

CITY UNIVERSITY OF HONG KONG

Module code & title : EE2921 Power Electronics and Drive Systems

Session : Semester B, 1997-98

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

Q1.

- (a) A Germanium transistor, type D67DE is used as a switch and the waveforms are referred in Figure Q1(a). Given $V_{cc} = 200V$, $V_{BE(sat)} = 3V$, $I_B = 8A$, $V_{CE(sat)} = 2V$, $I_{CS} = 100A$, $t_d = 0.5 \mu s$, $t_r = 1 \mu s$, $t_s = 5 \mu s$, $t_f = 3 \mu s$ and $f_s = 10 \text{ kHz}$. The duty cycle $k = 50\%$. The collector-emitter leakage current is $I_{CEO} = 3mA$.

Plot the instantaneous power due to the collector current, $P_c(t)$.

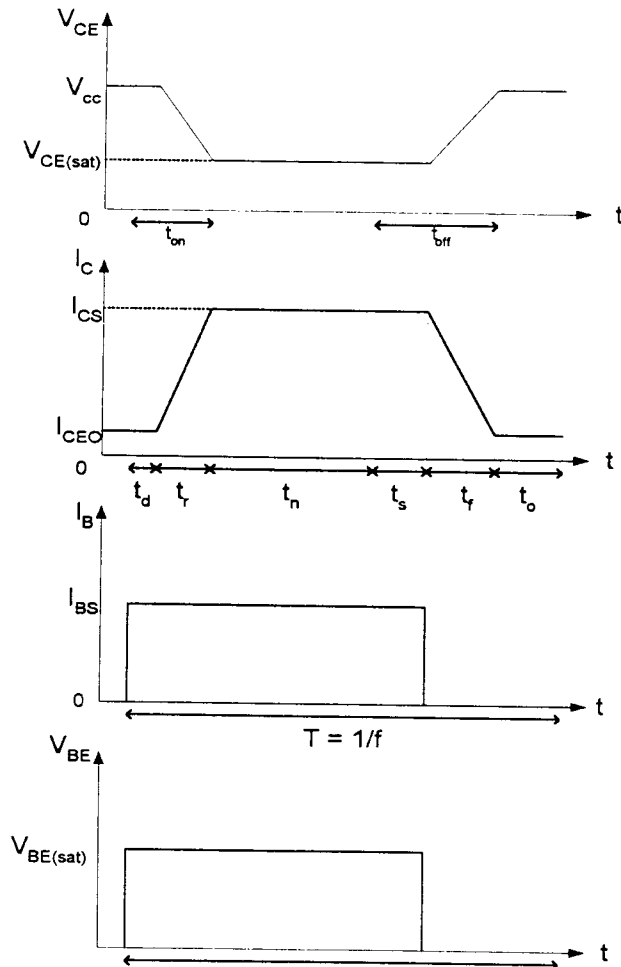


Figure Q1 (a)

[13 marks]

Q1.

- (b) The holding current, I_H of the thyristor T_1 in the chopper circuit shown in Figure Q1(b) is $I_H = 200\text{mA}$ and the delay time of T_1 is $1.5\mu\text{s}$. The d.c. voltage is 220V and source inductance L_s is negligible. It has a load of $L = 10\text{mH}$ and $R = 2\Omega$. Determine the minimum width of gate-pulse width of the thyristor T_1 .

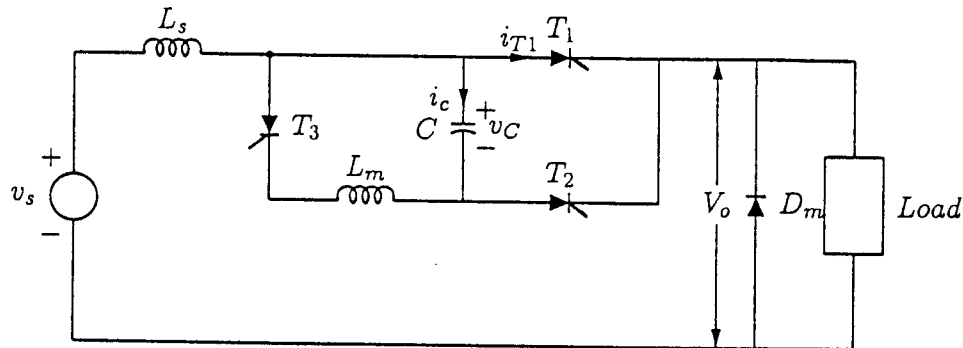


Figure Q1(b)

[12 marks]

Q2.

