



**FINAL  
ALTERNATIVE ASSESSMENT**

(COVER PAGE)

Session : April 2020

Programme : Diploma in Electrical & Electronic Engineering (DEEI)

Course : EEE2112: Introduction to Power Electronics & Drives

Date of Examination : 8 August 2020 (Saturday)

Time : 8.00am – 11.00am Reading Time : Nil

Duration : 3 Hours

**Special Instructions :**

This paper consists of **FOUR (4)** questions. Answer **ALL 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.

Material permitted : Non-Programmable Scientific Calculator

Materials provided : Laplace Transform Table

Examiner(s) : Mr Chan Tse Wei

Chief Moderator : Mr Chai Yoon Yik

*This paper consists of 6 printed pages, including the cover page*

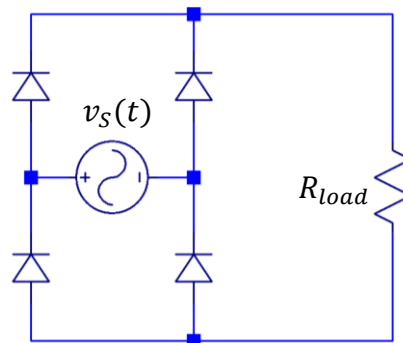
## INTI INTERNATIONAL COLLEGE PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME (DEEI)  
 EEE2112: INTRODUCTION TO POWER ELECTRONICS AND DRIVES  
 FINAL ALTERNATIVE ASSESSMENT: APRIL 2020 SESSION

**Instructions:** This paper consists of **FOUR (4)** questions. Answer **ALL 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**

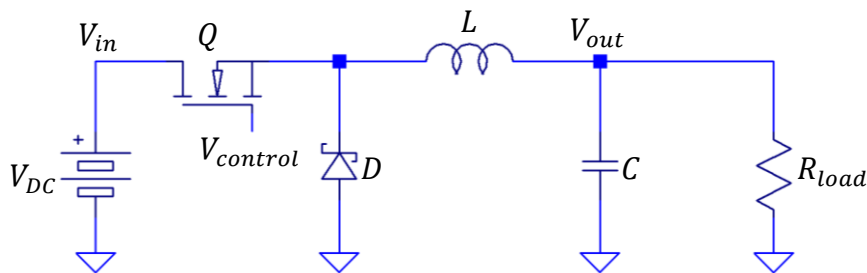
- a. Distinguish between MOSFETs and IGBTs in the field of power electronics applications. [ 5 ]
- b. Distinguish controlled rectifiers from uncontrolled rectifiers. [ 5 ]
- c. Figure-Q1(c) shows an AC-DC converter with resistive load. The switching devices in the converter are assume ideal. The AC supply voltage is a pure sinusoidal voltage.

**Figure-Q1(c)**

- i. Show the quantitative proof that the average voltage across the resistive load is  $0.9V_{S(RMS)}$ . [ 6 ]
- ii. Show the quantitative proof that the RMS voltage across the resistive load is  $V_{S(RMS)}$ . [ 6 ]
- iii. Calculate the efficiency (rectification ratio) of the rectifier in percentage. [ 3 ]

**Question 2**

- a. i. Draw the circuit analogy of an SCR. [ 2 ]
- ii. Explain the operation of an SCR as a solid-state switch. [ 3 ]
- b. Distinguish buck choppers from boost choppers. [ 5 ]
- c. Figure-Q2(c) shows an ideal buck chopper. The inductance,  $L$  and the capacitance,  $C$  are sufficiently large such that the circuit is operating in continuous current mode (CCM) and the output voltage,  $V_{out}$  is held constant during steady-state condition. MOSFET  $Q$  acts as a solid-state switch that turns on when  $V_{control}$  is at its high state and turns off when  $V_{control}$  returns low.

