

THE ELECTRONICS OF RADIO

This innovative book provides a stimulating introduction to analog electronics by analyzing the design and construction of a radio transceiver. Essential theoretical background is given at each step, along with carefully designed laboratory and homework exercises. This structured approach ensures a good grasp of basic electronics as well as an excellent foundation in wireless communications systems.

The author begins with a thorough description of basic electronic components and simple circuits. He then goes on to describe the key elements of radio electronics, including filters, amplifiers, oscillators, mixers, and antennas. In the laboratory exercises, he leads the reader through the design, construction, and testing of a popular radio transceiver (the NorCal 40A), thereby illustrating and reinforcing the theoretical material. A diskette containing the widely known circuit simulation software, *Puff*, is included in the book.

This is the first book to deal with elementary electronics in the context of radio. It can be used as a textbook for introductory analog electronics courses, or for more advanced undergraduate classes on radio-frequency electronics. It will also be of great interest to electronics hobbyists, radio enthusiasts, and to anyone who wants to find out more about the field of wireless communications.

David Rutledge is Professor of Electrical Engineering at the California Institute of Technology. He attended Williams College and the University of Cambridge and received his Ph.D. from the University of California at Berkeley. He is a recipient of the IEEE Microwave Prize and the Distinguished Educator Award of the Microwave Theory and Techniques Society. He is a Fellow of the IEEE and the holder of an Amateur Extra Class radio license with the call sign KN6EK.

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*To my children
Robb, Kate, and Alan*

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The first rule of tinkering is to keep all the pieces.

– Aldo Leopold

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Preface

A modern electrical-engineering textbook is formidable. One thousand pages of matrices and theorems and problems sap enthusiasm from the hardiest students. Even after wading through this massive amount of material, students may be no closer to designing or building electronic circuits. A delightful contrast to these books is Paul Nahin's *The Science of Radio*. Nahin, who is also a historian of great skill, approaches the mathematics of communications engineering in top-down fashion, by telling a history of early radio and introducing the mathematics only when ("just in time") he needs it for his story. However, in one sense, Professor Nahin only tells half the story, and we would like to tell the rest of it. The mathematics of communications, although beautiful, is limited – engineering products must be built. Today's electrical-engineering students have usually not built stereos or tinkered with cars, and this means that they do not know the smoke and smell of construction or the excitement of electronic circuits coming to life. Many universities encourage this trend, with exercises where students switch components in and out of a circuit, never even heating up the soldering iron.

This is an introduction to electronics based on the progressive construction of a radio transceiver, the NorCal 40A, through thirty-nine exercises. At Caltech, beginning electrical-engineering students complete one problem as homework for each lecture. These exercises may also be useful for students in radio engineering classes. Radio amateurs who want to learn more about the transceivers they build have also found the material helpful.

The approach is not traditional. The reader will not find Laplace transforms or matrix-circuit solutions. On the other hand, Philips's SA602AN double-balanced mixer and oscillator looms large in our story. In addition, as the students progress through the material, they will become adept at working with complex numbers and learn about Fourier series. Our experience is that it is valuable for students to learn to put knobs on without destroying the screw heads and to learn to completely strip the enamel from magnet wire before soldering it into the circuit. One benefit of this approach is that when the transceivers are finished, students can do quite sophisticated tests on complete systems with only modest equipment.

The first chapter introduces the fundamental ideas in radio, and the second discusses basic components in circuits. We tackle phasors in the third chapter and begin the construction of the transceiver, which proceeds through much of the rest of the book. I have included a chapter on transmission lines because of the connections to filters and acoustics. The focus is on material and measurements that

show how the transceiver works. The discussions of power amplifiers and oscillators as nonlinear circuits are more serious than those usually found in introductory electronics textbooks. I conclude with a chapter on antennas and propagation.

There are problems at the end of each chapter. After introductory exercises, the problems take a student through the transceiver construction. They include background and construction notes. The parts with numerical answers and plots that students do for homework are distinguished by boldface letters, **A**, **B**, and so on. Appendix A by Kent Potter gives a list of the supplies and equipment we use in the measurements. Appendix B explains Fourier series. Appendix C has the instructions for the circuit-simulator program *Puff* that is included and is used in the problems. Appendix D has a set of data sheets for the parts in the transceiver.

It is a pleasure to acknowledge the many ideas of longtime friend and colleague Kent Potter, laboratory engineer at Caltech. I wish to thank William Bridges, Carl F. Braun Professor of Engineering, for introducing me to the community of amateurs. Paul Nahin contributed the epigraph. The teaching assistants for the 96–97 class, Lon Christensen, Kai-Wai Chiu, John Davis, and Jonathan Little, were exceptional and made many perceptive suggestions. I would like to thank Alwin Chi for proofreading and indexing, and Connie Rodriguez for handling the correspondence. Bob Dyer at Wilderness Radio and Wayne Burdick, the designer of the NorCal 40A, have been extremely helpful. I also appreciate the suggestions from reviewers. Finally, this book would never have been written without the encouragement of my wife Dale and my editor, Philip Meyler. We have worked hard to fix errors, but many surely remain. Please let me know about them at rutledge@caltech.edu.