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**POWER ELECTRONICS LAB**

**EXPERIMENT 1 : BUCK, BOOST, BUCK-BOOST CONVERTER**

**PART A :**

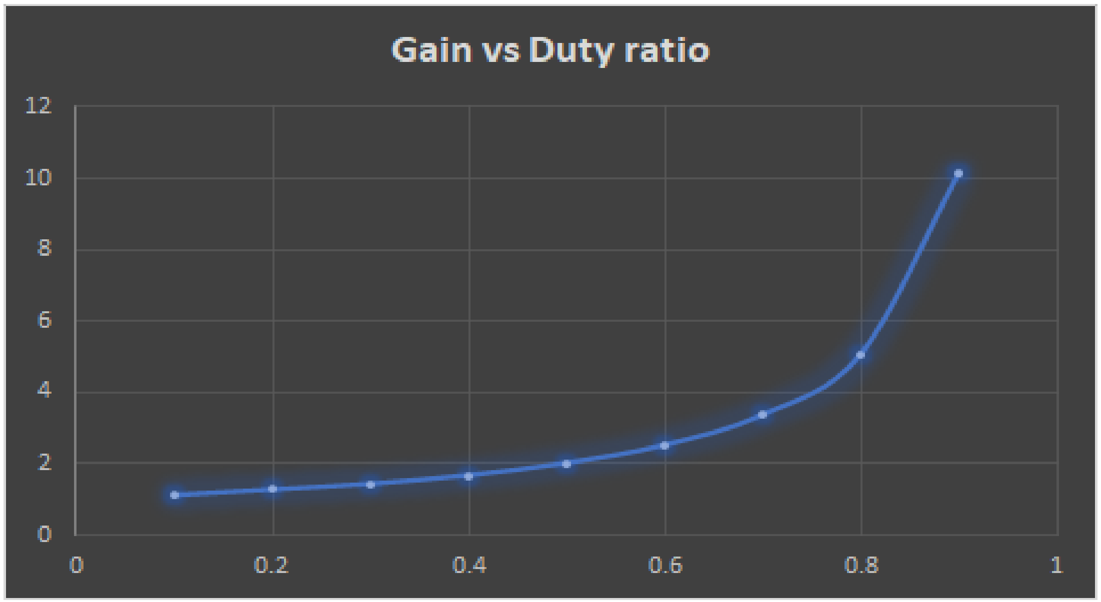
BOOST CONVERTER :

- Input Voltage (Vin) =24V
- Inductor L = 115μH
- Capacitance C = 54μF
- Load resistance RL = 11.52Ω
- Switching Frequency = 50 kHz
- Duty Cycle = 0.5
- MOSFET and diode resistance as 1μΩ
- diode voltage drop as 0.
- Parasitic resistance of inductor case (i) - rl = 0 in and case (ii) rl = 5% of RL.
- Duty ratio is varied in range 0.1 to 0.9 in steps of 0.1

I.

