Exercise 5: Boost Converter with Peak-Current-Mode Control

A widely used alternative to Pulse Width Modulation (PWM) are the so called Peak-Current-Mode (PCM) and Average-Current-Mode (ACM). Peak-Current-Mode with constant switching frequency turns on the transistor at the beginning of each switching period. The switch-off time instant of the transistor is determined by the inductor current hitting the positive reference current. For duty ratios lower than 50% the generated signal forms look similar to the ones generated by a PWM. Interesting effects occur if the converter is operated with a duty cycle greater than 50%. Figure 1 shows the circuit diagram of a boost converter that is controlled by a cascaded control structure:

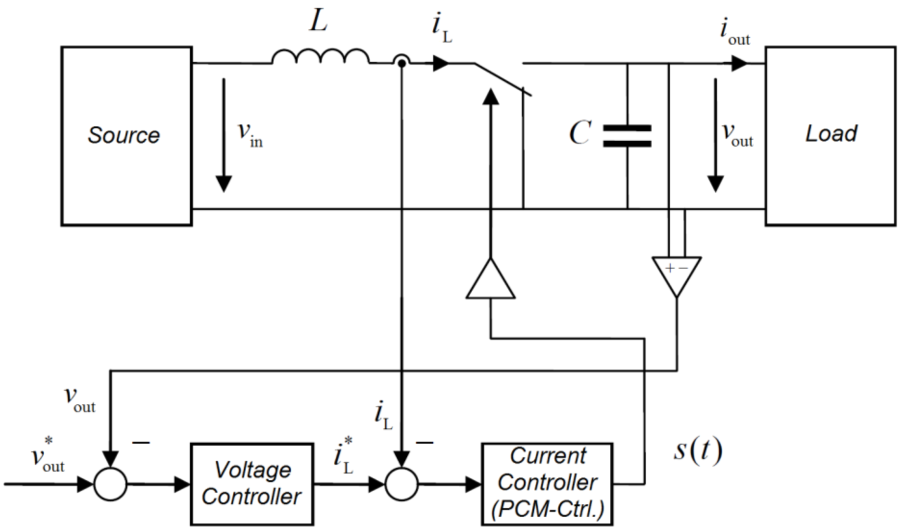


Figure 1: Voltage controller with subordinated Peak-Current-Mode current controller driving a boost converter

The specification of the boost converter is given below:

Nominal input voltage:	$V_{in} = 100\ \mathrm{V}$	Boost inductance:	$L = 49\ \mu\mathrm{H}$
Nominal output voltage:	$V_{out} = 400\ \mathrm{V}$	Output capacitor:	$C = 1\ \mathrm{mF}$
Nominal output current:	$I_{out} = 30\ \mathrm{A}$	Switching frequency:	$f_s = 100\ \mathrm{kHz}$

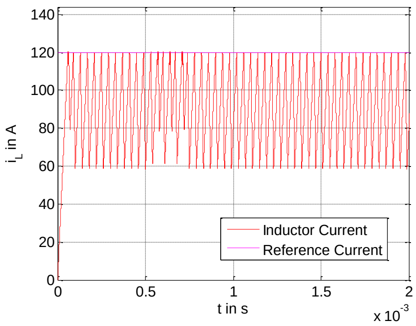
1. Calculate the duty ratio D, the average inductor current $\bar{i}_L$ and the inductor current ripple Δi_L for nominal operation.
2. The inductor current of the boost converter should be controlled by a Peak-Current-Mode controller. Draw a detailed schematic diagram of the controller. How large is the control error?
3. Explain why slope compensation has to be integrated in the PCM controller. Determine the minimum slope value m_{min} to guarantee stable operation for the considered operation point.
4. Add the slope compensation to your schematic diagram from problem 2) and make a proposal for control error reduction.

The following tasks will be presented in form of simulations in MATLAB/Simulink.

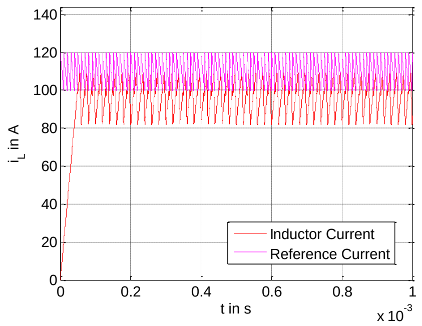
5. Open the simulation model and build up the PCM controller. Validate the performed calculations.
6. Add a voltage controller and simulate the complete system with different reference voltages. Vary the load and observe the behavior of the controlled system.

Simulation results of implemented PCM controller:

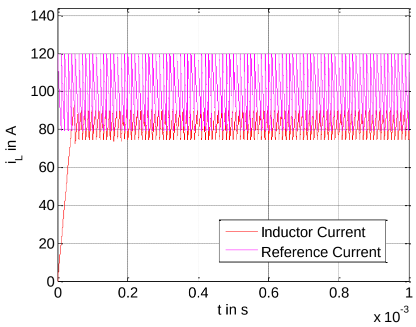
$V_{\text{in}} = 100\ \text{V};\ V_{\text{out}} = 400\ \text{V};\ i_{\text{L}}^{*} = 120\ \text{A};\ m' = 0$



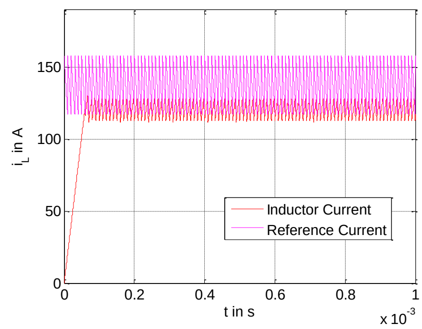
$V_{\text{in}} = 100\ \text{V};\ V_{\text{out}} = 400\ \text{V};\ i_{\text{L}}^{*} = 120\ \text{A};\ m' = 0.5$



$V_{\text{in}} = 100\ \text{V};\ V_{\text{out}} = 400\ \text{V};\ i_{\text{L}}^{*} = 120\ \text{A};\ m' = 1.0$

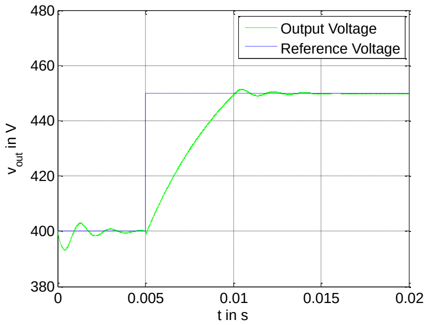


$V_{\text{in}} = 100\ \text{V};\ V_{\text{out}} = 400\ \text{V};\ i_{\text{L}}^{*} = 120\ \text{A}\ (\text{Ctrl. Err. Comp.})$



Simulation results of voltage controlled boost converter:

$V_{\text{in}} = 100\ \text{V};\ V_{\text{out}_0} = 400\ \text{V};\ v_{\text{out}}^{*} = 400\ \text{V} \rightarrow 450\ \text{V};\ m' = 1.0$



$V_{\text{in}} = 100\ \text{V};\ V_{\text{out}_0} = 400\ \text{V};\ v_{\text{out}}^{*} = 400\ \text{V};\ \text{I}_{\text{out}} = 30\ \text{A} \rightarrow 3\ \text{A}$