UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
SEPTEMBER 2014 SESSION

SUBJECT CODE : FLB24053
SUBJECT TITLE : POWER ELECTRONICS
LEVEL : BACHELOR
TIME / DURATION : 2.00 PM – 12.00 PM
( 3.0 HOURS )
DATE : 11 JANUARY 2015

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. Please write your answers on the answer booklet provided.
4. Answer should be written in blue or black ink except for sketching, graphic and illustration.
5. This question paper consists of TWO (2) sections, Section A and B. Answer all questions in Section A. For section B, answer TWO (2) questions only.
6. Answer all questions in English.

THERE ARE 6 PRINTED PAGES OF QUESTIONS, EXCLUDING THIS PAGE AND APPENDIX.
SECTION A (Total: 40 marks)

INSTRUCTION: Answer ALL questions.
Please use the answer booklet provided.

Question 1

(a) Give the definition of POWER ELECTRONICS. 

(3 marks)

(b) Explain by using a simple table, 2 advantages of IGBT in terms of power rating and switching frequency as compared to bipolar transistor and MOSFET. 

(6 marks)

(c) A portable electric hair dryer is equivalent to 200 $\Omega$ load. It is to be supplied with adequate DC power. The DC power shall be converted using a type of rectifier which input is sourced from Malaysian utility system (240 Vrms, 50 Hz). Determine:

i. The DC Power, $P_{DC}$, and the AC power, $P_{AC}$, obtained using a half wave rectifier. 

(4 marks)

ii. The DC Power, $P_{DC}$, and the AC power, $P_{AC}$, obtained using a full wave rectifier. 

(4 marks)

iii. Compare/calculate the efficiencies of both systems. State which rectifier type that can produce more heat. 

(3 marks)

(Hint: HALF WAVE : $V_{DC} = \frac{V_M}{\pi}; V_{RMS} = \frac{V_M}{2}$ and
FULL WAVE BRIDGE : $V_{DC} = \frac{2\cdot V_M}{\pi}; V_{RMS} = \frac{V_M}{\sqrt{2}}$)
Question 2

(a) Explain the following thyristor turn-off method:
   i. Natural / line commutation
   ii. Forced commutation
   (6 marks)

(b) In a certain portable walkie-talkie project, the engineer is provided with a portable battery of 2AH 7V (can be operated from 5V to 9V). The walkie talkie has circuits which need a supply of 3.3V.

   (i) Draw the circuit of suitable DC-DC converter type.
   (ii) Produce the equivalent schematic when the main transistor switches ON
   (iii) Produce the equivalent schematic when the main transistor switches OFF.
   (6 marks)

(c) A student is designing a linear power supply using a power transistor. The load is supplied through the collector and the transistor is operated in common emitter configuration. Given $h_{FE} = 20$, find the required base current, $I_B$ if the transistor is used to supply current of 240.0 A to the load.
   (3 marks)

(d) A single-phase half-wave thyristor converter is supplied with Malaysian utility supply. (240Vrms 50Hz). The firing angle $\alpha$ is set to 30°. The converter supplies a 100 $\Omega$ load. Calculate the DC and RMS values of output voltages.
   (5 marks)
SECTION B (Total: 60 marks)

INSTRUCTION: Answer TWO (2) questions only.
Please use the answer booklet provided.

Question 3

A railway vehicle uses an inverter shown in Figure 1. It is used to supply an industrial load which can be assimilated as a resistor and an inductor. Given $V_{DC} = 750V$, $R=15$ ohms, $L=30mH$, $f=50Hz$.

(a) Prove that the amplitudes of the Fourier series output voltage is

$$V_n = \frac{4V_{DC}}{n\pi}.$$

(10 marks)

(b) Calculate the amplitudes of Fourier series for output voltage $V_n$, output current $I_n$, impedance $Z_n$, and power absorbed by load, $P_n$, for $n = 1, 3$ and $5$. Show your calculation for each amplitude values ($V_n$, $I_n$, $Z_n$, $P_n$, $P_{RMS}$). Summarize all amplitudes values in a table as shown in Figure 2.

(17 marks)

(c) Compute the power absorbed by load, $P = \sum P_{n,RMS}$.

(3 marks)

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<table>
<thead>
<tr>
<th>n</th>
<th>F(hz)</th>
<th>$V_n$(V)</th>
<th>$Z_n$(ohms)</th>
<th>$I_n$(A)</th>
<th>$P_n$(W)</th>
<th>$P_{RMS}$(W)</th>
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<td>5</td>
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</tbody>
</table>

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Figure 1

Figure 2
Question 4

Express the output voltage waveform of the FULL WAVE rectifier shown in Figure 3 as a Fourier series.

(a) Find and derive the expression of average value of output voltage, $V_{\text{OUT(DC)}} = a_0$.  (8 marks)

(b) Find and derive the expression of the amplitudes of the even part of the fourier series, $a_n$.  (10 marks)

(c) Find and derive the expression of the amplitudes of the odd part of the fourier series, $b_n$.  (10 marks)

(d) Express the full expression of Fourier series of output voltage.  (2 marks)

Figure 3
Question 5

A certain electronic system is to be operated from 15 Vdc and is equivalent to 8 Ω. However the only source available is 48 Vdc. As an electronics trainee engineer, you are required to design a suitable DC-DC to address the problem. The design requires continuous inductor current. For a guaranteed performance of the DC circuit, the output voltage ripple must be no greater than 0.5 percent. Use a switching frequency of \( f = 100 \) kHz. Assume ideal components. Use also the assumption that the variation of inductor current, \( \Delta i_L \), to be 40% of average inductor current \( i_L \).