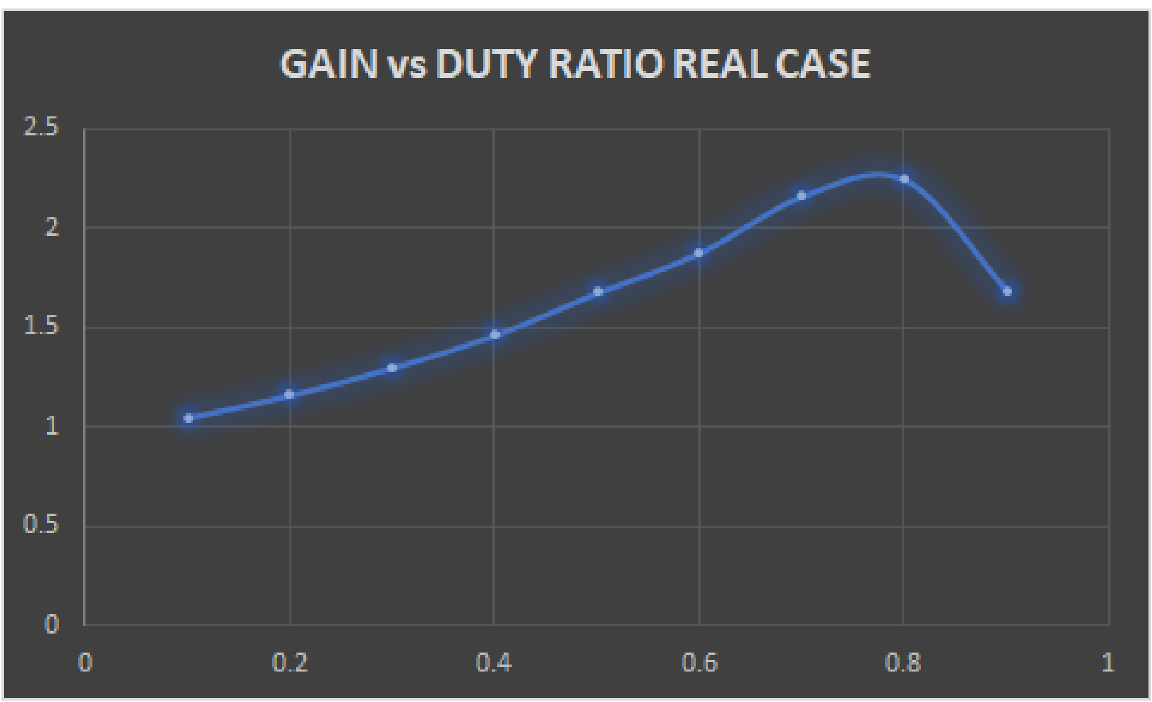
| Duty ratio | Vin(V) | Vout(V) Ideal Case [rl = 0] | Gain in Ideal case | Vout(V) rl = 5% of rl | Gain in case rl = 5% of RL |
|---|---|---|---|---|---|
| 0.1 | 24 | 26.7 | 1.1125 | 25.14 | 1.0475 |
| 0.2 | 24 | 30.05 | 1.2708 | 27.87 | 1.16125 |
| 0.3 | 24 | 34.4 | 1.433 | 31.2 | 1.3 |
| 0.4 | 24 | 40.1 | 1.6708 | 35.18 | 1.465 |
| 0.5 | 24 | 48.32 | 2.0133 | 40.29 | 1.6787 |
| 0.6 | 24 | 60.53 | 2.522 | 45.12 | 1.88 |
| 0.7 | 24 | 80.81 | 3.367 | 51.97 | 2.1654 |
| 0.8 | 24 | 121.6 | 5.0667 | 53.99 | 2.249 |
| 0.9 | 24 | 243.3 | 10 | 40.54 | 1.689 |

