

RT Box

DEMO MODEL

Multiphase Buck Converter

Use PWM triggered Analog In measurements for a three-phase interleaved buck converter with dynamic phase-shedding.

Last updated in RT Box TSP 3.1.3

www.plexim.com

- Request a PLECS and PLECS Coder trial license
- Get the latest RT Box Target Support Package
- Check the PLECS and RT Box TSP documentation

1 Overview

This RT Box demo features an interleaved multiphase buck converter in closed loop. The following sections describe in detail the implementation of the power stage and controls using the PLECS Electrical and Control domains. This demo model has the following features:

- The power circuit consists of a three-phase interleaved buck converter feeding a series of load.
- The number of active phases is dynamically changed through phase-shedding, which increases converter efficiency at light load conditions.
- The controller side samples the average inductor current of each phase synchronously, triggered by each phase PWM. This relationship is maintained also during phase-shedding where less phase PWMs are active. Also the current balancing control among all three phases is realized.

Note that this model is an adaptation from an existing STM32 Target Support Demo onto RT Boxes [1]. Therefore, the explanation of converter parameters and controller algorithms are not repeated in this document.

The focus of this document is to showcase the usage of the PWM triggered Analog In measurements, together with the Digital Output Override for dynamic phase-shedding when using the RT Box as a controller.

1.1 Requirements

To run this demo model, the following items are needed (available at www.plexim.com[1]):

- Two PLECS RT Boxes[2] and one PLECS[3] and PLECS Coder[4] license
- The RT Box Target Support Package[5], minimum version 3.1.1
- Follow the step-by-step instructions on configuring PLECS and the RT Box in the Quick Start guide of the RT Box User Manual[6].
- Two 37 pin Sub-D cables to connect the boxes front-to-front.

Note

This model contains model initialization commands that are accessible from:
PLECS Standalone: the menu **Simulation > Simulation Parameters... > Initializations**
PLECS Blockset: right click in the **Simulink model window > Model Properties > Callbacks > InitFcn***

2 Model

This demo is adapted from the Multiphase Buck Converter demo from the STM32 Target Support Demos. The Plant model for the RT Box is very similar; the Controller model is using the same control algorithm but utilizing the RT Box target blocks.

2.1 Plant

The power circuit is shown in Fig. 1. For description of circuit parameters please refer to the documentation of the STM32 Multiphase Buck Converter demo [1].

[1] http://www.plexim.com
[2] https://www.plexim.com/products/rt_box
[3] https://www.plexim.com/products/plecs/plecs_standalone
[4] https://www.plexim.com/products/plecs/plecs_coder
[5] https://www.plexim.com/download/rt_box
[6] https://www.plexim.com/sites/default/files/rtboxmanual.pdf

Each phase is modeled using a Buck Converter component from the Nanostep section of the PLECS library. The RT Box's Nanostep solver simulates the converter with time steps in the single-digit nanoseconds range. The step size of the Nanostep solver is fixed based on the RT Box hardware. It is 7.5 ns on RT Box 1 and CE; 4 ns on RT Box 2, 3 and 4.

An Electrical Model Settings block is connected to the phase leg. Inside this block, the **Target** can be chosen as **CPU** or **FlexArray**.

- CPU - available on all RT Boxes, also the default option for building onto an RT Box 1.
- FlexArray - only available on RT Box 2, 3 and 4, therefore the default option for building onto an RT Box 2, 3 or 4.

Also, the discretization step size `Ts_plant` may be adjusted slightly between different simulation targets. Please see the model initialization commands of each demo for more details.

