EE/KSSK/FRI/26012019/T1

Name:............................
Roll No:............................

DEPARTMENT OF ELECTRCAL ENGINEERING
National Institute of Technology Calicut
FIRST TEST-WINTER SEMESTER JAN 2019
EE6308D SWITCHED MODE & RESONANT CONVERTERS

Time: One Hour   Maximum: 15 Marks

*Answer **all** questions*

1. Both non-isolated Buck converters and non-isolated Boost converters employ an inductor L and a bulk capacitor C in their design. (a) Distinguish clearly between the roles of L and C in the two types of converters. (b) Explain how the size of L and C get affected in the two types of converters when the switching frequency is increased with current ripple and voltage ripple specifications kept constant. (2 Marks)

2. A Boost Converter has V_{in} = 24V, d = 0.5, f_s = 100kHz, C=100μF, CxESR = 30μs. The steady-state current in the inductor was a periodic raised triangular waveform varying between 2.7A and 3.3 A. Load is a resistance R. All components are ideal. Find (i) L (ii) R (iii) V_0 and % p-p ripple in output voltage. (1 ½ Marks)

3. A Buck Converter for 36V/5V, 10A was designed with a 60V, 25A, 40mΩ MOSFET. When this MOSFET was out of stock, it was substituted with a 300V, 75A, 20mΩ MOSFET with no other change made in the circuit board. Frequent burnout of MOSFETs on overheating was reported from units employing the new MOSFET despite the new MOSFET being a significantly over-rated one. Explain the possible reason/s for this with supporting arguments and suggest a possible solution. (1 ½ Marks)

4. In your capacity as a Design Engineer, you instructed your Technical Assistant to construct a 12V to 120VDC Converter to deliver a constant current source kind of load of 0.5A value. You were in a hurry and did not tell her which topology to use. She designed a Boost DC-DC Converter and tested it to find that she is not able to get the required 120V at the output. She varied the duty ratio in the entire range of 0 to 1 and found that the maximum output voltage she could get is about 50V. She wants to know what she did wrong. Explain it to her with supporting derivations and graphs. (2 Marks)

5. A 120V input / 24V Output non-isolated Buck Converter is operating with a fixed duty ratio of 0.2. The switching frequency is 20 kHz and the filter inductor has 0.48 mH inductance. The converter is delivering a load of 0.5A at its output. Assume ideal operation for all components. Identify whether the converter is in DCM or CCM and calculate the output voltage. **Derive** the formula you use from basic principles. Also **sketch** the important waveforms in the converter. (3 Marks)

6. A 48 V input / 12 V Output Buck Converter is delivering a 10A load at its output. It uses an inductor of value 100 μH and switches at 20 kHz. Neglect switch drop, diode drop and resistance drops. The power MOSFET used follows square law and its saturation current at V_{GS} = 7.5 V is 48A and it has a threshold voltage of 3.5 V. It is driven by a Gate-Source voltage of 12V through a 47Ω resistance. C_{iss1} = 2000pF, C_{iss2} = 1300pF, C_{rss1} = 600pF, C_{rss2} = 200pF, C_{oss1} = 1200pF and C_{oss2} = 400pF for the MOSFET. The diode used has a minority carrier storage that is proportional to forward current and has a value of 1.2μC when carrying 1 A forward current. Assume that parasitic inductances are negligible. (a) Calculate the switching delays in the voltage across the diode. (b)Find the switching power loss in the MOSFET. ***Show the relevant waveforms and calculations.*** (5 Marks)

EE/KSSK/FRI/08032019/Test2

Name:...........................
Roll No:.........................

DEPARTMENT OF ELECTRCAL ENGINEERING
National Institute of Technology Calicut

MID SEMESTER TEST 2- WINTER SEMESTER MARCH 2019

EE630SD SWITCHED MODE AND RESONANT CONVERTERS

Time : 75 Minutes **Maximum : 20 Marks**

1. Explain the effect of RCD Snubber and L-Snubber on switching loci, switching losses and total converter losses in a Buck Converter. Explain why when L-Snubber is used, a RC/RCD Snubber has to be used along with it. (3 marks)

2. In a particular design of a 200V/12V, 100W Push-Pull Converter, a 600V, 5A MOSFET was used in one primary limb and a 600V, 10A MOSFET was used in the other primary limb. Further, the two transistors are mounted on physically separate heat sinks.The switching speeds of both devices were matched by adjusting the gate resistance value. When the converter is on minimum load, it is found that one transistor works with a case temperature of 32^{0}C and the other with 50^{0}C with room temperature at 28° C. (a) Which one runs at higher temperature and why ? (b) Explain the possible solutions to reduce the problem. (2 Marks)

