Milestone #2
Initial Controller Design

Capstone Design Project
Coursera Specialization in Power Electronics
University of Colorado, Boulder

Milestones for Weeks 3-4

This is the submission of Milestone 2, documenting preliminary design of control loops around the converter to meet the project requirements. You are expected to construct an averaged circuit model of the closed-loop controlled converter and verify the design using transient (time-domain) and ac (frequency-domain) simulations of the averaged circuit model.
Your submission will be graded by three other learners, according to the instructions and rubrics defined in this document.
Please read these review criteria and follow them closely, both in your submission and in your grading of the submissions of other learners. Everybody must review at least three peer submissions; many learners choose to review more than three, to help their fellow learners.
You will be allowed to upload your submission only once, so be sure that all parts are correct and complete.

1 Approach

Take a screen shot of the LTspice averaged circuit model of your closed-loop converter. The screen shot should include only your averaged circuit model - it is not necessary to include the template header part provided in milestone2.asc (simulation commands and parameters, control signals, battery and bus models, measurement commands).
Upload the screenshot followed by a brief description of how you approached the design of the control loop(s) around your converter, the type of control loop(s) employed (PWM voltage mode, peak current mode, or averaged current mode control), and the parameters: crossover frequency and phase margin for each control loop. Express each crossover frequency in kHz, and as a fraction of the corresponding converter switching frequency.

1.1 Rubric 1

Is the approach briefly described, and is a schematic included?

- Yes [40 points]
- No [0 points]

1.2 Rubric 2

Based on inspection of the schematic, is the converter bidirectional and capable of both step-down and step-up operation?

- Yes [30 points]
- No [0 points]

1.3 Rubric 3

Have all cross-over frequencies been reported, and are they all less than or equal to 1/5 of the corresponding converter switching frequencies?

- Yes [20 points]
- No [0 points]

1.4 Rubric 4

Optional comments by reviewer, no points.

2 Simulations

Place your Milestone 2 LTspice files into a dedicated folder. Make sure all simulations run correctly using the files in that folder. Remove all .raw files, but include all files necessary to run the required simulations (all .sch. .asy, .lib files). Create a .zip file of the folder and upload this .zip file. The folder must include a single schematic (.sch) file that contains the template header from milestone2.sch and the averaged circuit model of your closed-loop converter. The template tests your converter averaged model at two operating points, in this order

1. USB output 20V at 3A, Vbatt = 9.6V (operating point 2)
2. USB output 5V at 2A, Vbatt = 12.6V (operating point 1)

In the template header you should adjust the parameters **t1**, and **Tend** as necessary so that the template measurements of the two operating points are made in steady state. Your simulation should use the control signal parameters **Vref1_5V**, **Vref1_20V**, (and **Vref2_5V**, **Vref2_20V** if the second control signal source is used), to set the references for your control loop(s) as necessary to reach the two operating points defined above, and you should adjust these parameters as well. Also define the switching period parameter **Ts** so that the template runs ac simulation over an appropriate range of frequencies for your design.

2.1 Rubric 1

The LTspice schematic can be downloaded and run. The simulation correctly employs the provided template. No dependent sources or independent sources or other excluded components are used, other than those provided in the template, and dependent sources that may be used to model pulse-width modulators. All inductors are implemented using the LTspice saturating inductor model.

- No LTspice file provided, zipped files are incomplete such that the simulation will not run, or simulation fails to complete. In this case, enter zero for the remaining rubrics. [0 points]

- The LTspice simulation runs. However, one or more of the following rules are violated:
  - The simulation correctly employs the provided template.
  - No dependent sources or independent sources or other excluded components are used, other than those provided in the template or dependent sources that may be used to model pulse-width modulator(s).
  - All inductors are implemented using the LTspice saturating inductor model.

  [5 points]
- The LTspice simulation runs. The LTspice simulation conforms to all of the following rules:
  - The simulation correctly employs the provided template.
  - No dependent sources or independent sources or other excluded components are used, other than those provided in the template or dependent sources that may be used to model pulse-width modulator(s).
  - All inductors are implemented using the LTspice saturating inductor model.

  [30 points]

2.2 Rubric 2

For this and the next rubric, run transient (**.tran**) simulation, plot v(out) and inductor current waveform(s), and inspect measurement results in the output .log file.
At time=t1, is the converter in steady state at operating point 2, and is the **Vout_20V** measurement within the range 20 V ± 0.1 V?

- Yes [20 points]
- No [0 points]

2.3 Rubric 3

At time=Tend, is the converter in steady state at operating point 1, and is the **Vout_5V** measurement within the range 5 V ± 0.1 V?

- Yes [20 points]
- No [0 points]

2.4 Rubric 4

Run ac (.ac) simulation of the submitted .sch schematic: plot v(out) magnitude and phase responses, corresponding to the converter closed-loop output impedance, and inspect measurement results in the output .log file. Is the converter measured output impedance **Zout_20V_Ohms** less than or equal to 0.5 Ω, at the dc operating point 2 (20 $\pm$ 0.1) V? If the ac simulation fails to converge, select No.

- Yes [40 points]
- No [0 points]

2.5 Rubric 5

Optional comments by reviewer, no points.