightarrow 0.5(1 - 0.75) = 0.125A$$

$$\therefore Output\ Current\ is\ 0.125A\ regarding\ the\ condition\ of\ BCM.$$

$$R_{crit} = -\frac{2V_o}{\Delta I_L(1 - D_{ON})} \rightarrow R_{crit} = \frac{(2)(48)}{(1)(1 - 0.75)} = 384\Omega$$

$$\therefore Load\ Resistance\ is\ found\ to\ be\ 384\Omega$$

f. The output voltage when the load resistance becomes 384Ω with the duty ratio of $D_{ON} = 0.75$ without any loss consideration can be calculated as follows:

$$V_o = \frac{R\Delta I_L(1 - D_{ON})}{2} = \frac{384(1 - 0.75)(1)}{2}$$

$$\rightarrow \therefore V_o = 48V$$

g. When the load resistance becomes 500Ω, the on-state duty ratio to maintain the specified output voltage $48V$ without any loss consideration is:

$$(2T_{sw}L){V_o}^2 + (-2V_{in}T_{sw}L)V_o + \left(-{V_{in}}^2 R {T_{UP}}^2\right) = 0$$

$$T_{UP} = D_{ON}T_{sw}$$

$$\left(2\frac{T_{UP}}{D_{ON}}L\right){V_o}^2 + \left(-2V_{in}\frac{T_{UP}}{D_{ON}}L\right)V_o + \left(-{V_{in}}^2 R {T_{UP}}^2\right) = 0$$

$$\left(\frac{2 \times 7.5 \times 10^{-6} \times 48^2}{D_{ON}} 90 \times 10^{-6}\right) + \left(-2 \times 48 \times 90 \times 10^{-6} \times 12 \times \frac{7.5 \times 10^{-6}}{D_{ON}}\right) - (12^2 \times 500 \times (7.5 \times 10^{-6})^2) = 0$$

$$D_{ON} = 0.65 = 65.73\%\ (2dp)$$

Simulation

a. Simulation Model:

