



INTI International College Penang

FINAL
Examination Paper

(COVER PAGE)

Session : April 2019

Programmes : Diploma in Electrical and Electronic Engineering (DEEI)

Course : EEE2112: Introduction to Power Electronics and Drives

Date of Examination : 26 July 2019 (Friday)

Time : 2:00pm – 4:00pm

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 : Non-programmable Scientific Calculator (e.g. Model fx570 Series)

Materials Provided : Laplace Transform Table

Examiner(s) : Chan Tse Wei

Moderator : Dr. Ooi Beng Lee

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

INTI INTERNATIONAL COLLEGE PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME (DEEI)
 EEE2112: INTRODUCTION TO POWER ELECTRONICS AND DRIVES
 FINAL EXAMINATIONS: APRIL 2019 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. Present your answers neatly and clearly. The assessor reserves the rights to ignore your answers if they are ambiguous.

Question 1

a. List five (5) ideal characteristics of a power electronic switch. [5]

b. Figure-Q1(b)(i) shows the timing diagram of the current flowing through an idealized solid state switch and the corresponding voltage drop across the switch is shown in Figure-Q1(b)(ii). However, an actual solid state switch does not possess such characteristics.

Sketch synchronized timing diagrams of $i_{sw}(t)$, $v_{sw}(t)$ and its corresponding power dissipation $p_{sw}(t)$ to illustrate the ON/OFF characteristics of an actual non-linear solid state switch. [10]

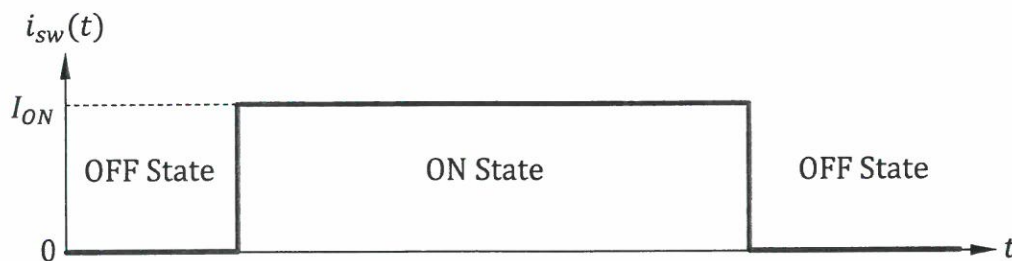


Figure-Q1(b)(i)

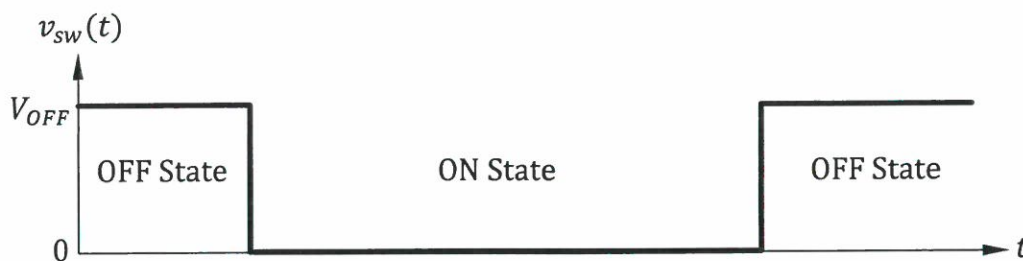


Figure-Q1(b)(ii)

- c. Figure-Q1(c) show a simplified buck chopper circuit. The CR time constant at the output stage is relatively larger than the switching period of the pulse width modulation (PWM) signal that is responsible of turning the power electronic switch ON and OFF.

Analyze the circuit during the switch ON state and OFF state, thus clearly sketch a graph of the average rate of change the inductor current (di_L/dt) as a function of the PWM duty cycle (D).

