ECE 4643: Power Electronics

Exam 2: Solution

Time: Wednesday, March 28^{th}, 2018, 9:30-10:25 AM

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Q1 [6 marks]

Q1.1–

Q1.2–

Q1.3–

Q2 [4 marks]

A DC buck-boost PEC has a supply voltage of $V_s = 24$, a duty cycle of $D = 0.4$, a switching frequency $f = 100$ kHz, $L = 200\ \mu$H, and $C = 80\ \mu$F. If this PEC supplies a load of $R_L = 5\ \Omega$. For this converter, determine:

a) The output average voltage V_O.

In oder to specify V_O, the mode of the dc PEC has to be determined. Using the boundary values of L_B and C_B, as:

$$L_B = \frac{(1-D)^2 R_L T}{2} = \frac{(1-0.4)^2 \times 5}{2 \times 100 \times 10^3} = 9.0\ \mu H$$

$$C_B = \frac{DT}{2R_L} = \frac{0.4}{2 \times 100 \times 10^3 \times 5} = 0.4\ \mu F$$

Since $L > L_B$ and $C > C_B$, then this dc PEC is operating in CCM. The output average voltage V_O can be determined as:

$$V_O = -V_s\left(\frac{D}{1-D}\right) = -24\left(\frac{0.4}{1-0.4}\right) = -16\ \ V$$

b) The inductor average current I_O.

The value of the average inductor current I_L is determined as:

$$I_L = \frac{DV_s}{R(1-D)^2} = \frac{24 \times 0.4}{5(1-0.4)^2} = 5.33\ \ A$$

c) The maximum and minimum values of the inductor current.

The maximum (I_1) and minimum (I_2) inductor currents can be determined using the current

ripple in the inductor Δi_L, which is determined as:

$$\Delta i_L = \frac{DV_s}{fL} = \frac{0.4 \times 24}{100 \times 10^3 \times 200 \times 10^{-6}} = 0.48 \ \ A$$

$$I_1 = I_L + \frac{\Delta i_L}{2} = 5.33 + \frac{0.48}{2} = 5.57 \ \ A$$

$$I_2 = I_L - \frac{\Delta i_L}{2} = 5.33 - \frac{0.48}{2} = 5.09 \ \ A$$

d) The output voltage ripple.

The ripple in the output voltage Δv_O can be determined as:

$$\Delta v_O = \frac{V_O D}{f R_L C} = \frac{16 \times 0.4}{5 \times 100 \times 10^3 \times 80 \times 10^{-6}} = 0.16 \ \ V$$

Q3 [5 marks]

A flyback DC converter has to feed a resistive load ($R_L = 12\ \Omega$) with $V_O = 12$ V from a supply of $V_s = 84$ V. If this PEC has a high frequency transformer with $N_1/N_2 = 3$, and is operated at a switching frequency $f = 40$ kHz, $L = 500\ \mu$H, and $C = 200\ \mu$F, determine:

a) The duty cycle D [1 mark]. The duty-cycle can be determined as:

$$\frac{V_O}{V_s} = \frac{D}{1-D}\left(\frac{N_2}{N_1}\right) \Longrightarrow \frac{D}{1-D} = \frac{12}{84} \times 3 \Longrightarrow D = 0.3$$

b) The inductor average current I_L [1 mark]. The average inductor current I_L can be determined using I_s as:

$$I_L = \frac{I_s}{D} = \frac{V_O^2/(V_s R_L)}{D} = \frac{12^2/(84 \times 12)}{0.3} = 0.4762 \ \ A$$

c) The maximum and minimum values of the inductor current [1 mark]. The maximum (I_1) and minimum (I_2) inductor currents can be determined using the current ripple in the inductor Δi_L, which is determined as:

$$\Delta i_L = \frac{DV_s}{fL} = \frac{0.3 \times 84}{40 \times 10^3 \times 500 \times 10^{-6}} = 1.26 \ \ A$$

$$I_2 = I_L + \frac{\Delta i_L}{2} = 0.4762 + \frac{1.26}{2} = 1.1062 \ \ A$$

$$I_1 = I_L - \frac{\Delta i_L}{2} = 0.4762 - \frac{1.26}{2} = -0.1538 \rightarrow I_1 = 0 \ \ A$$

Since $I_1 < 0$, the this PEC is operating on the boundary.

d) The output voltage ripple [1 mark]. The ripple in the output voltage Δv_O can be determined as:

$$\Delta v_O = \frac{V_O D}{f R_L C} = \frac{12 \times 0.3}{12 \times 40 \times 10^3 \times 200 \times 10^{-6}} = 0.0375 \ \ V$$

e) The efficiency of this PEC [1 mark]. The efficiency can be determined as:

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_O I_O}{V_s I_s} = \frac{12 \times 0.4762}{84 \times 0.4762 \times 0.3} = 47.6\%$$