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International College Penang
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FINAL
Examination Paper

(COVER PAGE)

Session	:	**August 2017**
Programmes	:	Diploma in Electrical and Electronic Engineering (DEEI)
Course	:	**EEE2112: Introduction to Power Electronics and Drives**
Date of Examination	:	11 December 2017 (Monday)
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 : Scientific Calculator (Model fx570 Series)

Materials Provided : **Worksheet-Q3(c)**

Examiner(s)	:	**Chan Tse Wei**
Moderator	:	Dr. Ooi Beng Lee

This paper consists of 9 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: AUGUST 2017 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. Quantitatively show that the average power delivered by a constant DC voltage source is the product of the DC voltage source magnitude and the average current flowing from the voltage source. [3]

b. Figure-Q1(b) shows the classical power control circuit, utilizing a variable resistor, R_v as a current limiting device to control the delivery of power to the fixed resistive load, R_L.

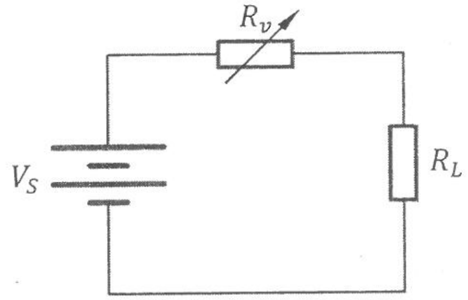


Figure-Q1(b)

i. Show that the circuit power efficiency, η is expressed as,

$$\eta = \frac{1}{kR_v + 1}$$

Where $k = \frac{1}{R_L}$ [4]

ii. Explain the condition for the circuit to be 100% power efficient. [3]

iii. Sketch the graph of η versus R_v for $0 \leq R_v \leq 10R_L$. [4]

iv. Appraise and conclude this power delivery technique. [3]

c. Figure-Q1(c) shows a simplified block diagram of a modern power control circuit, utilizing a solid state switch, SW operating at high frequency, to control the delivery of power to the fixed resistive load, R_L.

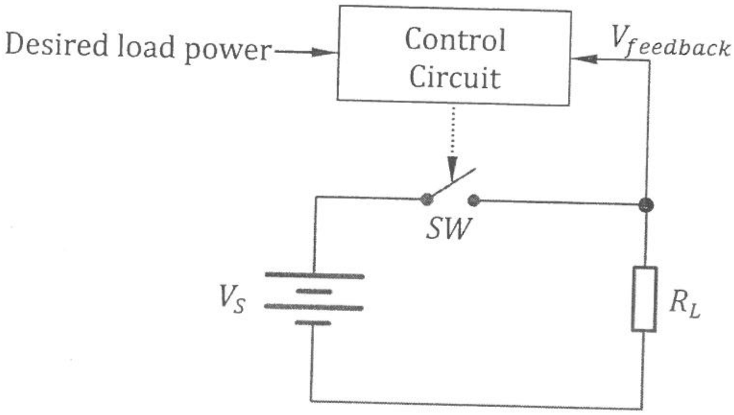


Figure-Q1(c)

i. Appraise and conclude this power delivery technique assume an ideal switch is used. [5]

