

CITY UNIVERSITY OF HONG KONG

Module code & title : EE3918 Power Electronics and Drive Systems
Session : Semester A 2002-03
Time allowed : Two hours and thirty minutes

This paper has **Six** pages.

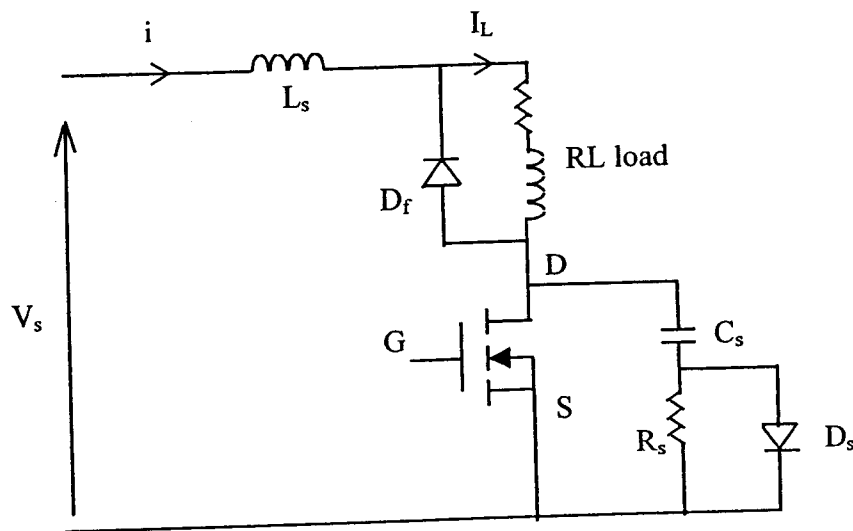
1. This paper consists of 5 questions. All questions carry equal marks.
 2. Answer any **Four** questions.
 3. Start on a new page for each question.
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Question 1

- (a) List four advantages of a power MOSFET over a power bipolar junction transistor. [2 marks]

- (b) A power MOSFET is operated as a chopper switching at a frequency f_s of 40 kHz. The chopper circuit is shown in Fig. Q1b and is supplying to a highly inductive load. The dc input voltage V_s of the chopper is 50V and the load current I_L is 10A. The snubber plus stray inductance L_s of the circuit is 0.5 μ H. The turn off time is given by 25 ns. It is assumed that the reverse recovery time of the free-wheeling diode D_f , the turn-on delay time and the turn-off delay time of the power MOSFET, are negligible.

- (i) State the functions of L_s , C_s , R_s and D_s . [3 marks]
- (ii) Describe the operating modes of the chopper with the aid of equivalent circuits. [9 marks]
- (iii) Determine the transfer function relating $V_{DS}(s)/V_s(s)$ during which the free-wheeling diode D_f has just been turned on, and evaluate the values of C_s and R_s for the critically damped condition. The initial conditions and the effect of D_s can be neglected. [11 marks]

