

CITY UNIVERSITY OF HONG KONG

Module code & title : EE2921 Power Electronics and Drive Systems

Session : Summer Term 1997

Time allowed : 2 hours and 30 minutes

This paper has SEVEN pages. (Including this page)

Instructions to candidates:

1. The paper consists of SIX questions in two sections.
 2. Attempt a total of FOUR questions and not more than TWO questions from each section.
 3. All questions carry equal marks.
 4. Use a separate answer book for each section.
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Materials, aids & instruments permitted to be used during examination:

Approved portable battery operated calculator

Special materials (other than standard materials e.g. answer book or supplementary sheets)
to be supplied to students.

1 graph paper

Section A

Question 1

- (a) With the aid of a diagram, define the following diode's parameters:-
- (i) softness factor
 - (ii) reverse recovery time
 - (iii) peak reverse current
 - (iv) storage charge
- (b) A BJT is operated as chopper switch at a frequency of $f_s = 100\text{KHz}$. The circuit arrangement is shown below. The dc input voltage of the chopper is $V_s = 100\text{V}$ and the load current is $I_L = 50\text{A}$. The switching times are $t_r = 40\text{ns}$ and $t_f = 15\text{ns}$. Determine the value of
- (i) L_s
 - (ii) C_s
 - (iii) power loss due to the RC snubber, P_s . Neglecting the effect of inductor L_s on the voltage of snubber capacitor, C_s . Assume the $V_{CE(sat)} = 0$.

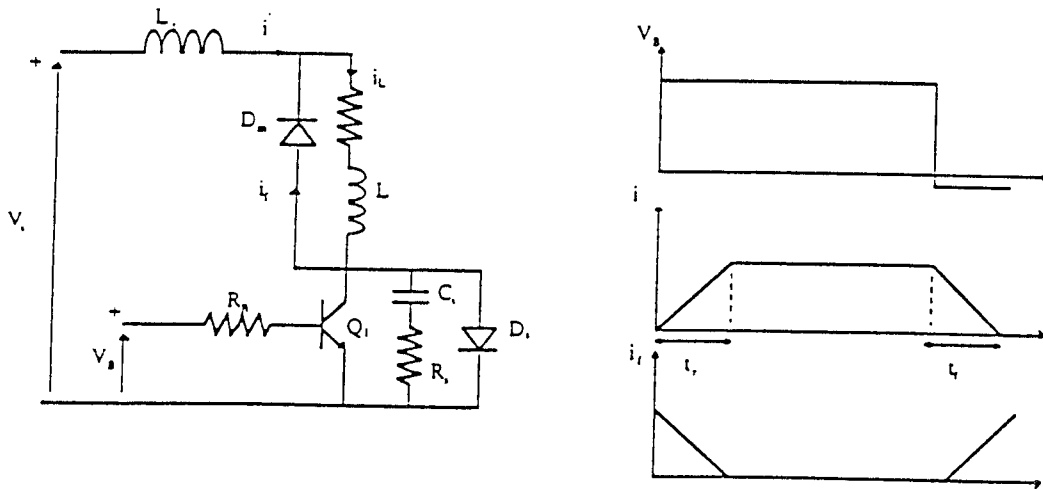


Fig.Q1

[25 marks]

Question 2

- (a) Define the following terms:
- displacement factor,
 - form factor,
 - ripple factor.
- (b) A single phase half-wave converter in Fig. Q2 is operated from a $V_m=200V$, $50Hz$ supply. If the resistive load $R=5\Omega$ and the firing angle, $\alpha=30^\circ$.
- Express the DC voltage, V_{dc} and root-mean-square voltage, V_{rms} output of the load in term of firing angle, α .
 - Determine the form factor and ripple factor for the output of the load.

