Experiment 7
Design and Experimentation of a Boost Converter

7.1 Pre-laboratory Assignment

Given the following specifications:
An input voltage of $5 < V_{in} < 15V$ and an output of $V_{out} = 20V$ and $2W < P_{out} < 5W$. Switching frequency is $f_{sw} = 25kHz$.

a) Design the inductor (L) and capacitor (C). The current ripple $\Delta i_L$ should be below 5% of the average inductor current $I_L$ at the maximum load. The steady state ripple $\Delta V_{out}$ should be below 0.5% of the steady-state value of the output voltage (the converter should operate in CCM under all operating conditions).

b) Determine the rated values for MOSFET, diode, and capacitor.

c) Analytically determine the effect of the non-idealities (the diode has an on-state voltage drop of $V_{D_{on}}$ and the MOSFET has an on-state resistance of $R_{D_{son}}$). Derive a mathematical expression for the voltage conversion ratio and efficiency of the converter. Since the available diode and MOSFET in the lab are MUR405G and IRFIZ48NPBF, replace the values of $V_{D_{on}}$ and $R_{D_{son}}$ from the corresponding datasheet and calculate the numerical values of the voltage conversion ratio and the efficiency (for this section, Chapter 3 of “Fundamentals of Power Electronics” by Erickson is strongly recommended to be studied).

d) Analytically determine and draw the expected current and voltage waveforms for each component of the buck converter.

e) Consider an ideal boost converter. Analyze the converter under very light-load conditions and derive a mathematical expression for the voltage conversion ratio. Based on the expression, what would you expect to see at the output of a boost converter under no-load condition?

7.2 In-laboratory Simulation

f) Using SimPowerSystems toolbox of MATLAB/SIMULINK software, simulate the designed circuit. Include the non-idealities of part c) in your simulation program. Plot the voltage and current of each component over 3 switching intervals in the steady-state. Validate that the simulation results are matched with your analytical calculations in d). Make sure that the designed values meet the design requirements of part a). Also, measure the voltage conversion ratio and the efficiency of your circuit by simulation and compare with what you calculated in part c). Do the simulation under four extreme cases, the minimum and the maximum load and under the minimum and maximum input voltage.

g) Change the duty cycle and observe its effect on the circuit and report the observation.

h) In the simulation, increase and decrease the value of the inductor and observe the effect on the average value of the inductor current and the ripple. Also observe the effect on the output voltage ripple.
i) Set the circuit to ideal conditions and simulate the boost converter under no-load condition. What happens and why?

7.3 Experimentation

NOTE: DO NOT RUN THE BOOST CONVERTER UNDER NO-LOAD CONDITION!!

PLEASE USE THE SAFETY GLASSES DURING THE EXPERIMENTATION. BE CAREFUL!

In this part you will set up the boost converter you designed and you will be able to compare experimental results with the simulation results.

- Construct the boost converter circuit. Check your circuit with the TA.
- Develop a MATLAB/GUI control interface program to communicate with your converter and to adjust the duty cycle and switching frequency of the converter.
- Once you are confident that your circuit is configured correctly (check it with the TA), power up the circuit.
- Observe the circuit current and voltage waveforms and compare them with those from simulations.
- Adjust the input voltage to 5V and vary the duty cycle within the allowable range and observe the effect on the dc- and ripple component of the output voltage, dc- and ripple component the inductor current.
- Adjust the output voltage 20V for a specific value of input voltage within the specified range. Observe the effect of changing the switching frequency. Measure the peak-peak output ripple voltage and the peak-peak ripple in inductor current for the following switching frequencies, $f_s = 40$ kHz, 25 kHz, and 10kHz. Make sure that the output voltage remains at 20 V. Observe and make a copy of the inductor current and capacitor current waveforms at 40kHz and at 10kHz.
- Increase and decrease the value of the inductor and observe the effect on the average value of the inductor current and the ripple. Also observe the effect on the output voltage ripple. Record the waveforms and compare with simulation.
- Measure the average output voltage and average output current as well as the average input voltage and average input current. Calculate the efficiency of the converter and compare it to the efficiency from calculation and simulation.