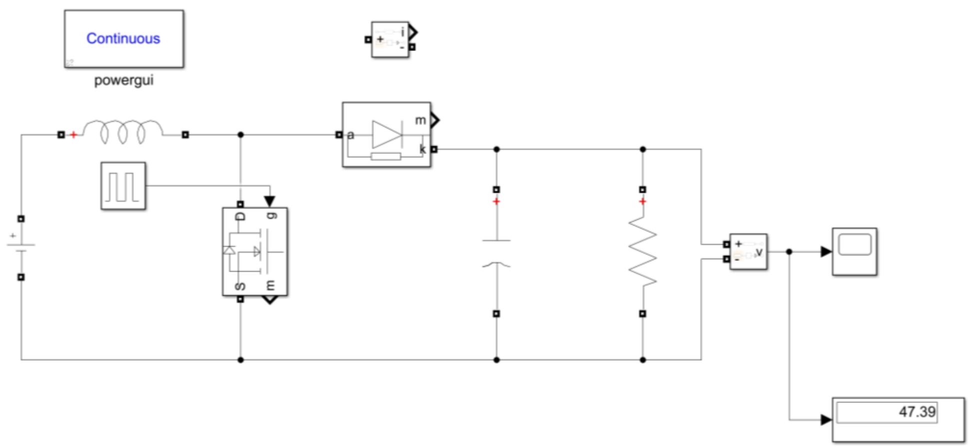

Figure 2: Boost Converter Design – Simulation Model

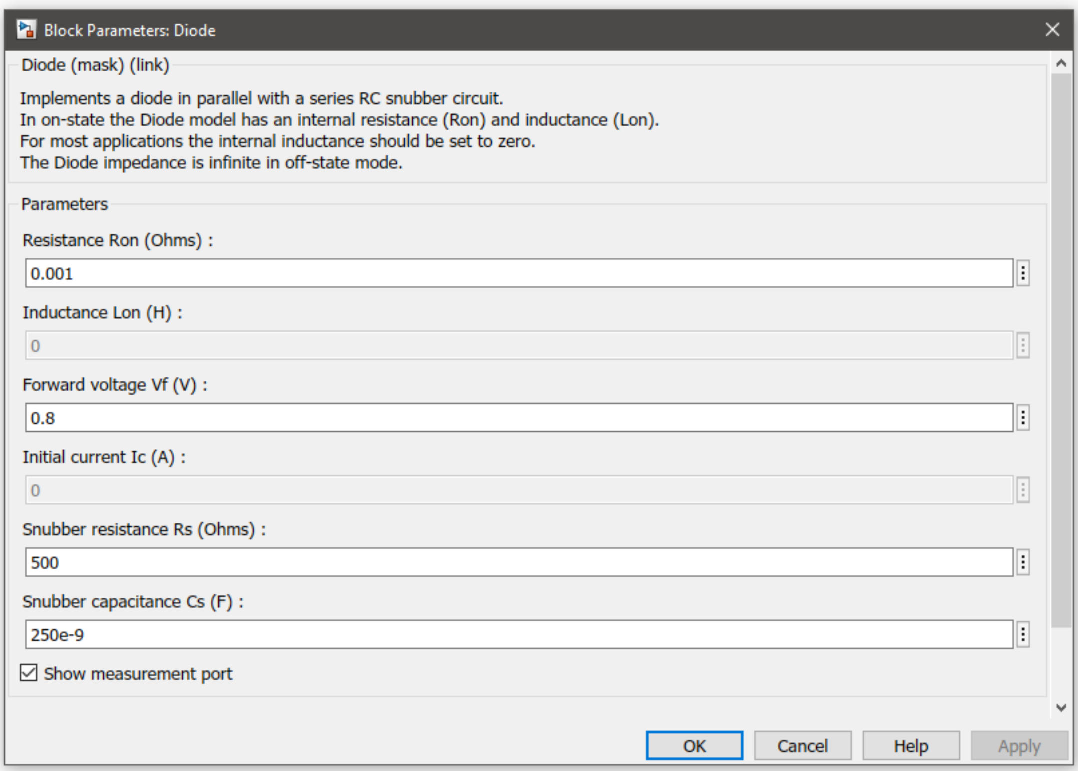

Figure 3: Diode Specifications

Note: The forward voltage of the diode has been set to 0.8V hence, resulting in the results specified below with the slight drop in output voltage.

b. Based on the nominal operating condition, the simulated results for;

<u>Note:</u> The resistance value utilized for the resistor displayed in the circuit design has been set to the calculated value of 384 ohms.

i. v_{sw}:

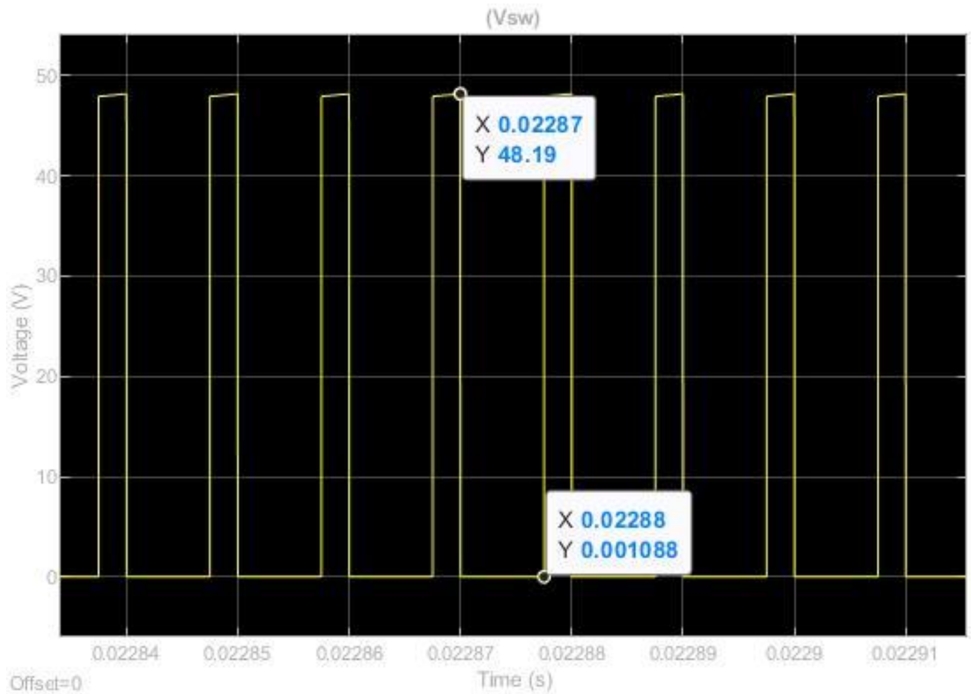

Figure 4: Voltage at Vsw

ii. v_L:

