Exercise no.6 with solution

Question 1:

The input and output of a buck converter is 6 V and 1.5 V, respectively. The resistance is 3 Ω, inductance is 5 μH, capacitance is 10 μF and the switching frequency is 400k Hz. Find,

a) Duty ratio.

b) Average and peak inductor current.

c) Average source current.

d) Peak and average diode current.

a) Duty Ratio:

For the buck converter we have,

$$D = \frac{V_0}{V_s} = \frac{1.5}{6} = 0.25$$

b) Average and Peak Inductor Current:

Average Inductor Current:

$$i_{L\,(avg)} = \frac{V_0}{R} = \frac{1.5}{3} = 0.5\ A$$

Peak Inductor Current:

$$i_{L\,(max)} = V_0\ x\ \left[\frac{1}{R} + \frac{1-D}{2Lf}\right]$$

$$i_{L\,(max)} = 1.5\ x\ \left[\frac{1}{3} + \frac{1-0.25}{2x5x10^{-6}x400x10^{3}}\right] = 0.78\ A$$

c) Average Source Current:

Let us assume ideal converter,

$$\text{Input Power} = \text{Output Power}$$

$$V_{in}\ x\ i_{in} = \frac{V_o^2}{R}$$

$$i_{in} = \frac{V_o^2}{R\ xV_{in}}$$

$$i_{in} = \frac{(1.5)^2}{3\ x\ 6} = 0.12\ A$$

d) Peak and Average Diode Current:

The average diode current is given as,

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

$$i_{D\,(avg)} = 0.5\; x\; (1 - 0.25) = 0.37\; A$$

The maximum diode current is given as,

$$i_{D\,(max)} = i_{L\,(max)} = 0.78\; A$$

Question 2:

An input of 100 V is applied to buck converter and the output is 50 V. The switching frequency is 100 kHz and the output power to load resistance is 165 W. Determine,

a) Duty ratio.

b) Value of inductance to limit the maximum inductor current

to 6.25 A.

c) The minimum inductor current.

a) Duty Ratio:

For the buck converter we have,

$$D = \frac{V_0}{V_s} = \frac{50}{100} = 0.5$$

b) Value of Inductor:

Average Inductor Current:

$$i_{L\,(max)} = V_0\; x\; \left[\frac{1}{R} + \frac{1 - D}{2Lf}\right]$$

$$i_{L\,(max)} = \left[\frac{V_0}{R} + \frac{V_0(1 - D)}{2Lf}\right]$$

$$i_{L\,(max)} - \frac{V_0}{R} = \frac{V_0(1-D)}{2Lf}$$

$$L = \frac{V_0(1-D)}{2f\left(i_{L\,(max)} - \frac{V_0}{R}\right)}$$

For R,

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

$$R = \frac{V_o^2}{P_{out}} = \frac{(50)^2}{165} = 15\,\Omega$$

So,

$$L = \frac{50(1-0.5)}{2\,x\,100\,x\,10^3\left(6.25 - \frac{50}{15}\right)} = 42.8\,\mu H$$

c) Minimum Inductor Current:

We have the formula,

$$i_{L\,(min)} = V_0\,x\left[\frac{1}{R} - \frac{1-D}{2Lf}\right]$$

$$i_{L\,(min)} = 50\,x\left[\frac{1}{15} - \frac{1-0.5}{2x42.8x10^{-6}x100x10^3}\right]$$

$$i_{L\,(min)} = 0.412\,A$$