[10]

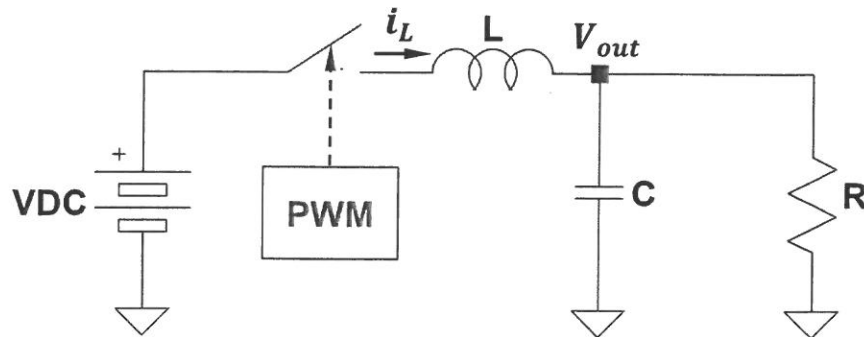


Figure-Q1(c)

Question 2

- a. State three examples of semiconductor devices that are used as switches in power electronics circuits. [3]
- b. Explain the principle of operation of an SCR as a solid-state switch. [5]
- c. Figure-Q2(c) shows a linearized diode reverse recovery characteristics.
- i. Determine the diode's reverse recovery time, t_{rr} . [2]
 - ii. Calculate the diode's rate of current reduction, dI_D/dt . [2]
 - iii. Calculate the diode's recovery charge, Q_{rr} . [3]

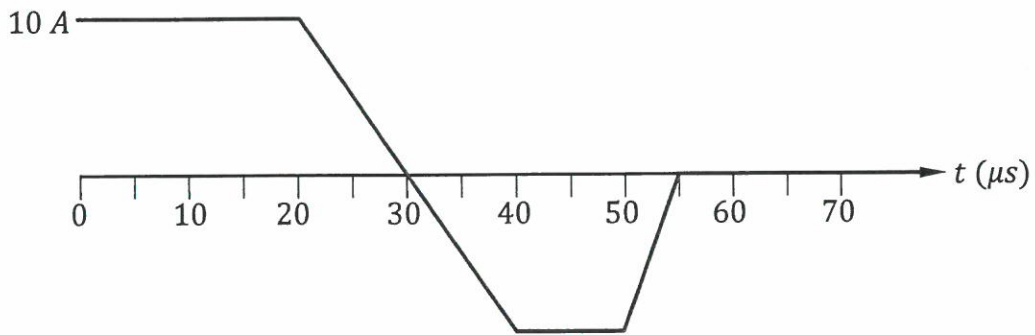


Figure-Q2(c)

- d. Figure-Q2(d)(i) shows the reverse bias IV characteristics of two different diodes. The two diodes are utilized in a circuit as shown in Figure-Q2(d)(ii). Diode D_1 is to drop 60% of the supply voltage, V_s across it.

