Calculation exercises

Exercise 1

a) The duty cycle of boost converter is D = 0.6 and it is supplied from 12 V power source. What is the output voltage value?

b) The input voltage of buck converter is 50 V and the output voltage is 35 V. What is the duty cycle D?

Exercise 2

The buck converter is shown in Fig. 1. The converter operates in CCM, hence the inductor current is continuous.

a) What kind of switching device is required? How it is controlled?

b) Draw the current route in the circuit when the switch is conducting. Why the diode is not conducting at the same time?

c) Draw the current route in the circuit when the switch is not conducting. Why the diode conducts this time?

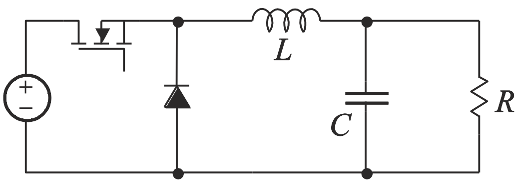


Fig. 1. Main circuit of buck converter

Exercise 3

The boost converter is shown in Fig. 2.

a) Draw the main circuit diagram of the boost converter during the on- and off-times i.e. the switch is conducting or not conducting. The converter operates in CCM, hence the inductor current is continuous.

b) Derive the equations for derivatives of inductor current and capacitor voltage during both conditions, on-time and off-time. Use Kirchhoff voltage- and current laws, the equation of inductor voltage $v_\mathrm{L} = L\dfrac{\mathrm{d}i_\mathrm{L}}{\mathrm{d}t}$ and equation of capacitor current $i_\mathrm{C} = C\dfrac{\mathrm{d}v_\mathrm{C}}{\mathrm{d}t}$.

c) Draw the inductor current waveform during one switching cycle. The converter operates in steady state (no start-up transient). Assume that capacitor voltage ripple is negligible. Mark the peak-to-peak inductor current ripple value to the figure.

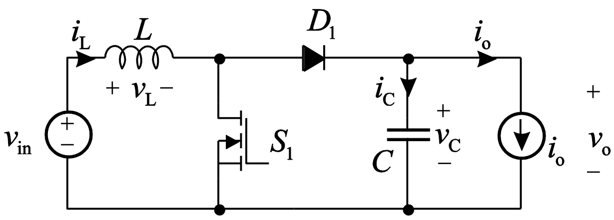


Fig. 2. Boost converter

Exercise 4

The duty cycle of the boost converter is 0.6 and it supplied from 12 V battery. The load requires 10 W power and the average inductor current value is 0.83 A. The switching frequency is 100 kHz.

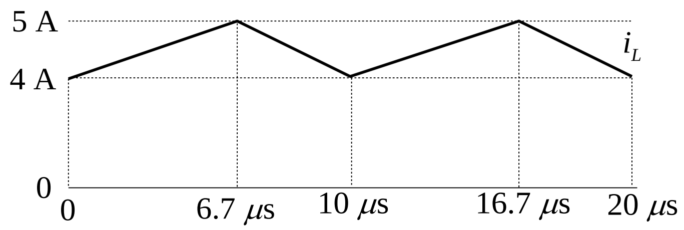
a) How large inductor is required for boost converter shown in Fig. 2 to limit the inductor current ripple Δi_L to be 20 % of the inductor current average value at maximum? Assume that capacitor voltage ripple is negligible. In addition, suppose that the inductor currrent varies linearly $\mathrm{d}i_L / \mathrm{d}t = \Delta i_L / \Delta t$

b) How the inductor current ripple change, if smaller inductor is used?

Exercise 5

The inductor current waveform of ideal boost converter is shown in Fig. 3a. The output voltage is 50V.

a) What is the operating mode of the converter (CCM, DCM, BCM)?
b) What is the duty cycle D value?
c) What is the average input current value?
d) What is the output voltage value?
e) How large is the inductor L inductance value?
f) What is the average output current value?



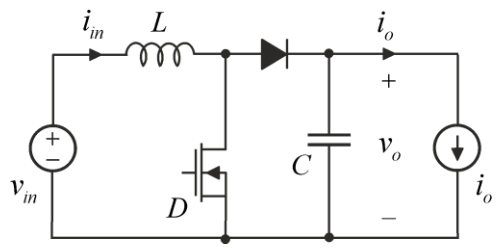


Fig 3. a) Inductor current waveform b) Boost converter

Exercise 6

Look at the boost converter shown in Exercise 5

a) What is the MOSFET average current value?
b) What is the MOSFET average voltage value?
c) What is the diode average current value?
d) What is the diode average voltage value?
e) What is the capacitor average voltage value?

Exercise 7

The measured input current of an ideal buck converter is shown in Fig. 4 when the input voltage equals 10 V. Assume that capacitor voltage ripple is negligible. Compute

a) The output voltage
b) The switching frequency
c) The size of the inductor

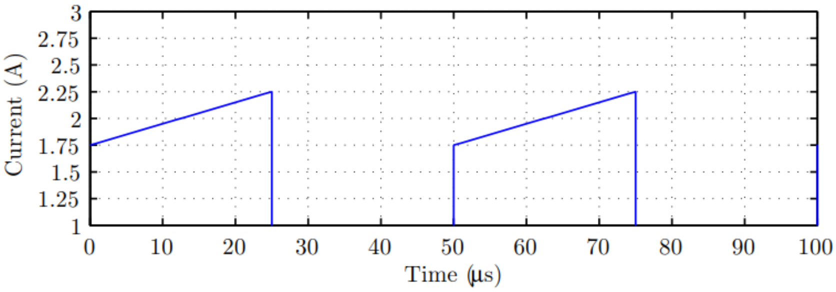


Fig. 4. Input current waveform

Exercise 8

In a diode-switched boost (step-up) converter shown in Fig. 3b consider all components to be ideal. Let input voltage be 12 V, output voltage 24 V, switching frequency 20 kHz and inductor L = 260µH. Does the converter operate always in continuous conduction mode (CCM) if output power $P_o \geq 50W$? Assume that capacitor voltage ripple is negligible.

Hint:

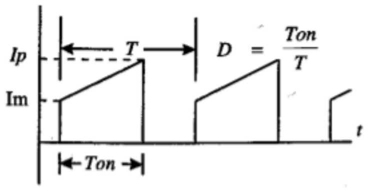
$$V_o = \frac{1}{1-D} V_{in}$$

$$v_L = L \frac{di_L}{dt}$$

$$R_{eq} = \frac{V_o}{I_o}$$

Exercise 9

Sketch the waveform of the diode voltage and diode current of the ideal boost converter analyzed in Exercise 8 when the output power equals 100 W. Based on the derived current waveform, compute the conduction power loss of the diode. Diode properties are $V_D = 0.7$ V and $r_D = 25\text{m}\Omega$ (assume that the diode behaves as a series connection of a voltage source and a resistor during on-state).

Waveform	Irms	Idc	Iac(rms)
	$\sqrt{D\left(Ip\times Im+\frac{1}{3}(Ip-Im)^2\right)}$	$\frac{D\,(Ip+Im)}{2}$	$\sqrt{Irms^2-Idc^2}$