INTI International College Penang

**FINAL**
**ALTERNATIVE ASSESSMENT**

(COVER PAGE)

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| Session | : | **August 2020** |
| Programme | : | Diploma in Electrical & Electronic Engineering (DEEI) |
| Course | : | **EEE2112: Introduction to Power Electronics & Drives** |
| Date of Examination | : | 17 December 2020 (Thursday) |
| Time | : | 2.00pm – 5.00pm Reading Time : Nil |
| Duration | : | 3 Hours |

**Special Instructions :**

This paper consists of **FOUR (4)** questions. Answer **ALL FOUR (4)** questions. All questions carry equal marks.

Material permitted : Non-Programmable Scientific Calculator

Materials provided : Nil

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| Examiner(s) | : | **Chan Tse Wei** |
| Chief Moderator | : | Johnny Wong Kee Hui |

*This paper consists of **7** 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 ALTERNATIVE ASSESSMENT: AUGUST 2020 SESSION

**Instructions**: This paper consists of **FOUR (4)** questions. Answer **ALL FOUR (4)** questions. 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. Qualitatively explain the operation of a silicon control rectifier (SCR) in the field of power electronics. [ 5 ]

b. Figure-Q1(b)(i) shows the application of SCR in a power converter circuit. The SCRs are respectively triggered by gate currents $I_{G_1}(t)$ and $I_{G_2}(t)$. Figure-Q1(b)(ii) shows the timing diagrams of the SCR triggering currents for one complete cycle of $v_S(t)$.

