

---

**UNIVERSITI SAINS MALAYSIA**

First Semester Examination  
2013/2014 Academic Session

December 2013 / January 2014

**EEK 471 – ADVANCED POWER ELECTRONIC**

**[ELEKTRONIK KUASA LANJUTAN]**

Duration 3 hours  
Masa : 3 jam

---

Please check that this examination paper consists of **THIRTEEN (13)** pages of printed material before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **TIGA BELAS (13)** muka surat bercetak sebelum anda memulakan peperiksaan ini]*

**Instructions:** This question paper consists **SIX (6)** questions. Answer **FIVE (5)** questions. All questions carry the same marks.

**Arahan:** Kertas soalan ini mengandungi **ENAM (6)** soalan. Jawab **LIMA (5)** soalan. Semua soalan membawa jumlah markah yang sama]

Answer to any question must start on a new page.

*[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru]*

“In the event of any discrepancies, the English version shall be used”.

***[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai]***

1. (a) Huraikan perbezaan di antara penerus 3 fasa semi kawalan dan kawalan penuh  
*Describe the differences between a semi controlled and a fully controlled 3 phase rectifier*

(20 markah/marks)

- (b) Penerus terkawal 3 fasa digunakan untuk membekalkan kuasa ke beban induktif tinggi dari punca AU  $450 V_{rms}$  50 Hz. Arus beban pada sisi AT ialah 20A. galangan talian pada setiap fasa ialah 5 mH.

*A three-phase fully controlled bridge rectifier is used to supply power to a highly inductive load from a  $450 V_{rms}$  50 Hz ac supply. The load current on dc side is 20 A. The line inductance of each phase is 5 mH.*

- (i) Lakarkan voltan keluaran untuk sudut picuan  $\alpha=30^\circ$   
*Draw the output voltage for firing angle  $\alpha=30^\circ$*

(30 markah/marks)

- (ii) Tentukan sudut picuan  $\alpha$  yang diperlukan untuk menghasilkan voltan keluaran 230V  
*Determine the firing angle  $\alpha$  required to produce an output voltage of 230V*

(30 markah/marks)

- (iii) Kirakan jumlah kuasa  
*Calculate the total power.*

(20 markah/marks)

2. (a) Lakarkan tatarajah litar pengawal dwihala satu fasa menggunakan satu tiristor dan 4 diod. Huraikan operasi litar dengan bantuan bentuk gelombang keadaan malar untuk beban berperintang

*Sketch the circuit diagram of a single-phase bidirectional controller with one thyristor and four diodes. Describe operation of the circuit with the aid of key steady state waveforms for the case of resistive load.*

(20 markah/marks)

- (b) Terbitkan persamaan voltan keluaran rms untuk pengawal dwihala satu fasa seperti dalam S2(a).

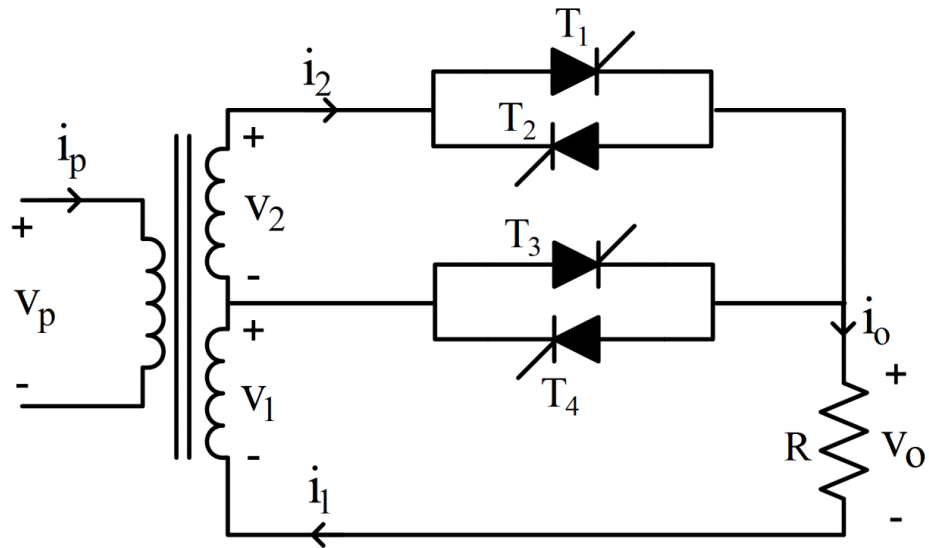
*Derive the expression for rms output voltage for the single-phase bidirectional controller given in Q2(a).*

(10 markah/marks)

- (c) Suatu transformer satu fasa penukar top (ditunjukkan oleh Rajah S2c) membekalkan beban perintang tulen  $6 \Omega$  dari sumber AU  $230 V_{rms}$ , 50 Hz. Voltan sekunder masing-masing  $V_1$ ,  $V_2$  adalah 140V dan 120 V. Sistem beroperasi pada julat kawalan  $3 [V_1 < V_o < (V_1 + V_2)]$  dan sudut picuan tiristor  $T_1$  dan  $T_2$  ialah  $90^\circ$ . Tentukan

*A single-phase transformer tap changer (shown in Figure Q2C) is feeding a purely resistive load of  $6 \Omega$  from an ac source of  $230 V_{rms}$  50 Hz. The secondary voltages  $V_1$  and  $V_2$  are 140V and 120 V respectively. The system is operating in control range  $3 [V_1 < V_o < (V_1 + V_2)]$  and firing angle of thyristors  $T_1$  and  $T_2$  is  $90^\circ$ . Determine*

- (i) Voltan keluaran rms  $V_o$ ,  
*the rms output voltage  $V_o$ ,* (15 markah/marks)
- (ii) Arus rms tiristor  $T_1$  dan  $T_2$ ,  
*the rms currents of thyristor  $T_1$  and  $T_2$ ,* (10 markah/marks)
- (iii) Arus rms tiristor  $T_3$  dan  $T_4$ ,  
*the rms currents of  $T_3$  and  $T_4$ , and* (10 markah/marks)
- (iv) Faktor kuasa masukan  
*the input power factor.* (35 markah/marks)



Rajah S2C  
Figure Q2C

3. (a) Dengan bantuan tatarajah litar dan bentuk gelombang keadaan malar huraikan operasi inverter titi-penuh satu fasa dengan keluaran gelombang segiempat untuk beban jenis RL. Huraikan juga fungsi diod meroda bebas yang digunakan secara balikan selari dengan suis kuasa.

*With the aid of circuit diagrams and steady state waveforms explain the operation of single-phase full-bridge inverter with square wave output for RL-type load. Also explain the function of free-wheeling diodes used in anti-parallel with the power switches.*

(25 markah/marks)

- (b) Terbitkan persamaan voltan keluaran asas rms untuk inverter gelombang segiempat yang diberi dalam S3(a).

*Derive expression for the fundamental rms output voltage for the square-wave inverter given in Q3(a).*

(27 markah/marks)

- (c) Inverter PWM titi penuh satu fasa digunakan untuk membekal kuasa ac ke beban induktif dari punca dc 250 V. Komponen perintang dan induktif beban masing-masing mempunyai  $10\Omega$  dan 2mH. Inverter beroperasi pada frekuensi 50Hz dan kitar tugas 60%. Kirakan

*A single-phase full-bridge PWM inverter is used to supply ac power to an inductive load from a dc source of 250 V. The resistive and inductive components of the load are  $10\Omega$  and 20mH respectively. The inverter operates at a frequency of 50Hz and duty cycle is 60%. Determine the following:*

...6/-

- (i) Nilai rms jumlah voltan keluaran ac  
*The rms value of total ac output voltage.* ( 4 markah/marks)
- (ii) Nilai rms harmonic asas dan 2 peringkat terendah (3<sup>rd</sup> dan 5<sup>th</sup>).  
*The rms value of the fundamental and two lowest-order harmonics (3<sup>rd</sup> and 5<sup>th</sup>).*  
(24 markah/marks)
- (iii) Nilai rms jumlah komponen harmonik voltan keluaran  
*The rms value of total harmonic component of the output voltage.*  
(8 markah/marks)
- (iv) Jumlah Herotan Harmonik  
*The total harmonic distortion THD* (8 markah/marks)
- (v) Nisbah pindah voltan ( $T_{vv}$ ) dari komponen asas inverter  
*The voltage transfer ratio ( $T_{vv}$ ) of the fundamental component of the inverter*  
(4 markah/marks)
4. (a) Senaraikan 2 penggunaan penukar boost  
*List down two applications of boost converters.*  
(4 markah/marks)

- (b) Lakarkan tatarajah litar penukar buck-boost dan huraikan operasinya dengan bantuan bentuk gelombang keadaan malar menjurus ke terbitan persamaan antara voltan masukan  $V_{in}$  dan voltan keluaran  $V_o$ .

*Sketch circuit diagram of a buck-boost converter and describe its operation with the aid of key steady state waveforms leading to the derivation of an expression between input voltage  $V_{in}$  and output voltage  $V_o$ .*

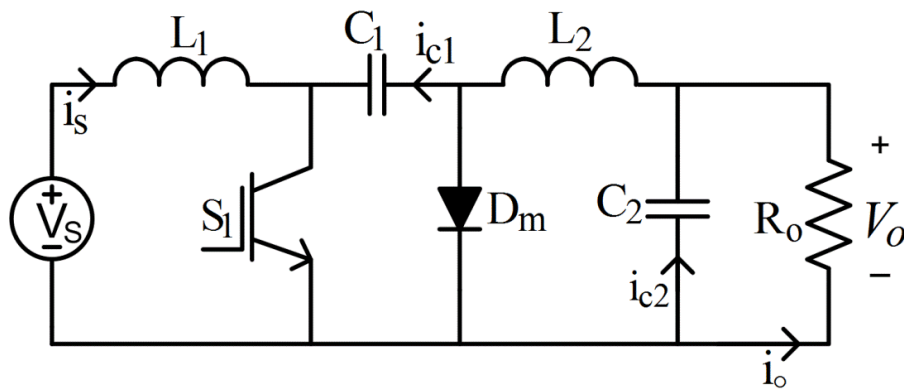
(48 markah/marks)

- (c) Penukar Cuk (seperti ditunjukkan oleh Rajah 4c) digunakan untuk mengatur kuasa AT ke beban perintang 35W dari sumber dc 50V. Nilai komponen litar:  $L_1 = 200 \mu H$ ,  $L_2 = 170 \mu F$ ,  $C_1 = 220 \mu F$ , dan  $C_2 = 180 \mu F$ . Penukar beroperasi pada frekuensi pensuisan 30 kHz dan kitar tugas  $D=0.60$ . Kirakan

*A Cuk converter (shown in Figure Q4c) is used to supply regulated dc power to resistive load of  $35 \Omega$  from a dc source of 50 V. The value of the circuit components are:  $L_1 = 200 \mu H$ ,  $L_2 = 170 \mu F$ ,  $C_1 = 220 \mu F$ , and  $C_2 = 180 \mu F$ . The converter operates at a switching frequency of 30 kHz and duty cycle  $D = 0.60$ . Determine;*

- (i) Purata voltan keluaran  $V_o$   
*the average output voltage  $V_o$  ,* (5 markah/marks)
- (ii) Purata arus masukan  $I_s$   
*the average input current  $I_s$  ,* (5 markah/marks)

- (i) Riak arus puncak ke puncak induktor  $L_1$  dan  $L_2$  ,  
*the peak to peak ripple current of inductors  $L_1$  and  $L_2$  ,*  
(10 markah/marks)
  
- (ii) Riak voltan puncak ke puncak kapasitor  $C_1$ , dan  $C_2$ ,  
*the peak to peak ripple voltage of the capacitors  $C_1$ , and  $C_2$ ,*  
(10 markah/marks)
  
- (iii) Arus puncak transistor  $I_p$   
*the peak current of the transistor  $I_p$ .*  
(18 markah/marks)



Rajah S4c  
Figure Q4c

5. (a) Lakar tatarajah litar inverter titi penuh salunan siri yang terdiri dari suis dwi hala dan huraikan operasinya untuk mod tindihan lampau?

*Sketch circuit diagram of a full-bridge series resonant inverter with bidirectional switches and describe its operation for overlapping mode of operation?*

(20 markah/marks)

- (b) Untuk litar salunan siri berbeban dari S5(a), terbitkan persamaan yang menghubungkan gandaan voltan litar dan frekuensi pensuisan.

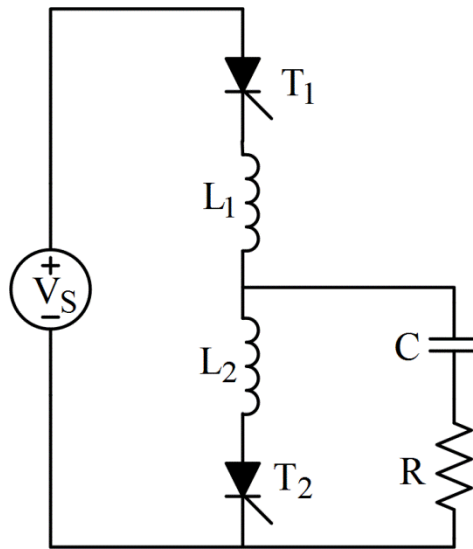
*For the series loaded resonant circuit given in Q5(a), derive an expression that relates the voltage gain of the circuit with its switching frequency.*

(20 markah/marks)

- (c) Inverter salunan siri digunakan untuk membekalkan kuasa ac ke beban perintang dari sumber dc seperti ditunjukkan oleh Rajah S5(c). Voltan masukan ke inverter ialah 200V dan frekuensi pensuisan ialah 5 kHz. Nilai komponen litar:  $L_1 = L_2 = 50\mu H$ ,  $C = 5\mu F$  and  $R = 5\Omega$ . Nilai masa buka tiristor yang digunakan dalam litar ialah  $t_q = 9\mu S$ . Dari sistem ini kirakan parameter berikut:

*A series resonant inverter is used to supply ac power to a resistive load from a dc source as shown in Figure Q5C. The input dc voltage to the inverter is 200 V and its switching frequency is 5 kHz. The values of other circuit components are:  $L_1 = L_2 = 50\mu H$ ,  $C = 5\mu F$  and  $R = 5\Omega$ . The turn of time of the thyristors that are used in the circuit is  $t_q = 9\mu S$ . Evaluate the following parameters of the system*

- (i) Faktor anjalan  $\alpha$  dan frekuensi salunan  $f_r$   
*the damping factor  $\alpha$  and resonant frequency  $f_r$ ,* (6 markah/marks)
- (ii) Masa tutup  $t_{off}$ ,  
*the available turn off time  $t_{off}$ ,* (4 markah/marks)
- (iii) Frekuensi maksimum yang dibenarkan  $f_{max}$ ,  
*the maximum permissible frequency  $f_{max}$ ,* (4 markah/marks)
- (iv) Voltan puncak ke puncak kapasitor  $V_{pp}$   
*the peak to peak capacitor voltage  $V_{pp}$ ,* (28 markah/marks)
- (v) Arus beban puncak  $I_{peak}$   
*the peak load current  $I_{peak}$ .* (18 markah/marks)



Rajah S5(c)  
Figure Q5(c)

6. (a) Lakarkan tatarajah litar penukar dc-dc titi penuh dan huraikan operasinya dengan bantuan bentuk gelombang keadaan malar menjurus ke terbitan dan persamaan yang menghubungkan voltan keluaran dan voltan masukan menerusi kitar tugas  $D$

*Sketch the circuit diagram of a full-bridge dc-dc converter and describe its operation with the aid of relevant steady state waveforms leading to the derivation of an expression that relates its output voltage with the input voltage through the duty cycle  $D$ .*

(32 markah/marks)

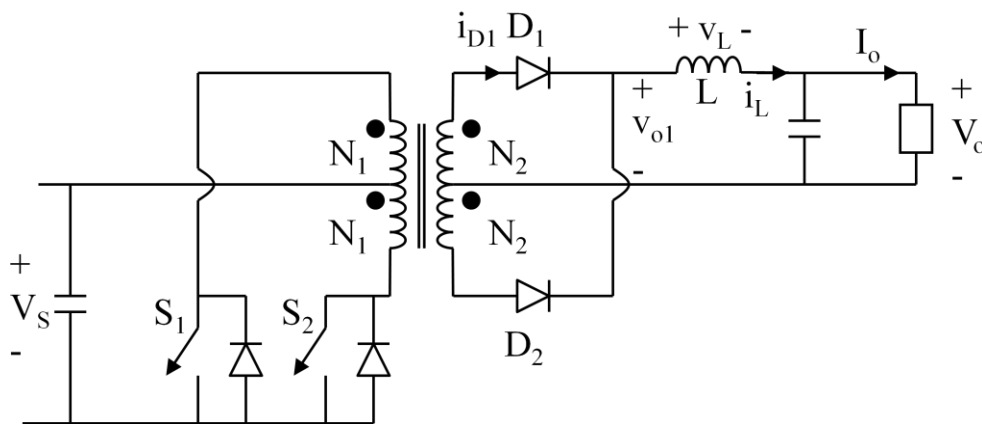
- (b) Penukar tolak-tarik dari Rajah S6b menghasilkan voltan keluaran  $V_o = 45\text{ V}$  merentasi beban perintang  $2\ \Omega$  apabila beroperasi pada kitar tugas 0.5. Kejatuhan voltan keadaan bukaan diod adalah masing-masing 1.2 V dan 0.7 V. Nisbah pusingan pengubah ialah  $a = N_s/N_p = 0.25$ . Abaikan kehilangan dalam pengubah, arus riak beban dan sumber masukan. Tentukan:

*The push-pull converter of Figure Q6b produces an output voltage  $V_o = 45\text{ V}$  across a resistive load of  $2\ \Omega$  when operating at a duty cycle of 0.5. The on-state voltage drop of transistors and diodes are 1.2 V and 0.7 V, respectively. The turn ratio of the transformer is  $a = N_s/N_p = 0.25$ . Neglect the losses in the transformer and the ripple current of the load and input supply is negligible. Determine*

- (i) Purata arus masukan  $I_s$   
*The average input current  $I_s$ ,* (20 markah/marks)
- (ii) Kecekapan  $\eta$   
*The efficiency  $\eta$ ,* (8 markah/marks)
- (iii) Purata arus ( $I_A$ ), arus rms ( $I_{rms}$ ) dan arus puncak transistor ( $I_p$ )  
*The average current ( $I_A$ ), rms current ( $I_{rms}$ ) and peak transistor current ( $I_p$ )* (12 markah/marks)
- (iv) Voltan transistor litar terbuka  
*The open circuit transistor voltage.* (4 markah/marks)

- (c) Lakarkan tatarajah litar pembekal kuasa ac mod salunan dan dwihala  
*Draw the circuit diagrams of resonant mode ac power supply and bidirectional ac power supply.*

(24 markah/marks)



Rajah S6(b)  
Figure Q6(b)