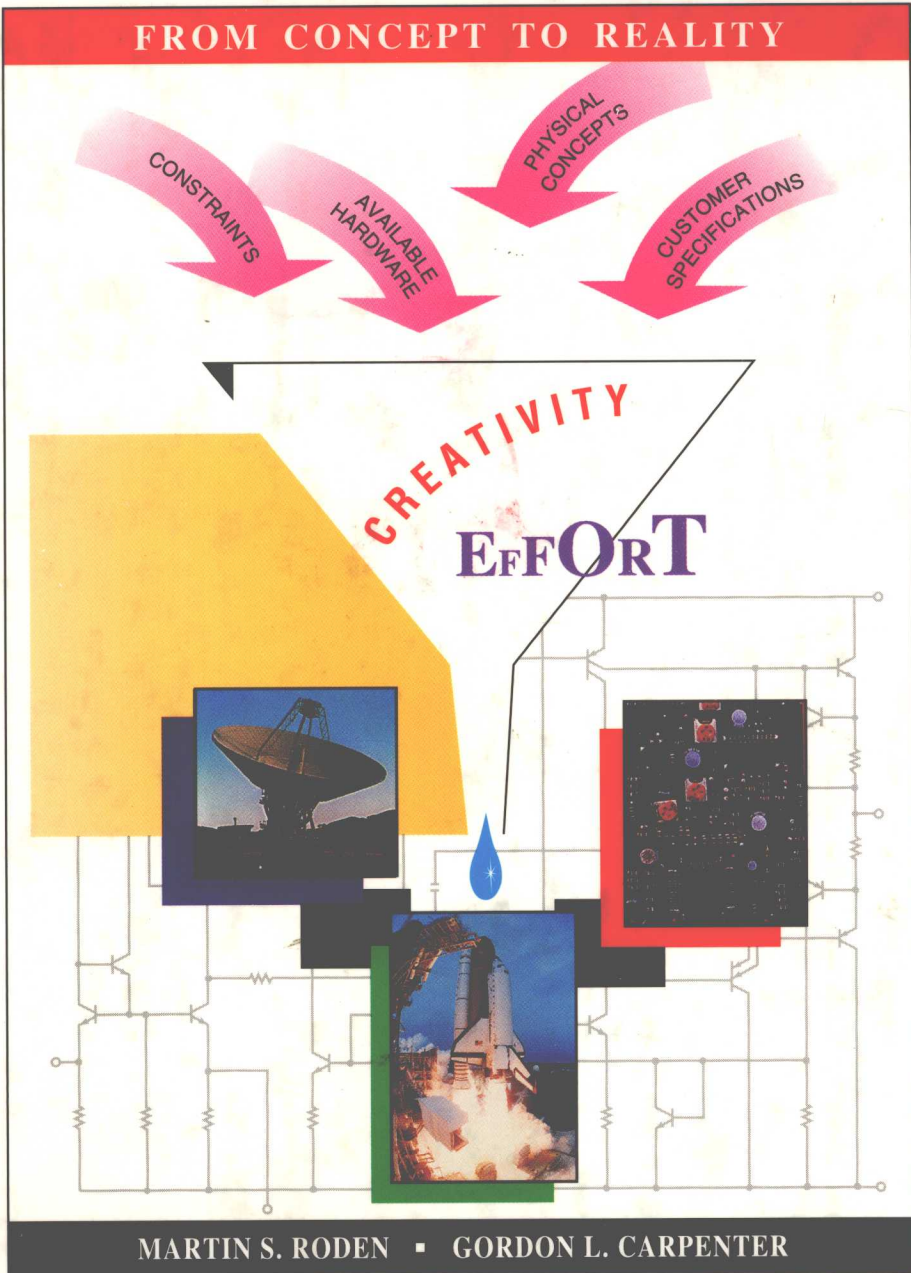


Electronic Design

FROM CONCEPT TO REALITY



THIRD EDITION

ELECTRONIC DESIGN

From Concept to Reality

THIRD EDITION

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From Concept to Reality

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PREFACE

Electronic Design, Third Edition is written for use in the core electronics courses in undergraduate programs in electrical engineering. The book provides coverage of three areas: discrete devices, linear integrated circuits, and digital integrated circuits. A practicing engineer looking for a current reference for self-study will also find this book valuable. The only prerequisite for understanding the material in this text is a basic knowledge of circuit analysis.

Why This Book?

