UNIVERSITY OF SWAZILAND

SUPPLIMENTARY EXAMINATION, SECOND SEMESTER

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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 NINE (9) PAGES INCLUDING THIS PAGE

Question 1

The power absorbed by an IRF4104 MOSFET is the pulsed-power waveform like that of Figure below (Not to scale)

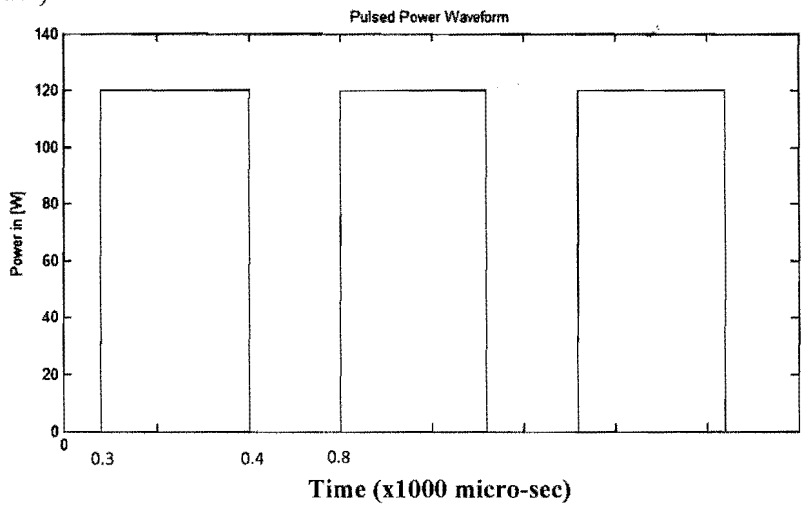


Figure Q.1 (i)

Thermal impedance characteristics of the IRF4104 MOSFET.

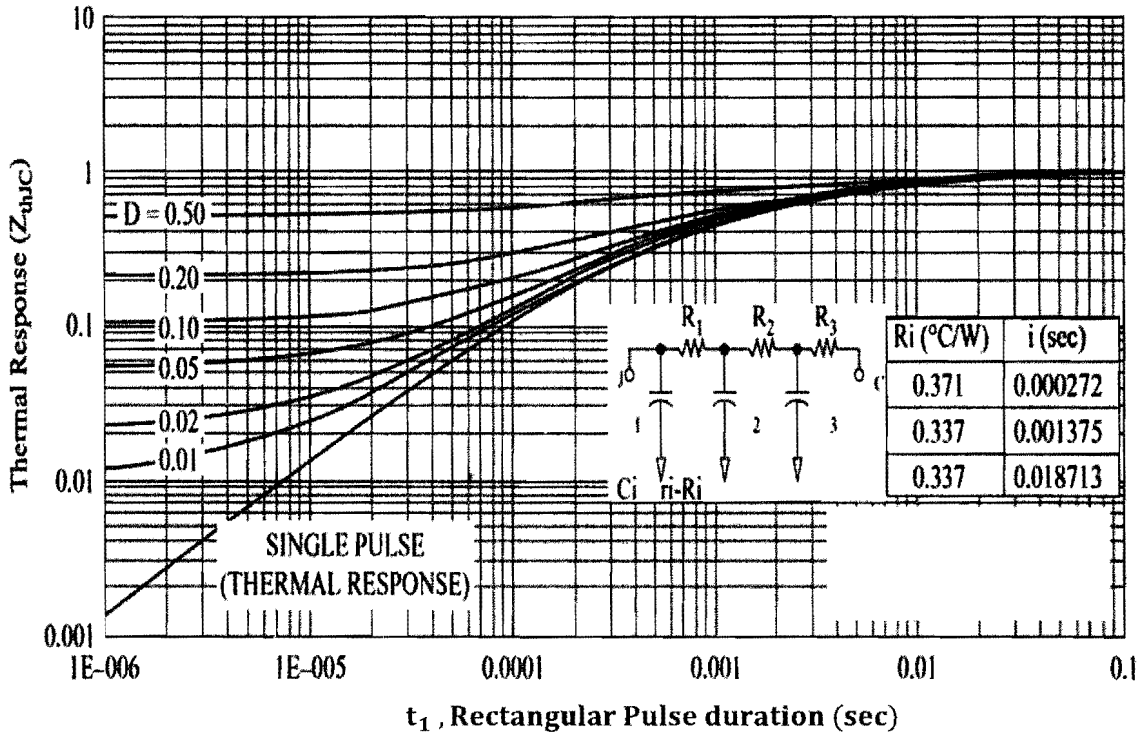


Figure Q.1 (ii)

