EE6325_11_2017 Name: ……………………

Roll. No.:…………..…….

DEPARTMENT OF ELECTRICAL ENGINEERING, NIT CALICUT

FIRST SEMESTER M.Tech. END SEMESTER EXAMINATION, NOV- 2017

EE6325 SWITCHED MODE AND RESONANT CONVERTERS

Time : Three Hours **Maximum : 50 Marks**

Answer All Questions

PART A (7x3 = 21 Marks)

1. A Buck Converter for 48V/12V, 4A was designed with a 100V, 16A, 60mΩ MOSFET. When this MOSFET was out of stock, it was substituted with a 200V, 60A, 20mΩ MOSFET. 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..
2. In your capacity as a Design Engineer, you instructed your Technical Assistant to construct a 12V to 250VDC Converter to deliver a constant current source kind of load of 2A 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 250V 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 100V. She wants to know what she did wrong. Explain it to her with supporting derivations and graphs. She understands that the average voltage across the boost inductor has to be zero under steady-state, but she does not understand state-space modeling.
3. 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.
4. In a particular design of a 200V/12V, 100W Push-Pull Converter, 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^{o}C and the other with 50^{0}C with room temperature at 28^{o} C. Explain the possible reasons for this and suggest solutions to alleviate the problem.
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. Explain why the small signal transfer function between output voltage and duty ratio in a Boost Converter has a right-half zero. Further, explain how this right-half zero affects the compensator design for such a converter.
7. Draw the block diagram of a typical voltage mode control IC and explain its functioning with relevant waveforms.

PART B

8. A 12 V input / 48 V Output Boost Converter is delivering a 10A load at its output. It uses an inductor of value 50 μH and switches at 40 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_{gs} = 400pF and C_{gd} = 100 pF 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)

9. Design a DCM mode Flyback converter to operate from 250V – 400V input to generate a 12V with p-p ripple < 120mV output using a 1000V rated MOSFET. The load current can vary between 2A to 6 A. Use a switching frequency of 50kHz. Specify primary inductance, turns ratio, average and rms current ratings for MOSFET and diode, voltage rating of diode, output capacitor assuming CxESR = 30μs. 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.* (6 Marks)

OR

Design a Half Bridge Converter to satisfy the following specifications: Input : 250V – 400V, Output: 12V, 5A – 20A, Output Ripple : <2% peak to peak, Inductor Current Ripple : < 4A peak to peak, Magnetising current in Transformer : < 0.05A peak, Switching frequency : 50kHz, Permitted peak to peak ripple in voltage-splitting capacitors and DC Blocking capacitor : 5%. Specify the MOSFETs and Diodes completely. Use 50us Electrolytic capacitors and specify the capacitor completely including ripple rms current rating. Specify the rms current rating needed in voltage splitting capacitors and DC Blocking capacitors. Design the transformer (only 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. (6 Marks)

10. A Buck Converter for 48V/24V, 4A was designed to operate with ±20% current ripple when input voltage is 48V. It uses a 60mΩ MOSFET and a diode with cut-in voltage of 0.5V and dynamic resistance of 30mΩ. Switching frequency is 100kHz.
    (a) Calculate L value and its series resistance assuming that the series resistance is 1/50 times the reactance of the inductor at 100 kHz. (1 Mark)
    (b) Calculate the C value, assuming that poly-propylene capacitors are going to be used, if the output voltage ripple is to be less than 2% in amplitude. (1 Mark)
    (c) Recalculate the C value if an electrolytic capacitance from 40μs family is to be used. (1 Mark)
    (d) Calculate the natural frequency of oscillations, damping factor of oscillations and the location of zero in the control to output small signal transfer function of the converter in both cases.(1 Marks)
    (e) Which solution is better from control design point of view – using poly-propylene capacitor or the electrolytic capacitor? Explain why with the help of Bode plots? (2 Marks)

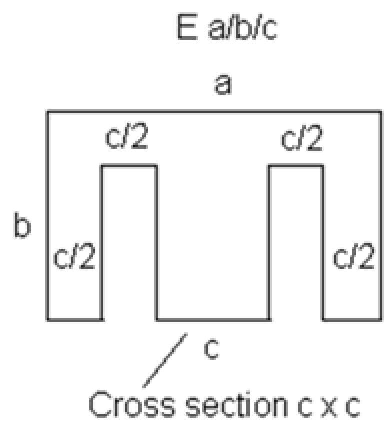
11. (a) Explain the need for slope compensation in current mode control and derive the optimum value for compensation slope. (3 Marks)
    (b) As a part of a complex project that you are managing, you need a Buck Converter to generate 12V / 5A output from input voltage in the range 20V to 60V with about ±5V 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. (2 Marks)
    (c) After about two weeks you gave another assignment to the same person to make a Buck Converter to operate from a 3x12V Lead Acid Battery System to produce an output voltage that can be set in the range 6V to 18V as per requirement with an output load current of 2A 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. Explain to him why he has to choose voltage mode control this time. (1 Mark)

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

    (b) The A Boost Converter operating from an input voltage that is between 10.8V to 13.6V to generate 24V at the output uses 25μH inductance 680μF capacitor of 40μs family and switches at 50kHz. The load current can vary between 1A and 4A. Design a CT using toroidal ferrite core to sense the current in the switch with a sensing gain of 0.125 V/A. Explain the design considerations and design equations clearly. (4 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

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
