Preface

Switching power converters are at the crossroads of a notable number of researchers from various disciplines, including circuit theorists, physicists, mathematicians, and power electronics engineers. This book is addressed to electrical engineering students and practicing engineers with interests and needs in the field of nonlinear dynamical behavior and bifurcation analysis and control of switch-mode power supplies. This book takes an engineering-oriented standpoint at bifurcation prediction in these circuits by combining different mathematical tools. The ultimate goal of this book is to explain how these phenomena can take place, that is, how to characterize, predict, and control their occurrence, in particular in the framework of progress lines in the field of power converters, namely for miniaturized and in particular integrated on-chip power management as well as for emerging applications such as wideband power amplifiers.

In contrast to other existing works in this field, nonlinear behavior is predicted by using simple design-oriented circuit-centric expressions which depend upon the circuit power stage parameters and which can explain consistently such behavior without necessarily resorting to the language of mathematical formulations widely used hitherto. The approach in this book is more like that of the systems engineer, hence considering the whole system as a set of well-defined subsystems, so that via an approximately top-down manner the effect of each subsystem upon the overall dynamical behavior is revealed.

The book begins in Chap. 1 with a short survey of switching power converters for modern power management architectures along with an introduction to dynamics and stability models of switching power converters. The review argues and instantiates that design-oriented models for predicting the complete (and rich) behavior of such circuits are missing, even for basic switching power converters.

Chapter 2 characterizes the dynamics exhibited by the converter circuits as a function of a complete parametric design space thereby revealing the different complex behaviors. The characterization is extended by evaluating the impact of the different dynamic modes upon the final application by means of defining a set of circuit-centric application-aware performance metrics.

In Chap. 3, the prediction of the boundaries between different dynamic behaviors is tackled from a design standpoint, starting from the simple hypothesis that the ripple magnitude at the PWM modulator can predict the boundary between the desired stability and nonlinear behavior. The hypothesis is validated with numerical simulation, experimental and discrete-time models results, and extended to different controllers. Maintaining the design-oriented standpoint, this book moves toward facilitating the synthesis and design of controllers oriented to avoid unstable dynamic modes by presenting a frequency domain perspective—a common working domain for power electronic engineers—of the conditions of occurrence of the various nonlinear behaviors. The model oriented to predict bifurcations is then used, complementary to classical linear modeling approaches, to carry out a complete system stability analysis in which both slow-scale and fast-scale instabilities are considered. The availability of such frequency domain interpretation is used in Chap. 4 for exploring strategies to design and implement new controllers which can alter the conditions of occurrence of period-doubling bifurcations. As a result from the development of such design-oriented tools, this chapter presents a set of controllers which are sensitive to implementation issues while they also consider other figures of merit such as the impact upon the complete stability boundaries or the ability to extend the miniaturization limits, set by area, efficiency, and ripple tradeoffs.

Finally, Chap. 5 explores the nonlinear dynamics of more complex switching power converter circuits, such as a multilevel converter, in which additional state variables are added, or a switching power converter operating in tracking conditions as a switching power amplifier in which the quasi-static time-invariant assumption is not valid.

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