3. (a) In your capacity as a Design Engineer, you instructed your Technical Assistant to construct a forward converter to generate 5V/10A output from a 100V input. She came up with a design that uses n = 8, total leakage inductance measured from primary = 5uH, switching frequency = 50kHz, tertiary winding with same number of turns as that of primary and diodes that take 1.1 V forward drop @ 10A. Explain to her why her design will not work. (1 ½ Marks)

   (b) After she understood what is wrong with the design, she suggested that she will make the number of turns of tertiary equal to 50% of number of turns of the primary. She claims that will solve the problem. Decide whether her claim is correct with proper reasoning and, if she is correct, identify the price paid for solving the problem this way. (1 ½ Marks)

4. Justify the following statement with suitable derivation:" A 1mH inductor carrying 10A DC bias and a 100mH inductor carrying 1A DC bias can be designed using same core size provided same working flux density, current density and space factor are used in the design." (2 Marks)

5. The EE 65/32/13 core from CEL has the following parameters. Core area = 266 sq.mm, Window area = 537 sq.mm, A_L value = 4833 nH/T^2. Find the maximum value of inductance that can be designed using this core if the inductor is to carry 30 A ± 3A ? Assume that B_{max} = 0.2 Wb/sq.m , J = 4 A/sq.mm and space factor is 0.36. (2 Marks)

6. Discuss the effect of leakage inductance on the ratio between output voltage and input voltage at a constant duty ratio in a Full-bridge isolated DC-DC converter with relevant derivations? How does this effect depend on load current? (3 Marks)

7. Explain the need for and operation of voltage clamp circuit used in Flyback converters and develop equations for choosing the component values. (3 Marks)

8. Explain why a toroidal core based CT cannot be used to monitor the inductor current in a Buck Converter. Also explain how else can you measure that current using CTs? (2 Marks)

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Name: ....

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DEPARTMENT OF ELECTRICAL ENGINEERING, NIT CALICUT

END SEMESTER EXAM-WINTER SEMESTER 2018-19 APRIL 2019

EE6308D SWITCHED MODE AND RESONANT CONVERTERS

Time : Three Hours

Maximum : 50 Marks

Answer All Questions

PART A (10x 2 ½ = 25 Marks)

1. Explain what is meant by reverse recovery of a diode? How does reverse recovery of diode used in a buck converter affect the switching transients, switching times and switching loss?.

2. (a)Theoretically, the maximum duty ratio for a switch in a half-bridge converter can be 50%. But it is limited to about 45% in practice. Explain why?

   (b) In a particular design of a 200V/12V, 250W Half-Bridge Converter that does not employ a DC Blocking capacitor in the primary side, the two identical transistors are mounted on physically separate heat sinks. When the converter is on minimum load, it is found that one transistor works with a case temperature of 32°C and the other with 50°C with room temperature at 28° C. Explain the possible reasons for this and suggest solutions to alleviate the problem.

3. A half-bridge converter running from 300V DC employs 35μH inductance and 220μF capacitor as filter components at output. 300V DC is split into two 150V sources by means of two 4.7μF capacitors. The output voltage is maintained at 12V. Turns ratio of primary winding to one-half of secondary winding is 9. Primary winding has 27mH self inductance. Find and plot the currents flowing through the 4.7μF input splitting capacitors when the converter is delivering 10A at its output. Assume ideal components.

4. As a part of a SMPS project, you instructed your technical assistant to design and test a Flyback Converter in CCM mode with a suitable voltage clamp assuming 3% leakage inductance to satisfy the following specifications: Input : 250V – 400V, Output: 12V, 2A – 5A, Output Ripple : <2% peak to peak, Switching frequency : 100kHz. MOSFET Voltage Rating = 900V. She designed the unit and tested it with no load applied across output and applied a small fixed duty ratio of 10%. She did so since her Professor had told her that when she tests a SMPS unit first time she must do it in open loop with minimum load and lowest input voltage. However, on testing like this with 250V input, 10% duty ratio and 0 A load current, she ended up with a blown capacitor and blown switch. (i) Explain to her what went wrong. (ii) Did her Professor teach her wrong? Discuss.

5. (i) Clearly distinguish between *state-space averaged variable, cyclic averaged variable, running averaged variable and local averaged variable*? (ii) What is meant by State-space averaged model of a Power Electronic System? What are the conditions under which this model will yield satisfactory results? (iii) What is meant by local average model of a Power Electronic System? How do you prepare this model from the Switched Model of the Converter? Under what conditions will this model coincide with the State-space averaged model?.

6. Electrolytic Capacitors have a small resistance in series – called ESR. Discuss the effect of ESR in a Buck Converter with reference to voltage ripple, efficiency, line regulation and load regulation transient and compensator design.

7. Explain why Boost Converters often require Type-3 Compensators whereas Buck Converters can often be designed with Type-2 Compensators. Justify your answer with a comparison of small-signal transfer functions of both converters.

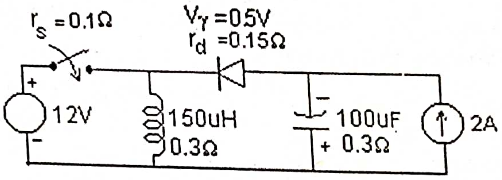
8. How are the output power rating and area product of the transformer core related in the case of a half-bridge converter? Derive the relevant relationship from basic principles.

9. Explain Peak Current Mode Control of DC-DC Converters with a suitable schematic diagram and compare it with Voltage Mode Control.

10. A Linear Regulator provides a very clean output voltage which adjusts rapidly against line/load variations. However, it has low efficiency. A switched-mode regulator has high efficiency ; but has a noisy and sluggish output. Suggest a suitable scheme to combine the advantages of these two in a 'linear assisted switched-mode converter' and explain a suitable control strategy for it.

PART B (5 x 5 = 25 Marks)

11. (a) Find the output voltage and peak-to-peak ripple in output voltage in the following converter by deriving the equations from basic principles when running at 0.5 duty ratio with 100kHz switching. The resistances of switch, diode, inductor and capacitor must be accounted. (3 Marks)



(b) You instructed your technical assistant to set up this converter and experimentally obtain its efficiency. She came up with about 82%. You asked her to carry out suitable modifications such that full load efficiency is at least 94%. She decided to parallel three identical switches instead of one switch and drove the parallel combination using same gate drive that she used before for one switch. Then she found that efficiency went down to 75%. Explain to her what went wrong? Also, what suggestions will you offer her to improve the efficiency of the converter? (2 Marks)

12. Design a Flyback Converter in CCM mode with a suitable voltage clamp assuming 3% leakage inductance to satisfy the following specifications: Input : 250V – 400V, Output: 12V, 2A – 5A, Output Ripple : <2% peak to peak, Switching frequency : 100kHz. MOSFET Voltage Rating = 900V

Specify the MOSFET and Diode completely. Use 30us Electrolytic capacitors and specify the capacitor completely including ripple rms current rating. Design the transformer using ferrite EE cores and round enameled copper wire. Use B_m = 0.2 Wm/sq.m, J = 3A/sq.mm, k_s = 0.35 for transformer. Take the coil former thickness as 1mm and creepage distance as 2mm. *Design steps should be explained clearly with relevant waveforms.* (5 Marks)

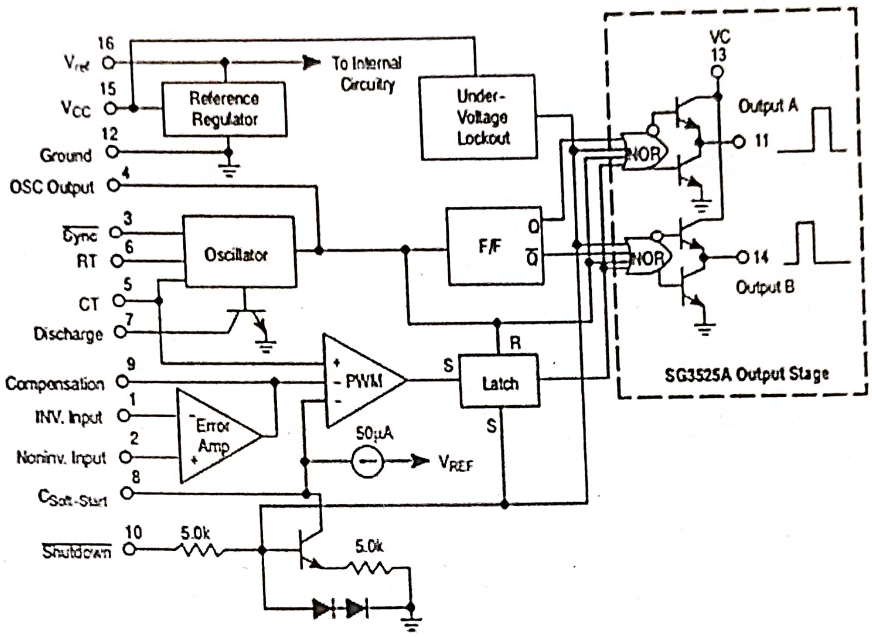
OR

Design a Forward Converter to satisfy the following specifications: Input : 108V – 135V, Output: 12V, 2A – 5A, Output Ripple : <1% peak to peak, Inductor Current Ripple : < 1A peak to peak, Magnetising current in Transformer : < 0.05A peak, Switching frequency : 40kHz

