**Boost Converter** (PE_boost_5.sqproj)

**Question:** For the converter shown in Fig. 1, assume steady state operation. The duty ratio of the controllable switch is 50 % and its switching frequency is 20 kHz. For the minimum and maximum values of the inductor current to be 6 A and 10 A respectively, determine

(i) the value of inductance required.

(ii) minimum value of smoothing capacitor to be used such that the output voltage peak-to-peak magnitude ($\Delta V_o$) remains limited to 100 mV.

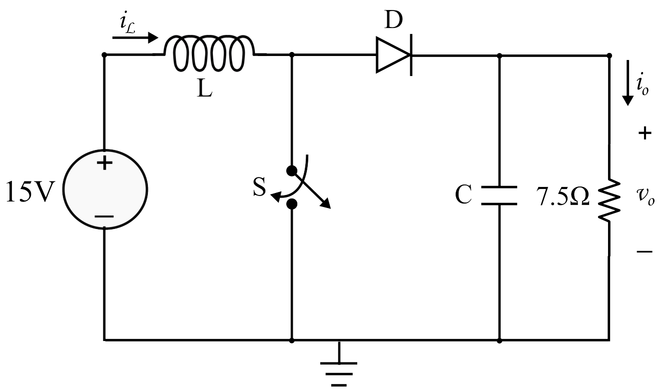


Figure 1: Boost converter

**Solution :**

Figs. 3 (a) and 3 (b) shows ON and OFF conditions of switch S, respectively.

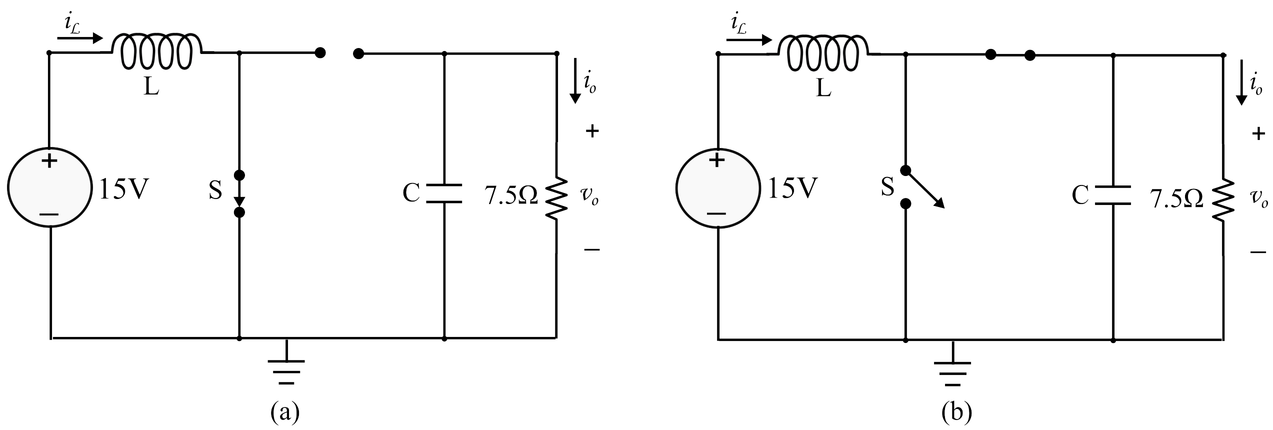


Figure 2: Boost converter circuit. (a) switch is ON, (b) switch is OFF

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**Operation :** When the switch is ON ($0 < t < DT$), the diode is reverse biased and the inductor stores energy. Alternatively, if the inductor current is continuous, when the switch is off ($DT < t < T$), the diode is forward biased and the inductor releases energy. 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.

The minimum value of inductor current is given as 3 A. Therefore the inductor current is continuous as shown in Fig. 3 (a).

