INTI
International College Penang

FINAL
Examination Paper

(COVER PAGE)

Session	:	**August 2019**
Programmes	:	Diploma in Electrical and Electronic Engineering (DEEI)
Course	:	**EEE2112: Introduction to Power Electronics and Drives**
Date of Examination	:	13 December 2019 (Friday)
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 :

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

Materials Provided :

Worksheet for Q1(b)

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

*This paper consists of **11** 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 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. Figure-1(a) shows a simple power electronic circuit utilizing a solid-state switch. Clearly explain the assumptions that should be made on the switch if one needs to estimate the ideal maximum current flowing through the switch and the ideal maximum voltage drop across the switch. [5]

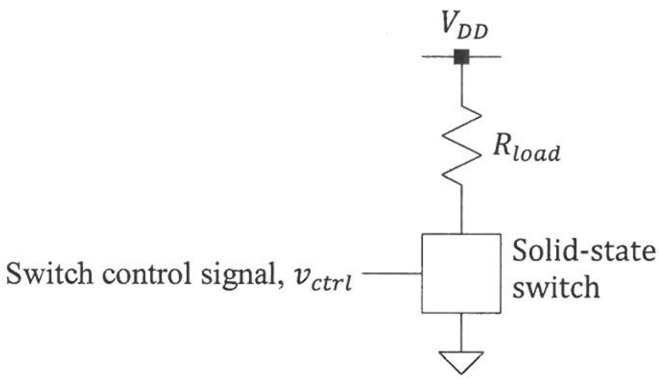

Figure-Q1(a)

b. Figure-Q1(b) shows the timing diagrams of the switch control signal, $v_{ctrl}(t)$ and the voltage across the solid-state switch, $v_{sw}(t)$ in Figure-Q1(a), when $V_{DD} = 12$ V and $R_{load} = 100\ \Omega$.

Complete "Worksheet for Q1(b)" by sketching the timing diagrams of $i_{sw}(t)$ and $p_{sw}(t)$. $i_{sw}(t)$ is the instantaneous current flowing through the solid-state switch, while $p_{sw}(t)$ is the instantaneous power dissipate by the switch. [10]

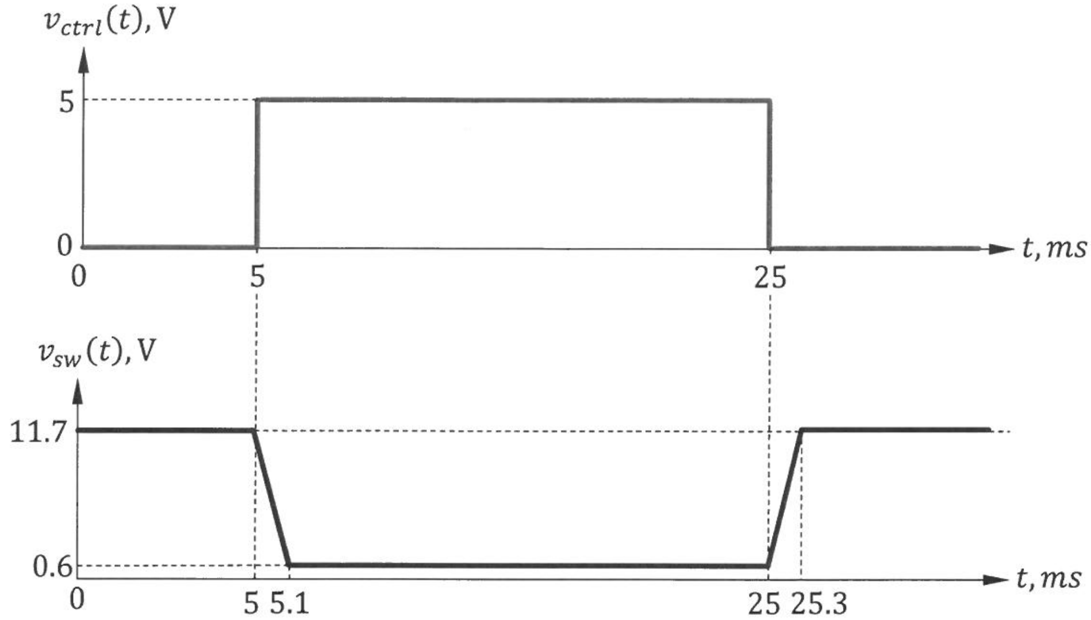

Figure-Q1(b)

c. Figure-Q1(c) shows a DC-DC converter, operating at steady-state condition such that V_{out} has negligible ripple. V_{PWM} is the pulse width modulated control signal to turn on and turn off MOSFET T_1. The operation of the Schottky diode D_1 can be assumed ideal.

