



**FINAL**  
Examination Paper

(COVER PAGE)

Session : April 2016

Programmes : Diploma in Electrical and Electronic Engineering (DEED)

Course : EEE2102: Introduction to Power Electronics

Date of Examination : 25 July 2016, Monday

Time : 11.00am – 1.00pm

Duration : 2 Hours Reading Time : Nil

Special Instructions :

This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks.

**IMPORTANT NOTE : THIS PAPER SHOULD NOT BE TAKEN OUT OF THE EXAMINATION HALL BY THE STUDENTS.**

Materials Permitted : Scientific Calculator (Model fx570 Series)

Materials Provided : NIL

Examiner(s) : Mr. Chan Tse Wei

Moderator : Dr. Ooi Beng Lee

*This paper consists of 8 printed pages, including the cover page.*

## INTI INTERNATIONAL COLLEGE

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING (DEEI)  
 EEE2102: INTRODUCTION TO POWER ELECTRONICS  
 FINAL EXAMINATIONS: APRIL 2016 SESSION

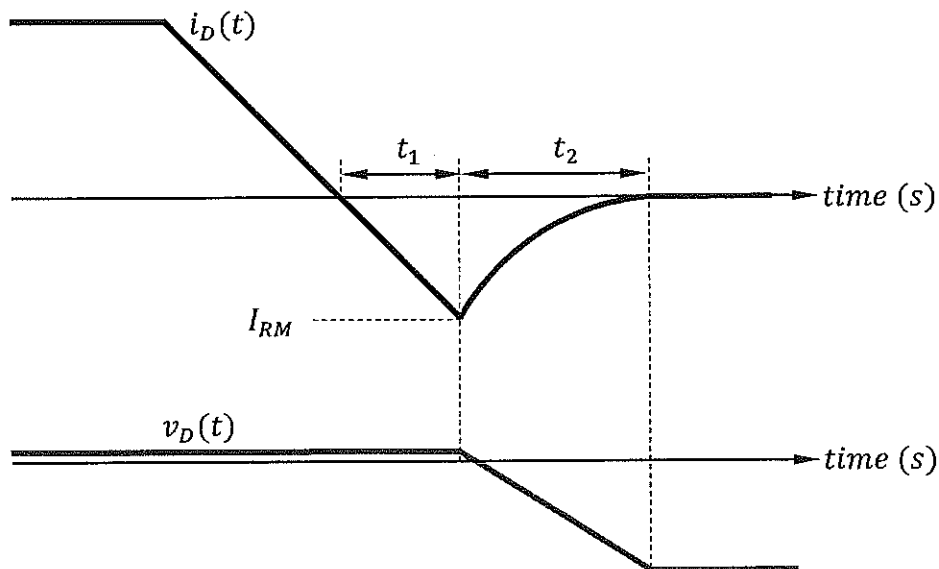
**Instructions:** This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks. The marks allocated to each sub-question are shown in square brackets at the right-hand margin. The assessor reserves the rights to ignore your answers if they are ambiguous.

**Question 1**

a. Define the following AC diode parameters:

- i. Forward recovery time,  $t_{FR}$ . [ 2 ]
- ii. Reverse recovery time,  $t_{RR}$ . [ 2 ]
- iii. Reverse recovery storage charge,  $Q_{RR}$ . [ 2 ]

b. Figure-Q1(b) shows a diode current and voltage characteristic during a recovery interval.



