PROBLEMS

2.1 Analysis and design of a buck-boost converter: A buck-boost converter is illustrated in Fig. 2.28(a), and a practical implementation using a transistor and diode is shown in Fig. 2.28(b).

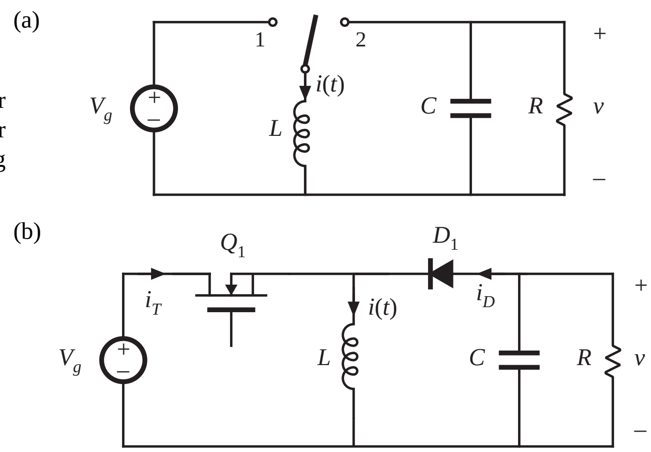

Fig. 2.28 Buck-boost converter of Problem 2.1: (a) ideal converter circuit, (b) implementation using MOSFET and diode.

(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 $0 \leq D \leq 1$.

(c) Dc design: for the specifications

$V_g = 30$ V	$V = -20$ V
$R = 4\ \Omega$	$f_s = 40$ kHz

(*i*) Find D and I

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

(*iii*) Choose C such that the peak output voltage ripple Δv is 0.1 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).

2.2 In a certain application, an unregulated dc input voltage can vary between 18 and 36 V. It is desired to produce a regulated output of 28 V to supply a 2 A load. Hence, a converter is needed that is capable of both increasing and decreasing the voltage. Since the input and output voltages are both positive, converters that invert the voltage polarity (such as the basic buck-boost converter) are not suited for this application.

One converter that is capable of performing the required function is the nonisolated SEPIC (single-ended primary inductance converter) shown in Fig. 2.29. This converter has a conversion ratio $M(D)$ that can both buck and boost the voltage, but the voltage polarity is not inverted. In the normal converter operating mode, the transistor conducts during the first subinterval ($0 < t < DT_s$), and the diode conducts during the second subinterval ($DT_s < t < T_s$). You may assume that all elements are ideal.

(a) Derive expressions for the dc components of each capacitor voltage and inductor current, as functions of the duty cycle D, the input voltage V_g, and the load resistance R.

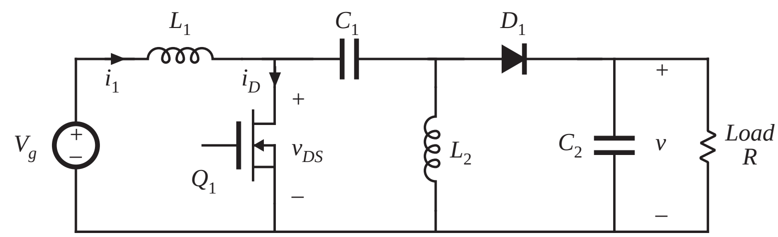

Fig. 2.29 SEPIC of Problems 2.2 and 2.3.

(b) A control circuit automatically adjusts the converter duty cycle D, to maintain a constant output voltage of V = 28 V. The input voltage slowly varies over the range 18 V ≤ V_g ≤ 36 V. The load current is constant and equal to 2 A. Over what range will the duty cycle D vary? Over what range will the input inductor current dc component I_1 vary?

2.3 For the SEPIC of Problem 2.2,

(a) Derive expressions for each inductor current ripple and capacitor voltage ripple. Express these quantities as functions of the switching period T_s; the component values L_1, L_2, C_1, C_2; the duty cycle D; the input voltage V_g; and the load resistance R.

(b) Sketch the waveforms of the transistor voltage $v_{DS}(t)$ and transistor current $i_D(t)$, and give expressions for their peak values.

2.4 The switches in the converter of Fig. 2.30 operate synchronously: each is in position 1 for $0 < t < DT_s$, and in position 2 for $DT_s < t < T_s$. Derive an expression for the voltage conversion ratio $M(D) = V/V_g$. Sketch $M(D)$ vs. D.

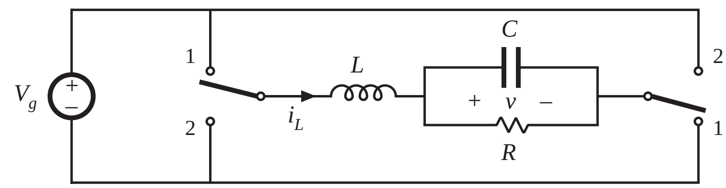

Fig. 2.30 H-bridge converter of Problems 2.4 and 2.6.

2.5 The switches in the converter of Fig. 2.31 operate synchronously: each is in position 1 for $0 < t < DT_s$, and in position 2 for $DT_s < t < T_s$. Derive an expression for the voltage conversion ratio $M(D) = V/V_g$. Sketch $M(D)$ vs. D.

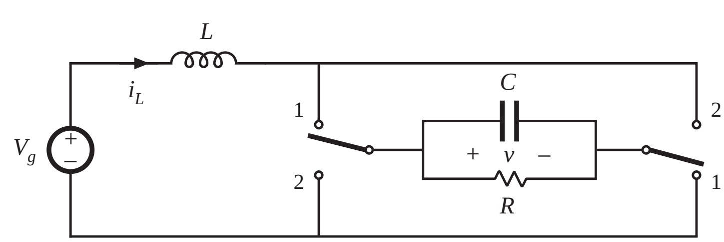

Fig. 2.31 Current-fed bridge converter of Problems 2.5, 2.7, and 2.8.

2.6 For the converter of Fig. 2.30, derive expressions for the inductor current ripple Δi_L and the capacitor voltage ripple Δv_C.

2.7 For the converter of Fig. 2.31, derive an analytical expression for the dc component of the inductor cur-