ENGINEERING TRIPOS PART IIB

Friday 6 May 2011 2.30 to 4

Module 4B2

POWER MICROELECTRONICS

Answer not more than **three** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1. (a) Explain the *second breakdown* in the Bipolar Junction Transistor (BJT). Sketch the primary and second breakdown on the reverse characteristics of the BJT. [20%]

(b) Fig. 1 shows the waveforms of a BJT switch in a simplified resistive switching circuit. The switch operates at a switching frequency $f = 10$ kHz with a duty cycle $D = 50\%$. The other parameters are: line voltage $V_{dc} = 250$ V, off-state leakage current $I_{OFF} = 3$ mA, on-state collector current $I_C = 100$ A, on-state base current $I_B = 8$ A, collector-emitter on-state voltage drop $V_{CE} = 2$ V, base-emitter on-state voltage drop $V_{BE} = 1$ V, turn-on delay time $t_d = 0.5$ μs, turn-on current rise time $t_r = 1$ μs, turn-off delay time $t_s = 5$ μs, turn-off current fall time $t_f = 3$ μs.

(i) Estimate the static, switching and total power losses in the switch. [40%]

(ii) Plot the instantaneous power vs time for one period. [25%]

(iii) Calculate the power loss due to the base current. [15%]

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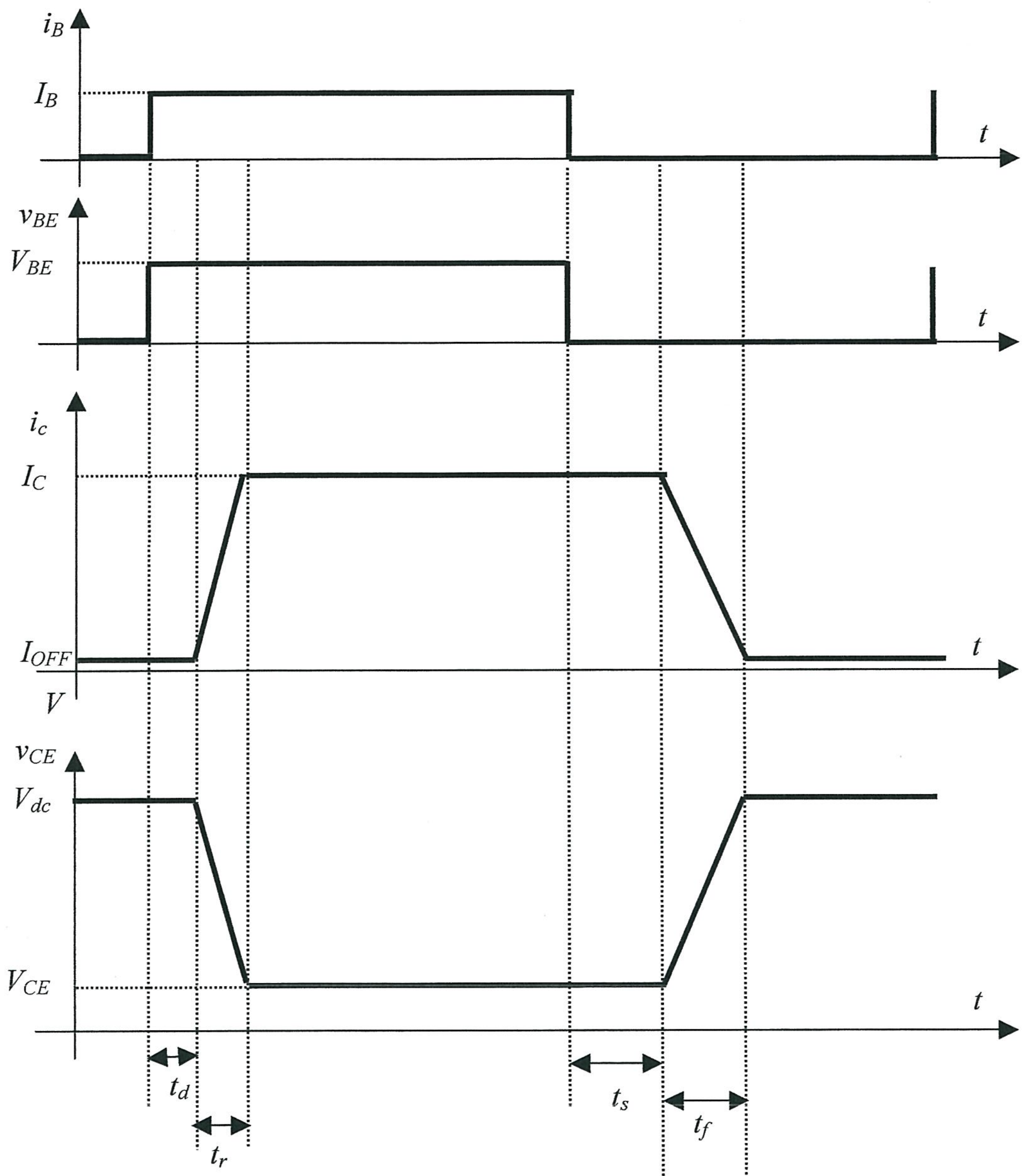

Fig. 1

2 (a) Explain the latch-up effect in Insulated Gate Bipolar Transistors (IGBTs). Draw an IGBT equivalent circuit that includes the parasitic latch-up elements. Give two solutions to improve the latch-up immunity in IGBTs. [30%]

(b) The two IGBTs T_1 and T_2 shown in Fig. 2 are operated in parallel. Two resistors R_1 and R_2 are placed in series with the cathodes of the two IGBTs, T_1 and T_2, respectively.

