EE270: Homework 1

Due: Oct. 19th, 2023 before class

Problem 1

Analysis and design of a buck-boost converter: A buck-boost converter is illustrated in Fig. 1(a), and a practical implementation using a transistor and diode is shown in Fig. 1(b).

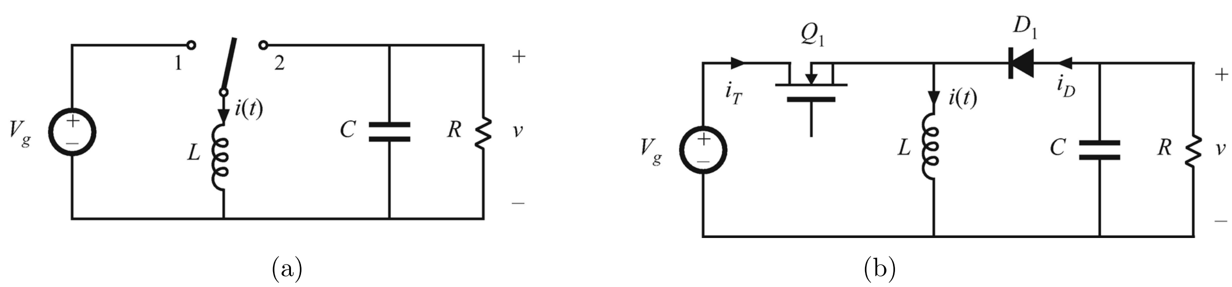

Figure 1: Buck-boost converter of Problem 1: (a) ideal converter circuit, (b) implementation using MOSFET and diode

(a) Find the dependence of the equilibrium output voltage V and inductor current I on the duty ratio D, input voltage V_g, and load resistance R. You may assume that the inductor current ripple and capacitor voltage ripple are small.

(b) Plot your results of part (a) over the range $0 \le D \le 1$.

(c) Dc design: for the specifications

$$V_g = 80\text{V} \qquad V = -50\text{V}$$
$$R = 25\Omega \qquad f_s = 60k\text{Hz}$$

(i) Find D and I

(ii) Calculate the value of L that will make the peak inductor current ripple Δi equal to five percent of the average inductor current I.

(iii) Choose C such that the peak output voltage ripple Δv is 0.3 V.

(d) Sketch the transistor drain current waveform $i_T(t)$ for your design of part (c). Include the effects of inductor current ripple. What is the peak value of i_T ? Also sketch $i_T(t)$ for the case when L is decreased such that Δi is 50% of I. What happens to the peak value of i_T in this case?

(e) Sketch the diode current waveform $i_D(t)$ for the two cases of part (d).

Problem 2

An ideal boost converter is shown in Fig. 2. For the converter operating in steady state, derive exact analytical expressions for:

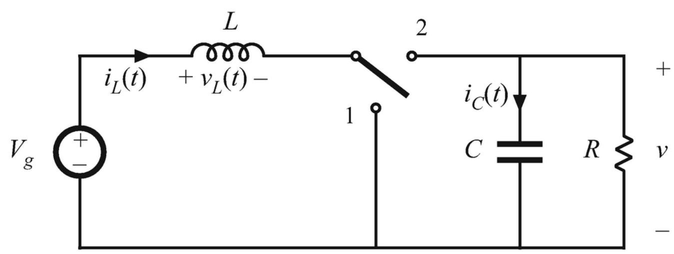

Figure 2: Boost converter with ideal switch

(a) the dc component of the output voltage.

(b) the peak-to-peak inductor current ripple.

(c) the peak-to-peak capacitor voltage ripple.

(d) Given the following values:

$$V_g = 18\text{V} \quad V = 30\text{V}$$
$$R = 10\Omega \quad L = 100\mu\text{H}$$

(i) Derive the switching frequency f_s, such that the peak inductor current ripple, Δi_L, is 5% of i_L.

(ii) Based on (i), select the value for C, such that the peak voltage ripple on C, Δv is 30 mV.

Your answer for (a)(b)(c) should be written in terms of the circuit parameters V_g, R, T_s, L, C, and duty cycle D.

Problem 3

In the buck converter of Fig. 3, the MOSFET has on-resistance R_{on} and the diode forward voltage drop can be modeled by a constant voltage source V_D. All other losses can be neglected.

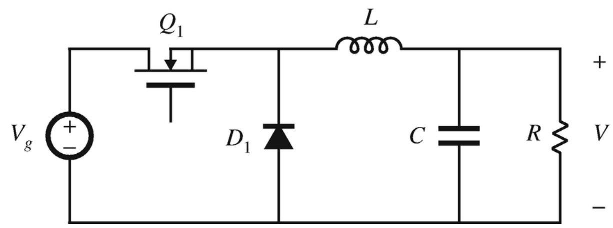

Figure 3: Nonideal buch converter.

(a) Derive a complete equivalent circuit model for this converter.

(b) Solve your model to find the output voltage V.

(c) Derive an expression for the efficiency. Manipulate your expression into a form similar to Eq. (3.35) in the textbook.

Problem 4

For Problems 4, a transistor having an on-resistance of 0.2Ω is used. To simplify the problems, you may neglect all losses other than the transistor conduction loss. You may also neglect the dependence of MOSFET on-resistance on rated blocking voltage. These simplifying assumptions reduce the differences between converters, but do not change the conclusions regarding which converter performs best in the given situations.
It is desired to interface a 600V dc source to a 400V, 10A load using a dc-dc converter. Two possible approaches, using buck and buck–boost converters, are illustrated in Fig. 4. Use the assumptions described above to:

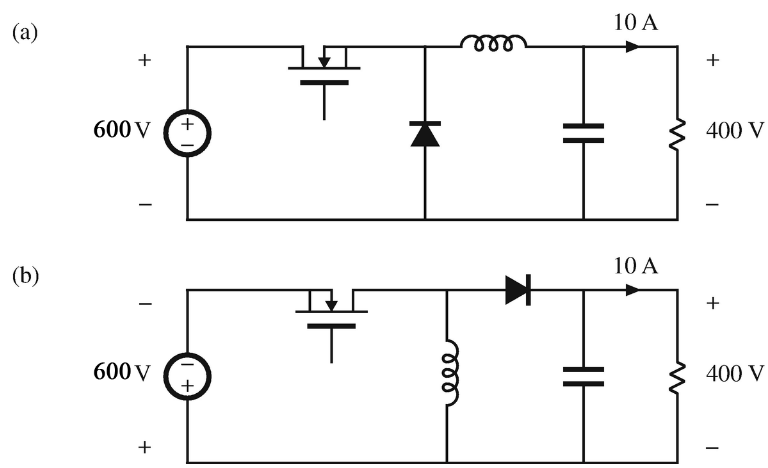

Figure 4: Interfacing a 600 V source to a 400 V load, using: (a) a buck converter, (b) a buck–boost converter.

(a) Derive equivalent circuit models for both converters, which model the converter input and output ports as well as the transistor conduction loss.

(b) Determine the duty cycles that cause the converters to operate with the specified conditions.

(c) Compare the transistor conduction losses and efficiencies of the two approaches, and conclude which converter is better suited to the specified application.