The Open University of Sri Lanka
Faculty of Engineering Technology

Study Programme	:	Diploma in Technology/Bachelor of Technology (Engineering)
Name of the Examination	:	Final Examination
Course Code and Title	:	**MEX5270 Power electronics and motor drives**
Academic Year	:	2013/14
Date	:	23rd August 2014
Time	:	0930 hrs – 1230hrs
Duration	:	3 hours

General instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer any 5 questions only.

Q1. (a) Briefly explain "conduction loss" and "switching loss" of real power semiconductor switches using appropriate diagrams.

(5 marks)

(b) In an non-ideal static switching device, the current and voltage values during the switching transitions follow parabolic laws as stated by the following equations.

$$i = I\left(\frac{t}{t_{on}}\right)^2 \quad , \quad v = V\left(\frac{t_{on} - t}{t_{on}}\right)^2 \quad \text{for "ON" transition.}$$

$$i = I\left(\frac{t_{off} - t}{t_{off}}\right)^2 \quad , \quad v = V\left(\frac{t}{t_{off}}\right)^2 \quad \text{for "OFF" transition}$$

Assume that the static performance of the switch is ideal.
Derive an expression for the switching power loss at a frequency of f in Hz.

(12 marks)

(c) Sketch a turn-off snubber circuit configuration which could be used to reduce turn-off switching loss in a power semiconductor switch feeding a constant current load.

(3 marks)

Q2. (a) The converter and snubber circuit as shown in Fig. Q2 has $V_s = 100V$ and $I_L = 5A$. The switching frequency is 100 kHz with a duty ratio of 50%. The transistor current takes 0.5 μs to fall during turn off.

(i) Determine the turn-off losses of the transistor without a snubber if the transistor voltage reaches the full supply voltage, V_s in 0.1 μs (after which the current starts to fall.)

(2 marks)

(ii) Design a turn-off snubber circuit using the criterion that the transistor voltage reaches its final value at the same time that the transistor current reaches zero.

(6 marks)

(iii) Determine the transistor turn-off losses, the resistor power with the snubber added and the total power loss during turn-off. Compare the total power loss with that obtained in part (i). Assume $t_{on} = 5RC$.

(5 marks)

(b) Two identical transistors are mounted on a common heat sink, which has a thermal resistance of 2° C/W. It the thermal resistance of each transistor from the junction to case, $R_{\theta(jc)}$, is 2° C/W and the contact thermal resistance between the transistor and the heat sink, $R_{\theta(cs)}$, is 0.2 ° C/W. Determine the maximum power that can be dissipated

(i) with all the power dissipated in one transistor, and
(ii) the power being equally divided between the two transistors.

(7 marks)

Assume an ambient temperature of 55° C and maximum junction temperature of 125 °C.

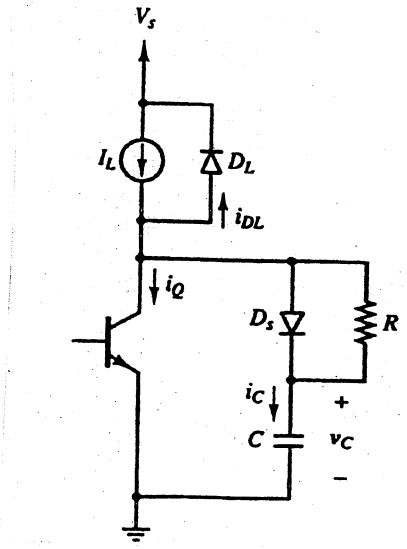


Fig. Q2

Q3. (a) full- wave controlled converter operating as an inverter is used to transfer power from a wind generator to a single-phase 240V RMS 60Hz AC system. The generator produces a DC output of 150V and is rated at 5000W. The equivalent resistance of the generator circuit is 0.6Ω.

(i) Determine the converter delay angle for rated generator output power.

(4 marks)

(ii) Determine the power absorbed by the AC system.

(4 marks)

(iii) Determine the inductance required to limit the peak-to peak current ripple to 10% of the average current.

(4 marks)

(b) Show that the power factor for the controlled full-wave rectifier with a resistive load is

$$pf = \sqrt{1 - \frac{\alpha}{\pi} + \frac{Sin(2\alpha)}{2\pi}}$$

where α = firing delay angle.

(8 marks)

Q4. (a) Sketch the power circuit of a buck (step-down) dc-dc converter feeding a resistive load.

(2 marks)

(b) Assuming steady-state operation and the capacitor used in the converter has a finite value, sketch the following waveforms.

(i) Voltage drop across the inductor.
(ii) Current through the capacitor, and
(iii) Output voltage across the resistive load.

