ENGINEERING TRIPOS PART IIA

Wednesday 9 May 2007 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.*

There are no attachments.

STATIONERY REQUIREMENTS

Single-sided script paper

SPECIAL REQUIREMENTS

Engineering Data Book

CUED approved calculator allowed

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

1 (a) A single phase rectifier is to be used to supply a three phase inverter for a small variable speed drive. Sketch the smoothing capacitor voltage waveform and the capacitor charging current waveform for a constant current load. Explain briefly why the inverter may be considered as such a load.

The load is 0.25 kW at the smoothing capacitor and the ac supply is 230 V , 50 Hz . Estimate the smoothing capacitor required for 10% ripple in the capacitor voltage, stating your assumptions. [50%]

(b) A second rectifier circuit is proposed for the inverter system of Part (a), as shown in Fig. 1. The voltage across the smoothing capacitor C is held at 400 V by the operation of the power factor correction circuit, which switches at 10 kHz . Sketch the inductor current for operation in *discontinuous mode* for the pulse at the voltage peak of the ac supply. How should the current pulses be controlled to give unity power factor? What additional component is required at the input to the rectifier? [20%]

By considering the unity power factor ac supply current waveform, assuming the converter is 100% efficient, estimate the value of the smoothing capacitor required, stating your assumptions. [30%]

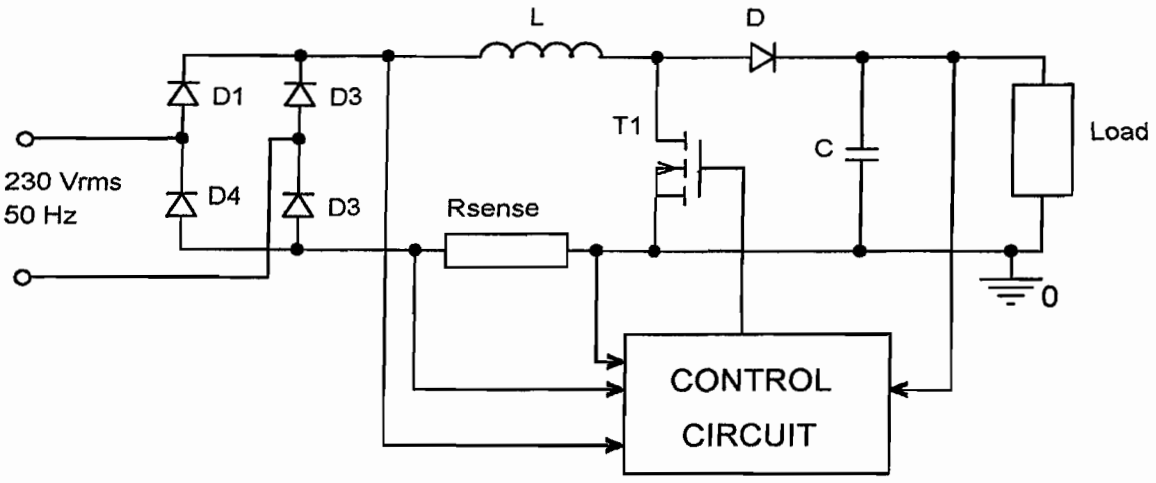

Fig. 1

2 (a) State three factors influencing the choice of switching device for inverter systems employing *Pulse Width Modulation* (PWM). [15%]

(b) Making reference to a table of states, explain briefly the meaning of the expression *Space Vector Modulation* (SVM) when applied to a three phase IGBT inverter, as shown in Fig. 2. Under what circumstances will the operation of the inverter according to SVM be advantageous compared to naturally sampled PWM? [40%]

By considering only the states bounding a particular output voltage, express the output voltage magnitude in terms of the relative times spent in each state. [25%]

(c) IGBT inverters of the form of Fig. 2 are to be used as part of a HVDC system for a wind farm, where the inverters are connected using undersea dc cables. The shore-side inverter is connected to the ac grid via a three phase transformer. Each phase of the transformer is found to have a stray input capacitance of 10 nF . Discuss briefly the difficulties this imposes to such an inverter system and suggest one method of eliminating the problem. [20%]