**Figure-Q1(b)**

- i. State the relationship of  $t_1$  and  $t_2$  in Figure-Q1(b) and the reverse recovery time,  $t_{RR}$  in part (a)(ii). [ 2 ]
- ii. Approximate the softness factor of the diode in Figure-Q1(b). [ 2 ]

- iii. Derive the approximated relationship between the reverse recovery time,  $t_{RR}$  and the diode storage charge,  $Q_{RR}$ . State any assumption(s) made. [ 4 ]
- c. An inductor  $L$  of  $100 \mu\text{H}$  is connected as shown in Figure Q1(c) to a  $5\text{V DC}$  source. Switch  $S$  is closed for  $100 \mu\text{s}$  and then left opened permanently. Assume ideal operation for the freewheeling diode,  $D$ .
- Calculate,
- the approximated inductor current  $100 \mu\text{s}$  after the switch is closed, assuming  $R = 0\Omega$  and zero initial currents for all branches. [ 4 ]
  - the inductor current at  $t = 100\mu\text{s}$  if  $R = 0.01\Omega$ . Assume the initial inductor current is  $1\text{A}$ . [ 4 ]
  - the inductor current for part (c)(ii) after the switch has been open for  $200\mu\text{s}$ . [ 3 ]

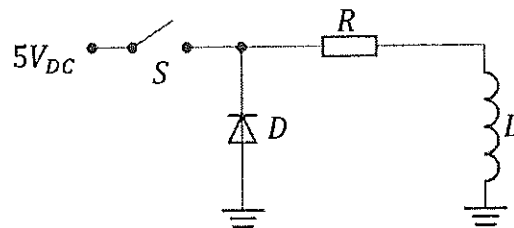


Figure-Q1(c)

### Question 2

- State one advantage and one disadvantage of power transistors as compared to thyristors in power electronic applications. [ 4 ]
  - Explain the requirement(s) to drive a bipolar junction transistor (BJT) into saturation, and state the characteristic of a saturated BJT. [ 4 ]
  - Draw the large signal DC operation model of a power NPN transistor which includes a current dependent current source, the junction diodes and the collector leakage current. [ 4 ]

- b. Figure-Q2(b) shows a transistor switching circuit with a resistive load,  $R_{load}$ . Switch  $S_1$  is a semiconductor device with switching time shorter than the switching time of the transistor.

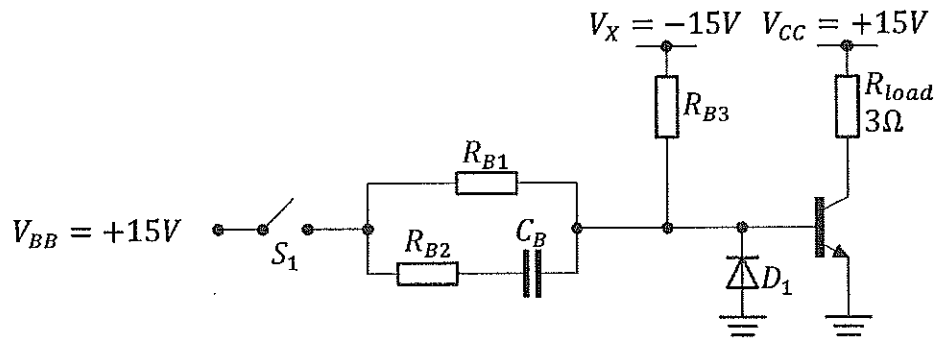


Figure-Q2(b)

- i. State the functions of voltage source  $V_x$  and diode  $D_1$  respectively. [ 2 ]
- ii. Explain the function of capacitor  $C_B$ . [ 4 ]
- iii. Given that the transistor has

$$\beta_F = 10 \text{ at the moment of turn on}$$

$$\beta_F = 20 \text{ at the end of conduction}$$

$$V_{BE} = 0.9V$$

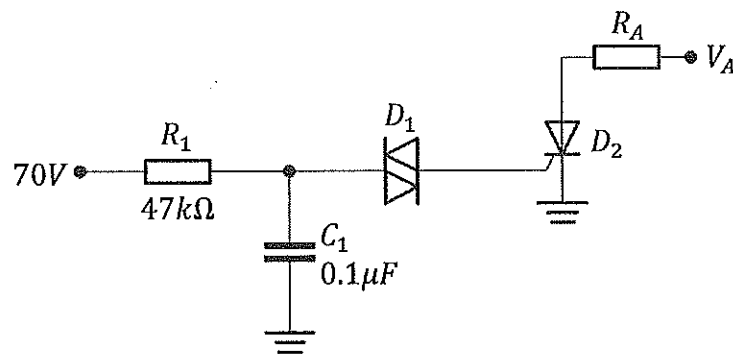
$$V_{CEsat} = 0.02V$$

A collector current of  $1 \mu s$  rise time and a time constant of at least 5 times bigger than the collector current rise time for the capacitor  $C_B$  are desirable.

