ET4119 Electronic Power Conversion 2009/2010
Homework assignment 2

1. Figure 1 shows a boost converter used in the Toyota Prius hybrid electric vehicle for stepping up the battery voltage from 150-250 V to 500 V. The converter's switching frequency is f_s= 20kHz.

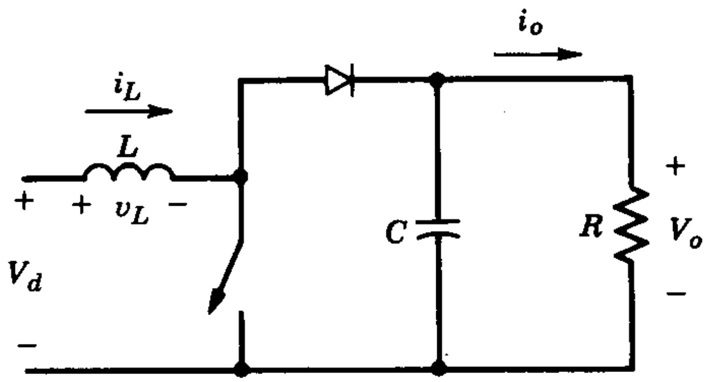


Figure 1

1.1. Calculate the critical (maximum) inductance value of the output filter inductor to ensure that the converter operates in the discontinuous conduction mode for the given input voltage range and the load current up to I_o= 10A.

1.2. Given the inductance value obtained in 1.1 calculate the duty cycle range to keep the output voltage V_o constant (500V) for the given range of the input voltage and the nominal current of I_{nom}= 4A.

1.3. Calculate the required capacitance value of the output filter capacitor to ensure that at the nominal input voltage (Vin_{nom} = 200V) the peak-to-peak output voltage ripple is less than 2% of the nominal output voltage (V_o).

Solutions

1.1:

$I_o := 10A$

$$L_{crit}(V_{in}) := \frac{V_o \cdot \left(1 - \frac{V_{in}}{V_o}\right) \cdot \left(\frac{V_{in}}{V_o}\right)^2}{2 \cdot I_o} \cdot T_s$$

$L_{crit}(V_{inmin}) = 78.75\mu H$

$L_{crit}(V_{inmax}) = 156.25\mu H$

1.2

$L_o := L_{crit}(V_{inmin})$

$I_{onom} := 4A$

$$D(V_{in}) := \sqrt{\frac{2}{1} \cdot \frac{I_{onom}}{\left(\frac{T_s}{L_o}\right) \cdot \frac{V_{in}^2}{V_o - V_{in}}}}$$

$D(V_{inmin}) = 0.443$

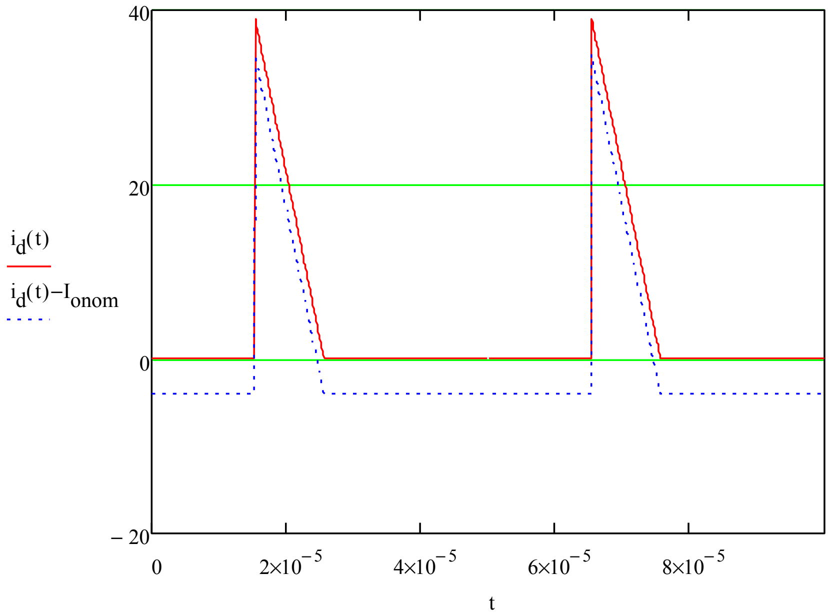
$D(V_{inmax}) = 0.224$

1.3

$$\Delta(V_{in}) := \frac{I_{onom} \cdot 2 \cdot L_o}{T_s \cdot D(V_{in}) \cdot V_{in}}$$

$V_{in} := 200V$

$D_1 := D(V_{in})$ $\quad \Delta_1 := \Delta(V_{in})$ $\quad D_1 = 0.307$ $\quad \Delta_1 = 0.205$



$$t_1 := D_1 \cdot T_s \qquad t_2 := \frac{\frac{V_{in}}{L_o} \cdot D_1 \cdot T_s - I_{onom} + \frac{V_o - V_{in}}{L_o} \cdot D_1 \cdot T_s}{\left(\frac{V_o - V_{in}}{L_o}\right)}$$

$t_1 = 15.37\mu s$ $\qquad$ $t_2 = 24.567\mu s$

$$Q := \left[\int_{t_1}^{t_2} \left(i_d(t) - I_{onom}\right) dt\right] \qquad Q = 1.611 \times 10^{-4} C$$

$$C_{req} := \frac{Q}{2\% \cdot V_o} \qquad C_{req} = 16.111\mu F$$

2. Figure 2 shows a full-bridge DC-DC converter for conversion of the input voltage of V_d=300V to V_o=120V. The switching frequency is f_s=10kHz, the load resistance is R= 5 Ohm and the filter inductance is L = 2 mH.

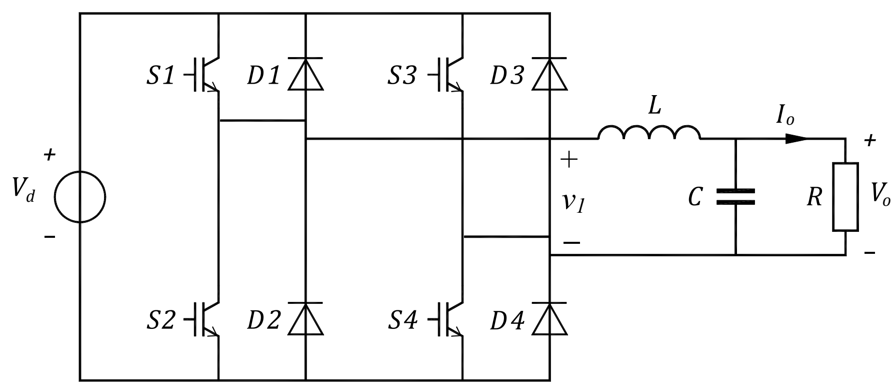


Figure 2

2.1 Calculate D, sketch $v_I(t)$, $i_L(t)$ and indicate which switches are conducting at what time.

2.2 Calculate the required capacitance value of the output filter capacitor to ensure that the output voltage ripple is less than 5% of the nominal output voltage (V_o)

Solutions:

2.1

$$V_0 = (2D-1)V_d$$

D_1=0.7

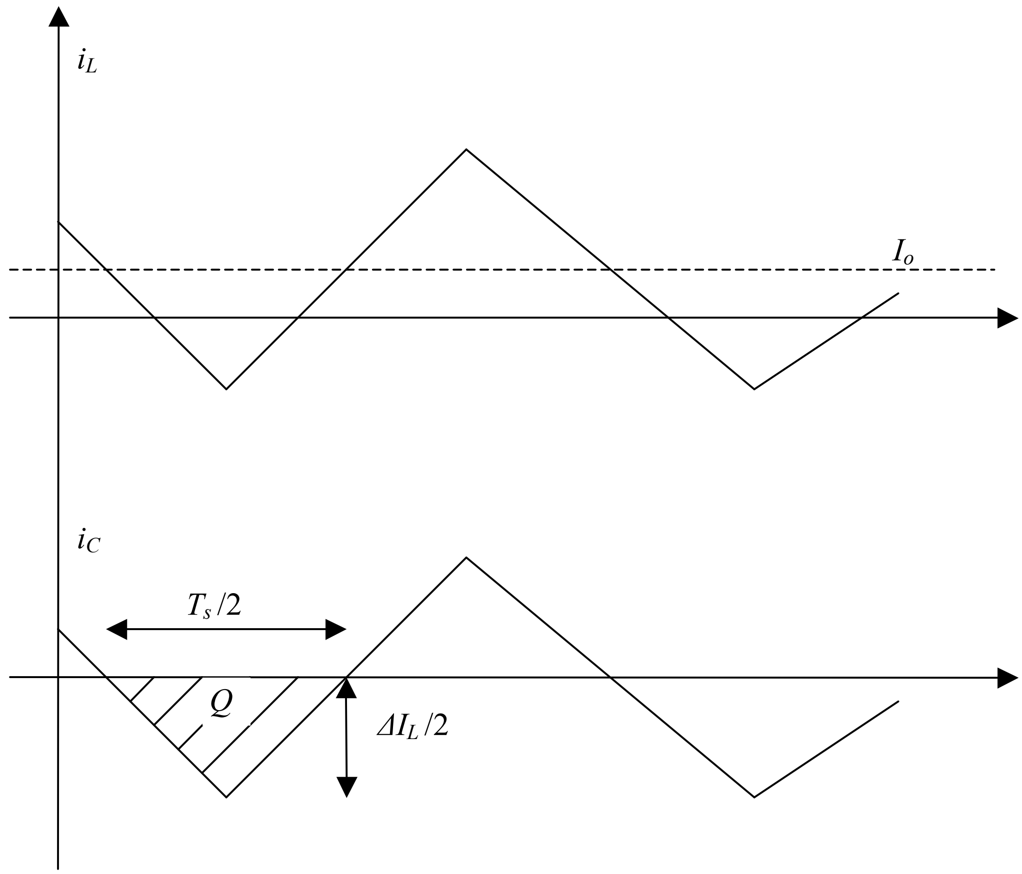
The time waveforms are shown in the book.

2.2

$$C = \frac{Q}{\Delta V}$$

$$Q = \frac{1}{2}\cdot\frac{\Delta I_L}{2}\cdot\frac{T_s}{2}$$

$$\Delta I_L = \frac{2DV_d}{L}(1-D)T_s$$


i_L
I_o
i_C
$T_s/2$
Q
$\Delta I_L/2$