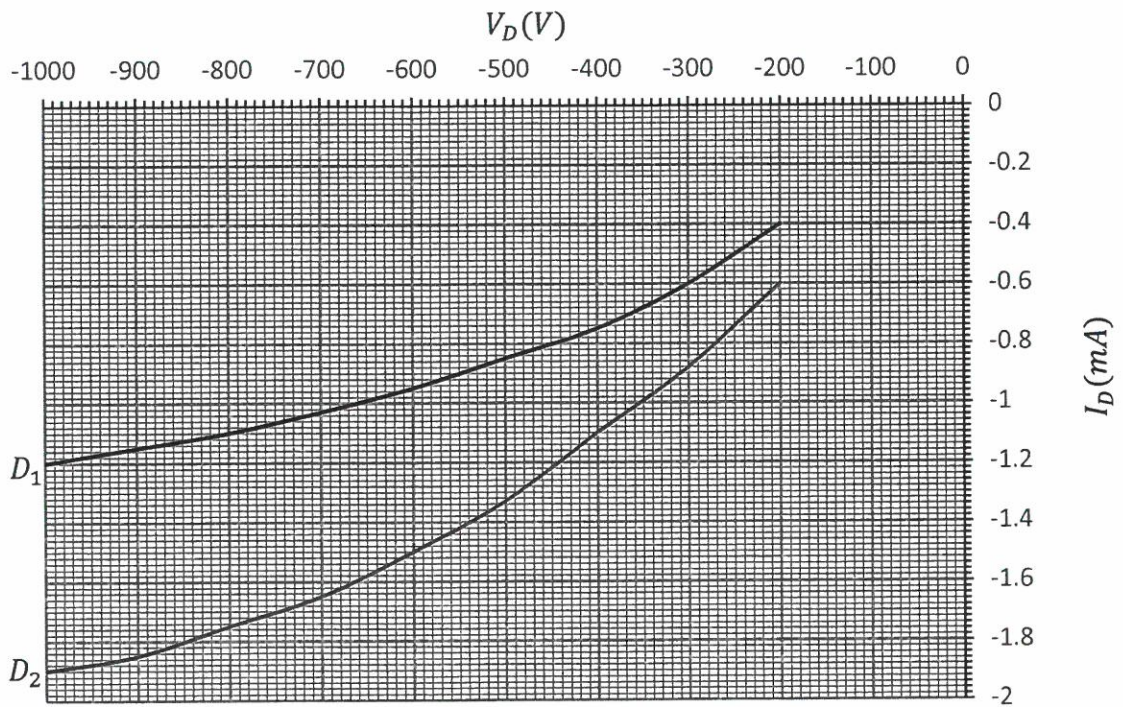


Figure-Q2(d)(i)

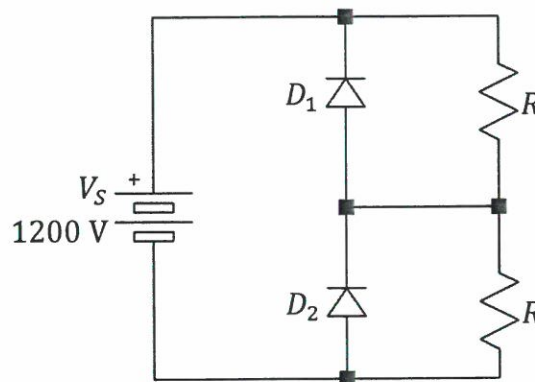


Figure-Q2(d)(ii)

- i. Identify the appropriate resistance R to be implemented in the circuit. [6]
- ii. Examine the power delivered by the supply voltage, V_s if the resistance identified in part (d)(i) is implemented into the circuit. [4]

Question 3

- a. Explain phase-controlled rectifier and the two reasons that makes SCR a unique power switch to be used in this type of power converter. [5]
- b. A thyristor half-wave controlled converter has a supply voltage $240 V_{RMS}$ at 50 Hz and a load resistance of 100Ω . Calculate the average load voltage and load current when the firing angle is at 30° of the supply cycle. [5]
- c. Figure-Q3(c) shows a full-wave controlled rectifier with inductive load. The AC source is $240 V_{RMS}$ at 50 Hz. The triggering of SCR S_1 and S_2 is delayed by 60° during the positive cycle of the AC source while the triggering of SCR S_3 and S_4 is also delayed by 60° but is during the negative cycle.