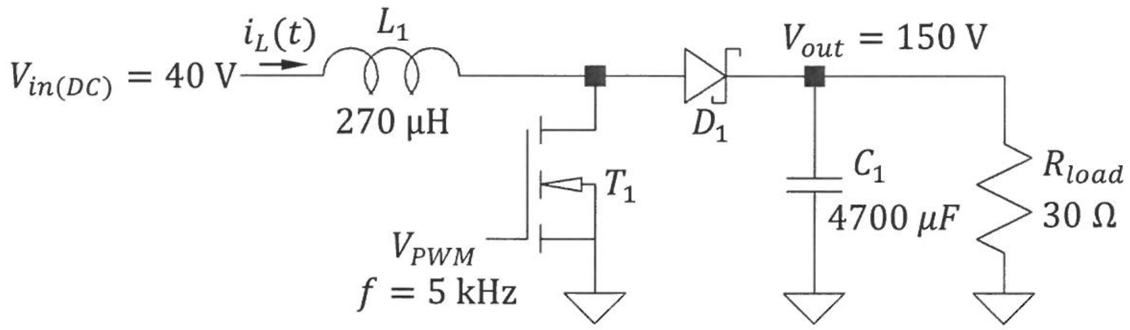

Figure-Q1(c)

i. Determine the rate of change of the inductor current, $di_L(t)/dt$ the moment MOSFET T_1 is turned on. [3]

ii. If 7.84 A of current flows through inductor L_1 right before MOSFET T_1 is turned on, sketch the timing diagram of $i_L(t)$ ranging from the moment MOSFET T_1 is turned on to one full cycle of V_{PWM}. Clearly show all the workings that lead to the sketch of the required timing diagram. [7]

Question 2

a. State the difference in the control signal to turn on an SCR (silicon controlled rectifier) as compared to the control signal to turn on an n-channel power MOSFET (metal oxide semiconductor field effect transistor). [3]

b. Explain the following parameters found in a datasheet of an SCR.

i. Peak ON-state voltage, V_{TM} [1]

ii. Holding current, I_H [1]

iii. Latching current, I_L [1]

iv. Peak gate current, I_{GM} [1]

v. Peak reverse gate voltage, V_{RGM} [1]

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]

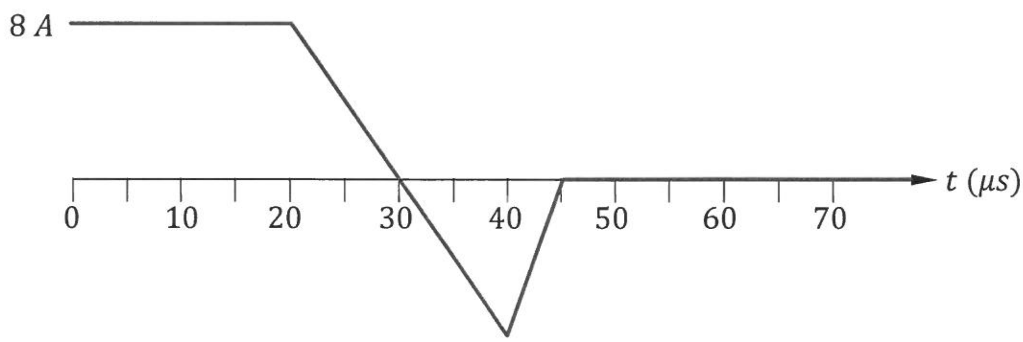

Figure-Q2(c)

d. Figure-Q2(d) shows the application of a freewheeling diode to prevent high rate of change of current in the inductive load when the switch turns off. Switch SW is turned on and off with a period of 15 ms at 4% duty cycle.

