

CITY UNIVERSITY OF HONG KONG

Coursecode & title : EE 6427 Modern Power Electronics
Session : Semester B 2004/2005
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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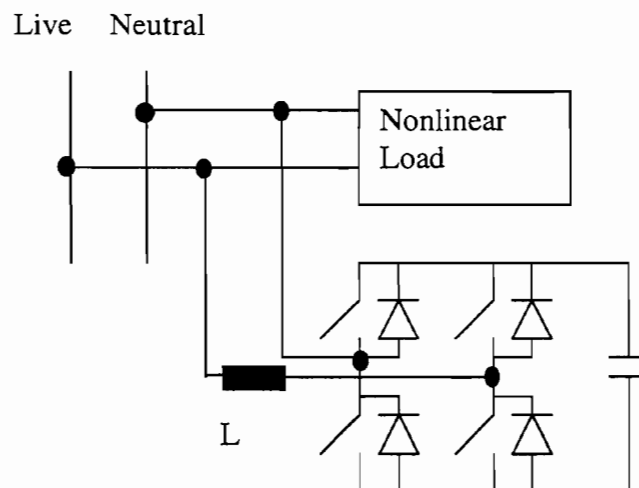
Answer any FOUR questions:

Q1

- (a) Assuming that the ac input voltage source is sinusoidal, write down the algebraic expression of the power factor. (4 marks)
- (b) State the two conditions for achieving unity power factor. (4 marks)
- (c) A single-phase 220V, 50Hz ac voltage supply is used to feed a non-linear load, which absorbs an ac current of “rectangular” shape. Using the harmonic injection principle, an active power filter (shown in Fig.Q1) is used to improve the power quality of the voltage supply.
- (i) Explain the function of the 4 diodes and the capacitor of the active power filter.
- (ii) With the aid of sketched current waveforms and equivalent circuits, describe the operating principle of the active power filter for improving the power quality of the power system. (You may use the switching operation during the positive half of the mains cycle for the explanation.)

(12 marks)

Fig.Q1



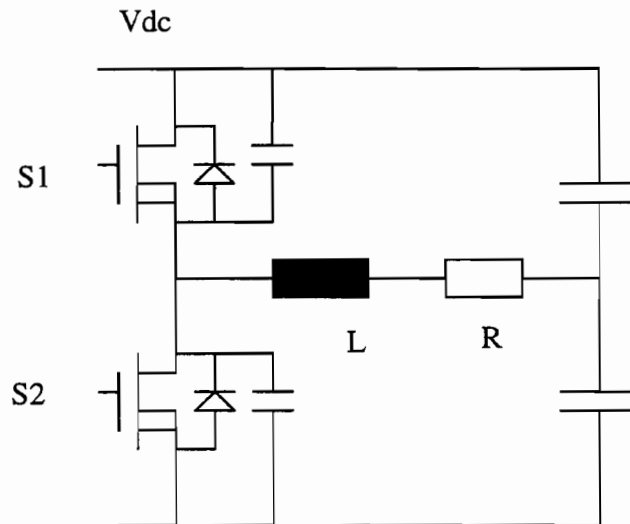
- (d) State the basic differences between a power factor correction circuit and an active power filter.

(5 marks)

Q2

- (a) Sketch a typical safe operating area (SOA) of a power MOSFET and explain the reasons for the limitations of the SOA of a power MOSFET. (3 marks)
- (b) Briefly explain why power MOSFETs can be used in parallel to increase the current capability. (4 marks)
- (c) In terms of the structures of the devices, briefly explain why power MOSFETs generally have lower current capability than power Bipolar Transistors (BJTs) (5 marks)
- (d) Fig.Q2 shows a half-bridge power inverter feeding an inductive load. With the aid of the circuit diagrams showing the current path, explain how soft-switching can be achieved in this circuit.

Fig.Q2



- (i) Sketch typical switching waveforms of the gating signals of power switches S1 and S2. (3 marks)
- (ii) With the aid of equivalent circuits and the switching waveforms in (d-i), explain the six operating modes of this inverter in order that both S1 and S2 be zero-voltage-switched. (10 marks)

