

CITY UNIVERSITY OF HONG KONG

Module code & title : EE 6427 Modern Power Electronics

Session : Semester B 2002/03

Time allowed : Three hours

This paper has SEVEN pages (including this page).

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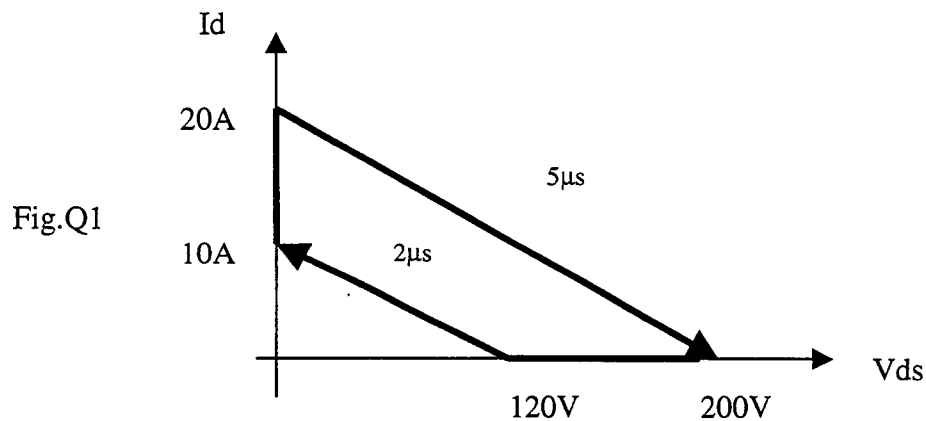
1. This paper consists of 5 questions.
 2. Choose **ANY FOUR** questions. (25 marks per question)
 3. The full mark of this paper is 100.
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Materials, aids & instruments permitted to be used during examination:

1. Approved calculator
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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 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 $125^{\circ}C$
- 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 $40^{\circ}C$.

(12 marks)

Q.2

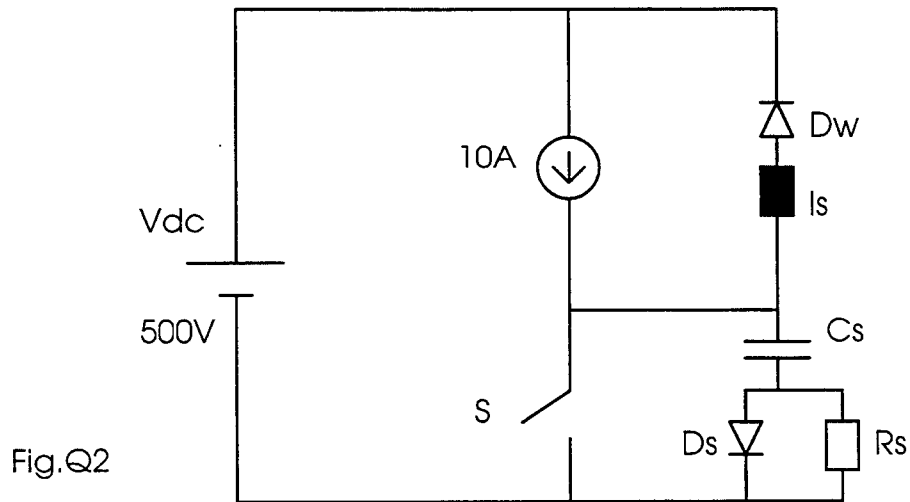


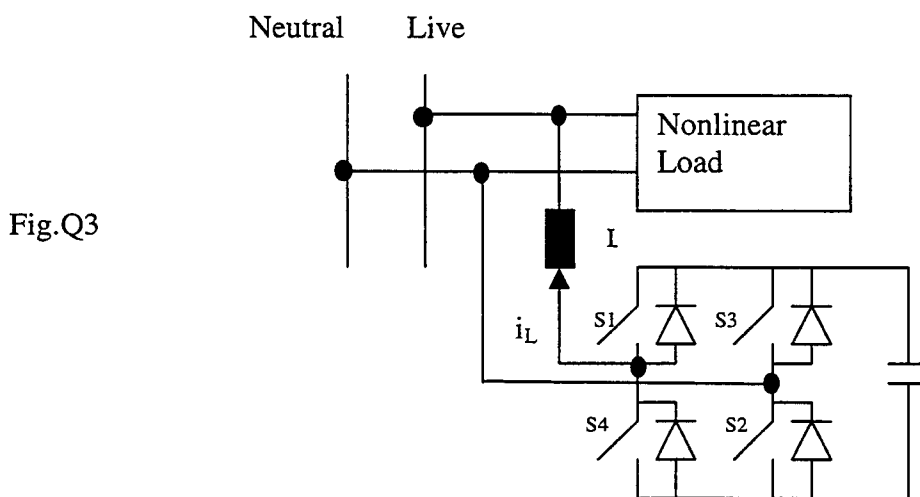
Fig.Q2 shows a power electronic switching circuit consisting of a highly inductive load represented as a current source of 10A, a power switch S and a free wheeling diode D_w . Additional components (l_s , R_s , C_s , D_s) are added to this circuit to ensure safe operation.

