Abstract

In the recent decades, shortage of fossil fuels and global warming have increased the demand for renewable energy resources. Dc-dc converters are widely used in renewable energy systems, electric vehicles, and battery chargers. In practical applications, dc-dc converters are required to be regulated by a closed-loop controller.

The Peak Current Mode Control (PCMC) is one of the most promising control methods for dc-dc converters. It has been known for high bandwidth (speed), and inherent current protection. Increasing the controller bandwidth decreases the output filter size and cost. Analog controllers (including PCMC) are sensitive to temperature drift, component aging and noise. Digital controllers do not have the aforementioned drawbacks of analog controllers; but they have lower bandwidth than analog controllers due to the sampling and calculation delays. Generally, analog controllers have a bandwidth of 1/10 of the switching frequency. In the current state-of-the-art, the best reported digital PCMC has crossover frequency of 1/15 of the switching frequency.

In this PhD study a novel digital PCMC with negligible delay in the inner current loop has been proposed. The proposed solution has a bandwidth of 1/10 of the switching frequency; which is an improvement of 50% compared to the best reported digital solution, also the achieved crossover frequency is nearly equal to analog controller crossover frequency. Furthermore, the proposed solution offers an adaptive compensation slope; therefore the controlled converter can maintain a high bandwidth over wide range of the operating points. The proposed digital PCMC is modeled and the stability criteria are defined. The digital PCMC is implemented in a Field-Programmable Gate Array (FPGA). The experimental results verify the modeling method and the high predicted bandwidth of the proposed controller.

Additionally, the small signal model of the isolated full-bridge boost converter is obtained and the modeling method is verified by experimental results. In modeling, the Equivalent Series Resistance (ESR) of the inductor and capacitor are also included. Analyzing the obtained model reveals that the small values of capacitor and inductor ESR results in a large resonance peak of complex poles in the voltage to duty cycle transfer function. High efficiency dc-dc converters essentially have low ESR in the capacitor and the inductor. Since the complex poles are eliminated in current mode control; applying the current mode control in high efficiency dc-dc converters results in much higher controller bandwidth.