SKEE4643 **TEST1** **1 hour 15 minutes**

Question 1

In the boost converter of Figure Q1, the averaged model of the switch network is desired. The terminals voltage and current of the switch network are given as v_1, v_2, i_1 and i_2. The input voltage is a constant, v_g. The capacitor, C, is sufficiently large so that the output voltage, v_o, is considerably constant. The converter operates in CCM with inductor current repeatedly changes between i_{Lmin} and i_{Lmax} in steady state.

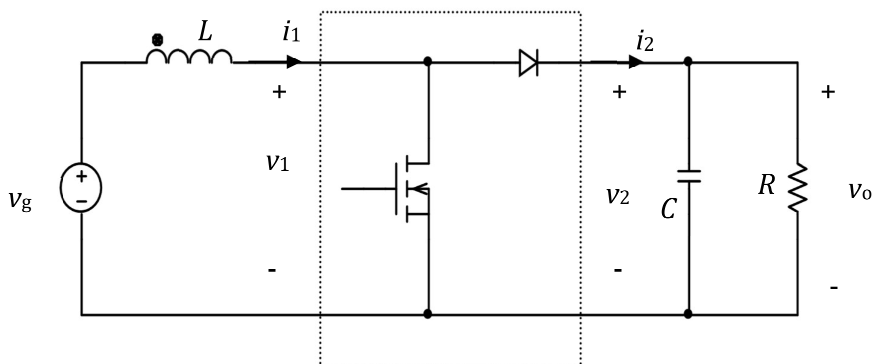

Figure Q1

(i) Draw the terminal switch network waveforms: v_1, v_2, i_1 and i_2. Label key quantities. [3 marks]

(ii) Find the average voltage conversion ratio, $\langle v_2 \rangle / \langle v_1 \rangle$ and the average current conversion ratio, $\langle i_2 \rangle / \langle i_1 \rangle$ of the switch network. [2 marks]

(iii) Construct averaged circuit model of the complete buck converter by replacement of the switch network by the averaged switch model (dependent sources) based on the equations found in (ii). [2 marks]

(iv) If v_g = 10 V, v_o = 15 V and R = 5 Ω, find $\langle i_1 \rangle$, $\langle i_2 \rangle$, $\langle v_1 \rangle$, and $\langle v_2 \rangle$ under steady-state condition. [3 marks]

Question 2

In a buck-boost converter, the MOSFET has on resistance, R_Q = 65 mΩ, the diode forward voltage drop can be modeled by constant voltage V_D = 0.8 V, with resistor R_D = 75 mΩ, and the inductor has an internal resistance r_L = 200 mΩ. The load equivalent resistance R = 10 Ω. The input voltage, v_g = 40 V and the output voltage, $|v_o|$ = 30 V.

(i) Draw an equivalent circuit which shows the DC properties of this converter. The averaged switch model can be represented by dependent sources or a DC transformer. [2 mark]

(ii) Derive the efficiency, η, and the voltage conversion ratio, M_v. [3 marks]

(iii) Use SECANT method to determine the required duty cycle, D. [3 marks]

(iv) Determine the efficiency of the converter. [2 marks]

Question 3

Show that the efficiency, η, for the buck converter including the inductor resistance, R_L, and the diode forward voltage drop, V_D, is given by

$$\eta = \frac{1}{1 + \frac{R_L}{R} + \frac{(1-D)V_D}{V_o}}$$

Based on the equation, Suggest ONE method to improve the efficiency of the buck converter for the low voltage application.

[4 marks]

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Potentially Use Formula

$$D_{k+1} = D_k - f(D_k)\frac{D_k - D_{k-1}}{f(D_k) - f(D_{k-1})} \qquad D_0 = D_{ideal} \quad D_1 = D_{ideal} + 0.1$$

$$\eta = \frac{1}{1 + \frac{P_{loss}}{P_o}} = M_V M_I$$

$$R_{EQ} = r_L + DR_Q + D^{'}R_D$$

$$V_{EQ} = DV_Q + D^{'}V_D$$

$$\int_0^T v_L dt = 0$$

$$\frac{1}{L}\int_0^{DT} v_L dt = \Delta i_L$$

$$-\frac{1}{L}\int_{DT}^{T} v_L dt = \Delta i_L$$

$$\frac{V_o}{V_g} = D, \ \frac{V_o}{V_g} = \frac{1}{1-D}, \ \frac{V_o}{V_g} = \frac{D}{1-D}$$