a) Determine the peak temperature difference between the junction and the case, using the transient thermal impedance from the curves Assume that the case temperature is a constant 75°C. [15]

b) The thermal resistance $R_{\theta,JC}$ for this MOSFET is 1.05°C/W. Compare the result in (a) with a calculation based on the average MOSFET and $R_{\theta,JC}$ [5]

c) A MOSFET with no heat sink absorbs a thermal power of 2.0 W. The thermal resistance from junction to ambient is 40 °C/W, if the ambient temperature is 30°C.

i. Determine the junction temperature. [3]

ii. If the maximum junction temperature is 150°C, how much power can be absorbed without requiring a heat sink? [2]

Question 2

(a) Define the following terms

(i) Frequency modulation ratio,M_f [2]

(ii) Amplitude modulation ratio,M_a [2]

(iii) Total Harmonic Distortion (THD) [2]

(b) The full-bridge inverter is used to produce a 50-Hz voltage across a series *RL* load using bipolar PWM. The dc input to the bridge is 100 V, the amplitude modulation ratio M_a is 0.8, and the frequency modulation ratio ,M_f is 21. The load has a resistance of $R = 10$ and series inductance $L = 20$ mH.

Determine

(i) Frequency of the carrier signal. [2]

(ii) The amplitude of the 50-Hz component of the output voltage and load current, [4]

(iii)The power absorbed by the load resistor, [11]

(iv)The THD of the load current. [2]

Question 3

a)

i. Draw the circuit diagram of a dc to dc buck converter. [4]

ii. Sketch the waveforms for V_L and I_L of the circuit in (i) assuming that C is very large. [3]

iii. Show that the output voltage circuit in (i) depends on the source voltage and the duty ratio. [3]

b) Assume the following data for the converter in (a)

$V_s = 80\,V \quad D = 0.6 \quad L = 450\,\mu H \quad C = 100\,\mu F \quad f = 100\,kHz \quad R = 50\,\Omega$

Calculate the following

i. The output voltage [2]

ii. Output ripple amplitude [2]

iii. Verify if the inverter is operating in CCM. [6]

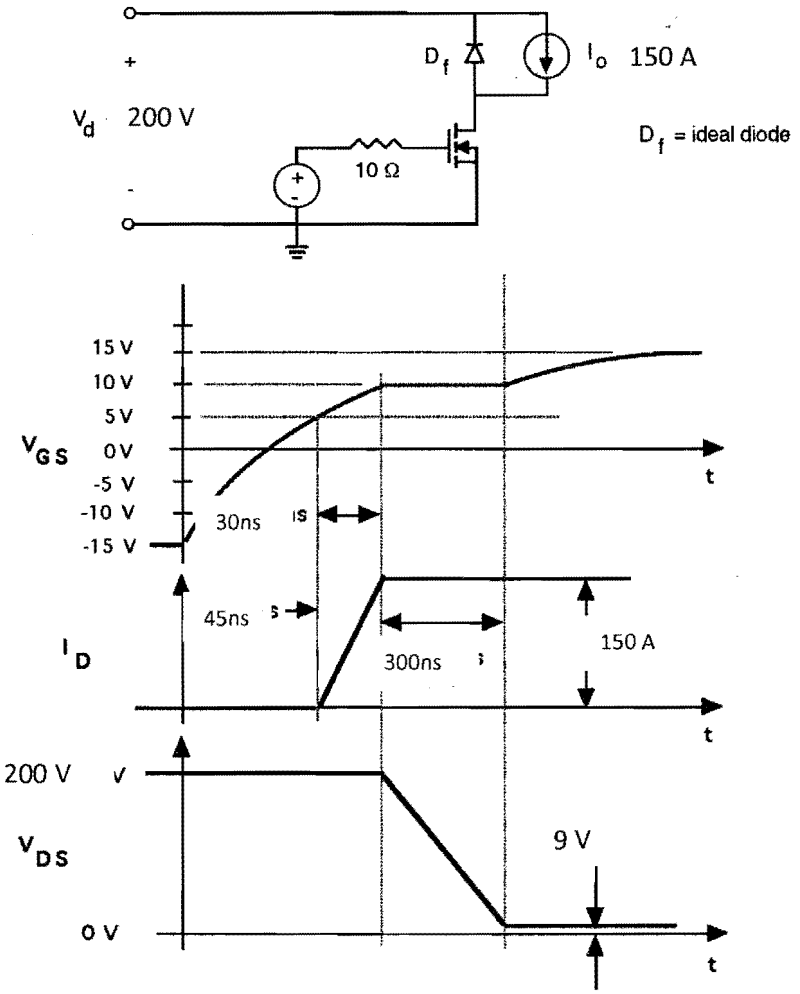
c) A boost converter is required to supply 24 V from a 15 V source for a load resistance of 5 Ω. Determine

