Power Electronic Circuits

Power Electronic Circuits

Issa Batarseh
University of Central Florida

John Wiley & Sons, Inc.

EXECUTIVE EDITOR Bill Zobrist

MARKETING MANAGER Katherine Hepburn

SENIOR PRODUCTION EDITOR Valerie A. Vargas

SENIOR DESIGNER Dawn Stanley

PRODUCTION MANAGEMENT SERVICES Publication Services

This book was set in 10/12 Times Roman by Publication Services and printed and bound by Hamilton Printing. The cover was printed by Phoenix Color.

This book is printed on acid-free paper.

Library of Congress Cataloging in Publication Data:
Author's name entry.
Brief title entry: Subtitle if any xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

(Series Statement)
Notes xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
L.C. Subject Heading Joint Author Entry
Title and Series added entries

L.C. Call no. Dewey Classification No. L.C. Card No.
ISBN 0-471-12662-4
ISBN 0-471-45228-9 (WIE)

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Dedicated to my late advisor

Professor Chu Quon Lee

University of Illinois at Chicago

Preface

In recent years the field of power electronics has witnessed unprecedented research and teaching growth worldwide, emerging as a specialization in electrical engineering. This growth is due to expanding market demand for power electronic circuits for the energy conversion process. The need for power electronics engineers equipped with knowledge of new energy conversion technologies has never been greater.

Power Electronic Circuits is intended as a textbook to teach the subject of modern power electronics to senior undergraduate and first-year graduate electrical engineering students. Because of the breadth of the field of power electronics, teaching this subject to undergraduate students is a challenge. This textbook is designed to introduce the basic concepts of power electronics to students and professionals interested in updating their knowledge of the subject. The objective of this textbook is to provide students with the ability to analyze and design power electronic circuits used in various industrial applications.

The prerequisites for this text are a first course in circuit analysis techniques and a basic background in electronic circuits. Chapter 3 gives an overview of diode switching circuits and basic analysis techniques that students will find useful in the remaining chapters.

Material Presentation

Since the text is intended to be used in a three-credit-hour course in power electronics, topics such as power semiconductor devices, machine drives, and utility applications are not included. Because of limited lecture times, one course at the undergraduate level cannot adequately cover such topics and still present all power electronic circuits used in energy conversion. This text contains sufficient material for a single-semester introductory power electronics course, while giving the instructor flexibility in topic treatment and course design.

The text is written in such a way as to equip students with the necessary background material in such topics as devices, switching circuit analysis techniques, converter types, and methods of conversion in the first three chapters. The presentation of the material is new and has been recommended by many power electronics faculty. The discussion begins by introducing high-frequency, nonisolated dc-to-dc converters in Chapter 4, followed by isolated dc-to-dc converters in Chapter 5. Resonant soft-switching converters are treated early on in Chapter 6. The traditional diode and SCR converters and dc-ac inverters are presented in the second part of the text, in Chapters 7, 8, and 9, respectively.

Examples, Exercises, and Problems

Unlike many existing texts, this text provides students with a large number of examples, exercises, and problems, with detailed discussion of resonant and softswitching dc-to-dc converters.

Examples are used to help students understand the material presented in the chapter. To drill students in applying the basic concepts and equations, and to help them understand basic circuit operations, several exercises are given within each chapter. The text has more than 250 problems at different levels of complexity and difficulty. These problems are intended not only to strengthen students' understanding of the materials presented, but also to introduce many new concepts and circuits. To help meet recent Accreditation Board for Engineering and Technology (ABET) requirements for design in the engineering curriculum, special emphasis is made on providing students with opportunities to apply design techniques. Such problems are designated with the letter "D" next to the problem number, such as D5.32. Students should be aware that such problems are open-ended without unique solutions.

A bibliography is included at the end of the text and a list of textbooks is given separately.