With many books in the field of analog and digital electronics to choose from, you may wonder why we have written yet another book on the subject. Our principal goal in writing this text is to relieve our frustrations. We had attempted to teach electronics to undergraduates using traditional texts. These other texts look at the field from a theoretical point of view, emphasizing analysis and the physics of semiconductors, but paying little attention to the important and exciting design applications. Dealing only with fundamentals detracts from the excitement of the subject, and, indeed, the student may never develop the design skills required for a career position in electronics. While our book covers the fundamentals in a thorough and direct fashion, it goes one step further toward a balanced approach to designing electronic systems. The requirements of the Accreditation Board for Engineering and Technology (ABET) and the industry demand that this type of approach be taken.

It is our hope that this book will inspire the imaginations of tomorrow's engineers. These professionals will be called upon to *design*, not just to analyze, electronic systems.

Retained from Earlier Editions

We have retained many of the outstanding qualities of the first two editions of this text that have helped to make them a success. These include:

- Heavy emphasis on design.
- Numerous design *Examples* that provide a real-world flavor. These are taken from the years of engineering experience of the authors.
- A readable writing style that results from class teaching and student evaluation of the earlier editions.
- A proper balance among the three areas of the text.
- Extensive use of *Exercises*. Unlike the examples, these exercises contain only the answers (not solutions). They allow students to reinforce the concepts.

New to the Third Edition

Suggestions from many colleagues, advances in the field, and our own classroom use of the first two editions have led us to make the following improvements:

- Both the analog and digital portions of the text have been thoroughly updated. Data sheets are taken from current references.
- A new introductory chapter has been created to set the stage for the design approach used throughout the text.
- Computer simulations using PSPICE have been added to many sections of the text. Extensive discussion of computer models is included.
- Each chapter begins with a list of objectives and ends with a summary.
- Many of the design approaches taught in the book have been enhanced to help the student understand the reasons leading to various design decisions. Although design problems are under-specified (i.e., fewer equations than number of unknowns), the student must not get the impression that any decisions are arbitrary.
- Any hints of the dreaded "cook book approach" have been removed from design discussions.
- Chapters have been reordered so that the frequency analysis chapter can be more comprehensive than in earlier editions.
- MOSFET coverage has been expanded and relocated to precede JFETs.
- The digital integrated circuits portion of the text has been enhanced with more detailed examination of the internal workings of the devices.
- The end-of-chapter problem sets have been greatly expanded. The problems have been ordered to make them coincide with the order of presentation in the text.

Uniqueness of the System Design Approach

Contacts with practicing engineers and engineering recruiters have encouraged us to place significant emphasis on *design* of electronic *systems*. The new engineer will be asked to design systems using an ever-increasing inventory of new linear and digital ICs, discrete components, and electromechanical devices. Thus, we attempt to teach engineering students to *think* as system designers, rather than to mimic just a few design approaches. Our goal is to "educate" rather than to "train."

Elementary design procedures are introduced early in the text to motivate the student. It is our experience that electronic design is best comprehended through a "learn by doing" approach. Thus, topics such as small-signal analysis have been presented immediately following *dc* analysis to allow for presentation of some early meaningful and realistic design problems.

Appendices

The book includes appendices covering:

- SPICE and Micro-Cap Circuit Simulation
- Standard Component Values
- Manufacturers' Data Sheets for selected devices
- Answers to Selected Problems

Micro-Cap V, Student Edition

Included with this text is the most recent version of the very popular electronic circuit analysis program, Micro-Cap. This program, from Spectrum Software, adapts a SPICE engine to a user-friendly input and output format. The software is described on the inside cover of the text and in Appendix A. This brief description coupled with the extensive help screens and demonstration programs should be sufficient for the student to gain expertise in application of the program. The new version retains many of the popular features of the best-selling Micro-Cap IV. But significantly, it adds mixed analog and digital simulation including timing diagrams. The description on the inside cover gives instructions to downloading new libraries and updates from the World Wide Web.

Accuracy of the Book

Nobody likes errors! As authors, we have nightmares about them. Every effort has been made to write and publish an *accurate* book. Many reviewers have picked through the earlier editions of the text, and users of the first two editions were often vocal in pointing out typographical errors. This new edition evolved out of extensive use in the classroom environment. It has been thoroughly checked and class-tested with students.

Instructional Adjuncts

The following materials are available to instructors:

- An **Instructor's Manual** containing complete solutions to all the exercises and end-of-chapter problems in the book. The manual includes design case studies.
- Problem sets on computer disk (in popular word processing formats).
- Overhead projector **Transparency Masters** of the important figures in the text
- Instructors using the text will receive a periodic **Newsletter** sharing approaches toward teaching the subject material. The newsletter includes sections on new developments, pedagogical approaches to the subject material, and resource listings (including examination files).
- A **Laboratory Manual** is available separately from the publishers. It is keyed to sections of the book.

Guide for Classroom Use

The material in this book can be presented in a series of two or three one-semester courses or three one-quarter courses in the junior and/or senior years.