The load current $i_o(t)$ is given as,

$$i_o(\omega t) = \frac{V_m}{Z} \left[\sin(\omega t - \theta) - \sin(\alpha - \theta) e^{-\frac{(\omega t - \alpha)}{\omega\tau}} \right] \quad \text{for } \alpha \leq \omega t \leq \beta$$

where,

$$Z = \sqrt{R^2 + (\omega L)^2} \quad \theta = \tan^{-1} \left(\frac{\omega L}{R} \right) \quad \tau = \frac{L}{R} = \text{time constant}$$

$$\alpha = \text{firing angle} \quad \beta = \text{extinction angle} \quad V_m = \text{peak AC voltage}$$

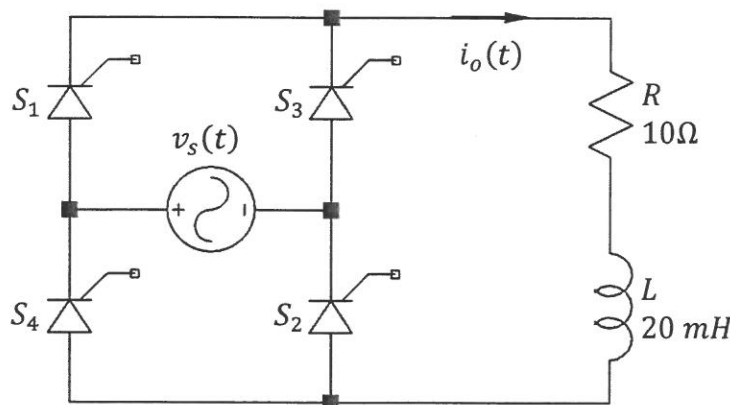


Figure-Q3(c)

- i. Examine if the load current $i_o(\omega t)$ is continuous. [7]
- ii. Approximate the power absorbed by the load, by using a time interval of 1 ms in the calculation. [8]

Question 4

- a. Distinguish between a single phase half-bridge inverter and a single phase bridge inverter by showing their respective schematic diagram and explain their respective principle of operation. [10]

- b. Figure-Q4(b)(i) shows a basic full-bridge square wave inverter, while Figure-Q4(b)(ii) shows the steady-state timing diagrams of the circuit's output voltage, $v_o(t)$ and output current, $i_o(t)$.

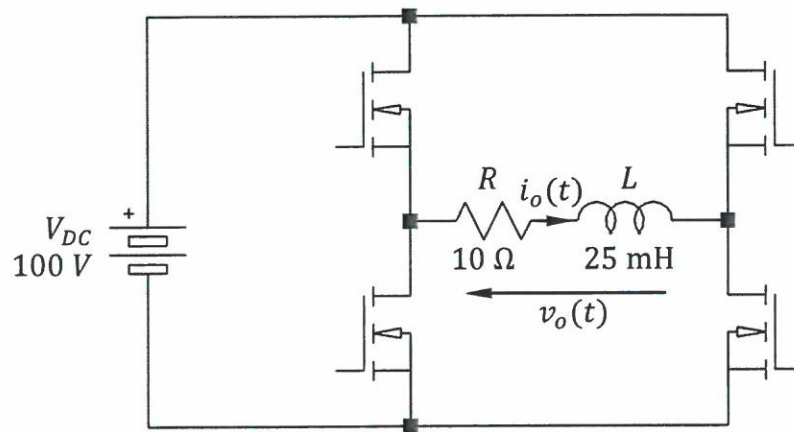


Figure-Q4(b)(i)