About the Text

Like the majority of textbooks, this book was developed from class notes the author prepared over the last eight years while teaching power electronics at the University of Central Florida. The author started teaching power electronics in 1991, when only a limited number of power electronic textbooks were available. Since then, a handful of additional textbooks have been published with very similar material coverage. Unlike many existing texts, *Power Electronic Circuits* targets mainly senior undergraduate students majoring in electrical engineering.

Web-Based Course Material

Ancillaries to this text are available on a dedicated Web site, www.batarseh.org, established for both faculty and students to provide them with access to

- A complete set of lecture notes
- Sample quizzes
- PSPICE- and Mathcad-based simulation examples
- A complete solutions manual
- Transparency masters
- Up-to-date text corrections and the opportunity to submit new corrections

Even though the author's Web site is very useful in providing students and faculty with teaching material, at the time of this writing it doesn't offer an interactive platform. The author believes that due to the nonlinear interdisciplinary nature of the field of power electronics, computer simulations and computer tools must play an important role in delivering effective power electronics education. This is why any useful Web-based education in the area of power electronics must include a platform that allows students to do design and simulation interactively online. To the author's knowledge, this has not been effectively achieved yet. However, one of the most useful interactive Web-based facilities in power electronics is the Interactive Power Electronics Seminar (iPES) developed by the Swiss Federal Institute of Technology, Zurich (ETH Zurich), http://www.ipes.ethz.ch/. The Java applets are designed to allow a degree of interactivity and animation to aid in learning the basics of power electronics typically taught in an introductory course. The Web site is designed as a list of seminar topics and made "available on the Internet for private use and non-commercial use in classroom only." Also, the site provides course translations in Japanese, Korean, Chinese, and Spanish!

Acknowledgments

Over the last five years, many of my power electronics students have had the opportunity to read my lecture notes and solve many problems. Their feedback and comments were instrumental in presenting, to the best of our knowledge, error-free examples, exercises, and problems. I am grateful for reviewers' constructive suggestions for the students' sake. I am highly indebted to Khalid Rustom, Chris Iannelo, and Osama Abdel-Ruhman for spending many hours reviewing the examples, exercises, and problem solutions. Without their tireless work, this text would suffer from numerous errors and omissions! I am very fortunate to have such dedicated people work with me. I was also fortunate to have Dr. Kazi Khairul Islam visit our power electronics laboratory at UCF. He helped greatly in providing insightful suggestions on the inverters chapter, as well as in developing the appendixes. His suggestions and comments are greatly appreciated.

Special thanks go to the young, bright students from Princess Sumaya University for Technology in Amman, Jordan, who helped in typing and solving text problems during their stay at the University of Central Florida (UCF). Their names are Osama Abdul Rahman, Reem Khair, Ruba Amarin, Amjad Awwad, Bashar Nuber, Abeer Sharawi, Rami Beshawi, and Mohhamad Abu-Sumra. Specifically, I wish to acknowledge the help of two of my students, Khalid Rustom and Abdelhalim Alsharqawi, in solving problems and providing helpful insights throughout their undergraduate and graduate study at UCF. I would also like to thank my graduate students Guangyong Zhu, Huai Wei, Joy Mazumdar, Songquan Deng, and Jia Luo for their help and suggestions. Finally, thanks are due to Shadi Harb, Maen Jauhary, Samanthi Nadeeka, and William Said for their help in typing the solutions manual and developing the text Web site. Indeed, it was a pleasure working with all my students who made writing this text a gratifying and enjoyable experience.

Also, I would like to express my sincere thanks to Bill Zobrist, John Wiley & Sons Executive Editor, for his patience and support during the writing of the text, and special thanks to Jan Fisher, Project Manager at Publication Services, for her understanding and for keeping me on schedule.

Finally, I will never forget my late advisor, Professor C. Q. Lee, for introducing me to the field of power electronics and for being my advisor, teacher, mentor, and friend. On behalf of all of his students, I am dedicating this text to him. Of course, without my parents' love, patience, and support, this text would have never been written.

Issa Batarseh
Orlando, Florida

Condensed Table of Contents

Contents