If  $|I_{B2}/I_{B1}| = 1$  at turn off, where  $I_{B1}$  is the current required to turn on the transistor to achieve the desired level of saturation and  $I_{B2}$  is the current required to turn off the transistor rapidly, determine the component values for  $R_{B1}$ ,  $R_{B2}$ ,  $R_{B3}$  and  $C_B$  so that the desired circuit performance is achieved. [ 7 ]

**Question 3**

- a. i. Define power electronics. [ 2 ]
- ii. List any four types of thyristors. [ 4 ]
- iii. What is a commutation circuit? [ 2 ]
- iv. List the six general categories of power electronics. [ 6 ]
- b. Figure-Q3(b) shows an SCR circuit.

**Figure-Q3(b)**

- i. The SCR and DIAC used in the circuit have the following specifications:  
 SCR:  $V_{GK} = 1V$  (in series with  $R_{GK} = 25\Omega$ )  
 DIAC:  $V_{ON} = 12V$ ,  $R_{ON} = 4\Omega$ ,  $I_{ON} = 10mA$ ,  $V_{BO} = 30V$   
 Based on the given specifications, draw an SCR gate circuit model. [ 3 ]
- ii. Determine the capacitor's peak voltage. [ 2 ]
- iii. Determine the peak gate current. [ 3 ]
- iv. Determine the time where the gate current ceases. [ 3 ]

### Question 4

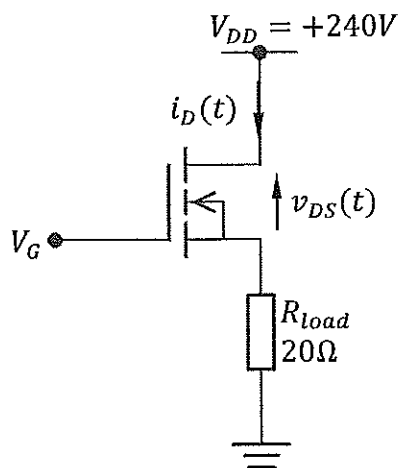
Figure-Q4(i) shows a simple MOSFET based switching circuit. The wave shape of  $V_G$  is show in Figure-Q4(ii). The MOSFET has the following specifications:

Drain current rise time,  $t_r = 2\mu s$

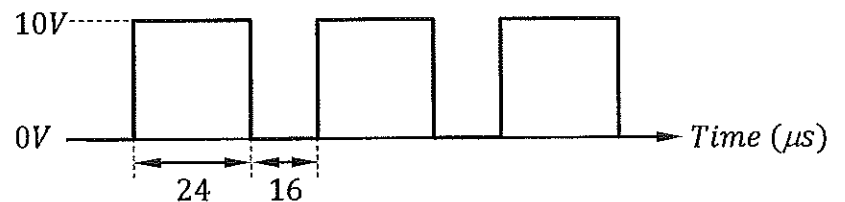
Drain current fall time,  $t_f = 3\mu s$

$R_{DS(ON)} = 1\Omega$

Drain-source leakage current,  $I_{DSS} = 3mA$



(i) MOSFET switching circuit.



(ii) Wave shape of  $V_G$ .

