UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, SECOND SEMESTER MAY 2013

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	POWER ELECTRONICS
COURSE CODE:	EE422
TIME ALLOWED:	THREE HOURS

INSTRUCTIONS:

1. There are five questions in this paper. Answer any FOUR questions. Each question carries 25 marks.
2. If you think not enough data has been given in any question you may assume any reasonable values.

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THIS PAPER CONTAINS SIX (6) PAGES INCLUDING THIS PAGE

QUESTION ONE *(25 marks)*

(a) A switch in a power converter is a BJT having the following parameters.

$t_{ri} = t_{fi} = 200ns$ $t_{rv} = t_{fv} = 100ns$ $t_{d(on)} = t_{d(off)} = 100ns$

$V_{CE(sat)} = 1.5V$ $\theta_{ja} = 1^0 \frac{C}{W}$ $T_{j(max)} = 170^0C$

$T_{amb} = 25^0C$

You may assume usual notation.

The load current in the BJT is $30A$ and the transistor is driven by a square wave signal with 50% duty cycle. The collector voltage is $150V$.

(i) Draw the voltage and current waveforms (linearised) for one switching cycle and mark the relevant parameters.

(5 marks)

(ii) Find the device power dissipation in terms of frequency.

(8 marks)

(iii) Determine the maximum switching frequency if the device is operating in free air.

(6 marks)

(b) The base drive circuit of a BJT consists with a source providing a voltage signal of $-8V\ to\ +8V$. This source is connected to the base in series with a 50Ω resistance. Find the turn on delay time.

$V_{BE} = 0.7V$ $C_{BE} = 3nF$ $C_{CB} = 1.5nF$

(6 marks)

QUESTION TWO *(25 marks)*

Consider the fully controlled bridge rectifier shown in Figure-Q2. The supply voltage $V_s = 220V_{rms}$ at $50Hz$, $R = 10\Omega$, $L = 100mH$ and the delay angle $\alpha = 45^0$.

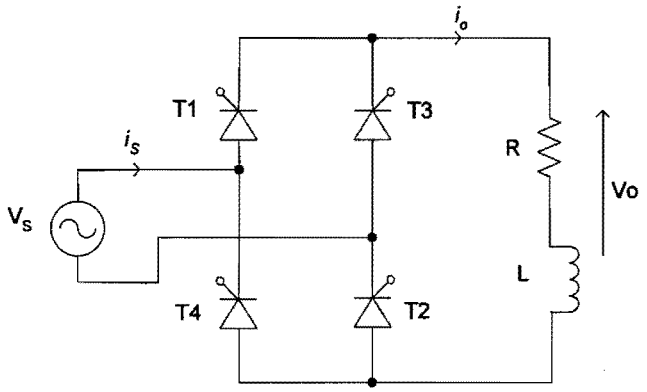


Figure - Q2

(a) Show that if the delay angle $\leq tan^{-1}\left(\frac{\omega L}{R}\right)$, then the current in the load is continuous. (3 marks)

(b) Verify whether the load current is continuous for the given data. Draw the following waveforms with reference to V_S.

(i) Load current i_O. (ii) Load voltage v_O.

(iii) Currents in the thyristors. (iv) Source current i_S.

(5 marks)

(c) Show that the average load voltage is given by $V_{dc} = \frac{2V_m}{\pi} cos\alpha$, where α = delay angle and V_m = max. value of V_S. (5 marks)

(d) Determine the average load voltage and average load current. (2 marks)

(e) Find the power absorbed by the load and the power factor seen by the source. Consider the effects up to 2nd harmonic. (10 marks)

Note: From the Fourier series expansion,

$$v_O(\omega t) = V_O + \sum_n^\infty V_n cos(n\omega_O t + \theta_n); \qquad V_n = \sqrt{a_n^2 + b_n^2}$$

$$a_n = \frac{2V_m}{\pi}\left[\frac{\cos(n+1)\alpha}{(n+1)} - \frac{\cos(n-1)\alpha}{(n-1)}\right]$$

$$b_n = \frac{2V_m}{\pi}\left[\frac{\sin(n+1)\alpha}{(n+1)} - \frac{\sin(n-1)\alpha}{(n-1)}\right] \qquad n = 2, 4, 6, \ldots\ldots$$