Earlier versions of this book have been successfully used in both individual courses (e.g., analog electronics or digital electronics), and comprehensive sequences of courses. Examples of some approaches are given in the following table:

One quarter course in basic electronics	Chapters 1, 3, 4, 5 and 6
One semester course in basic electronics	Chapters 1, 3, 4, 5, 6, and 7.
Two-quarter sequence in basic electronics	Chapters 1, 3, 4, 5, 6, 7, 10, 11, 12
Two-semester sequence in basic electronics	Chapters 1 through 12
One quarter or one semester course in digital electronics	Chapters 14, 15 and 16

Acknowledgments

We express our appreciation to the students in the various electronic design classes the authors have taught while using the earlier versions of this text. Sincere thanks are extended to our colleagues, Professor Hassan Babaie, Lou Balin, Roy Barnett, Fred Daneshgaran, Ed Evans, Mike Hassul, Ken James, George Killinger, and Sid Soclof for their comments and assistance with various portions of the manuscript.

A very special acknowledgement to the late Dr. C. J. Savant, Jr. Twelve years ago, Dr. Savant had a dream of authoring a core electronics book that "broke the mold" and prepared graduates for the real world in a way no other books were doing. We are pleased that he lived to see his dream fulfilled with a text whose first two editions were used and enjoyed by students at well over 100 major universities in the United States. His influence stretched around the world with the many translations of those texts. This book would not have been possible without the pioneering vision of this outstanding professor and unique human being.

Every book is the result of a number of iterations and revisions based on classroom experience and the expert advice of reviewers. We were fortunate to have forty four readers review all or part of the manuscripts for the first, second and third editions. We hereby thank the following reviewers, and the many others who are not mentioned by name, for their efforts:

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We truly hope that all of the people who contributed to this book and had a hand in its development are as pleased with the finished product as we are.

Gordon L. Carpenter
Martin S. Roden

Introduction to the Student

You are embarking on an exciting adventure in your undergraduate education. Electronics is the backbone, and the driving force behind much of Electrical Engineering.

When many of your (more senior) professors were undergraduates, very few students could say they specialized in *electronics*. An Electrical Engineering major claiming to be specializing in electronics was similar to a Math major claiming to specialize in *addition*. Each "specialization" was viewed as a necessary tool on the way toward a particular application such as communications, computers, or power. The passage of time has dramatically altered the situation! The rapidly accelerating pace of electronic developments has been the necessary catalyst for most of the newer technologies, from high-speed personal computers to cellular telephones. While electronics *must* be understood and appreciated by all Electrical Engineers, the need for specialists has never been greater.

We sincerely hope this book serves both purposes—to lay the foundation for use by all specializations within Electrical Engineering, and to motivate some of you to specialize in electronics.

This is not an easy task, since the field is changing at a rapid pace. You must be careful to concentrate upon *education* rather than *training*. Those who were *trained* in vacuum tube electronic design during the 1950s found their training to be useless a decade later when transistors replaced vacuum tubes in all but a few high-power or high-frequency applications. Likewise, those who were *trained* in transistor design during the 1960s and early 1970s found that training to be obsolete with the advent of integrated circuits and op-amp systems. It is therefore important that you prepare yourself for the next revolution by both learning the fundamentals and "learning how to learn."

Many texts approach this challenge by overemphasizing the theory and completely avoiding applications. This is certainly not the case with our text! A sterile theoretical presentation could leave you with some basic knowledge that you could *someday* apply. However, you would probably not experience the excitement of applying this knowledge to practical situations as you learn. Indeed, you would not even know if you are capable of it.

For that reason, this text is *design oriented*. You will be guided through many practical applications of the theory—and we do mean *practical*! We emphasize that the practical design procedures presented in this text represent *one way* of reducing the theory to practice. True design requires many tradeoff decisions, and there is more than one correct answer given the system constraints. For this reason, the

procedures we illustrate are **not** the only ways in which the theory can be applied to practical situations. You are encouraged to seek other procedures, either independently or with the help of your professor. We hope you will be motivated to construct some of the systems you will design on paper, for that will truly "close the loop" and make your education more meaningful.

Some of the problems at the back of the chapters might seem overwhelming at first glance. Learning design is a gradual process, so don't become discouraged. You will find you are capable of making progress on even the most complex design problems.

Most of all, enjoy the subject material. You have chosen an exciting career, but the same factors that make it exciting also make it challenging. You must sometimes strain to the limits of your mental abilities if you are to succeed, but the rewards of success will be fine compensation.

If you have any comments or suggestions about the text, please feel free to communicate them to either of the authors. Because we take a genuine interest in engineering education, we welcome all your comments and suggestions.

Gordon Carpenter

Martin S. Roden

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