**GAIN vs DUTY RATIO in IDEAL case**



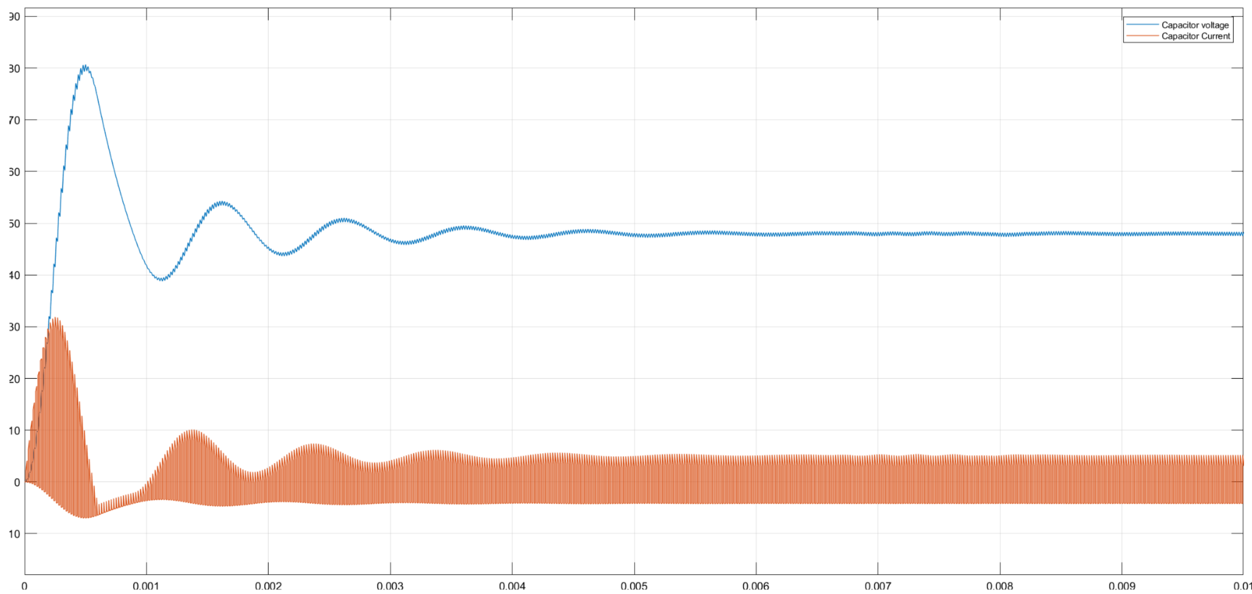

The graph follows the gain of boost converter i.e. Gain = 1/(1-D). This is the ideal case where there is no parasitic resistance in induction. The curve is exponential and increases with duty ratio.

**GAIN vs DUTY RATIO in CASE II rl = 5% of RL**

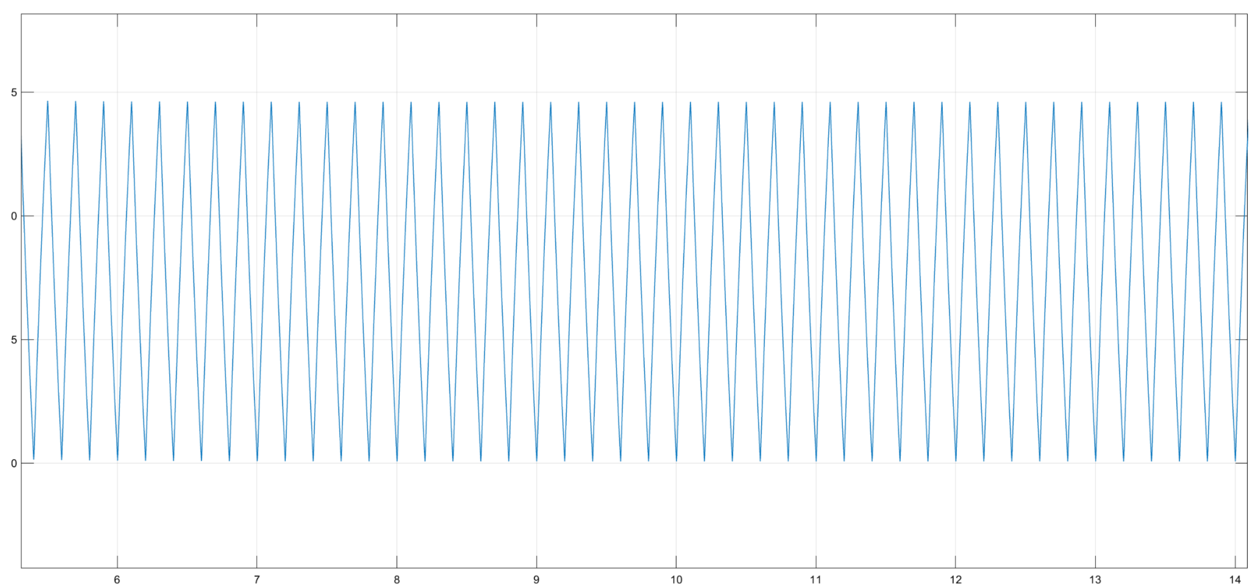



There is power dissipation in practical cases due to the presence of parasitic inductance. Hence its not exactly a rising exponential curve. For a very high value of duty ratio, gain decreases as more power gets dissipated.

