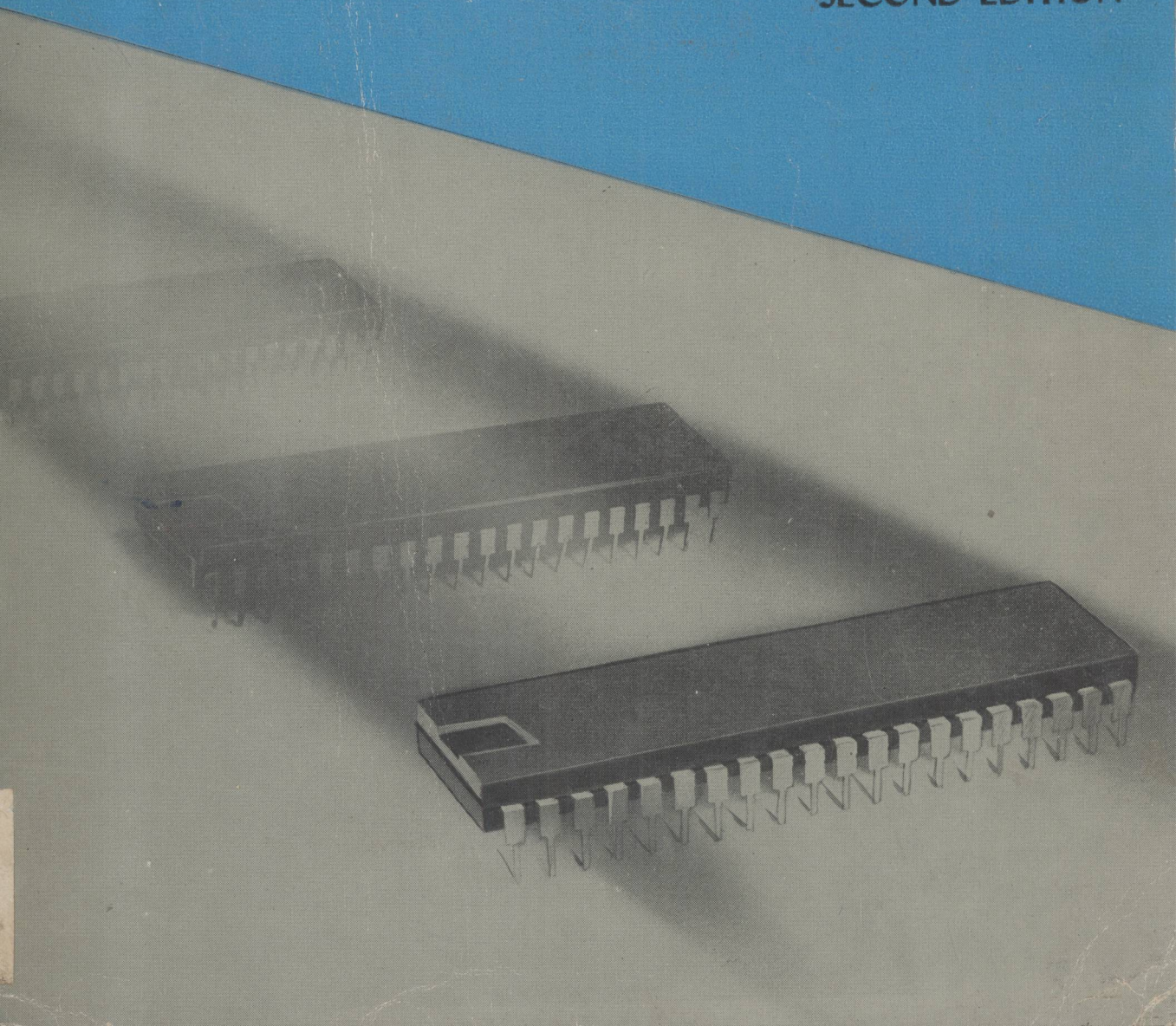
ADITYA P. MATHUR

Introduction to Microprocessors

SECOND EDITION



Introduction to MICROPROCESSORS

Second Edition

ADITYA P MATHUR

Birla Institute of Technology and Science
Pilani

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To
My Parents

Preface to Second Edition

I strongly believe that the second edition is due to the unexpectedly enthusiastic response received from a wide range of readers. I would like to thank all these readers for their comments, criticisms, appreciation and for going through the book. At the same time I would like to apologize to readers for so many errors, that crept into the first edition due to one reason or the other. Sincere efforts have been made to ensure that errors are minimized in this edition.

