UNIVERSITY OF CAMBRIDGE

ENGINEERING TRIPOS PART IIA

Wednesday 5 May 2004 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.

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 supplying a constant current 10 A electronic load is shown in Fig. 1. The impedance of the ac supply is negligible. The switch S and 0.5 Ω resistor comprise a soft-start circuit. Choose a value for the capacitor C which will reduce the voltage ripple to 5 % under the condition of the switch S closed, stating your assumptions.

Estimate the peak capacitor current for the first cycle of operation starting at the supply voltage zero (C discharged), with the switch S closed. [40%]

(b) For the circuit of Fig. 1, following start-up with the switch S open, the output voltage settles at an average value of 310 V in less than 1 s. Sketch the capacitor voltage and supply current for this condition. Calculate the peak magnitude of the supply current, stating your assumptions. [40%]

Estimate the magnitude of the first half cycle of supply current following the closing of the switch and comment on the result.

Describe briefly an alternative method of ensuring a soft start in ac-dc circuits with electronic loads. [20%]

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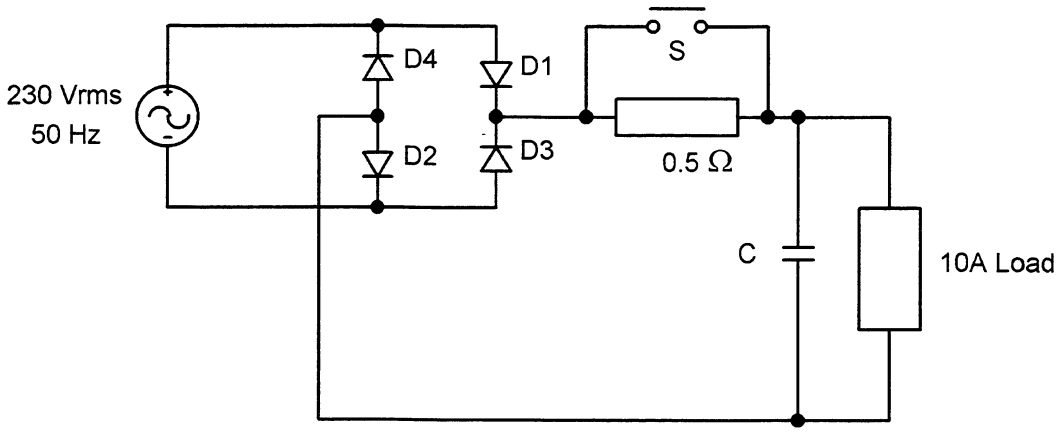

Fig. 1

2 (a) A full bridge circuit for a motor drive is shown in Fig. 2. Discuss briefly why the single leg output voltage V_A is given by $\rho_A V_{DC}$, when used in a dc motor drive, where ρ_A is the duty ratio for the upper switch M1.

The bridge is to be operated in the Bipolar mode. Explain how the pwm waveforms for the two legs may be generated in a microcontroller. [40%]

(b) An induction motor drive employs the three-phase bridge inverter shown in Fig. 3. Sketch a single cycle of the bridge-leg output voltage, under sinusoidal pwm taking care to account for the precautions necessary to eliminate sub-harmonics.

The inverter may be operated using *Space Vector Modulation*, according to the list of states in Table 1. Consider a vector in the segment of operation bounded by $\mathbf{V}_1$ (100) and $\mathbf{V}_2$ (110). Write down three possible vector sequences for generating such a vector, taking care to account for the depth of modulation.

Hence or otherwise list in binary form the sequence of states which gives minimal switching losses for the inverter. [40%]

For the sequence identified above, sketch the waveforms V_a, V_b, V_c seen at the inverter leg outputs for an example voltage vector in the sector bounded by $\mathbf{V}_1$ and $\mathbf{V}_2$ and sketch the vector with respect to $\mathbf{V}_1$ and $\mathbf{V}_2$. [20%]

Table 1.

