ELEC-E8412 Power Electronics

HW#3_ Solutions

Problem1:

A single-phase full-wave rectifier has a resistive load of 10 Ω and an ac source of $150\sin(2\pi 60t)$. Determine

(a) the average, peak, and rms currents in the load and in each diode.

(b) the peak reverse voltage across each of the diodes

Solution:

Part (a)

The average current in the load and in each diode:

$$\langle i_o \rangle = \frac{\langle V_o \rangle}{R} = \frac{2V_m}{\pi R} = \frac{2 * 150}{\pi * 10} = 9.55\ A$$

$$\langle i_D \rangle = \frac{\langle i_o \rangle}{2} = 4.775\ A$$

The peak current of load and each diode:

$$\langle i_{o,m} \rangle = \langle i_{D,m} \rangle = \frac{V_m}{R} = \frac{150}{10} = 15\ \ A$$

The rms current of load and each diode:

$$I_{o,rms} = \frac{V_{o,rms}}{R} = \frac{(\frac{150}{\sqrt{2}})}{10} = 10.608\ A$$

$$I_{D,rms} = \frac{I_{o,rms}}{\sqrt{2}} = 7.5\ A$$

Part (b)

The maximum voltage across a reverse-biased diode is the peak value of the source voltage

$$V_m = 150\ V$$

Problem2:

The full-wave rectifier has a 130-V rms 60 Hz source, R=150 Ω and C=300 μF. Determine

(a) the peak-to-peak voltage variation of the output
(b) the filter capacitance required to limit the peak-to-peak output voltage ripple to 3 volt.

Solution:

Part (a)

$\theta = \pi - tan^{-1}(RCw) = \pi - tan^{-1}(150 * 300 * 10^{-6} * 377) = 1.6297\ rad$

$sin\alpha - sin\theta . e^{-(\pi+\alpha-\theta)/\omega RC} = 0$

$\alpha = 59.23° = 1.0337\ rad$

$\Delta V_0 = V_m(1 - sin\alpha) = 130\sqrt{2}(1 - 0.8592) = 25.882\ V$

Part (b)

$\Delta V_0 \approx \frac{V_m}{2fRC} \rightarrow C \approx \frac{V_m}{2fR.\Delta V_0} = \frac{130\sqrt{2}}{2(60)(150)(3)} = 3404\ \mu F$

Problem3:

A boost converter has an input of 5 V and an output of 25 W at 15 V. The switching frequency is 100 kHz. Determine

(a) the duty ratio,
(b) the minimum inductor value which allows the converter to work in continuous conduction mode (CCM)
(c) the average and the peak value of inductor current
(d) the average and peak value of diode current

Assume ideal components

Hint: Continuous conduction mode means the inductor current is positive through the whole period.

Solution:

$$P_{out} = 25 = \frac{V_o^2}{R} = \frac{(15)^2}{R} \quad \rightarrow \quad R = 9\Omega$$

Part (a):

$$\frac{V_o}{V_{in}} = \frac{15}{5} = \frac{1}{1-D} \quad \rightarrow \quad D = 0.666$$

Part (b):

Working in continuous conduction mode means the inductor current is positive through the whole period, so, to calculate the minimum value for inductor, we should consider $I_{min} = 0$:

$$I_{min} = \frac{V_{in}}{(1-D)^2 R} - \frac{V_{in}.D}{2L_{min}f} = 0 \quad \rightarrow L_{min} = \frac{D.(1-D)^2.R}{2f} = 3.34\ \mu\text{H}$$

Part (c):

$$\langle i_L \rangle = \frac{V_{in}}{(1-D)^2 R} = \frac{5}{(1-0.666)^2 * 9} = 4.98\ A$$

$$I_{max} = \frac{V_{in}}{(1-D)^2 R} + \frac{V_{in}}{2L} DT = 9.96\ A$$

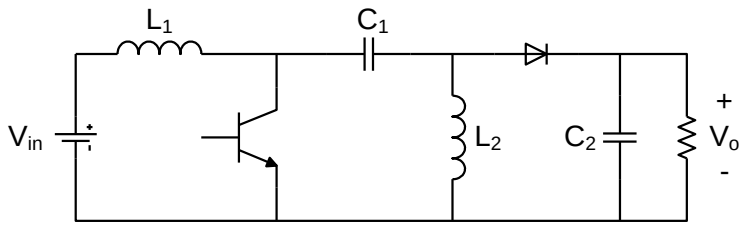
Part (d):

$$I_{D-max} = I_{max} = 9.96\ A$$

$$\langle i_D \rangle = \langle i_L \rangle * (1-D) = 4.98 * (1-0.666) = 1.663\ A$$

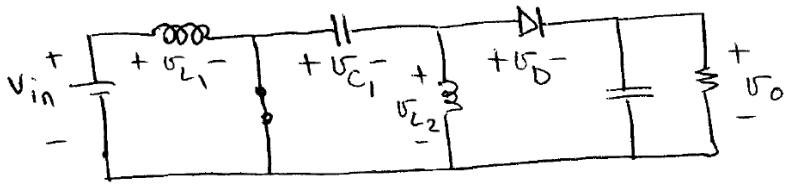
Problem4:

For the dc-dc converter (operating in CCM) depicted in the figure below, make all the required assumptions and find the input-output voltage ratio (V_o/V_{in} =?).



Solution:

Mode 1: S:on , $0 < t < DT$



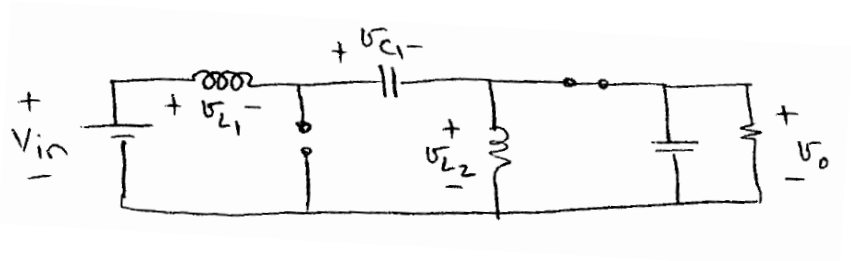
$V_D = -V_{c1} - V_o \qquad if \quad V_{c1} > 0 \quad \& \quad V_o > 0$

Diode is off

$V_{L1} = V_{in} \quad , \quad V_{L2} = -V_{c1}$

Mode 2: S:off , $DT < t < T$

L1 and L2 force diode to conduct



$V_{L1} = V_{in} - V_o - V_{c1} \quad , \quad V_{L2} = V_o$

Steady state: $\langle V_{L1} \rangle = \langle V_{L2} \rangle = 0$

$\langle V_{L1} \rangle = 0 \quad \longrightarrow \quad DV_{in} + (1-D)(V_{in} - V_o - V_{c1}) = 0$

$\langle V_{L2} \rangle = 0 \quad \longrightarrow \quad D(-V_{c1}) + (1-D)(V_o) = 0 \quad \longrightarrow \quad V_{c1} = \frac{1-D}{D} V_o$

$$\frac{V_o}{V_{in}} = \frac{D}{1-D}$$

$V_{c1} > 0 \quad \& \quad V_o > 0 \quad \longrightarrow \quad "Diode\ is\ off" \quad was\ a\ correct\ assumption$