

CITY UNIVERSITY OF HONG KONG

Course code & title : EE 6427 Modern Power Electronics

Session : Semester B 2007/2008

Time allowed : Three hours

This paper has SIX pages (including this page).

-
1. This paper consists of 5 questions.
 2. Choose **ANY FOUR** questions. (25 marks per question)
 3. The full mark of this paper is 100.
-

Materials, aids & instruments permitted to be used during examination:

1. Approved calculator
-

Answer any FOUR questions:

Q.1

(a) Sketch typical switching trajectories of a power MOSFET under each of the following conditions:

- (i) hard switching
- (ii) protected with a standard RCD snubber
- (iii) soft switching

(6 marks)

(b) Fig.Q1 shows a half-bridge power inverter feeding an inductive load.

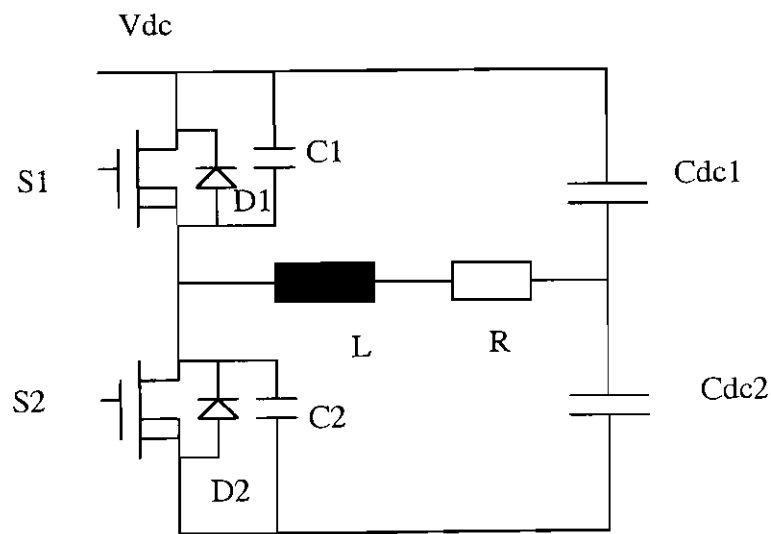


Fig.Q1

- (i) Sketch the timing diagram of the gating signals of power switches S1 and S2, and also typical load current (assuming that the load current is continuous).
(4 marks)
- (ii) With the aid of equivalent circuits, the current paths and the switching waveforms in (b-i), explain the six operating modes of this inverter ensuring that both S1 and S2 can be soft-switched under zero-voltage condition.
(10 marks)
- (c) Give one condition that may not allow soft-switching to occur in the circuit and suggest one solution to solve this problem.
(5 marks)

Q.2

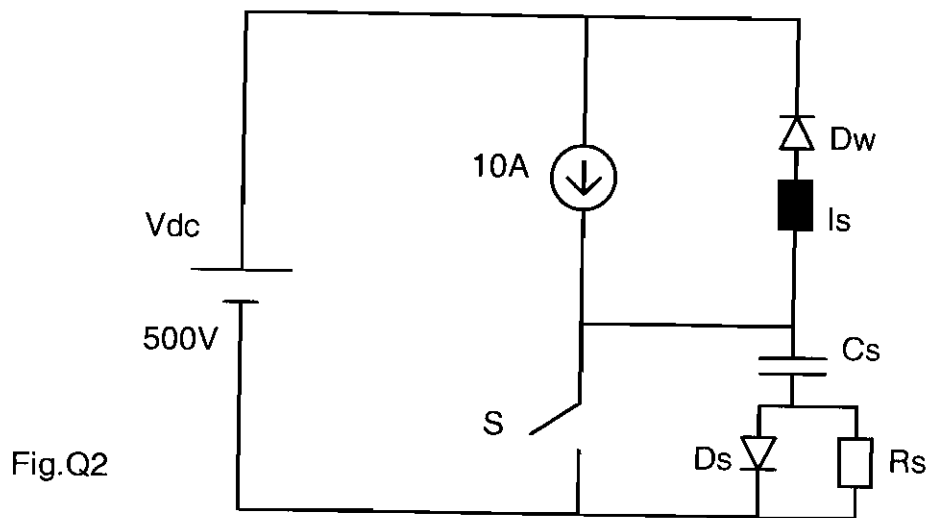


Fig.Q2 shows a power electronic switching circuit consisting of a highly inductive load represented as a current source of 10A, a power switch S and a free wheeling diode D_w . Additional components (l_s , R_s , C_s , D_s) are added to this circuit to ensure safe operation.

Given that the rate of change of voltage (dv/dt) and the rate of change of current (di/dt) of the switch are to be limited at $150V/\mu s$ and $20A/\mu s$, respectively, and that the minimum ON time of the switch S is $10\mu s$,

- explain the functions of the additional components l_s , R_s , C_s and D_s ; (4 marks)
- determine suitable values for l_s , R_s and C_s ; (6 marks)
- estimate the peak voltage across the switch S immediately after its turn-off. (5 marks)
- If the free-wheeling diode D_w has a stored charge Q_{rr} of $2\mu C$ and its snappiness factor is $1/3$, calculate the reverse recovery time t_{rr} of and peak reverse current I_{rr} in the diode D_w . (8 marks)
- What is the power dissipation in the resistor R_s if the switching frequency of S is $4kHz$? (2 marks)

Q3

(a) Fig.Q3a shows a simplified circuit of a 2-level power inverter. Given that a switching pattern (or voltage vector) refers to the labeling of the conducting switches for each switching state, write down the 6 non-zero voltage vectors and the 2 zero-vectors.

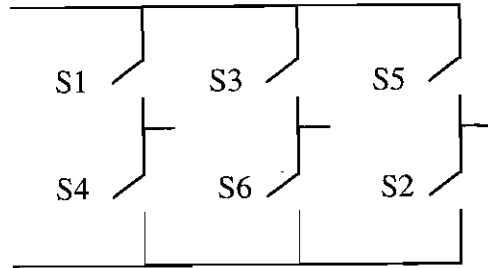


Fig.Q3a

(8 marks)

(b)

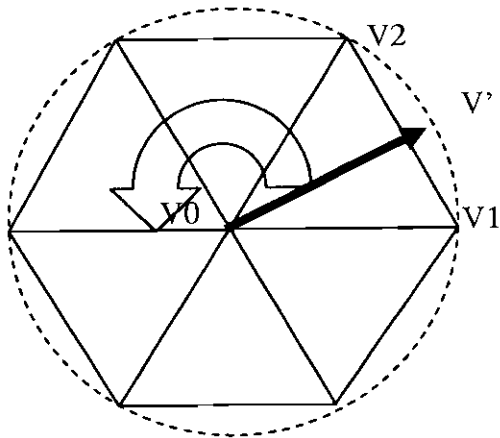


Fig. Q3b

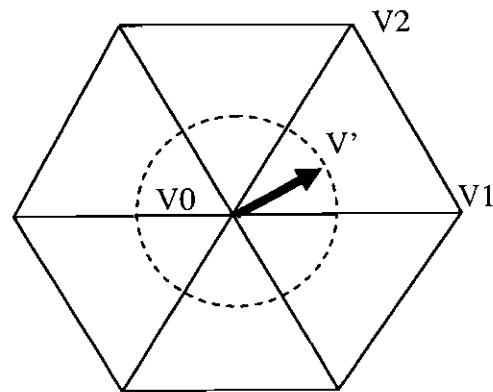


Fig. Q3c

Label the non-zero voltage vectors in the 6 vertices of the hexagon as V1 to V6 and the 2 zero vectors V0 and V7 in the centre. With the help of the vector diagram in Fig.Q3b, and given that the space vector switching period is T_s , and switching times for V0 to V6 are T_0 to T_6 , respectively, write down the 6 sets of "general" voltage-vector equations for the large vector V' (shown in Fig.Q3a.) as it moves into the 6 triangular sectors (i.e. each 60-degree sections)

Hint: use the right vectors for each triangular sector.

(12 marks)

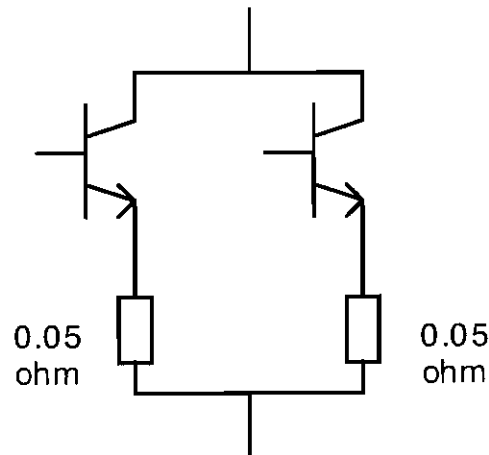
(c) For the specific small voltage vector V' in Fig.Q2b, write down the "specific" voltage vector expression and the time equation assuming that T_s is larger than the sum of T_1 and T_2 .

(5 marks)

Q4 A forward converter is fed by a dc voltage source of 320V. The output voltage is 24V. The switching frequency is set at 50kHz. The rated power is 120W. The inductor current becomes discontinuous when the load is at 30%.

- (a) Determine the nominal duty cycle.
(3 marks)
- (b) Find the nominal rated output current.
(2 marks)
- (c) Find the inductance value of the converter inductor.
(5 marks)
- (d) Find the maximum inductor current at rated load.
(7 marks)
- (e) Find the root-mean-square current of the inductor at rated power.
(4 marks)
- (f) Find the root-mean-square current of the output capacitor at rated power.
(4 marks)

Q5



In order to increase the current capability, two power bipolar transistors (BJT) are used in parallel with current sensing resistors of $0.05\ \Omega$. The two switches and the sensing resistors are mounted on the same heatsink. Each switch has a thermal resistance (junction to heatsink) of $1.2\ ^\circ\text{C}/\text{W}$. The sensing resistor has a thermal resistance (resistor to heatsink) of $1\ ^\circ\text{C}/\text{W}$. The thermal resistance of the heatsink is $0.5\ ^\circ\text{C}/\text{W}$. The energy loss per switch is $5\text{mJ}/\text{A}$ per switching cycle. The maximum current in the switch is 20A . The ambient temperature is $40\ ^\circ\text{C}$, maximum allowable junction temperature is $125\ ^\circ\text{C}$ and the maximum allowable resistor temperature is $140\ ^\circ\text{C}$. The maximum duty cycle is 99.9%.

If each switch carries 20A , calculate

- (a) the maximum switching frequency and (12 marks)
- (b) the heatsink temperature. (5 marks)
- (c) Sketch a typical safe operating area of a power BJT, giving reasons for the limits. (6 marks)
- (d) Explain a major difference between the safe operating areas of a power BJT and a power MOSFET. (2 marks)

- END -