PLECS

DEMO MODEL

Buck Converter with Analysis Tools

Last updated in PLECS 4.6.6

1   Overview

This demonstration shows how to perform a Steady-State Analysis and use small-signal analysis to obtain different open-loop transfer functions for an unregulated buck converter. The transfer function can be calculated by performing an AC Sweep or Impulse Response Analysis, which both inherently first execute a Steady-State Analysis, or alternatively, using the 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 and a resistive load. The circuit is clocked with a fixed frequency of $100\,\text{kHz}$ with a fixed duty cycle of $15/28$.

The system is configured with two Small Signal Perturbation instances. One perturbation is applied to the duty cycle and other perturbation is applied as a load current injection. There is a Small Signal Response component connected to the converter output voltage to measure the response of the circuit to the perturbations. The system is configured to measure the

- control-to-output transfer function with the perturbation "m" and the response block "vo_co' " and
- output impedance of the converter with the perturbation "i' " and the response block "vo_oi' ".
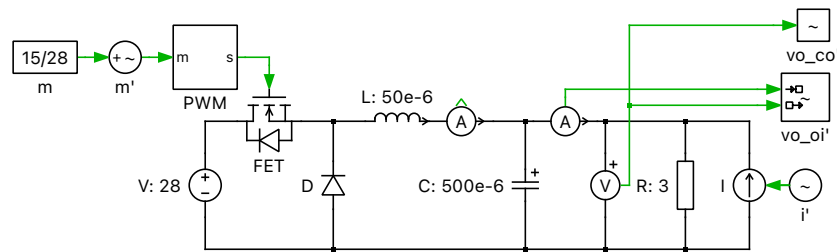

Figure 1: Buck converter with analysis tools

2.2   AC Sweep and Impulse Response Analysis

The AC Sweep Analysis applies a set of sinusoidal perturbations to the system under study. At each of these user-specified frequencies it then finds the periodic steady-state operating point of the perturbed system and then extracts the system response using Fourier analysis. One advantage is that the user can choose specific frequencies of interest when investigating a transfer function.

The Impulse Response Analysis provides an alternative and faster method to determine the open-loop transfer function of a system. Instead of perturbing a system with sinusoidal stimuli of different frequencies, one at a time, a single impulse is applied when the system is in steady state. The system transfer function can then be calculated very efficiently over a wide frequency range by computing the Laplace transform of the transient impulse response.

For detailed information on AC Sweep and Impulse Response Analysis please check the example in the chapter "Analysis Tools" of the official PLECS manual.

2.3   Multitone Analysis

Multitone Analysis is similar to an AC Analysis where the response of the system to a small perturbation signal is analyzed. However, 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.

Compared to the AC Sweep Analysis the Multitone Analysis only needs to compute the response to one signal instead of a set of signals for each frequency. One requirement for the Multitone Analysis to work properly is that the value for the initial simulation period parameter must be sufficiently large for the system to have reached steady-state conditions from a transient simulation. Since no information about the system period is needed for the Multitone analysis, this algorithm also works for systems with variable frequency control such as resonant converters.

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.
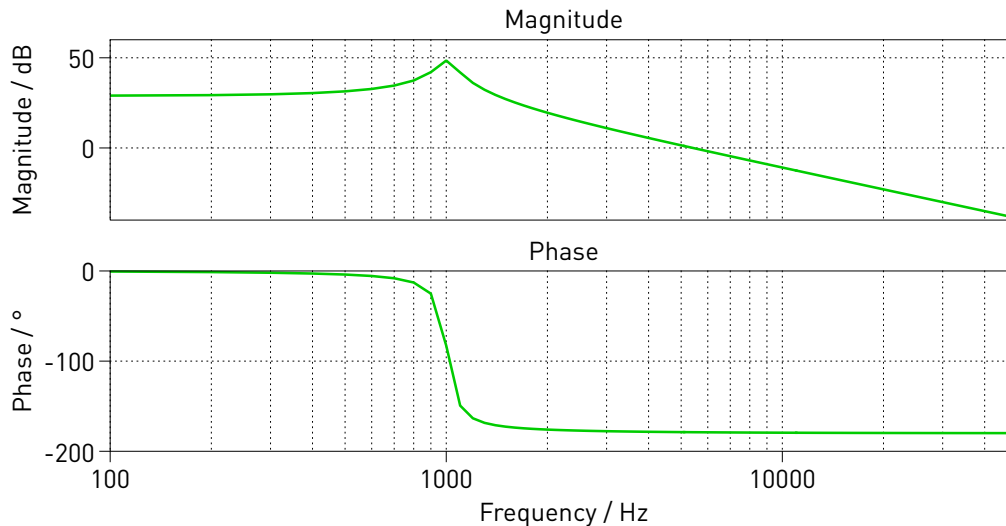

Figure 2: Control-to-output frequency response of open loop buck converter

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. Following the Impulse Response Analysis the scope shows the result of a perturbation in the form of a discrete impulse for the duration of one period. Multitone Analysis shows the simulation with the superimposed perturbation signal in the time domain.

3.1 Converter Output Impedance

The small-signal analysis tools can also be used to calculate the output impedance of the power converter. The output impedance is defined as the transfer function between the converter output current and voltage, $Z_{o(s)} = V_o(s)/I_o(s)$. The perturbation signal i' cannot be used to calculated the output impedance as it will also include the effect of the output resistor. To set a different reference signal in
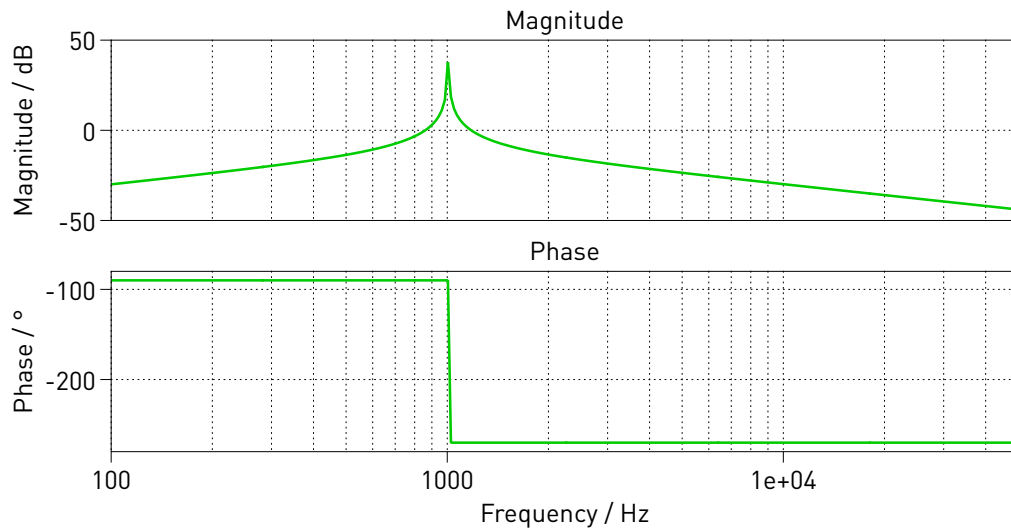
Figure 3: Output impedance frequency response of open loop buck converter

PLECS Standalone double-click on the "Small Signal Response" block and set the **Show reference input** to on, and feed the measured converter output current to the reference input port.

A demonstration of a closed loop gain analysis is given in the demo model "Buck Converter with Loop Gain Analysis" in the PLECS demo models library.

Revision History:

PLECS 4.3.1	First release
PLECS 4.6.6	Fix output impedance calculation

How to Contact Plexim:

PLECS Demo Model