Buck−Boost Converter (`PE_buck_boost_1.sqproj`)

Question : In Fig. 1, the chopper feeds a resistive load from a DC source. Switch (S) is switched at 25 kHz, with a duty ratio (D) of 0.4. All the elements of circuit are ideal and the circuit is operating under steady state. Find

(i) the average load voltage.

(ii) the average and peak-to-peak value of the inductor current in steady state.

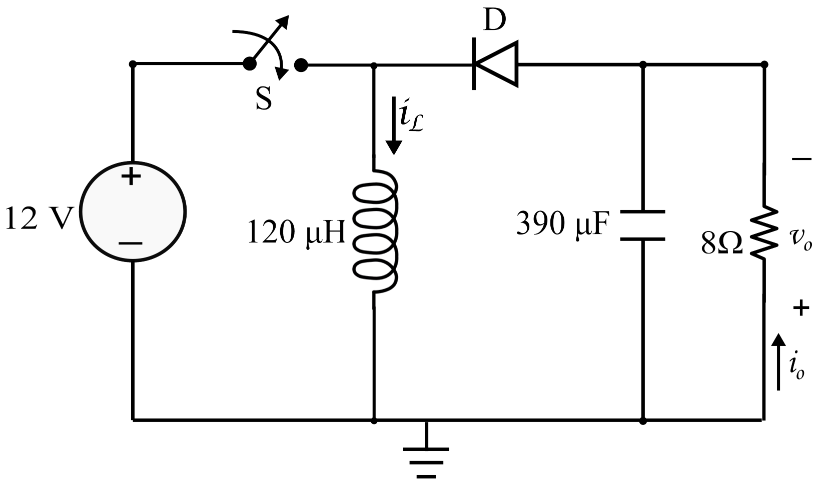

Figure 1: Buck−Boost Converter

Solution :

Assume that the inductor current is continuous.

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

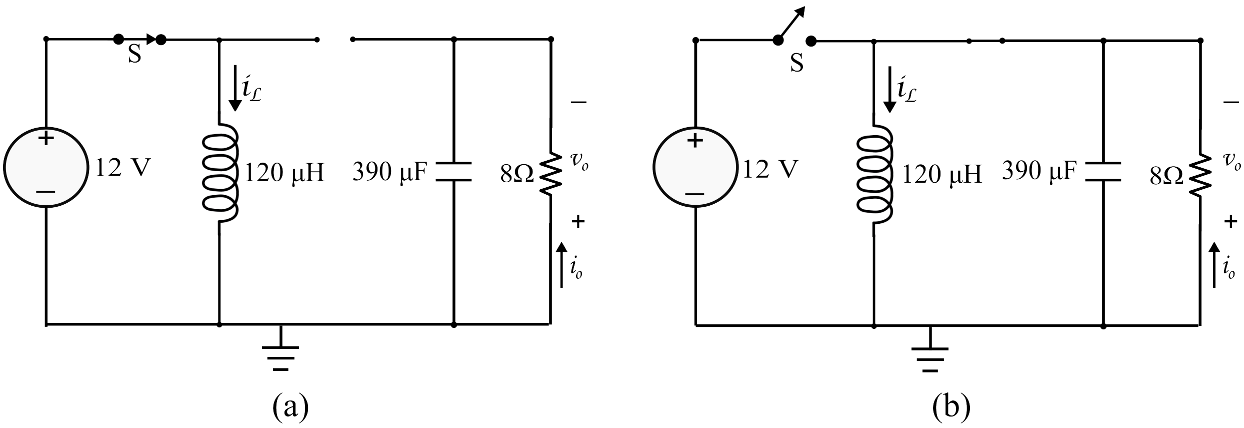

Figure 2: Buck−Boost converter circuit. (a) switch is ON, (b) switch is OFF

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 $\Delta\, I_L$ is the peak-to-peak ripple inductor current.

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 as shown in Fig .3.

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.

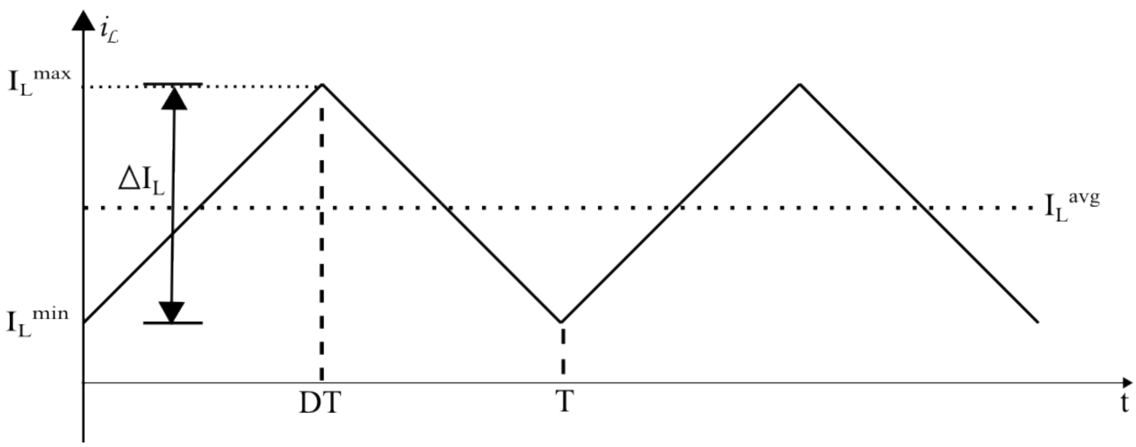

Figure 3: Inductor current waveform for continuous conduction

(i) 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,

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

$$\therefore V_o = V_{in}\Big(\frac{D}{1-D}\Big) = \frac{12 \times 0.4}{0.6} = 8\,\text{V}$$

(ii) 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,

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

$$I_o = \frac{V_o}{R} = 1\text{A} \quad ; \quad \therefore I_L^{\text{avg}} = \frac{1}{1-0.4} = 1.67\,\text{A}$$

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

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

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

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

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

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

$$\therefore \Delta I_L = \frac{V_{in}\, D}{L\, f} = \frac{12 \times 0.4}{(120 \times 10^{-6}) \times (25 \times 10^3)} = 1.6\,\text{A}$$

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) If the peak-to-peak ripple inductor current $\Delta I_L = 1.2\,\text{A}$, find the new duty ratio and the output voltage, keeping all other circuit parameters same.

Verify your answer using SequelApp.