(i) If the series resistances of R_1 and R_2 are equal, explain the mechanism through which the two series resistors help equal current sharing between the two IGBTs in steady state conditions. [20%]

(ii) Propose modifications to the circuit in Fig. 2 to improve the current sharing in dynamic conditions [20%]

(iii) In Fig. 2, the total current $I_T = 20$ A, $R_1 = 0.5\ \Omega$, $R_2 = 0.5\ \Omega$, the anode-to-cathode voltage of T_1 is $V_{AK} = 2.5$ V and that of T_2 is $V_{AK} = 3$ V. Determine the drain current in each transistor and the percentage difference in current sharing. [30%]

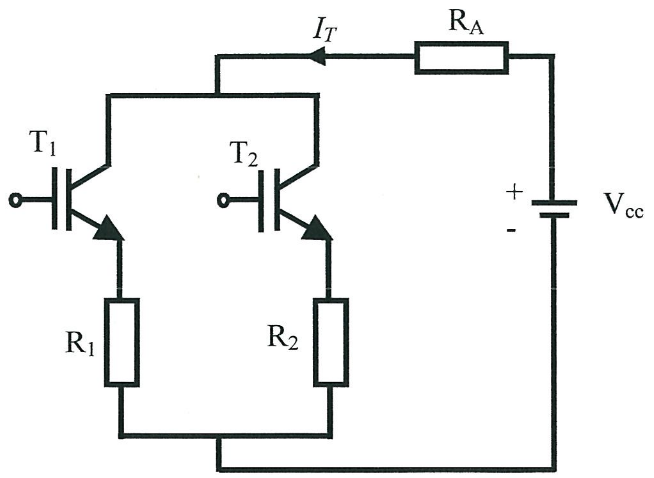

Fig.2

3. The cell structure in Fig. 3 is a junction controlled power device.

(a) Explain its operation during on-state, off-state, turn-on and turn-off. [35%]

(b) Draw an equivalent circuit for the device and the output characteristics. [30%]

(c) Give one advantage and one disadvantage of this device compared to a conventional Insulated Gate Bipolar Transistor (IGBT). [10%]

(d) Draw a termination structure for the device using layers already present in the cell structure. Show schematically the potential contour in the cell and the termination structure. [25%]

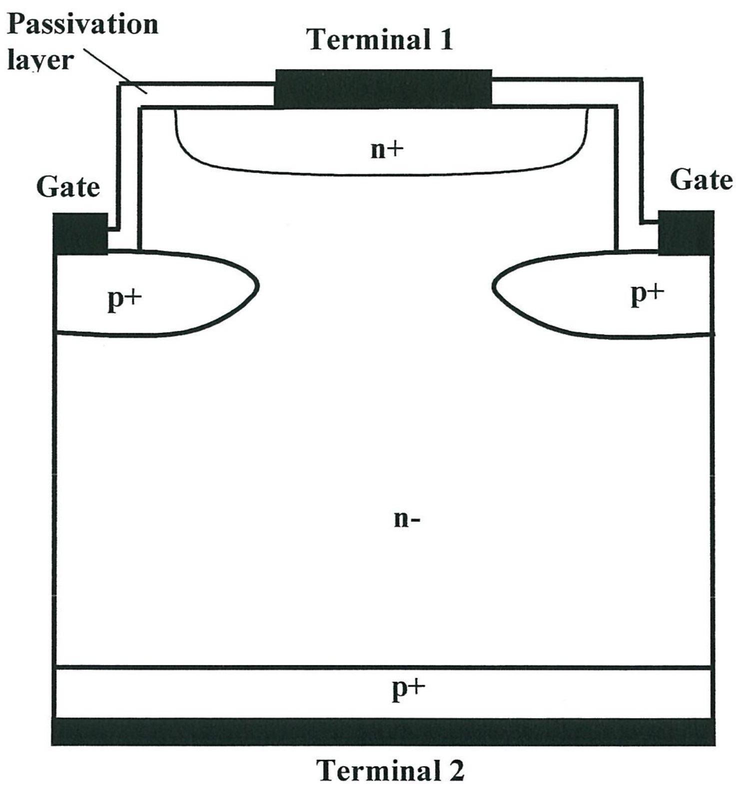

Fig. 3

4. (a) Describe the RESURF effect in a lateral high voltage diode. Show schematically the electric field distribution at the surface of the diode. [30%]

(b) Draw a double RESURF LDMOSFET and explain its advantages compared to a single RESURF LDMOSFET. [20%]

(c) Draw and explain the operation of a lateral Insulated Gate Bipolar Transistor (LIGBT) based on the RESURF effect. Draw an equivalent circuit of the LIGBT and explain its performance when compared to a vertical IGBT. [30%]

(d) Draw and briefly explain the operation of an LDMOSFET featuring a superjunction in the drift region. [20%]

END OF PAPER