# THE INTEL MICROPROCESSORS

## 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, and Pentium Pro Processor

## Architecture, Programming, and Interfacing

**Fourth Edition**

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*This text is dedicated to the memory of my father,*
*Wilmer A. Brey,*
*who worked for over 40 years in the steel industry*
*to provide America with the raw materials*
*to become a great industrial power.*

# PREFACE

This fourth edition text is written for the student in a course of study that requires a thorough knowledge of programming and interfacing of the Intel family of microprocessors. It is a very practical reference text for anyone interested in all programming and interfacing aspects of this important microprocessor family. Today, anyone functioning or striving to function in a field of study that uses computers must understand assembly language programming and interfacing. Intel microprocessors have gained wide applications in many areas of electronics, communications, control systems, and particularly in desktop computer systems.

## ORGANIZATION AND COVERAGE

In order to cultivate a comprehensive approach to learning, each chapter of the text begins with a set of objectives that briefly define the contents of the chapter. This is followed by the body of the chapter, which includes many programming applications that illustrate the main topics of the chapter. At the end of each chapter, a numerical summary, which doubles as a study guide, reviews the information presented in the chapter. Finally, questions and problems are provided to promote practice and mental exercise with the concepts presented in the chapter.

This text contains many example programs, using the Microsoft MACRO assembler program, to provide an opportunity to learn how to program the Intel family of microprocessors. Operation of the programming environment includes the linker, library, macros, DOS function, and BIOS functions.

Also provided is a thorough description of each family member, memory systems, and various I/O systems that include disk memory, ADC and DAC, 16550 UART, PIAs, timers, keyboard/display controllers, arithmetic coprocessors, and video display systems. Also discussed are the personal computer system buses (ISA, VESA, and PCI). Through these systems, a practical approach to microprocessor interfacing is learned.

## APPROACH

Because the Intel family of microprocessors is quite diverse, this text initially concentrates on real mode programming, which is compatible with all versions of the Intel family of microprocessors. Instructions for each family member, which includes the 80386, 80486, Pentium, and

Pentium Pro processors are compared and contrasted with the 8086/8088 microprocessors. This entire series of microprocessors is very similar, which allows more advanced versions to be learned once the basic 8086/8088 microprocessors are understood. Please note that the 8086/8088 are still used in controllers, along with their updated counterparts, the 80186/80188 and 80386EX embedded controllers.

In addition to fully explaining the programming and operation of the microprocessor, this text also explains the programming and operation of the numeric coprocessor (8087/80287/80387/80486/80487/Pentium/Pentium Pro). The numeric coprocessor functions in a system to provide access to floating-point calculations that are important in applications such as control systems, video graphics, and computer-aided design (CAD). The numeric coprocessor allows a program to access complex arithmetic operations that are otherwise difficult to achieve with normal microprocessor programming.

Also described are the pin-outs and functions of the 8086–80486 and Pentium/Pentium Pro microprocessors. Interfacing is first developed using the 8088/8086 with some of the more common peripheral components. After learning the basics, a more advanced emphasis is placed on the 80186/80188, 80386, 80486, Pentium, and Pentium Pro microprocessors. Because of its similarity to the 8086 and 80386, coverage of the 80286 is minimized so that the 80386, 80486, Pentium, and Pentium Pro can be covered in complete detail.

By studying the operation and programming of the microprocessor and numeric coprocessor, as well as the interfacing of all family members, you will be provided with a working and practical background on the Intel family of microprocessors. On completion of a course of study based on this text, you should be able to:

- Develop control software to control an application interface to the 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, and Pentium Pro microprocessors. Generally, the software developed will function on all versions of the microprocessor. This software also includes DOS-based applications.
- Program using DOS function calls to control the keyboard, video display system, and disk memory in assembly language.
- Use the BIOS functions to control the keyboard, display, and various other components in the computer system.
- Develop software that uses macro sequences, procedures, conditional assembly directives, and flow control assembler directives.
- Develop software that uses interrupt hooks and hot-keys to gain access to terminate and stay resident software.
- Program the numeric coprocessor (80287/80387/80486/80487/Pentium/Pentium Pro) to solve complex equations.
- Explain the differences between the family members and highlight the features of each member.
- Describe and use real and protected mode operation of the 80286, 80386, 80486, Pentium, and Pentium Pro microprocessors.
- Interface memory and I/O systems to the microprocessor.
- Provide a detailed and comprehensive comparison of all family members, their software, and hardware interface.
- Explain the operation of disk and video systems.
- Interface small systems to the ISA, VESA local, and PCI bus in a personal computer system.

