

ECE 433 Project #1– Due February 23, 2022

- 1) Given the following specifications for a converter circuit: The output is to have an average of 48 V with a maximum peak-peak ripple of 2 V for a load range of 2 kW to 20 kW. The input to the converter is 480 V. A switching frequency of 10 kHz is desired.
  - a. Determine an inductance  $L = 1.1L_{crit}$  and the minimum C needed to satisfy these requirements.
  - b. Use approximation techniques presented in class, analytically determine the expected steady-state current and voltage waveforms expected for each component under both light and heavy load. Plot these values. You can plot via hand, provided it is neat. Key values on the plots are the expected currents and voltages (including amplitude and time scale).
  - c. Use a **Backward Euler** Integration algorithm that you program in Matlab to simulate the ideal circuit behavior by numerically solving the differential equations. There are a few specifications for your code:
    - i. You should create 4 files (switching.m, buck.m, buckpostproc.m, avrg.m) . The first file (switching.m) contains a function (switching) that accepts the duty cycle D, and instant of time as an input, and outputs the state of the transistor at that time instant as an output. A Fourier series-based triangle wave that you create within this function should be compared with the duty cycle D to determine the state of the transistor. The file (buck.m) is used to simulate the circuit and calls switching to establish the state of the transistor at each instant of time. The 3<sup>rd</sup> is used to initialize circuit parameters (inductor value, capacitor value, switching frequency, time step, initial conditions etc.), invoke buck.m, and perform your plotting and calculations that are done using the simulated data (such as computing average values, efficiency, etc.). The fourth file (avrg.m) contains a function you create to compute the average of a waveform. Specifically, the function is of the form  
function av = avrg(x,T,dt)  
where x is the waveform to be averaged, T is its period, and dt is the period of time between samples.  
Within buck.m file, the computations of the algorithm and calculations of the instantaneous value of the current and voltage of all circuit components must be performed within a **'while'** loop. Computation within the loop continues until t<tend (tend is user-specified). DO NOT USE A FOR LOOP.

- ii. Switch2 in your buck converter is a diode. Your code must account for the fact that the diode current cannot be less than zero and thus the transistor and inductor currents cannot be less than zero as well.

Using your code, perform the following simulations:

- iii. With D set to a value to achieve the desired output, simulate the startup of the circuit under heavy load. Specifically, set the initial conditions of the inductor current and capacitor voltage to zero. Run your simulation until the output voltage reaches steady-state. Plot the output voltage, inductor current, switch current, and diode current over the time period simulated.
  - iv. With D set to achieve the desired output, set your initial conditions for the inductor current and capacitor voltage to values you expect to see in the steady-state under heavy load. Run your simulation until the circuit does reach a steady-state and then obtain plots of the voltage and current of each component over 2 cycles. Use your avg function to compute the average output voltage and the efficiency of the circuit. In the final report these should be compared to those obtained in b.
  - v. Repeat part c (iv) for the light load conditions.
- d. Analytically determine the effect of non-ideal switches. Specifically, assume the switch and diode have on-state voltage drops of 3 V and 2 V, respectively. Solve for the duty cycle to have an output of 48 V, the expected values of  $I_1$  and  $I_2$ , and the efficiency under the heavy power condition.
  - e. Edit the model you created in c) to include the non-idealities in d). Use the results of part d to establish expected values. Set D to the value needed to obtain the required output voltage. Then use your code to simulate the circuit under heavy load conditions. Plot the output voltage, the inductor current, and the diode and transistor power loss across the diode and transistor over 2 cycles. Finally, compute the simulated efficiency of your circuit using your avg function. In the final report these should be compared to expected values.
- 2) Write a report that documents your analytical and numerical results. Make sure all plots are well labeled and explanations contain solid analytical foundations. Attach your Matlab Code to your report.