Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-15 (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.** Explain the operation of an over-voltage snubber network applied to a BJT switching device and why it may be needed. Your answer should include a circuit diagram with voltage and current waveforms. **(8)**

b. A 40kHz square wave voltage is applied across a load by a switching circuit with stray inductance of 6μH. The supply voltage for the switching circuit is 350V and the load current is a constant 2A. Calculate suitable component values for the resistor and capacitor in an over-voltage snubber network if the maximum voltage seen by the switch is to remain below 400V. **(6)**

c. Explain the problems which may be encountered when paralleling BJT switching devices directly, and outline a possible solution for reliable parallel operation of the BJT switching devices. **(6)**

2. **a.** The state-space equations for the inductor current and capacitor voltage, averaged over the duty cycle, for a Buck converter 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 Audio Susceptibility transfer function for the converter is:

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

(12)

b. Calculate the values of capacitor and inductor required for use in a Buck converter that generates a regulated 24V dc output from a 36 to 48V input. The circuit is to supply an output current ranging from a minimum of 0.5A to a maximum of 6A. The output voltage ripple for the converter should be less than 1%. Ignore switch and diode voltage drops, and assume the converter is to operate at a frequency of 20kHz.

(4)

c. With the aid of a circuit diagram, describe how an ideal Forward converter may be derived from a Buck converter (You may neglect the requirement for volt-second balance).

(4)

3. a. Derive an expression for the switching loss within a semiconductor switching device operating at a frequency 'f' with an inductive load. **(8)**

b. Four MOSFET switching devices with parallel Schottky diodes are used in a H-bridge inverter configuration (as shown below in figure 1) to provide a near-constant 5A DC in the load. The inverter is to operate at 40kHz and the devices have the parameters given below:

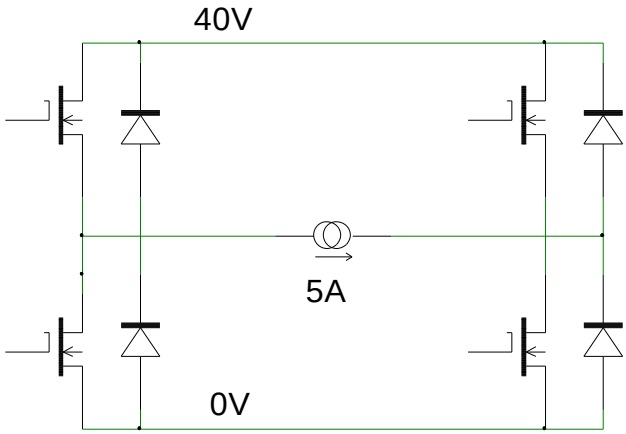

Figure 1. H-bridge inverter

Given that the duty cycle of the top-left switch is 33%, infer the duty cycles of the other devices and calculate the power dissipated in a common heatsink onto which all 8 devices are mounted. Also give a required thermal resistance for the heatsink if the devices are to be kept below 40°C in an environment where the ambient temperature is 18°C.

MOSFETS			Diodes		
$R_{ds(on)}$	=	0.5Ω	V_{fwd}	=	0.5V
V_{max}	=	60V	I_{max}	=	10A
I_{max}	=	10A	V_{max}	=	50V
t_{on}	=	200ns			
t_{off}	=	300ns			

(8)

c. Given that the circuit above was to operate at 100Hz, would Thyristors be a suitable choice in this circuit configuration? Justify your answer. **(4)**

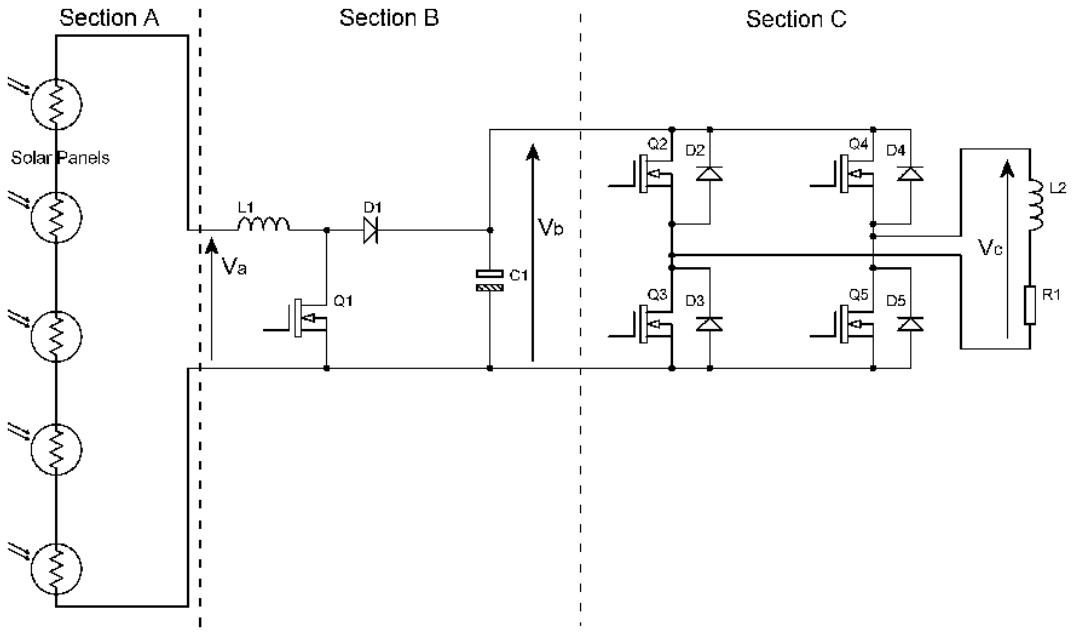

Figure 2 – Standalone solar power supply.

4. **a.** The circuit diagram of a standalone solar power supply shown in Figure 2 is divided into 3 sections, A, B & C by the vertical dotted lines. With the aid of circuit diagrams, voltage waveforms and current waveforms, derive the transfer function Vb/Va for the DC-DC converter in section B. **(8)**

b. If the total voltage output, V_a, of the solar panels in section A of Figure 2 varies between 120V and 300V, and the voltage output, V_b, of section B needs to be 400V and supply between 0.1A and 7A, find the values of the inductor and capacitor in the converter (L1 and C1), and suggest ratings for the switch and diode in the converter (Q1 and D1). Assume the converter operates at 100kHz and the output voltage of section B should have less than a 2% ripple. **(8)**

c. Highlight and explain the key features of components D1 and C1 in the converter circuit. **(4)**

CG/SM