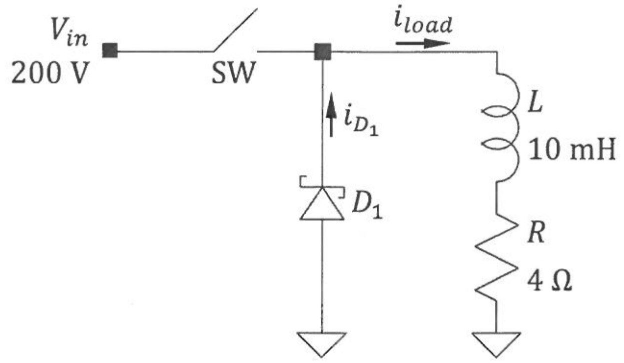

Figure-Q2(d)

i. Identify the minimum peak forward current of diode D_1. [6]

ii. Sketch the synchronized timing diagrams of $i_{load}(t)$ and $i_{D_1}(t)$ for one complete on/off cycle of switch SW. [4]

Question 3

a. Figure-Q3(a) shows a simple phase-controlled half-wave rectifier which converts a step-down AC voltage source to the desired positive voltage. Clearly explain the most critical requirement for the SCR trigger pulses to achieve the desired phase-control action. [5]

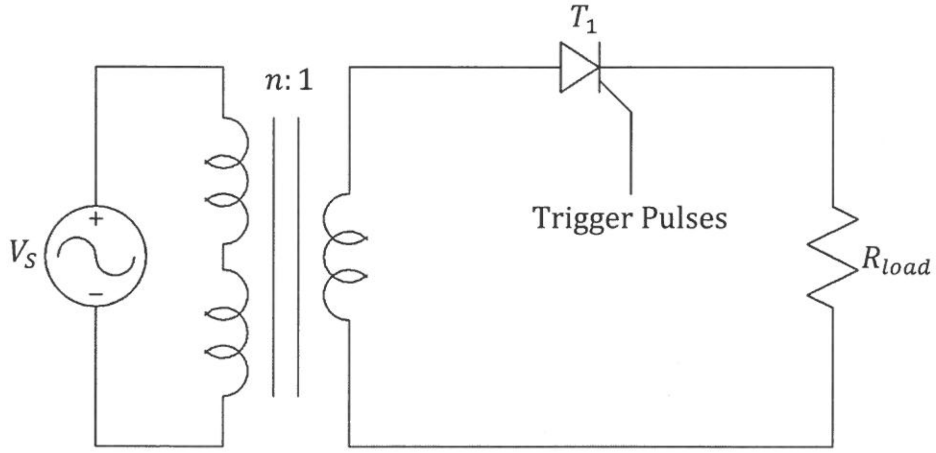

Figure-Q3(a)

b. Assume the following for the circuit in Figure-Q3(a):

$V_S = 240\ \mathrm{V_{RMS}}$ (sinewave)

$f = 50$ Hz

$n = 10$

$R_{load} = 180\ \Omega$

Firing angle $= 110°$

Calculate the average load voltage and load current when the firing angle is at 30° of the supply cycle. [5]

c. Figure-Q3(c)(i) 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 by V_{trig1} is delayed by 2 ms during the positive cycle of the AC source while the triggering of SCR S_3 and S_4 by V_{trig2} is also delayed by 2 ms but is during the negative cycle.

Figure-Q3(c)(ii) & Figure-Q3(c)(iii) shows the timing diagrams of $V_{load}(t)$ and $V_R(t)$ for one complete cycle of the AC source.

i. Examine if the load current $i(t)$ is continuous. Justify your answer. [3]

ii. Approximate the power delivered to the load as accurate as possible. Show all your workings clearly. [12]

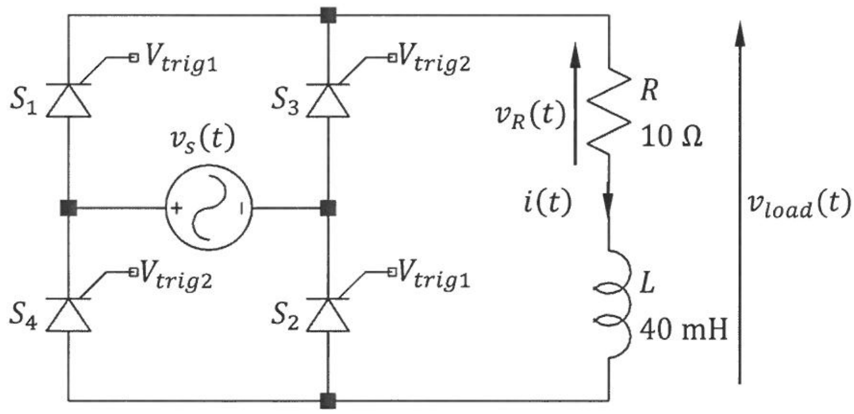

Figure-Q3(c)(i)

