Boost Converter (`PE_boost_3.sqproj`)

Question : In Fig. 1, the chopper feeds a resistive load from a DC source. Switch S is switched at 50 kHz, with a duty ratio (D) of 0.6. All the elements of circuit are ideal. Find the value of R that will make the inductor current just continuous (Take $V_{in} = 15\,\text{V}$).

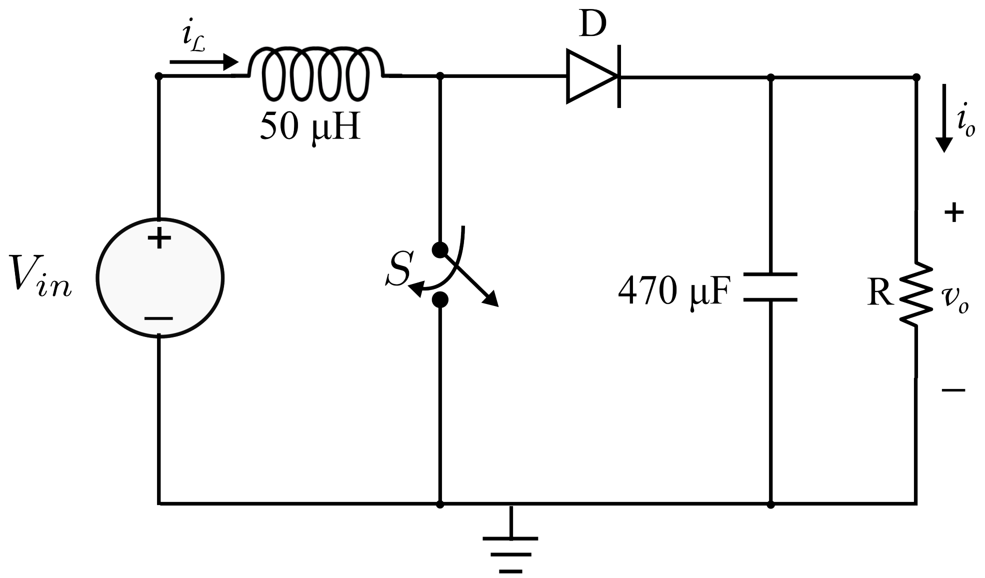

Figure 1: Boost converter

Solution :

Figs. 2 (a) and 2 (b) shows ON and OFF conditions of switch S, respectively.

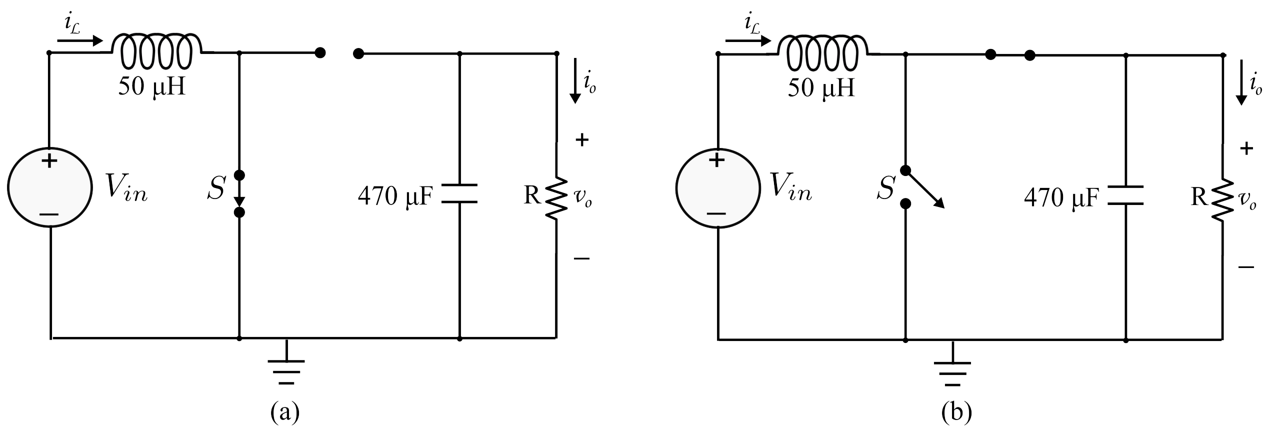

Figure 2: Boost converter circuit. (a) switch is ON, (b) switch is OFF

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Operation: When the switch is ON ($0 < t < DT$), the diode is reverse biased and the inductor stores energy. Alternatively, when the switch is OFF ($DT < t < T$), the diode is forward biased and the inductor releases energy as shown in Fig. 3.

