UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION JULY, 2009

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	POWER ELECTRONICS AND DRIVES
COURSE CODE:	EIN510
TIME ALLOWED:	THREE HOURS

INSTRUCTIONS:

1. **Answer any <u>FOUR</u> (4) of the following five questions.**
2. **Each question carries 25 marks.**
3. **If you think not enough data has been given in any question you may assume reasonable values**

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THIS PAPER CONTAINS SIX (6) PAGES INCLUDING THIS PAGE

QUESTION ONE ***(25 marks)***

(a) Give sketches which illustrate three ways in which a bi-directional (4-quadrant) switch can be implemented using IGBTs or BJTs. *(9 marks)*

(b) (i) For a BJT used as a power switch distinguish between the following:
Conduction losses, Turn-off losses and Switching losses. *(6 marks)*

(ii) A BJT is used for switching on and off a load which takes 6A from a 50 V dc supply. The switching frequency is 40 kHz and the device takes 2 μs to change state from on to off or from off to on. Assuming that currents and voltages change linearly during the switching transition, calculate the average power dissipation in the BJT caused by the switching transients. The saturation and leakage currents can be assumed negligible. *(10 marks)*

QUESTION TWO ***(25 marks)***

(a) (i) Why are LC filters preferred for smoothing in switched mode power supplies? *(2 marks)*

(ii) A switched power converter is used between a 12 V battery supply and a load which takes 5V, 20 A at full load. The switching frequency is 20 kHz. Calculate the value of inductor which would result in a peak-to-peak current ripple of 10% at full load current. *(6 marks)*

(b) The power in an inductive load of $R_1 = 5\ \Omega$, $L_1 = 6$ mH is controlled by a MOSFET as shown in Fig.Q.2b. The MOSFET is switched at 40 kHz with a duty cycle of 0.4. The MOSFET and diode both have voltage drops of 0.7 V when on. Calculate the following:

(i) The average voltage in the load. *(6 marks)*

(i) The average current in the load. *(2 marks)*

(ii) The peak-to-peak magnitude of the ripple in the load current. *(6 marks)*

(iii) The power dissipation in the MOSFET, neglecting switching losses and leakage currents. *(3 marks)*

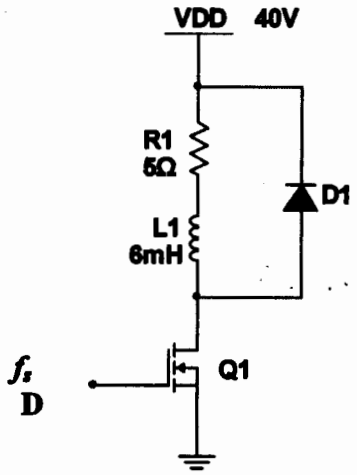

Fig.Q.2b

QUESTION THREE **(25 *marks*)**

The converter shown in Fig. Q.3, supplies a voltage of 18 V from a 24 V battery. The converter draws a current of 2.4 A from the battery. The switching frequency is 100 kHz and L = 40 μH. Neglect all losses and assume that the BJT saturating voltage and diode voltage drop are both negligible.

(a) What value of duty cycle should be used? *(4 marks)*

(b) What is the current in the load resistor R? *(4 marks)*

(c) Calculate the peak-to-peak inductor current and show that the inductor current is continuous (i.e. not reaching zero). *(7 marks)*

(d) Sketch and clearly label, key numerical values for the following waveforms:

(i) The inductor voltage waveform, $v_L(t)$. *(2 marks)*

(ii) The inductor current waveform, $i_L(t)$. *(3 marks)*

(iii) Diode voltage waveform, $v_D(t)$. *(2 marks)*

(iv) Diode current waveform, $i_D(t)$. *(3 marks)*

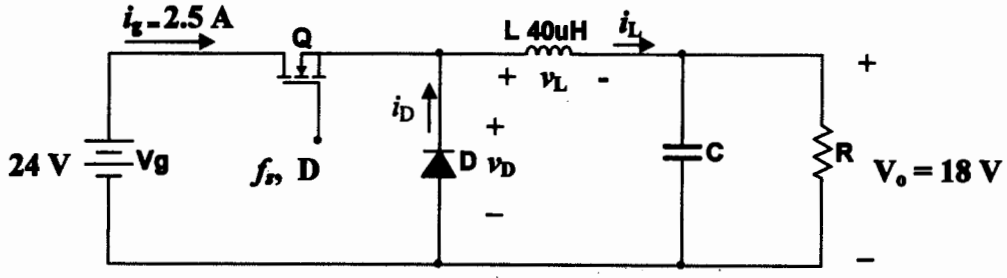

Fig.Q.3

QUESTION FOUR **(25 *marks*)**

The equivalent circuit of a separately excited dc motor is shown in Fig. Q4. Take the back e.m.f. V_g of the motor as $V_g = KI_f\omega$ where KI_f is the field constant of the motor, and the torque developed by the motor as $T = KI_f I_a$.

(a) Show that in steady state operation, the angular speed ω of the motor is given by

$$\omega = \frac{V_a - I_a R_a}{KI_f}. \qquad \textit{(9 marks)}$$

(b) Give two ways in which the speed of the motor can be controlled. *(4 marks)*

(c) The motor has a constant torque load of 50 N-m and is driven by a full-wave converter connected to a 230 V single-phase a.c. supply. The field constant is 3.0 and the armature resistance is 1.5 Ω. The motor operates at 250 r.p.m. Assuming continuous current operation, calculate the following:

(i) Its armature current. *(2 marks)*

(ii) The armature voltage required. *(5 marks)*

(iii) The conduction (triggering) angle of the converter.

$$\left(\text{For a full-wave converter } V = \frac{2V_m}{\pi}\cos\alpha\right). \qquad \textit{(5 marks)}$$

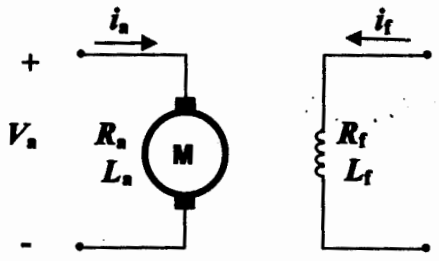

Fig.Q4

QUESTION FIVE ***(25 marks)***

(a) A diode in a power switching converter has a forward voltage drop of 0.9 V when conducting pulses of 15 A amplitude. The pulses have a duration of 5 μs and a repetition of 20 μs. The diode has a thermal resistance between junction and case of 2.5°C/W and it is mounted on a heat sink of thermal resistance 3°C/W. The ambient temperature is 25°C and the diode losses when in an off state are negligible. Calculate the diode junction temperature. Hint: You must first find the average power dissipation of the diode. *(10 marks)*

(b) The boost (step-up) chopper shown in Fig.Q.5b has L = 10 mH, R = 10 Ω and switching frequency of 3 kHz with a duty cycle of 0.6. The supply voltage V_g is 100 V. Assuming lossless operation, calculate the following:

(i) The average output voltage. *(3 marks)*

(ii) The peak-to-peak inductor current. *(12 marks)*

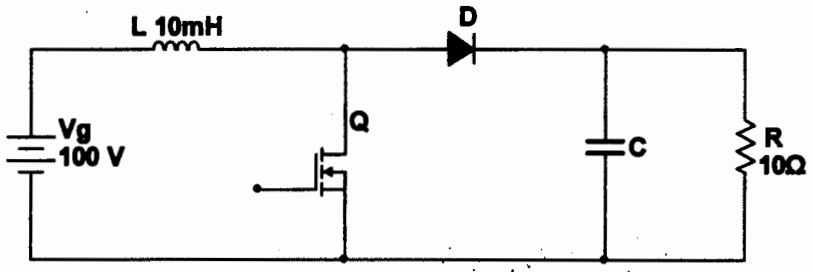

Fig.Q5b