Boost Converter (PE_boost_1.sqproj)

Question : In Fig. 1, the chopper feeds a resistive load from a battery source. Switch (S) is switched at 250 kHz, with a duty ratio (D) of 0.4. All the elements of circuit are ideal. Find

(i) the source current in steady state.

(ii) peak-to-peak ripple in the source current.

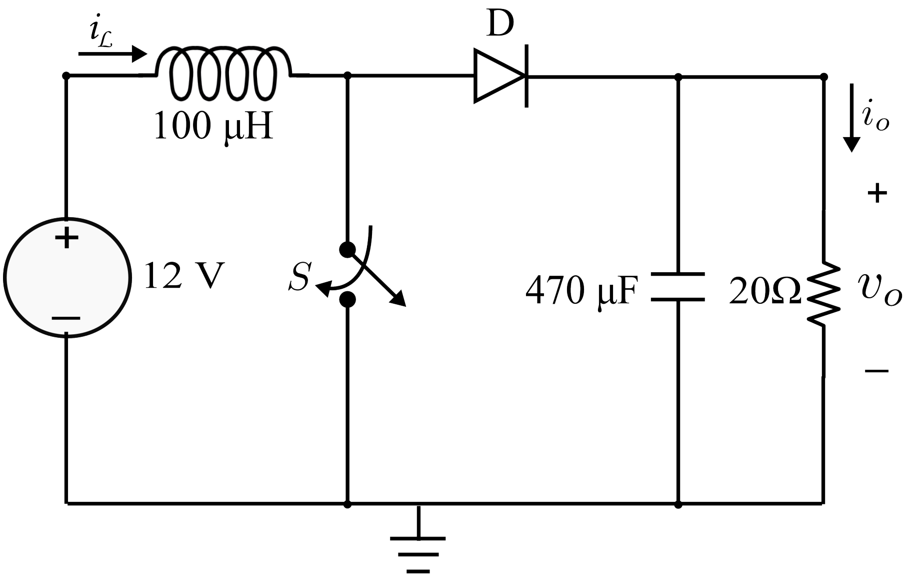

Figure 1: Boost converter

Solution :

Assume that the inductor current is continuous.

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

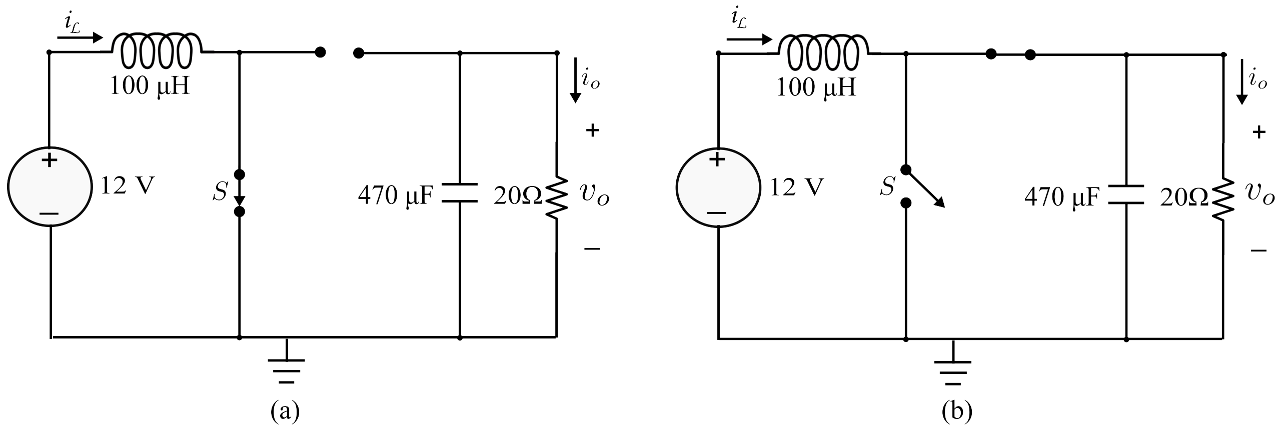

Figure 2: Boost converter circuit. (a) switch is ON, (b) switch is OFF

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When the inductor current is continuous, $I_L^{\text{avg}} > \dfrac{\Delta I_L}{2}$, where I_L^{avg} is the average inductor current and ΔI_L is the peak-to-peak ripple inductor current as shown in Fig. 3.

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. 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.

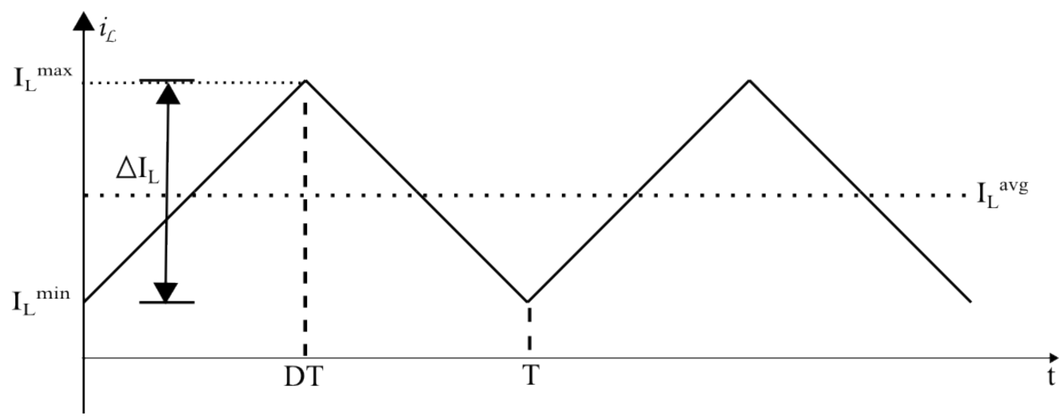

Figure 3: Inductor current waveform for continuous conduction

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,

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

(i) $$V_o = \frac{V_{in}}{1-D} = \frac{12}{0.6} = 20\text{V} \quad ; \quad I_o = \frac{V_o}{R} = 1\text{A}$$

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

$$\therefore V_o I_o = V_{in} I_{in} \implies I_{in} = I_L^{\text{avg}} = \frac{V_o I_o}{V_{in}} = \frac{20 \times 1}{12} = 1.67\text{A}$$

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

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

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

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

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

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

As the voltage source is in series with the inductor, the source ripple current (ΔI_s) and inductor ripple current (ΔI_L) are same.

$$\therefore \Delta I_s = \Delta I_L = \frac{V_{in}\,D}{L\,f} = \frac{12 \times 0.4}{(100 \times 10^{-6}) \times (250 \times 10^3)} = 0.192\text{A}$$

From the above calculations $I_L^{\text{avg}} > \dfrac{\Delta I_L}{2}$, i.e., the inductor current is continuous and hence our assumption is correct.

SequelApp Exercises:

1. Let $V_{in} = 15\,V$. If the peak-to-peak ripple inductor current $\Delta I_L = 0.15$A, find the new duty ratio and the output voltage, keeping all other circuit parameters same. Also calculate the average source current.

Verify your answer using SequelApp.