ECE692

Analysis of a Multi-Resonant Buck Converter

Fig. 1 gives the circuit schematic of a multi-resonant buck converter. This topology is capable of maintaining soft switching of all transistors across a wide range of loads with appropriate modulation. Though it can be operated in multiple modes, this problem will focus on the mode shown by the switching signals in Fig. 2. All passives are ideal; transistors exhibit drain-to-source capacitance as shown in Fig. 1 and on-resistance r_{on}.

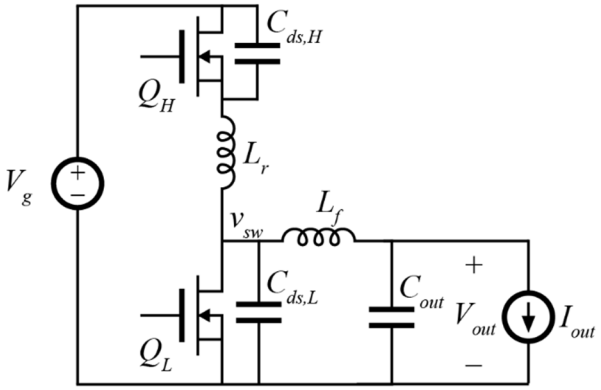

Fig. 1: Synchronous MR Buck converter

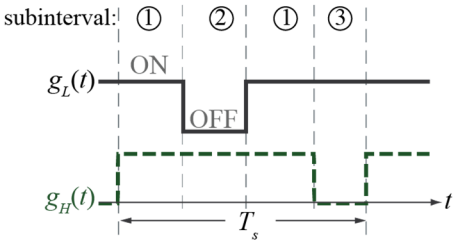

Fig. 2: Switching sequence

a) Solve for matrices $\mathbf{A}_i$ and $\mathbf{B}_i$, $i \in [1,2,3]$, which model the topology in this operating mode.
b) Write an expression for the steady-state state vector $\mathbf{X}_0$ for the converter in this operating mode, as a function of the matrices in (a) and subinterval durations t_i

For the remaining subparts, use the following converter implementation parameters. The converter is designed to produce V_{out} = 3 V with high efficiency, and an output voltage ripple less than 50 mV. Complete the following using MATLAB.

$C_{ds,H}$	$C_{ds,L}$	r_{on}	L_r	L_f	C_o	V_g	I_{out}
1.5 nF	1.5 nF	2 mΩ	20 nH	1 µH	1 µF	12 V	1 A

c) First, assume all timing intervals take on equal value, $t_1 = t_2 = t_3 = t_4 = 25$ ns. Solve for the steady-state $\mathbf{X}_0$ and plot full time-domain waveforms for all states.
d) Comment on the above waveforms. Do they correctly model converter operation, and do they meet the design specifications?
e) The duration of the four intervals is no longer equal. Find values for $t_i = [t_1, t_2, t_3, t_4]$ which meet the output voltage and ripple specs with a high efficiency and valid converter operation. Report your solved values for t_i and describe how you obtained them.

Note: You do not need to prove or actually optimize operation of the system in part (e). Solely meeting the objectives with a high efficiency is sufficient.