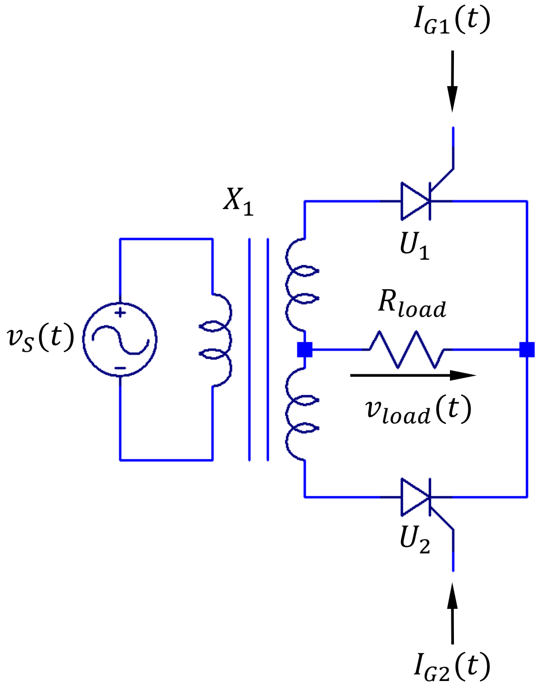



**Figure-Q1(b)(i)**

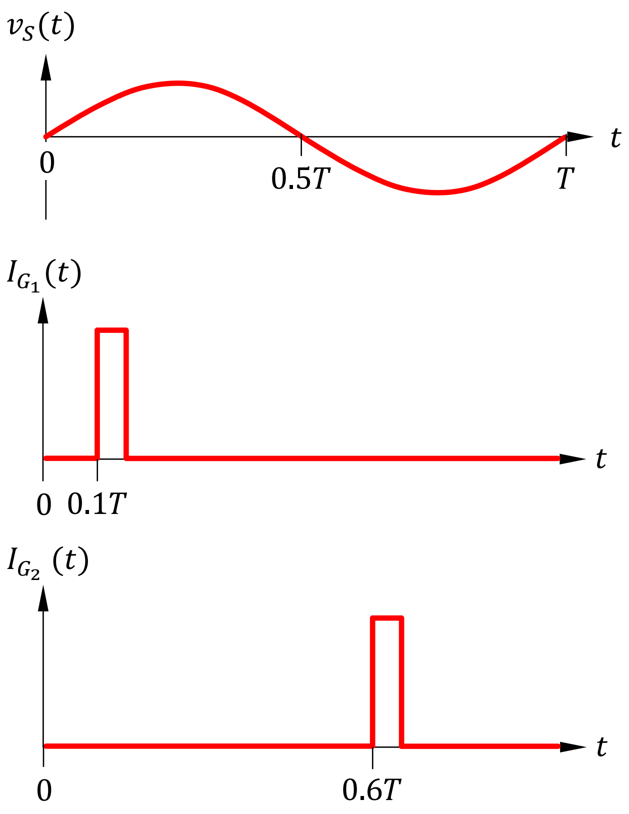



**Figure-Q1(b)(ii)**

If $v_S(t) = V_p sin(100\pi t)$ and the step-down transformer, $X_1$ has a turn ratio of 10:1, clearly sketch the timing diagram of $v_{load}(t)$ by assuming the SCRs in Figure-Q1(b)(i) is ideal. [ 5 ]

c. Figure-Q1(c) shows a single phase controlled rectifier with an inductive load. The supply voltage, $v_S(t)$ is a 50 Hz sinusoidal voltage with 200 V amplitude. The characteristics of the SCR can be assumed ideal.

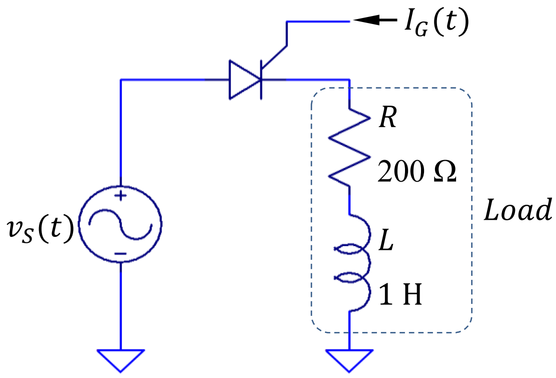



**Figure-Q1(c)**

i. If the SCR triggering current is pulsed at 2 ms after the input voltage first enters its positive cycle, calculate the conduction duration of the SCR within one complete cycle of the input voltage. [10]

ii. Determine the lowest voltage drop across the load based on the triggering condition in part (c)(i). [ 5 ]

## Question 2

a. Qualitatively explain the operation of a bipolar junction transistor (BJT) in the field of power electronics. [ 5 ]

b. Due to the need to charge mobile phone battery when one is traveling, many car manufacturers are equipping their products with USB ports for the drivers or passengers to conveniently charge their mobile phones. State the type of circuit that is suitable for such applications. Explain your answer. [ 5 ]

c. Figure-Q2(c) shows a step-down converter operating at 50 kHz switching signal ($V_{ctrl}$) and is fed by a 200 V low-ripple DC voltage ($V_{in}$). All the components in the converter are assumed ideal.

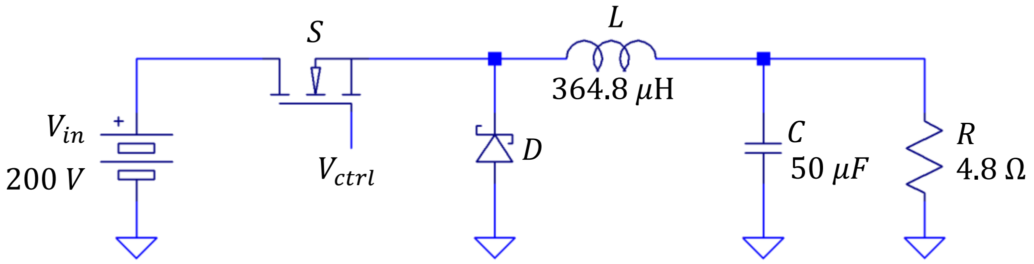



**Figure-Q2(c)**

Consider the converter is delivering 48 V of voltage to a nominal load resistance of 4.8 Ω.