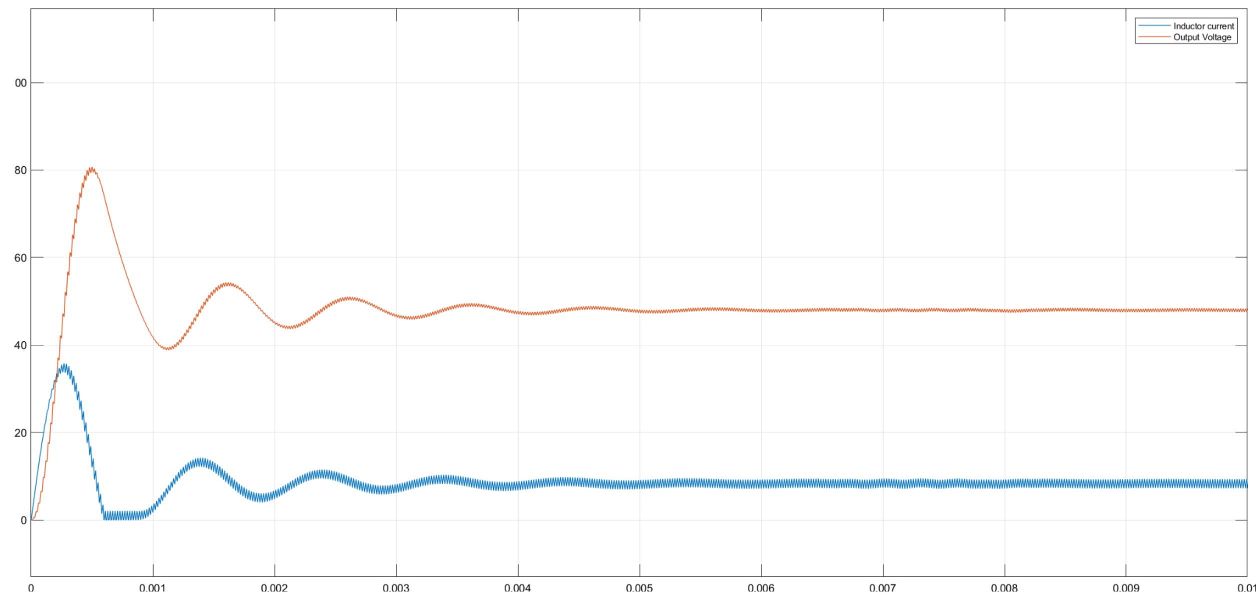
II. Capacitor voltage and current waveforms in the ideal case at D=0.5
RMS Value of capacitor current = 5.563 A




III. When rl = 5% RL , the inductance for which converter falls under CCM mode.
For CCM mode Inductor value = 13.3uH
The waveform of the practical inductor current

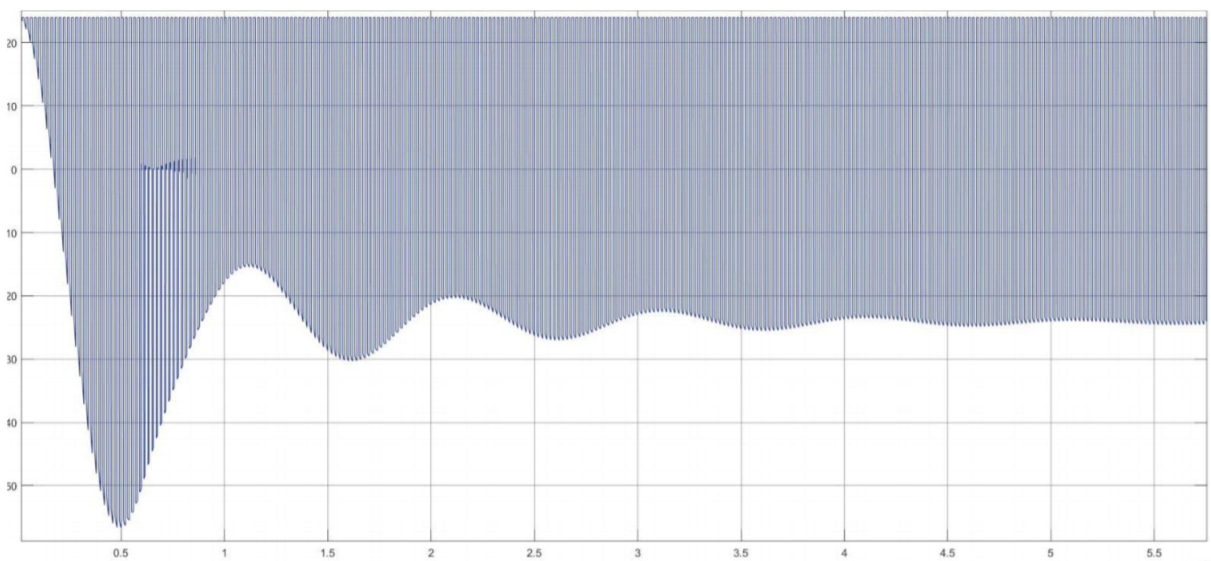


IV. For case (i) with D=0.5 , Initial output voltage = 0 V, Plot of Inductor current, and output voltage builds up from starting to steady state.



