Buck Converter (PE_buck_2.sqproj)

Question : In the chopper circuit shown in Fig.1, the switching frequency is 10 kHz and the duty ratio is 0.4. The converter is operating under steady state. If the inductance and capacitance are sufficiently large to ensure continuous inductor current and ripple-free capacitor voltage, find

(i) the charging current of the 5 V battery.

(ii) the average input current, if the converter is lossless.

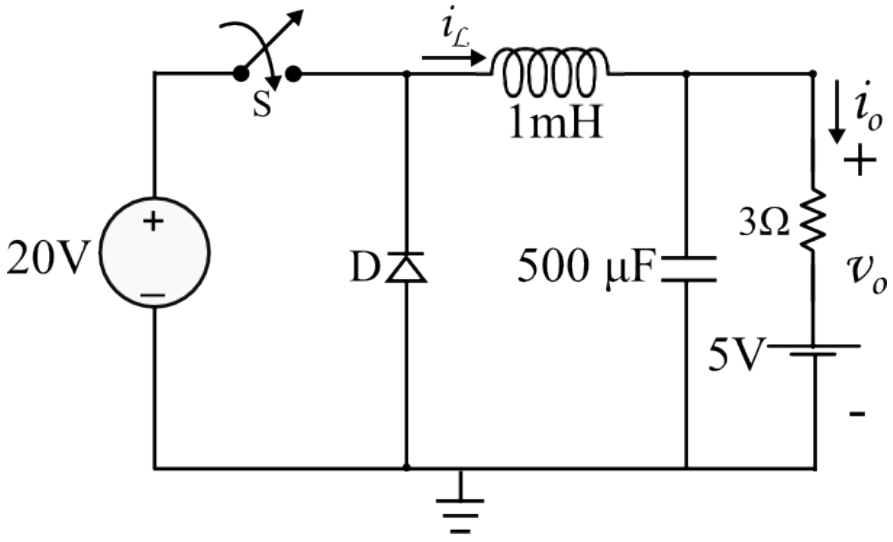

Figure 1: Buck converter

Solution:

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

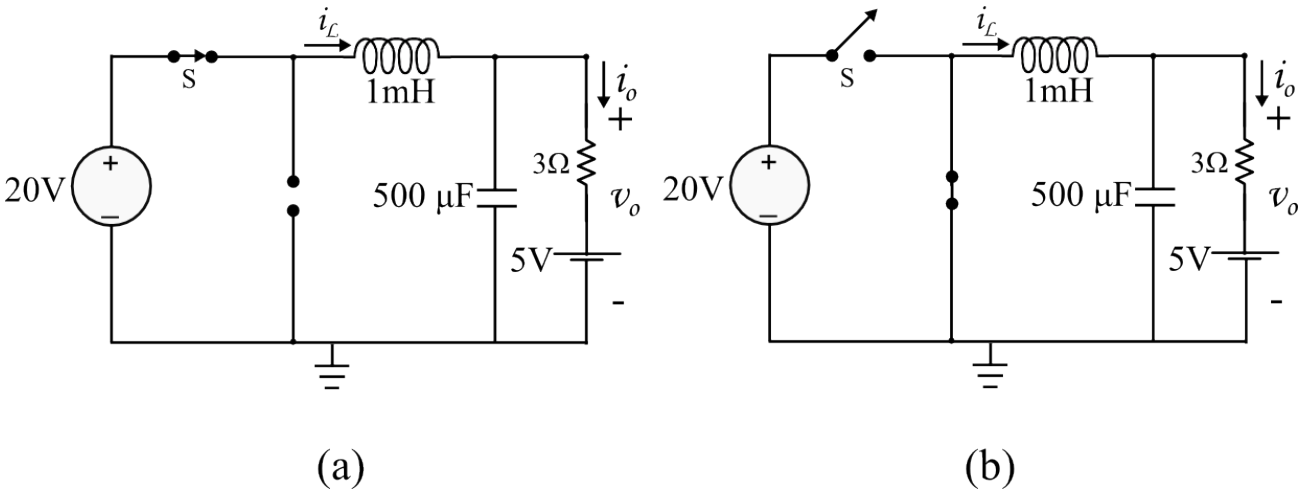

Figure 2: Buck converter circuit. (a) switch is ON, (b) switch is OFF.

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.

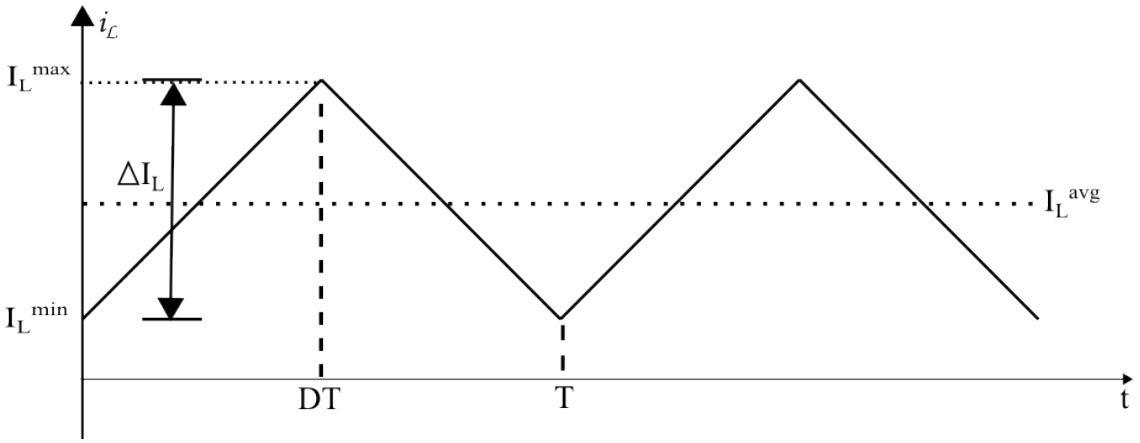

Figure 3: Inductor current waveform for continuous conduction

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.

It is given that the value of inductor is sufficiently large to ensure continuous current.

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

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

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

$$L \frac{di_L}{dt} = -v_o(t).$$

Applying the volt-sec balance equation ,

$$\boxed{V_o = DV_{in}}$$

(i) $\therefore V_o = 0.4 \times 20 = 8\text{V}$

$V_o = RI_o + E$ (Applying KVL at the load terminals)

$$\implies I_o = \frac{(V_o - E)}{R} = 1\text{A}$$

(ii) For loss less conversion, $V_o I_o = V_{in} I_{in}$

$$\therefore I_{in} = \frac{V_o I_o}{V_{in}} = 0.4\text{A}$$

SequelApp Exercises:

1. For the power absorbed by the battery to be 4 W, find the new value of E and I_o. (Assume all other circuit parameters to remain the same and the inductor current to be continuous.)

2. Also find the average source current for the same.

Verify your answer using SequelApp.