UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, SECOND SEMESTER

MAY 2018

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Power Electronics

COURSE CODE : EE422

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. There are five questions in this paper. Answer any four questions. Each question carries 25 marks.
2. If you think not enough data has been given in any question you may assume any reasonable values.

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THIS PAPER CONTAINS FIVE (5) PAGES INCLUDING THIS PAGE

Question 1

(a) A gate turn off thyristor is shown in Figure Q. *1* below

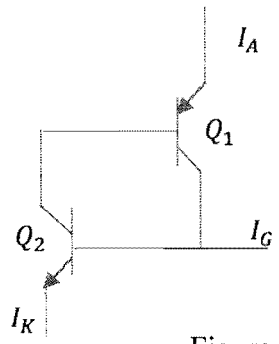


Figure Q. 1

If I_{co1} and I_{co2} are the leakage currents of the two transistors and α_1 and α_2 their gains, Prove that the anode current of the combination is given by:

$$I_A = \frac{\alpha_2 I_G + I_{co1} + I_{co2}}{1 - (\alpha_1 + \alpha_2)} \qquad [8]$$

(b) In the step-down converter circuit shown in Figure Q. *2* has $V_d = 250\,V$ and $I_o = 50A$ The MOSFET parameters are listed below:

BV_{DSS} = 400 V , $I_{D,max}$ = 80 A, $V_{GS,th}$ = 5 V, $r_{DS(on)} = 0.05\Omega$, $T_{j,max}$ = 175 °C,

$R_{\theta,ja}$ = 0.5 °C/W, $t_d(on) = t_d(off) = 10ns, t_{ri} = t_{fi} = 25ns$,

$t_{rv} = t_{fv} = 175ns$

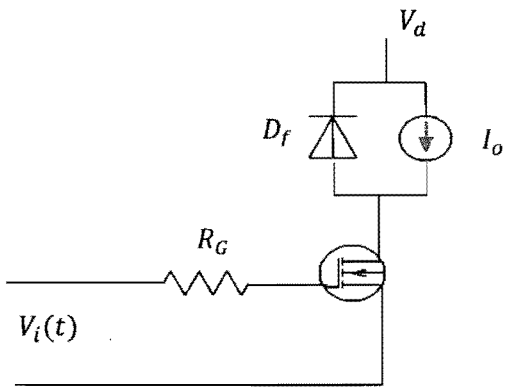


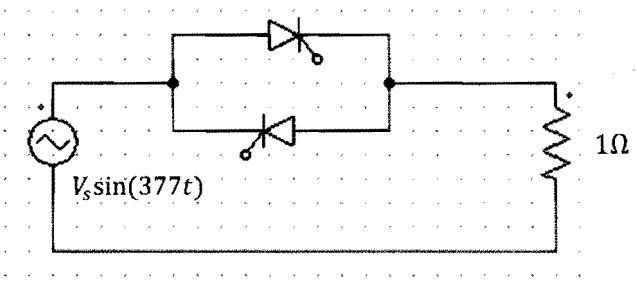
Figure Q. 2

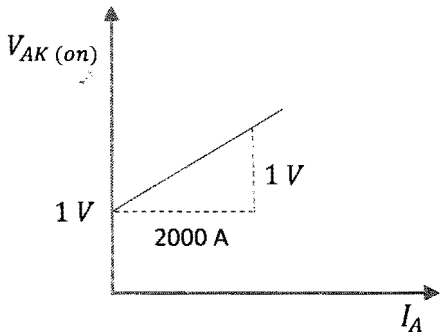
i. What is the power dissipation in the MOSFET assuming a switching frequency f_s= 10 kHz and a duty cycle D = 50%? [3]

ii. What is the maximum average power that can be dissipated in the MOSFET? Assume an ambient temperature of 25 °C. [2]

iii. The duty cycle D will vary from 20% to 90%. What is the maximum permissible switching frequency f_s ? Assume that the period $\frac{1}{f_s}$ is large compared to the switching times of the MOSFET. [3]

(c) Consider the SCR circuit shown below. The SCR has the following characteristics:
Tj,max = 125 °C ; $V_{B0} = 3000\,V$; $I_{A-max} = 2000A$; $R_{\theta j-c} = 0.05°C/w$





Assume that the case temperature is 50 °C.

i. What is the maximum average power $P_{SCR,max}$ that can be dissipated in the thyristors?

ii. Estimate the maximum power that can be delivered to the load.

Question 2

(a) What are the different methods to turn on the thyristor? [5]

(b) Design a circuit to produce an average voltage of 80 V across a 100 Ω resistive load from a 220-V rms 50-Hz ac source. Determine the power absorbed by the resistance and the power factor. Draw the circuit diagram, source and output voltage wave form. [20]

Question 3

(a) Draw a circuit diagram of a buck regulator and explain its working principle with necessary waveforms , assume continuous operation mode. Derive expression for peak to peak ripple voltage of the capacitor that is present across the load. [15]

(b) A MOSFET manufacturer's datasheet lists the junction-to-ambient thermal resistance R_{θ_JA} as 62°C/W. The maximum junction temperature is listed at 175°C, but the designer wishes for it not to exceed 150°C for increased reliability. If the ambient temperature is 40°C, determine the maximum power that the MOSFET can absorb. [2]

(c) The datasheet for the MOSFET in (b) lists the thermal resistance from the junction to case as 1.87°C/W and the thermal resistance from the case to the heat sink as 0.50 °C/W.

i. If the device is mounted on a heat sink that has a thermal resistance of 7.2°C/W, determine the maximum power that can be absorbed without exceeding a junction temperature of 150°C when the ambient temperature is 40°C. [4]

ii. Determine the junction temperature when the absorbed power is 15 W. [2]

iii. Determine R_{θ_SA} of a heat sink that would limit the junction temperature to 150°C for 15 W absorbed. [2]

Question 4

(a) Draw the ideal characteristics for

i. A diode [1]
ii. A thyristor [2]

(b) What is SMPS? Mention the types of SMPS. Draw the circuit diagram of fly-back SMPS and briefly explain its operation. [10]

(c) A BJT is specified to have a β range of 10 to 50. The load resistance is $R_c = 15\ \Omega$. The dc supply is $V_{cc} = 240\ V$ and the input voltage to the base of the circuit is $V_B = 12\ V$. If $V_{CE(sat)} = 1.0\ V$ *and* $V_{BE(sat)} = 1.5\ V$. Find

i. The value of R_B that results in saturation with an overdrive factor of 8. [8]
ii. The forced β_f [2]
iii. The power loss P_T in the transistor. [2]

Question 5

A boost converter is required to have an output voltage of 12 V and supply a load current of 0.5 A. The input voltage varies from 2.0 to 5 V, switching frequency of 100 kHz. A control circuit adjusts the duty ratio to keep the output voltage constant.

(i) Give an advantage for selecting high switching frequency. [1]

(ii) Determine a value for the inductor such that the variation in inductor current is no more than 30 percent of the average inductor current for all operating conditions. [15]

(iii) Determine a value of an ideal capacitor such that the output voltage ripple is no more than 2 percent. [2]

(iv) Determine the maximum capacitor equivalent series resistance for a 2 percent ripple. [7]