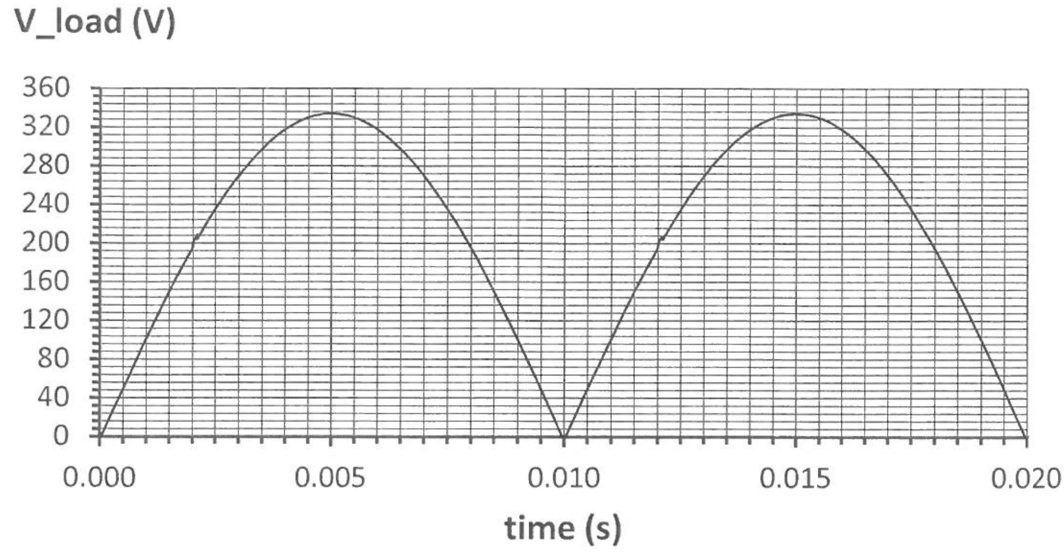

Figure-Q3(c)(ii)

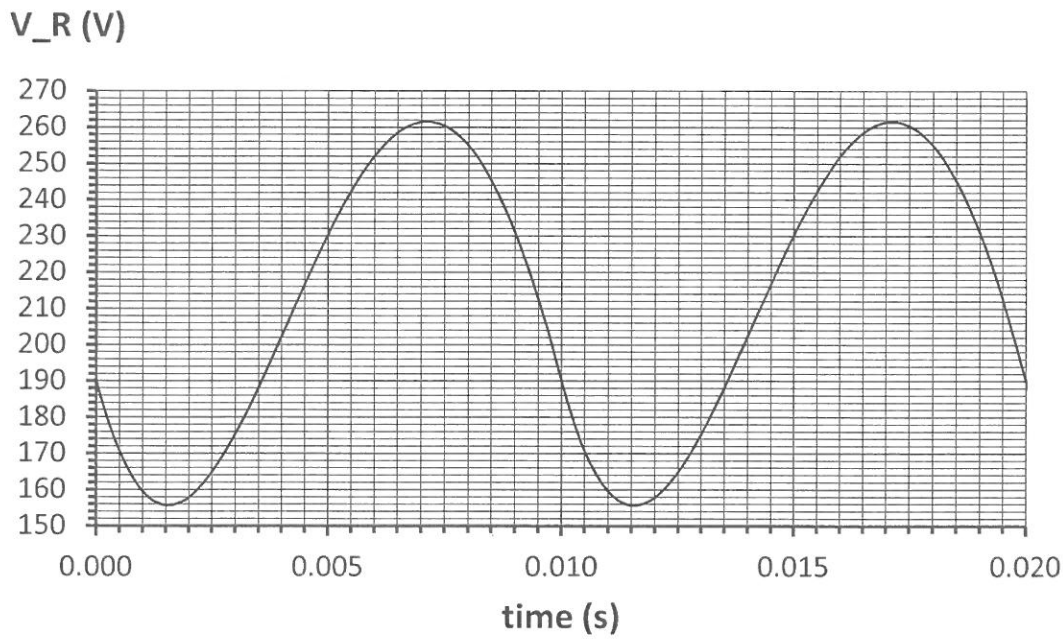

Figure-Q3(c)(iii)

Question 4

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

b. Figure-Q4(b) shows a basic full-bridge inverter to control the rotational direction of a permanent magnet motor. V_{BB_1} and V_{BB_2} are two digital control voltages that drives transistors T_5 and T_6 into saturation when these voltages rise to their logic 1 level. V_{BB_1} and V_{BB_2} turn off transistors T_5 and T_6 when these voltages are at the logic 0 level.