State	'ON' IGBTs	$\frac{V_a}{V_{dc}}$	$\frac{V_b}{V_{dc}}$	$\frac{V_c}{V_{dc}}$
$\mathbf{V}_1$	T_1, T_6, T_2	1	0	0
$\mathbf{V}_2$	T_1, T_3, T_2	1	1	0
$\mathbf{V}_3$	T_4, T_3, T_2	0	1	0
$\mathbf{V}_4$	T_4, T_3, T_5	0	1	1
$\mathbf{V}_5$	T_4, T_3, T_5	0	0	1
$\mathbf{V}_6$	T_1, T_6, T_5	1	0	1
$\mathbf{V}_7$	T_1, T_3, T_5	1	1	1
$\mathbf{V}_8$	T_4, T_6, T_2	0	0	0

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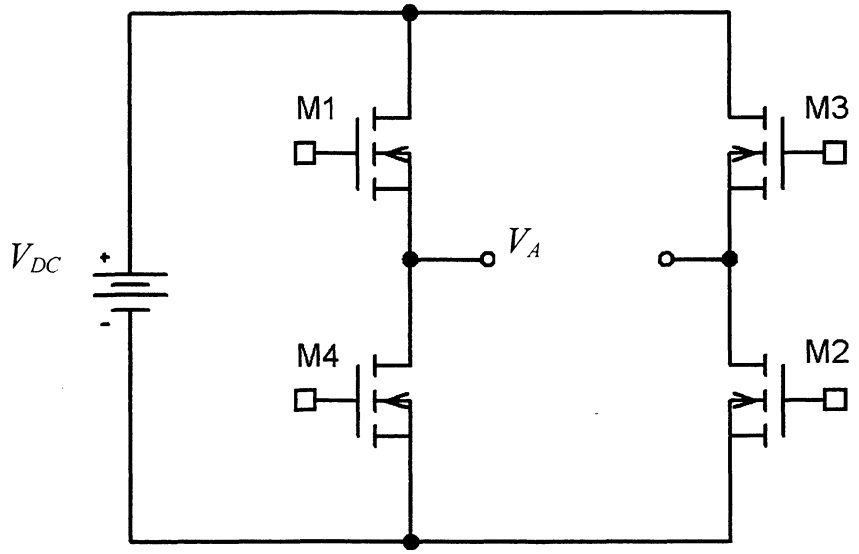

Fig. 2

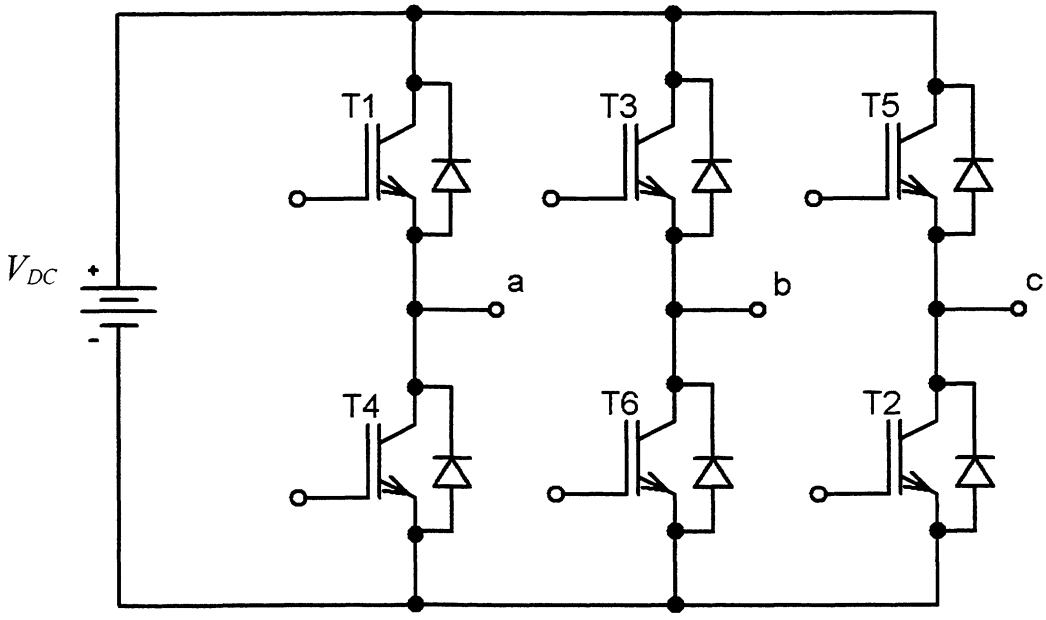

Fig. 3

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3 A step up converter for a vehicle electrical system is shown in Fig. 4. It is to convert 12 V dc to 42 V dc , with a maximum rating of 0.5 kW . Assuming a high efficiency, state the voltage and current ratings for the MOSFET. Hence explain the choice of the MOSFET for this application.

