EE/KSSK/EE6308D/Winter2022-23/EndSem **Name:………...................**
Roll No:………….............

DEPARTMENT OF ELECTRCAL ENGINEERING, NIT CALICUT

END SEMESTER EXAM- WINTER SEMESTER : 24th APRIL 2023

EE6308D SWITCHED MODE & RESONANT CONVERTERS

Time : 3 Hrs **Maximum : 40 Marks**

Answer ALL Questions

1. A half-bridge converter running from 400V DC employs 70μH inductance and 220μF capacitor as filter components at output and the switches switch at 25kHz. 400V DC is split into two 200V sources by means of two 3.3μF capacitors. The output voltage is maintained at 12V. Turns ratio of primary winding to one-half of secondary winding is 11. Primary winding has 2.7mH self inductance.
   (a) **Find and plot the currents** flowing through the 3.3 μF input splitting capacitors when the converter is delivering 10A at its output. Assume ideal components. (1 ½ marks)
   (b) If the transformer has 3% leakage inductance, **find the duty ratio** required in the converter to maintain 12V at output while delivering 10A load. You may ignore all other non-idealities. (1 ½ marks)
   (c) The magnetic flux density in the core in a half-bridge converter switching at 50kHz is found to oscillate asymmetrically between -0.1 Wb/sq.m and +0.3 Wb/sq.m at a certain operating condition**. List** all the possible reasons for this kind of asymmetric behavior in flux density and **explain**. (1 ½ marks)
   (d) Flux-walking problem in a full-bridge converter can be solved by connecting a blocking capacitor in series with the primary of the transformer. **Explain how** this solves the problem? How do we size this capacitor? **And why** this solution will not work in the case of a push-pull converter? (1 ½ Marks)

2. (a) **Explain the need for and operation of** voltage clamp circuit used in Flyback converters and develop equations for choosing the component values. (2 Marks)
   (b) 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**. (2 Marks)

3. (a) The EE 65/32/13 core from CEL has the following parameters. Core area = 266 sq.mm, Window area = 537 sq.mm, Mean turn length = 150 mm, Magnetic path length = 146.3 mm, Relative permeability = 2200, 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 10 A ± 2A ? Assume that B_{max} = 0.25 Wb/sq.m , J = 2.5 A/sq.mm and space factor is 0.35. Also, **calculate the air gap** that is required. (2 Marks)
   (b) **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. (2 Marks)
   (c) **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. (2 Marks)

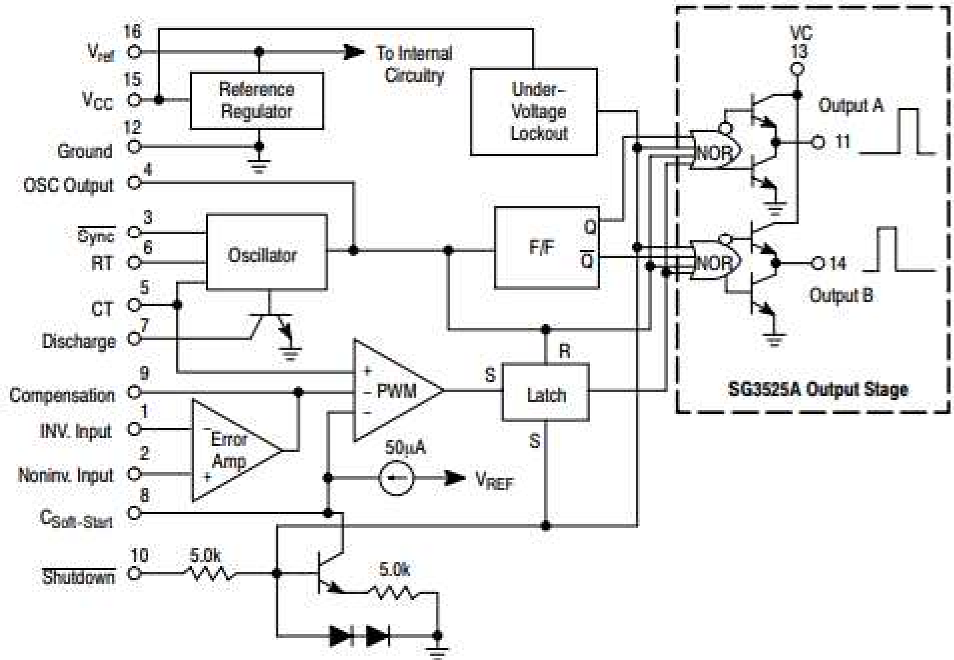
4. (a) **Distinguish between** Duty Ratio, Duty Ratio Function and Switching Function in the context of mathematical modelling of SMPS and **discuss the relationships** among them. (1 Marks)
(b) **Distinguish between** State Space Averaged Model and Exact Local Average Model in the context of mathematical modelling of SMPS and **explain** under what conditions the State Space Averaged Model will describe the behaviour of local averaged versions of state variables and output variables. (1 ½ Marks)
(c) **Distinguish between** Running Average, Cycle Average and Local Average of variables in the context of mathematical modelling of SMPS. (1 Marks)
(d) **Explain the role and function** of PWM Modulator that comes after the Compensator and provides drive to the switch. This Modulator is usually taken as a unity gain block in controller analysis. **Discuss** the validity of this assumption. (1 ½ Marks)

5. (a) **Explain the different factors** that lead to a choice of gain crossover frequency in the design of compensators for Voltage Mode Control of SMPS. (1 Marks)
(b**) Explain the origin** of the right-half zero in the control-to-output transfer function of a Boost Converter on open loop and **discuss how** the right-half zero affects the compensator design for Voltage Mode Control. (2 Marks)

6. (a) All the three types of compensators commonly employed in Voltage Mode Control of SMPS have a common factor 1/s in their transfer functions. **Explain why** this factor is needed in all compensator transfer functions. (1 Marks)
(b) You, in your capacity as a Project Lead, instructed your Technical Assistant to design a non-isolated Buck Converter to convert 110V DC Input into 48V/1A output. She came up with a design that switches at 100 kHz, uses 500uH inductance and 22uF polystyrene capacitor with zero ESR. The wire size she used in the inductor and the switch and diode she used were such that she needed a Type-3 compensator. And even with a Type-3 compensator, she was getting an overshoot of 40% in the step response of the closed loop converter. She wants to know whether she can put a small-valued resistor in series with the inductor in order to damp the converter better. But you advised her to put that resistor in series with the capacitor. **Explain the different reasons** that motivated you to advise her so. You may use the Buck Converter Transfer Function that appears in Question-7 as a starting point of your explanation. (2 Marks)

7. (a) **Explain how** Current Mode Control is implemented ? **List and explain** all the advantages of Current Mode Control (2 Marks)
(b) **Explain the need** for slope compensation in current mode control and derive the optimum value for compensation slope for Buck/Buck-derived converters. (1 ½ Marks)
(c) As a part of a complex project that you are managing, you need a Push-Pull Converter to generate 24V / 5A output from input voltage in the range 150V 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 in this application, **why** current mode control is needed (provide a detailed explanation on all the advantages of CMC) and **how** current mode control can be implemented using SG3525 itself by sensing the input supply current. (1 ½ Marks)

8. A representative diagram of a PWM Control IC SG3525 is shown below. (5 x 1 = 5 Marks)
   (a) **Explain** the functions of the under-voltage lockout, latch and the flip flop.
   (b) **Explain** the need for soft start and how soft start is implemented using this IC.
   (c) **Explain** how a half-bridge converter can be driven by a SG3525 with the help of a pulse transformer.
   (d) **Explain** how a Type-2 Compensator can be implemented by using the Error amplifier.
   (e) **Explain** how current mode control can be implemented by using the shut down pin judiciously.



9. A Buck Converter data is given : 110V input, 48V/4.8A resistive load output, 100kHz Switching, L = 250uH/0.2 Ω, C = 47µF/0.2Ω, Switch Resistance and Diode resistance = 0.2Ω, Diode Cut-in Voltage = 0.5V.

(a) The Buck Converter Small Signal Control to Output Transfer Functions is given below.

$$\frac{\overline{\Delta v_o(s)}}{\Delta d(s)} = \frac{\left(\frac{r_d - r_s}{LC} I_o + \frac{V_{ino} + V_\gamma}{LC}\right)(s r_c C + 1)}{s^2 + \frac{r_{eff}}{L} s + \frac{1}{LC}}.$$

$$where \quad r_{eff} = r_c + r_l + d_o r_s + (1 - d_o) r_d$$

Explain how this transfer function may be derived from state space equations by detailing the various steps involved in the derivation and **evaluate** this transfer function for the operating condition specified. (1 ½ Marks)

(b) **Design a Type-2 compensator** function such that crossover frequency is 1.5kHz and Phase Margin of the closed loop system is 60 deg. (1 ½ Marks)

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