**Figure-Q2(c)**

- i. Quantitatively show that the output voltage,  $V_{out} = \alpha V_{DC}$ , where  $\alpha$  is the duty cycle of the  $V_{control}$  signal. [ 7 ]
- ii. If the buck chopper is to regulate a 5 V output voltage across a  $10 \Omega$  load from a 12 V DC voltage source, and  $220 \mu\text{H}$  is chosen for inductance  $L$ , calculate the lowest switching frequency of  $V_{control}$  so that the chopper operates in CCM. [ 4 ]
- iii. With the same parameters in part (b)(ii), calculate the output voltage ripple if  $330 \mu\text{F}$  is chosen for capacitance  $C$ . [ 4 ]

### Question 3

- a. Figure-Q3(a) shows the output characteristics of a power MOSFET with a typical gate threshold voltage of 2 V. Explain the characteristics of the MOSFET in terms of its constant current and ohmic operations. [ 5 ]

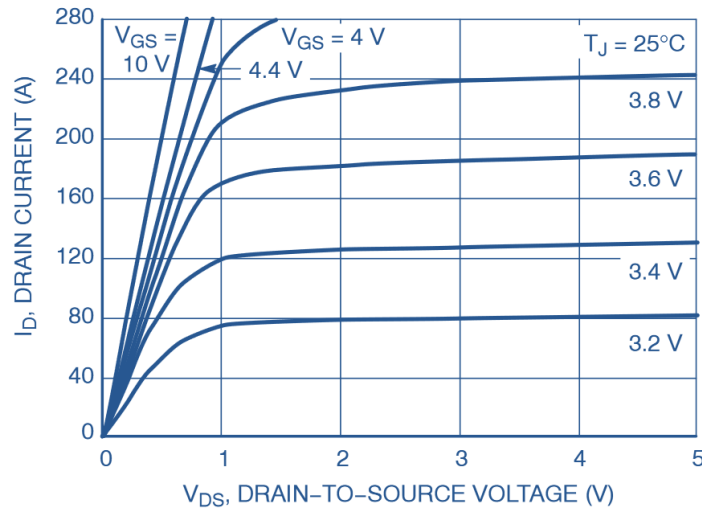


Figure-Q3(a)

- b. Figure-Q3(b) shows a power converter circuit utilizing an SCR as a solid-state switch. Clearly explain the operation of the power converter circuit. [ 5 ]

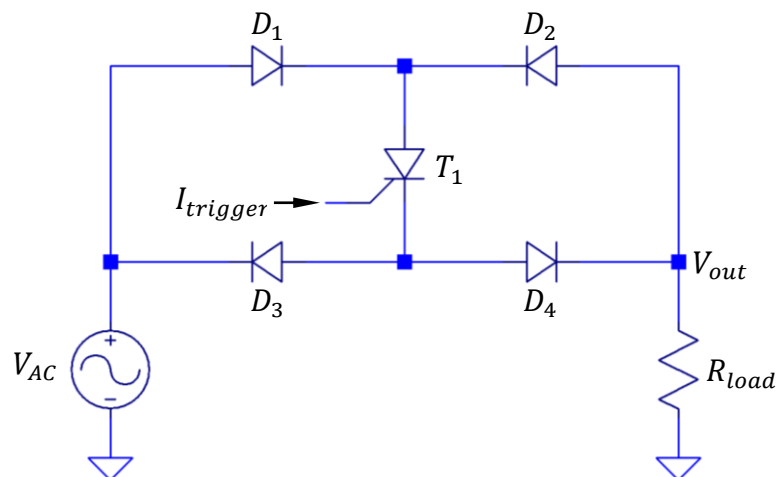


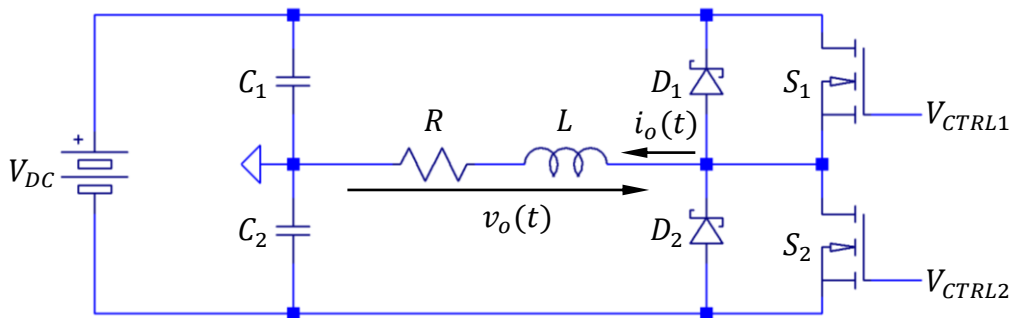
Figure-Q3(b)

