UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *ELECTRICAL ENGINEERING*
SUBJECT	:	**POWER ELECTRONICS 3**
CODE	:	**EEP321**
DATE	:	NOVEMBER EXAMINATION 11 NOVEMBER 2014
DURATION	:	(SESSION 1) 08:30 – 11:30
WEIGHT	:	40 : 60
FULL MARKS	:	100

EXAMINER	:	MR. BA KLETTE
MODERATOR	:	DR CG RICHARDS
NUMBER OF PAGES	:	5 PAGES 1 ANNEXURE

INSTRUCTIONS	:	POCKET CALCULTATORS PERMITTED
REQUIREMENTS	:	NONE

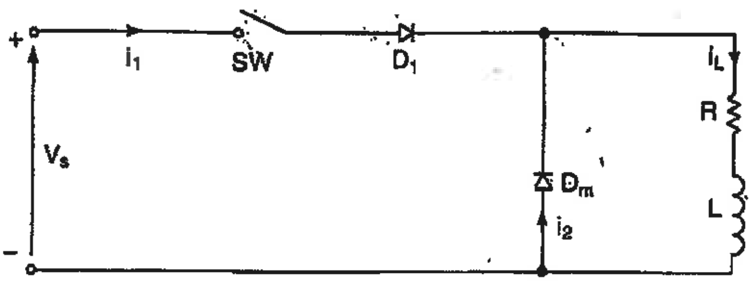
INSTRUCTIONS TO CANDIDATES:

1. DETAILED WAVEFORMS AND CIRCUIT DIAGRAMS ARE REQUIRED FOR ALL MATHEMATICAL DEDUCTIONS, CALCULATIONS AND CIRCUIT-THEORY OR DEVICE-THEORY DESCRIPTIONS.
2. THEORY TYPE QUESTIONS MUST BE ANSWERED IN POINT FORM BY CAREFULLY CONSIDERING THE MARK ALLOCATION.
3. ALL WORK MUST BE WELL PRESENTED IN YOUR EXAMINATION SCRIPT.
4. ANY ASSUMPTIONS MADE SHOULD BE STATED CLEARLY.
5. ONLY DRAWINGS MAY BE IN PENCIL.
6. POCKET CALCULATORS ARE PERMITTED BUT NO INFORMATION BOOKLETS ARE ALLOWED.
7. QUESTIONS THAT ARE NOT CLEARLY NUMBERED WILL NOT BE MARKED.
8. KEEP PARTS OF THE QUESTION TOGETHER AND WORK FROM TOP TO BOTTOM AND NOT ALL OVER THE PAGE.

QUESTION 1

1.1 The only ideal component in the diagram below is the switch. Sketch the waveforms that represent the current in the load and freewheeling diode with respect to the current flowing through the switch if the switch is turned on at 0 seconds, turned off at 100mS and turned back on at 200mS. Assume that the inductor never discharges to zero.

If Vs=50V, R=13Ω, charge stored in Dm = 5μC and the rate of change in diode current is 10A/μsec , indicate the steady state current value, Irr and Trr on your waveforms.



(11)

1.2 A MOSFET dissipates 50W during conduction and $10^{-3}f_s$ during switching. f_s is the switching frequency in Hz. The junction to case temperature $R_{\theta jc}$ is 1°C/W and the maximum junction temperature is 150°C. If the case temperature of the MOSFET is 50°C. Determine the maximum switching frequency. (6)

1.3 The application of a gate current is one method of turning an SCR on. Explain the other methods that will cause turn-on in an SCR. (8)

[25]

QUESTION 2

2.1 A power switching device operates in a 90Vdc circuit and supplies a current of 13A to the load. Turn-off times are indicated in figure 2. Calculate the average power losses due to the turn-off time at a frequency of 40kHz. (10)

