

In the forward to the first issue of the *IEEE Journal of Solid-State Circuits* in September 1966, Dr. James D. Meindl wrote

*“Within the past two decades, perhaps no sector of electronics has developed more rapidly than solid-state circuits. The nature of this development has imposed an expanding set of requirements on the breadth of knowledge one must possess in order to design a circuit well. – Most recently, the uniquely interdependent material, device, circuit, and system design considerations of large scale integration have again extended the scope of the problem of circuit design.”*

It is remarkable that such broad statements, written over 30 years ago, are still accurate today. Given the complexity of present-day integrated circuits, circuit designers need to have a greater breadth of knowledge than ever before. This text is intended to provide an introduction to this important and rapidly changing discipline.

Many engineers who will never design an electronic circuit need to have a basic understanding of the characteristics of electronic circuits because they fabricate, test, or use these circuits, or they design systems that eventually have to be implemented using these circuits. In addition, there are many techniques and principles used in the design of electronic circuits that find widespread use outside of this discipline (e.g., small-signal linearity and feedback). Therefore, for those of you who will not become circuit designers this text still has much to offer that will be important in your careers.

The field of electrical engineering changes very rapidly. What can you expect to learn from this book that will still be useful in ten or twenty years? A great deal I hope. Although the devices, the economics of which components you favor, (e.g., resistors used to be cheaper than transistors, but the opposite is true in integrated circuits), and the computer-aided design tools will definitely change, there is still much that will stay the same. I can't predict exactly what will remain useful, but it seems unlikely that the *concept* of how to analyze a circuit so that you can see how to improve it will change, or that the *concept* of small-signal linearity will become unimportant, and certainly the ability you develop to solve problems will always be useful; after all, that is what engineers do.

I have tried to concentrate on helping you learn the *concepts* in this book. To be good at circuit design and many other engineering disciplines requires a healthy dose of intuition. While you certainly need to know how to write nodal equations and solve them, no one is going to pay you to do that because you can't possibly

compete with a computer program. As soon as any area of engineering is well enough understood that we can write rigid procedures guaranteed to produce a correct answer, a computer program will take over. Therefore, it is true that you will always be working with systems that you don't completely understand and systems that cannot be analyzed exactly. Design will always require an ability to model the real system with a model that is simultaneously simple enough to allow you to "see" what is going on and think of ways to improve the performance, while being complete enough to adequately model the salient characteristics of the system. In addition, design requires that we do our analyses in a different way; we aren't just seeking the *answer*, but an understanding of how we can *modify* the system and/or *choose* the component values to achieve a desired result. That is, at least in part, what it takes to do design.

Therefore, I have focused on providing explanations and examples of how different circuits work and have focused on the underlying principles more than "rules of thumb" or design procedures, although some of these are certainly given. If you are searching for a cookbook approach, you won't find it here. However, remember that no one will pay you to follow set procedures. A designer is only valuable if he or she understands the problem well enough to come up with a good solution, even when no "procedure" exists.

This textbook came together when the second author, who was looking for someone to revise an existing text, met with the first author, who was contemplating writing a new book. After discussion, it was agreed that a new textbook was needed, but that material from the older text could be used. The result is the book you have in your hands; most of the material is completely new and written by the first author, but some of it is adapted from *Electronic Devices and Circuits: Discrete and Integrated*, by Mohammed S. Ghausi.

## Organization and Features of the Text

The material in this text is organized logically by topic, rather than sequentially in the order I would present it. Therefore, I *do not expect* that you will read this book linearly. Rather, I expect that you will at times, jump around a bit. Organizing the book in this way has two advantages; first, I do not dictate the order of presentation and second, it emphasizes the different types of analyses that must be used in the design process.

Not specifying the order of presentation is important, because it allows each instructor more flexibility in choosing the topics to be covered and the depth of coverage of each topic. For example, you may cover field-effect transistor (FET) circuits first, or bipolar junction transistor (BJT) circuits first. This flexibility is partly brought about by placing the material on small-signal linearity in a separate chapter, and partly through the use of a generic transistor to present certain information that is common to both FETs and BJTs.

