EE 452 – Power Electronics Design
Experiment 3: Part A

Department of Electrical & Computer Engineering
University of Washington

Introduction

The purpose of this experiment is to analyze the synchronous boost converter that you will be assembling during experiment 4. The synchronous boost converter is slightly different from the conventional boost converter. In it you will see that there are two active switches, while the conventional boost converter has an active switch and a diode. The inherent advantage is that this converter will not go into Discontinuous Conduction Mode (DCM) when operating under light load conditions. The disadvantage of this circuit is that it needs a bootstrap circuit for switching the high side switch of the converter (which is what 1B was all about!). Note that the results expected from this will be required for upcoming experiments.

For each problem, please provide written analysis where appropriate, show your work, and clearly label all plots, if any.

Parts

In Experiment 3 you will be building the boost converter in Figure 1. In addition to the components from Experiment 2, you can select components from the selection below.

Description	Manufacturer	Part number
150 V, 35 A HEXFET Power MOSFET	International Rectifier	IRFB4615PBF
100 V, 150 A NexFET Power MOSFET	Texas Instruments	CSD19535KCS

Objectives

The purpose of this experiment is to provide an analytical base to begin designing your magnetics and pick your power-stage MOSFETs. In particular, the objective of this experiment is to begin creating an analytical model and simulation of your hardware build. For the report, you are expected to shows analytical and simulation results to accompany your measurements.

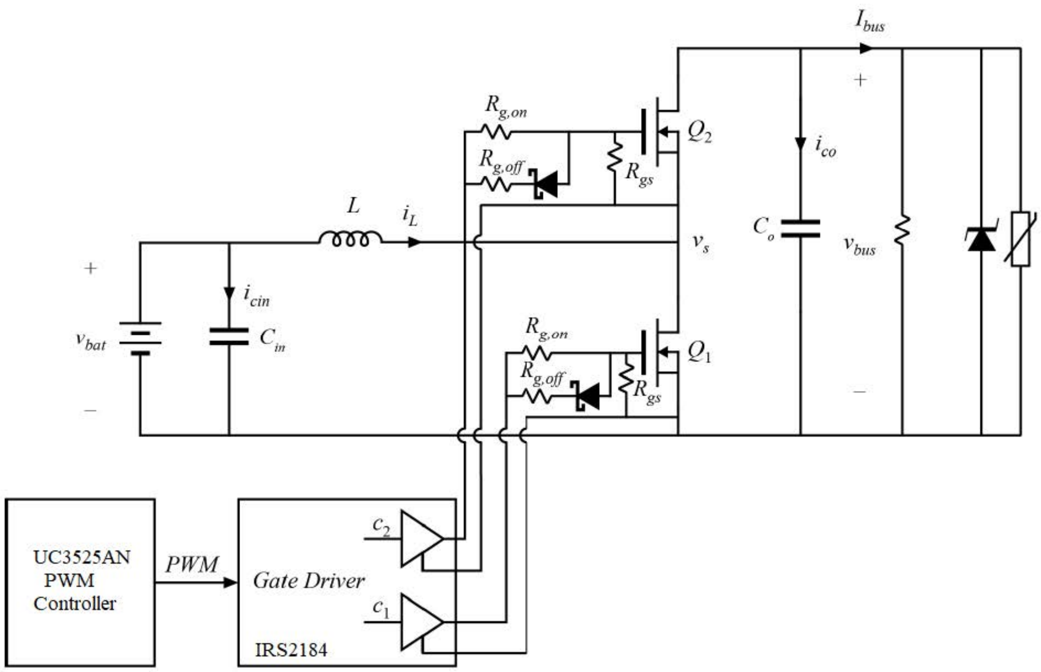

Figure 1: Diagram of circuit to be assembled in Experiment 4.

Loss Modeling and Simulation

Consider again the boost converter in Figure 1. The MOSFETs on-state resistance used in your analysis R_{on} can be obtained from the datasheet of the component you select. In your analysis, denote the dc component of the inductor currents as I. Assume the inductor winding resistance and inductance are R_L and L respectively. Assume an ideal capacitance C at the output.

For the following analysis and simulations, include the following non idealities - inductor winding resistance, Mosfet On state resistance.

For EE 559 students, include the ESR effect of the capacitor in your analysis.

(PS: "Analytical model" refers to a derivation written in terms of variable names such as D and R_{on}, and that does not have numerical values substituted.)

(a) *Analytical Model:*

- Using volt-second/charge-balance equations, derive an analytical model of the converter voltage conversion ratio V/V_g and plot the variation of the conversion ratio with variation of duty ratio D for $R_L = 40m\Omega, R_{on} = 10m\Omega, R_{load} = 50\Omega$. Grads use $R_{c,esr} = 0.1\Omega$**(15 pts)**
- Using the inductor current ripple equations, derive an analytical expression for the value of the inductance that will be included in your converter. **(5 pts)**
- Give expressions for the average conduction loss and switching loss. Assume switching transition includes delay time and rise/fall time (details in lab lecture). **(10 pts)**

- Derive an expression for the efficiency of the boost converter. Plot the variation of the efficiency with duty cycle variation.**(15 pts)**

For the following, use a switching frequency of 50kHz and an inductor current ripple of 15%.

- Given $V_{in} = 24V$, $V_{out} = 48V$, $R_L = 40m\Omega$,$R_{load} = 50\Omega$ and R_{on} values from both sets of MOSFETS, compute an inductance value from question 1. Compute the value of the duty cycle needed in both cases. **(20 pts)**
- Given $V_{in} = 24V$, $V_{out} = 48V$, $R_L = 40m\Omega$,$R_{load} = 50\Omega$ and R_{on} values from both sets of MOSFETS, compute the average conduction and switching loss in both cases.**(10 pts)**
- Given $V_{in} = 24V$, $V_{out} = 48V$, $R_L = 40m\Omega$,$R_{load} = 50\Omega$ and R_{on} values from both sets of MOSFETS, compute converter efficiencies.**(5 pts)**

Assume a capacitance C of 200 uF in all cases.

Based on the efficiencies calculated for each MOSFET, select one of the MOSFETS for your converter. Explain why **10 pts**.

(b) *Simulation:* Simulate your converter in PLECS and do your best to make it closely match your actual hardware. You only need to do this part for the MOSFET you selected. Download the buck converter file from Canvas and update it into a synchronous boost converter. Use a MOSFET with a body diode (your power MOSFETs have them) and make sure to update relevant non-idealities. Simulate the efficiency at 50 W, 100 W, 150 W, and 200 W.

- **Capture 1:** Capture the steady state inductor current I and the load voltage V in separate graphs (one placed below the other).**(10 pts)**
- **Capture 2:** Capture the inductor current and switch drain to source voltage of the bottom MOSFET. Explain the relation between these two parameters in two lines. This is to measure the switch level understanding of your converter fundamentals.**(10 pts)**

For EE559 students

- **Capture 3:** Compare your analytical efficiency calculation with the simulation result with 50 Ω load.**(10 pts)**

Hardware instructions: You should be now in a position to choose your switch carefully given the computations. Once this is done, solder your switch pair with the heat sink and thermal pad on it. Complete soldering the rest of the circuit upto the switches i,e include your gate on/off resistances. Be careful to ground the source of the bottom MOSFET. This should be connected at only one ground point with the gate driver circuitry.