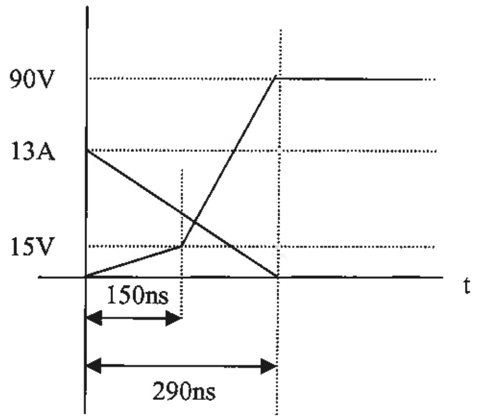


Figure 2

2.2 A pnp transistor is used in a switch mode power supply application. The load is 5Ω resistive driven from a 50V supply and the original transistor has a β=50. V_{BE} =0.7V and V_{CEsat} =2V for this transistor driven with a base driver output signal which swings from -20V to 50V. The base resistor calculated for these conditions is 360Ω.

A person not suitably qualified replaces the transistor with one of which β=20!

2.2.1 Sketch the circuit diagram for the power circuit and the driver circuit. (2)

2.2.2 Sketch the load voltage waveforms for the original circuit and the modified circuit with respect to the driver voltage and indicate the exact voltage levels on the waveforms. (10)

2.2.3 Calculate the percentage increase in the power dissipated in the transistor (8)

2.2.4 Compare the levels of power dissipation and give your opinion on the reliability of the resulting circuit. (3)

2.3 Design a driver circuit for a npn-transitor, which allows the base current to peak during turn-on from a 10V base drive circuit. The transistor has to switch a resistive load of 5Ω on and off from a 100V supply. The transistor gain is approximately 20. V_{BE}=1V and V_{CESAT}=2V. The initial peak value of the base current needs to be three times the initial value required to saturate under load conditions described. The base current must then return to $I_{B(SAT)}$ Sketch a circuit diagram and also calculate the losses in the transistor and base resistors. Motivate all assumptions and design parameters chosen. (10)

2.4 Discuss the following concepts with respect to power transistors:

2.4.1 Second breakdown (2)

2.4.2 Breakdown voltages (2)

[47]

QUESTION 3

3.1 A single-phase half-wave controlled rectifier is used to power the field and a single phase full-converter is connected to the armature circuit of this dc-motor. The motor parameters are:
Armature resistance=0.25Ω, Field resistance = 100 Ω. The voltage constant = torque constant = 0.4V/A-rad/s. The full converter firing angle is equal to 30° and the half wave controlled rectifier firing angle is set for half the maximum voltage. The armature and field circuits are fed from a 120Vrms supply.

3.1.1 Sketch neat armature and field circuit diagrams. Show the possible quadrants of operation for the armature and the field and the equations used to calculate the average armature and field voltages. (4)

3.1.2 Derive the equations for calculating the average output voltage of the full converter from first principles. (5)

3.1.3 What is the speed of the motor if the armature current corresponding to the load demand is 30A? (6)

3.2 A three-phase half-wave converter is operated from a three-phase Y-connected 200V (line voltage), 50Hz supply with a reactive load of 15Ω. Calculate the firing angle if the average output voltage has to be 35% of the maximum possible voltage. (8)

3.3 A Class C converter is used to power an electric motor. Recommend a suitable protection scheme to protect the two switches in the phase arm against short-circuiting of the dc-bus. Also discuss its principle of operation using a block diagram showing the scheme implemented on only one of the switches only. (10)

[33]