QUESTION THREE *(25 marks)*

A three phase uncontrolled half wave rectifier is shown in Figure-Q3. The rectifier is supplied from a $400V_{rms}$, $50Hz$ three phase supply and feeds a resistive load of 5Ω. Assume the phase sequence as $a, b, c.$. Use the sheets provided at the end of the paper for drawing the waveforms.

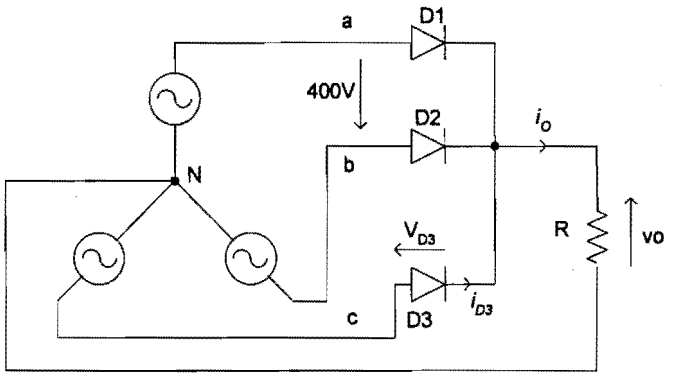


Figure - Q3

(a) Draw the following waveforms.

(i) The output voltage v_o and the output current i_o for one input period showing important values. (2 marks)

(ii) The phase voltage and phase current of phase 'c' for one input period. (4 marks)

(iii) The diode voltage $v_{D3}$and the current i_{D3}. (4 marks)

(b) Determine the following.

(i) Frequency of the harmonic current having highest amplitude

(ii) Average dc output voltage and the average dc output current. (5 marks)

(c) Find the value of inductor which can be used to limit the p-p ripple current to less than 5% of the I_{dc}. State your assumptions. (10 marks)

Note: $$v_o = V_m \frac{3}{\pi} sin \frac{\pi}{3} \left(1 - \sum_n^{\infty} \frac{2}{n^2-1} cos\left(\frac{n\pi}{3}\right) \cos\ n\omega t\right)$$

Where $n = 3, 6, 12, \ldots..$

QUESTION FOUR (*25 marks*)

A dc to dc buck converter is shown in Figure-Q4, in which the switching frequency is f and the duty ratio is D.

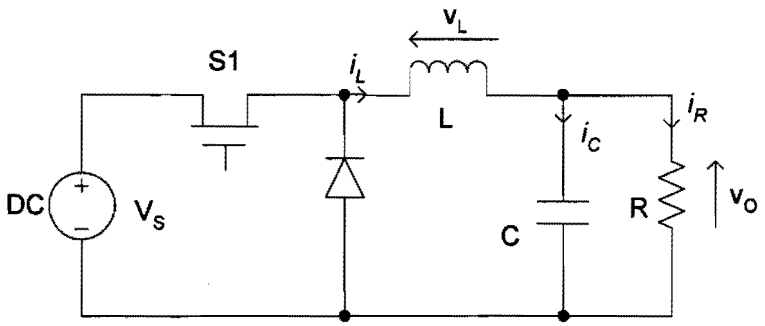


Figure-Q4

(a) (i) Draw the waveforms of v_L and i_L assuming that the C is large.

(2 marks)

(ii) Show that the peak to peak variation of the inductor current is given by $\frac{V_O(1-D)}{Lf}$ assuming that the V_O is constant.

(5 marks)

(iii) Find an expression for the amplitude of the ripple voltage at the output.

(5 marks)

(iv) Assume the following data for this converter.

$V_S = 50V$ $D = 0.6$ $L = 450\mu H$ $C = 100\mu F$

$f = 25KHz$ $R = 25\Omega$

Calculate the following using the above data.