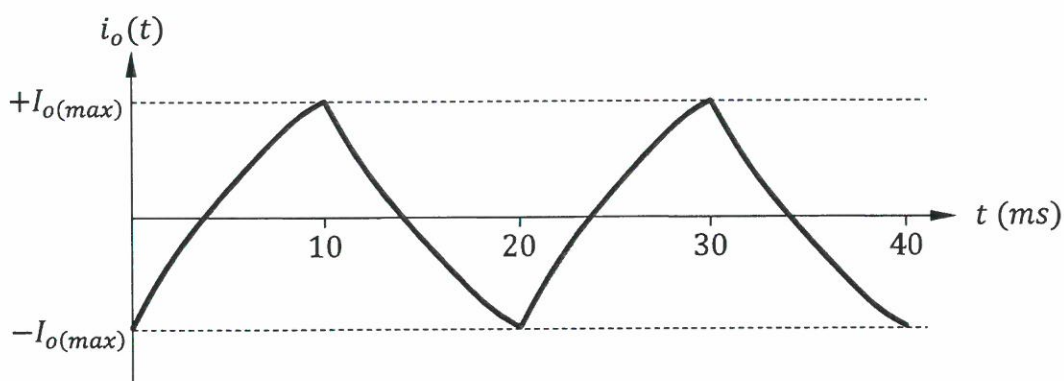
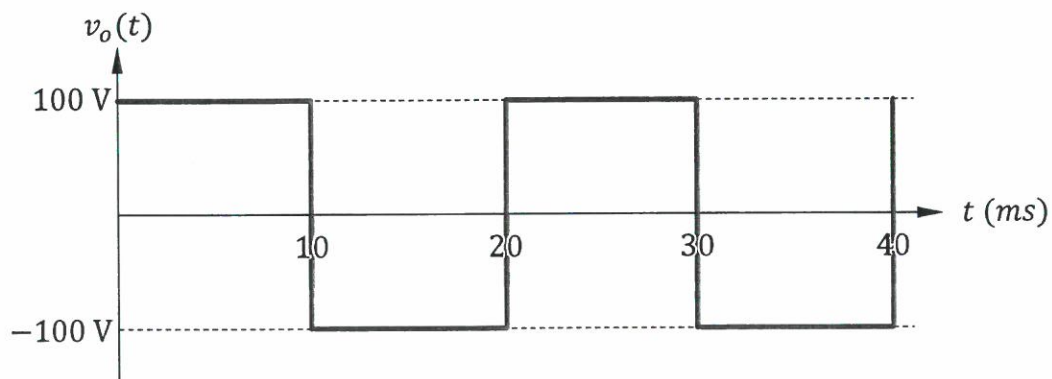


Figure-Q4(b)(ii)

- i. Derive the mathematical equations for $i_o(t)$ within one period by assuming all the solid-state switches have negligible leakage current during OFF state and negligible barrier voltage during ON state. [10]
- ii. Determine the maximum ON-state current for the solid-state switches. [5]

Question 5

- a. Explain the function of an AC-to-AC converter and give two application examples of such converters. [5]
- b. Figure-Q5(b)(i) shows a AC-AC converter utilizing a burst-firing (integral-cycle control) controller and Figure-Q5(b)(ii) shows the controlled voltage across R_{load} .

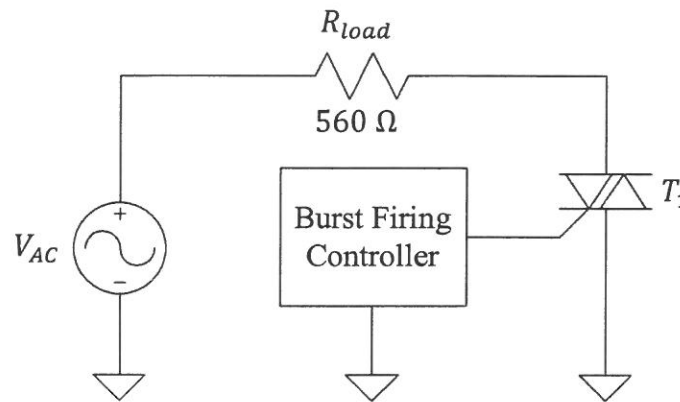


Figure-Q5(b)(i)