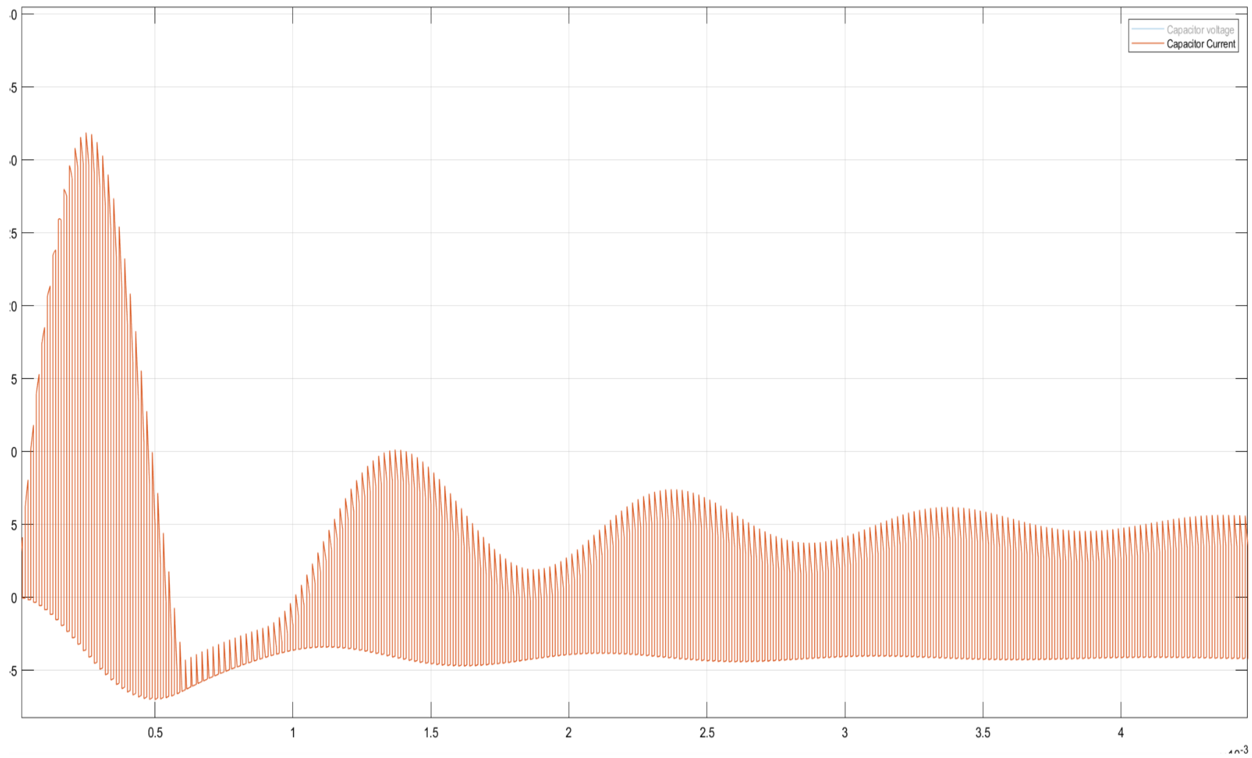

INDUCTOR VOLTAGE

Transient Current



Steady state condition

CAPACITOR CURRENT
Transient State

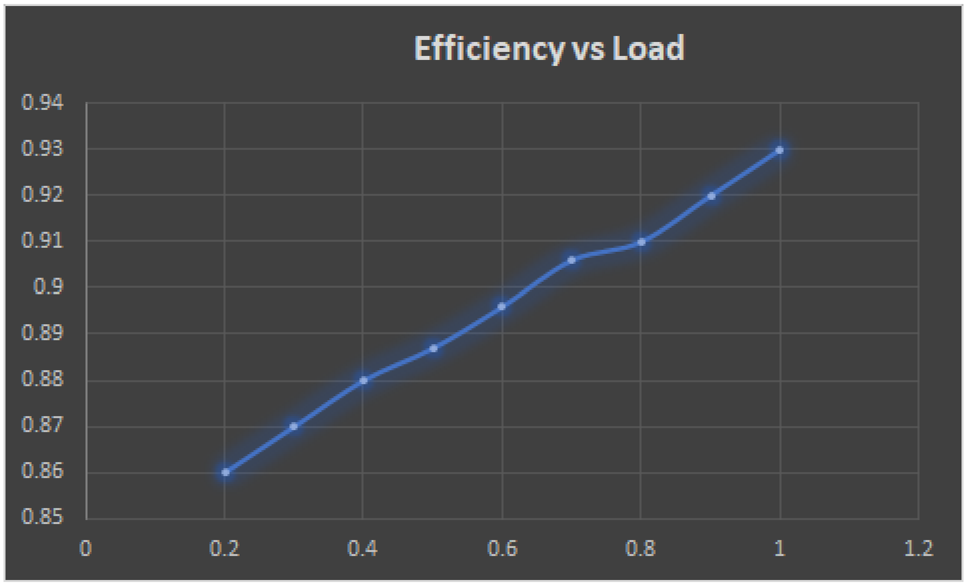



Steady State

V. The load is varied between 0.2 PU to 1 PU in steps of 0.1. Plot of load vs efficiency characteristics

| LOAD (PU) | Efficiency |
|---|---|
| 0.2 | 0.86 |
| 0.3 | 0.87 |
| 0.4 | 0.88 |
| 0.5 | 0.887 |
| 0.6 | 0.896 |
| 0.7 | 0.906 |
| 0.8 | 0.91 |
| 0.9 | 0.92 |

| | |
