Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2015-16 (2.0 hours)

EEE307 Power Electronics

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. a. Give the relative disadvantages of both inductor-coupled (non-isolated) and transformer-coupled (isolated) switched mode power converters with respect to each other. **(4)**

b. **i)** Explain with the aid of diagrams how a flyback converter may be derived from a simple non-isolated switched mode power converter. **(4)**

ii) Derive a relationship between the input and output voltage for this converter. **(4)**

c. A flyback converter is required to provide a +5V output from a rectified $230V_{rms}$ input for a piece of equipment. If the converter is to switch at 125kHz and deliver 80W to the load, calculate the necessary transformer turns ratio, minimum primary inductance and filter capacitance required to operate with continuous inductor current and less than 5% voltage ripple on the output. State any assumptions you have made. **(6)**

d. If the converter was re-designed to operate at 18kHz, what potential problems could be present? **(2)**

2. **a.** Derive an expression for the power lost in a semiconductor switch due to the switching action, when the device is switching the current in an **inductive** load at a given frequency, f (Hz). **(5)**

b. Four BJT switching devices are used in a H-bridge configuration, together with 4 Schottky diodes, to regulate the current, 'I_L', in the **resistive** load shown in figure 1a:

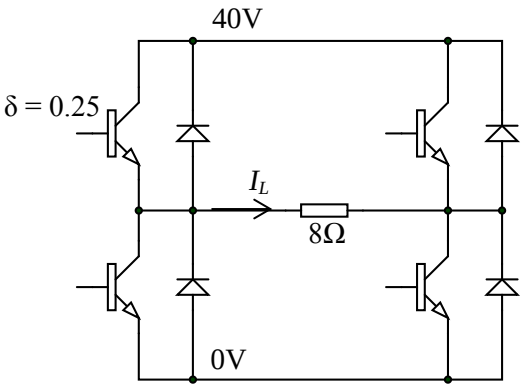

Figure 1a

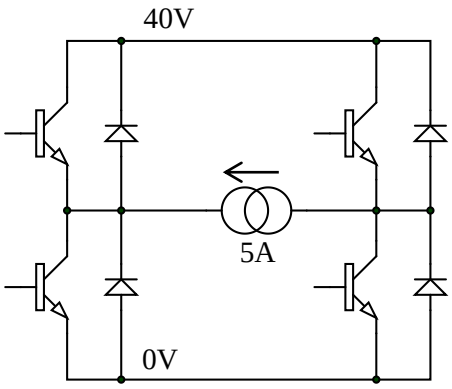

Figure 1b

Given the duty cycle shown in Figure 1a, list the remaining duty cycles of each switch and calculate the approximate power dissipated in the load. State any assumptions you have made. **(3)**

c. If all 8 semiconductor devices in Figure 1a are mounted onto a common heatsink, give its required thermal resistance if the devices are to be kept below 60°C at all times, in an environment with an ambient temperature of 25°C. The inverter is to operate at 50kHz and the devices have the ratings shown below. State any assumptions you have made. **(5)**

Device ratings:

BJTs			**Diodes**		
I_{max}	=	25A	V_{fwd}	=	0.3V
V_{max}	=	60V	I_{max}	=	25A
$V_{CE(sat)}$	=	0.85V	V_{max}	=	50V
t_{on}	=	200ns	R_f	=	10mΩ
t_{off}	=	300ns			

d. If the resistive load was replaced by a load which drew a constant 5A current, as shown in Figure 1b, given the switch duty cycles and switching frequency remain the same:

i) What power does the load consume? **(2)**

ii) What is the total loss in all of the devices? (You may assume zero switching loss in the diodes) **(5)**

3. **a.** Compare and contrast a semi-converter and a full converter. **(4)**

b. Explain, with the aid of suitable diagrams, the operation of a single-phase full converter operating with an inductive load, in a condition where the firing angle (α) is less than the load angle (ϕ). **(10)**

c. **i)** Calculate the firing angle required for a full converter that is used to produce an average of 80V across a 4Ω load, when fed from a 230V 50Hz ac supply. **(3)**

ii) Given that the load inductance is 50mH, also calculate whether the current in the load is continuous or discontinuous. **(3)**

4. **a.** The state-space equations for the inductor current and capacitor voltage, averaged over the duty cycle, for a Buck converter operating with duty cycle 'd' are below:

$$\dot{i}_L = \frac{dv_i}{L} - \frac{Ri_L}{L} + \frac{CR\dot{v}_o}{L} \qquad \dot{v}_o = \frac{i_L}{C} - \frac{v_o}{CR}$$

where $\dot{i}_L$ and $\dot{v}_o$ denote the derivatives with respect to time

Prove the following small signal transient transfer function for the duty controlled converter is:

$$\frac{v_o}{d} = \frac{v_i}{LC\left(s^2 + \frac{s}{CR} + \frac{1}{LC}\right)}$$

(10)

b. Explain the problems which may be encountered when paralleling power diodes directly, and outline a possible solution for reliable parallel operation of power diodes. **(5)**

c. With reference to the diode characteristics below, and given that two diodes are now connected in series, calculate the values of sharing resistors needed to ensure a maximum of 10% variation in the voltage seen by the diodes. The maximum reverse voltage seen across the pair of diodes is 1000V. Give a suitable power rating for the sharing resistors. **(5)**

Diode Characteristics:

Maximum Reverse Voltage = 700V, *Max reverse leakage current = 400μA*

Diode Junction voltage drop = 0.7V, *Incremental on-state Resistance = 50mΩ*

CG/DAS