We assume that the circuit is operating under steady state, i.e., the energy stored in the inductor during the ON interval should be released during the OFF interval.

When the inductor current is just continuous, i.e., at the boundary of continuous conduction mode (CCM) and discontinuous conduction mode (DCM), $I_L^{\text{avg}} = \dfrac{\Delta\, I_L}{2}$, where I_L^{avg} is the average inductor current and $\Delta\, I_L$ is the peak to peak ripple inductor current.

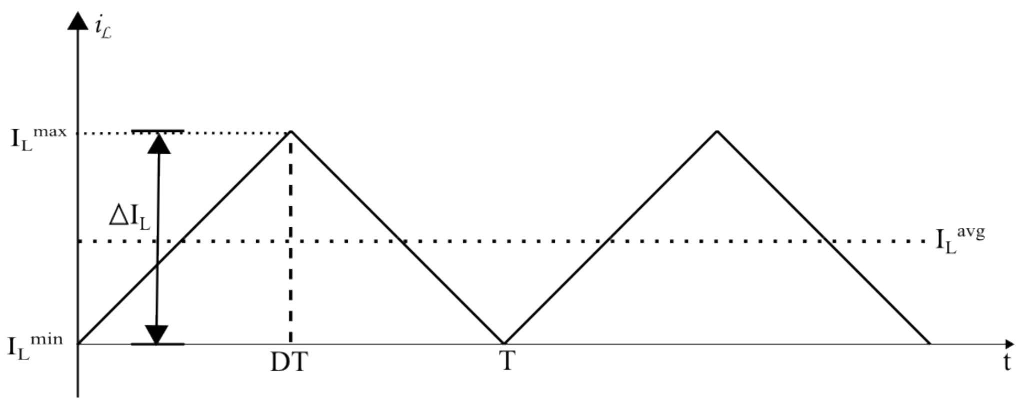

Figure 3: Inductor current waveform at the boundary of CCM and DCM mode

When the switch is ON, applying KVL gives

$$L\,\frac{di_L}{dt} = V_{in}$$

Similarly, when the switch is OFF, applying KVL gives

$$L\,\frac{di_L}{dt} = V_{in} - v_o(t)$$

Applying the volt-sec balance equation,

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

$$\implies V_o = \frac{15}{1-0.6} = 37.5\,\mathrm{V}$$

From Fig. 3, we can see that the peak to peak inductor current is

$$\Delta I_L = I_L^{\max} - I_L^{\min}$$

For $0 < t < DT$, $\qquad i_L(t) = \dfrac{V_{in}\times t}{L} + I_L^{min}$

At $t = DT$, $\qquad i_L(t) = I_L^{\max}$

$$\therefore\ I_L^{\max} = \frac{V_{in}\,DT}{L} + I_L^{\min}$$

$I_L^{\min}$ is zero when the inductor current is at the boundary of continuous and discontinuous conduction.

$$\boxed{\Delta I_L = \frac{V_{in}\,D}{L\,f}}$$

$$\Delta I_L = \frac{15\times 0.6}{(50\times 10^{-6})\times(50\times 10^{3})} = 3.6\,\mathrm{A} \qquad , \qquad I_L^{\mathrm{avg}} = \frac{\Delta I_L}{2} = 1.8\,\mathrm{A}$$

As the voltage source is in series with the inductor, the average source current (I_{in}) and average inductor current (I_L^{avg}) are same.

The overall circuit is lossless, i.e., $P_{out} = P_{in}$.

$$\therefore V_oI_o = V_{in}I_{in} \qquad \implies I_o = \frac{V_{in}I_{in}}{V_o} = \frac{15\times 1.8}{37.5} = 0.72\mathrm{A}$$

$$V_o = RI_o \qquad \implies R = \frac{V_o}{I_o} = \frac{37.5}{0.72} = 52.08\,\Omega$$

SequelApp Exercises:

(1) In a boost converter, $L = 100\,\mu\,\mathrm{H}$ and $D = 0.4$. If the peak-to-peak ripple inductor current $\Delta I_L = 3\,\mathrm{A}$, what is the input voltage? (Take switching frequency to be $50\,\mathrm{kHz}$).

(2) Also, find the value of the load resistance such that the inductor current is at the boundary of continuous and discontinuous conduction modes.

Verify your answer using SequelApp.