(a) Calculate main parameters as follows.

(i) Calculate the duty cycle, \( D \). (3 marks)

(ii) Determine the value of the inductor. (7 marks)

(iii) Calculate the value of capacitor. (5 marks)

(b) Specify the components ratings as follows:

(i) Determine the maximum subjected voltage for the main transistor switch, \( V_{\text{max, switch}} \). (2 marks)

(ii) Determine the maximum subjected voltage for the diode, \( V_{\text{max, diode}} \). (2 marks)

(iii) Determine the maximum subjected current for the main transistor switch, \( I_{\text{max, switch}} \). (3 marks)
(iv) Determine the average subjected current for the main transistor switch, $I_{avg,\, \text{switch}}$. (3 marks)

(v) Determine the maximum subjected current for the diode, $I_{\text{max, \, diode}}$. (2 marks)

(vi) Determine the average subjected current for the diode, $I_{avg, \, \text{diode}}$. (3 marks)

END OF QUESTION PAPER
APPENDIX: FORMULAS

BUCK CONVERTERS

\[ D = \frac{V_o}{V_i} \]

\[ I_L = \frac{V_o}{R} \]

\[ L = \frac{(V_i - V_o)D}{\Delta i_L f} \]

\[ C = \frac{1-D}{8L} \left( \frac{\Delta V_o}{V_o} \right) f \]

SPECIAL INTEGRATION RESULTS

\[ \int_0^\pi \cos(\theta) \cos(n\theta) d\theta = \begin{cases} 0 & n > 1, n = 2, 3, 4, 5, 6, 7... \\ \pi/2 & n = 1 \end{cases} \]

\[ \int_0^\pi \sin(\theta) \sin(n\theta) d\theta = \begin{cases} 0 & n > 1, n = 2, 3, 4, 5, 6, 7... \\ \pi/2 & n = 1 \end{cases} \]

\[ \int_0^\pi \sin(\theta) \cos(n\theta) d\theta = \begin{cases} 2/1-n^2 & n > 1, n = 2, 4, 6, 8... \\ 0 & n > 1, n = 3, 5, 7, 9... \end{cases} \]

FOURIER SERIES

\[ v(\theta) = a_0 + \sum_{n=1}^{\infty} (a_n \cos n\theta + b_n \sin n\theta) \]

\[ a_0 = \frac{1}{T} \int_0^T v(\theta) d(\theta) \]

\[ a_n = \frac{2}{T} \int_0^T v(\theta) \cdot \cos n\theta d(\theta) \]

\[ b_n = \frac{2}{T} \int_0^T v(\theta) \cdot \sin n\theta d(\theta) \]

BOOST CONVERTERS

\[ V_o = \frac{V_i}{1-D} \]

\[ V_L = L \cdot \frac{\Delta I_L}{D \cdot T} \]

\[ (\Delta i_L)_{\text{closed}} = \frac{V_o DT}{L} \]

\[ |\Delta Q| = \left( \frac{V_o}{R} \right) DT = CAV_o \]

\[ \frac{\Delta V_o}{V_o} = \frac{D}{RCf} \]

HALF WAVE THYRISTOR CONVERTER

\[ V_{dc} = \frac{V_m}{2\pi} (1 + \cos \alpha) \]

\[ V_{rms} = \frac{V_m}{\sqrt{2}} \sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}} \]
### APPENDIX: FORMULAS

#### COMMONLY USED FUNCTIONS

<table>
<thead>
<tr>
<th>-A</th>
<th>90 ± A</th>
<th>180 ± A</th>
<th>270 ± A</th>
<th>360 k ± A</th>
</tr>
</thead>
<tbody>
<tr>
<td>-A</td>
<td>cos A</td>
<td>sin A</td>
<td>- sin A</td>
<td>± sin A</td>
</tr>
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<td></td>
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<td>± sin A</td>
</tr>
<tr>
<td>cos A</td>
<td>± sin A</td>
<td>- cos A</td>
<td>± sin A</td>
<td>cos A</td>
</tr>
</tbody>
</table>

\[
\sin (A \pm B) = \sin A \cos B \pm \cos A \sin B \\
\cos (A \pm B) = \cos A \cos B \mp \sin A \sin B \\
\sin 2A = 2 \sin A \cos A \\
\cos 2A = 1 - 2 \sin^2 A = 2 \cos^2 A - 1 \\
\sin A + \sin B = 2 \sin \frac{A + B}{2} \cos \frac{A - B}{2} \\
\sin A - \sin B = 2 \cos \frac{A + B}{2} \sin \frac{A - B}{2} \\
\cos A + \cos B = 2 \cos \frac{A + B}{2} \cos \frac{A - B}{2} \\
\cos A - \cos B = 2 \sin \frac{A + B}{2} \sin \frac{B - A}{2} \\
\sin A \sin B = \frac{1}{2} [\cos (A - B) - \cos (A + B)] \\
\cos A \cos B = \frac{1}{2} [\cos (A - B) + \cos (A + B)] \\
\sin A \cos B = \frac{1}{2} [\sin (A - B) + \sin (A + B)] \\
\int \sin nx \, dx = \frac{-\cos nx}{n} \\
\int \sin^2 nx \, dx = \frac{x}{2} - \frac{\sin 2nx}{4n}