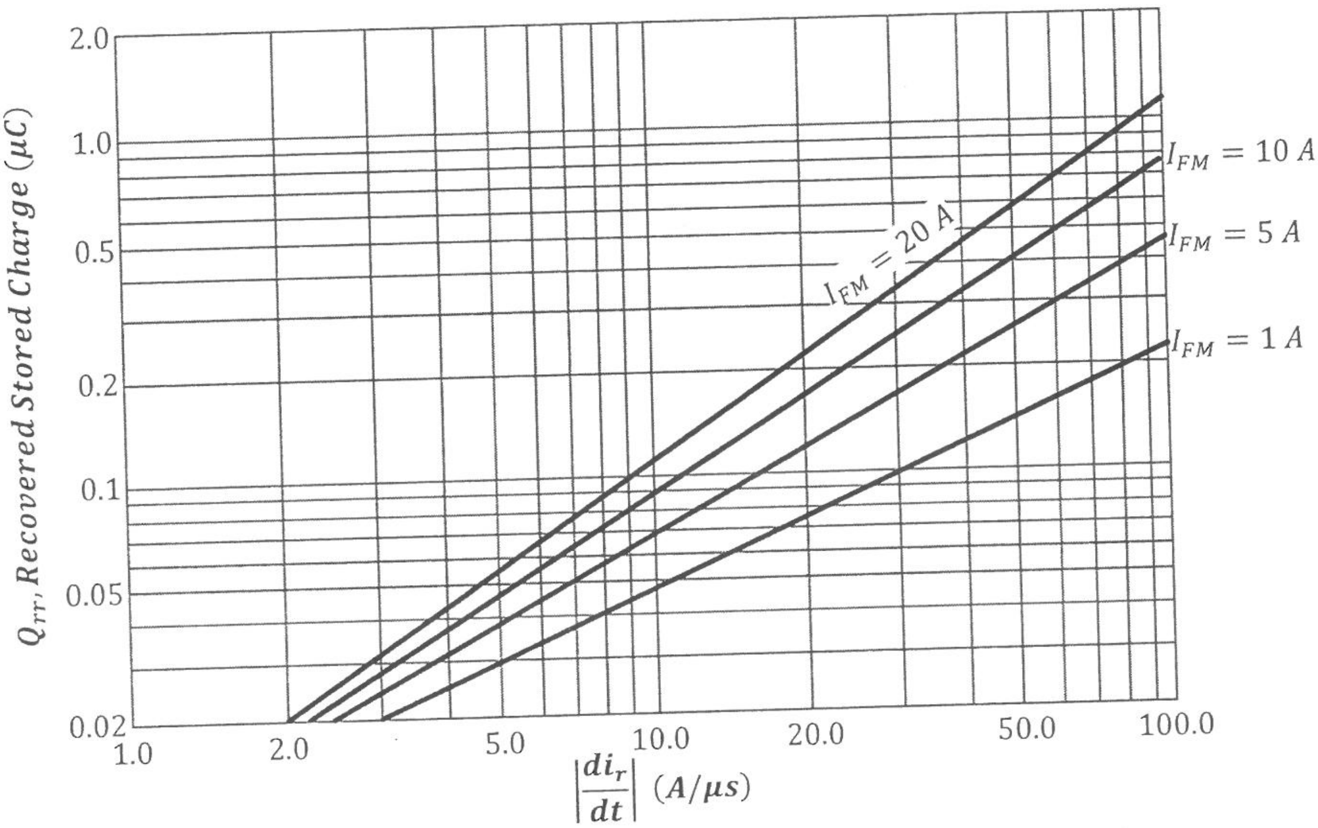
ii. Explain the importance of having a feedback loop in the system. [3]

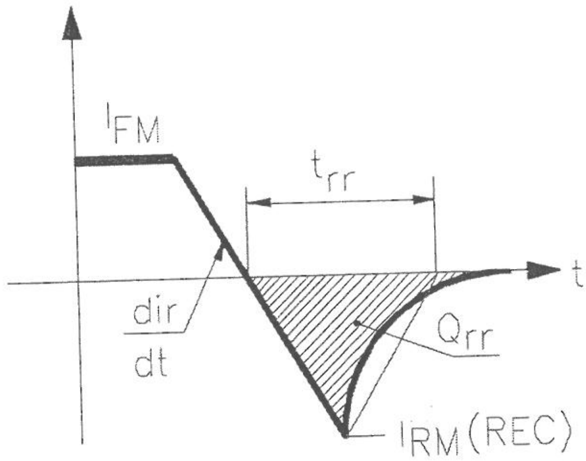
Question 2

a. Figure-Q2(a) shows several extractions from a datasheet for the 1N3879 power diode.

i. In the approximated formulas used for calculating t_{rr} and $I_{RM}(REC)$, quantitatively explain the assumption that has been made. [8]

ii. If the 1N3879 diode operates with an initial current of 10 A, and it recovers blocking capability in a circuit in which the current is reverse at a rate of 50 $A/\mu s$, calculate t_{rr} and $I_{RM}(REC)$. [6]