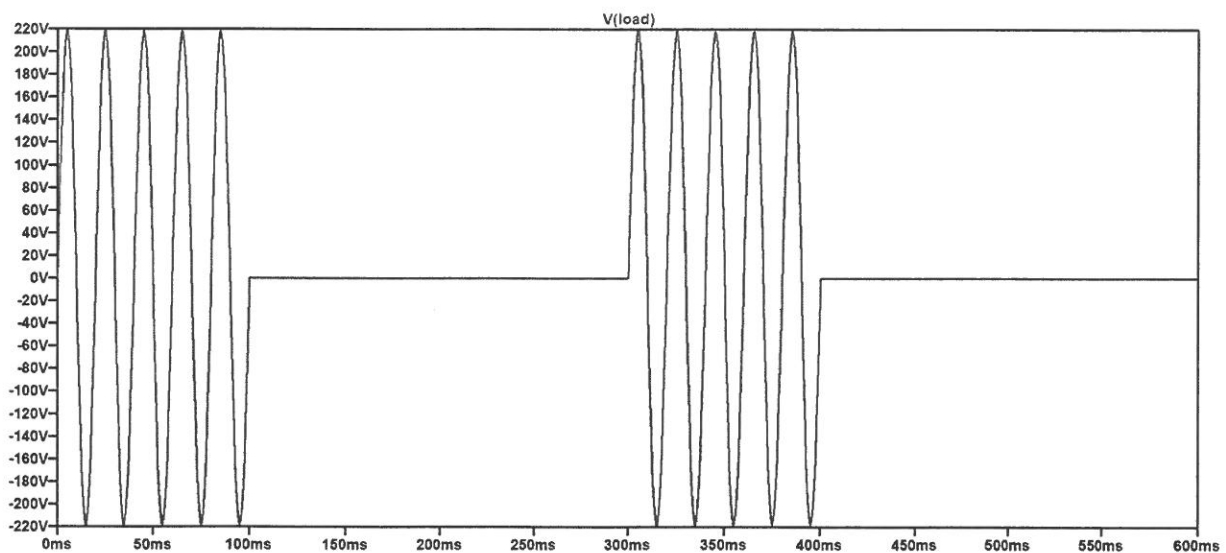


Figure-Q5(b)(ii)

- i. Calculate the power absorbed by R_{load} . [6]
- ii. Calculate the power factor of the circuit. [4]

- c. If a phase controlled AC-AC converter is implemented to control the power delivery to the resistive load in Figure-Q5(b)(i),
- derive the mathematical expression for $V_{load(RMS)}$. [5]
 - determine the firing angle (θ) needed for each half cycle of the input voltage to achieve the same power absorbed by R_{load} obtained in part (b)(i). [3]
 - comment on one disadvantage for adopting this power control scheme. [2]

Question 6

- State the function of snubber circuits used in association with transistor switching. [5]
- Define thermal resistance of an electronic device. [5]
- Figure-Q6(i) and (ii) show two different switching circuits utilizing power MOSFETs. Distinguish the requirement of the respective gate drive voltage, V_G to deliver power to the respective loads. [5]

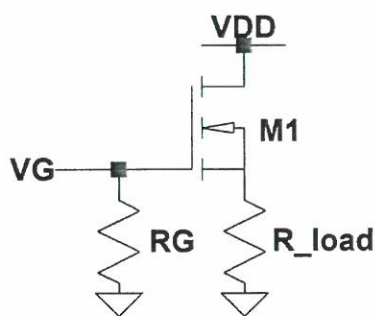


Figure-Q6(i)

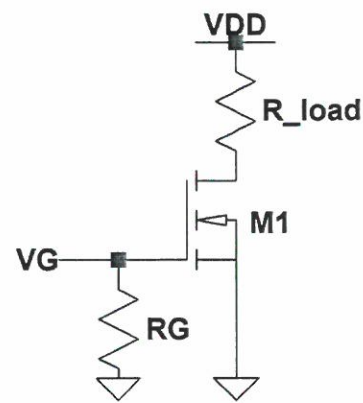


Figure-Q6(ii)

- Explain the principle of operation of an RC snubber circuit to protect an SCR. [5]
- Explain the electric circuit analogy for steady-state thermal power flow of an electronic device with heat-sink. [5]

~ The End ~