ENGINEERING TRIPOS PART IIA

Wednesday 7 May 2003 9 to 10.30

Module 3B3

SWITCH MODE ELECTRONICS

*Answer not more than **three** questions*

All questions carry the same number of marks

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin*

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

(TURN OVER

1 (a) A single phase bridge rectifier is shown in Fig. 1(a). Sketch the smoothing capacitor voltage waveform and the supply current waveform for a constant current load. Explain why rectifier loads produce unwanted supply harmonics.

Find an expression for the ripple voltage in terms of the supply frequency stating your assumptions. [40%]

(b) A three phase diode rectifier bridge is shown in Fig. 1(b). The load current is smooth, with a dc value of 100 A. Estimate the smoothing capacitance required to reduce the output ripple voltage to 5% of the peak rectified voltage for an ac line voltage of 415 V .

For your chosen value of capacitance, estimate the peak charging current drawn from the supply.

The ripple voltage at the output is to be reduced to 1% of the peak rectified voltage by adding a smoothing inductance. Comment on the expected supply current waveform. [40%]

By considering the ac filter effect, find a value for the inductance. [20%]

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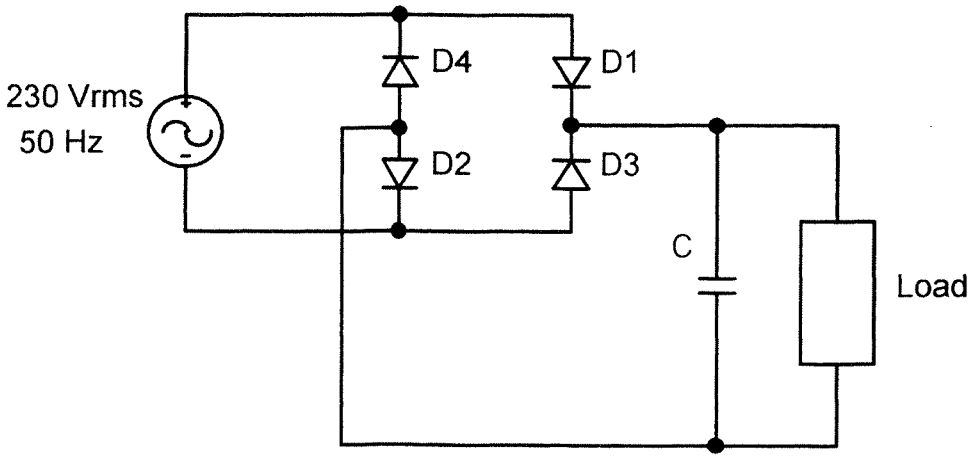

Fig. 1 (a)

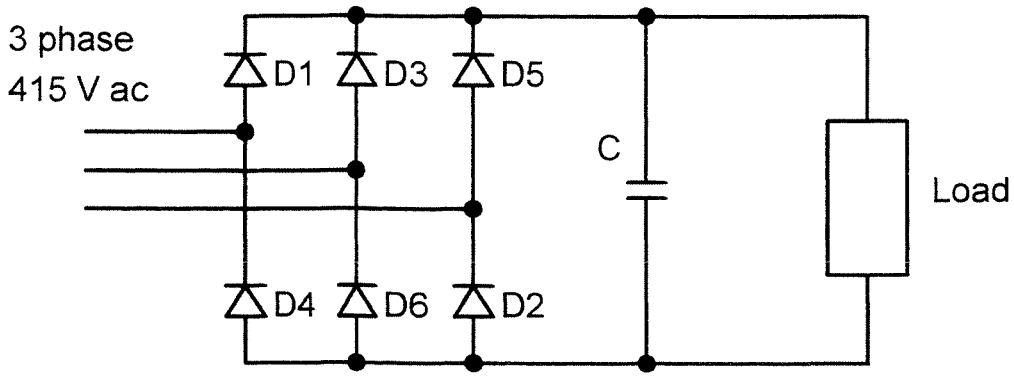

Fig. 1 (b)

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2 (a) A three-phase bridge inverter for supplying a 50 kW induction motor is shown in Fig. 2. Give three reasons why the IGBT is a good choice for such a circuit.

Explain carefully how the switches may be controlled according to the principles of sinusoidal *pulse width modulation* (PWM) to give a variable voltage variable frequency output. State how the gate signals produced for the three legs differ to produce a three-phase output.

What is meant by *gear changing* and what advantages does it offer in the application of inverters in induction motor drives? [45%]

(b) The same bridge may be controlled using *space vector modulation* (SVM). In this case, list the states and illustrate the SVM principle using the corresponding vector representation of the states. [30%]

By referring to the list of states and vector representation or otherwise, show that the total number of switching instants per cycle for the whole inverter may be reduced by using SVM when compared to PWM, for the same effective modulation frequency.

Under what conditions are PWM and SVM the same? [25%]

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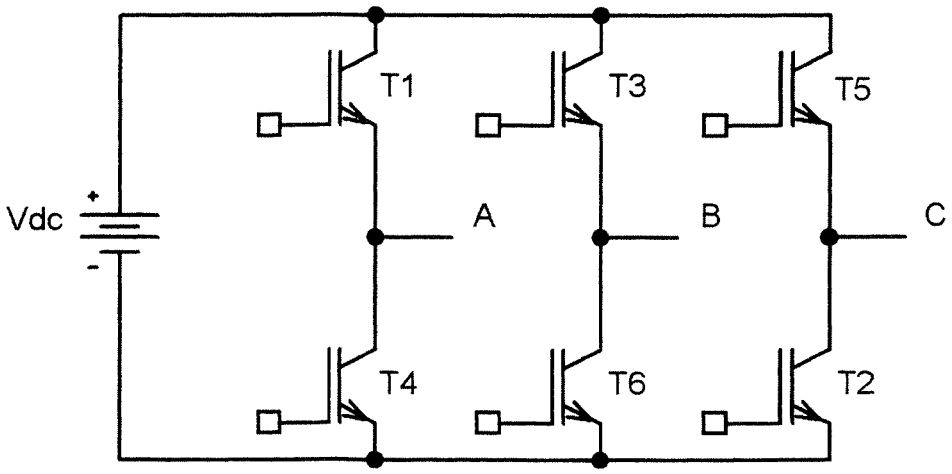

Fig. 2

(TURN OVER

3 (a) Give two advantages of switch-mode power supplies compared to linear regulator supplies. Outline an example circuit where they are used in combination. [30%]

(b) A flyback converter with an isolating transformer for use in a mains backup supply is shown in Fig. 3. The transformer has a magnetising inductance, but is otherwise ideal.

The dc supply has a minimum value of 48 V and the required output voltage is 400 V. The maximum average output current is 0.4 A .

For operation with a continuous current in the magnetising inductance, show that the output voltage is given by

$$V_O = V_{DC} \frac{N_2}{N_1} \frac{\rho}{1-\rho}$$

where ρ is the duty cycle, V_O is the output voltage and V_{DC} is the battery voltage. [30%]

Calculate the magnetising inductance required if the limit of continuous current in the magnetising inductance occurs at $\rho = 0.3$ and the switching frequency is 100 kHz . [20%]

For this design, use energy balance considerations to find the duty ratio required when the output current is halved. [20%]

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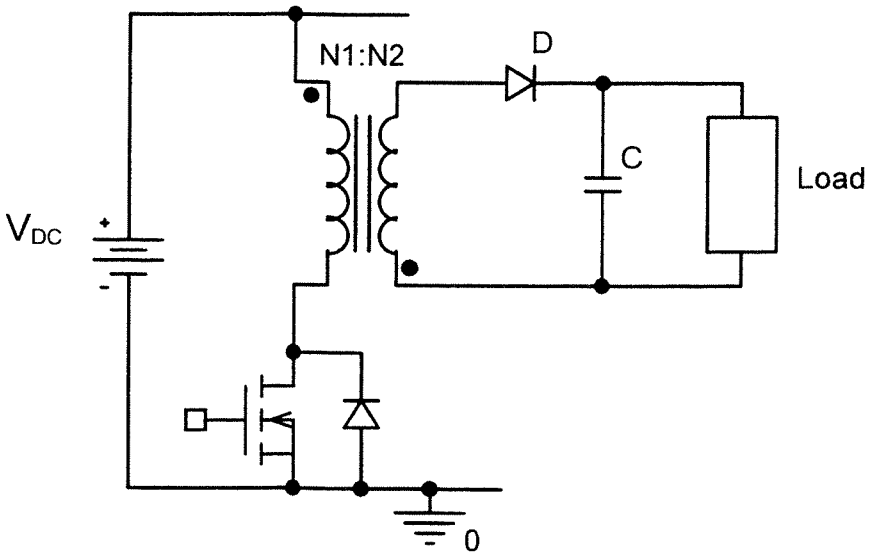

Fig. 3

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4 (a) Give two advantages associated with the use of high switching frequencies in switch-mode circuits. A conventional step down converter is shown in Fig. 4(a). With the aid of sketches of the MOSFET current and voltage, explain why the switching losses are high when it is operated at a high switching frequency. [30%]

(b) A zero voltage switching resonant converter is shown in Fig. 4(b). Explain why all four switching states are possible for the MOSFET and free-wheel diode switches, even when there is continuous current I_O in the smoothing inductor L_O.

Describe carefully each state in turn, starting with the case where only the MOSFET is on and conducting I_O. [40%]

Hence or otherwise, show that the maximum voltage across the MOSFET is given by

$$Z_O I_O + V_{DC}$$

where Z_O is the characteristic impedance of the L - C resonant circuit. [20%]

Making reference to the operating conditions, describe briefly how the resonant frequency for this circuit may be chosen. [10%]

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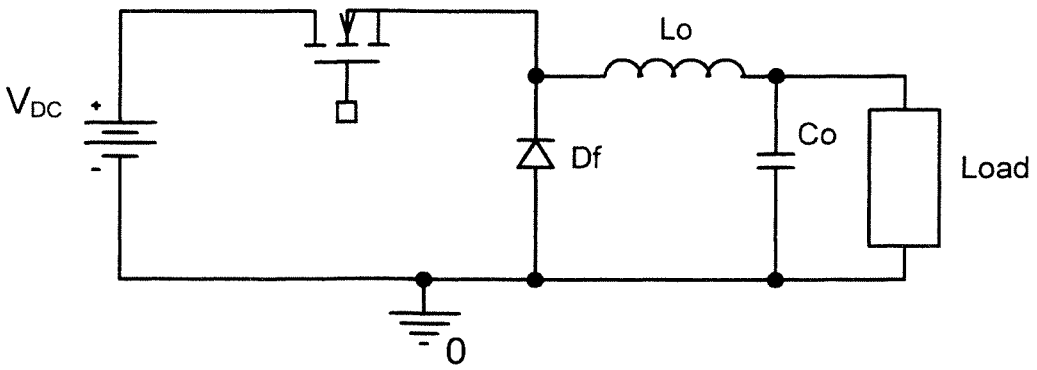

Fig. 4(a)

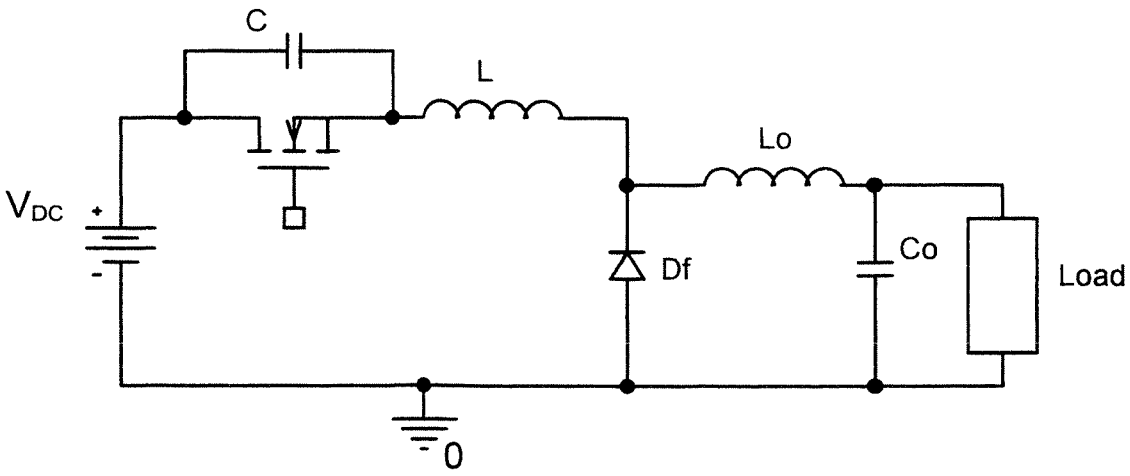

Fig. 4(b)

END OF PAPER

No answers have been received from the Examiner for this Module