means of designing synchronous and combinatorial logic. Once the basic methodology of designing logic has been discussed, common support logic solutions, including address decoding, control/status registers, and interrupt control logic, are shown with detailed design examples. Designing logic to handle asynchronous inputs across multiple clock domains is presented with specific examples. More complex logic circuits capable of implementing arbitrary algorithms are built from finite state machines—a topic explored in detail with design examples to ensure that the concepts are properly translated into reality. Finally, state machine optimization techniques, including pipelining, are discussed to provide an understanding of how to design logic that can be reliably implemented.

Chapter 11, "Programmable Logic Devices," explains the various logic implementation technologies that are used in a digital system. GALs, PALs, CPLDs, and FPGAs are presented from the perspectives of how they work, how they are used to implement arbitrary logic designs, and the capabilities and features of each that make them suitable for various types of designs. These devices represent the glue that holds some systems together and the core operational elements of others. This chapter aids in deciding which technology is best suited to each logic application and how to select the right device to suit a specific need.

PART 3 ANALOG BASICS FOR DIGITAL SYSTEMS

All electrical systems are collections of analog circuits, but digital systems masquerade as discrete binary entities when they are properly designed. It is necessary to understand certain fundamental topics in circuit analysis so that digital circuits can be made to behave in the intended binary manner. Part 3 addresses many essential analog topics that have direct relevance to designing successful digital systems. Many digital engineers shrink away from basic DC and AC circuit analysis either for fear of higher mathematics or because it is not their area of expertise. This needn't be the case, because most day-to-day analysis required for digital systems can be performed with basic algebra. Furthermore, a digital systems slant on analog electronics enables many simplifications that are not possible in full-blown analog design. On completing this portion of the book, you will be able to apply passive components, discrete diodes and transistors, and op-amps in ways that support digital circuits.

Chapter 12, "Electrical Fundamentals," addresses basic DC and AC circuit analysis. Resistors, capacitors, inductors, and transformers are explained with straightforward means of determining voltages and currents in simple analog circuits. Nonideal characteristics of passive components are discussed, which is a critical aspect of modern, high-speed digital systems. Many a digital system has failed because its designers were unaware of increasingly nonideal behavior of components as operating frequencies get higher. Frequency-domain analysis and basic filtering are presented to explain common analog structures and how they can be applied to digital systems, especially in minimizing noise, a major contributor to transient and hard-to-detect problems.

Chapter 13, "Diodes and Transistors," explains the basic workings of discrete semiconductors and provides specific and fully analyzed examples of how they are easily applied to digital applications. LEDs are covered as well as bipolar and MOS transistors. An understanding of how diodes and transistors function opens up a great field of possible solutions to design problems. Diodes are essential in power-regulation circuits and serve as voltage references. Transistors enable electrical loads to be driven that are otherwise too heavy for a digital logic chip to handle.

Chapter 14, "Operational Amplifiers," discusses this versatile analog building block with many practical applications in digital systems. The design of basic amplifiers and voltage comparators is offered with many examples to illustrate all topics presented. All examples are thoroughly analyzed in a step-by-step process so that you can learn to use op-amps effectively on your own. Op-amps are useful in data acquisition and interface circuits, power supply and voltage monitoring circuits, and for implementing basic amplifiers and filters. This chapter applies the basic AC analysis skills explained previously in designing hybrid analog/digital circuits to support a larger digital system.

Chapter 15, “Analog Interfaces for Digital Systems,” covers the basics of analog-to-digital and digital-to-analog conversion techniques. Many digital systems interact with real-world stimuli including audio, video, and radio frequencies. Data conversion is a key portion of these systems, enabling continuous analog signals to be represented and processed as binary numbers. Several common means of performing data conversion are discussed along with fundamental concepts such as the Nyquist frequency and anti-alias filtering.

PART 4 DIGITAL SYSTEM DESIGN IN PRACTICE

When starting to design a new digital system, high-profile features such as the microprocessor and memory architecture often get most of the attention. Yet there are essential support elements that may be overlooked by those unfamiliar with them and unaware of the consequences of not taking time to address necessary details. All too often, digital engineers end up with systems that almost work. A microprocessor may work properly for a few hours and then quit. A data link may work fine one day and then experience inexplicable bit errors the next day. Sometimes these problems are the result of logic bugs, but mysterious behavior may be related to a more fundamental electrical flaw. The final part of this book explains the supporting infrastructure and electrical phenomena that must be understood to design and build reliable systems.

Chapter 16, “Clock Distribution,” explores an essential component of all digital systems: proper generation and distribution of clocks. Many common clock generation and distribution methods are presented with detailed circuit implementation examples including low-skew buffers, termination, and PLLs. Related subjects, including frequency synthesis, DLLs, and source-synchronous clocking, are presented to lend a broad perspective on system-level clocking strategies.

Chapter 17, “Voltage Regulation and Power Distribution” discusses the fundamental power infrastructure necessary for system operation. An introduction to general power handling is provided that covers issues such as circuit specifications and safety issues. Thermal analysis is emphasized for safety and reliability concerns. Basic regulator design with discrete components and integrated circuits is explained with numerous illustrative circuits for each topic. The remainder of the chapter addresses power distribution topics including wiring, circuit board power planes, and power supply decoupling capacitors.

Chapter 18, “Signal Integrity,” delves into a set of topics that addresses the nonideal behavior of high-speed digital signals. The first half of this chapter covers phenomena that are common causes of corrupted digital signals. Transmission lines, signal reflections, crosstalk, and a wide variety of termination schemes are explained. These topics provide a basic understanding of what can go wrong and how circuits and systems can be designed to avoid signal integrity problems. Electromagnetic radiation, grounding, and static discharge are closely related subjects that are presented in the second half of the chapter. An overview is presented of the problems that can arise and their possible solutions. Examples illustrate concepts that apply to both circuit board design and overall system enclosure design—two equally important matters for consideration.

Chapter 19, “Designing for Success,” explores a wide range of system-level considerations that should be taken into account during the product definition and design phases of a project. Component selection and circuit fabrication must complement the product requirements and available development and manufacturing resources. Often considered mundane, these topics are discussed because a successful outcome hinges on the availability and practicality of parts and technologies that are designed into a system. System testability is emphasized in this chapter from several perspectives, because testing is prominent in several phases of product development. Test mechanisms including boundary scan (JTAG), specific hardware features, and software diagnostic routines enable more efficient debugging and fault isolation in both laboratory and assembly line environments. Common computer-aided design software for digital systems is presented with an emphasis on Spice