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Buck dc-dc Hardware in the loop with core-independent peripherials evaluation

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***Abstract*— The paper presents a study of a switching mode power converter of buck topology, evaluated using hardware-in-the-loop (HIL) testbench. The purpose is to illustrate how HIL testbenches are constructed, what measurements and control could be achieved and how this approach could benefit the researchers and trainees. This is achieved using electronic control peripherials such as ADC, DAC and PWM blocks.**

***Keywords*— dc/dc converter, digital control, core-independent peripherials, hardware-in-the-loop**

I. Introduction

Switch mode power supplies are more efficient at DC-DC conversion than the linear voltage regulators but their higher complexity and cost can be revolting for numerous applications, particularly to low-power application. The offered dedicated controller ICs will typically only operate with predetermined voltage ranges and switching parameters, meaning that different designs have to be used in different use cases. Implementing the switching controller using microcontrollers and their core independent peripherals makes for a highly flexible system, adding only passive components to the bill of materials, thereby reducing the number of different ICs. The downside of the approach is the complexity of the design software, but this can be overcome by reusing software blocks and algorithms for the different designs.

This paper shows how to implement a feedback switching controller for a buck converter using the core independent peripherals of the general microcontroller devices. After the initial set-up, the core independent peripherals are independent of the CPU, allowing the microcontroller to do other computing or control tasks in parallel.

II. Test setup

The proposed test setup is realized using standard (IVI compatible) instruments, interfaced using National Instruments VISA library. The software interface is generated using NI visual programming using block-diagrams and instrument panels. The hardware used is the MPLAB-Xpress microchip board, programmed via the MPLAB Cloud IDE programmer [3]. More details regarding the software and hardware setup are given below

A. *LabVIEW Virtual instrument*

The block-diagram of the Hardware-in-the-Loop test bench is shown on figure 1. It is composed of control blocks responsible for VISA communication, DAQmx channels for ADC and PWM control. The implemented feedback switching controller for a buck converter using the core independent peripherals of the microcontroller is using the noted internal peripherals. They are independent of the CPU, allowing the microcontroller to do the computational and communicational tasks in parallel. да се допълни и цитира за конкретната платка какво съдържа!!!

B. *Hardware testbench*

The hardware is composed of the MPLAB Xpress board, shown on figure 2. A Closed Loop Voltage and Current Control using Core Independent Peripherals is designed, the feedback controller is based upon a hysteretic control, because of its simplicity, compared to the digital z-transformed 2P2Z, PID or other complex discrete controllers. The general design of the buck converter is covered in [1, 2, 3]. Setting the output voltage or the output of the buck converter is covered made using the front panel, shown on figure #. The buck converter was designed using following

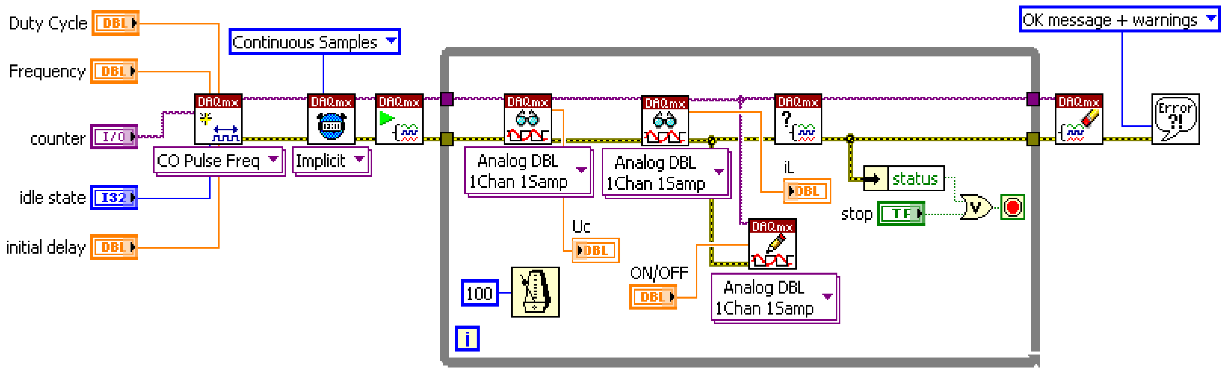

Fig. 1. Block diagram of the Hardware-in-the-Loop testbench.

parameters: rated input voltage V_d = 20V; rated output voltage V_0 = 10V, rated output current I_0 = 1A, operating frequency f = 200 kHz is selected. The design was carried out according to the standard methodology presented in [2, 3, 4], and the following values of the circuit elements L = 0.47mH; C = 10μF; R = 10Ω were obtained and the transistor control pulse duty cycle D = 50%.

