ELECTRICAL, ELECTRONICS, AND DIGITAL HARDWARE ESSENTIALS FOR SCIENTISTS AND ENGINEERS

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To my lovely wife Ruty

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PREFACE

For several years I taught an introductory analog and digital essentials course for the University of California Extensions at Berkeley and Santa Cruz. Teaching there motivated me to put together, under one cover, a textbook that contains fundamentals of electrical, electronics, analog, and digital circuits. That is the reason for the word "essentials" in the title. There are not that many books in the market that try to accomplish this task in about 600 pages.

The book is divided into 10 chapters. It is useful for surveys of electrical and electronics courses, for college students as well as practicing scientists and engineers; it is also useful for introductory circuit courses at the undergraduate level. The book provides many examples from beginning to end. Within the examples, specific components part numbers were avoided to prevent this book from becoming obsolete. The book can be used by students who have some to no previous knowledge of the material, and for graduate-level and working professionals' circuit courses. The prerequisites for using this book are freshman-level calculus and algebra. Nevertheless, the level of math needed is quite light. The book is a gentle introduction to electrical and electronic circuit analysis with many examples.

Physical concepts are emphasized not only with text but also with specially prepared figures that should help the first-time readers study the material.

This book emphasizes problem solving, using different circuit analysis methodologies. These techniques allow readers to understand when one method is more appropriate than another. Ultimately, it is the student who is responsible for adopting the methods that make the most sense. No one thinks exactly in the same way. An example is differentiation and integration. For some people, differentiation is simpler than integration; for others, is the other way around.

Chapter 1 covers the three basic circuit elements: resistors, inductors, and capacitors. Additionally, *ideal* and *real* independent DC current and voltage sources are addressed. Chapter 2 emphasizes AC circuits, as they are applied to the three basic circuit elements. Their *time-domain* and *frequency-domain* behavior is seen throughout examples. A brief refresher on *operations with complex numbers* is embedded in this chapter and not in an appendix for reasons of reading continuity. The concept of power drawn by a circuit and its different types are addressed. The chapter ends with the coverage of dependent voltage and current sources. Chapter 3 addresses methods to solve circuits; it should be studied with the greatest attention and as many problems with different circuit analysis methods as possible should be solved. From a practical point of view, this is a core chapter to master.

Chapter 4 describes with plenty of detail the behavior of first-order and second-order circuits in the time and frequency domains. Many textbooks do not put as much emphasis on first-order circuits, because they are considered too simple. It has been my experience with students that first-order high-pass filters are particularly more difficult to understand than first-order low-pass filters. Chapter 5 is dedicated to *operational amplifiers*. Even though op amps consist of to-be-covered electronic components, it is useful to have the reader think with some high level of abstraction. Under some conditions op amps are seen as functional blocks and not as circuits with transistors and resistors. Linear and nonlinear applications with op amps are covered with many examples.

Chapter 6 covers electronic devices. Much information on devices is provided. One can say that entire books have been written just on the electronic components addressed by this chapter. The textbook takes a systematic approach to study the circuits using diodes and transistors, hardly dwelling on device physics. Chapter 7 begins with digital logic. *Combinational* (and not "combinatorial," as it is sometimes mistakenly called) logic circuits do not have any memory. Logic operations or Boolean algebra is presented, and logic simplification methods such as the Karnaugh map method are illustrated. Chapter 8 deals with more advanced combinational circuits such as multiplexers, decoders, and some arithmetic circuits. A method to produce a very fast arithmetic sum of two operands is covered. Chapter 9 is about state machine design or sequential logic. Sequential logic has memory, unlike combinational logic, and it is the core subject when designing logic circuits that perform useful and complete functions. Chapter 10 describes piece by piece the construction of a simple CPU. The CPU basic functional blocks, such as its instruction set, the data path architecture, its memory interface, and the control logic, are described step by step. Some insights into capacitor power decoupling and reliable reset circuits are also presented. The problems at the end of this chapter provide tremendous insight into the CPU functionality. This chapter can be thought as a very light introduction to a computer architecture course.

Writing this book has been a very rewarding experience for me. This book should be very useful to college students and those professionals who need an essential analog and digital source.

I want to thank my wife Ruty and daughter Denise for their infinite patience and support while I was preparing the manuscript.

Eduardo (Ed) M. Lipiansky

ABOUT THE AUTHOR

Eduardo (Ed) Lipiansky received his undergraduate degree in electrical engineering from the National University of La Plata, Argentina (UNLP). He performed graduate studies at the University of California, Berkeley, obtaining a master of science degree in electrical engineering. Mr. Lipiansky has 25 years of industry experience, having worked at Varian Associates, Tandem Computer, Sun Microsystems, Cisco Systems, and Google.

He is author or co-author of six patents; four have been issued by the U.S. Patent Office, and two more have been submitted. Mr. Lipiansky's key interests are maintenance and diagnostics subsystems for servers, networking line cards, analog and digital electronic design for medical instrumentation and computers, and power engineering. Ed wrote *Embedded Systems Hardware for Software Engineers* (2011), which deals with more advanced hardware concepts and can be used as an add-on to the present textbook. For about 20 years, he taught a variety of courses such as circuit analysis, digital design, operational amplifiers, and microprocessor interfacing techniques at the University of California Berkeley and Santa Cruz Extensions. Mr. Lipiansky lives with his family in the San Francisco Bay area in northern California.