(i) The output voltage.

(ii) Maximum and Minimum inductor currents.

(iii) The output ripple amplitude.

(8 marks)

(b) In a dc to dc boost converter, the supply voltage is $15V$. If the load voltage is $24V$ for a load resistance of 5Ω, find

(i) the required duty ratio,

(ii) the average current drawn from the power supply.

(5 marks)

QUESTION FIVE (25 *marks*)

The switching arrangement for a full bridge IGBT inverter producing a square wave output voltage is shown in Figure-Q5.

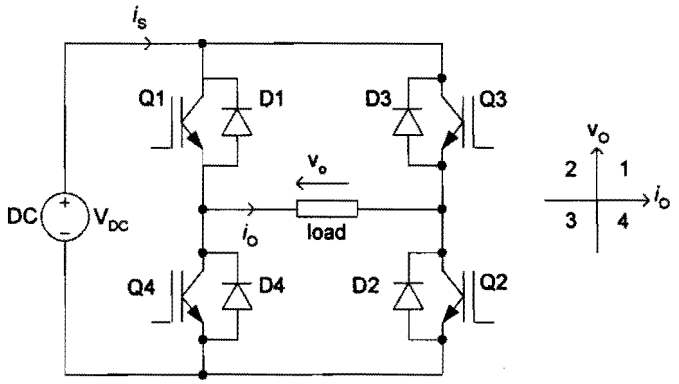


Figure-Q5

(a) Draw the following waveforms assuming that the components are ideal and the load consists of R and L in series. Mark and identify the critical points of the waveforms.

(i) Load voltage v_O.

(ii) Load current i_O.

(iii) Current through Q_1/D_1 and Q_2/D_2.

(iv) Current through Q_3/Q_3 and Q_4/D_4.

(v) Current through the supply, i_S.

(10 marks)

(b) On a drawing of a complete output voltage cycle and with the corresponding output current, mark the devices which are ON in each sub-interval of the cycle specifying the relevant quadrant of operation.

(5 marks)

(c) Assume that the switching frequency of this inverter is $50Hz$, $V_{DC} = 200V$, $R = 20\Omega$, and $L = 40mH$. The load current for the period $0 < t < \frac{T}{2}$ where T is the cycle time, is given by $i_o(t) = \frac{V_{DC}}{R} + \left(I_{min} - \frac{V_{DC}}{R}\right) e^{-\frac{t}{\tau}}$; $\tau = \frac{L}{R}$.

Determine the answers to the following.

(i) Maximum and minimum load current values.

(ii) Power absorbed by the load.

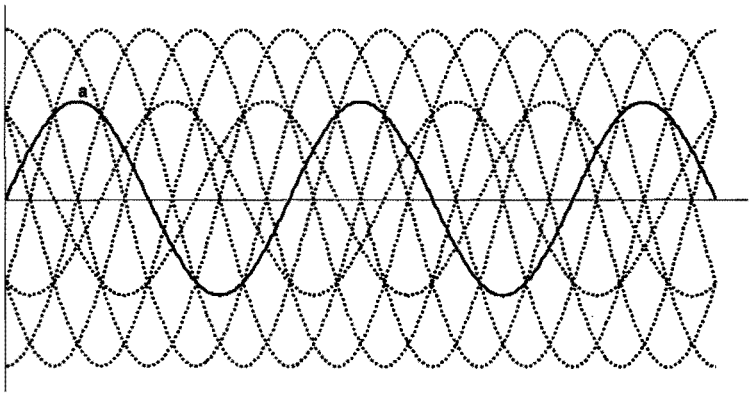
(iii) Average current in the dc source.

