Exercise No. 7

Question No.1

A boost converter has parameter Vs =20 V, D =0.6, R =12.5 Ω, L=10 µH, C =40 µF, and the switching frequency is 200 kHz. Determine
(a) the output voltage
(b) the average, maximum, and minimum inductor currents.
(c) the average current in the diode
Assume ideal components.

Part (a):

$$V_o = V_{in} * \frac{1}{1-D} = 20 * \frac{1}{1-0.6} = 50\ V$$

Part (b):

$$\langle i_L \rangle = \frac{I_{max} + I_{min}}{2} = \frac{V_{in}}{(1-D)^2 R} = \frac{20}{(1-0.6)^2 * 12.5} = 10\ A$$

$$I_{max} = \frac{V_{in}}{(1-D)^2 R} + \frac{V_{in}}{2L} DT = \frac{20}{(1-0.6)^2 * 12.5} + \frac{20 * 0.6}{2 * 10 * 10^{-6} * 2 * 10^5} = 13\ A$$

$$I_{min} = \frac{V_{in}}{(1-D)^2 R} - \frac{V_{in}}{2L} DT = \frac{20}{(1-0.6)^2 * 12.5} - \frac{20 * 0.6}{2 * 10 * 10^{-6} * 2 * 10^5} = 7\ A$$

Part (c):

$$\langle i_D \rangle = \langle i_L \rangle * (1-D) = 10 * (1-0.6) = 4\ A \quad or \quad \langle i_D \rangle = \frac{V_o}{R} = \frac{50}{12.5} = 4\ A$$

Question 2:

A boost converter has the input voltage of 50 V, duty cycle of 0.6, resistance of 10 Ω , inductance of 30 μH and the switching frequency of 200 kHz. Determine,

a) Output voltage.

b) Average, minimum and maximum inductor current.

c) Average diode current.

a) Duty Ratio:

For the boost converter we have,

$$\frac{V_0}{V_s} = \frac{1}{1-D}$$

$$V_0 = \frac{V_s}{1-D} = \frac{50}{1-0.6} = 125\ V$$

b) Average, Minimum and Maximum Inductor Current:

For average inductor current we have,

$$i_{L\,(avg)} = \frac{V_s}{(1-D)^2\ x\ R}$$

$$i_{L\,(avg)} = \frac{50}{(1-0.6)^2\ x\ 10} = 31.25\ A$$

For maximum inductor current we have,

$$i_{L\,(max)} = \frac{V_s}{(1-D)^2\ x\ R} + \frac{V_s DT}{2L}$$

$$i_{L\,(max)} = \frac{50}{(1-0.6)^2\ x\ 10} + \frac{50\ x\ 0.6}{2\ x\ 30\ x\ 10^{-6} x\ 200\ x\ 10^3} = 33.75\ A$$

For minimum inductor current we have,

$$i_{L\,(min)} = \frac{V_s}{(1-D)^2\ x\ R} - \frac{V_s DT}{2L}$$

$$i_{L\,(min)} = \frac{50}{(1-0.6)^2\ x\ 10} - \frac{50\ x\ 0.6}{2\ x\ 30\ x\ 10^{-6} x\ 200\ x\ 10^3} = 26.25\ A$$

c) Average Diode Current:

The average diode current in boost converter is given as,

$$i_{D\,(avg)} = i_{L\,(avg)}\ x\ (1-D)$$

$$i_{D\,(avg)} = 31.25\ x\ (1-0.6)$$

$$i_{D\,(avg)} = 12.5\ A$$

or

$$i_{D\,(avg)} = \frac{V_o}{R}$$

$$i_{D\,(avg)} = \frac{125}{10} = 12.5\ A$$

Question 3:

A buck-boost converter has input voltage of 24 V, duty cycle of 0.65, the load resistance of 7.5 Ω, inductance of 50 μH and capacitance of 200 μF. The switching frequency is 10 kHz.