The recovery time, t_{rr} and peak reverse recovery current $I_{RM}(REC)$ can be closely approximated using the following formulas:

$$t_{rr} = 1.41\sqrt{\frac{Q_{rr}}{di_r/dt}}$$

$$|I_{RM}(REC)| = 1.41\sqrt{Q_{rr} \times \frac{di_r}{dt}}$$

Figure-Q2(a)

b. Figure-Q2(b) shows the application of 1N3879 power diode in a power electronic circuit. Solid state switch S is turned off for a long period, resulting $i_2(t) = 5\ A$, which is the current flowing from the constant current source I_{DC}, and $i_1(t) = 0\ A$.

Comparatively, the forward-bias voltage across the diode can be assumed negligible the moment switch S is turned on.

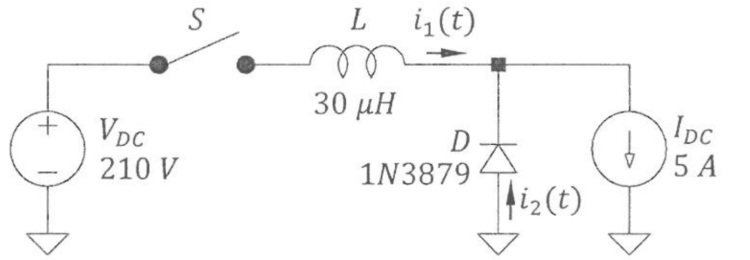


Figure-Q2(b)

For the given information in Figure-Q2(a) and Figure-Q2(b), when switch S is turned on, calculate,

i. the maximum reverse current, $I_{RM}(REC)$ of the diode [6]

ii. the total transient period. [5]

Question 3

Figure-Q3(a) shows a controlled rectifier circuit with resistive load.

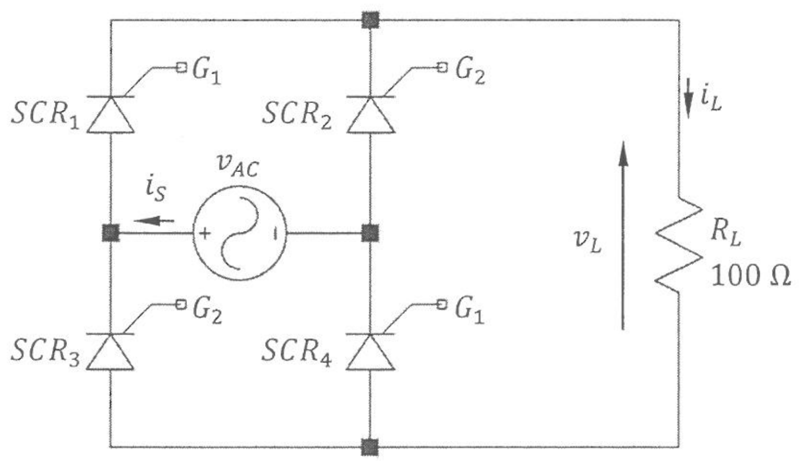


Figure-Q3(a)

a. State the name of the control scheme used in the rectifier circuit. [2]

b. State the type of SCR commutation scheme used in the rectifier circuit. [2]

c. Assume ideal SCR operation, complete the timing diagrams of $i_S(t)$ and $v_L(t)$ in "Worksheet Q3(c)" for the given trigger signal at gate terminals G_1 and G_2. Calculate the initial and peak values of $i_S(t)$ and $v_L(t)$. Label these values in the respective timing diagrams clearly. [10]

d Calculate the RMS load voltage, $V_{L(RMS)}$. Show all formula derivation clearly. [8]

e. Calculate the power delivered to the load. [3]

Question 4

a. Study the diagram in Figure-Q4(a) and suggest the most suitable power regulator solution to the problem. Justify your answer. [4]