|---|---|
| 1 | 0.93 |




**PART - B**

BUCK-BOOST CONVERTER :

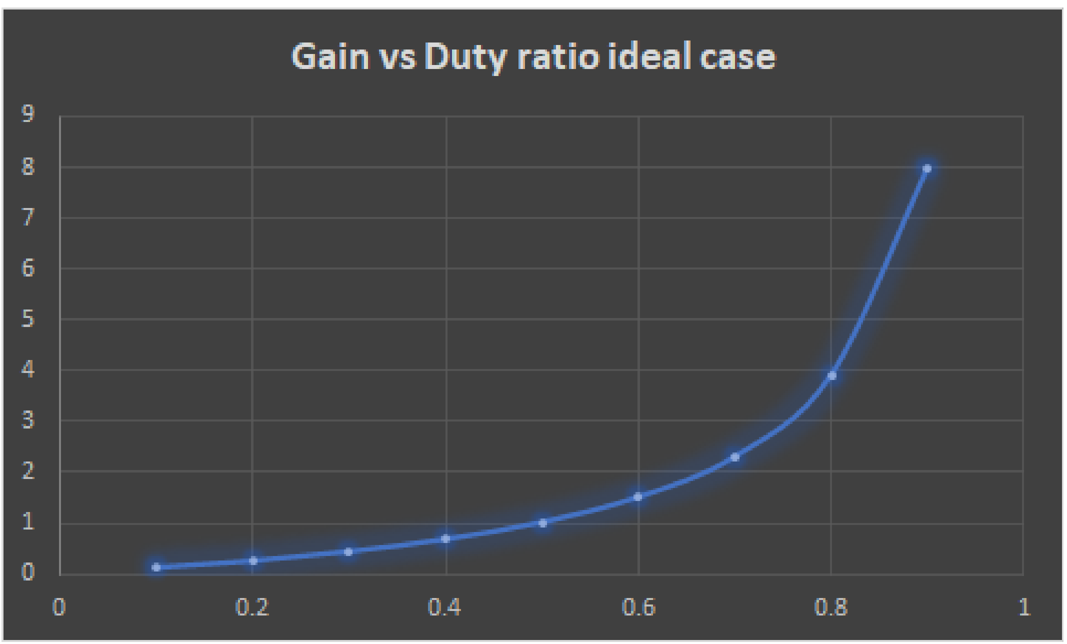
- Input Voltage (Vin) =57V
- Inductor L = 226μH
- Capacitance C = 54μF
- Load resistance RL = 11.52Ω
- Switching Frequency = 50 kHz
- Duty Cycle = 0.5
- MOSFET and diode resistance as 1μΩ
- diode voltage drop as 0.
- Parasitic resistance of inductor case (i) - rl = 0 in and case (ii) rl = 5% of RL.
- Duty ratio is varied in range 0.1 to 0.9 in steps of 0.1