i. Sketch the steady-state timing diagram of the voltage across inductor, $v_L(t)$, for one cycle of $V_{ctrl}$. [ 5 ]

ii. Sketch the steady-state timing diagram of the current flowing through inductor, $i_L(t)$, for one cycle of $V_{ctrl}$. [ 4 ]

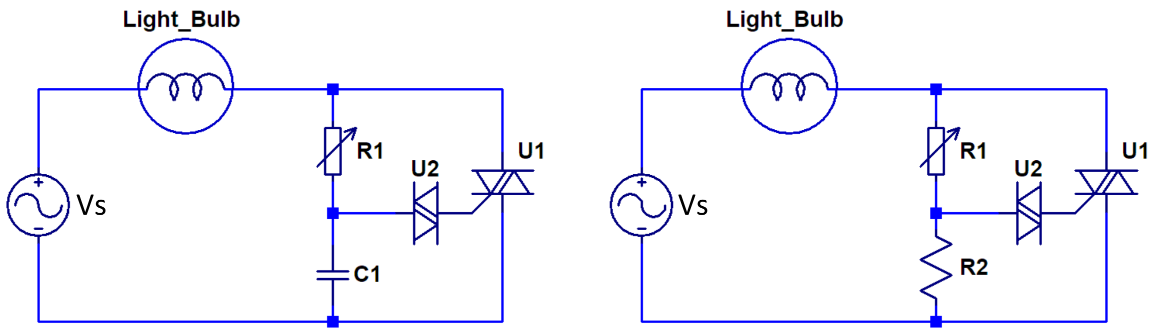
iii. Sketch the steady-state timing diagram of the current flowing through diode $D$, $i_D(t)$, for one cycle of $V_{ctrl}$. [ 2 ]

iv. Calculate the output voltage ripple value. [ 4 ]

## Question 3

a. Qualitatively explain the need for Insulated Gate Bipolar Transistors (IGBT) in power electronics applications even though with the presence of BJTs and MOSFETs. [ 5 ]

b. Figure-Q3(b)(i) and (ii) show two AC-AC power converter circuits. Distinguish the operation between the two circuits in terms of controlling power at the light bulb using phase control scheme. [ 5 ]




(i) (ii)

**Figure-Q3(b)**

c. Figure Q3(c) shows a single-phase AC voltage controller, $v_{AC}(t)$ is a sinusoidal voltage and the diode and SCR can be assumed ideal.

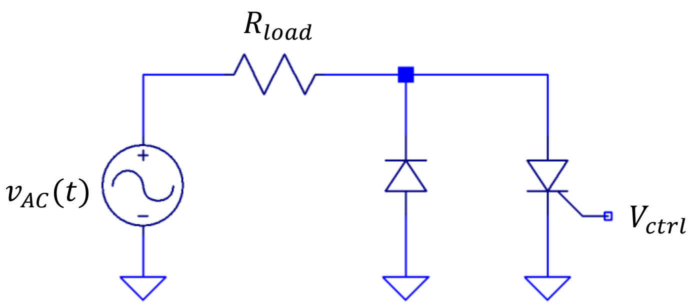



**Figure-Q3(c)**

i. Show that the RMS voltage across $R_{load}$ is expressed as,

$$V_{load(RMS)} = V_{AC(RMS)}\sqrt{1 - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$

where $\alpha$ is the firing angle of the SCR in radian. [ 9 ]

ii. If $R_{load} = 100\ \Omega$, $V_{AC(RMS)} = 240$ V and $\alpha = \pi/2$, calculate the power factor of the circuit. [ 6 ]

**Question 4**

a. Figure-Q4(a) shows the I-V characteristics of a power MOSFET. State the region where the MOSFET exhibits an ON switch characteristics. Explain your answer. [ 5 ]

