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CHAPTER 1

Digital Logic

All digital systems are founded on logic design. Logic design transforms algorithms and processes conceived by people into computing machines. A grasp of digital logic is crucial to the understanding of other basic elements of digital systems, including microprocessors. This chapter addresses vital topics ranging from Boolean algebra to synchronous logic to timing analysis with the goal of providing a working set of knowledge that is the prerequisite for learning how to design and implement an unbounded range of digital systems.

Boolean algebra is the mathematical basis for logic design and establishes the means by which a task's defining rules are represented digitally. The topic is introduced in stages starting with basic logical operations and progressing through the design and manipulation of logic equations. Binary and hexadecimal numbering and arithmetic are discussed to explain how logic elements accomplish significant and practical tasks.

With an understanding of how basic logical relationships are established and implemented, the discussion moves on to explain flip-flops and synchronous logic design. Synchronous logic complements Boolean algebra, because it allows logic operations to store and manipulate data over time. Digital systems would be impossible without a deterministic means of advancing through an algorithm's sequential steps. Boolean algebra defines algorithmic steps, and the progression between steps is enabled by synchronous logic.

Synchronous logic brings time into play along with the associated issue of how fast a circuit can reliably operate. Logic elements are constructed using real electrical components, each of which has physical requirements that must be satisfied for proper operation. Timing analysis is discussed as a basic part of logic design, because it quantifies the requirements of real components and thereby establishes a digital circuit's practical operating conditions.

The chapter concludes with a presentation of higher-level logic constructs that are built up from the basic logic elements already discussed. These elements, including multiplexers, tri-state buffers, and shift registers, are considered to be fundamental building blocks in digital system design. The remainder of this book, and digital engineering as a discipline, builds on and makes frequent reference to the fundamental items included in this discussion.

1.1 BOOLEAN LOGIC

Machines of all types, including computers, are designed to perform specific tasks in exact well defined manners. Some machine components are purely physical in nature, because their composition and behavior are strictly regulated by chemical, thermodynamic, and physical properties. For example, an engine is designed to transform the energy released by the combustion of gasoline and oxygen into rotating a crankshaft. Other machine components are algorithmic in nature, because their designs primarily follow constraints necessary to implement a set of logical functions as defined by