(i) 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,

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

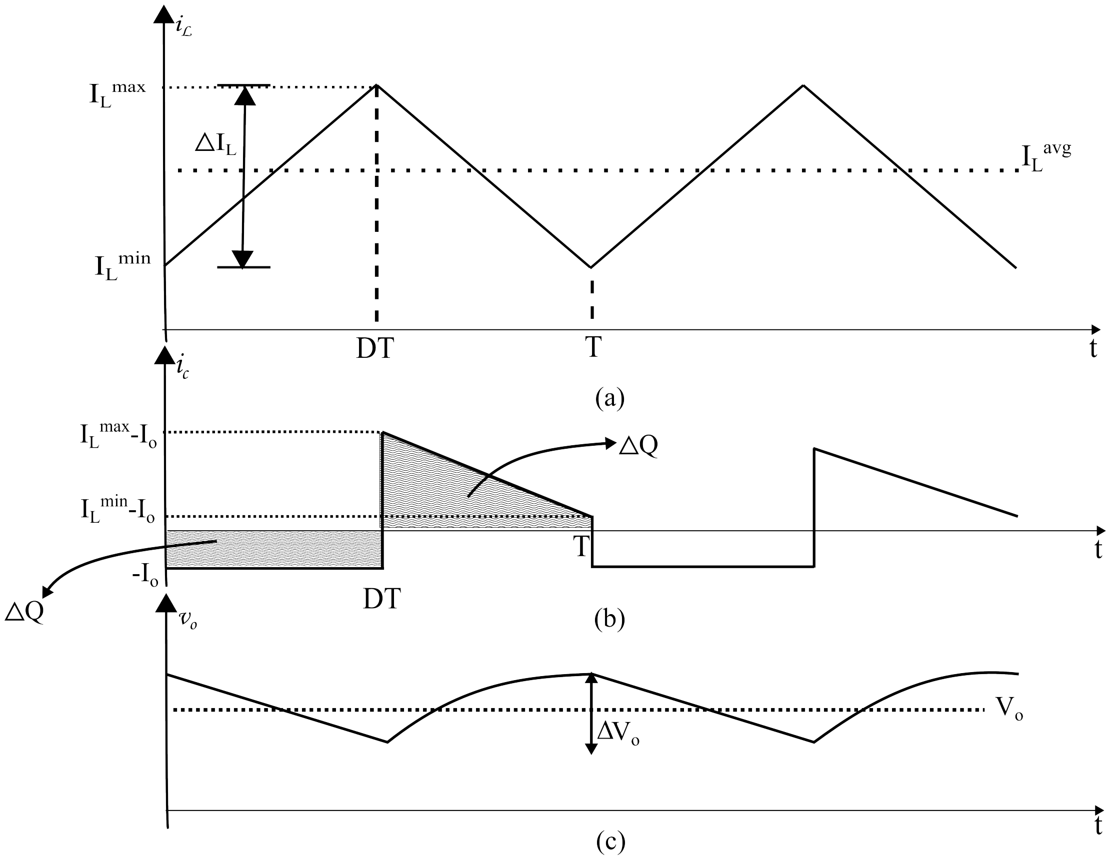


Figure 3: Waveforms (a) inductor current, (b) capacitor current, (c) output voltage

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$$V_o = \frac{V_{in}}{1-D} = \frac{15}{0.5} = 30\,\text{V} \qquad ; \qquad I_o = \frac{V_o}{R} = 4\,\text{A}$$

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

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

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

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

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

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

$$\therefore\ 4\,\text{A} = \frac{15 \times 0.5}{L \times (20 \times 10^3)} \qquad \Longrightarrow \qquad L = 93.75\,\mu\,\text{H}$$

(ii) Fig. 3 (b) is the capacitor current waveform. Shaded area ($\Delta$ Q) represents the charge stored in the capacitor. $\Delta$ Q in ($0 < t < DT$) and ($DT < t < T$) in the figure are equal since the average current through the capacitor is zero.

Fig. 3 (c) is the output voltage waveform. Assuming steady state operation, the voltage across the capacitor at the starting of the cycle should be same as that at the end of the cycle. Therefore, the peak-to-peak voltage ($\Delta V_o$) across the capacitor is given by

$$\Delta V_o = \frac{\Delta Q}{C} = \frac{I_o DT}{C} \qquad \Longrightarrow \qquad C = \frac{I_o DT}{\Delta V_o} = \frac{4 \times 0.5}{(100 \times 10^{-3}) \times (20 \times 10^3)} = 1\,\text{mF}$$

**NB :** The above equation of peak-to-peak voltage is valid only when $I_L^{\min}$ is greater than $I_o$. If the capacitor current becomes negative in the range $DT < t < T$, the shape of the output voltage waveform changes and hence peak-to-peak voltage cannot be calculated as in the above case in steady state.

**SequelApp Exercises:**

(1) In a boost converter, for an input voltage of 15 V and duty ratio of 0.4, the minimum inductor current and average output current are 3 A and 2 A, respectively. The peak-to-peak ripple capacitor voltage ($\Delta V_o$) is 80 mV. If the switching frequency is 20 kHz, determine the values of load resistance, inductance and capacitance used.

Verify your answer using SequelApp.