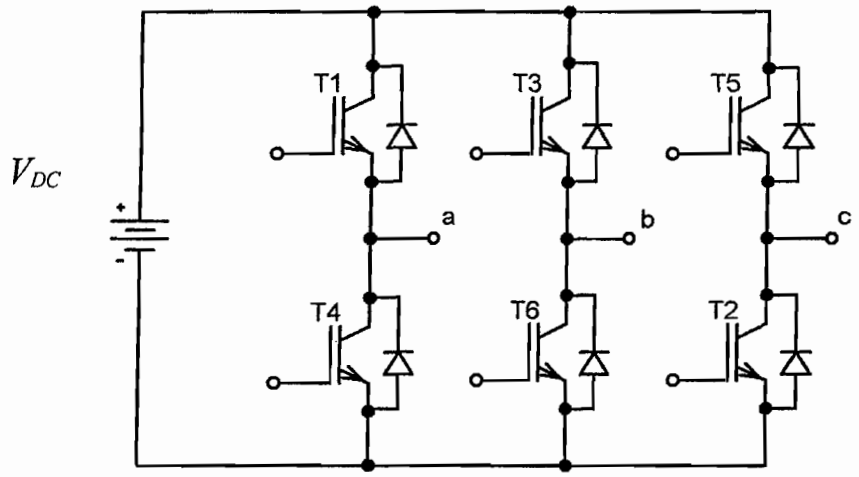

Fig. 2

3 A step down converter is required for an on-chip 10 MHz power supply, as shown in Fig. 3. For this circuit, explain briefly what is meant by *discontinuous current mode* and give one advantage and one drawback of operating in this mode. [20%]

Continuous current mode is chosen for the full load output of 1 A at 1.5 V with a 3 V input. What duty ratio is required, if the device on-state losses can be neglected? Assuming the output voltage is effectively smoothed by the capacitance C of the integrated circuit load, estimate the current ripple under these conditions, if the inductance L is 0.1 μH . Carefully sketch the corresponding waveforms of the inductor current and the voltage V_A , and mark on your sketch the value of the peak current in the MOSFET. [30%]

The controller reduces the voltage at the output to 1.2 V when the load current is 0.25 A . Find the duty ratio required for this condition stating your assumptions. Sketch the MOSFET current waveform under these conditions and estimate its peak value. [50%]

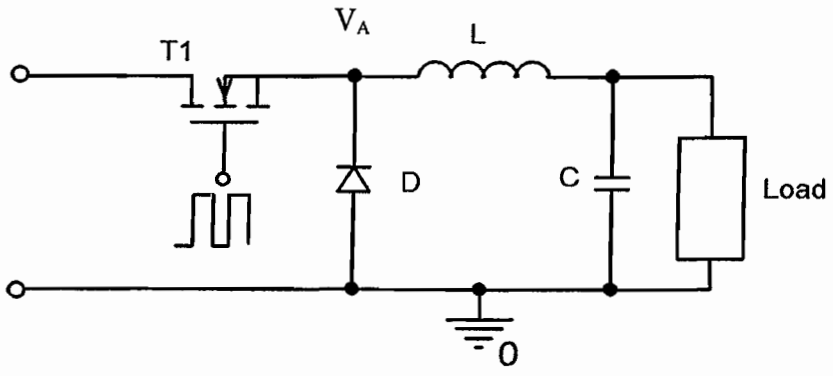

Fig. 3

4 A full bridge resonant dc-dc converter is shown in Fig. 4. The converter is to be used in the mode where the switching frequency is less than half the resonant frequency of the ideal components L and C. Give two reasons why this is an attractive mode of operation. Sketch the waveform of the voltage V_T applied to the resonant link for steady state operation with the value of V_O equal to 70% of V_{dc}, with negligible ripple. You may assume that the initial voltage on the capacitor C is $-2V_O$. [40%]

On the same time axis, sketch the current in the inductor L. Hence sketch the current charging C_O as a separate figure. [20%]

By considering the peak charge stored on C during a half cycle, and equating it to the charge transferred to C_O, find an expression relating the switching period to the output current for steady state operation. What are the implications for the control?

If V_{dc} is 48 V, and V_O is to be controlled to be 30 V for battery charging, suggest which components will account for the majority of the losses. [40%]

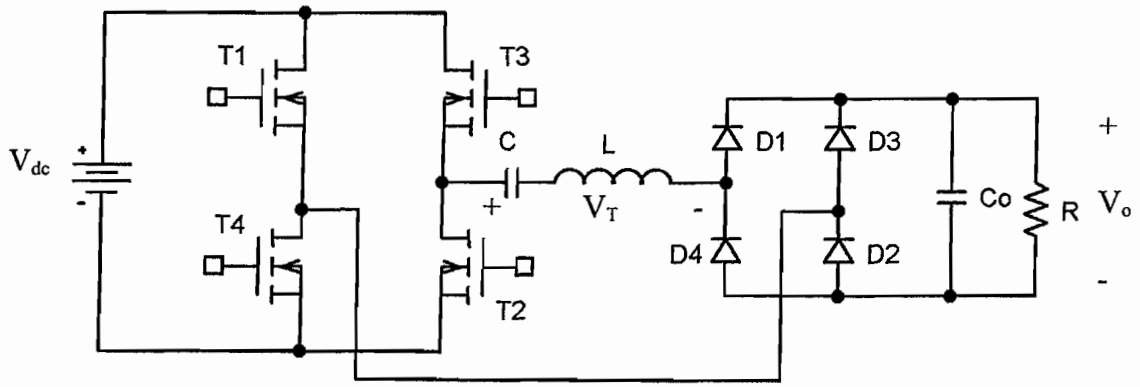

Fig. 4

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