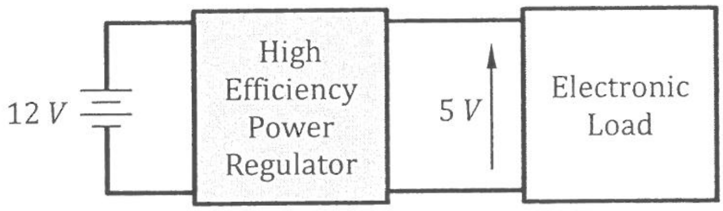


Figure-Q4(a)

b. Figure-Q4(b) shows a circuit to regulate a 40 V DC voltage across a 50 Ω load. $S1$ is a voltage-controlled switch which turns on when V_{ctrl} is 5 V and off when V_{ctrl} returns to 0 V. The chosen capacitance value is sufficient to maintain negligible output ripple. V_{ctrl} operates at 5 kHz.

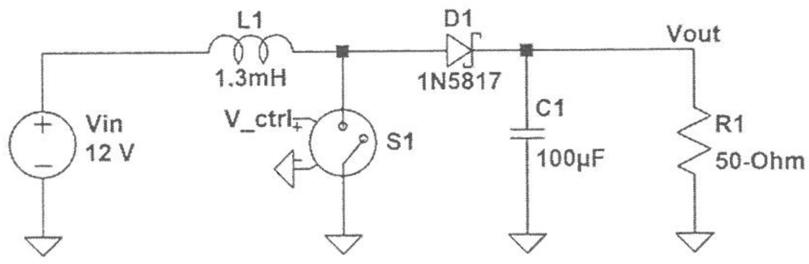


Figure-Q4(b)

i. Calculate the required duty cycle for V_{ctrl}. [3]

ii. Calculate the maximum and minimum current drawn from the 12 V supply. [6]

iii. Calculate the average power drawn from the 12 V supply. [5]

iv. Sketch the ideal timing diagram of the current flowing through diode D_1. Hence, calculate the RMS value of the diode current. [7]

Question 5

a. i. Explain the need of an inverter in a photovoltaic system. [2]

ii. Draw a half-bridge inverter circuit delivering power to an inductive load. [4]

iii. Explain the operation of the inverter circuit drawn in part (a)(ii). [6]

b. Figure Q5(b) shows a single-phase full bridge inverter circuit. The transistors are turned on alternatively in diagonal pairs at 50% of the time. In other words, Q_1 and Q_4 are turned on simultaneously for half cycle, followed by Q_2 and Q_3 for the second half cycle.

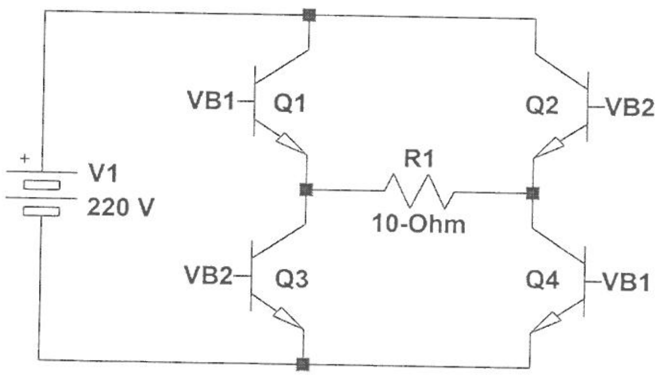


Figure-Q5(b)

i. Explain the flaws in the circuit design if the resistive load, R_1 is replaced with an inductive load. [2]

ii. Calculate the RMS voltage across R_1 at the fundamental frequency. [4]

iii. Calculate the power delivered to R_1. [3]

iv. Calculate the peak current flowing through each transistor. [2]

v. Calculate the peak off state voltage across each transistor. [2]

Question 6

a. Steady-state heat flow analysis in power electronic devices is similar to the solution of simple series resistor circuits. State the electrical analogy of the following thermal quantities:

i. Heat flow in watts. [2]

ii. Thermal resistance in °C/W [2]

iii. Temperature (°C) at a spatial location [2]

iv. Thermal loop [2]

v. Ambient air temperature. [2]

b. A MOSFET operates in a steady-state thermal condition and dissipates 10 W of power. It is mounted on a heat sink with heat rejection to the surrounding ambient environment of $2.5\ °C/W$. The surrounding ambient air is at $70\ °C$. The MOSFET is rated with a thermal resistance between junction and case of $0.83\ °C/W$. Calculate the device junction temperature if the MOSFET is mounted directly on the heat sink using a thermal grease which contributed a thermal resistance of $0.15\ °C/W$. [5]

c. Figure-Q6(c)(i) & (ii) show two power electronic circuits controlling the brightness of a bulb.