The threshold voltages to turn on the respective MOSFETs are:

$V_{GS(on)}$ threshold voltage for T_1 & $T_2 = -4$ V

$V_{GS(on)}$ threshold voltage for T_3 & $T_4 = 4$ V

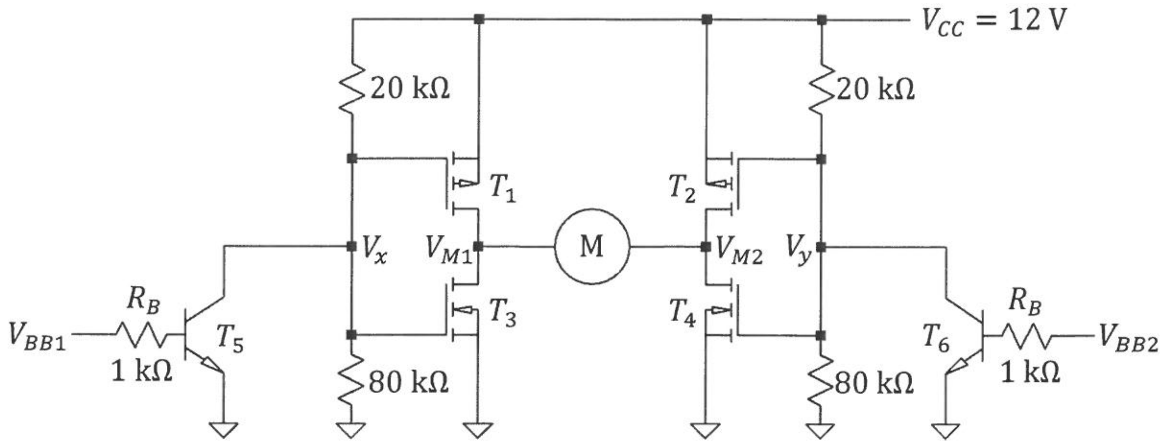

Figure-Q4(b)

i. Determine the voltage values of V_x and V_y when $V_{BB1} = V_{BB2} =$ logic-0. [2]

ii. Based on the voltage values obtained in part (b)(i), clearly describe the state of the motor. [2]

iii. Determine the voltage values of V_x and V_y when $V_{BB1} = V_{BB2} =$ logic-1. [2]

iv. Based on the voltage values obtained in part (b)(iii), clearly describe the state of the motor. [2]

v. Determine the respective gate-to-source voltages, V_{GS} that turns on each of the MOSFET in the bridge inverter. [4]

vi. Set up a function table that list all the possible logical input states that control the operation of the motor. [3]

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) shows a single phase AC-AC converter. The phase trigger controller fires TRIAC T_1 at specific moments to control the RMS voltage across the resistive load.

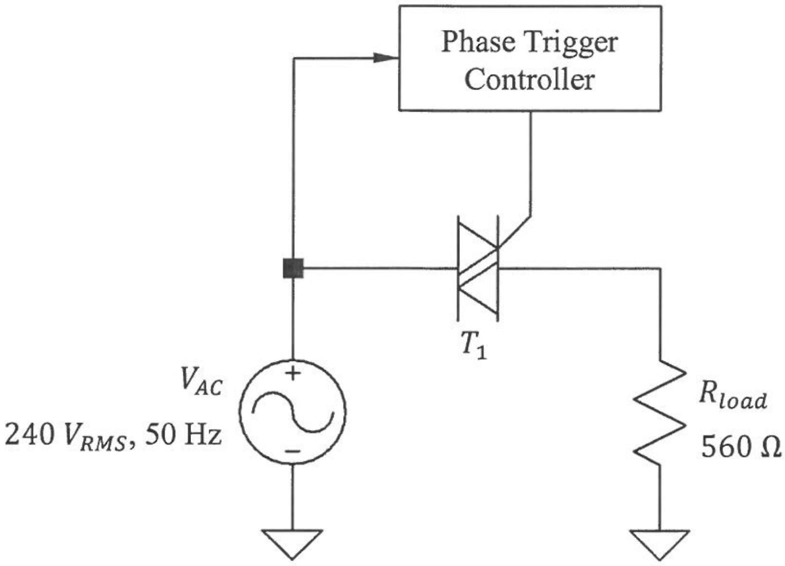

Figure-Q5(b)

i. Calculate the power delivered to R_{load} if TRIAC T_1 is triggered at 2 ms delay after every 0 V crossing point of V_{AC}. [6]

ii. Calculate the power factor of the circuit. [2]

iii. Explain the reason for applying V_{AC} to Phase Trigger Controller. [2]

c. The TRIAC in Figure-Q5(b) can be visualized as two SCRs connected in inverse parallel orientation, sharing a common gate terminal.