Discuss briefly why a feedback controller is essential in this application and state why in this case the converter is operated in the discontinuous current mode. [30%]

Find the duty ratio ρ of the MOSFET, when operating at the boundary between continuous and discontinuous current. Find the value of the inductance L required for this condition, if the switching frequency is 25 kHz. [30%]

Carefully sketch on one set of axes the inductor current waveform for the duty ratio found above and for the condition when $\rho = 0.3$.

Identify the common features in the two waveforms. Hence or otherwise find the output power for this value of ρ . [40%]

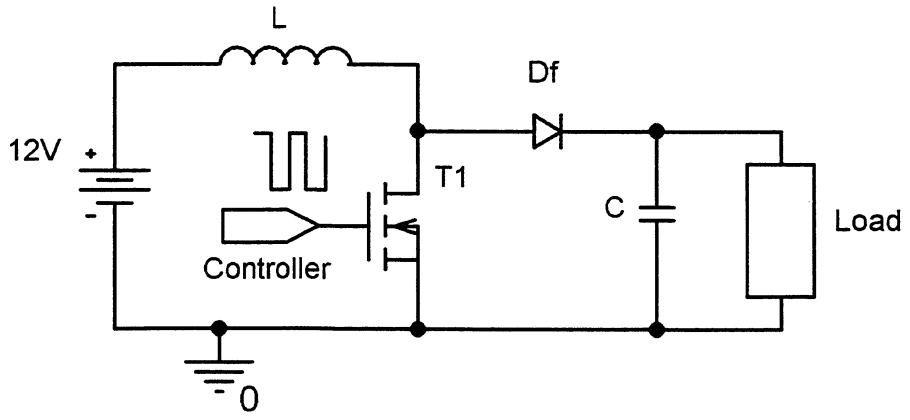

Fig. 4

4 A full bridge resonant dc-dc converter is shown in Fig. 5. Making reference to sketches of the current in the inductor L, describe carefully three distinct modes of operation associated with the switching frequency of the inverter bridge.

The bridge is to be operated above resonant frequency. State two advantages of operating in this manner particularly in respect to a circuit with a high resonant frequency. [40%]

Sketch waveforms for the voltage V_{AB}, the inductor current and the voltage V_{XA} showing the phase relationships between them when transferring a significant power to the load. [30%]

By considering the fundamental components of each waveform, find an expression for the voltage transfer ratio input to output. You may assume that the rectifier, smoothing capacitance and load may be replaced by an equivalent resistor when operating in the steady state.

How may the circuit be modified to reduce the turn off losses in the MOSFETs ? [30%]

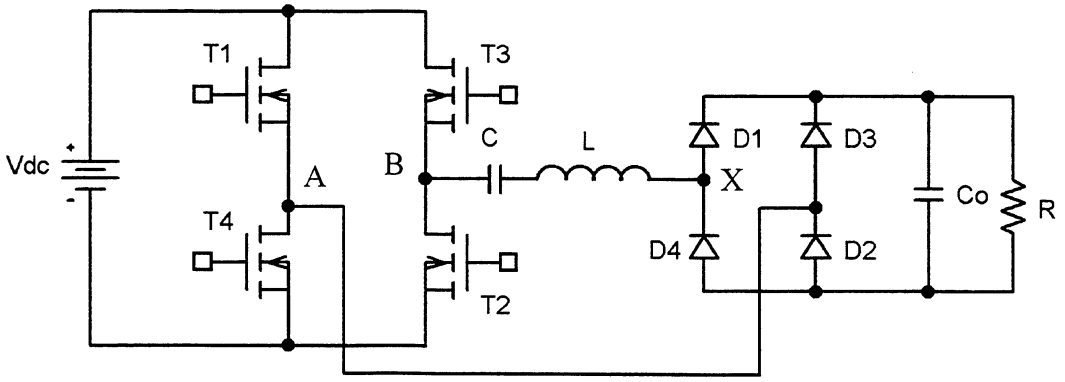

Fig. 5

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