- (a) In Figure Q2(a), the SCR is able to withstand a dv_{AK}/dt value of $50\text{ V}/\mu\text{s}$, and the initial discharge from the snubber capacitor must be limited to 3A . The switch S may be closed to energize the circuit randomly on the sinusoid of v_s (i.e. the supply voltage); similarly in normal operation, the SCR may be gated on at any point on the voltage waveform of v_s . If $R_L = 20\Omega$, find:

- the snubber capacitor value, and
- the snubber resistor value.

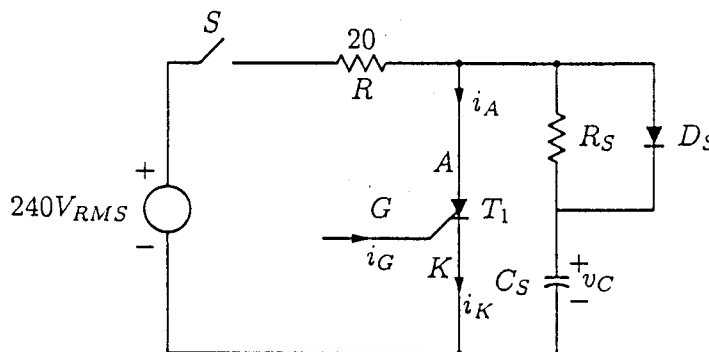


Figure Q2(a)

[10 marks]

Q2.

(b) The GTO in Figure Q2(b) operates in a periodic on-off arrangement. The value of L is large enough that the load current essentially is constant at a value of 40A.

- (i) For a turnoff gain of 6, find the required value of negative gate current.
- (ii) Find the value of L_G such that the gate current at turnoff changes at the rate of $2 \text{ A}/\mu\text{s}$. Neglect v_{GK} .
- (iii) Find the value of C_S that limits dv_{AK}/dt to $500\text{V}/\mu\text{s}$ after turnoff.
- (iv) Find R_S to limit subsequent discharge current from C_S to 5 A.
- (v) Find the power dissipated in R_S if the GTO is turned off 1000 times per second.

[15 marks]

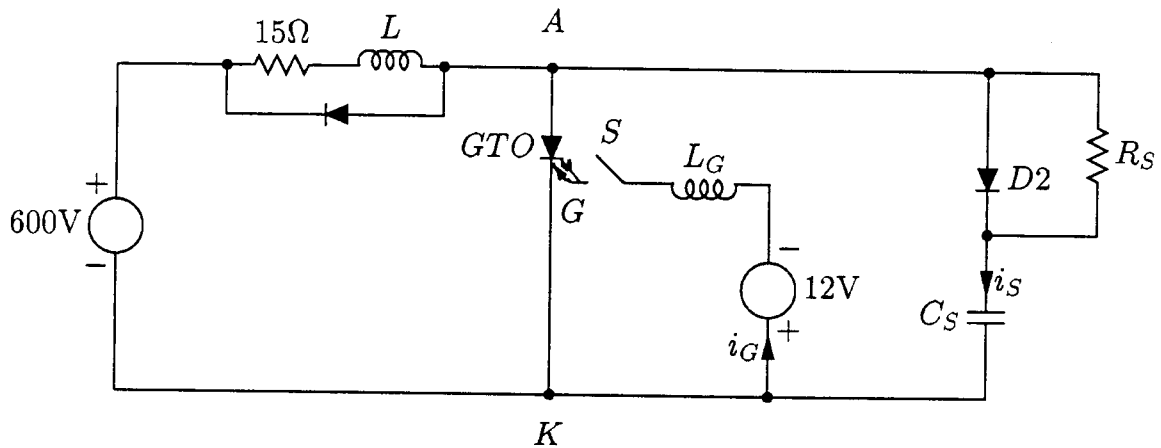


Figure Q2(b)

Q3.

- (a) A three-phase controlled bridge rectifier is supplied by a $240 \text{ V}_{\text{RMS}}$, 60 Hz source. The load is highly inductive and a Free Wheel Diode is used. For a phase-control angle of $\alpha = 30^\circ$, the average load power is 20 kW . Find

(i) the load resistance, [3 marks]

(ii) the AC line current fundamental and fifth-order harmonic current, and [3 marks]

(iii) the fundamental and fifth-order harmonic current if α is increased to 75° . [4 marks]

- (b) A boost chopper with the configuration in Figure Q3(b) supplies 150 V to 25Ω load from a 40 V source. The capacitor is large enough that negligible load voltage ripple occurs; $L = 200 \mu\text{H}$ and $T = 200 \mu\text{s}$. Find

(i) the value of D ,

(ii) the value of $I_{\min}$,

(iii) the value of $I_{\max}$,

(iv) the average diode current, and

(iv) the RMS value of capacitor current.