- c. Assume that the diodes and the SCR in Figure-Q3(b) are ideal,  $V_{AC}$  is a  $240 V_{RMS}$  mains voltage supply with 50 Hz frequency, and  $R_{load} = 1 \text{ k}\Omega$ . The power converter circuit is operated in phase-controlled mode.
- Determine the delayed firing angle (in radian) of  $I_{trigger}$  and its frequency if  $120 V_{RMS}$  is to drop across  $R_{load}$ . Show all workings clearly. [ 8 ]
  - Determine the power dissipated by  $R_{load}$  based on the delayed firing angle found in part (c)(i). [ 3 ]

- iii. Show the quantitative proof that the converter's power factor is the ratio of  $V_{load(RMS)}$  to  $V_{AC(RMS)}$ . [ 4 ]

#### Question 4

- a. Explain the characteristics and operation of a line-frequency power diode. [ 5 ]
- b. Explain inverters in power electronics applications in terms of its function and output characteristics. [ 5 ]
- c. Figure-Q4(c) shows an example of a basic inverter.



**Figure-Q4(c)**

The followings are assumed when analyzing the inverter steady-state operation:

- Diodes  $D_1$  and  $D_2$  are ideal.
  - MOSFETs  $S_1$  and  $S_2$  are acting as ideal voltage-controlled switches. Both of them are turned on and off complementarily at 50% duty cycle.
  - Capacitors  $C_1$  and  $C_2$  have equal capacitance that is sufficiently large to maintain constant voltage drop across them.
- i. Show that the peak current value of  $i_o(t)$  is given by,

$$I_{o(peak)} = \frac{V_{DC}}{2R} \left( \frac{1 - e^{-T/2\tau}}{1 + e^{-T/2\tau}} \right)$$

where  $T$  = switching period of  $S_1$  and  $S_2$  and  $\tau$  = load time constant. [ 9 ]

- ii. Show the current flow directions in every branch of the inverter in Figure-Q4(c) when MOSFET  $S_1$  is turned on for half of the switching period. Assume that  $I_o = -I_{o(peak)}$  the moment when MOSFET  $S_1$  is just turned on. [ 6 ]

– The End –

**THE LAPLACE TRANSFORM TABLE**

Definition	$f(t)$ from $t > 0$	$F(s) = \mathcal{L}[f(t)] = \int_0^{\infty} f(t)e^{-st} dt$
1. Constant	$k$	$\frac{k}{s}$
2. First Derivative	$\frac{d}{dt}[f(t)]$	$sF(s) - f(0)$
3. $n^{\text{th}}$ Derivative	$\frac{d^n}{dt^n}[f(t)]$	$s^n F(s) - s^{n-1}f(0) - s^{n-2}f'(0) \dots f^{(n-1)}(0)$
4. Definite Integral	$\int_0^t f(u)du$	$\frac{F(s)}{s}$
5. Exponential multiplier	$e^{-at}f(t)$	$F(s + a)$
6. Unit impulse at $t = 0$	$\delta(t)$	1
7. Unit step	$u(t)$	$\frac{1}{s}$
8. Unit ramp	$r(t) = t$	$\frac{1}{s^2}$
9. $n^{\text{th}}$ order ramp	$t^n$	$\frac{n!}{s^{n+1}}$
10. Exponential decay	$e^{-at}$	$\frac{1}{s + a}$
11. Exponential growth	$1 - e^{-at}$	$\frac{a}{s(s + a)}$
12. Exponential $\times t$	$te^{-at}$	$\frac{1}{(s + a)^2}$
13. Exponential $\times t^n$	$t^n e^{-at}$	$\frac{n!}{(s + a)^{n+1}}$
14. Difference of exponentials	$e^{-at} - e^{-bt}$	$\frac{b - a}{(s + a)(s + b)}$
15. Difference of exponentials	$\frac{1}{b - a}(be^{-bt} - ae^{-at})$	$\frac{s}{(s + a)(s + b)}$
16. Sine	$\sin(\omega t)$	$\frac{\omega}{s^2 + \omega^2}$
17. Exponentially decaying sine	$e^{-at}\sin(\omega t)$	$\frac{\omega}{(s + a)^2 + \omega^2}$
18. Cosine	$\cos(\omega t)$	$\frac{s}{s^2 + \omega^2}$
19. Exponentially decaying cosine	$e^{-at}\cos(\omega t)$	$\frac{s + a}{(s + a)^2 + \omega^2}$