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Author of *Inside the 80286*

80386

TECHNICAL REFERENCE

The guide for getting the most from Intel's 80386

Foreword by Robert Childs, *80286 Architect*

80386
Technical Reference

Edmund Strauss

A Brady Book
New York, New York 10023

Also by Edmund Strauss

Inside the 80286

BRADY

Simon & Schuster, Inc.
Gulf + Western Building
One Gulf + Western Plaza
New York, New York 10023

DISTRIBUTED BY PRENTICE HALL TRADE

Manufactured in the United States of America

1 2 3 4 5 6 7 8 9 10

Library of Congress Cataloging in Publication Data

Strauss, Edmund.
80386 technical reference.

"A Brady book."
Includes index.
1. Intel 80386 (Microprocessor) I. Title.
QA76.8.I2684S77 1987 004.16 87-10962
ISBN 0-13-246893-X

DEDICATION

To my wonderful and dedicated parents,
Edmund and Paulina,
as a sign of appreciation for all their efforts
throughout many years.

ACKNOWLEDGEMENTS

I am deeply indebted to Robert E. Childs for his contributions in carefully reviewing the content and form of this entire book.

And I am grateful to Monika Feldmeier for providing the support and enthusiasm that made this book much easier to create. Thank you very dearly, Monika, once again!

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FOREWORD

The Personal Computer became a household word and a fact of life in business during the early 1980s. The introduction of the 80386 micorprocessor by Intel, and the Personal System /2, Model 80 by IBM, brings the power of a traditional mainframe computer to the desk of every office worker.

The available software base is even more significant than the computer hardware. The 80386 enters business establishments with a huge software base directly developed to serve the end-user of information. These users focus on the work result; they have no interest in becoming computer experts. The result is a major increase in office workers' productivity.

This text is unique in addressing the 80386 hardware and assembly language interfaces, while including the underlying concepts and suggestions for use by programmers. The author's unique experience in helping numerous designers complete 80286 and 80386-based machines shows through in the text. Ed Strauss has seen the full range of system issues and devised many practical solutions during his work for Intel.

I highly recommend this book to those seeking a very readable and practical introduction into the fundamentals of the 80386.

Robert E. Childs
80286 Architect
ROLM / an IBM Company

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PART 1

INTRODUCING THE INTEL 80386 32-BIT MICROPROCESSOR

This section provides an introduction to the positive effects brought about by the power of the 80386. It describes the new 80386 features in comparison with those of the previous Intel microprocessors and in terms of their benefits to users of the new 80386 computers. Then it begins delving into the 80386 as a highly capable computing machine.

As it becomes more technical, this section lays the groundwork for a clear understanding of the 80386 by covering such basic topics as its datatypes and 32-bit memory-addressing abilities. Finally, this part of the book covers each category of the 80386 instruction set and provides detailed instruction-summary tables.

CHAPTER 1

THE 80386 MICROPROCESSOR

The Intel 80386 is perhaps the most versatile and exciting microprocessor yet developed. Certainly its performance has long been desired by computer users and computer designers alike. The appeal of the 80386 is worldwide, yet particular strengths are more important for some persons than for others. To some, the versatility of the 80386 is the key, allowing any 80386 computer to operate both as a new 32-bit processor and as a compatible 16-bit machine. To others, the 80386's computing speed is paramount, since it brings powerhouse performance to nearly every computer application. For most of us, its versatility and performance are *both* of interest, since our existing software will run faster than ever before, yet the new 32-bit software promises even more speed and added features. In this tutorial and reference book, as we come to understand the 80386, we shall learn about both its versatile architecture and its power.

Why the 80386 Is Important

The 32-bit architecture of the 80386 is important to users of the IBM Personal Computer or Personal Computer/AT built around the 8086 or 80286 microprocessors, although they have only a 16-bit architecture. The 16-bit architecture of those important chips is contained entirely within the 32-bit 80386, as a subset of its full abilities. For that reason, the 32-bit 80386 can mimic a 16-bit 8086 or 80286, making the 80386 microprocessor entirely upward-compatible with the vast pool of software written for its popular predecessors. That is, the 80386 runs the thousands of programs written for the IBM Personal Computer and for all other computers based on the 8086 and 80286.

The 80386 is the most significant microprocessor affecting the business and technical world, both because of its heritage in the 8086 family and because of the fantastic potential of its new features. These two attributes, strong heritage and future potential, together on one chip, are a bond between the present and future of much software development. Prominent technical journals, financial journals, and even general newspapers confirm that the 80386 has garnered the attention of designers and decision-makers in all areas of computer-related products.

Already, the PC software base of applications and operating systems is moving forward to take advantage of the new features offered by the 80386. This is a very promising sign that the 80386 will have continued positive impact on all of us.