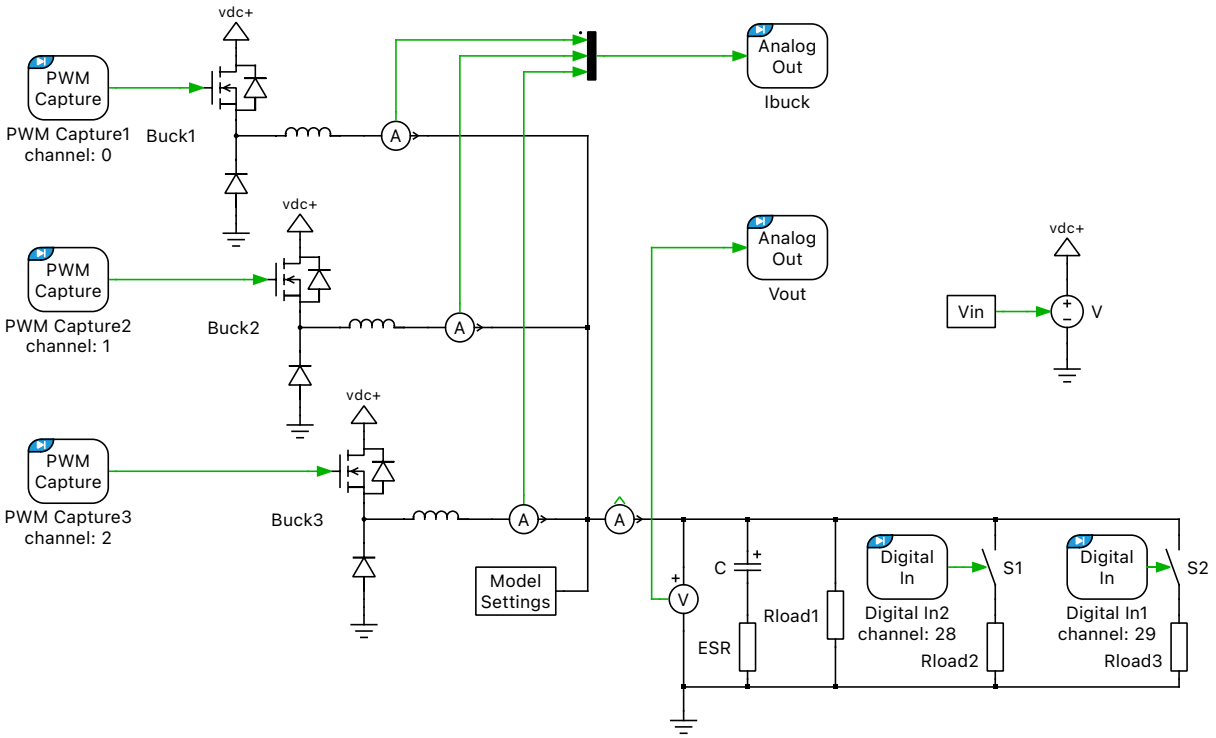


Fig. 1: Power circuit of the multiphase buck converter

The total load resistance can be changed based on the position of two Digital In signals (DI-28 and DI-29). The number of active phases is a function of the total load current. As the load resistance decreases, more phases become active.

2.2 Controller

The controller model is shown in Fig. 2. The subsystems named " Voltage Controller", "Current Controller", "Phase Shedding", and "Phase Calc" are the same as those in the corresponding STM32 Target Support Demo.

The controller part contains the following components from the RT Box Target Support Library:

- a PWM Out block with **ADC trigger output: On carrier minimum** configured in its **Advanced** tab.
- an Analog In block is configured with **Trigger source: Use PWM trigger port**.
- a Digital Out Override block to dynamically control the phase-shedding.
- a Digital Out block which outputs two digital signals on DO-28 and DO-29 to control the load resistance on the Plant side.

