UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2009/2010

SUBJECT NAME	:	POWER ELECTRONICS
SUBJECT CODE	:	BEE 4113
COURSE	:	4 BEE
EXAMINATION DATE	:	NOVEMBER 2009
DURATION	:	2 ½ HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS FROM **FIVE (5)** QUESTIONS

THIS EXAMINATION PAPER CONSISTS OF (9) PAGES

Q1 (a) Define the purpose of Power Electronics Converters.
(3 marks)

(b) List three causes of rapid growth in power electronics.
(3 marks)

(c) State three effects of reverse recovery of power diode and sketch the forward current characteristic for soft-recovery and fast-recovery operation.
(5 marks)

(d) Differentiate between a snubber circuit and a gate driver circuit.
(6 marks)

(e) Figure Q1(e) shows the control signal, voltage and current of a MOSFET which operates at 100 kHz. V_d is the voltage across the switch during off-state and I_o is the current flowing through the switch during on-state. The current rise time, t_{ri} is 12 ns and the turn-off interval time, t_{off} is 60% of its switching period. The total average power dissipated is 8 W while the current flowing through the switch during on-state is 4 A. Determine

(i) the turn-on interval time, t_{on}, of the switch
(ii) the average power dissipated during on-state, P_{on}
(iii) the average switching power loss, P_s
(iv) the voltage fall time, t_{fv}, if the turn-off crossover interval $t_{c(off)}$ = 50 ns.
(8 marks)

Q2 (a) Describe briefly the function of a rectifier. List two advantages of full-wave rectifiers as compared to half-wave rectifiers.
(3 marks)

(b) Given the full bridge uncontrolled rectifier as shown in Figure Q2(b) with resistance and inductance as load. Assuming that inductance L is large enough to provide constant current.
(i) Sketch output voltage, V_o across the load of rectifier
(ii) Sketch waveform of the current flowing through diode 1, I_{D1}.
(iii) Sketch waveform of the current flowing through the inductance, I_o.
(6 marks)

(c) Switching devices for the full-bridge rectifier in Figure Q2(b) had been changed from diodes to thyristors. It receives a supply voltage of 240Vrms at 50 Hz frequency. The output current of the load in the discontinuous current mode is given by the expression

$$i_o(\omega t) = 9.58\left[\sin(\omega t - 32.14°) - 0.388e^{\frac{-(\omega t - 0.96)}{0.628}}\right] A$$

From information given, determine

(i) The resistance R and inductance L of the load;

(ii) The delay angle, (α);

(iii) The average output voltage, V_{oavg}, if extinction angle β=212°;

(iv) The average output current, $I_{o,avg}$;

(v) The power absorbed by the load if the rms output current is 6.03A; and

(vi) The efficiency of the rectifier.

(16 marks)

Q3 (a) Define what is switching-mode regulator and list down four basic types of switching-mode regulators.

(5 marks)

(b) State the two ways to vary the output voltage of DC-DC converter with the aid of the signal waveforms.

(4 marks)

(c) Define the duty cycle D, for switching frequency f_s, of a DC converter.

(2 marks)

(d) Explain briefly the operation of the converter in Continuous Current Mode (CCM) and Discontinuous Current Mode (DCM).

(4 marks)

(e) A buck-boost converter circuit as shown in Figure Q3(e) has Vs = 9V, D = 0.6. R = 15Ω, L = 60 μH, C = 400 μF and switching frequency f_s= 40 kHz.

(i) Derive the output voltage formula using volt-second balance technique.

(ii) Calculate the output voltage.

(iii) Determine the average, maximum. and minimum inductor current.

(iv) Find the output voltage ripple.

(10 marks)

Q4 (a) Draw the equivalent circuit of the single phase full bridge inverter as given in Figure Q4(a) when

(i) Power Semiconductor devices T_1 - T_2 are closed and T_3 - T_4 are open.
(ii) Power Semiconductor devices T_1 - T_2 are open and T_3 - T_4 are closed.
(iii) Draw the output voltage of the inverter during for Q4 a(i).
(iv) Draw the output voltage of the inverter during for Q4 a(ii).

(8 marks)

(b) A quasi square-wave full-bridge inverter has a fundamental current of 10A rms at $\alpha = 0^0$, an output frequency of 50Hz and RLC series load with R=20Ω, L=25.465mH and C=455μF.

(i) Calculate the suitable source voltage.
(ii) Calculate the THD of the load current up to 9^{th} order harmonic when the value of $\alpha = 0^0$.
(iii) Calculate the THD of the load current up to 9^{th} order harmonic when the value of $\alpha = 30^0$.

(17 marks)

Q5. (a) Although the half-wave AC phase controller can vary the output voltage by varying the delay angle α, it is not generally used in practical applications. State two disadvantages of single phase half-wave AC phase controllers.

(4 marks)

(b) Figure Q5(b) shows a single phase full wave ac voltage controller is being employed for controlling the power flow from 220 Vrms, 50 Hz source into a load circuit consisting of a 4Ω load resistor and a 6 Ω load inductance.

(i) Calculate the control range of the firing angle α.
(ii) Sketch the gate current i_{g1}, i_{g2}, output current, i_o, and the output voltage v_o, at the minimum value of the firing angle $\alpha = 0$.
(iii) Determine the maximum value of RMS load current.
(iv) Determine the maximum value of output power and power factor.
(v) Determine the maximum value of average and RMS thyristor current.

(21 marks)

FINAL EXAMINATION

SEMESTER/SESION	: I/2009/2010	COURSE : 4 BEE	
SUBJECT NAME	: POWER ELECTRONICS	SUBJECT CODE : BEE 4113	

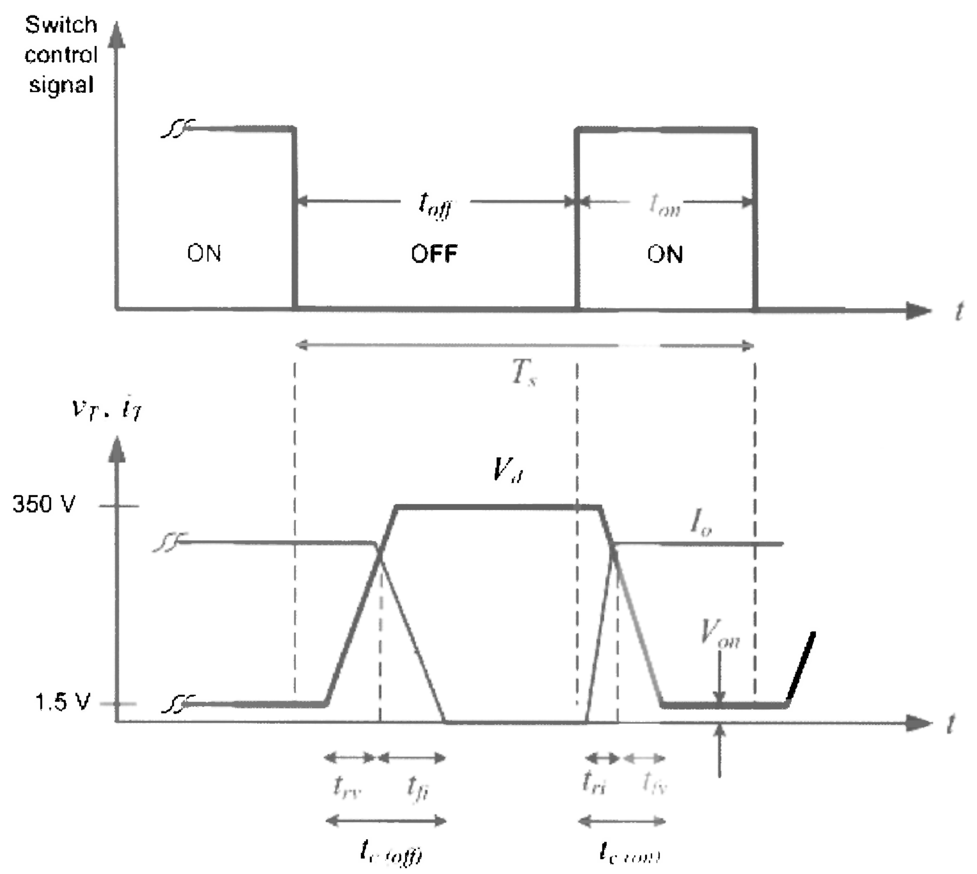

FIGURE Q1(e)

FINAL EXAMINATION

SEMESTER/SESION : I/2009/2010 COURSE : 4 BEE
SUBJECT NAME : POWER ELECTRONICS SUBJECT CODE : BEE 4113

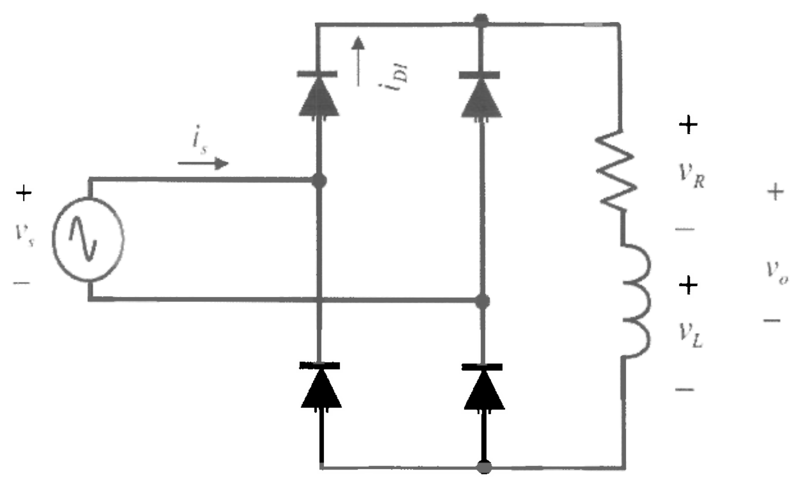

FIGURE Q2(b)

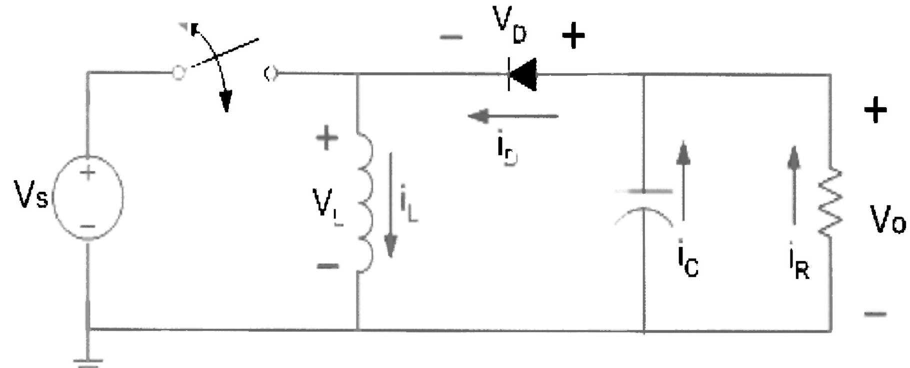

FIGURE Q3(e)

FINAL EXAMINATION

SEMESTER/SESION : 1/2009/2010 COURSE : 4 BEE
SUBJECT NAME : POWER ELECTRONICS SUBJECT CODE : BEE 4113

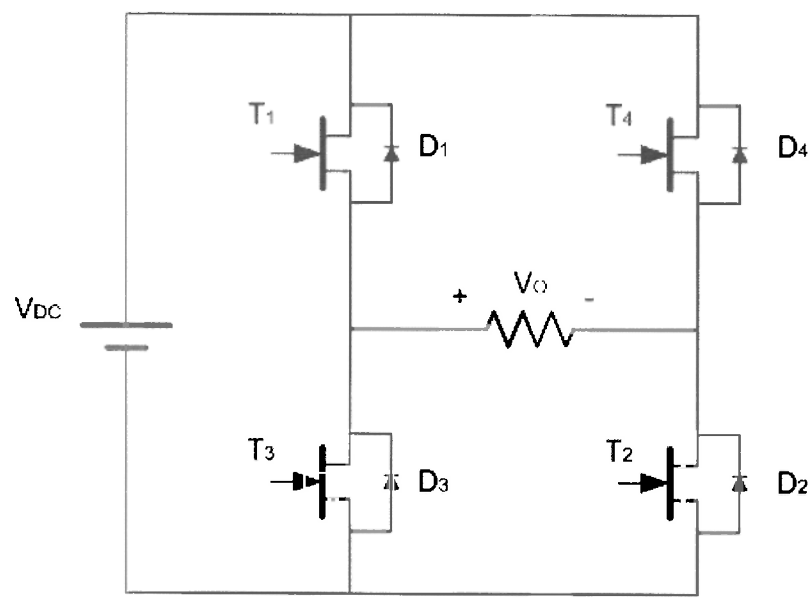

FIGURE Q4(a)

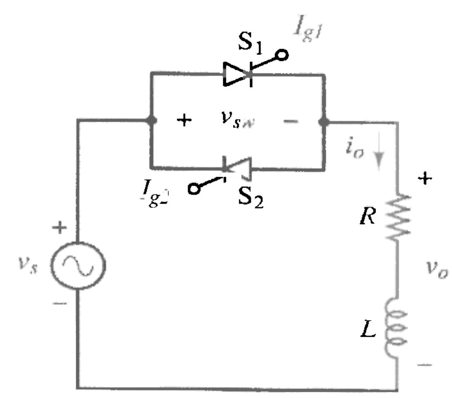

FIGURE Q5(b)

FINAL EXAMINATION

SEMESTER/SESION : 1/2009/2010 COURSE : 4 BEE
SUBJECT NAME : POWER ELECTRONICS SUBJECT CODE : BEE 4113

Formulas

Trigonometry Identity
$2\sin^2 A = 1 - cos2A$

Exponential Integration
$\int e^{ax}dx = \frac{e^{ax}}{a}$

Switching Power Loss
$t_{c(on)} = t_{ri} + t_{fv}$
$t_{c(off)} = t_{rv} + t_{fi}$
$P_s = \frac{1}{2}V_d I_o f_s(t_{c(on)} + t_{c(off)})$
$P_{on} = V_{on} I_o \frac{t_{on}}{T_s}$
$P_T = P_{on} + P_s$

Full Bridge Rectifier with R-L load
$i_o(\omega t) = \frac{V_m}{Z}[\sin(\omega t - \theta) - \sin(\alpha - \theta)\, e^{-\frac{(\omega t - \alpha)}{\omega \tau}}]$
$V_{oavg} = \frac{1}{\pi}\int_{\alpha}^{\beta} V_m sin\omega t d\omega t$
$Z = \sqrt{R^2 + (X_L)^2}$
$\theta = tan^{-1}\left(\frac{X_L}{R}\right)$
$\tau = \frac{L}{R}$

DC-DC Converter

$$I_{max} = I_L + \frac{\Delta i_L}{2} = \frac{V_S D}{R(1-D)^2} + \frac{V_S DT}{2L}$$

$$I_{min} = I_L - \frac{\Delta i_L}{2} = \frac{V_S D}{R(1-D)^2} - \frac{V_S DT}{2L}$$

$$\frac{\Delta V_O}{V_O} = \frac{D}{RCf}$$

FINAL EXAMINATION

SEMESTER/SESION : I/2009/2010
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Single-phase Full-wave AC Voltage Controller

$$i_{S1} = \frac{V_m}{Z}\left[\sin(\omega t - \theta) - \sin(\alpha - \theta)\, e^{\frac{R}{\omega L}(\omega t - \alpha)}\right]$$

$$V_{o(rms)} = \frac{V_m}{\pi}\left[\beta - \alpha + \frac{sin2\alpha}{2} - \frac{sin2\beta}{2}\right]^{1/2}$$

$$I_{T(avg)} = \frac{1}{2\pi}\int_{\alpha}^{\beta} i_{S1}\, d(\omega t)$$

$$I_{T(rms)} = \left[\frac{1}{2\pi}\int_{\alpha}^{\beta} (i_{S1})^2 d(\omega t)\right]^{1/2}$$

$$\beta - \alpha = \delta = \pi$$