Specify the MOSFET and Diodes completely. Use 40us Electrolytic capacitors and specify the capacitor completely including ripple rms current rating. Design the transformer using ferrite EE cores and round enameled copper wire. Use B_m = 0.2 Wm/sq.m, J = 3A/sq.mm, k_s = 0.35 for transformer and 0.4 for inductor. Take the coil former thickness as 1mm and creepage distance as 2mm. *Design steps should be explained clearly with relevant waveforms* (5 Marks)

13. 13. A representative diagram of a PWM Control IC SG3525 is shown below. (5 x 1 = 5 Marks)

$$\frac{2V_c(V_c-n(V_o+V_d))}{f_s L I_p^2}$$



(a) Explain the functions of the under-voltage lockout, latch and the flip flop.
(b) Explain how soft start is implemented using this IC.
(c) Explain the various functions that can be obtained by using the shut down pin judiciously.
(d) Explain how a full-bridge converter can be driven by a SG3525 with the help of a pulse transformer.
(e) Explain how a Type-3 Compensator maybe built around the Error Amplifier of SG3525.

14. (a) Explain the need for slope compensation in current mode control and derive the optimum value for compensation slope. (2 Marks)

(b) As a part of a complex project that you are managing, you need a Push-Pull Converter to generate 12V / 5A output from input voltage in the range 120V to 240V with about ±20V ripple of 100Hz in it. You instructed your Technical Assistant to make it using current mode control. He told you that he is very familiar with SG3525 PWM Control IC and wanted to know whether Voltage-mode control using that IC won't be enough. Explain to him why that is not enough, why current mode control is needed and how current mode control can be implemented using SG3525 itself by sensing the input supply current. (1 ½ Marks)

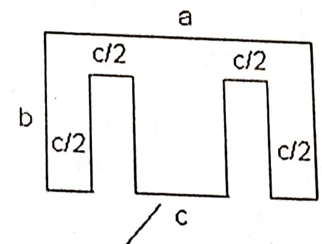
(c) After about two weeks you gave another assignment to the same person to make a Boost Converter to operate from a 12V Lead Acid Battery System to produce a variable output voltage that can be set in the range 48V to 96V as per requirement with an output load current of 1A at all settings. Having been thoroughly convinced about the superiority of current mode control by now, he came to you with a current mode control design with a fixed compensation slope. Will you approve his design? If yes, why? If no, why and what modification will you suggest to him? (1 ½ Marks)

15. (a) Explain, with the help of frequency response behavior, why the secondary winding of a CT has to be wound on a toroidal core with the winding occupying the entire periphery with uniform pitch and preferably in a single layer. (1 ½ Marks)

(b) A Push-Pull Converter operating from an input voltage that is between 180V to 240V to generate 12V at the output uses a transformer with turns ratio 6 and magnetizing inductance of 0.5mH and switches at 40kHz. It uses 40µH inductance 680µF capacitor of 40µs family at the output. The load current can vary between 4A and 10A. Design a CT using toroidal ferrite core to sense the current in the input line with a sensing gain of 0.5 V/A. Explain the design considerations and design equations clearly. (3 ½ Marks)

Core	Ac (mm^2)	Aw (mm^2)	Ap (mm^4)	AL ($nH/Turn^2$)	Volume (mm^3)
E30/15/7	60	49	2940	1700	4000
E32/16/9	83	81.4	6756	2100	6140
E36/18/11	120	112	13440	2900	9720
E40/16/12	149	143	21307	3800	11500
E42/21/15	178	175	31150	3500	17300
E47/20/16	233	226	52658	5100	20700
E56/28/19	340	327	111180	6300	36400

E a/b/c



Cross section c x c

Core	Ac (mm^2)	Aw (mm^2)	Ap (mm^4)	AL ($nH/Turn^2$)
T10	6.2	19.6	2940	765
T12	12	44.2	6756	1180
T16	20	78.5	13440	1482
T20	22	95	21307	1130
T27	42	165	31150	1851
T32	61	165	52658	2427
T45	93	616	111180	2367

SWG	Dia with enamel (mm)	Area of copper (sq.mm)	R/km @ 20°C (Ohms)
40	0.142	0.012	1477
38	0.175	0.018	945
34	0.264	0.043	402
30	0.351	0.078	221
28	0.417	0.111	155
26	0.505	0.164	105
24	0.612	0.245	70.3
22	0.77	0.397	43.4
20	0.978	0.657	26.3
19	1.082	0.811	21.3
18	1.293	1.167	14.8
17	1.501	1.589	10.8
15	1.92	2.627	10.8
14	2.129	3.243	5.3