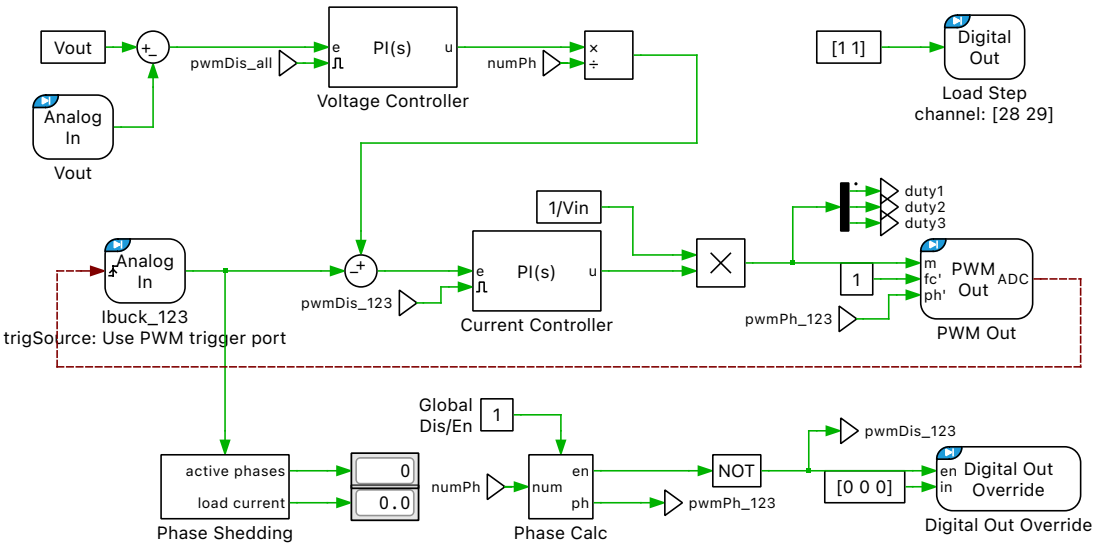


Fig. 2: Controller model of the multiphase buck converter

3 Simulation

This model can run both in offline mode on a computer or in real-time mode on the PLECS RT Box. For the real-time operation, two RT Boxes (referred to as “Plant” and “Controller”) need to be set up as demonstrated in Fig. 3. The figure shows an RT Box 1 in the setup, but it is for illustrative purpose only.

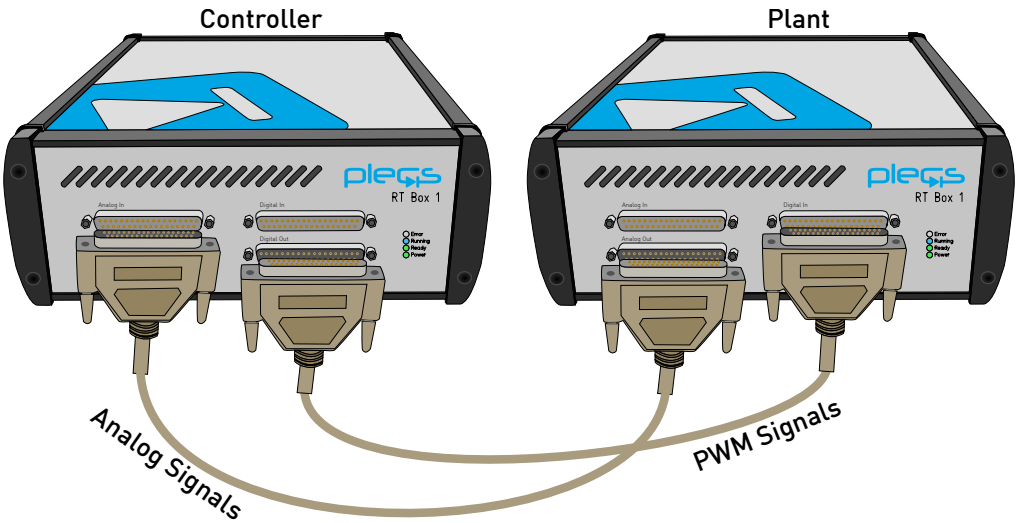


Fig. 3: Hardware configuration for the real-time operation of the demo model (example), RT box model is illustrative only

- After building each subsystem inside the model onto the corresponding Box, the real-time simulation waveforms should look like in Fig. 4. In the default setup of the demo, both extra load resistor branches are turned on. This gives the minimum load resistance, therefore the highest load current. In this scenario all three buck converter branches are controlled to be active, balanced and interleaved with a 120-degree phase shift among them.
- Next under External Mode, one can change the Constant block controlling the load step inside the Controller Box from the default `[1 1]` to `[1 0]`. This increases the load resistance, therefore decreases the load current. The real-time simulation waveforms should look like in Fig. 5 on p. 6. In

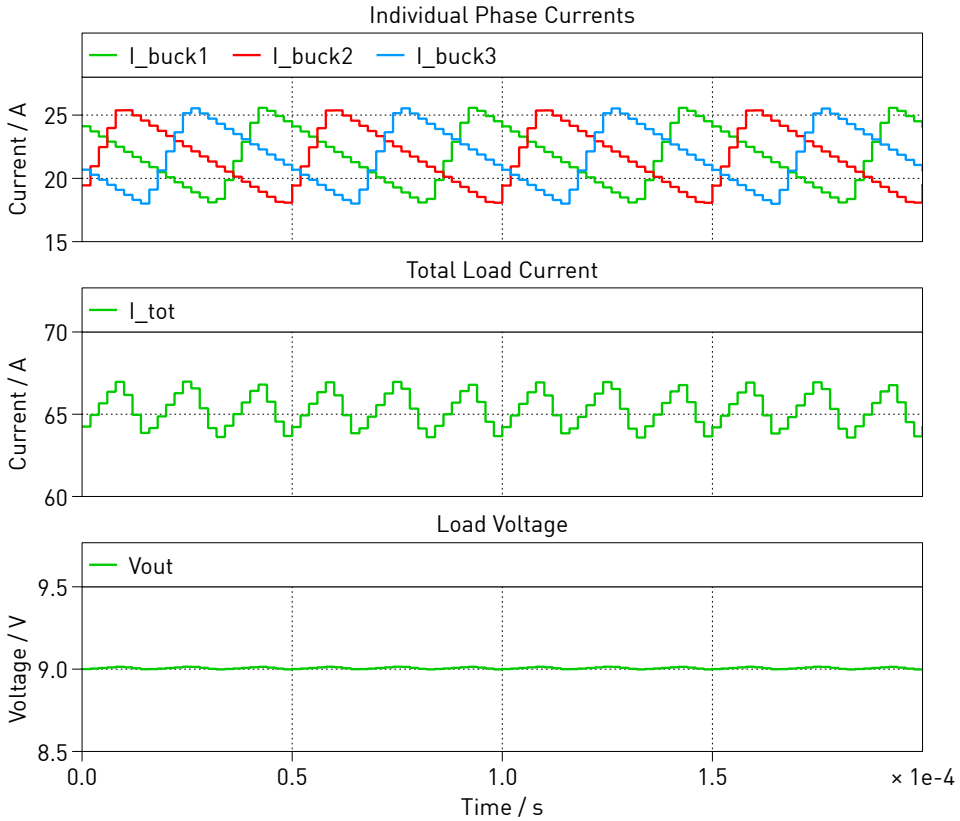


Fig. 4: Simulation results with all three phases active

this scenario only the first two buck converter branches are controlled to be active, balanced and interleaved with a 180-degree phase shift between them.

- Under External Mode, one can further change the aforementioned Constant block from `[1 0]` to `[0 0]`. This gives the biggest load resistance, hence the smallest load current. The real-time simulation waveforms should look like in Fig. 6, where only the first phase is active.

4 Conclusions

This model demonstrated how to use the PWM triggered Analog In block for measuring interleaved multiphase currents on an RT Box, as well as the Digital Out Override block for dynamic phase shedding.

5 Bibliography

[1] STM32 Interleaved Buck Converter Demo, URL: https://plexim.com/sites/default/files/demo_models/interleaved_buck_converter.pdf

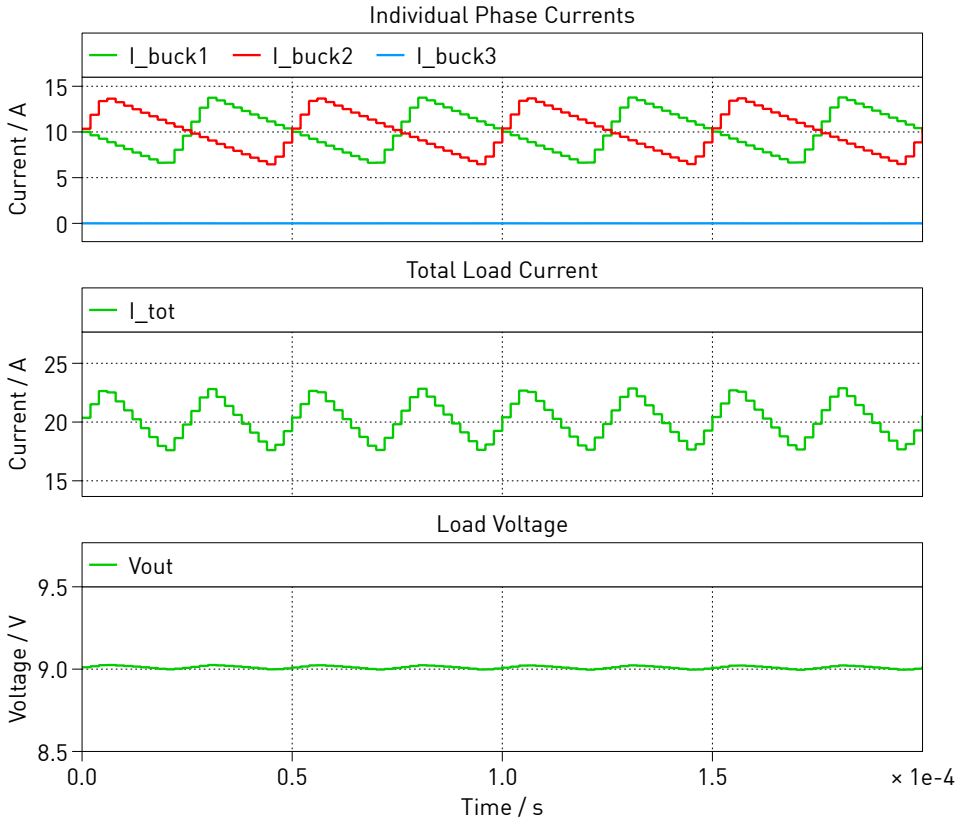


Fig. 5: Simulation result with two active phases

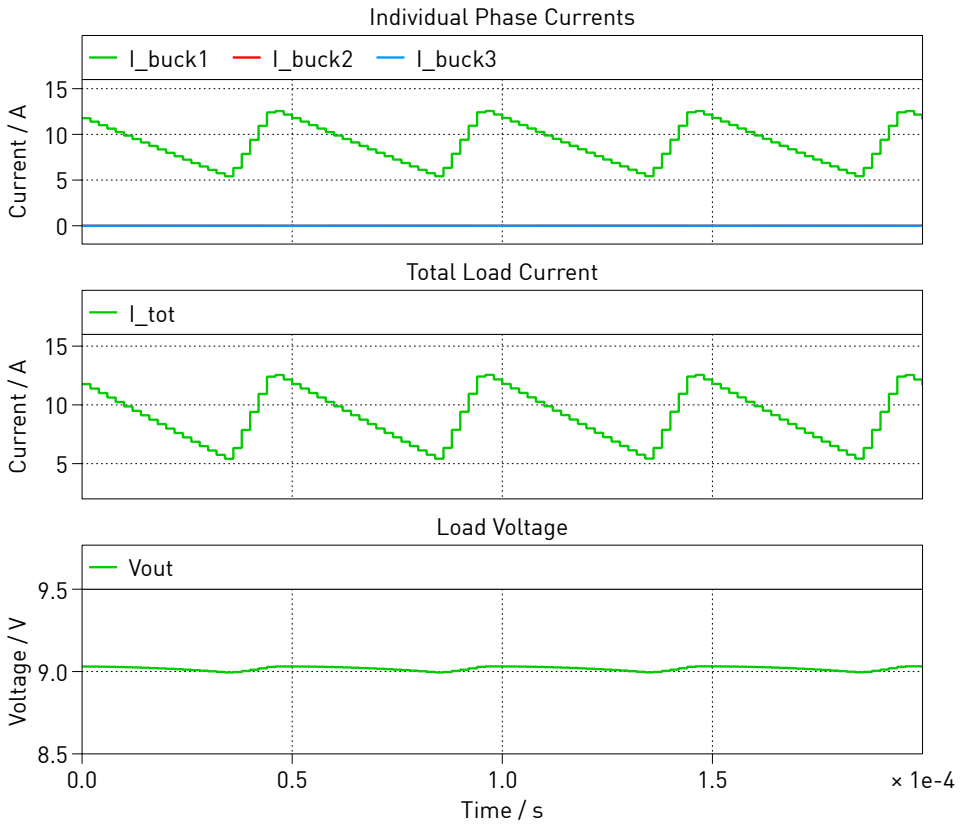


Fig. 6: Simulation result with only one active phase

Revision History:

RT Box TSP 3.1.2	First Release
RT Box TSP 3.1.3	Update to use the Nanostep library Buck Converter component

How to Contact Plexim:

☎	+41 44 533 51 00	Phone
	+41 44 533 51 01	Fax
✉	Plexim GmbH Technoparkstrasse 1 8005 Zurich Switzerland	Mail
@	`info@plexim.com`	Email
	`https://www.plexim.com`	Web

RT Box Demo Model

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