Q.3

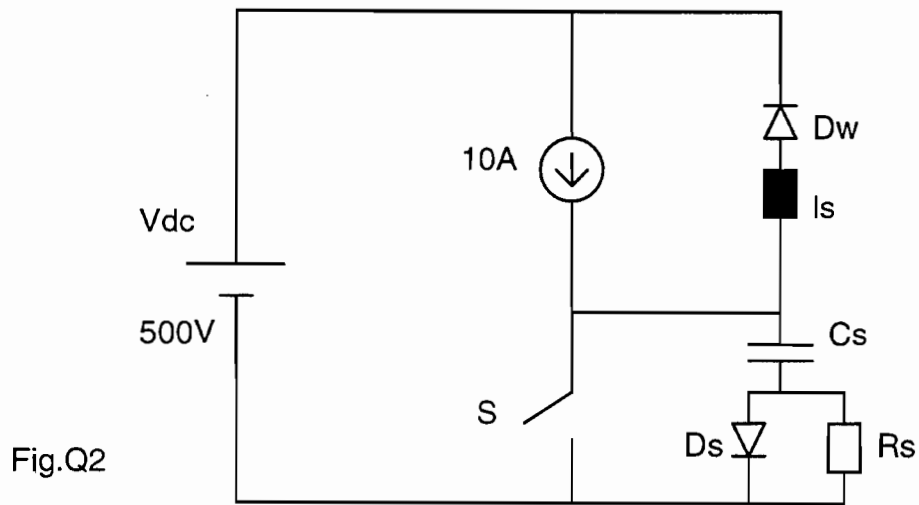


Fig.Q3 shows a power electronic switching circuit consisting of a highly inductive load represented as a current source of 10A, a power switch S and a free wheeling diode D_w . Additional components (l_s , R_s , C_s , D_s) are added to this circuit to ensure safe operation.

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 $5kHz$? (2 marks)

Q4

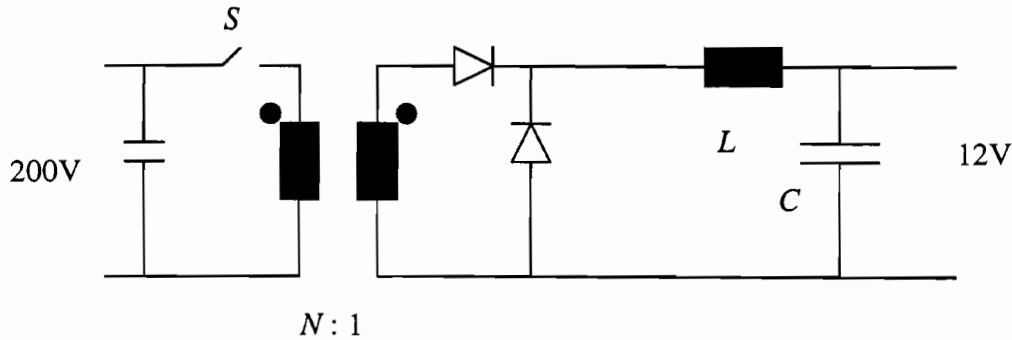


Fig.Q4

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 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 0.45 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. The switching frequency is set at 40kHz.

- Determine the turns ratio N of the transformer. (5 marks)
- Calculate the filter inductance L . (5 marks)
- Determine the peak switch current. (5 marks)
- Estimate the peak-to-peak output voltage ripple at full load, given that the output filter capacitor C is 220 μ F and assuming that the load consumes a constant dc current of 5A. (5 marks)
- Explain how the circuit should be modified in order to recover the energy stored in the magnetizing inductance. (5 marks)

Q5

Fig.Q5

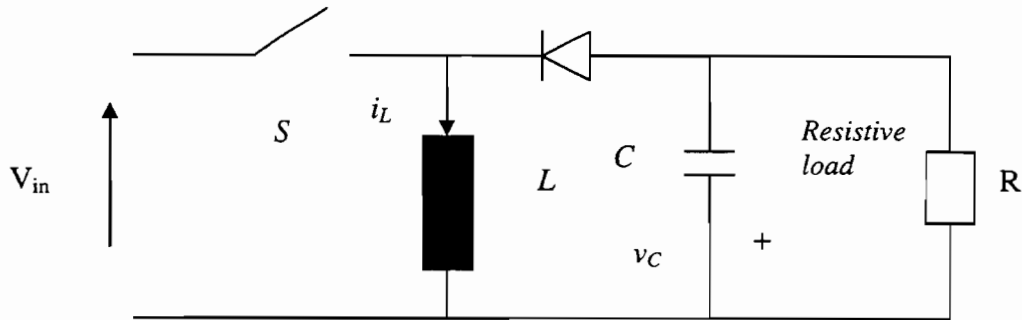


Fig.Q5 shows the schematic of a flyback converter.

The general form of its state-space equation 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.

- (a) Assuming that the inductor current is continuous, sketch the equivalent circuits for the conducting paths and 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.

(10 marks)

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

(6 marks)

- (c) If the dc output must be isolated from the power supply, sketch the basic circuit diagram of an electrically isolated flyback converter.

(4 marks)

- (d) Modify the basic circuit in (c) so as to avoid large transients in power switch S . Give your reasons.

(5 marks)

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