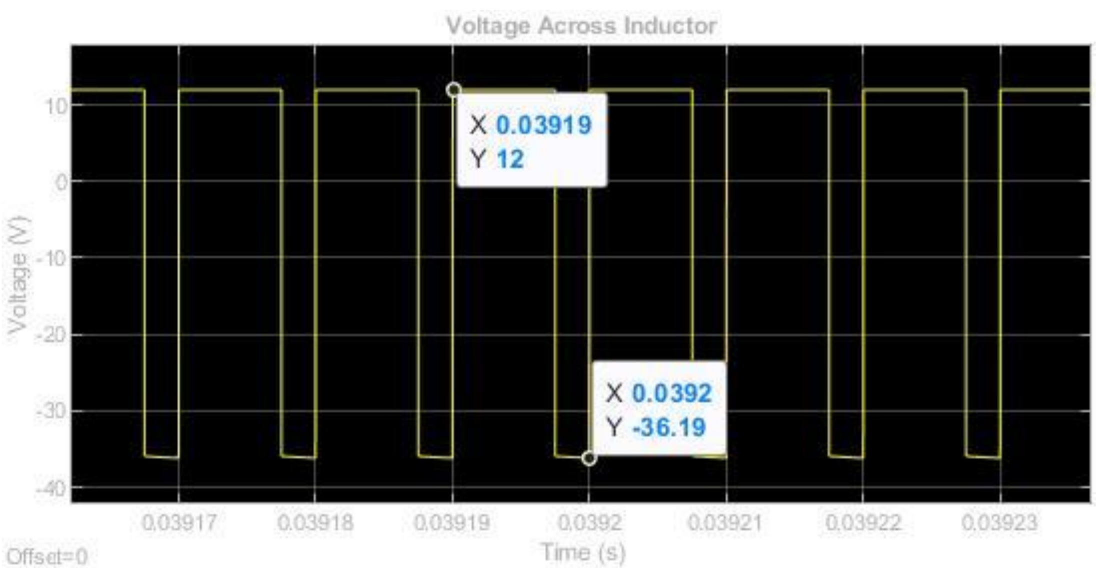

Figure 5: Voltage across the Inductor

iii. i_L:

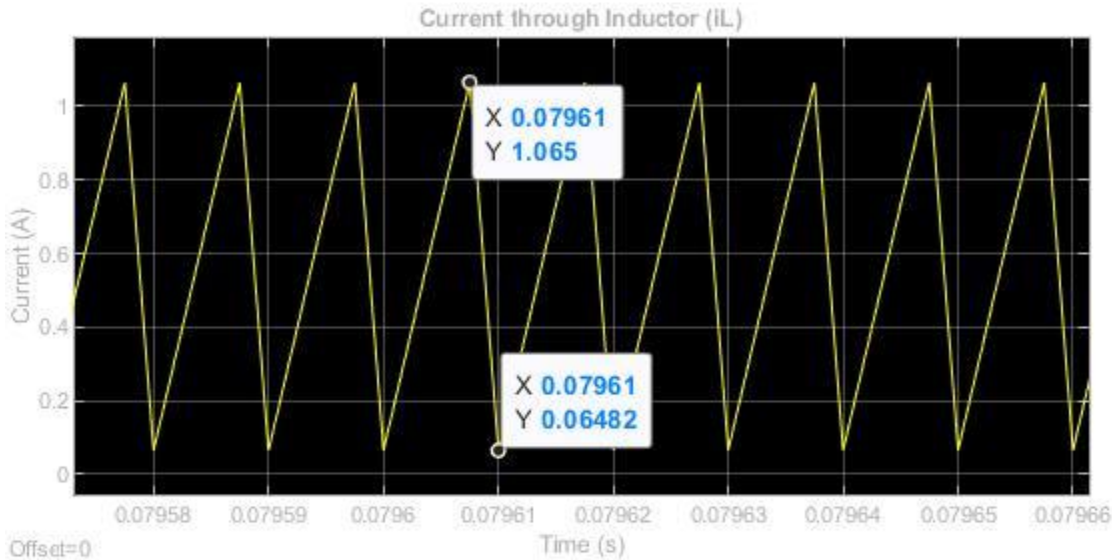

Figure 6: Current into the Inductor

iv. i_Q:

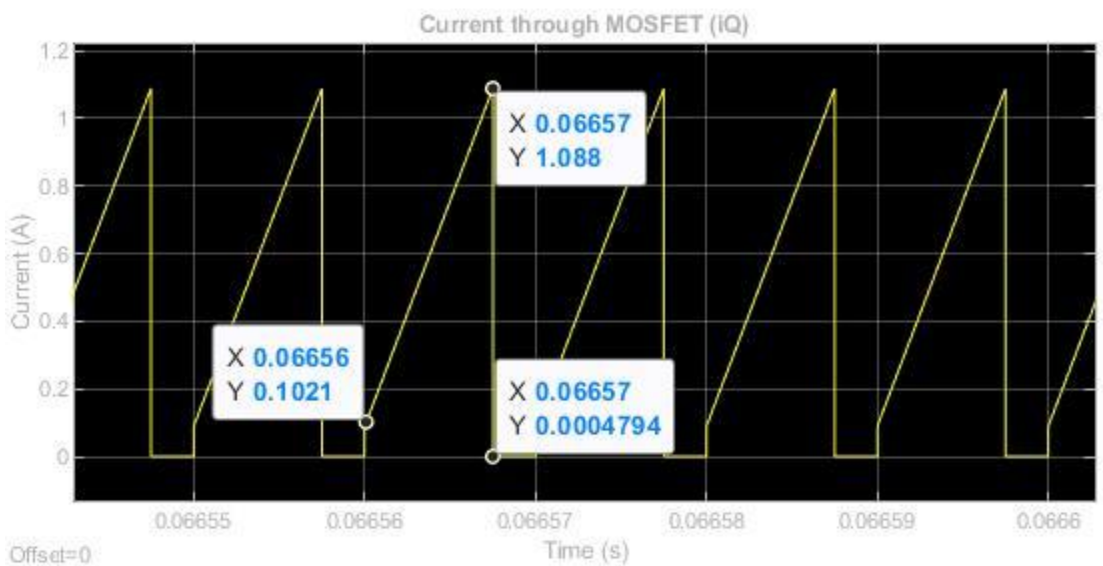

Figure 7: Current through the MOSFET

v. i_D:

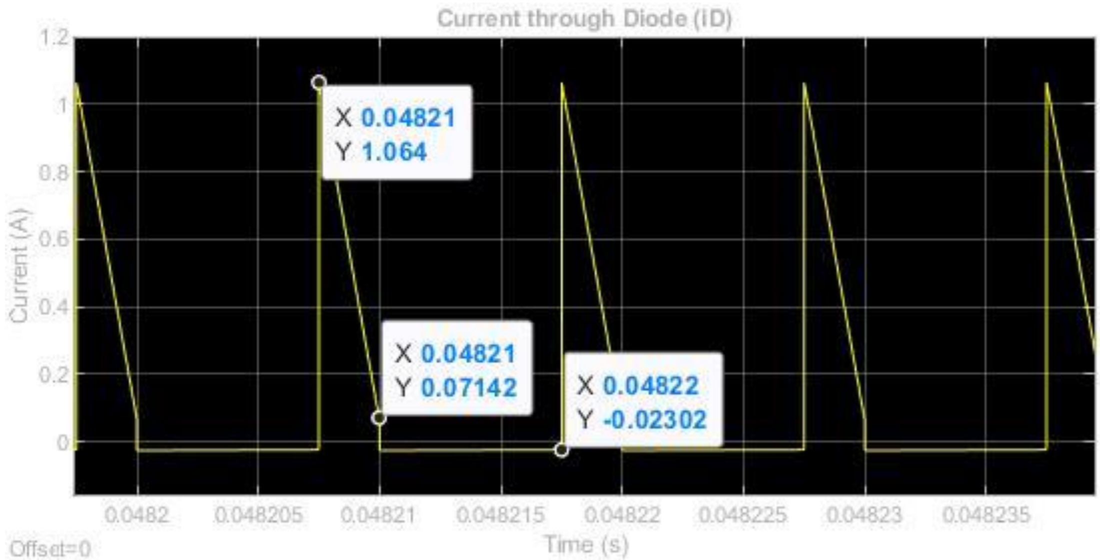

Figure 8: Diode Current Output

vi. i_{CO}:

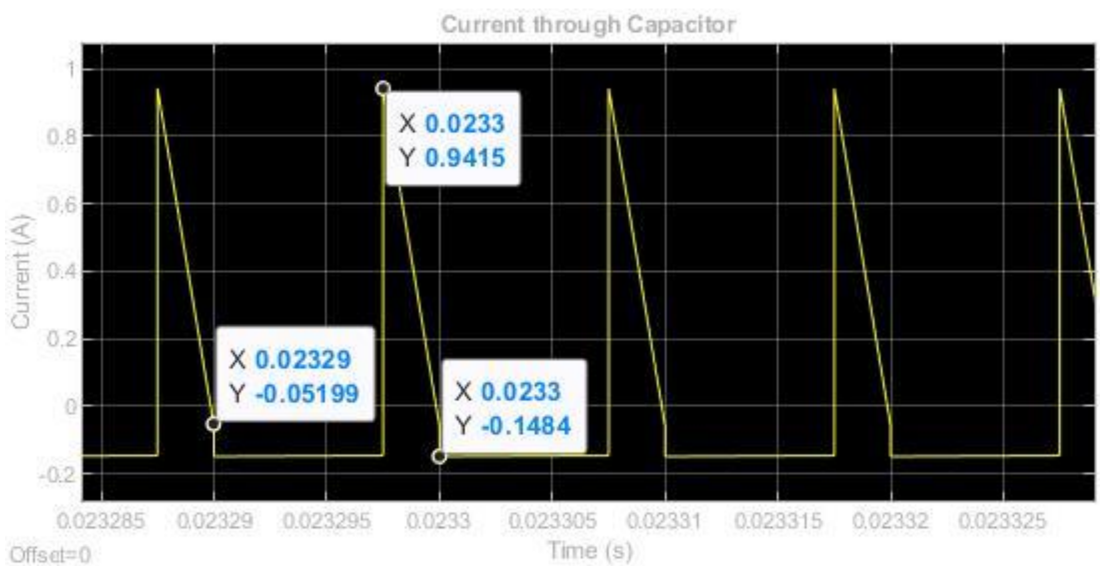

Figure 9: Current through Capacitor

vii. v_o:

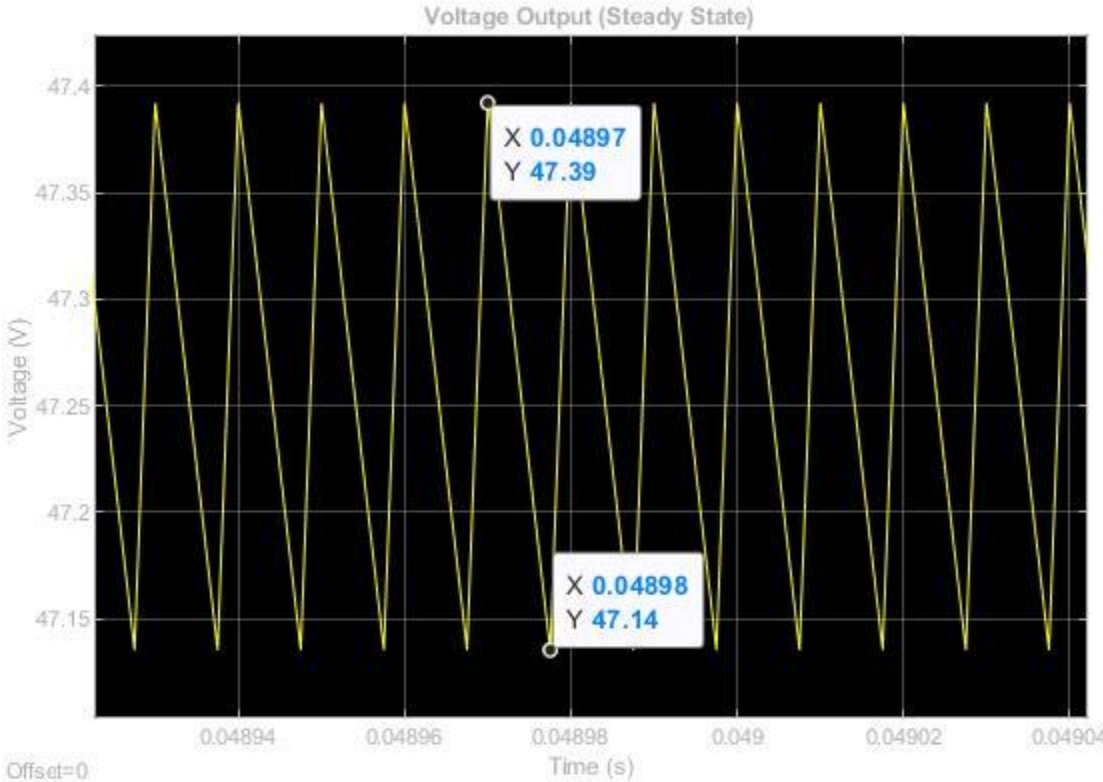

Figure 10: Voltage Output

c. The simulation displays the ripple condition as denoted in *figure 10* alongside the nominal condition with an expected ΔI_L of approximately $1A$. The v_o is the expected $48V$ indicating the validity of the first component of the investigation. Furthermore, the negative voltage with the diode output indicates a nominal condition, as highlighted in *figure 7*.

