Preface

Analog integrated circuit (IC) design is often viewed as a "black art," accessible only to those with special talent or years of experience. As an attempt to disprove this stereotype, this book was written to provide a customized introduction for the beginner with a minimum amount of prerequisite knowledge. Specifically, the material is positioned to fill the gap between general introductions on analog circuits, which are usually centered on discrete (printed circuit board) components, and advanced graduate books on integrated circuits. The need for filling the gap between these two types of texts has become stronger over the past decade for several reasons. The first is that advanced material has become less accessible for the inexperienced learner due to the growing complexity associated with the state-of-the-art. A second reason is that today's typical intro course sequence has been expanded to include embedded system design; this leaves very little time to cover analog circuit principles at a level that is required for a continuation toward advanced study.

There are multiple usage scenarios for this book. The material can be taught following an introduction to analog circuits in the junior or senior year of undergraduate study. In addition, the text can be used to prepare incoming graduate students for an advanced course sequence in analog IC design. Lastly, we believe that the book will be valuable for engineers that are pursuing a career change toward analog ICs, but do not possess the prerequisites to follow advanced literature. The reader of this module is expected to be familiar with the basic concepts of linear circuit analysis, including Kirchhoff's laws and the frequency response analysis of passive networks. We also assume familiarity with basic solid-state physics and electrostatics.

Since the study of analog circuits is strongly coupled to semiconductor device physics and linear system theory, it has and will always be difficult to teach this subject from the ground up, without causing too many distractions and challenges that are related to the required tool set, rather than the core principles themselves. This book follows a "just-in-time" treatment of semiconductor device modeling aspects to alleviate this problem. Instead of covering all of the detailed device physics in one isolated chapter, we begin with the simplest possible model, and augment this model only where needed to resolve new questions that arise as we learn more about circuits. This approach eases the device physics overhead and gives the reader a chance to internalize the transistor models from a well-motivated basis.

The book starts with an introduction (Chapter 1) that motivates the selection of topics and reviews prerequisite material on linear two-port modeling. Chapters 2-4 form the core of this book and analyze the "atoms" of linear analog circuit design: the common-source, common-gate and common-drain stages. This material emphasizes the relevant principles in the context of integrated (as opposed to dis-

crete) circuit design, and assumes complementary metal-oxide-semiconductor (CMOS) devices as the underlying technology platform. In Chapter 2, we begin by deriving the simplest possible expressions for a transistor's I-V characteristic. This model is then immediately used to build a (common-source) voltage amplifier and refined "just-in-time" as we progress. Chapter 3 uses the constructed voltage amplifier as a motivation to study frequency response. Again, we will find here that extra modeling is needed to make accurate predictions. In the same spirit, Chapter 4 explores the behavior of the common-gate and common-drain stages and gives a preview of their applications. Since biasing is a very important aspect in analog design, we have dedicated the entire Chapter 5 to this topic. As a clear distinction from many other intro texts, we provide important insight into CMOS matching and variability, which plays a substantial role in identifying practical biasing approaches. Lastly, Chapter 6 ties together the findings from the core chapters to construct multi-stage amplifiers. At the end of this chapter, we provide an example of a systematic design procedure for a transresistance amplifier. This material is meant to serve as a segway into more advanced design problems and will help prepare the student for the transition from analysis toward the true design and systematic synthesis of circuits. The end of each chapter contains a set of problems that can be used to test the reader's understanding. Instructors who adopt this book can contact the publisher for access to the problem solutions.

This book belongs to the Modular Series of Microelectronic Device & Circuit Design. Each module in the series, like this book, provides a brief fundamental look at a specific topic. Selecting multiple modules of interest can allow an instructor to customize content for a class more economically than by selecting chapters from a single large textbook, or a single module can supplement a course whose textbook omits an important relevant topic. More information about the series appears on the back cover of this book.

Acknowledgments

I would like to thank Charlie Sodini and Roger Howe for establishing this book series and for their help during the creation of this module. Special thanks go to my loving wife Yukiko, who patiently supported me during the preparation of this book.

Boris Murmann