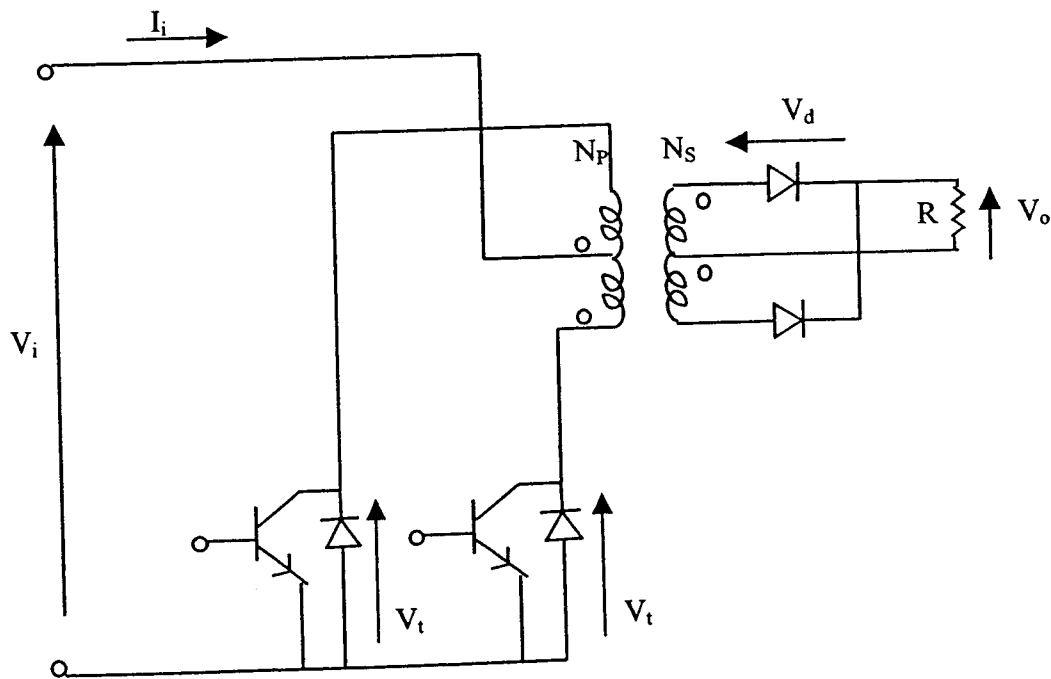
**Fig. Q1b**

Question 2

- (a) For a single-phase, full-bridge, unipolar and uniform-pulse-width modulated inverter,
- (i) sketch the gate signal generation diagram and the output voltage waveforms indicating the carrier signal, reference signal and all the modulation variables, **[5 marks]**
 - (ii) derive the expression of the output voltage in a Fourier series in terms of the modulation variables. **[8 marks]**
- (b) The inverter as described in (a) is operated with only two pulses per half-cycle for voltage control, with modulation index $M = 0.6$ and output frequency $f_o = 60$ Hz. It is supplied to a series RL load of $R = 2 \Omega$ and $L = 10$ mH. The d.c. input voltage is $V_s = 200$ V.
- (i) Express the output voltage in a Fourier series (up to two frequency components), in terms of the given system parameters. **[6 marks]**
 - (ii) Express the instantaneous load current $i_o(t)$ in a Fourier series (up to two frequency components), in terms of the given system parameters. **[6 marks]**

Question 3

- (a) Draw the closed-loop control block diagram of a switched-mode dc power supply. [2 marks]
- (b) Derive the control to output voltage transfer function of a buck type switched-mode dc power supply using voltage feedforward control method, by which the effect of input voltage V_i is eliminated or reduced. Explain, with the aid of diagrams, how the output voltage pulse widths are controlled by this method. [7 marks]
- (c) With the aid of diagrams, describe the limitations of the Push-Pull circuit shown in Fig. Q3. [6 marks]
- (d) The average dc output voltage V_o of the Push-Pull circuit in Fig. Q3 is 25 V supplying to a resistive load of $R = 1.0 \Omega$. The operating duty cycle k is 0.5. The on-state voltage drops of transistors and diodes are $V_t = 1.0$ V and $V_d = 0.7$ V respectively. The transformer turns ratio $N_s/N_p = 0.6$. If the switching losses and the losses in the transformer are neglected, and the ripples of the load current and input current are negligible, determine
- (i) the average input current I_i , and the open circuit transistor voltage V_{oc} , [4 marks]
- (ii) the efficiency of the circuit, [6 marks]

**Fig. Q3**

Question 4

The speed of a separately excited dc motor is controlled by a single-phase thyristor-diode semiconverter. The field current is also controlled by a similar semiconverter and the field current is set to the maximum possible value.

The ac supply voltage to the armature and field converter is one-phase, at 200 V, 50 Hz. The armature resistance is $R_a = 0.1 \, \Omega$, the field resistance is $R_f = 200 \, \Omega$, and the motor voltage constant is $K_v = 1.05 \, \text{V/A-rad/s}$. The load torque is $T_L = 75 \, \text{Nm}$ at a steady speed of 700 rpm.

The viscous friction and no-load losses are negligible. The armature and field currents are continuous and ripple-free.

- (i) Draw the semiconverter drive circuit diagram including the dc motor load equivalent circuit. [3 marks]
- (ii) Sketch the waveforms of the armature circuit: supply voltage, output voltage, armature current, and supply current. [4 marks]
- (iii) Derive the output voltage of the semiconverter in terms of its firing angle α . [2 marks]
- (iv) Evaluate the field current, I_f . [3 marks]
- (v) Evaluate the delay angle of the converter in the armature circuit, α_a . [6 marks]
- (vi) Evaluate the input power factor of the armature circuit. [7 marks]

Question 5

A three-phase 56-kW 2968-rpm 460-V 50-Hz two-pole Y-connected induction motor has the following parameters: $R_s = 0.27 \, \Omega$, $R_r = 0.18 \, \Omega$, $X_s = 0.13 \, \Omega$, $X_r = 0.2 \, \Omega$, and $X_m = 11.4 \, \Omega$.

It is fed by a 3-pulse half-wave triac cycloconverter. The three-phase 50Hz line-to-neutral supply voltage input to the cycloconverter is 110 V. The air gap flux of the motor is kept constant using the volts/hertz control. The 'cosine wave crossing' method is used for firing instants determination.

- (i) Sketch the power circuit of one output phase of the cycloconverter. [2 marks]
- (ii) Derive the expressions of the firing angles of the positive and negative converters. [8 marks]
- (iii) Derive the expression of the 'modulation factor' of the cycloconverter and evaluate its value when the cycloconverter is feeding an output frequency of 12 Hz to the induction motor using the volts/hertz control. [6 marks]
- (iv) Calculate the maximum torque, T_m and the corresponding speed, ω_m for the motor fed by cycloconverter supply in (iii). [9 marks]

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