ELEC_E8412 Power Electronics

Exercise#5 12.11.2020

Problem 1:

A buck converter has an input of 6 V and an output of 1.5 V. The load resistor is 3 Ω, the switching frequency is 400 kHz, L = 5 μH, and C =10 μF. Determine

(a) the duty ratio

(b) the average and peak inductor currents

(c) the average source current,

(d) the peak and average diode current.

Solution:

Part (a):

$$D = \frac{V_o}{V_{in}} = \frac{1.5}{6} = 0.25$$

Part (b):

$$\langle i_L \rangle = \frac{I_{max} + I_{min}}{2} = \frac{V_o}{R} = \frac{1.5}{3} = 0.5\ A$$

$$I_{max} = V_o\left(\frac{1}{R} + \frac{1-D}{2Lf}\right) = 1.5\left(\frac{1}{3} + \frac{1-0.25}{2*5*10^{-6}*4*10^{5}}\right) = 0.78\ A$$

Part (c):

$\langle i_{in} \rangle$ =?

$$V_{in}.\langle i_{in} \rangle = \frac{V_o^2}{R} = \frac{(D*V_{in})^2}{R} \qquad \longrightarrow \qquad \langle i_{in} \rangle = \frac{D^2 V_{in}}{R} = \frac{(0.25)^2*6}{3} = 0.125\ A$$

Part (d):

Fig 5-5 b

$$I_{D\_max} = I_{max} = 0.78\ A$$

$$\langle i_D \rangle = \langle i_L \rangle * (1-D) = \frac{V_o}{R}*(1-D) = \frac{1.5}{3}*(1-0.25) = 0.375\ A$$

Problem 2:

A buck converter has an input of 50 V and an output of 25 V. The switching frequency is 100 kHz, and the output power to a load resistor is 125 W. Determine

(a) the duty ratio

(b) the value of inductance to limit the peak inductor current to 6.25 A.

(c) the minimum inductor current

Solution:

$$R = \frac{V_o^2}{P_{out}} = \frac{(25)^2}{125} = 5\ \Omega$$

Part (a):

$$D = \frac{V_o}{V_{in}} = \frac{25}{50} = 0.5$$

Part (b):

$$I_{max} = V_o\left(\frac{1}{R} + \frac{1-D}{2Lf}\right) = 25\left(\frac{1}{5} + \frac{1-0.5}{2 * L * 10^5}\right)$$

$$I_{max} = 6.25\ A \quad \longrightarrow \quad L = 50\ \mu H$$

Part (c):

$$I_{min} = V_o\left(\frac{1}{R} - \frac{1-D}{2Lf}\right) = 25\left(\frac{1}{5} - \frac{1-0.5}{2 * 50 * 10^{-6} * 10^5}\right) = 3.75\ A$$

Problem 3:

A boost converter has the following parameters:

V_{in} = 5 V, V_{out} = 20 V, and P_{out} = 40 W

The minimum value of the inductor current must be at least 80% of the average inductor current. The switching frequency is 85 kHz. Determine the duty ratio and the minimum inductor value.

Solution:

$$I_{min} > 0.8\,\langle i_L\rangle \;\longrightarrow\; \langle i_L\rangle - \frac{\Delta i_L}{2} > 0.8\,\langle i_L\rangle \;\longrightarrow\; 0.2\langle i_L\rangle > \frac{\Delta i_L}{2}$$

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

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

D=? R=?

$$\frac{V_o}{V_{in}} = \frac{20}{5} = \frac{1}{1-D} \;\rightarrow\; D = 0.75$$

$$P_{out} = 40 = \frac{V_o^2}{R} = \frac{(20)^2}{R} \;\rightarrow\; R = 10\Omega$$

$L >$13.79 µH

Problem 4:

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.

Solution:

Part (a):

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

Part (b):

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

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

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

Part (c):

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

Problem 5:

A buck-boost converter has the following parameters:

V_{in} = 24 V, D= 0.65, R = 7.5 Ω, L = 50 µH, C = 200 µF, and switching frequency = 100 KHz. Determine

(a) the output voltage,

(b) the average, maximum, and minimum inductor currents.

Solution:

Part (a):

$$\frac{V_o}{V_{in}} = \frac{D}{1-D}\ , D = 0.65,\ V_{in} = 24\ V \quad \rightarrow \quad V_o = 44.571\ V$$

Part (b):

$$\langle i_L \rangle = \frac{V_{in}D}{(1-D)^2R} = \frac{24 * 0.65}{(1-0.65)^2 * 7.5} = 16.98\ A$$

$$\Delta i_L = \frac{V_{in}DT}{L} = \frac{24 * 0.65}{50 * 10^{-6} * 10^5} = 3.12\ A$$

$$I_{max} = \langle i_L \rangle + \frac{\Delta i_L}{2} = 16.98 + \frac{3.12}{2} = 18.54\ A$$

$$I_{min} = \langle i_L \rangle - \frac{\Delta i_L}{2} = 16.98 - \frac{3.12}{2} = 15.42\ A$$

Problem 6:

A buck-boost converter has parameters Vs=12 V, D=0.6, R=10 Ω, L =10 μH, C =20 μF, and a switching frequency of 200 kHz. Determine

(a) the output voltage

(b) the average, maximum, and minimum inductor currents, and

(c) the average value of input current.

Solution:

Part (a):

$$V_o = V_{in} * \frac{D}{1-D} = 12 * \frac{0.6}{1-0.6} = 18\,V$$

Part (b):

$$\langle i_L \rangle = \frac{V_{in}D}{(1-D)^2 R} = \frac{12 * 0.6}{(1-0.6)^2 * 10} = 4.5\,A$$

$$\Delta i_L = \frac{V_{in}DT}{L} = \frac{12 * 0.6}{10 * 10^{-6} * 2 * 10^5} = 3.6\,A$$

$$I_{max} = \langle i_L \rangle + \frac{\Delta i_L}{2} = 4.5 + \frac{3.6}{2} = 6.3\ A$$

$$I_{min} = \langle i_L \rangle - \frac{\Delta i_L}{2} = 4.5 - \frac{3.6}{2} = 2.7\,A$$

Part (c):

$\langle i_{in} \rangle =?$

$$V_{in}.\langle i_{in} \rangle = \frac{V_o^2}{R} = \frac{(D * V_{in})^2}{(1-D)^2 R} \quad \longrightarrow \quad \langle i_{in} \rangle = \frac{D^2 * V_{in}}{(1-D)^2 R} = \frac{(0.6)^2 * 12}{(1-0.6)^2 * 10} = 2.7\,A$$