Saturation-Generated Oscillation and its Mitigation in Voltage-Mode Digital Control of DC-DC Converters

ABSTRACT

Power management has come to assume a prominent role in the rapidly advancing world of electronics. In power management systems, a dc-dc switching converter is a key component, which performs the task of voltage level conversion and provides a stable regulated supply to the load. The regulation and the dynamic control of the converters are traditionally achieved through *analog control*. However, of late, the ubiquitous low-cost digital processors and the ever increasing demand on functionality are providing strong impetus towards *digital control*.

Converters are nonlinear systems, the nonlinearity arising mainly from the feedback controlled switching and the constraints due to physical limitations. Often, the nonlinearity manifests itself as oscillations over and above the switching ripple. In digital control, quantization causes the system to have further degrees of nonlinearity, producing, for example, the well known phenomena of limit cycle oscillations. Under normal usage, these oscillations are undesirable as they cause higher-losses, degrade regulation, and produce electro-magnetic interference. Successful application of digital control warrants study of such oscillations and ways to control them.

In this work, a different, and hitherto unreported class of oscillations in digitally controlled converters has been described. Its origin has been traced to the interaction of the analog-to-digital converter's deadzone and the asymmetric saturation in the duty cycle. The oscillation has been termed saturation-generation oscillation (SGO). The thesis describes the phenomenon providing a physical insight, calculating the oscillation-free operating-zone, and analyzing the nonlinear dynamics.

For useful deployment of digital control in a tight-regulation environment, oscillations such as SGO are to be avoided. Towards this end, a number of schemes are proposed, some of which are based on the modifications of the digital controller while others exploit specific features of the oscillation itself. The principal schemes are well suited for hardware description language (HDL) based implementation. The respective pros and cons of the proposed schemes have been presented to help the practicing designers choose among the alternatives. Throughout the thesis, key ideas and findings have been supported through simulation and experimental results.

The thesis concludes with a summary of achievements and a discussion of future directions.