i. The required duty ration [3]

ii. The average current drawn from the power supply. [2]

Question 4

a) The MOSFET-driven step-down converter circuit shown below produces the turn-on waveforms which are shown with the circuit diagram.



i. What is the threshold voltage V_{GSth} of the MOSFET explain you're answer? [2]

ii. What is the MOSFET transconductance g_m? [2]

iii. What is the on-state resistance $r_{DS(on)}$ [2]

iv. Given that $t_{ri} = t_{fi}$ and $t_{rv} = t_{fv}$ find the device power dissipation if the switching frequency is 15 kHz. [11]

b) The circuit below shows a controlled half wave rectifier using a thyristor.

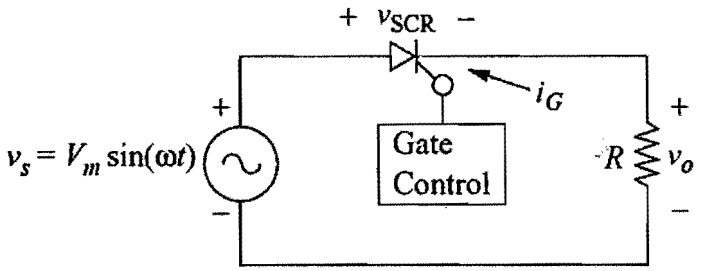


Figure Q.4

(i) Draw the waveforms of the source voltage V_s, the source controlled reactor voltage V_{SCR} and output voltage voltage V_0 for two cycles. [3]

(ii) Find the delay angle to give and output voltage $V_0 = 20$ V , if the RMS voltage of the source $V_{S\_RMS} = 155.56$ V. [5]

Question 5

(a) Refer to the diagrams in figure Q.5(i) and Figure Q.5(ii). Draw the PWM signals for two cycles of the three voltages. Show only for S_1, S_4, S_3, S_5 [5]

Assume that:

- S_1 is on when $V_a < V_{tri}$
- S_4 is on when $V_a > V_{tri}$
- S_3 is on when $V_b < V_{tri}$
- S_6 is on when $V_b > V_{tri}$
- S_5 is on when $V_c < V_{tri}$
- S_2 is on when $V_c > V_{tri}$

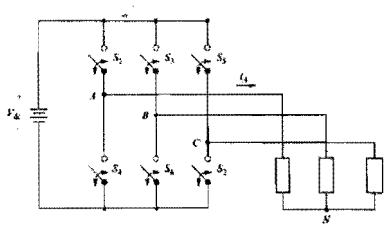


Figure Q.5 (i)

