PLECS

DEMO MODEL

Buck Converter with Loop Gain Analysis

Last updated in PLECS 5.0.2

1 Overview

This demonstration shows how to obtain the loop gain of a voltage-regulated buck converter with a resistive load. This can be done by performing an AC Sweep Analysis, which inherently first executes a Steady-State Analysis, or alternatively, using Multitone Analysis, which does not execute a Steady-State Analysis.

2 Model

2.1 Electrical model

This schematic shows a simple buck converter using a MOSFET. The circuit is clocked with a fixed frequency of $100\,\mathrm{kHz}$. The output voltage of the converter is regulated to the voltage reference by a proportional integral derivative (PID) controller.

The system is configured with a Loop Gain Meter placed in the feedback path of the voltage regulator. A current source with a Small Signal Perturbation component and Small Signal Response block are placed at the output of the converter to measure the output impedance with closed loop controls.

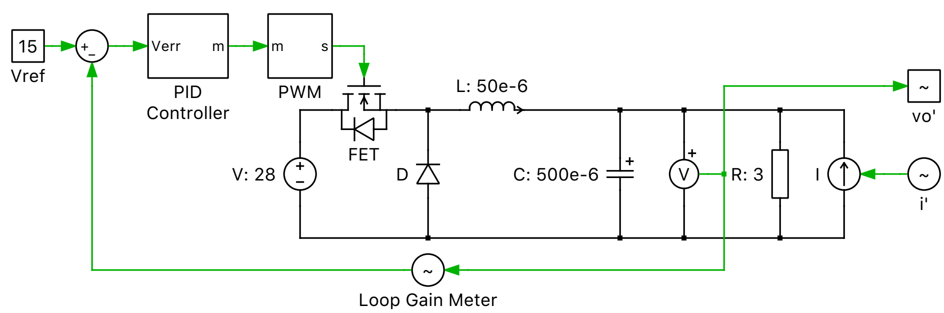

Fig. 1: Buck Converter with Loop Gain Analysis

2.2 Small-Signal Analyses

The Frequency Response, AC Sweep, and Multitone Analyses are similar in the sense that they analyze the frequency response of a system by applying sinosoidal perturbations and using Fourier analysis. Nevertheless, there are difference is how the different analysis work, which provide different advntages and disadvantages.

The AC Sweep Analysis applies a set of sinusoidal perturbations at discrete frequencies. At each of these user-specified frequencies finds the periodic steady-state operating point of the perturbed system, by using the Steady-State Analysis, and extracts the system response. For detailed information see this tutorial.

The Multitone Analysis does not use the Steady State Anaylsis, it runs a trnasient simulation to drive the system into steady-state. Also, instead of multiple sinusoidal signals of different frequencies, only one multitone signal is applied. The multitone signal is composed of several sinusoidal signals and therefore contains all investigated frequencies at once.

The Frequency Response Analysis, like the AC Sweep Analysis, applies a series of sinusoidal perturbations to the system. However, instead of using a Steady State Analysis to determine the steady operating point, it relies on a transient simulation, similar to the Multitone Analysis.

Compared to the AC Sweep and Multitone Analyses, the Frequency Response Analysis employs the most robust approach for reaching steady state and applying perturbations. The Steady-State Analysis often suffers from convergence issues and requires a known system period, so the AC Sweep inherits these limitations. Regarding the perturbation method, the multitone signal does not allow for freely selecting frequency points, as they must be integer multiples of the minimum frequency within the defined range. Moreover, when analyzing switched power converters, the accuracy of the frequency response beyond half of the switching frequency degrades due to interference from sideband harmonics generated by the perturbation signals and the switching operation.

In conclusion, the Frequency Response Analysis does not suffer from these issues at the expense of being potentially slower.

3 Simulation

For PLECS Standalone and PLECS Blockset the different analysis can be run using the following steps:

- *Standalone:* Choose **Analysis tools...** from the **Simulation** menu, then select an analysis from the list and click **Start analysis**. Clicking **Show results** will display the output of the analysis.
- *Blockset:* Double-click on a PLECS Analysis blocks on the Simulink level. A window opens up that allows to set analysis parameters and to run the analysis by clicking the **Start analysis** button.

While running the analyses, keeping the time domain scope open will provide additional insight into the operation of each analysis tool. However, please note that this will also substantially slow down simulations because of the additional graphics processing so that for maximum speed all scope windows should always be closed. During the execution of the AC Sweep Analysis the scope shows that simulations are executed for each operating point in the set of user defined frequencies, starting from the calculated steady-state operating point. Multitone Analysis shows a longer duration simulation with the superimposed perturbation signal in the time domain.

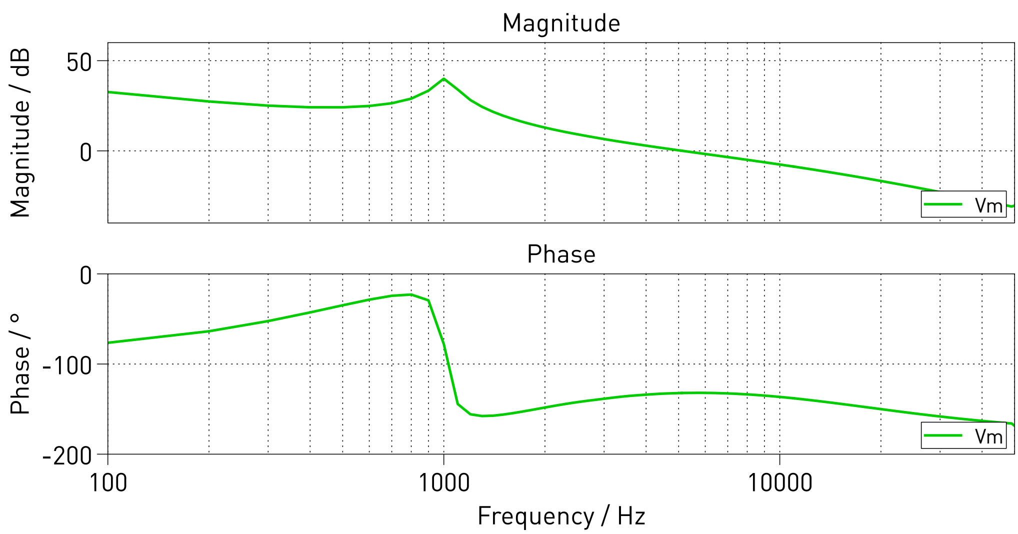

Fig. 2: Loop gain of buck converter

A demonstration of using small-signal analyses to obtain different open-loop transfer functions for an unregulated buck converter is given in the demo model ”Buck Converter with Analysis Tools”.

Revision History:

PLECS 4.3.1	First release
PLECS 5.0.2	Frequency response analysis was added as option in the small-signal analyses

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PLECS Demo Model