Assume that the firing angle of the TRIAC during the positive and negative cycles of the supply voltage is α, derive a mathematical expression that models the RMS current flowing through each SCR as a function of α and R_{load}. Show all workings clearly. [10]

Question 6

a. The main challenge in utilizing MOSFET in high side switching is requirement of the gate drive voltage being higher than the supply voltage V_{DD}. Figure-Q6(a) shows a gate drive circuit commonly known as a bootstrap circuit for driving a high-side MOSFET using a low gate drive voltage. Explain, with the aid of relevant circuit models, the circuit operation to achieve the stated gate drive capability. [10]

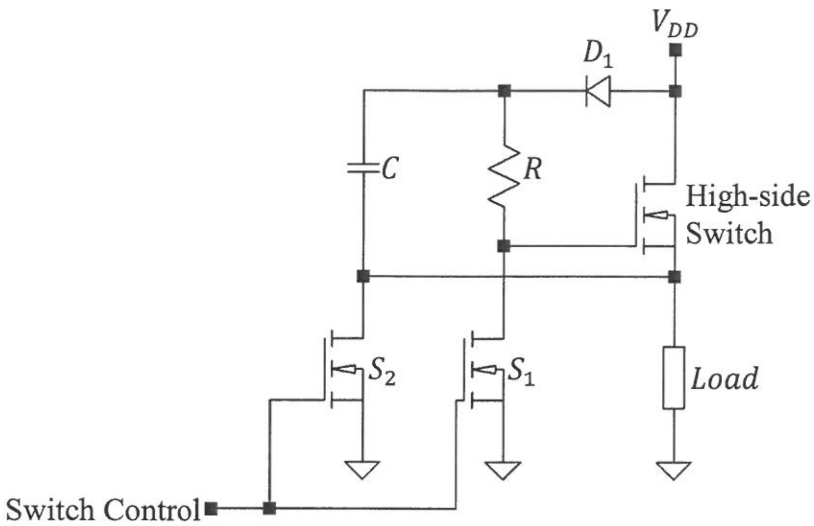

Figure-Q6(a)

b. Figure-Q6(b) shows a common transistor switching circuit model controlling power delivery to a large inductive load, such that it can be approximately modelled by a current source, I_L. Due to the switching transitions of the transistor and the diode, a significant power dissipated by the transistor during this period.

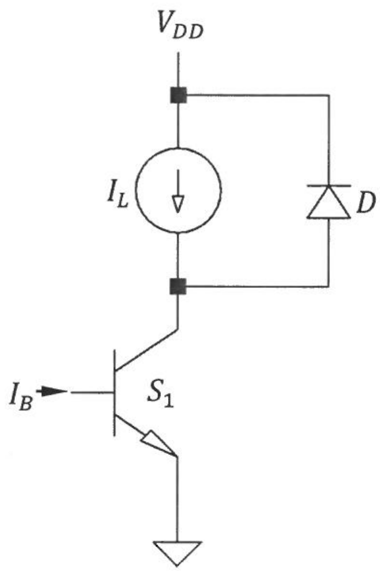

Figure-Q6(b)

i. Add a circuit to the transistor switching circuit model in Figure-Q6(b) so that the transistor power dissipation during switching transition can be minimized. [3]

ii. Explain the operation of the circuit added in part (b)(i) to minimize transistor power dissipation during switching transition. [4]

c. Figure-Q6(c) shows the thermal data extracted from a power MOSFET datasheet.

THERMAL DATA

Symbol	Parameter	Value		Unit
		TO-220	TO-220FP	
$R_{thj\text{-}case}$	Thermal resistance junction-case Max	1.67	4.17	°C/W
$R_{thj\text{-}a}$	Thermal resistance junction-ambient Max	62.5		°C/W
Rthc-sink	Thermal resistance case-sink typ	0.5		°C/W
T_l	Maximum lead temperature for soldering purpose	300		°C

Figure-Q6(c)

i. Define "thermal resistance". [2]

ii. A same type of power MOSFET with TO-220 package is used in a power control circle. It has a maximum junction temperature measured at 190°C and needs to absorb 2 W of power. Determine the minimum thermal resistance of a heat sink that needs to be attached to the MOSFET to ensure safe operation if the maximum ambient temperature is 32 °C. [6]

~ The End ~