UNIVERSITY OF CALIFORNIA, BERKELEY
DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCES

EE 113B/213B: Power Electronics Design
Final Design Report and EE 213B Presentations

Overview

Write a report summarizing your final MPPT dc-dc power converter design. Your target audience should be aspiring power electronics engineers who know a bit about power electronics from taking EE 113 but have no experience with designing or testing hardware. This manual should be written in your own words, and you are encouraged to pull from your previous pre-lab and post-lab submissions (if correct).

Format

Your design report should adhere to the following format guidelines:

- The report should be typed and presented in a professional manner.
- You should present information in a clear, concise way.
- When possible, use photos and figures to aid your description. Figures should be clearly labeled and should use fonts that are easy to read.
- There is no page limit.

Contents

At minimum, your design report should include the following information. All of your design decisions should be justified and calculations should be clear enough for the reader to repeat your exact design in the future if desired.

Introduction

- Overview of design specifications and application.
- Converter topology, including a schematic. Describe why this topology is a good fit for this application.
- Converter operating sequence. Show each consecutive switch state. Describe what happens during each switch state. Describe what happens during dead time.

Frequency Selection and Component Sizing

- How you selected the switching frequency, and the tradeoffs associated with this decision. You should include how this decision affected the size and loss of the converter.
- How you sized passive/filter components according to ripple specifications or other means. When sizing components without ripple constraints, you should describe how this decision affected the part being sized but also other parts of the converter in terms of size and efficiency. Show that your component sizes are adequate at all corner operating points.

- How you calculated voltage stresses and rms currents for each switch in your design, including ripple. Provide these voltage stresses and rms currents for each switch at the nominal operating point and all four corner operating points.

Switches

- Which switch losses, including conduction loss, C_{oss} loss, and overlap loss, occur in each switch. You should explain whether or not C_{oss} and overlap losses are present during each transition, and why. Ambitious students may also include reverse recovery loss if applicable.
- How you calculated each loss type for each switch.
- How you determined the temperature rise of each switch, with or without a heat sink.
- Provide the switch parts you selected along with the voltage rating, temperature-adjusted $R_{ds,on}$, equivalent C_{oss}, and all other relevant information. Also provide your thermal design for each switch (i.e., whether or not each switch has a heat sink), and the tradeoffs associated with this decision.
- Provide the complete loss breakdown and expected junction temperature for each switch at the nominal and four corner operating points. Note: These calculations should reflect your *final design*. Overlap loss should be calculated using actual rise and fall times with your selected gate driver.

Magnetics

- Which type(s) of magnetic components (dc, ac, or both) occur in your topology. Provide all relevant assumptions for this (e.g., ripple size).
- Which type(s) of losses occur in each magnetic component, and how you calculated each loss type.
- How you selected a magnetic material for this component(s).
- How you designed the magnetic component(s), and what assumptions were made in the design process. For example, if using the K_g method to design an inductor, provide the inductance needed, your budgeted power loss, your assumed packing factor, your assumed maximum flux density, and whether or not Litz wire is needed.
- Provide your final magnetic component design(s). Include the material, core size, number of turns, wire size, and gap length. Provide your characterized inductance and ESR for each magnetic component design.
- Provide your expected loss breakdown for each magnetic component at the nominal and four corner operating points. Provide the expected temperature rise at each of these operating points. Note: These calculations should reflect your *final design*.

Capacitors

- Which type(s) of capacitors are best for implementing your power stage capacitors.
- How you selected each capacitor. You should provide technical justification for the capacitor parts you selected, as well as the number of parts you chose to use in parallel.
- How you calculated loss for each capacitor.
- Provide your final design for implementing each power stage capacitor (i.e., which parts, and how many in parallel). For each electrolytic part(s), provide the voltage rating, capacitance, ESR, and current rating from the datasheet. Provide the expected rms current in your design, and show that it is below the safe limit. For each MLCC, provide the voltage rating, derated capacitance value at the intended voltage, and ESR value at the frequency of use.
- Provide your expected loss for each capacitor at the nominal and four corner operating points. Note: These calculations should reflect your *final design*.

