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PROBLEMS

6.1 Tapped-inductor boost converter. The boost converter is sometimes modified as illustrated in Fig. 6.41, to obtain a larger conversion ratio than would otherwise occur. The inductor winding contains a total of $(n_1 + n_2)$ turns. The transistor is connected to a tap placed n_1 turns from the left side of the inductor, as shown. The tapped inductor can be viewed as a two-winding $(n_1{:}n_2)$ transformer, in which the two windings are connected in series. The inductance of the entire $(n_1 + n_2)$ turn winding is L.

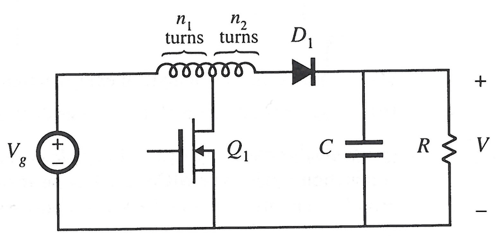

Fig. 6.41 Tapped-inductor boost converter, Problem 6.1

(a) Sketch an equivalent circuit model for the tapped inductor, which includes a magnetizing inductance and an ideal transformer. Label the values of the magnetizing inductance and turns ratio.

(b) Determine an analytical expression for the conversion ratio $M = V/V_g$. You may assume that the transistor, diode, tapped inductor, and capacitor are lossless. You may also assume that the converter operates in continuous conduction mode.

(c) Sketch $M(D)$ vs. D for $n_1 = n_2$, and compare to the nontapped $(n_2 = 0)$ case.

6.2 Analysis of the DCM flyback converter. The flyback converter of Fig. 6.30(d) operates in the discontinuous conduction mode.

(a) Model the flyback transformer as a magnetizing inductance in parallel with an ideal transformer, and sketch the converter circuits during the three subintervals.

(b) Derive the conditions for operation in discontinuous conduction mode.

(c) Solve the converter: derive expressions for the steady-state output voltage V and subinterval 2 (diode conduction interval) duty cycle D_2.

6.3 Analysis of the isolated inverse–SEPIC of Fig. 6.39. You may assume that the converter operates in the continuous conduction mode, and that all inductor current ripples and capacitor voltage ripples are small.

(a) Derive expressions for the dc components of the magnetizing current, inductor current, and capacitor voltages.

(b) Derive analytical expressions for the rms values of the primary and secondary winding currents. Note that these quantities do not simply scale by the turns ratio.

6.4 The two–transistor flyback converter. The converter of Fig. 6.42 is sometimes used when the dc input voltage is high. Transistors Q_1 and Q_2 are driven with the same gating signal, such that they turn on and off simultaneously with the same duty cycle D. Diodes D_1 and D_2 ensure that the off state voltages of the transistors do not exceed V_g. The converter operates in discontinuous conduction mode. The magnetizing inductance, referred to the primary side, is L_M.

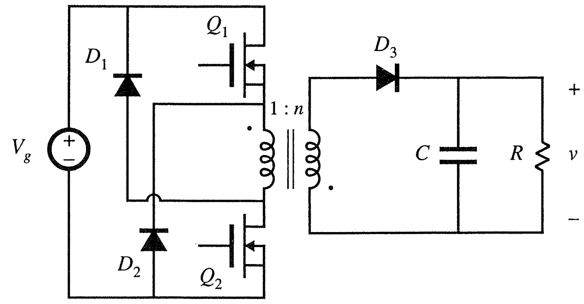

Fig. 6.42 Two-transistor flyback converter, Problem 6.4.

(a) Determine an analytical expression for the steady-state output voltage V.

(b) Over what range of duty cycles does the transformer reset properly? Explain.

6.5 A nonideal flyback converter. The flyback converter shown in Fig. 6.30(d) operates in the continuous conduction mode. The MOSFET has on-resistance R_{on}, and the diode has a constant forward voltage drop V_D. The flyback transformer has primary winding resistance R_p and secondary winding resistance R_s.

(a) Derive a complete steady-state equivalent circuit model, which is valid in the continuous conduction mode, and which correctly models the loss elements listed above as well as the converter input and output ports. Sketch your equivalent circuit.

(b) Derive an analytical expression for the converter efficiency.

6.6 A low-voltage computer power supply with synchronous rectification. The trend in digital integrated circuits is towards lower power supply voltages. It is difficult to construct a high-efficiency low-voltage power supply, because the conduction loss arising in the secondary-side diodes becomes very large. The objective of this problem is to estimate how the efficiency of a forward converter varies as the output voltage is reduced, and to investigate the use of synchronous rectifiers.

The forward converter of Fig. 6.22 operates from a dc input of $V_g = 325$ V, and supplies 20 A to its dc load. Consider three cases: (*i*) $V = 5$ V, (*ii*) $V = 3.3$ V, and (*iii*) $V = 1.5$ V. For each case, the turns ratio n_3/n_1 is chosen such that the converter produces the required output voltage at a transistor duty cycle of $D = 0.4$. The MOSFET has on-resistance $R_{on} = 5\ \Omega$. The secondary-side schottky diodes have