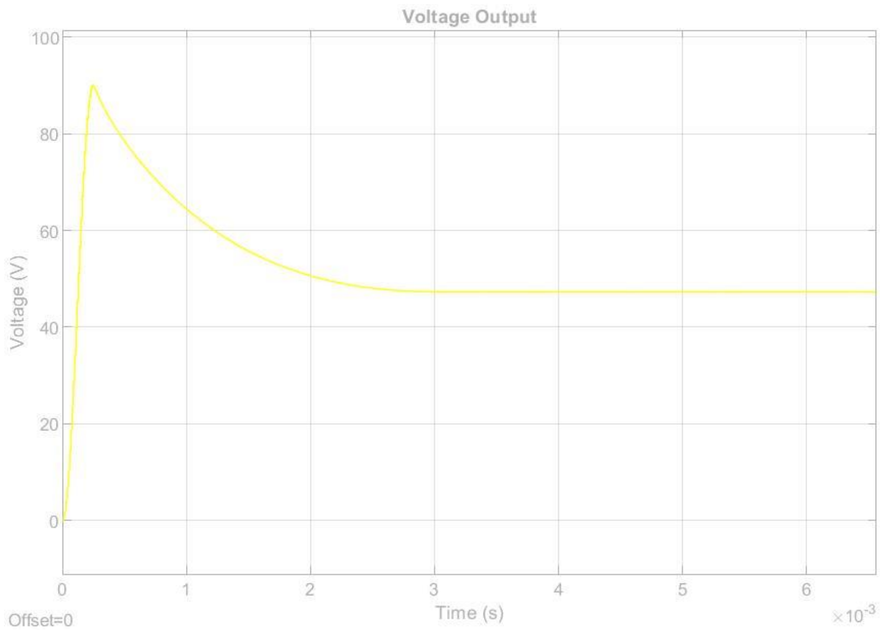

Figure 11: Ripple Condition - Voltage Output

d. The following displays the v_o, i_{CO} and i_L for a resistor values of 384 ohms as previously calculated earlier in the report, respectively;

The results of v_o is demonstrated to be under the expected output voltage close to 48 volts:

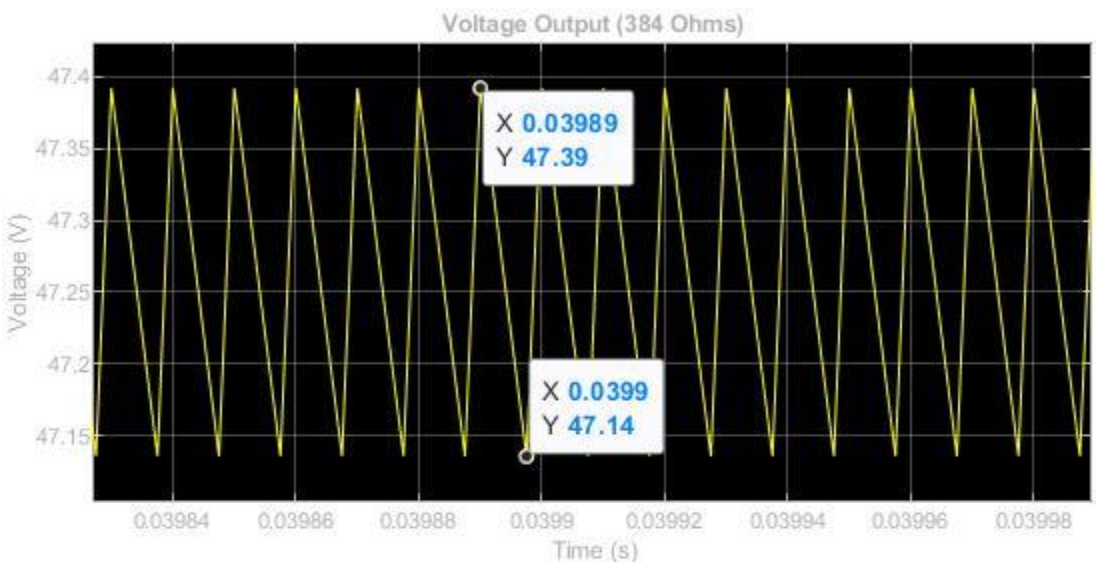

Figure 12: Voltage Output – 384Ohms

The following displays the i_{CO} response of the boost converter:

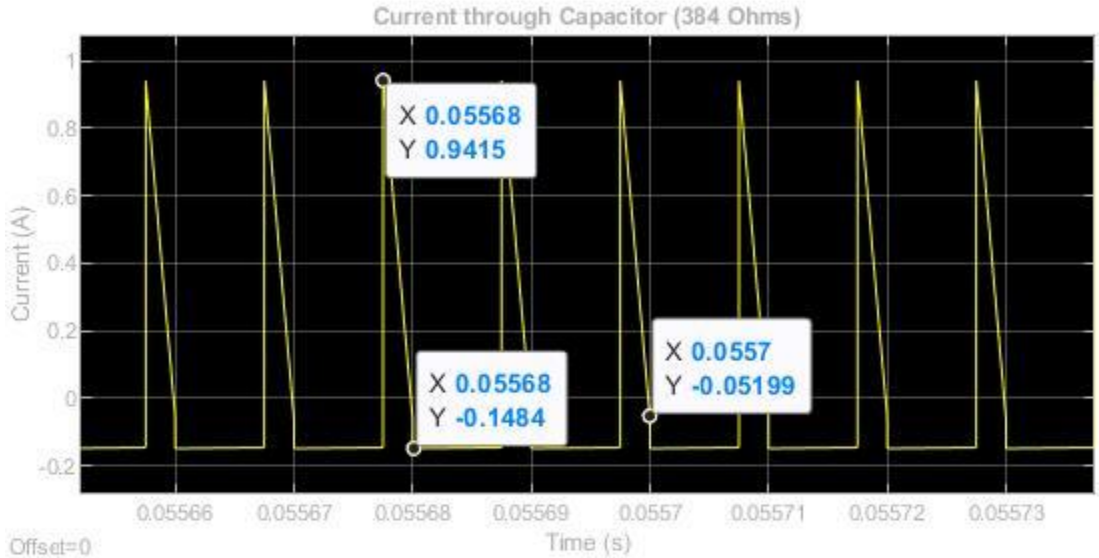

Figure 13: Capacitor Current - 384Ohms

The following displays the i_L response of the boost converter:

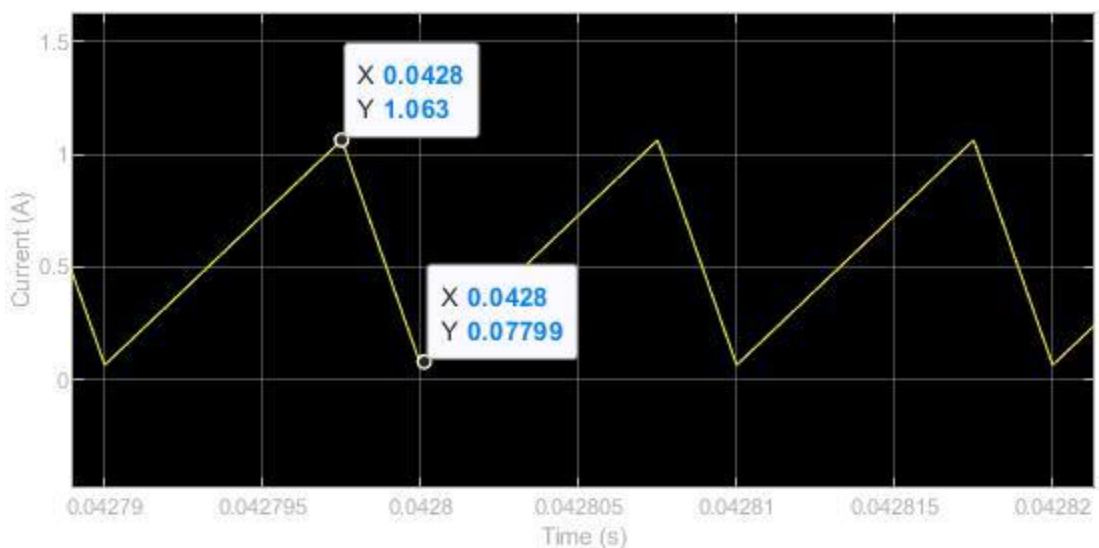

Figure 14: Inductor Current - 384 Ohms

e. The following section encompasses the simulated condition of the specified $48V$ output with a on-duty cycle of 0.65 which corresponds with the resistor value of 500 ohms;

i. The v_o response is as follows:

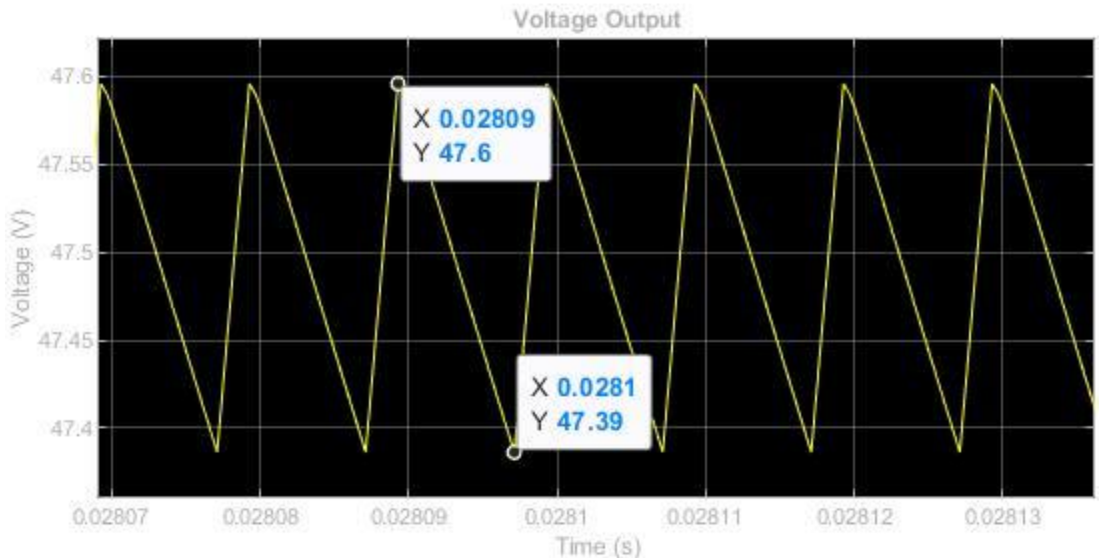

Figure 15: Output Voltage - 500Ohms

ii. The i_L response is as follows:

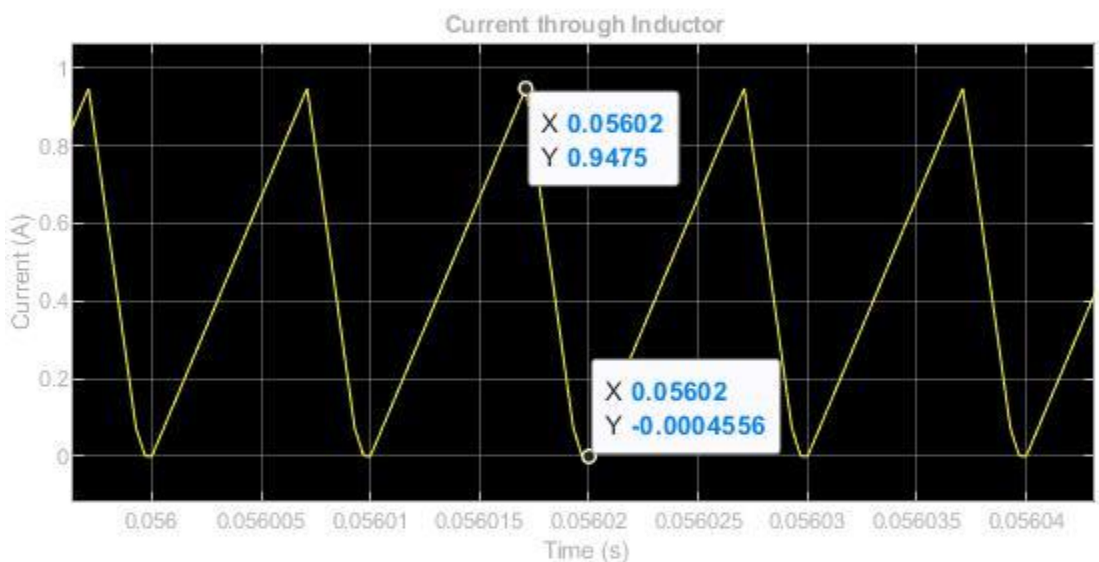

Figure 16: Inductor Current - 500 Ohms

iii. The i_{CO} response is as follows:

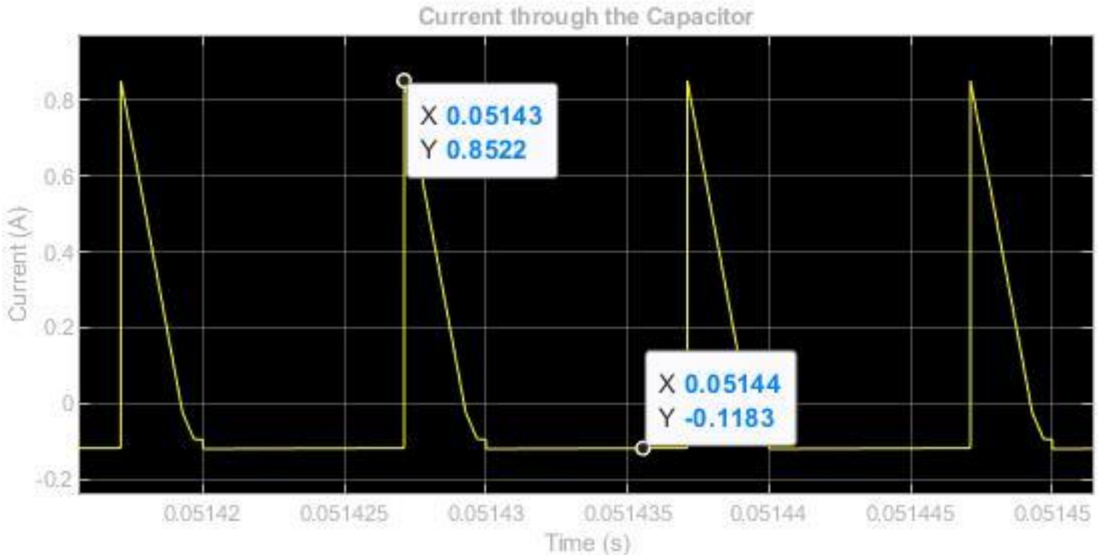

Figure 17: Capacitor Current - 500 Ohms

The operation of the boost converter is now in DCM with an expected similar voltage output. It can be concluded that the current is altered to satisfy the specified voltage with the increased resistance.

References

Hart, D. (2011). *Power Electronics.* Valparaiso: Pearson Education, Inc.