Aside from its generally uplifting effect on all users of personal computers—and more from a programmer's viewpoint—the 80386 is an interesting and formidable computer. Technically, the 80386 programming architecture is quite good and efficient. Its hardware implementation is sleek and powerful, and its level of on-chip integration is wonderfully economical. Yet the sophisticated 80386 is so affordable that 80386 PCs now placed casually in offices and factories pack the computation power of 4 MIPS (Million Instructions Per Second)[1] and are programmed to perform tasks formerly reserved for dedicated workstations and minicomputers. Indeed, the 80386 is advancing our computing world a generation.

How the 80386 Operates

The 80386 is fully designed to perform 32-bit operations, yet it can also function as a fast 16-bit 8086 and 80286. To understand the 80386 easily, we need a basic knowledge of the three ways, or modes, in which it can operate. These operating modes, named REAL, PROTECTED, and VIRTUAL 8086 modes, give the 80386 a great deal of compatibility and flexibility. The main distinctions are the method of addressing memory and the amount of memory that can be addressed.

Figure 1.1 shows these modes and their development over time. The figure begins with the 16-bit 8086/8088, which support only REAL mode, a mode that addresses one megabyte of memory. The 16-bit 80286 added an advanced 16-bit PROTECTED mode and sixteen times as much memory addressability. Now, the 80386 adds 32-bit operation in the PROTECTED mode to address at least four gigabytes of memory. The 80386 also provides a subordinate VIRTUAL 8086 mode, the compatibility link for existing 8086 software.

The 32-bit 80386 always begins operation in the 8086-compatible mode of operation, the REAL mode. Although this is perhaps surprising at first, you can see that such a feature allows existing software, unchanged, to immediately use the speed of the 80386. The REAL mode is so-named because 8086-compatible software deals with *real*, (i.e., physical) addresses. In REAL mode, the 80386 simply operates as an extremely fast 8086. After startup, the 80386 may then be instructed to operate in its PROTECTED mode. The 80386 PROTECTED mode provides 32-bit data and addressing and full-fledged VIRTUAL memory with paging support. This mode is the target for new software development.

Table 1.1 summarizes 16-bit operation and 32-bit operation using these modes. Full 32-bit operation is hardware-provided in PROTECTED mode (16-bit operation can also occur in this mode, as the 16-bit 80286 processor can operate in PROTECTED

[1] This is sixteen to twenty times the power of the original PC.

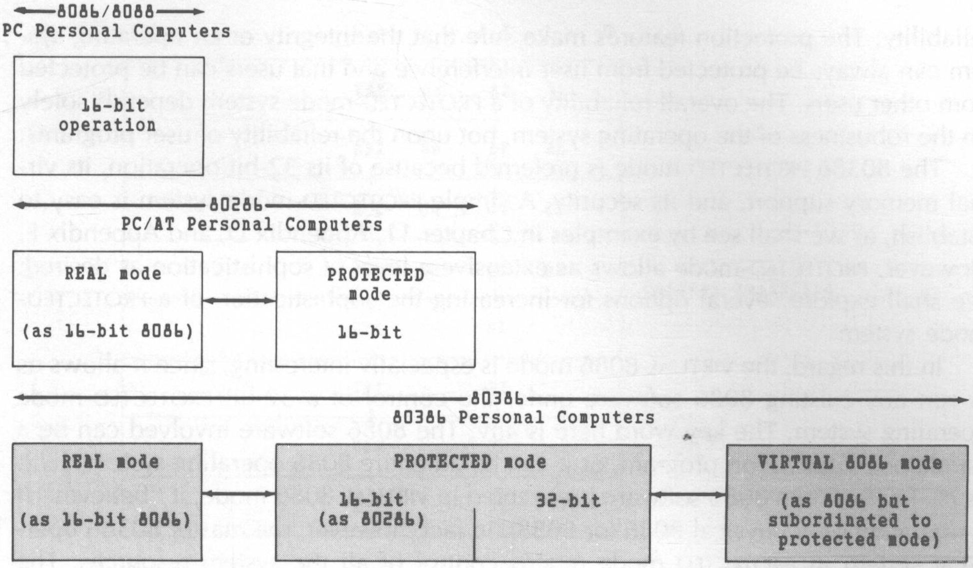

Figure 1.1 8086/8088, 80286, and 80386 Operating Mode Development.

mode). In PROTECTED mode, during either 32-bit or 16-bit operation, the 80386 can enable its paging unit for full support of VIRTUAL memory, freeing the typical programmer from the limitations of physical addressing. The 80386 protection hardware is simultaneously activated, hence the name PROTECTED mode. This on-chip protection hardware enforces several sensible policies that ensure greater system

Table 1.1 16-bit and 32-bit Operating Modes

16-bit Operation	32-bit Operation	Comments
REAL mode		8086-compatible mode
executing 16-bit code segment in PROTECTED mode		80286-compatible PROTECTED mode
VIRTUAL 8086 mode		8086 environment created within PROTECTED mode
	executing 32-bit code segment in PROTECTED mode	full 32-bit addressing and performance