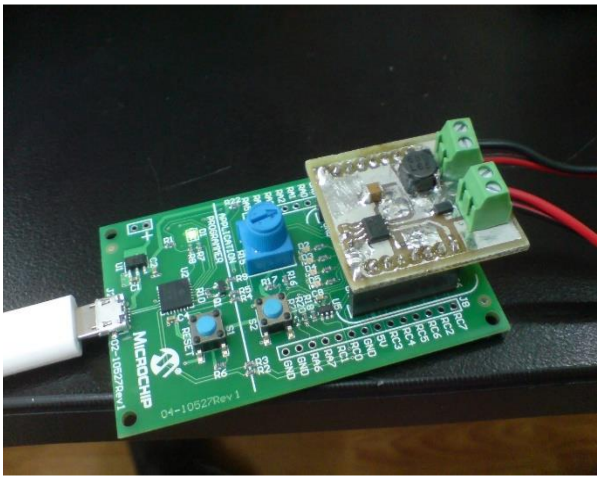

Fig. 2. The MPLAB Xpress board with the converter power circuit on top.

III. Evaluation System Design

The study presents a Hardware-in-the-loop configuration using IVI and VISA compatible virtual instruments. The communication with the core-independent modules is achieved via a dedicated embedded program on the MPLAB Xpress board with the PIC16F18855 microcontroller. The controller itself features a 10-bit Analog-to-Digital Converter alongside with enhanced Computation modules for automated signal analysis, 2 channels 5-bit Digital-to-Analog Converter, 2 channels of 10-bit Pulse-Width-Modulation, along with additional 5 8bit-channels on the capture and compare block [5, 11].

On figure 2 is shown the hardware block with the MPLAB express evaluation board as a motherboard, hosting the experiment and the power circuit attached as a daughter board on top of the provided prototyping header. The board contains a dual MOSFET in a SO-8 package, along with the inductor, capacitors and the diode, all mounted via SMD technology. The control and measurement signals are provided to the motherboard via the headers and routed to the appropriate pin positions.

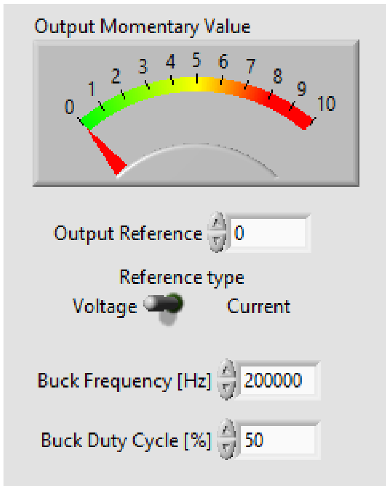

Fig. 3. The MPLAB Xpress board with the converter power circuit on top.

The feedback control algorithms are based on a modified hysteretic mode control with ability to monitor both the pulses of the inductor current or the

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output voltage. The hysteretic mode is chosen due to the following advantages. There is direct monitoring of the output voltage using the ADC inputs, without the need of extra computing power to process the acquired samples. This allows for extremely fast load transient responses and highly stable feedback loop. This also eliminates the need for phase compensation loop and algorithm and allows arbitrary variable switching frequencies. The downside of this method is the large jittering and possible low-frequency ringing

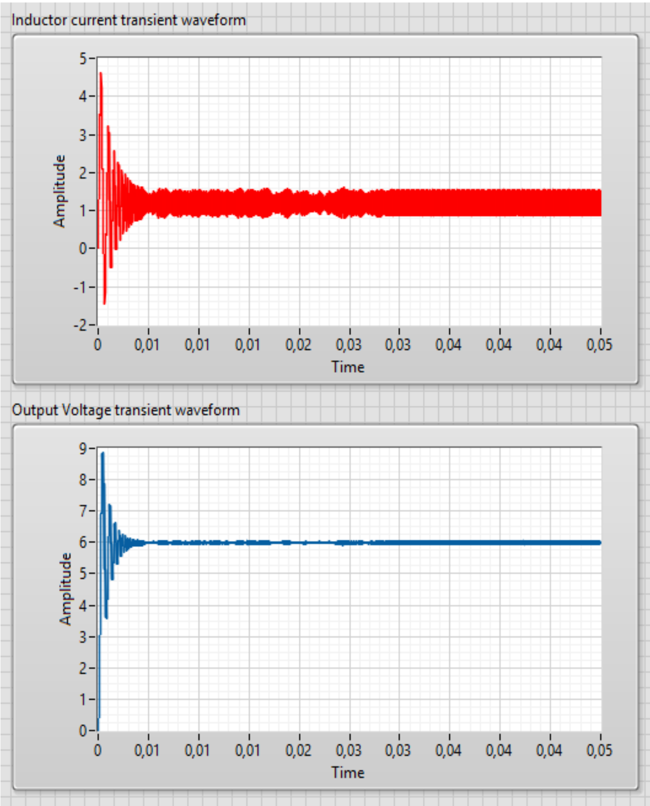

Fig. 4. Output voltage reference for 6V transient waveforms.

whenever the converter is in “skip-cycles” mode.

