DIGITAL SYSTEM DESIGN

Barry Wilkinson

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Preface

This book introduces the fundamental topics in digital system design, and is divided into three parts. Part 1 is devoted to logic design, and Part 2 is devoted to the components of a microprocessor system. Part 3 contains further aspects of digital system design and extends topics introduced in Part 1 and Part 2. Overall, the purpose of the book is to provide a broad but comprehensive coverage in concise chapters (seventeen in all).

Part 1 consists of Chaps. 1 to 5. Chapter 1 considers the basic topic of binary numbers and codes which are used in digital systems. Chapter 2 introduces Boolean variables, expressions and simplification methods including both the Karnaugh map method and Quine–McCluskey method. Chapter 3 describes the function of fundamental logic devices in which outputs depend upon present input values irrespective of any past values (i.e. combinational logic circuits). Logic devices in the TTL family are quoted as examples. Chapter 4 analyzes sequential logic circuits (whose outputs may depend upon past input values). The concept of a state diagram is introduced early in this chapter firstly to derive flip-flop logic circuits and subsequently for counters. Electronic circuit details of logic devices are separated into Chap. 5. This chapter could be omitted if electronic details are not required, though any essential electronic concepts are briefly explained where necessary.

Part 2 consists of Chaps. 6 to 11. Chapter 6 outlines the basic stored program concept embodied in computer and microprocessor systems. Various possible instruction formats are described. The general architecture of a microprocessor and a microprocessor system is then given. Assembly language programming aspects are outlined. It is normal practice to select a particular microprocessor for study, often an 8-bit microprocessor. Since the Z–80 microprocessor is perhaps the most widely used microprocessor, the Z–80 is selected in Chap. 7 for detailed study. The system configuration is presented including the components of a simple Z–80 system. Then, the instructions are described mostly by presenting a requirement first, rather than simply listing the instructions which can be found in the manufacturer's manual. However, a complete set of Z–80 instruction tables are given, showing valid source and destination operands as these tables are extremely useful. Chapter 8 outlines the 16-bit 68000 microprocessor, chosen because it is a popular 16-bit microprocessor and incorporates important techniques. Some differences in the assembly language notation are exposed. Valid source and destination operands of all 68000 instructions are given. Chapter 9 is devoted to semiconductor memory devices, as used in microprocessor systems and in computer systems generally. Chapter 10 deals with input/output circuits and operation, including interrupt and DMA operation. Chapter 11 is devoted to magnetic secondary memory (backing store) found in microprocessor systems. All the major magnetic recording codes are described.

Part 3 begins with Chap. 12, a continuation of Chap. 4 on sequential circuit design, and includes both synchronous and asynchronous sequential circuit designs. This chapter could be studied immediately after Chap. 4, or could be omitted if the extra detail is not required. A particularly relevant section for microprocessor system design and other computer system design is on synchronizing asynchronous signals (section 12.2.4). Chapter 13 considers the design of a central processor. The concept of a register transfer notation is introduced and applied to a model of the Z–80 microprocessor. Microprogramming is explained, using the Am2901A and Am2910A devices in an example of a bit-slice microprogrammed system. Finally overlap and pipelining are described. Chapter 14 considers the system schemes that can be employed to manage the memory hierarchy in a computer system, including a microprocessor system. The chapter contains both primary–secondary memory management schemes and the use of cache memory between the processor and the primary memory. Chapter 15 describes multiprocessor system architectures, particularly the time-shared bus architecture as applied to microprocessor systems. In a final section, the dataflow architecture is presented in detail, as one alternative to traditional von-Neumann computers. Chapter 16 is a continuation of Chap. 5 and considers engineering aspects of creating a working system. Assessments of transmission line reflections, cross-talk and noise are presented. In Chap. 17, the reliability of a digital system is calculated. Tables giving the reliability of devices are included to enable the reliability of typical systems to be computed. Methods to increase the reliability are discussed.

Problems are set at the end of chapters (except Chap. 6). A Teacher's Manual containing solutions to the problems is available from the publishers.

I am particularly grateful to have been able to undertake much of the work on the manuscript of this book at the College at New Paltz, State University of New York. I should also like to thank Mr. Glen Murray, Acquisitions Editor of Prentice-Hall International, for the support received throughout the preparation of this book.

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About the Author

Barry Wilkinson gained a BSc degree (first class hons.) in Electrical Engineering from Salford University in 1969, and MSc and PhD degrees from Manchester University (Department of Computer Science) in 1971 and 1974 respectively. From 1969 to 1970, he worked on process control computer systems at Ferranti Ltd. In 1973, he was appointed a Lecturer in the Computer Centre at Aston University and moved to the Department of Electrical and Electronic Engineering at University College, Cardiff in 1976. He was appointed an Associate Professor at the College at New Paltz, State University of New York in 1983 and joined the Department of Electrical and Electronic Engineering, Brighton Polytechnic as Principal Lecturer in 1984. He is a senior member of the IEEE, a member of the IEE, a member of the BCS, and the co-author of *Computer Peripherals* (1980).

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PART 1

LOGIC DESIGN

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CHAPTER

1

Binary Numbers

1.1 NUMBER SYSTEMS

When a number such as:

259

is written, it is generally taken to mean:

$$2 \times 10^2 + 5 \times 10^1 + 9 \times 10^0$$

i.e. two hundreds plus five tens plus nine units. In this number system, the *decimal* number system, there are ten different characters or digits 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 and the position of each digit indicates the power of ten to multiply the value represented by the digit. Formally, the number is defined as:

$$(a_n a_{n-1}, \cdots a_1, a_0)_b = a_n b^n + a_{n-1} b^{n-1} + \cdots a_1 b^1 + a_0 b^0$$

where a_n is the digit in position n and b is the base, ten in this case. Fractions are simply an extension of the above, i.e.

$$(0.145)_{10} = 1 \times 10^{-1} + 4 \times 10^{-2} + 5 \times 10^{-3}$$

Formally a number including a fractional part is defined as:

$$(a_n, \cdots a_1, a_0.a_{-1}, \cdots a_{-m})_b = a_n b^n + \cdots a_1 b^1 + a_0 b^0 + a_{-1} b^{-1} + \cdots a_{-m} b^{-m}$$

The subscript 10 is introduced to indicate that the base is 10, i.e. a decimal number. Using the base ten is only one possibility of this form of number representation. Whatever value we choose for b, there needs to be the same number of different symbols for the digits. For example, if $b = 8$, there need to be eight different digit symbols. The number system using the base 8 is known as the *octal* number system. The eight symbols used are 0, 1, 2, 3, 4, 5, 6 and 7. In the octal number system, the number:

$(257)_8$

would equal

$$2 \times 8^2 + 5 \times 8^1 + 7 \times 8^0$$

or

$$2 \times 64 + 5 \times 8 + 7 \times 1 = (175)_{10}$$

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