## CONTENT OVERVIEW

Chapter 1 introduces the Intel family of microprocessors, with an emphasis on the microprocessor-based computer system. This first chapter serves to introduce the microprocessor, its history, its operation, and the methods used to store data in a microprocessor-based system. In this edition, we also include a coverage of number systems for those who are unaware of them. Chapter 2 explores the programming model of the microprocessor and system architecture. Both real and protected mode operation are explained in this second introductory chapter.

Once an understanding of the basic machine is grasped, Chapters 3–6 explain how each instruction functions with the Intel family of microprocessors. As instructions are explained, simple applications are presented to illustrate their operation and to develop basic programming concepts.

After the basis for programming is developed, Chapter 7 provides applications using the assembler program. These applications include programming using DOS and BIOS function calls and the mouse function calls. Disk files are explained as well as keyboard and video operation on a personal computer system. This chapter provides the tools required to develop virtually any program on a personal computer system. It also introduces the concept of interrupt hooks and hot-keys.

Chapter 8 introduces the 8086/8088 family as a basis for learning the basic memory and I/O interfacing concepts that follow in later chapters. This chapter shows the buffered system as well as the system timing.

Chapter 9 provides complete detail on memory interface using both integrated decoders and programmable logic devices. Parity is illustrated as well as dynamic memory systems. The 8-, 16-, 32-, and 64-bit memory systems are provided so that the 8086–80486 and Pentium/Pentium Pro microprocessors can be interfaced to memory.

Chapter 10 provides a detailed look at basic I/O interfacing by discussing PIAs, timers, keyboard/display interfaces, 16550 UART, and ADC/DAC. It also describes the interface of both DC and stepper motors.

Once these basic I/O components and their interface to the microprocessor is understood, Chapters 11 and 12 provide detail on advanced I/O techniques that include interrupts and direct memory access (DMA). Applications include a printer interface, real-time clock, disk memory, and video systems.

Chapter 13 details the operation and programming for the 8087–Pentium Pro family of arithmetic coprocessors. Today, few applications function efficiently without the power of the arithmetic coprocessor. Remember that all Intel microprocessors since the 80486 contain a coprocessor.

Chapter 14 shows how to interface small systems to the personal computer through the use of the ISA, VESA, and PCI bus interfaces. This chapter, new to this edition, provides a launching point for the many cards being designed for use in the personal computer embedded in control systems in the industry.

Chapters 15 and 16 provide detail on the advanced 80186/80188–80486 microprocessors. In these chapters, we explore the differences between these microprocessors and the 8086/8088, as well as their enhancements and features. Cache memory, as well as interleaved and burst memory, are described with the 80386 and 80486 microprocessors. Also described are memory management and memory paging.

Chapter 17 details the Pentium and Pentium Pro microprocessors. These new microprocessors are based upon the original 8086/8088 and should carry Intel well into the next century.

Four appendixes are included to enhance the application of the text:

1. Appendix A includes a complete listing of the DOS INT 21H function calls. This appendix also details the use of the assembler program and many of the BIOS function calls, including BIOS function call INT 10H.

2. Appendix B gives a complete listing of all 8086–Pentium Pro instructions, including many example instructions and machine coding in hexadecimal, as well as clock timing information.
3. Appendix C provides a compact list of all the instructions that change the flag bits.
4. Appendix D provides answers for the even-numbered questions and problems from the text.

## ACKNOWLEDGMENTS

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## STAY IN TOUCH

You can stay in touch with me through the Internet. My Internet site contains information about all of my textbooks and many important links that are specific to the personal computer, microprocessors, hardware, and software. Also available is a weekly lesson that details many of the aspects of the personal computer. My Internet address is **http://users1.ee.net/brey/**

## LAB SUPPORT

A lab manual, *Instructor's Manual to Accompany The Intel Microprocessors: 8086/8088, 80186, 80286, 80386, 80486, Pentium, and Pentium Pro Microprocessors: Architecture, Programming, and Interfacing* (ISBN: 0-13-262981-X), is available from Prentice Hall to support the programming portion of this text.

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