Management Center Innsbruck

Department of Technology & Life Sciences

Master's program Mechatronics & Smart Technologies

Report

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about

Discrete PID Controller Design for a Buck Converter

from

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Contents

Chapter 1

Introduction

A discrete Proportional-Integral-Derivative (PID) controller for a 12 V to 5 V Buck-Converter is to be designed and tested using PLECS [1].

The self-imposed charcteristics of the buck converter and the chosen passive components according to [2] are given in Table 1.1 and Table 1.2 respectively.

Parameter	Value
$V_{\text{in,nominal}}$	12 V
$V_{\text{in,min}}$	8 V
$V_{\text{in,max}}$	16 V
V_{out}	5 V
I_{out}	1 A
ΔI_{L} at $V_{\text{in,max}}$	400 mA
f_{sw}	50 kHz

Table 1.1. Buck-Converter Characteristics

Component	Value
L	200 µH
C	50 µF
R	5 Ω

Table 1.2. Passive components of the Buck-Converter

A continous controller can be designed according to [3] – for simplicity, the parameters were kept the same for the discrete controller

Parameter	Value
K_D	$50LC$
K_P	$50\frac{L}{R}$
K_I	50

Table 1.3. PID Controller Parameters

Chapter 2

Methods

The PLECS model of the converter includes the following:

- a PID controlled duty cycle
- a noise source for the input voltage
- a variable load

all of which can be selected to be active or inactive as can be seen in Figure 2.1 and Figure 2.2.

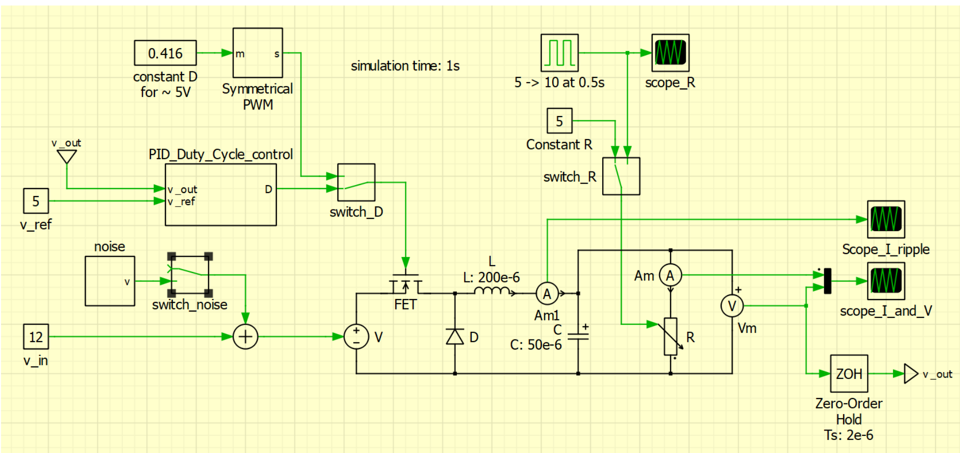
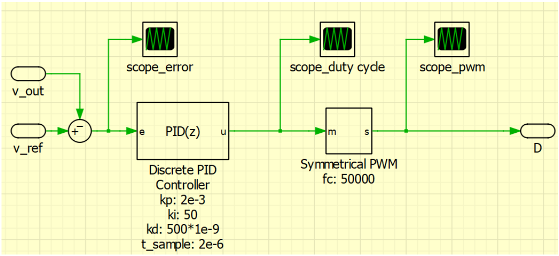


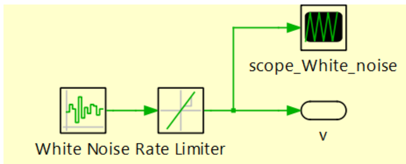
Figure 2.1. PLECS model of the Buck-Converter

The control of the converter was tested under the following conditions and compared to the behaviour of the converter with a fixed duty cycle:

- noise on the input voltage (white noise with a standard deviation of 1 V and a sample time of 50 ms as seen in Figure 2.3)
- a load step from 5 Ω to 10 Ω at 0.5 s
- startup behaviour



(a) PLECS model of the PID_Duty_Cycle_control subsystem



(b) PLECS model of the noise subsystem

Figure 2.2. PLECS model subsystems

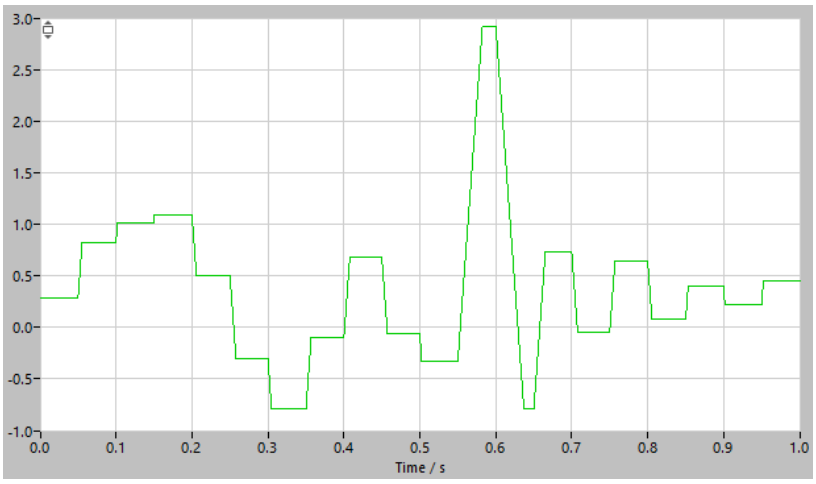
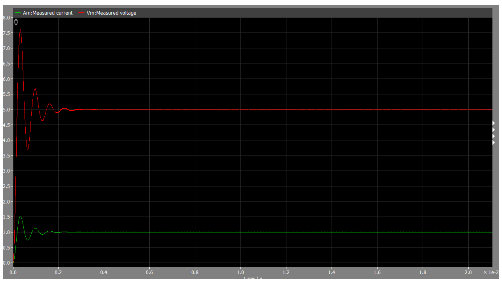


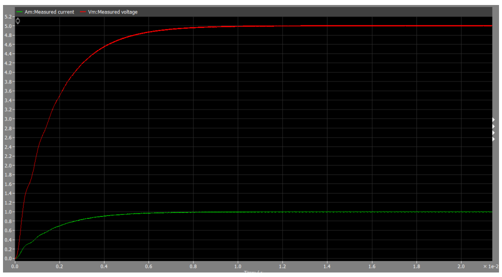
Figure 2.3. White noise with a standard deviation of 1 V and a sample time of 50 ms

Chapter 3

Results

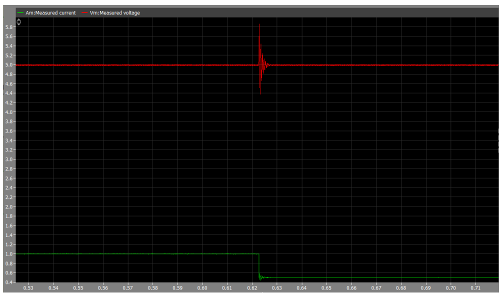


(a) Startup behaviour of the uncontrolled converter

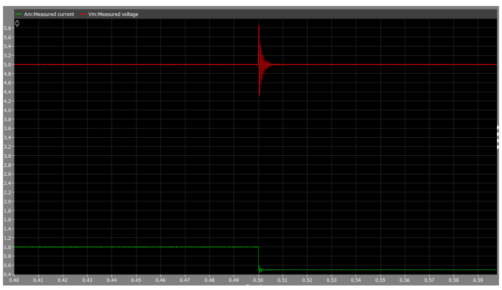


(b) Startup behaviour of the controlled converter

Figure 3.1. Comparison of the startup behaviour of the uncontrolled and controlled converter with current (green) and voltage (red) signals

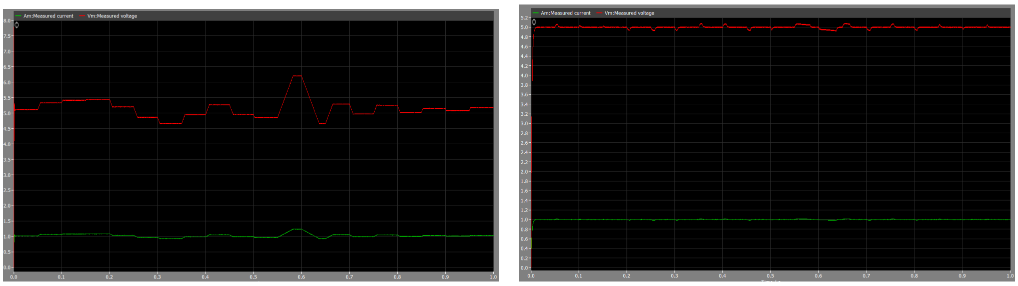


(a) load-jump behaviour of the uncontrolled converter



(b) load-jump behaviour of the controlled converter

Figure 3.2. Comparison of the load-jump behaviour of the uncontrolled and controlled converter with current (green) and voltage (red) signals



(a) input noise feedthrough of the uncontrolled converter

(b) input noise feedthrough of the controlled converter

Figure 3.3. Comparison of the input noise feedthrough behaviour of the uncontrolled and controlled converter with current (green) and voltage (red) signals

Chapter 4

Discussion

The uncontrolled converter shows a significant overshoot and oscillation before settling to the working point at startup. The controlled converter shows a much smoother startup behaviour, but the settling time is longer than for the uncontrolled converter as shown in Figure 3.1.

The load-jump behaviour of the controlled converter still shows a spike at the load-jump, but quickly settles to the working point as can be seen in Figure 3.2, whereas the uncontrolled converter delivers a higher unwanted constant ouput voltage after the jump.

The input noise feedthrough of the controlled converter is significantly reduced, although not completely eliminated, compared to the uncontrolled converter as can be seen in Figure 3.3.

Overall, the behavioural characteristics of the converter have improved with the addition of the PID-Controller.

Bibliography

[1] *PLECS | Plexim*. URL: https://www.plexim.com/de/products/plecs (visited on 01/16/2025).

[2] *Buck Converter*. URL: http://schmidt-walter-schaltnetzteile.de/smps_e/abw_smps_e.html (visited on 01/17/2025).

[3] Ahmad Saudi Samosir, Tole Sutikno, and Luthfiyyatun Mardiyah. “Simple Formula for Designing the PID Controller of a DC-DC Buck Converter”. In: *International Journal of Power Electronics and Drive Systems (IJPEDS)* 14.1 (1 Mar. 1, 2023), pp. 327–336. ISSN: 2722-256X. DOI: 10.11591/ijpeds.v14.i1.pp327-336. URL: https://ijpeds.iaescore.com/index.php/IJPEDS/article/view/22366 (visited on 01/13/2025).

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