[15 marks]

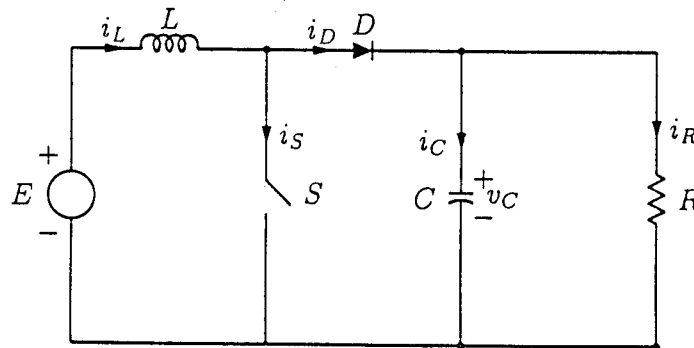


Figure Q3(b)

SECTION B

Q4.

(a) Compare the performance of the armature-controlled d.c. motor with the field-controlled d.c. motor. [8 marks]

(b) A field controlled d.c. motor system is shown in Figure Q4.

i) Derive the transfer function of the motor, $\Theta(s)/E_f(s)$ and draw the block diagram. [10 marks]

ii) For $e_f = 220$ V, $i_a = 15$ A, $\omega_{ss} = 1200$ rpm, $L_f = 200$ mH, $R_f = 110$ Ω , $J = 1.4$ Nm/rad/s² and $B = 0.95$ Nm/rad/s, determine the transfer function $\Theta(s)/E_f(s)$, where ω_{ss} is the steady-state angular velocity. [7 marks]

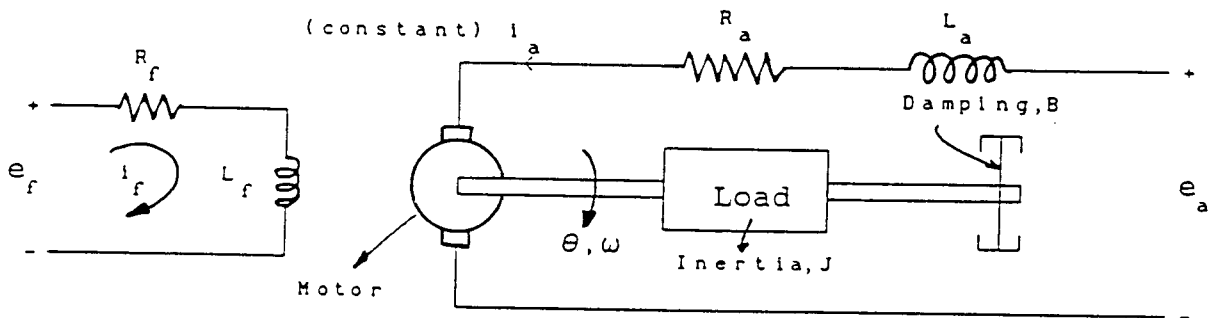


Figure Q4

Q5.

(a) With the aid of diagrams, briefly describe the principle of operation of four-quadrant chopper drive. [15 marks]

(b) For the following analogue motion transducers:

- i) potentiometer ;
- ii) LVDT ;
- iii) tachometer ;
- iv) piezoelectric accelerometer ; and
- v) semiconductor strain gauge.

Compare the measurand, frequency range, output impedance, accuracy and sensitivity of these transducers. [10 marks]

Q6.

A three-phase 460 V, 60 Hz four-pole wye-connected induction motor has the following circuit parameters :

stator resistance, $R_s = 1 \Omega$;
rotor resistance, $R_r = 0.7 \Omega$;
stator reactance, $X_s = 1.35 \Omega$;
rotor leakage reactance, $X_r = 1.95 \Omega$;
motor reactance, $X_m = 45 \Omega$.

The no-load loss, $P_{no\ load}$, is negligible. The load torque, which is proportional to speed squared, is 40 Nm at 1750 rpm. If the motor speed is 1500 rpm, determine

- (i) the load torque T_L , [4 marks]
- (ii) the rotor current, I_r , [3 marks]
- (iii) the stator supply voltage V_a , [2 marks]
- (iv) the motor input current I_i , [4 marks]
- (v) the motor input power P_i , [2 marks]
- (vi) the slip for maximum current S_a , [4 marks]
- (vii) the maximum rotor current $I_{r,max}$, [2 marks]
- (viii) the speed at maximum rotor current ω_a , and [2 marks]
- (ix) the torque at the maximum current T_a . [2 marks]