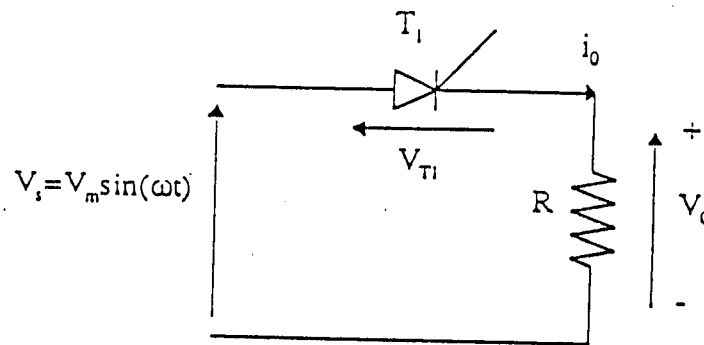


Fig. Q2

- (c) If the voltage source in Fig. Q2 is replaced by a $200V$ DC source. The junction capacitance of the thyristor is $C_j=10pf$ and can be assumed to be independent of the off-state voltage. The limiting value of charging current to turn on the thyristor is $5mA$ and the critical value of dv/dt is $100V/\mu s$. Determine the value of capacitance C_s which must be added in parallel with the SCR so that the thyristor will not be turned on due to dv/dt when the source voltage is first applied.

[25 marks]

Question 3

- (a) What is/are the advantage(s) of using a switched-mode power supplies in comparing to a linear power supplies.
- (b) With reference to the basic configuration of a buck-type dc-to-dc converter as shown in Fig. Q3 operating in continuous conduction mode, briefly describes its operation.

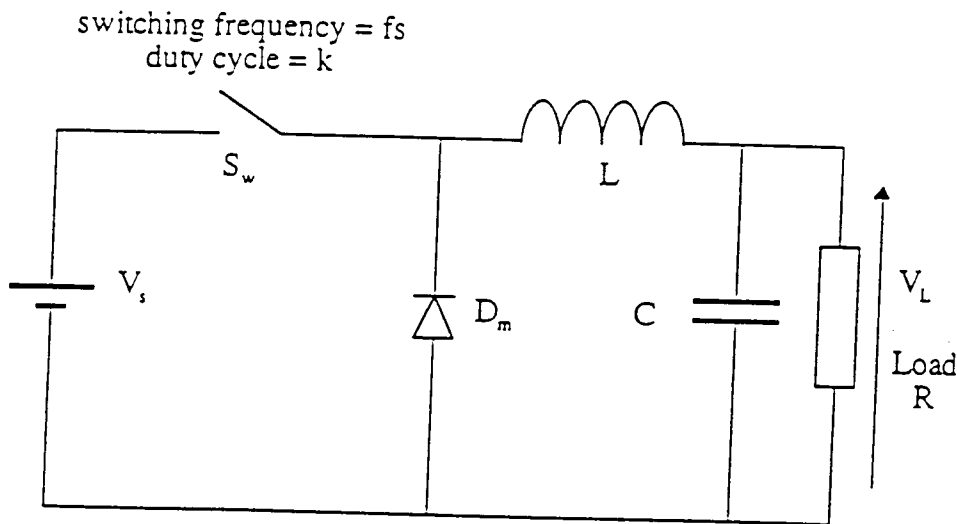


Fig. Q3

- (c) The required average output voltage of the above regulator is 6V and the peak-to-peak output voltage is 10mV. The switching frequency is 20KHz and the duty cycle is 0.5. If the peak-to-peak ripple current of inductor is to be limited to 0.4A, determine
- required average input voltage, V_s ,
 - filter inductance, L , and
 - filter capacitor, C .

Derive any equations used.

[25 marks]

Section B

Question 4

The speed of a 7.46 KW, 230 V, 1200 rpm separately excited dc motor is controlled by a single-phase full-converter as shown in Fig.Q4. The rated motor armature current is 38A, and the armature resistance is $R_a = 0.3 \Omega$. The ac supply voltage is 220V. The motor voltage constant is $K_a\phi = 0.182$ V/rpm. Assume that sufficient inductance is present in the armature circuit to make the motor current continuous and ripple free.

