Buck−Boost Converter (`PE_buck_boost_2.sqproj`)

Question: A buck−boost converter feeding a resistive load is shown in Fig. 1. The switching frequency is 50 kHz and the duty ratio (D) is 0.6. Assume that all the components are ideal, and the capacitor and inductor are operating in steady state. Find the value of minimum and maximum inductor current (in A).

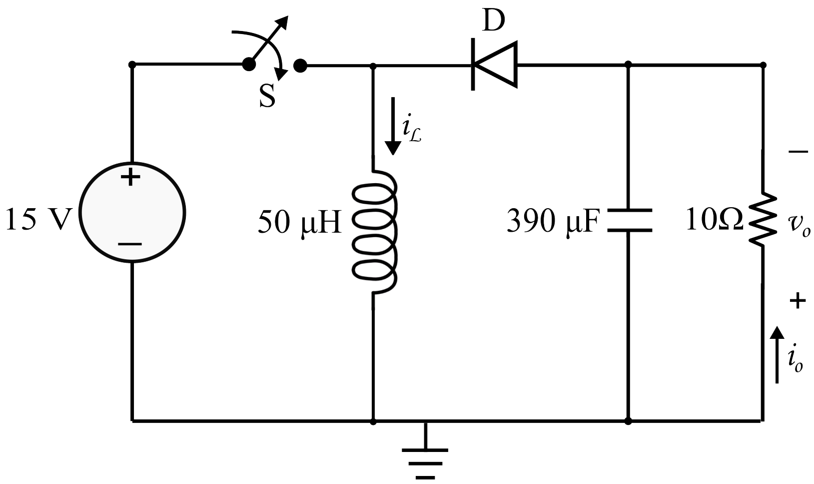

Figure 1: Buck-Boost converter

Solution :

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

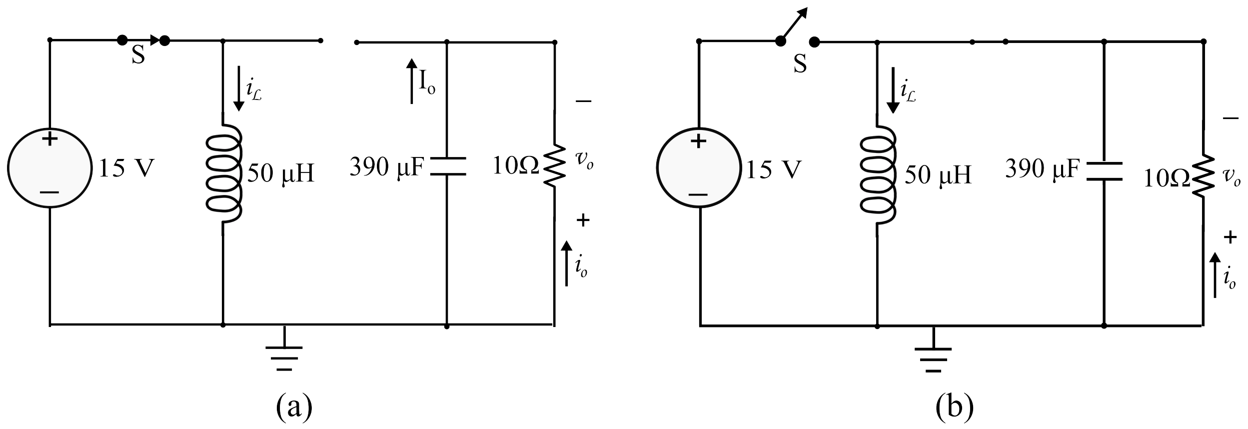

Figure 2: Buck−Boost converter circuit. (a) switch is ON, (b) switch is OFF

Assume that the inductor current is continuous 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, 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.

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.

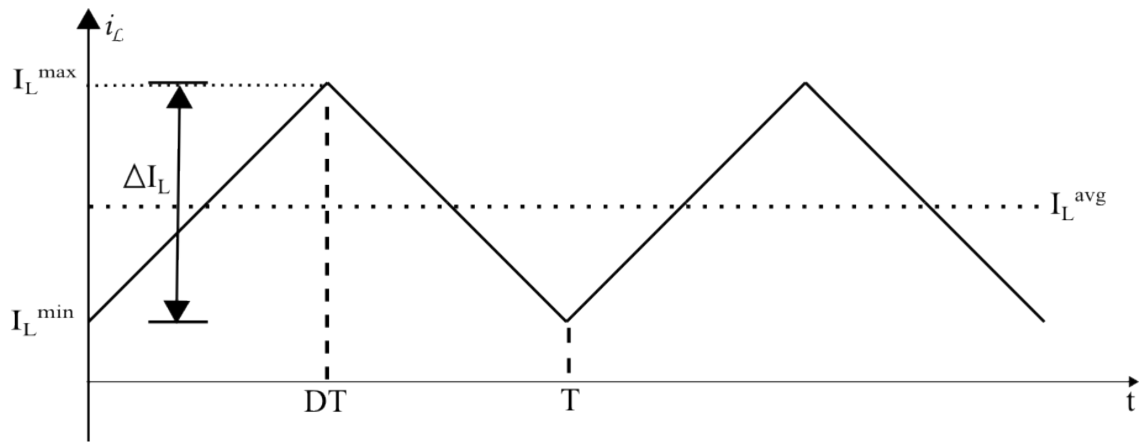

Figure 3: Inductor current waveform for continuous conduction

When the switch is ON ($0 < t < DT$), applying KVL gives

$$L\,\frac{d\,i_L}{dt} = V_{in}$$

Similarly, when the switch is OFF ($DT < t < T$), applying KVL gives

$$L\,\frac{d\,i_L}{dt} = -v_o(t)$$

Applying the volt-sec balance equation,

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

$$\therefore V_o = V_{in}\Big(\frac{D}{1-D}\Big) = \frac{15 \times 0.6}{0.4} = 22.5\,\mathrm{V}$$

When the switch is ON ($0 < t < DT$), applying KCL gives

$$C\,\frac{d\,v_o}{dt} + \frac{v_o}{R} = 0$$

Similarly, when the switch is OFF ($DT < t < T$), applying KCL gives

$$C\,\frac{d\,v_o}{dt} + \frac{v_o}{R} = i_L(t)$$

Applying the amp-sec balance equation,

$$\boxed{I_L^{\text{avg}} = \frac{I_o}{1-D}}$$

$$I_o = \frac{V_o}{R} = 2.25\,\mathrm{A} \quad ; \quad \therefore I_L^{\text{avg}} = \frac{2.25}{1-0.6} = 5.625\,\mathrm{A}$$

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

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

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

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

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

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

$$\therefore \Delta I_L = \frac{V_{in}\,D}{L\,f} = \frac{15 \times 0.6}{(50 \times 10^{-6}) \times (50 \times 10^3)} = 3.6\,\mathrm{A}$$

From the above calculations, $I_L^{\text{avg}} > \dfrac{\Delta I_L}{2}$ and hence our assumption is correct.
From Fig. 3,

$$I_L^{\max} = I_L^{\text{avg}} + \frac{\Delta I_L}{2} = 7.425\,\text{A} \quad ; \quad I_L^{\min} = I_L^{\text{avg}} - \frac{\Delta I_L}{2} = 3.825\,\text{A}$$

SequelApp Exercises:

(1) If the value of minimum and maximum inductor current are 4 A and 6.5 A respectively, find the value of inductance and load resistance, if all other circuit parameters remain same.

Verify your answer using SequelApp.