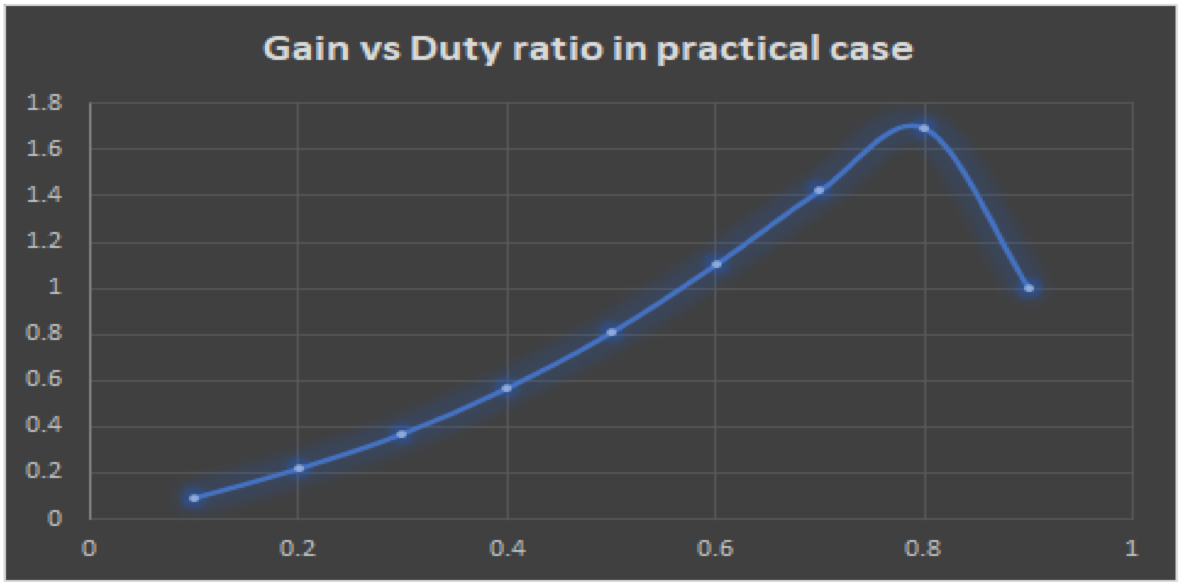
I.

| Duty ratio | Vin(V) | Vout(V) Ideal Case [rl = 0] | Gain in Ideal case | Vout(V) rl = 5% of rl | Gain in case rl = 5% of RL |
|---|---|---|---|---|---|
| 0.1 | 24 | 6.74 | 0.118 | 25.14 | 1.0475 |

| | | | | | |
|---|---|---|---|---|---|
| 0.2 | 24 | 14.53 | 0.2508 | 27.87 | 1.16125 |
| 0.3 | 24 | 24.85 | 0.4359 | 31.2 | 1.3 |
| 0.4 | 24 | 38.56 | 0.6765 | 35.18 | 1.465 |
| 0.5 | 24 | 57.66 | 1.0115 | 40.29 | 1.6787 |
| 0.6 | 24 | 86.01 | 1.5089 | 45.12 | 1.88 |
| 0.7 | 24 | 131.5 | 2.307 | 51.97 | 2.1654 |
| 0.8 | 24 | 223.2 | 3.9157 | 53.99 | 2.249 |
| 0.9 | 24 | 439.8 | 8 | 40.54 | 1.689 |

For ideal case graph is again exponential, according to the gain formula Gain - D/(1-D). For practical case where there is parasitic resistance with the inductor, hence there is power dissipation and curve isn't exactly exponential. With high duty ratio there is a greater power loss and gain decreases.




Gain vs Duty ratio in practical case
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1

II. CASE I :

Case 1 : $V_{in} = 57\ V$ $C = 54\ \mu F$ $R_{load} = 11.52\ \Omega$

$L = 226\ \mu H$ $R_L = 0\ \Omega$

Duty ratio $-$ 0.457

For buck-boost converter to work under CCM condition, ~~Ca~~ Gain $= \frac{D}{1-D}$ (abs value)

for DCM Gain $= \frac{V_{in} D^2 T_{SW}}{2 L I_{out}}$.

At boundary region, both gain will be same

$$\frac{D}{1-D} = \frac{V_{in} D^2 T_{SW}}{2 L I_{out}}$$

$$I_{out} = \frac{V_{out}}{R_{Load}}$$

$$f_{sw} = \frac{R_{Load} (1-D)^2}{2L}$$

$$= \frac{10 \times (1-0.457)^2}{2 \times 226 \times 10^{-6}} = 7.515\ kHz$$

At starting $f_s = 50\ kHz$. So we can vary switching frequency from 5kHz slowly to 10kHz, meaning transition from ~~E~~ DCM to CCM state should occur somewhere around this point. ~~We~~ Steady state current through inductor is observed. When it becomes zero, it means converter operates in DCM.

| Switching Frequency (in KHz) | Inductor current (in A) | Mode |
|---|---|---|
| 5 | -0.061 | DCM |
| 6 | -0.055 | DCM |
| 7 | -0.050 | DCM |
| 8 | 0.56 | CCM |
| 7.2 | -0.45 | DCM |
| 7.4 | -0.010 | DCM |
| 7.6 | 0.164 | CCM |
| 7.8 | 0.33 | CCM |
| 7.5 | 0.032 | CCM |

Hence we see that around frequency = 7.5 kHz, the converter transitions from DCM to CCM mode.