(6 marks)

(c) Derive an expression for the peak-to-peak ripple in the output voltage and show that

$$\frac{\Delta V_o}{V_o} = \frac{1 - D}{8LCf_s^2}$$

Where,

V_o = output voltage
ΔV_o = peak-to-peak ripple in output voltage
D = duty cycle
f_s = switching frequency
L and C are low pass filter circuit components

(4 marks)

(d) In a step-down converter, consider all components to be ideal. Let $v_o = V_o$ be held constant at 5V by controlling the switch duty ratio D. Calculate the minimum inductance required to keep the converter operation in a continuous-conduction mode under all conditions if V_d, the input voltage varies in the range of 10-40V, $P_o \geq 5W$, and f_s = 50 kHz. Derive the equation for minimum inductance required to keep the converter in CCM from the fundamental principle.

(8 marks)

Q5. A 230V, 1000 rpm 30A separately excited dc motor has an armature resistance and inductance of 0.7Ω and 50mH respectively. The motor is fed from a two-quadrant chopper and is controlled to operate in the regenerative braking mode (the dc machine would be operating as a generator providing negative motor torque). The chopper operates at a frequency of 800 Hz and is fed from a dc source of 230V. Assume continuous mode of conduction.

(a) Calculate the duty ratio of the chopper for rated torque and the speed of 800rpm.
(6 marks)

(b) What will be the motor speed for duty ratio of 0.6 and rated motor torque ?
(5 marks)

(c) What will be the maximum allowable speed of the motor, if the chopper has a maximum duty ratio of 0.9 and maximum allowable motor current is twice the rated current ?
(5 marks)

(d) Calculate the power fed to the source for the operating conditions in part (c).
(4 marks)

Q6. (a) A single phase ac voltage controller as shown in Fig. Q6 is operated with unequal firing angles for the two thyristors (firing angle α_1 for thyristor S_1 and α_2 for thyristor S_2 respectively).

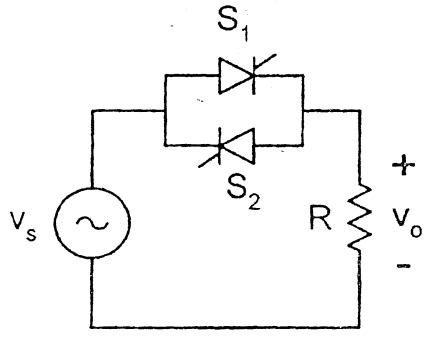


Fig. Q6

Show that the rms load voltage is

$$v_{o,rms} = \frac{V_m}{\sqrt{2}}\sqrt{1 - \frac{\alpha_1 + \alpha_2}{2\pi} + \frac{\sin 2\alpha_1 + \sin 2\alpha_2}{4\pi}}$$

where, V_m is the peak ac input voltage

(8 marks)

(b) Assume that the thyristor S_2 of the ac voltage controller shown in Fig. Q6 is replaced with a diode and the thyristor S_1 is operated with a firing angle of α.

(i) Show that the rms load voltage is given by

$$v_{o,rms} = \frac{V_m}{\sqrt{2}}\sqrt{1-\frac{\alpha}{2\pi}+\frac{\sin 2\alpha}{4\pi}}$$

(5 marks)

(ii) Determine the range of rms voltage across the load.

(4 marks)

(c) Give comments if load (R) is replaced by a ceiling fan.

(3 marks)

Q7. (a) A dc source of 100 V is supplying an inverter with a bipolar PWM output. The load is an R-L series combination with R = 30 Ω and L= 25 mH. The output has a fundamental frequency of 50Hz.

(i) Determine the amplitude modulation ratio to provide a 50 V rms fundamental frequency output.

(ii) If the frequency modulation ratio is 15, determine the corresponding total harmonic distortion factor.

You may make use of the normalized Fourier Coefficients V_n/V_{dc} for Bipolar PWM.

	$m_a = 1$	$m_a = 0.9$	$m_a = 0.8$	$m_a = 0.7$
n = 1	1.00	0.90	0.80	0.70
$n=m_f$	0.60	0.71	0.82	0.92
$n=m_f\pm2$	0.32	0.27	0.22	0.17

(12 marks)

(b) For a square-wave single-phase full-bridge inverter suggest a scheme to control the amplitude as well as eliminate selected harmonic components of the ac voltage output. Give necessary sketches of the waveforms to support your answer.

(8 marks)

Q8. (a) What is a rectifier? What is the difference between a rectifier and a converter?

(5 marks)

(b) What are the main differences between MOSFETs and BJTs ?

(5 marks)

(c) What is a four-quadrant converter?

(5 marks)

(d) What is a forced commutation? What are the advantages of forced commutation for ac-dc converters?

(5 marks)

END