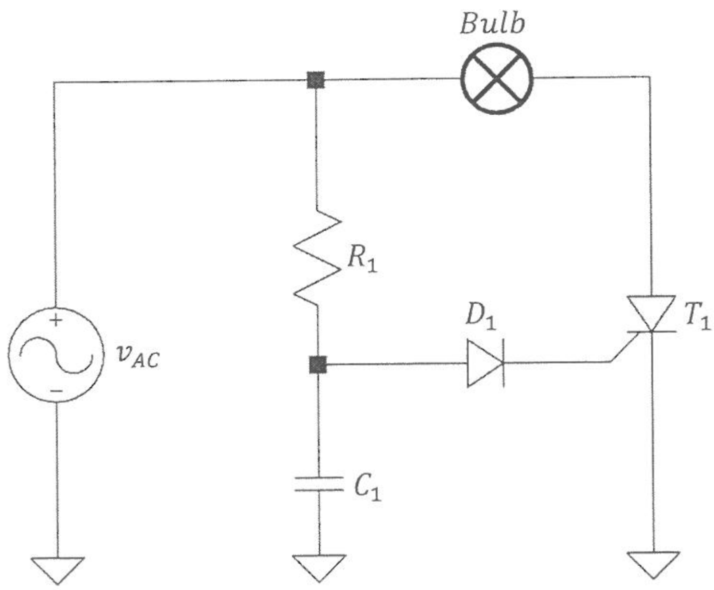


Figure-Q6(c)(i)

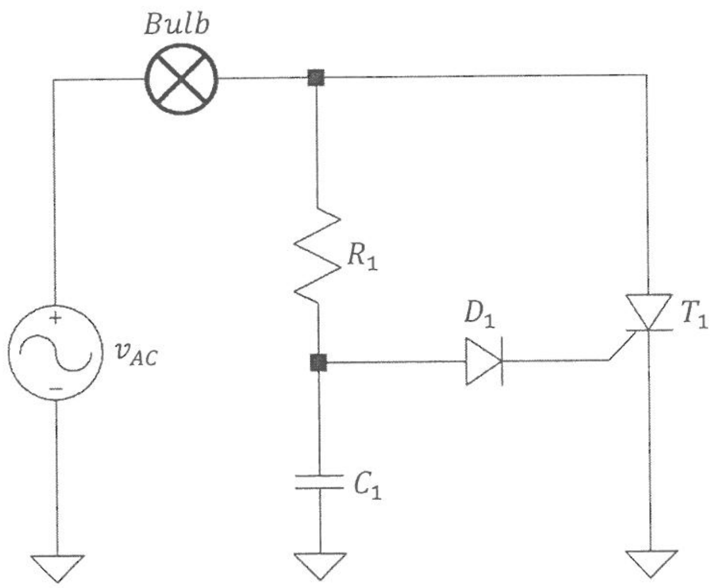


Figure-Q6(c)(ii)

i. Explain the advantage of the circuit in Figure-Q6(c)(ii) has over the one in Figure-Q6(c)(i). [2]

ii. If $v_{AC}(t) = 100\sin(100\pi t)$ and T_1 needs at least 1 V to be triggered for conduction, calculate the relevant values for R_1 and C_1 so that the firing time can be set at 2 ms after the negative-to-positive zero-crossing moment of $v_{AC}(t)$. Assume that $R_{BULB} \ll R_1$. [8]

~ The End ~

WORKSHEET-Q3(c)

Student Name:	
Matriculation No: