

# MICROPROCESSORS AND INTERFACING

## PROGRAMMING AND HARDWARE

SECOND EDITION

DOUGLAS V. HALL



McGRAW-HILL INTERNATIONAL EDITIONS  
Computer Science Series

8086 • 80286 • 80386 • 80486



# MICROPROCESSORS AND INTERFACING PROGRAMMING AND HARDWARE

SECOND EDITION

DOUGLAS V. HALL

SEMINAR LIBRARY  
Department of Computer Science  
UNIVERSITY OF KARACHI

**GLENCOE**

Macmillan/McGraw-Hill

Lake Forest, Illinois

Columbus, Ohio

Mission Hills, California

Peoria, Illinois

# CONTENTS

Preface xi

## CHAPTER 1

Computer Number Systems, Codes, and Digital Devices	1
Computer Number Systems and Codes	1
Arithmetic Operations on Binary, Hex, and BCD Numbers	6
Basic Digital Devices	10

## CHAPTER 2

Computers, Microcomputers, and Microprocessors—An Introduction	19
Types of Computers	19
How Computers and Microcomputers Are Used—An Example	20
Overview of Microcomputer Structure and Operation	23
Execution of a Three-Instruction Program	24
Microprocessor Evolution and Types	26
The 8086 Microprocessor Family—Overview	27
8086 Internal Architecture	28
Introduction to Programming the 8086	32

## CHAPTER 3

8086 Family Assembly Language Programming—Introduction	37
Program Development Steps	37
Constructing the Machine Codes for 8086 Instructions	47
Writing Programs for Use with an Assembler	53
Assembly Language Program Development Tools	59

## CHAPTER 4

Implementing Standard Program Structures in 8086 Assembly Language	65
Simple Sequence Programs	65
Jumps, Flags, and Conditional Jumps	71
If-Then, If-Then-Else, and Multiple If-Then-Else Programs	77
While-Do Programs	82
Repeat-Until Programs	84
Instruction Timing and Delay Loops	91

## CHAPTER 5

Strings, Procedures, and Macros	95
The 8086 String Instructions	95
Writing and Using Procedures	99
Writing and Using Assembler Macros	127

## CHAPTER 6

8086 Instruction Descriptions and Assembler Directives	131
Instruction Descriptions	131
Assembler Directives	158



## CHAPTER 7

8086 System Connections, Timing, and Troubleshooting	163
A Basic 8086 Microcomputer System	163
Using a Logic Analyzer to Observe Microprocessor Bus Signals	168
An Example Minimum-Mode System, the SDK-86	173
Troubleshooting a Simple 8086-Based Microcomputer	201

## CHAPTER 8

8086 Interrupts and Interrupt Applications	207
8086 Interrupts and Interrupt Responses	207
Hardware Interrupt Applications	216
8254 Software-Programmable Timer/Counter	221
8259A Priority Interrupt Controller	232
Software Interrupt Applications	240

## CHAPTER 9

Digital Interfacing	245
Programmable Parallel Ports and Handshake Input/Output	245
Interfacing a Microprocessor to Keyboards	260
Interfacing to Alphanumeric Displays	267
Interfacing Microcomputer Ports to High-Power Devices	277
Optical Motor Shaft Encoders	283

## CHAPTER 10

Analog Interfacing and Industrial Control	290
Review of Operational-Amplifier Characteristics and Circuits	290
Sensors and Transducers	295
D/A Converter Operation, Interfacing, and Applications	301
A/D Converter Specifications, Types, and Interfacing	304
A Microcomputer-Based Scale	307
A Microcomputer-Based Industrial Process-Control System	317
An 8086-Based Process-Control System	320
Developing the Prototype of a Microcomputer-Based Instrument	331
Robotics and Embedded Control	332
Digital Signal Processing and Digital Filters	336

## CHAPTER 11

DMA, DRAMs, Cache Memories, Coprocessors, and EDA Tools	345
Introduction	346
The 8086 Maximum Mode	346
Direct Memory Access (DMA) Data Transfer	348
Interfacing and Refreshing Dynamic RAMs	353
A Coprocessor—The 8087 Math Coprocessor	365
Computer-Based Design and Development Tools	379

## CHAPTER 12

C, a High-Level Language for System Programming	389
Introduction—A Simple C Program Example	389
Program Development Tools for C	391
Programming in C	395

## **CHAPTER 13**

<b>Microcomputer System Peripherals</b>	<b>435</b>
System-Level Keyboard Interfacing	435
Microcomputer Displays	439
Computer Mice and Trackballs	462
Computer Vision	463
Magnetic-Disk Data-Storage Systems	465
Optical Disk Data Storage	478
Printer Mechanisms and Interfacing	479
Speech Synthesis and Recognition with a Computer	481
Digital Video Interactive	483

## **CHAPTER 14**

<b>Data Communications and Networks</b>	<b>487</b>
Introduction to Asynchronous Serial Data Communication	487
Serial-Data Transmission Methods and Standards	493
Asynchronous Communication Software on the IBM PC	506
Synchronous Serial-Data Communication and Protocols	518
Local Area Networks	522
The GPIB, HPIB, IEEE488 Bus	529

## **CHAPTER 15**

<b>The 80286, 80386, and 80486 Microprocessors</b>	<b>534</b>
Multiuser/Multitasking Operating System Concepts	535
The Intel 80286 Microprocessor	543
The Intel 80386 32-Bit Microprocessor	547
The Intel 80486 Microprocessor	568
New Directions	570

## **BIBLIOGRAPHY 577**

## **APPENDIX A iAPX 86/10 16-BIT HMOS MICROPROCESSOR 579**

## **APPENDIX B INSTRUCTIONS: 8086/8088, 186, 8087 592**

## **INDEX 607**