The second edition introduces three topics in more detail. These are:

1. Memory organization, timing and interfacing.
2. Designing with the aid of 8255A Programmable Peripheral Interface.
3. Architecture and programming of two popular 16-bit uPs - the 8086 and 68000.

Chapters 4 and 6 cover the first of the above topics. The 8255A is covered in Chapter 7. Two design examples have been added in this chapter. Chapter 10 has been completely rewritten with the advanced reader in mind.

Both 8086 and 68000 are covered in depth and without any bias towards anyone of these uPs. Such a treatment should help a teacher in selecting any one of the two uPs for a course on microprocessors.

In a class where the majority of students do not have any prior background in programming and digital electronics, Chapters 1 to 9 can be included in a one semester course. However, for students without any of the these two deficiencies, the complete book could be covered in one semester assuming that only one of the two 16-bit uPs is selected for teaching from Chapter 10. Chapter 9 can be covered as a reading assignment.

Aditya P. Mathur

Preface to First Edition

The objective of this book is to teach the basic principles and techniques underlying the design of microprocessor based systems. The emphasis is on presenting in an integrated manner the general principles and techniques and not merely describing a set of microprocessors.

In order that the presentation be coherent, one microprocessor had to be chosen which could act as a vehicle to carry various concepts to the minds of the readers. Our choice has fallen on Intel's 8085A-- one of the recent, popular, third generation microprocessors. Apart from its popularity, we chose 8085 because of the ease with which several concepts can be illustrated. However, we hasten to add that several other devices may have proved to be as good as the 8085 for our task.

This book is ideal for those readers who have undergone one course each in Computer Programming and Basic Digital Electronics. However, for those who do not have this background, Chapter 2 and chapter 4 have been included to provide the necessary background material.

The book starts by introducing microprocessors/microcomputers at a very high level in chapter 1. Chapter 2 introduces the binary number systems. It explains how numbers--integer and real--are represented in a microcomputer memory and the rudiments of binary arithmetic.

Chapter 3 introduces the subject of Programming. Only assembly language programming is introduced. All those in the field of computer science know that higher level languages are much easier to use than the assembly languages. However, for quite sometime to come, microprocessor users will program in assembly languages due to various reasons, mainly the high cost of operating systems that support compilers. Though the assembly language introduced is the one for the 8085, the concepts involved are general. Thus, having learnt it, one has to merely scan the assembly language manual of any other microprocessor to learn its assembly language.

Chapter 4 reviews some of the commonly used semiconductor technologies. Semiconductor memories are also described in this chapter.

Chapter 5 presents the organization of the microprocessor itself. This chapter also introduces and explains timing diagrams an understanding of which is essential for any system designer.

Chapter 6 is, in our opinion, the most crucial of all for a reader who is contemplating design of systems involving I/O devices like card readers, floppy disk drives, etc. The chapter introduces general techniques for I/O device interfacing. All the commonly used techniques of data transfer have been described in sufficient detail. For the sake of completeness, interfacing of memories has also been introduced in this chapter.

A large number of special purpose peripheral chips are now offered by several manufacturers to aid a system designer in the task of interfacing. Chapter 7 describes the most commonly used of such devices, like the Peripheral Interface and the Interrupt controller. We strongly feel that any system designer should atleast know about the existence of these devices so that he does not waste his time designing discrete versions of these devices when the need arises.

Chapter 8 presents applications of microprocessors. One application-an open loop temperature control system is presented in detail. The complete hardware and software has been developed for this system. Several other applications are described in brief merely to acquaint the reader with the wide applications domain of microprocessors. The design example presented at the beginning of this chapter is intended to familiarize the reader with the system design methodology.

Chapter 9 cursorily describes the hardware and software subsystems that are available to the user of microprocessors. These subsystems are useful developement aids for a system designer.

The instruction sets of 8085 and 4004/4040 microprocessors have been included in the Appendices. Those who plan to work with the 8080 microprocessor should also find the instruction set useful as the 8080 is 100% upward compatible with the 8085 in software. The 8085 has only two extra instructions (the RIM and SIM) which are not recognized by the 8080.

