MACHAKOS UNIVERSITY

University Examinations for 2016/2017

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONICS ENGINEERING

EEE 405: POWER ELECTRONICS

DATE: 20/6/2017 **TIME: 8.30-10.30 AM**

Instructions

- *This paper consists of Five Questions*
- *Attempt* ***Question One*** *(Compusory) and any other* ***Two Questions***

QUESTION ONE (COMPULSORY)

a) The Figure Q.1 shows the switching characteristics for a power semiconductor device.

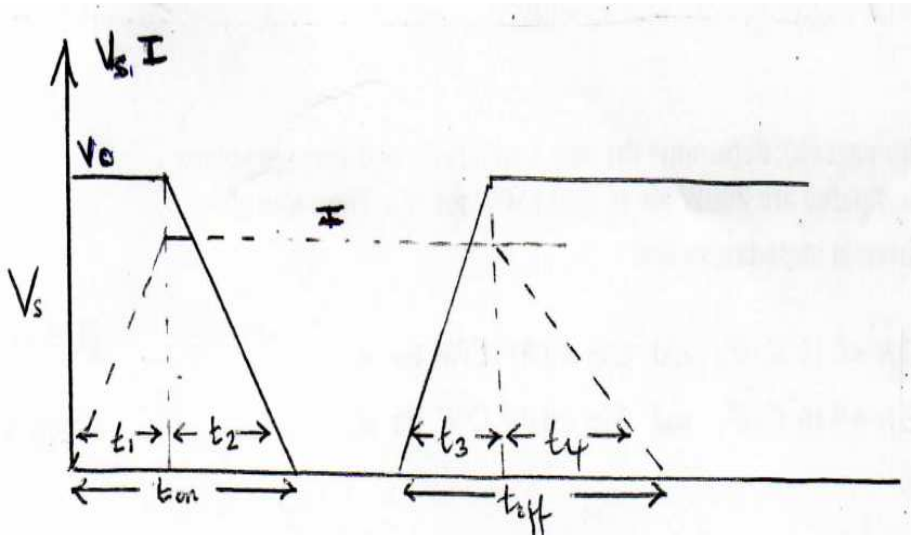

Fig Q. 1 Power Switching Characteristic

i. Derive the expressions for the energy loss during turn-on and turn-off periods (2 marks)

ii. Derive the expression for the average switching energy loss (2 marks)

iii. Sketch the variation of the variation of power loss during turn-on and turn-off periods (1 mark)

iv. For $V_s = 220V, I = 10A, t_1 = 1\mu s, t_2 = 2\mu s, t_3 = 1.5\mu s, t_4 = 3\mu s,$ determine the average power switching loss in the device for a switching frequency of 1KHz (3 marks)

b) A Bipolar transistor has a current gain $\beta = 50$, load resistance $R_C = 10\Omega$, DC supply voltage $V_{CC} = 120V$, and input voltage to base circuit $V_B = 10V$. For $V_{CES} = 1.2V$ and $V_{BES} = 1.6V$,

i. Sketch a well labelled transistor circuit with all the parameters shown (2 marks)

ii. Determine the value of R_B for operation in the saturation state (2 marks)

iii. Determine the value of R_B for an overdrive factor of 6 (3 marks)

iv. Determine forced current gain (1 mark)

v. Determine the power loss in the transistor for cases (f) and (g) above (4 marks)

c) State any Six qualities of a good industrial Inverter (3 marks)

d) A three phase M-3 converter is operated from a three phase,230V 50Hz supply with a load resistance of $R = 10\Omega$ .An average output voltage of 50% of the maximum possible output voltage is required. Determine from the first principles

i. The firing angle

ii. Average and Rms load current

iii. Rectification Efficiency (7 marks)

QUESTION TWO

a) Distinguish between *Step Up* and *Step Down* Chopper (1 marks)

b) For a *Step Up Chopper* show that

$$V_o = \frac{1}{1-\alpha} V_s$$

All the symbols carry their usual meaning (4 marks)

c) A step up chopper has input voltage of 220V and output voltage of 660V. The conducting time in the thyristor chopper is$100\mu S$. The pulse width of the output voltage is halved for a constant frequency. Determine the average value of the new output voltage (4 marks)

d) A step-down chopper, fed from 220V DC supply is connected to RL load with $R = 10\ \Omega$ and L=15mH. The Chopper frequency is 1250HZ and the duty cycle is 0.5. Determine

i. The maximum and minimum load currents (5 marks)

ii. The maximum ripple current (1 mark)

iii. The average and rms load voltages and currents (4 marks)

iv. Rms chopper current (1 mark)

