Dynamics and Control of DC-DC Converters

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ABSTRACT

DC-DC converters have many applications in the modern world. They provide the required power to the communication backbones, they are used in digital devices like laptops and cell phones, and they have widespread applications in electric cars, to just name a few.

DC-DC converters require negative feedback to provide a suitable output voltage or current for the load. Obtaining a stable output voltage or current in presence of disturbances such as: input voltage changes and/or output load changes seems impossible without some form of control.

This book tries to train the art of controller design for DC-DC converters. Chapter 1 introduces the DC-DC converters briefly. It is assumed that the reader has the basic knowledge of DC-DC converter (i.e., a basic course in power electronics).

The reader learns the disadvantages of open loop control in Chapter 2. Simulation of DC-DC converters with the aid of Simulink®is discussed in this chapter as well. Extracting the dynamic models of DC-DC converters is studied in Chapter 3. We show how MATLAB®and a software named KUCA can be used to do the cumbersome and error-prone process of modeling automatically. Obtaining the transfer functions using PSIM®is studied as well.

These days, softwares are an integral part of engineering sciences. Control engineering is not an exception by any means. Keeping this in mind, we design the controllers using MATLAB®in Chapter 4.

Finally, references are provided at the end of each chapter to suggest more information for an interested reader. The intended audiencies for this book are practice engineers and academians.

KEYWORDS

control of DC-DC converters, dynamics of DC-DC converters, loop shaping, PID control of DC-DC converters, state space averaging, system identification, modeling of power electronics converters

We dedicate this book to our parents
and our lovely families.

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Preface

DC-DC converters are an integral part of our modern life. They convert a voltage level to another with high efficiency.

DC-DC converters are nonlinear variable structure systems. They are subject to disturbances such as input voltage changes and output load changes. Obtaining stable output voltage seems impossible without some form of feedback control. This book help you design the control loop for DC-DC converters in a practical manner.

Although control engineering has made tremendous progress in the last decade, about 90% of applications use proportional-integral-derivative (PID) controllers. DC-DC converters are not an exception by any means and PID controllers are good enough for most common DC-DC converters. PID controller design for DC-DC converters is studied in Chapter 4.

This book discusses the dynamics and control of DC-DC converters. We assume that the reader already knows the basics of DC-DC converters and linear control theory. There are plenty of textbooks available on power electronics and linear control and one can refer to the references at the end of first chapter if a review of concepts is needed.

A brief summary of the book chapters is as follows:

Chapter 1 is a brief introduction to the world of DC-DC converters. Some of the applications of DC-DC converters are introduced in this chapter.

Chapter 2 describes the importance of control in DC-DC converters. Some simulations show what happens if the system works without any controller (i.e., open loop). This chapter also introduces the simulation of power electronics circuits with the aid of the Simscape library of Simulink®.

Chapter 3 describes the modeling procedure for DC-DC converters. DC-DC converters are nonlinear variable structure systems by nature. There are some methods available in the literature to obtain a Linear Time Invariant (LTI) small signal model of the converter. We used State Space Averaging (SSA) in this chapter to model converters working in Continuous Current Mode (CCM). A software developed by the first author is introduced to do the SSA procedure automatically. Using this software you can do the modeling automatically without any hand calculation. Computer methods of obtaining the converter frequency response is introduced in this chapter as well. A method to model converters working in DCM is introduced at the end of this chapter.

Chapter 4 describes the controller design procedure for DC-DC converters. These days, software and especially MATLAB®are an important part of control engineering. We use the MATLAB's "Control System Toolbox™" extensively in this book. Using this toolbox, a controller can be designed easily even by a novice.

We hope that this book will be useful to the readers, and we welcome comments on the book.

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