We would like to mention that this book is not intended to replace any manual. Complete technical specifications have not been given for any microprocessor. Thus, when designing an actual system this book will have to be supported by relevent manuals related to the microprocessor being used.

Aditya P. Mathur

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Contents

Chapter 1

AN INTRODUCTION TO MICROPROCESSORS

1.1 OBJECTIVES OF THIS BOOK

The purpose of this book is to introduce the reader to the world of microprocessors. A microprocessor (In this text we shall use the abbreviation uP for the word microprocessor wherever convenient. Similarly uC will be used for microcomputer.) is an electronic device which is of little use unless interfaced with several other peripheral devices. Thus, a study of microprocessors implies a study of a variety of useful peripheral devices and the techniques for interfacing them with a microprocessor. This book concentrates on both these aspects of the study of microprocessors also known as hardware design.

Like any other digital computer, a system designed by using a microprocessor needs to be programmed, that is, a sequence of instructions has to be written down and then fed to the microprocessor-based system for an effective operation. A sequence of instructions designed to perform a particular task is known as a program. A set of programs written for a microprocessor-based system is known as the software for that system. This book also aims at teaching the reader the art of programming microprocessors. Those who are already familiar with the programming of digital computers (both machine language and high level language programming) will not find much new material except, perhaps, for the instruction set that we present for a few microprocessors. In general, both hardware and software design are of paramount importance in microprocessor-based system design, though, in particular cases, one may be more difficult or significant than the other.

There are many distinct approaches by which the subject of microprocessors can be introduced to a novice. One approach could be the general to specific, according to which general concepts regarding the architecture and programming of microprocessors are introduced without reference to any particular microprocessor. Specific microprocessors are considered only as examples. According to another approach a particular microprocessor may be introduced first, followed by a generalization of the concepts and their illustration using other microprocessors. In this book, the second approach has been adopted.

2 Microprocessors

The specific microprocessor that we have chosen for illustration of architectural and programming concepts is Intel's 8085 which is a comparatively recent device. Our choice has fallen on 8085 because of the popularity of its predecessor, the 8080, and the fact that both these are almost 100% software compatible and can be made hardware compatible also with the addition of a few extra devices.

In order that the reader gains a thorough knowledge of the techniques for interfacing microprocessors with the real world, detailed design examples have been presented. A laboratory available for experimentation would be an asset for the reader.

We have tried our best to introduce the latest developments in the field of microprocessors. However, as this is a rapidly developing field, the reader may find a few things missing because of the unavoidable delay in the printing of any book.

1.2 EVOLUTION OF MICROPROCESSORS

The first microprocessor was announced in 1971 by Intel Corporation. This was the Intel 4004. It was a processor on a single chip. It had the capability to perform simple arithmetic and logical operations, e.g. add, subtract, compare, AND and OR. It also had a control unit which could perform various control functions like fetching an instruction from the memory, decoding it and generating control pulses to execute it. It was a 4-bit microprocessor operating upon 4-bits of data at a time.

The first microprocessor was quite a success in industry. It found many applications and attracted much attention from both application engineers and semiconductor industry. Soon, other microprocessors were also announced. Intel itself followed by announcing an enhanced version of 4004, the 4040. Since then, many other 4-bit microprocessors have been announced; Rockwell International's PPS4 and Toshiba's T3472 are two examples.

The first 8-bit microprocessor, which could perform arithmetic and logic operations on 8-bit words, was announced in 1973 again by Intel. This was the 8008 which was followed by a better version - the 8080 from the same company. Today there is a variety of 8-bit processors, some examples being Motorola's M6800, National Semiconductors' SC/MP, Zilog Corporation's Z80, Fairchild's F8 and Intel's 8085.

The 8-bit processor was followed by microprocessors operating on 12-and 16-bit data words respectively. Intersil's IM6100 and Toshiba's T3190 are examples of 12-bit processors. Examples of 16-bit microprocessors are Fairchild's 9440, Data General's mN601 and Texas Instrument's TMS9900. Intel's 8086 and 80286, Motorola's M68000 and Zilog's Z8000 are some of the most powerful 16-bit microprocessors available today.