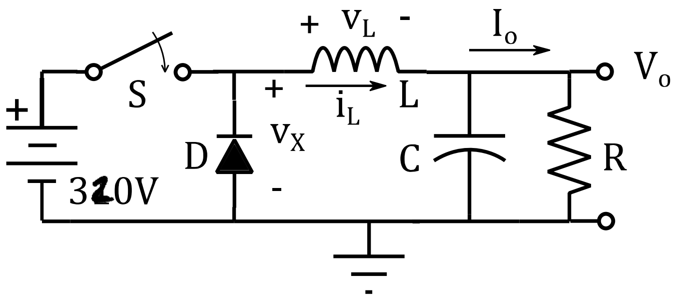
EE419/519 Homework Assignment #2

Due October 27, 2024

Design a Buck converter that converts 320V to 3.3V using the following circuit. Assume that there is no forward voltage drop on the diode D1. Set R=[5+mod(BilkentID,12)/4] Ω (hence, in the range 5 to 7.75Ω). (mod(xx,12) is the remainder of the division of xx by 12.)



a. Set the switching frequency to [30+5 mod(BilkentID,12)] KHz (hence, in the range 30 kHz to 85 kHz). Assume that the output voltage is a constant. Assuming continuous mode operation ($i_L(t)>0$ at all times), find the duty cycle, D, of the switch to get V_o=3.3V.
b. What is the minimum value of L to assure continuous mode operation? Choose an L value at least twice this value. Calculate and plot $i_L(t)$ in periodic steady state (PSS) for the chosen R and L.
c. Choose the capacitance C such that the peak-to-peak ripple voltage is 15 mV with zero ESR. Now assume that the ESR of the capacitance is 0.15Ω. Determine the peak-to-peak ripple voltage due to the ESR.
d. Choose an L value such that a discontinuous mode operation is achieved. Keeping the duty cycle the same as that in part (a), find the output voltage, V_o, under this condition. Assume that the output has no ripple. Calculate and plot $i_L(t)$ in PSS. Note that $I_o=V_o/R$ will change.
e. What should be the duty cycle to keep V_o=3.3V with the L value chosen in (d)? Calculate and plot $i_L(t)$ in PSS.
f. Simulate using LTSpice to compare with your results of (b) and (c) with ESR=0.15Ω. You can simulate the switch using “sw” (a voltage controlled switch). Include a Spice directive to define the properties of the switch: [.model SW SW(Ron=0.1 Roff=1Meg Vt=5 Vh=0)] This statement defines a threshold voltage with V_t. You need to apply a control voltage source that is larger than V_t to turn on the switch with an on resistance of R_{on}.
   You can use a fast recovery diode (like RFN5BM3S). Note that you need to simulate long enough to reach a steady state. You need to modify the duty cycle by trial-and-error to get the desired output voltage since the voltage drop on the diode was ignored in the theoretical calculation. You can plot two or three (an integer number of) periods of steady-state signals using the “Time to start saving data” option of the transient simulator. Plot $i_L(t)$ and $V_o(t)$.
g. Simulate using LTSpice to compare with your results of (d). Plot $i_L(t)$ and $V_o(t)$ while the duty cycle is unchanged (as in (f)).
h. Simulate using LTSpice to compare with your results of (e). Plot $i_L(t)$ and $V_o(t)$. Note that you must modify the duty cycle to get the desired output voltage.
i. Using the simulator, find the frequency of the sinusoidal signal in $v_X(t)$ during the time the switch and diode are both off. Use this frequency and the inductance value to estimate the reverse bias capacitance of the diode.
j. Consider the continuous case of (f). Assume that the inductor has an equivalent series resistance of 0.4 Ω. Find the efficiency of your converter using the simulator.