- (a) In rectifier operation (motoring action), for a firing angle $\alpha = 30^\circ$ and rated motor current, calculate

- i) The motor torque ; [4 marks]
- ii) The speed of the motor ; [6 marks]
- iii) The supply power factor. [7 marks]

- (b) In inverter operation (regenerating action), the polarity of the motor back emf, E_g is reversed by reversing the field excitation. Calculate

- i) The firing angle to keep the motor current at its rated value. [5 marks]
- ii) The power fed back to the supply. [3 marks]

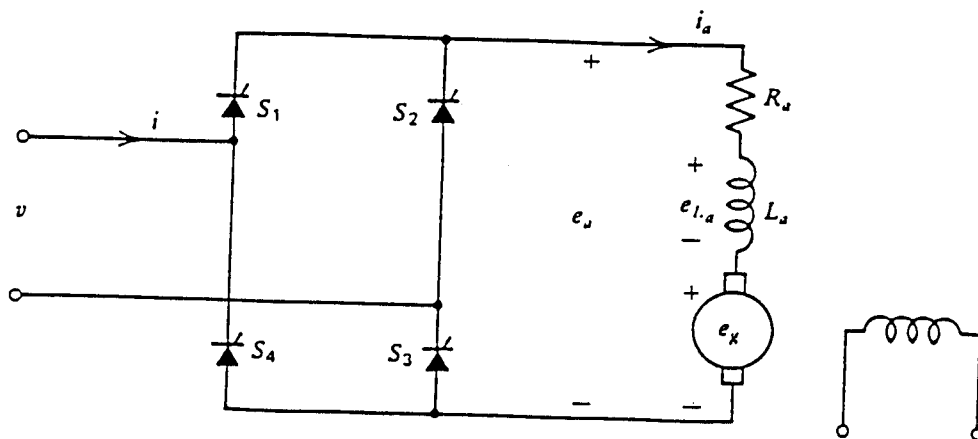


Fig.Q4

Question 5

A three-phase 30 KW, 880 rpm, 460 V, 160 Hz eight-pole Y-connected induction motor has the following parameters :

- stator resistance, $R_s = 0.19 \Omega$;
- rotor resistance, $R_r = 0.22 \Omega$;
- stator reactance, $X_s = 1.2 \Omega$;
- rotor leakage reactance, $X_r = 1.8 \Omega$;
- motor reactance, $X_m = 13 \Omega$;

The no-load loss is negligible. The motor is controlled by a current-source inverter and the input current is maintained constant at 50A. If the frequency is 80 Hz and the developed torque is 200 Nm, determine the

- (a) slip for maximum torque, s_m and maximum torque, T_m ; [6 marks]
- (b) slip, s ; [5 marks]
- (c) rotor speed, ω_m ; [2 marks]
- (d) terminal voltage per phase, V_a ; [10 marks]
- (e) power factor, PF_m . [2 marks]

Question 6

- (a) Consider a separately excited DC motor shown in Fig.Q6, derive from first principle, the transfer function $\theta(s)/V_a(s)$ and draw the block diagram for field control. [17 marks]

- (b) Briefly describe the factors in choosing motion transducers. [8 marks]

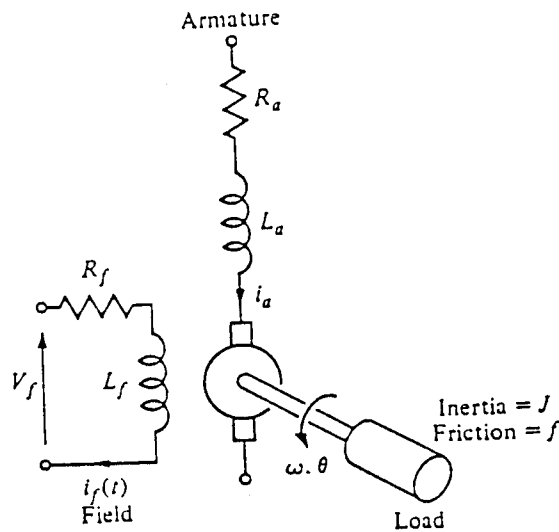


Fig.Q6