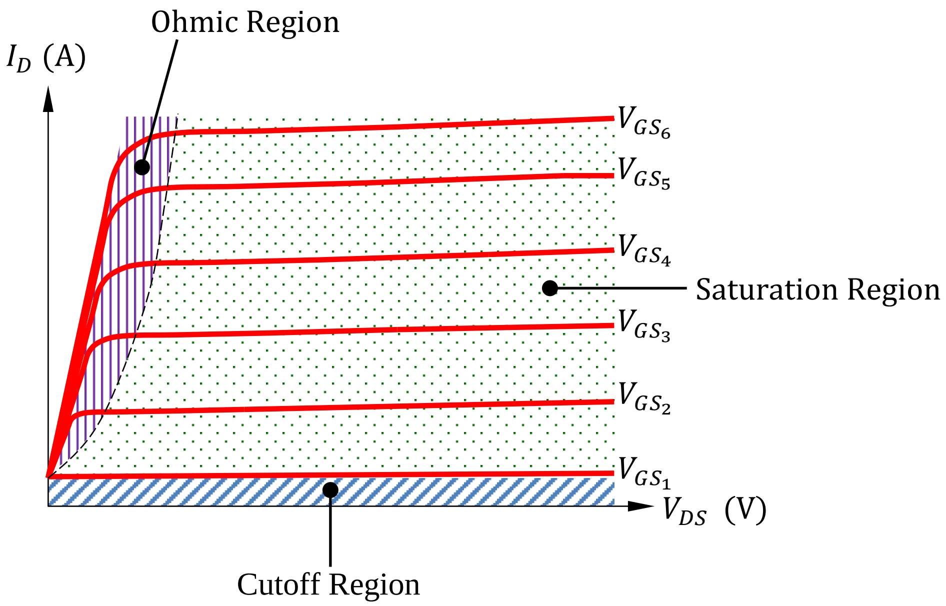



**Figure-Q4(a)**

b. Explain the reasons inverters play an important part in domestic solar-powered systems. [ 5 ]

c. Figure-Q4(c) shows the circuit model of a half-bridge inverter. $S_1$ and $S_2$ are switching devices that can be assumed ideal. $S_1$ and $S_2$ have a common switching period $T$ but may have different switching duty cycles, $D_1$ and $D_2$. Nevertheless, $D_1 + D_2 = 1$ needs to be complied and both $S_1$ and $S_2$ cannot turn on simultaneously.

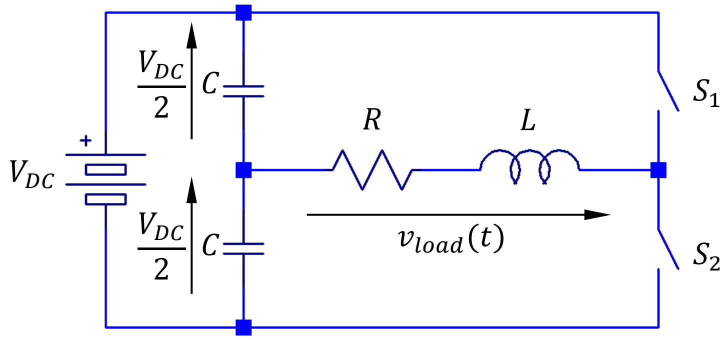



**Figure-Q4(c)**

i. If $S_1$ has a duty cycle of $D$, determine the expression of $V_{load(avg.)}/V_{DC}$ in terms of $D$, where $V_{load(avg)}$ is the average voltage of $v_{load}(t)$ in one complete switching cycle. [ 6 ]

ii. If $D = 0.5$, $V_{DC} = 100$ V, $R = 20\ \Omega$, $L = 50$ mH and $T = 20$ ms, calculate the peak load current. [ 5 ]

iii. Explain the impact on the circuit if $S_1$ and $S_2$ have delayed turn on time but with negligible turn off time. [ 4 ]

**~THE END~**