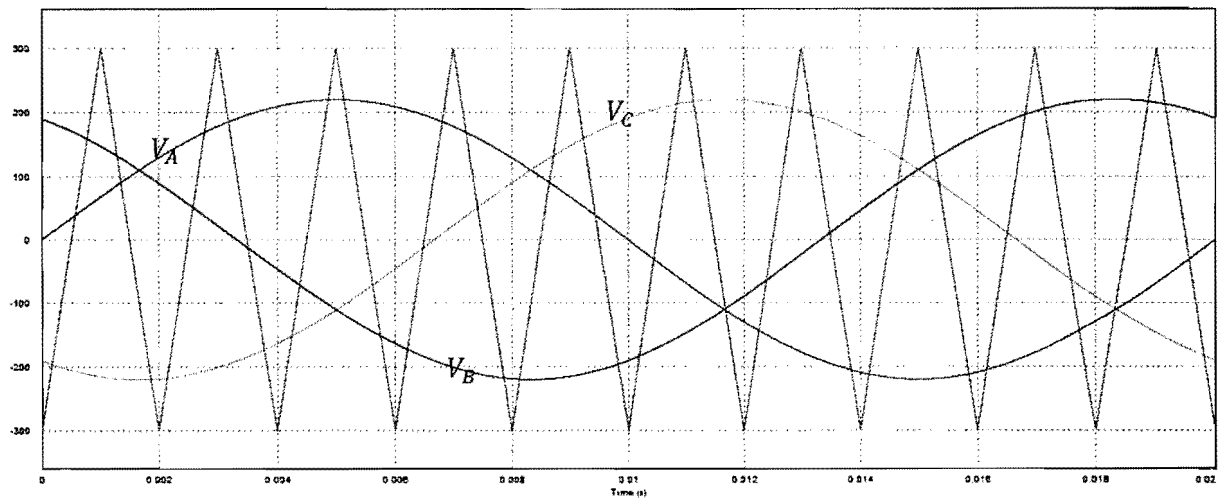
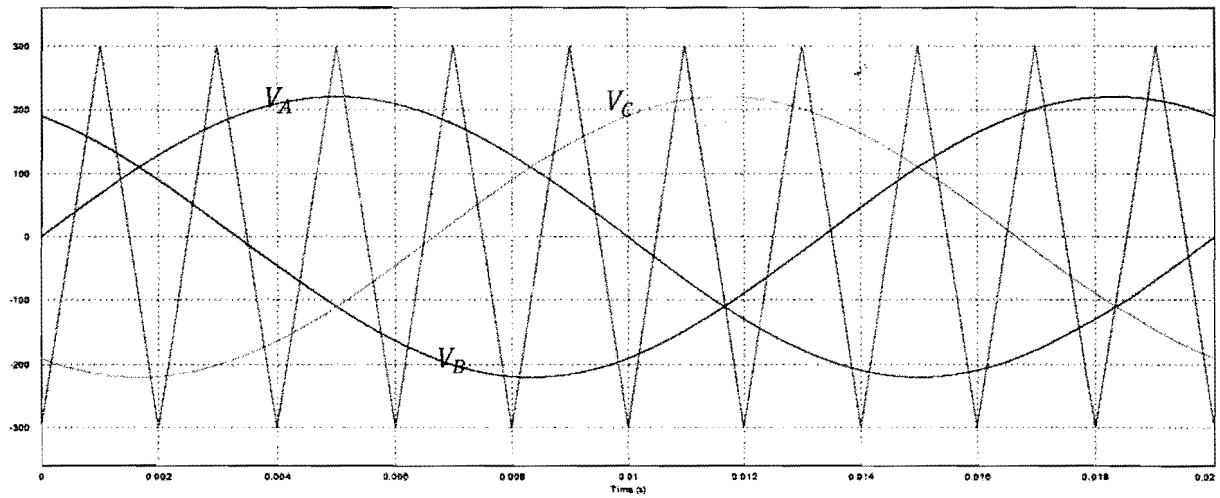


Figure Q.5 (ii)

(b) Design a converter to produce an output voltage of 40 V from a 4 V source. The output current is 500 mA. Design for an output ripple voltage of 5 percent. Include ESR when choosing a capacitor. Assume for this problem that the ESR is related to the capacitor value by $r_C = 10^{-5}/C$ [20]

Answer Question 5 (a) in this page and submit it with your answer sheet



Useful Information

Normalized Fourier Coefficients $\frac{V_n}{V_{dc}}$ for Bipolar PWM

	m_a=1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
$n=1$	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
$n=m_f$	0.60	0.71	0.82	0.92	1.01	1.08	1.15	1.20	1.24	1.27
$n=mf\pm2$	0.32	0.27	0.22	0.17	0.13	0.09	0.06	0.03	0.02	0.00