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) Assuming that the ac power supply voltage is sinusoidal, state the two conditions for achieving unity power factor. (5 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,
- (i) state the general functions of the capacitor, the inductor and the inverter bridge;
 - (ii) 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. (15 marks)



- (c) What are the differences in the features of an active power filter and an AC-DC power factor correction circuit? (5 marks)

Q4

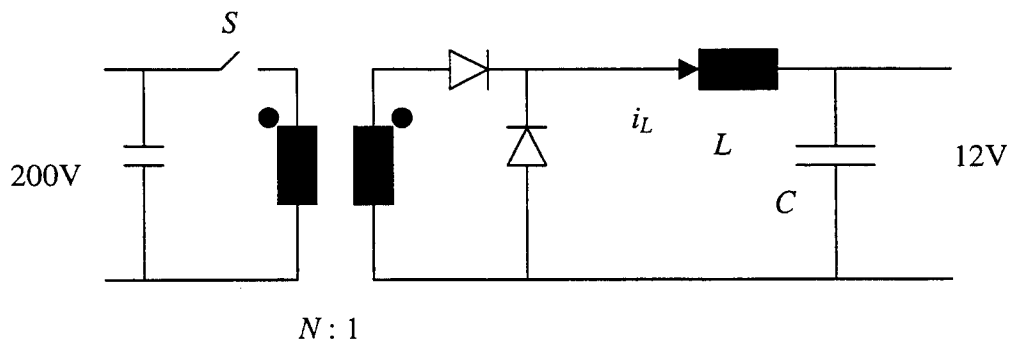


Fig.Q4

A forward converter (Fig.Q4) is required to provide an output dc voltage of 12V and an output dc current of 10A from a 200V dc voltage source. The switching frequency is set at 40kHz. The 12V voltage output must be isolated from the 200V dc voltage source using a transformer with a turns ratio $N:1$. The maximum duty cycle must not exceed 0.42 and N is an integer. The transformer has a magnetizing inductance of 2mH. The inductor current becomes discontinuous when the load is reduced to 20% of the rated load.

- Determine the turns ratio N of the transformer. (5 marks)
- Calculate the filter inductance L . (5 marks)
- Determine the peak inductor current i_L . (5 marks)
- Determine the peak switch current. (5 marks)
- Explain how the circuit should be modified in order to recover the energy stored in the magnetizing inductance. (5 marks)

Q5

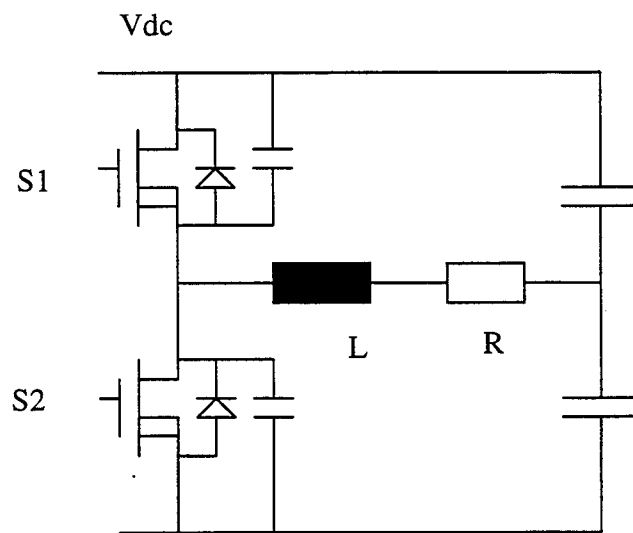
(a) For power inverter applications, briefly describe the operating principles of

- (i) Sinusoidal PWM method
- (ii) Delta Modulation method
- (iii) Random PWM method.

(12 marks)

(b) Fig.Q5 shows a half-bridge power inverter feeding an inductive load.

Fig.Q5



- (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.

(10 marks)

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