TOTAL = 105

POWER ELECTRONICS 3 EQUATIONS

$Vce_{off} = Vi_{max} + V_p \frac{N_p}{N_r}$

$Vo_{ave} = K\, Vs_{pk}$

$\frac{Ii_{pk}}{Io_{ave}} = \frac{Vo_{ave}}{Vi_{pk}} = \frac{K}{1-K}$

$V_f = R_f\, I_f$

$R_{eq} = \frac{V_s}{i_a}(1-K) + R_m$

$Vb_{ave} = Ia_{pk}(1-k)R_b$

$Vce_{off} \geq 2Vi_{max}$

$Is_{ave} = K\, Ia_{ave}$

$I_L = Vi_{pk} K\left(\frac{1}{R_O(1-K)^2} \pm \frac{T}{2L}\right)$

$T_d = B\omega + T_L$

$L_{crit} = \frac{R_O(1-k)^2}{2f}$

$P_{AVE} = \int_{t0}^{T} v_{(t)} i_{(t)}\, dt$

$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v_{(t)}^2\, dt}$

$P_d = E_g\, I_a$

$P_b = Ia_{pk}^2(1-k)R_b$

$f = \frac{1}{2RC\ln(3)}$

$Ib_{ave} = Ia_{pk}(1-k)$

$Rs = \frac{Ro}{k}$

$K_{max} = \frac{1}{1 + \frac{N_r}{N_p}}$

$P_g = I_a V_s(1-K)$

$Ic_{max} = \frac{N_s}{N_p} I_{L1} + \frac{V_p KT}{L_p}$

$Q_{gt} = I_{gq} T_{gq}$

$P_{ch} = Vch_{on}\, Ia_{pk}\, K$

$\frac{Ii_{pk}}{Io_{ave}} = \frac{Vo_{ave}}{Vi_{pk}} = \frac{K}{1-K}$

$Io_{ave} = K\, Is_{pk}$

$Ic_{ave} = K Ii_{pk}$

$Ip_{pk} = \frac{V_p K}{f L_p}$

$V_{dc} = \frac{V_m}{2\pi}(1 + \cos\alpha)$

$R_{eq} = \frac{V_s}{K\, Ia_{Aave}}$

$V_{dc} = \frac{3\sqrt{2}V_L}{2\pi}(1 + \cos\alpha)$

$V_O = KV_s$

$Vo_{ave} = \frac{Vs_{pk}}{1-K}$

$T_d = K_t\, I_f\, I_a$

$V_{dc} = \frac{V_m}{\pi}(1 + \cos\alpha)$

$Io_{rms} = \sqrt{K}\, Is_{pk}$

$V_a = E_g \pm R_a I_a$

$Po_{ave} = Vo_{ave}\, Is_{pk}$

$V_{dc} = \frac{2V_m}{\pi}\cos\alpha$

$Ic_{max} \geq Ii_{pk}$

$\omega_{min} = \frac{R_m I_a}{K_v I_f}$

$V_{dc} = \frac{3\sqrt{2}V_L}{\pi}\cos\alpha$

$Ich_{ave} = Ia_{pk}\, K$

$E_g = K_v\, \omega\, I_f$

$\Delta I_L = \frac{Vo_{ave}(1-K)KT}{L}$

$Q_{gt} = C_{gt}\, V_{gs}$

$\Delta I_L = \frac{Vi_{ave} K}{fL}$

$\omega_{max} = \frac{V_s}{K_v I_f} + \frac{R_m I_a}{K_v I_f}$

$R_{eq} = R_b(1-K) + R_m$

$I_L = Vi_{pk}\left(\frac{1}{R_O(1-K)^2} \pm \frac{KT}{2L}\right)$

$Po_{ave} = Vs_{PK}\, Io_{ave}$

$L_{crit} = \frac{R_O T}{2}(1-k)^2 K$

$P_d = T_d\omega$

$Vo_{rms} = \sqrt{K}\, Is_{pk}$

$P_{Lp} = \frac{(V_p K)^2}{2f L_p}$

$\Delta V_c = \frac{K Vo_{ave}}{R_O C f}$

$Vce_{off} \geq 2Vi_{max}$

$V_{dc} = \frac{3\sqrt{2}V_L}{2\pi}\cos\alpha$

$Ic_{max} \geq \frac{2P_{Lp}}{V_p K}$

$P_f = \frac{P_{AVE}}{V_{rms}\, I_{rms}}$

$P_d = C_{gt}\, V_{gs}^2\, f$

$V_{dc} = \frac{2V_m}{\pi}\cos\alpha$

$W_{AVE} = \int_{t0}^{T} p_{(t)}\, dt$

$f = \frac{1}{2RC\ln(3)}$

$Vch_{off} = (1-K)\, V_s$