Figure-Q4

- Calculate the steady-state load current,  $I_{D(max)}$  during ON state. [ 2 ]
- Calculate the saturated voltage across the drain and source terminals,  $V_{DS(sat)}$ . [ 2 ]
- Assume piecewise linear operation, sketch the respective timing diagram for  $i_D(t)$  and  $v_{DS}(t)$ , synchronized with the waveform of  $V_G$ . [ 6 ]
- Show that the maximum power dissipated by the MOSFET when  $V_G = 10V$  is,

$$P_{DON(max)} = \frac{I_{D(max)} V_{DD}^2}{4[V_{DD} - V_{DS(sat)}]}$$

Hence, calculate the maximum transistor power dissipation during this period of time. [15]

**Question 5**

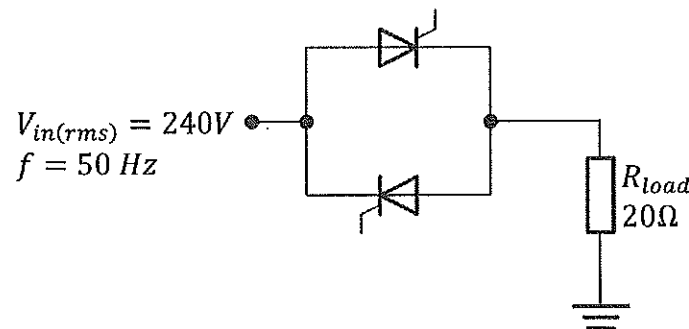
- a. i. What is an AC voltage controller? [ 3 ]
- ii. State the one advantage and one disadvantage of ON-OFF control scheme. [ 4 ]

b. In an ON-OFF control scheme, the AC input voltage is connected to a load for  $n$  cycles and is disconnected for  $m$  cycles.

- i. Express the duty cycle of the ON-OFF control scheme,  $k$  in terms of  $n$  and  $m$ . [ 3 ]
- ii. If the instantaneous AC input voltage is expressed as  $v_{in}(t) = V_m \sin(\omega t)$ , show that the rms voltage connected to the load,  $V_{load(rms)}$  is given by,

$$V_{load(rms)} = V_{in(rms)} \sqrt{k} \quad [ 8 ]$$

- c. Figure-Q5(c) shows a basic set up of an AC ON-OFF controller. The thyristors in the circuit are triggered as such that, 25 cycles of the input voltage are applied to the resistive load, followed by 75 cycles of OFF state. Assume ideal thyristor operations.

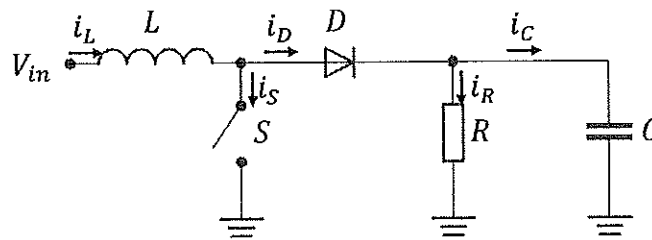


**Figure-Q5(c)**

- i. Calculate the rms voltage delivered and the rms current flowing through  $R_{load}$ . [ 4 ]
- ii. Calculate the input power factor, PF. [ 3 ]

**Question 6**

- a. i. What is a DC chopper circuit? [ 2 ]
- ii. What is the difference between buck chopper and boost chopper? [ 2 ]
- iii. State one advantage of DC chopper circuits. [ 1 ]
- b. Figure-Q6(b) shows a chopper circuit.

**Figure-Q6(b)**

- i. Comment on the characteristic of the circuit in relation to the duty cycle,  $D$ . [ 4 ]
- ii. Quantitatively show that the voltage across resistor  $R$  is given as,

$$V_R \approx \frac{V_{in}}{1 - D}$$

where  $D$  is the duty cycle of the switching action. Show all workings clearly and state the assumption made. [ 8 ]

- iii. For a specific value of  $D$ , derive an expression to calculate the minimum value of inductance,  $L$  in terms of  $R$ ,  $D$  and the period of switching action,  $T$  where the input current is continuous. Assume power loss is negligible. [ 8 ]