Transfer Functions of Switching Converters

Fast Analytical Techniques at Work with Small-Signal Analysis

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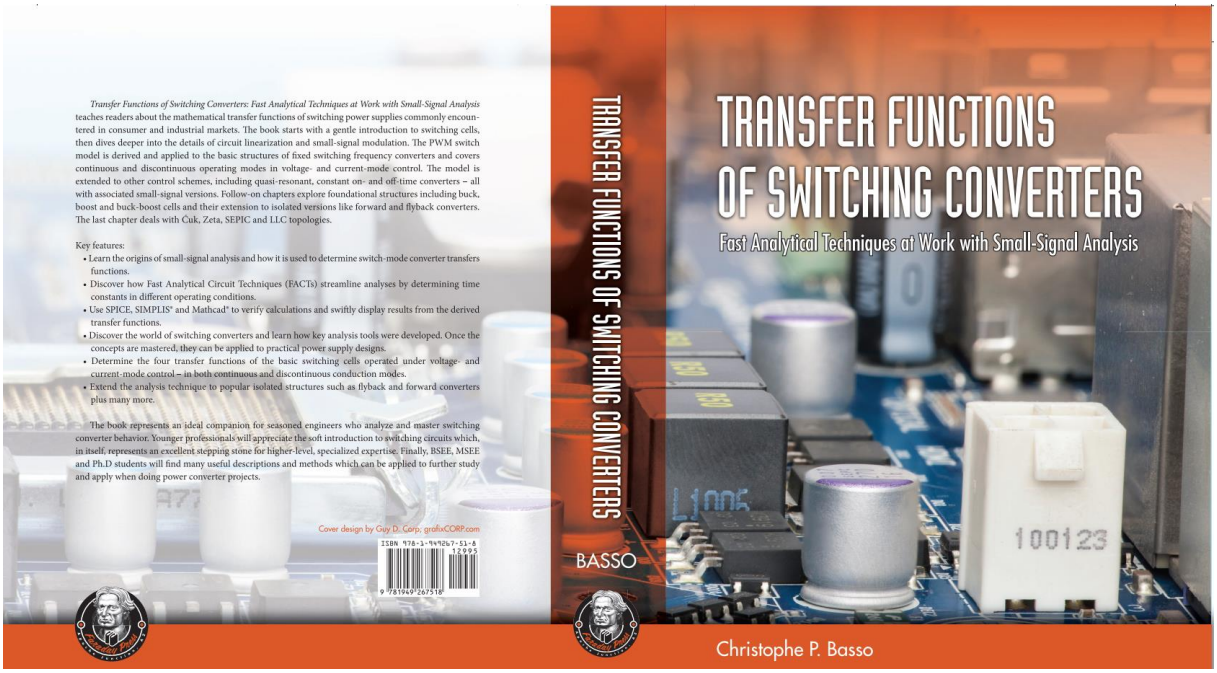

The book will teach readers how to determine transfer functions of switching power supplies commonly encountered in consumer and industrial markets. The book starts with a smooth introduction to switching cells, going into the details of the first steps of linearization and small-signal modulation. You will then learn how the PWM switch model was derived and how to apply it to the basic structures operated in fixed switching frequency and various operating conditions like continuous and discontinuous modes in voltage- or current-mode control. The model is extended to other control schemes like quasi-resonance, constant on- and off-time converters, all with an associated small-signal version. The following chapters explore the founding structures like the buck, the boost and buck-boost cells, later covering their isolated versions like forward or flyback converters. The last chapter deals with more complicated structures like Ćuk, Zeta, SEPIC and LLC.

The book is divided in five chapters and an appendix:

- Chapter 1: you will find a guided introduction to small-signal modeling, why you need it and how to apply it. Once the foundations are laid out, the chapter explores the basic switching cells and determines their basic transfer characteristics like conversion ratios for isolated and non-isolated structures. Operating schemes like voltage- and current-mode control are detailed as well as quasi-resonance operation. The PWM switch model is then introduced and its small-signal model derived for future use in the subsequent chapters.

- Chapter 2: this entire chapter is dedicated to the buck converter whose four transfer functions are determined for voltage- and current-mode controlled switching cells operated in the two conduction modes, CCM and DCM. Quasi-resonance is not forgotten as well as more exotic

modes like COT and FOT or even the tapped version. Isolated versions are described such as push-pull, half- and full-bridge versions as well as active-clamp.

- Chapter 3: the boost converter increases the input voltage and can be found in many applications like dc-dc and power factor correction circuits. The chapter starts with the dc-dc version and determines all the needed transfer functions as in the buck converter case. After the description of the tapped version, the boost operated in quasi-resonant current-mode version is also detailed. Finally, power factor correctors working in boundary control mode are described and operated in application examples.

- Chapter 4: the buck-boost converter is well known when operated in its isolated version, the flyback converter. In this chapter, you will enjoy determining the four transfer functions of the buck-boost converter and extend the analysis to the flyback version. The popular quasi-resonant version is not forgotten and described in the book. Finally, single-stage converters are also popular and part of the descriptions.

- Chapter 5: this final section deals with more complex higher-order converters like the Ćuk, SEPIC, Zeta and LLC. The analysis gains in complexity and the simulation examples help verifying the results analytically obtained. An LLC transfer function is proposed for the VCO-based control while the more recent current-mode version is also explored.

- Appendix A: this appendix can be seen as a crash course to let you discover the fast analytical circuits techniques and acquire a basic set of skills to understand how I derived all these transfer functions. Mastering the tool will require more efforts but the companion books given in the reference should let you strengthen your knowledge for a complete and firm acquisition of the method.

All examples and steps are thoroughly documented then verified through SPICE and SIMPLIS® simulations. For that purpose, I have released a set of 60+ ready-to-use SIMPLIS® simulation templates which should help you get up to speed for your next switching converter project. These files are freely available from my webpage.

This book represents an ideal companion for the young or seasoned engineer willing to study and stabilize her or his switching converter. Finally, BSEE, MSEE or Ph.D students will also find many useful descriptions and methods they can later apply during their studies or when facing their first industrial projects.