

CITY UNIVERSITY OF HONG KONG

Course code & title : EE 6427 Modern Power Electronics

Session : Semester B 2006/2007

Time allowed : Three hours

This paper has SIX pages (including this page).

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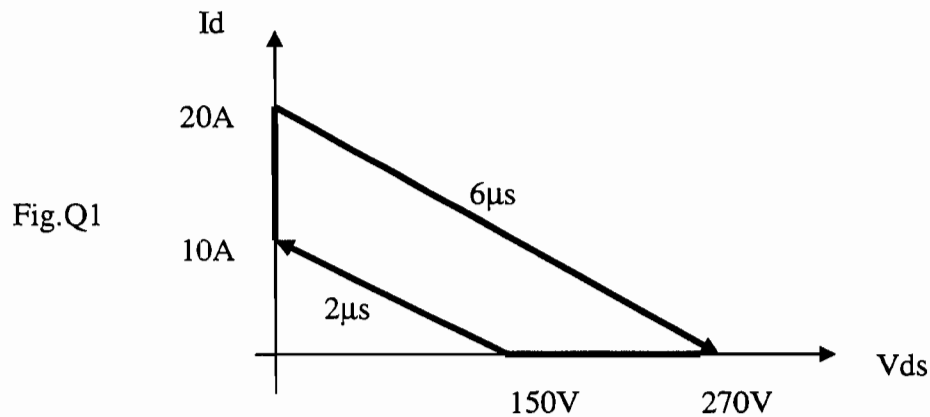
Materials, aids & instruments permitted to be used during examination:

1. Approved calculator
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Answer any FOUR questions:

Q.1

- (a) Sketch a typical safe operating area (SOA) of a power MOSFET. (2 marks)
- (b) Explain the limitations of the SOA of a power MOSFET. (3 marks)
- (c) Briefly explain why power MOSFETs can be used in parallel to increase the current capability. (4 marks)
- (d) Briefly explain why power MOSFETs generally have lower current capability than power Bipolar Junction Transistors (BJTs). (4 marks)



(e) Fig.Q1 shows the switching trajectory of a power MOSFET. The MOSFET is mounted on a heatsink. Using linear approximation, calculate the maximum switching frequency of the MOSFET, given that

- the maximum junction temperature is 125°C
- the junction to case thermal resistance is 0.25K/W
- the case to heatsink thermal resistance is 1.2K/W
- the heatsink thermal resistance is 0.75K/W
- the ambient temperature is 45°C .

(12 marks)

Q2

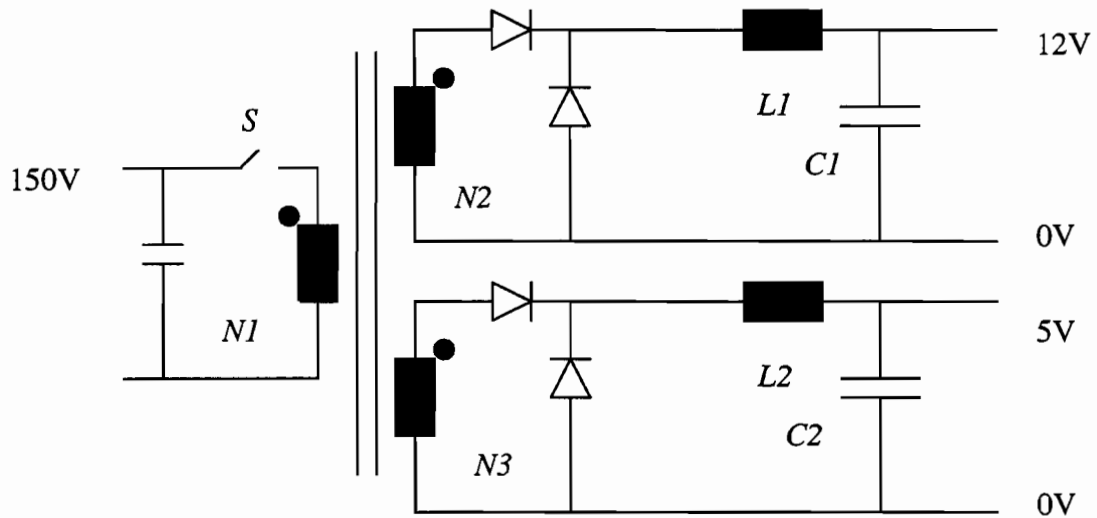


Fig.Q2

A forward converter (Fig.Q2) is required to provide two isolated dc voltage outputs of 12V and 5V. The input dc voltage is 150V. The switching frequency is set at 200kHz. The maximum duty cycle d must not exceed 0.4. The primary winding of the transformer has 100 turns (i.e. $N1=100$). The inductor currents become discontinuous when the load is reduced to 30% of the rated load. The 12V power supply is rated at 50W. The 5V power supply is rated at 20W.

(a) Determine the number of turns for the two secondary windings, i.e. $N2$ and $N3$.

(6 marks)

(b) If the duty cycle d is set at 0.4, calculate the filter inductances $L1$ and $L2$.

(6 marks)

(c) Determine the peak switch current.

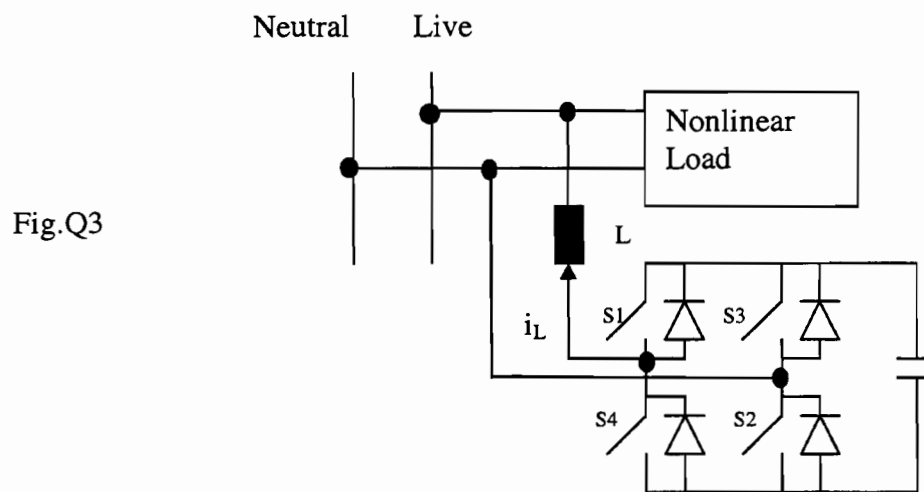
(8 marks)

(d) The transformer is not ideal, explain how the circuit should be modified in order to recover the energy stored in the magnetizing inductance.

(5 marks)

Q3

- (a) Assuming that the ac power supply voltage is sinusoidal, state the two conditions for achieving unity power factor. (4 marks)
- (b) A single-phase 220V, 50Hz ac voltage supply is used to feed a non-linear load, which takes an ac current of rectangular shape. Using the harmonic injection principle,
- state the general functions of the capacitor, the inductor and the inverter bridge;
 - for each half-cycle of the ac mains and using simplified equivalent circuit, describe how the switching actions of an active power filter (switches S1-S4 shown in Fig.Q3) can improve the power quality of the voltage supply. (12 marks)



- (c) Explain the statement that “active power filters handle reactive power”. (5 marks)
- (d) What are the differences in the features of an active power filter and an AC-DC power factor correction circuit? (4 marks)

Q4

(a) For power inverter applications, briefly describe the operating principles of

- (i) Sinusoidal PWM method
- (ii) Random PWM method
- (iii) Space-Vector PWM method

(12 marks)

(b) Fig.Q4 shows a half-bridge power inverter feeding an inductive load.

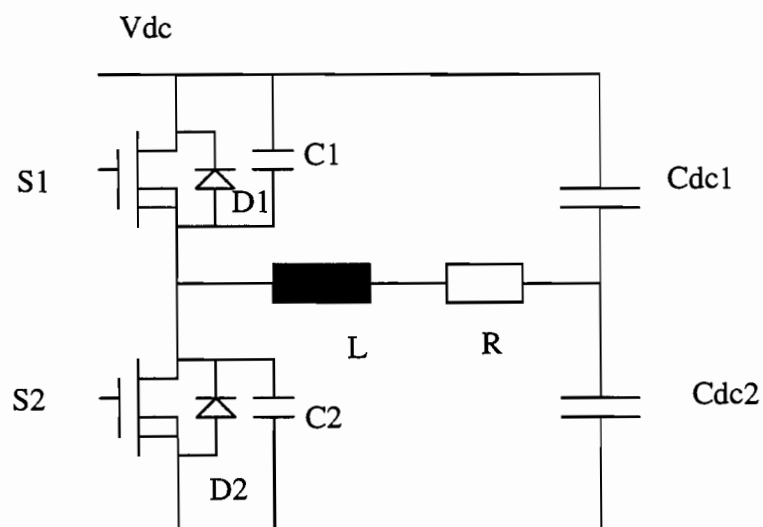


Fig.Q4

- (i) Sketch typical switching waveforms of the gating signals of power switches $S1$ and $S2$.
- (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 in order that both $S1$ and $S2$ can be soft-switched under zero-voltage condition.

(3 marks)

(10 marks)

Q5

Fig.Q5

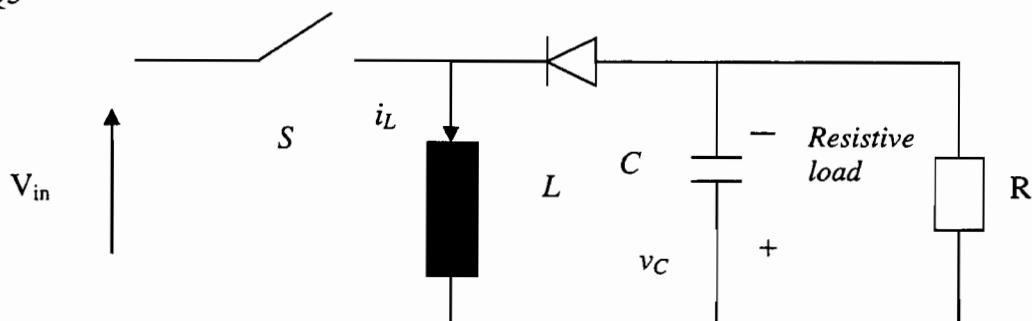


Fig.Q5 shows the schematic of a flyback (step-up/down) converter.

The general form of its state-space equation in time domain is

$$\frac{dX}{dt} = AX + BU$$

$$Y = CX$$

where X is the variable matrix, U is the forcing function and Y is the output; A, B and C are matrixes describing the characteristics of the system.

Let the state vector be $X = \begin{bmatrix} i_L \\ v_C \end{bmatrix}$ and the output Y is the output voltage of the flyback converter v_C .

- (a) Assuming that the inductor current is continuous, (1) sketch the equivalent circuits for the conducting paths and (2) derive the state-space equations (using i_L and v_C as state variables) in the time domain for the circuit shown in Fig.Q5 (including the effect of the load) when the

- (i) power switch S is turned on;
- (ii) power switch S is turned off.

(14 marks)

- (b) Using the results in (a) and for a nominal switching duty cycle of d , derive the “averaged” state-space equations in the time domain for the converter.

(6 marks)

- (c) Sketch the circuit diagram of an electrically isolated flyback converter and explain how it can be modified in order to reduced electromagnetic interference (EMI) emission.

(5 marks)

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