Find,

a) Output voltage.

b) Average, minimum and maximum inductor current.

a) Output Voltage:

As we know that for buck-boost converter,

$$\frac{V_0}{V_s} = \frac{D}{1-D}$$

$$V_0 = \frac{V_s \, x \, D}{1-D}$$

$$V_0 = \frac{24 \, x \, 0.65}{1-0.65} = 44.57 \, V$$

b) Average, Minimum and Maximum Inductor Current:

For Average Current:

$$i_{L\,(avg)} = \frac{V_s \, x \, D}{(1-D)^2 \, x \, R}$$

$$i_{L\,(avg)} = \frac{24 \, x \, 0.65}{(1-0.65)^2 \, x \, 7.5} = 16.98 \, A$$

a) Output Voltage:

As we know that for buck-boost converter,

$$\frac{V_0}{V_s} = \frac{D}{1-D}$$

$$V_0 = \frac{V_s \, x \, D}{1-D}$$

$$V_0 = \frac{24 \, x \, 0.65}{1-0.65} = 44.57 \, V$$

b) Average, Minimum and Maximum Inductor Current:

For Average Current:

$$i_{L\,(avg)} = \frac{V_s \, x \, D}{(1-D)^2 \, x \, R}$$

$$i_{L\,(avg)} = \frac{24 \, x \, 0.65}{(1-0.65)^2 \, x \, 7.5} = 16.98 \, A$$

For Maximum Current:

$$i_{L\,(max)} = \frac{V_s \text{ x } D}{(1-D)^2 \text{ x } R} + \frac{V_s \text{ x } D}{2Lf}$$

$$i_{L\,(max)} = \frac{24\ x\ 0.65}{(1-0.65)^2\ x\ 7.5} + \frac{24\ x\ 0.65}{2\ x\ 50\ x\ 10^{-6} x\ 10\ x\ 10^3} = 32.58\ A$$

For Minimum Current:

$$i_{L\,(min)} = \frac{V_s \text{ x } D}{(1-D)^2 \text{ x } R} - \frac{V_s \text{ x } D}{2Lf}$$

$$i_{L\,(min)} = \frac{24\ x\ 0.65}{(1-0.65)^2\ x\ 7.5} - \frac{24\ x\ 0.65}{2\ x\ 50\ x\ 10^{-6} x\ 10\ x\ 10^3} = 1.38\ A$$

Question. No 04

A boost converter has the input voltage of 5 V, output voltage of 20 V, output power of 40 W. The minimum value of inductor current must be at least 80% of the average inductor current. The switching frequency is 85 kHz. Find the duty cycle and the minimum inductor value.

Given that the minimum value of inductor current should be 80% of average inductor current. So,

$$i_{L\,(min)} > 0.8\ i_{L\,(avg)}$$

$$\frac{V_s}{(1-D)^2\ x\ R} - \frac{V_s DT}{2L} > \frac{0.8\ V_s}{(1-D)^2\ x\ R}$$

$$\frac{V_s}{(1-D)^2\ x\ R} - \frac{0.8\ V_s}{(1-D)^2\ x\ R} > \frac{V_s DT}{2L}$$

$$\frac{0.2\ V_s}{(1-D)^2\ x\ R} > \frac{V_s DT}{2L}$$

After rearranging we have,

$$L > \frac{D\ x\ (1-D)^2 x\ R}{0.4\ x\ f}$$

For D and R,

As we know for boost converter,

$$\frac{V_0}{V_s} = \frac{1}{1-D}$$

$$\frac{20}{5} = \frac{1}{1-D}$$

$$D = 0.75$$

and,

$$P_{out} = \frac{V_0^2}{R}$$

$$R = \frac{(20)^2}{40} = 10\ \Omega$$

Now, for inductance,

$$L > \frac{0.75\ x\ (1-0.75)^2 x\ 10}{0.4\ x\ 85\ x\ 10^3}$$

$$L > 13.79\ \mu H$$