Gate Drive Circuit

- What are the specific gate drive needs for each switch in your topology. You should include whether level shifting and/or isolation is needed for the gate signals and/or gate drive power supplies.
- A schematic for how you implemented the gate drive circuit for each switch in your converter design.
- Provide the parts you utilized in your gate drive circuit and how you selected/sized them.

Sensing Circuit

- Which voltages and currents need to be sensed for MPPT in your topology.
- A schematic for of how you implemented voltage and current sensing circuits in your converter design.
- Provide the parts you utilized in your sensing circuits and how you selected/sized them.

Control

- How you utilized a microcontroller to generate PWM signals for your converter design, including which C2000 pins and features you used.
- What control handle(s) are needed to generate the appropriate PWM signals for your topology.
- How you implemented a closed-loop MPPT algorithm. You should provide a flow chart illustrating your final algorithm. Provide screenshots of relevant microcontroller code and describe in prose what they accomplish. Provide relevant parameters such as dead time, ADC gains, etc.

PCB Layout

- The most critical aspects of PCB layout for your converter design. For example, describe which loops and nodes are most critical, and why. Then describe how you minimized the effects of parasitic inductance and capacitance in these loops/nodes in your design.
- Other important considerations for your converter's PCB layout. This should include everything from ground planes to analog circuit placement, etc., and the strategy you utilized to optimize these in your PCB layout.
- How you prioritized these considerations in your PCB design.
- Provide print outs of your PCB schematic and layout as an appendix to this design manual.

Experimental Setup and Operation

- Your systematic strategy for assembling and ramping up your power converter design.
- How you emulated the necessary source and load profiles for your power converter in a lab setup. Describe the necessary source/load equipment, and how it was used for different tests.
- How you gathered information about your converter's operating behavior with an oscilloscope, thermal camera, or other characterization/measurement equipment. Describe what information each piece of equipment gave you.
- Provide oscilloscope screenshots at the nominal operating point and all corner operating points showing that your power converter design meets ripple specifications.
- Provide the temperatures of your switches and magnetic components and compare these to their expected values. Discuss any discrepancies.
- Provide the final power density of your converter design, as measured by course staff.

Experimental Efficiency

- How you measured power stage efficiency for a single operating point, including where in the circuit voltage and current measurements were taken.
- Provide a full breakdown of expected power-stage losses based on your calculations in the previous sections, for the nominal operating point and each corner operating point. For components with multiple loss types (e.g., switches), you should explicitly show each type. Loss breakdowns like this are commonly visualized using pie charts. Then, provide the experimental efficiencies and loss totals at these operating points and discuss any discrepancies. Note: If you improved the way you model losses as part of your efficiency analysis in Module 12, the above loss calculations should reflect this. These calculations and results should reflect your *final design*.
- Provide efficiency sweeps from the automated test script spanning the converter's entire operating range. Plot similar sweeps of expected efficiency based on your loss calculations using a Matlab or Python script. Discuss the operating regions for which your converter is most and least efficient, and whether or not this is explained by your modeled efficiency. Discuss the trends you observe, and any additional discrepancies.
- Provide the auxiliary circuit power draw, and estimate what your nominal operating point efficiency would have been if this power loss had been included in your efficiency calculation.
- Provide your final efficiency score for the design competition.
- Describe how your efficiency could have been improved if it is not as high as expected. You should include strategies for identifying sources of unexpected loss.

Experimental MPPT

- How you evaluated MPPT tracking efficiency, and how you evaluated MPPT performance across an automated test profile.
- Provide the steady-state tracking efficiency of your MPPT algorithm. Discuss why it is not 100%.
- Provide your converter's dynamic MPPT test score for the design competition.
- Describe how your MPPT could be improved.

BOM and Budget

- A list of all parts, quantities, and prices for your converter, excluding the PCB.
- The total cost of your converter, excluding connectors, test points, and header pins.

Conclusion

- Provide final takeaways for your converter design. This may include key converter performance metrics, lessons learned, and potential ways your converter design could have been improved.

EE 213B Presentations

Prepare a 6-minute presentation with PowerPoint slides on your converter design, emphasizing the elements of your design process that are different than that of a buck converter. You may assume an audience of power electronics engineers who have converter design experience only in the context of a buck converter. Begin by illustrating your converter topology and operating sequence, and then step through the design aspects outlined above that are most unique to your design. Conclude with key performance metrics such as efficiency and power density.