Emphasizing the different types of analyses used in design is important, because students are frequently confused about when and why a particular analysis or model should be used. For example, why is a capacitor modeled as an open or short circuit for some analyses while it is retained for others? And how do I know which model I should use for the transistors in my circuit? By covering DC bias point analysis, small-signal midband AC analysis, frequency response, large-signal AC performance, and digital circuits in different chapters, I emphasize the models, methods, and motivation for each type of analysis. Where possible, one example will be used throughout several chapters so, for example, you can learn about the DC biasing, midband gain, frequency response and large-signal swing of a common-emitter amplifier using a single example circuit. But the distinctions between

the different types of analyses are emphasized by having each of them in a different chapter.

One feature of this text is the use of a generic transistor to present many of the basic principles that are common to FET and BJT circuits. While this transistor is fictitious, the terminal names used focus attention on the *functionality* of the device and the models used are the same as real transistors. The advantages of using this slight fiction are:

1. It helps to develop intuition about the operation of a given type of circuit without reference to the active device used (for example, a common-emitter BJT amplifier, common-source FET amplifier and even a common-cathode vacuum tube amplifier have much in common).
2. It allows common information to be presented once without dictating which type of transistor is covered first.
3. It helps to foster a modern device-independent way of thinking about circuits. With this mode of thinking, the designer first considers the functionality of the circuit and then considers which type of device is best suited to a given application.

Another feature of this text is that it often breaks complex topics up into different levels of coverage to enable an instructor to decide how much detail to cover on a given topic at a given time. For example, most sections in Chapter 2 describing the operation of solid-state devices have an intuitive description followed by a more detailed derivation of the equations. The intuitive description can be used by students who have already had—or will have—a more detailed course in device physics. The detailed derivations can be used by students who have only one course covering electronic circuits and devices. As another example, the frequency response chapter presents both first-order methods for estimating the bandwidth of simple circuits (e.g., the Miller effect) and the more general zero-value time constant method. The more advanced zero-value time constant method may be left out of an introductory course taken by general Electrical and Computer Engineering students and can then be added in during a second-term course for students specializing in the circuits area.

One other feature of this text is that full solutions are provided for the exercises, rather than just numerical answers. It is my belief that if an exercise is involved enough to be of any real use to the student, simply providing the numerical answer is insufficient.

The final major feature of this text is the use of Asides. Asides are used for two different purposes. Sometimes, they are used to present material that is essential, but the student may already know from a prerequisite course, or may want to refer to later. Having the material in a separate Aside allows students to skip it or easily refer to it later. Asides are also sometimes used to present optional material that may expand on or further explain the material covered in the section. A separate index is provided to the Asides.

The CD that accompanies this text is also important. In addition to containing an evaluation version of the MicroSim DesignLab 8 software, which includes PSPICE, a postprocessor (PROBE), and a schematic capture program, the CD also includes all of the simulation files for over 100 exercises, examples, figures, and comments in the text. There are indexes on the CD for these files so that you can find, for example, a simulation file that shows how to use PSPICE to find the input or output resistance of an amplifier. In addition, the CD contains companion sections for a few places in the text where material was not printed for the sake of brevity (including two appendixes). I felt that some students would want this material.

There is more than enough material in this text for a two semester or three quarter sequence in electronic circuit design. Several different instructors have

used drafts of this text for a two-quarter sequence at the University of California at Davis for several years. The first quarter of that sequence is required of all Electrical and Computer Engineering majors and covers Chapters 1 and 6, parts of Chapters 2, 7, and 8, the introductory material in Chapter 9, Chapter 14 and part of Chapter 15. The second quarter then adds the zero-value time constant method in Chapter 9, covers all of Chapter 10 and some of Chapters 4, 12, and 13. The material in Chapters 5 and 11 is used as reference material in other courses and Chapter 3 is left for the students to read, if they are interested.

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RICHARD SPENCER,  
Davis, CA