Nonetheless the algorithm can be modified to voltage mode or current mode control, either in ripple detection mode or with a PID, 2P2Z, 3P3Z control and alike. The advantages of voltage mode control is the simple control loop, taking samples from the output voltage via a resistor divider and using a single ADC channel. It has inherent ability to control shorter on-times. This control type has high noise tolerance, but requires complex compensation algorithm [6-9]. The current mode control is a modified voltage mode control, that uses circuit inductor current instead of triangular waves. It has high stability of the feedback loop and substantially simplified phase compensation circuit design. It has faster load transient response than the voltage mode, but requires that the feedback noise be taken into account.

On figure 3 is show the front panel of the developed virtual instrument. It is composed of the following items – a switch for choosing the control mode – be it either current mode control or voltage mode control; input box for the reference value; momentary value measurement – that is a meter gauge, showing either the output capacitor voltage or the inductor current, depending of the position of the control switch; numerical boxes for settling of the working switching frequency of the converter and the duty cycle. The measurement results are acquired, accumulated and displayed on adjacent waveform windows, as it is shown on the figures below.

IV. Results

The acquired waveforms of the transient process are displayed on the figures, using the different control references. On figure 4 is shown a reference

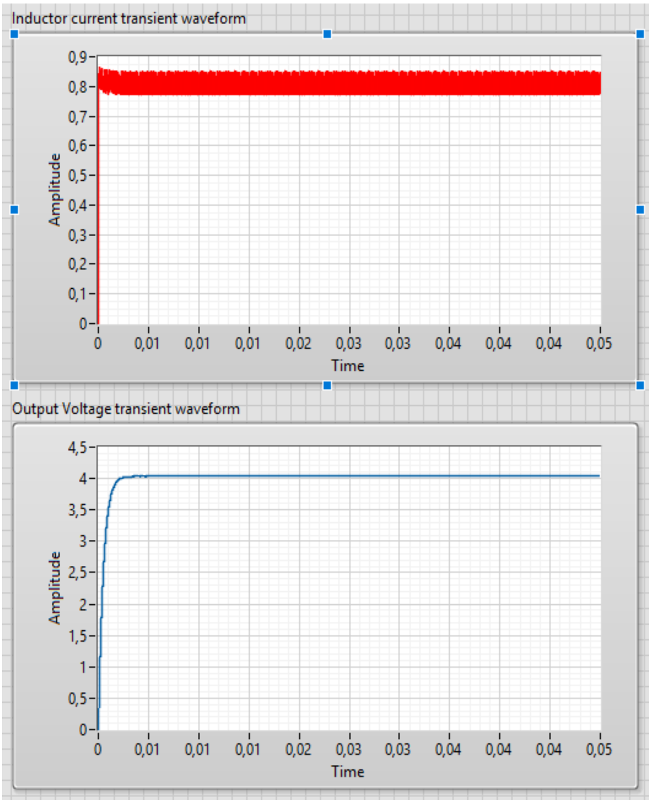

Fig. 5. Output current reference for 0,8A transient waveforms

stabilization using hysteretic voltage reference control for a 6V output voltage reference. It can be observed that it has relatively higher overshoot and startup oscillation, however the transient process is fast.

From the presented results is observed that for the normal operation of the converter it is necessary to use a soft-start system for better initial transient characteristics, because otherwise there would be a significant overload of the devices or the protection system will be activated. On the other hand, the presented example is suitable for using model-based optimization, through which it is possible to improve the dynamics of the converter. [8-10].

On figure 5 are shown the waveforms of the transient process using hysteretic current reference control for a 0.8A inductor current reference value. It can be observed that the settling of the output voltage is smoother and without oscillation. Relatively to the voltage reference method the transient process is faster.

When maintaining a constant reference output current, no such overshoot is observed as was the case with the output voltage. This gives reason to believe that hysteresis monitoring is more suitable for maintaining a constant output current than a constant output voltage. All this is applicable to the use of other control methods, both classical and innovative such as neural-network controllers, model predictive control, fuzzy logic and more. For this purpose, only the type of the controller is changed and the respective program is loaded. This flexibility and adaptability of the approach is useful in power electronics training.

V. Conclusion

The paper presents a study of a converter together with its controller, using two very modern and advanced technologies: Hardware-in-the-Loop and microcontroller core independent peripherals. Their integration allows a very clear and logical study of the operation of the power electronic devices and to improve the knowledge and skills of trainees and students. The general work environment is based on software for graphic programming LabVIEW, which is very clear and convenient both for setting the parameters and for visualization and subsequent processing of the obtained results.

On the other hand, this approach is suitable for use in the process of control synthesis and especially the setting of the controller. Also this allows automated data acquisition, collection and processing, which is the basis for the use of techniques based on artificial intelligence, in the training and design of power electronic devices and systems, etc.

Acknowledgment

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