QUESTION THREE

a) State *Four* Industrial Applications of Inverters (4 marks)

b) Distinguish between the following

i. Line-Commutated and Forced-Commutated inverters

ii. Voltage-Source and Current-Source Inverters (4 marks)

c) A single phase full bridge inverter is connected to an RL load . The Inverter has a DC source voltage of V_s and output frequency of $f = 1/T$.

i. Sketch a well labelled inverter circuit described in this case (2 marks)

ii. Obtain the expressions for load currents as a function of time for the first two half cycles of the output voltage (4 marks)

iii. Obtain the expressions for the steady state currents as a function of time for the first two half cycles (4 marks)

iv. For $R = 2\,\Omega$ L=0.1H, $V_s = 240V\ dc$ and the frequency of output voltage being 50HZ, determine the load currents in (ii) and (iii) above (4 marks)

QUESTION FOUR

A single phase transformer with secondary voltage of 230V 50HZ delivers power to a load $R = 10\,\Omega$ through a half wave controlled rectifier circuit. For a firing angle delay of 60^0,

a) Sketch a well labeled diagram of the Rectifier Circuit plus transformer (2 marks)

b) Determine from the *First Principles*

i. Average voltage current and DC power (4 marks)

ii. Rms output voltage, current and AC power (4 marks)

iii. Rectification efficiency (2 marks)

iv. Form factor (2 marks)

v. Voltage ripple factor (2 marks)

vi. Transformer utilization factor (2 marks)

vii. PIV of the thyristor (2 marks)

QUESTION FIVE

a) State the various anode voltage ratings as applicable to an SCR. Indicate these voltage ratings on a relevant voltage waveform (5 marks)

b) State *Any Four* Methods (Techniques) of Mounting Thyristors based on the thermal considerations (2 marks)

c) A Thyristor is rated to carry full-loads current with an allowable case temperature of $100℃$ for a maximum allowable junction temperature of $125℃$. The thermal resistance between case and ambient is $0.5℃/W$ and that between the sink and the ambient is$0.4℃/W$. Determine the sink temperature for an ambient temperature of $40℃$ (3 marks)

d) Figure Q.5 shows a snubber network connected across an SCR.

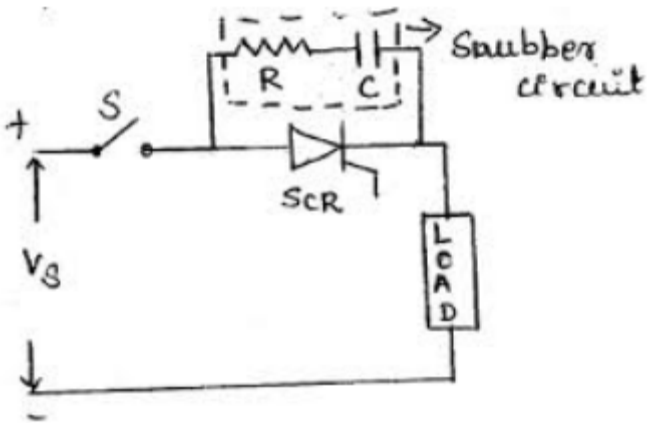

Fig Q. 5 Snubber Circuit for SCR

i. From the first principles, derive the expressions for the $\frac{di}{dt}$ and $\frac{dv}{dt}$ in terms of the circuit parameters (4 marks)

ii. Derive the expressions of the R-L-C circuit parameters in terms of the damping ratio and snubber network quantities (2 marks)

e) A thryristor is placed between a constant DC voltage source of 240V and a resistive load R. The specified limits of $\frac{di}{dt}$ and $\frac{dv}{dt}$ for the SCR are $60A/\mu s$ and $300V/\mu s$ respectively. The damping ratio is 0.5.

i. Determine the $\frac{di}{dt}$ inductor and the *Snubber Circuit* parameters (3 marks)

ii. Explain how these parameters may be modified to suit the working conditions in the circuit (1 mark)