CASE II : Again, switching frequency is varied from 5 kHz to 10 kHz, and minimum current through inductor under steady state is observed.

| Switching Frequency (in KHz) | Inductor current (in A) | Mode |
|---|---|---|
| 5 | -0.043 | DCM |
| 6 | -0.038 | DCM |
| 7 | -0.035 | DCM |
| 8 | -0.0071 | DCM |
| 9 | 0.589 | CCM |
| 8.2 | 0.0566 | CCM |
| 8.1 | 0.0112 | CCM |

From the table we can clearly observe that when switching frequency is in the range 8-8.1 kHz, the converter transitions from DCM to CCM.

III. Case I : Average input and output current measurement.

| Duty Ratio | Input Current (A) | Output Current (A) |
|---|---|---|
| 0.1 | 0.2442 | 0.5619 |
| 0.2 | 0.852 | 1.261 |
| 0.3 | 1.996 | 2.157 |
| 0.4 | 4.086 | 3.347 |
| 0.5 | 8.021 | 5.002 |
| 0.6 | 15.97 | 7.468 |
| 0.7 | 34.52 | 11.54 |
| 0.8 | 91.09 | 19.36 |
| 0.9 | 379.8 | 38.21 |

**PART C**

DO LATER **** DOUBT

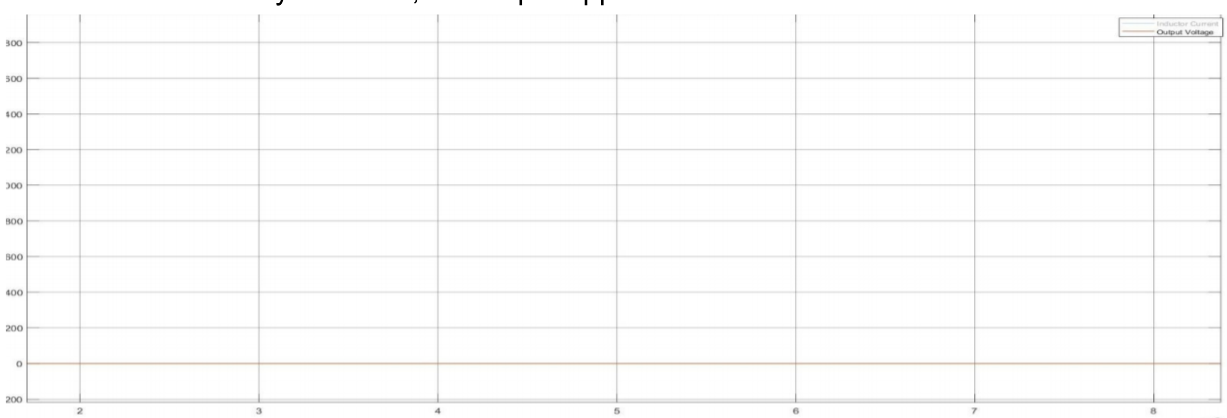
**DISCUSSION QUESTIONS :**

**1. Comment on the comparison of overall (both core and copper loss) loss of the inductor when the inductance is changed from specified value in CCM to critical inductance value. Assume inductor resistance has not changed.**

**Ans :** It is observed from the experiment that when inductance is changed from a specified value in CCM to critical inductance value, core loss increases but copper loss remains constant. Finally when critical state is achieved then, overall loss increases even more.

**2.Assuming ideal boost converter, compare the theoretical and simulated value of Vout for duty ratio=1, and write down your observations.**

**Ans :** In theoretical case, the output voltage of ideal boost converter should shoot to infinity. But in the simulation at duty ratio 0.1 , the output appears zero.




**3. For a given duty ratio and load, voltage gain is higher in DCM or CCM? Why? (Consider ideal Boost Converter)**

**Ans :**  For ideal boost converter, the voltage gain under CCM is greater than DCM condition.
*** doubt***