(10 marks)

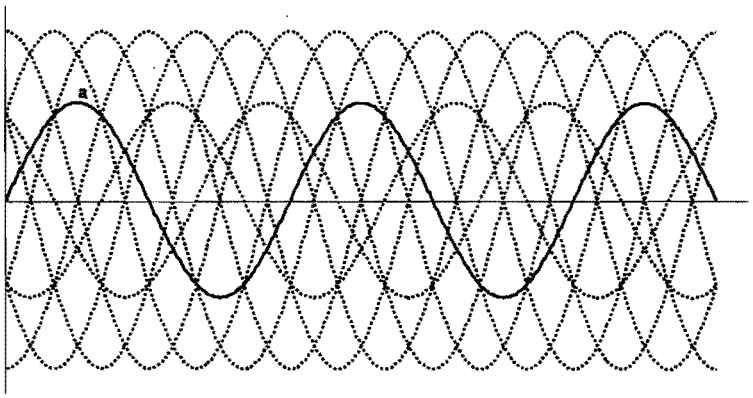
Name: Reg. No:

For question three:

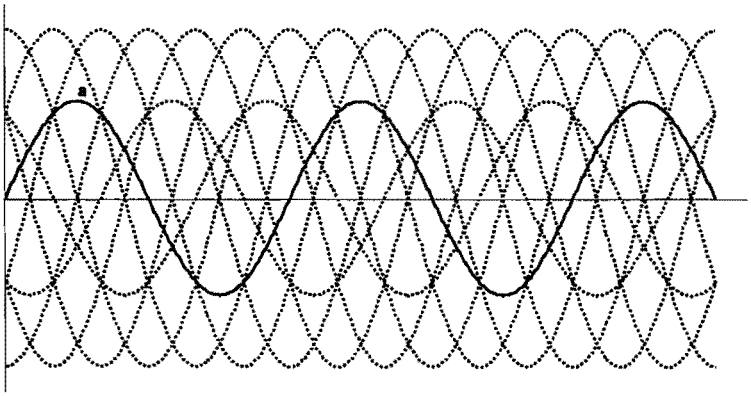
Waveform v_O:



Waveform i_O:



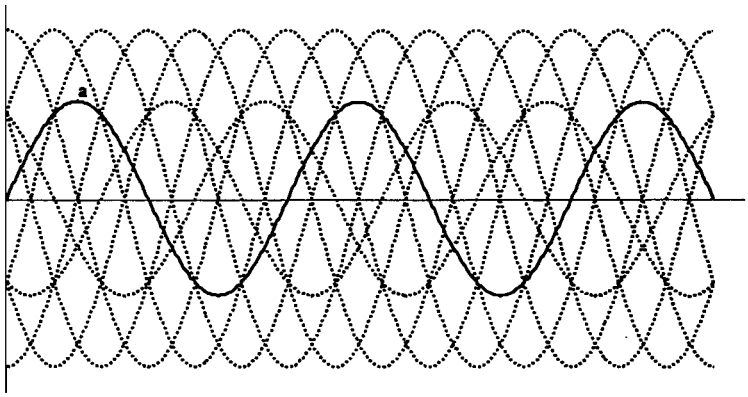
Waveform v_C:



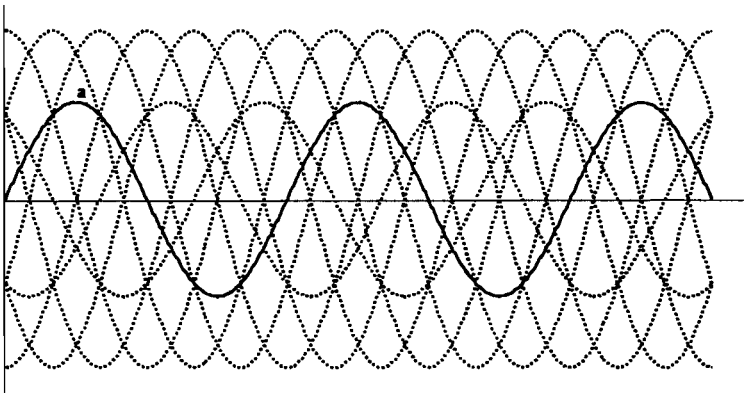
Name: Reg. No:

For question three:

Waveform i_C:



Waveform i_{D3}:



Waveform v_{D3}: