The Motorola MC68000 Microprocessor Family: Assembly Language, Interface Design, and System Design

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Preface

The introduction of the Motorola MC68000 family of microprocessors ushered in a new generation of processors. This family includes the MC68000 and the MC68010. Both are single-chip microprocessors designed to function as the central processing units of sophisticated computer systems. The characteristics and uses of these Motorola processors are treated in detail in this book. For these processors, the book covers assembly language; programming, interface design, and system design.

One important purpose of the book is to introduce the student or the practicing computer professional to all of the significant aspects of design using the MC68000. In addition, the book can serve as a reference in which topics are organized according to function and importance for the design of programs, interfaces, or systems.

This book is organized into three parts as indicated in the Chapter Descriptions below. The first four chapters present the MC68000 family to the reader and also cover other introductory material. Chapters 5 through 9 treat assembly language programming techniques for the processors. Chapters 10 through 12 are concerned with system design and development for MC68000-based computer systems. Appendices I through V summarize pertinent material about the MC68000, MC68008, and MC68010. Finally, selected answers to problems given in the chapters are included at the end of the book.

A detailed summary of the major topics covered in the book, a list of the acronyms used in the book, a list of programs by topic, and a list of additional materials that may be used in conjunction with this book are given on the following pages.

CHAPTER DESCRIPTIONS

Chapters 1 through 4 introduce the reader to the MC68000 family of products, microcomputers, fundamentals of machine arithmetic, and the MC68000 central processing unit.

- Chapter 1 presents a number of applications of the Motorola MC68000 microprocessor. The hardware and software support for the MC68000 family of integrated circuit devices is also described.
- Chapter 2 discusses the organization of typical microcomputer systems. The function of the major system components (CPU, memory, input/output) is described and the importance of the CPU word length and addressing range is presented. Three views of the system as seen by the system designer, the assembly language programmer, and the interface designer are given.
- Chapter 3 explains the internal representation of numbers and characters as used in MC68000 systems. Binary, decimal, and floating-point notations are treated along with details of arithmetic operations. The ASCII code for alphanumeric characters is also presented.
- Chapter 4 is devoted to a discussion of the characteristics of the MC68000 processor. The MC68000 is first introduced as an integrated circuit chip before its characteristics as a programmable processor are presented. The organization of memory in a typical MC68000-based system is also covered.

Chapters 5 through 9 are devoted to programming techniques using the MC68000. The assembly language for the processor is used to explain the many capabilities of the MC68000.

- Chapter 5 introduces the MC68000 assembly language. Software development, assembly language features, and the various addressing modes of the MC68000 are covered.
- Chapter 6 presents three important categories of instructions for the MC68000. Instructions for data transfer, program control, and subroutines are treated.
- Chapter 7 contains explanations and program examples concerning the arithmetic capability of the MC68000. Binary arithmetic, decimal arithmetic, and conversions between ASCII, binary, and BCD are covered.
- Chapter 8 introduces the logical instructions, shift and rotate instructions, and bit-manipulation instructions.
- Chapter 9 completes the study of basic programming techniques. Methods of creating position independent code are covered. Program examples are given for manipulation of data structures, including arrays and lists. More advanced subroutine techniques are presented.

Chapters 10, 11, and 12 are devoted to aspects of the MC68000 that determine the operation of the computer system. Chapters 10 and 11 are of concern to the system designer and the programmer who create supervisor programs. Chapter 12 covers I/O programming and details of hardware design.

- Chapter 10 considers the processor's various states and modes of operation. The assembly language instructions to control the processor and examples of initialization procedures are presented.
- Chapter 11 covers exception processing. The exceptions include interrupts, traps, and various error conditions recognized by the CPU during program execution.
- Chapter 12 presents the interfacing requirements and I/O programming for MC68000 systems.

Appendices I through V contain summary material. Appendix I contains the ASCII character codes and a table of powers of 2 and 16. Appendix II, Appendix III, and Appendix IV contain a summary of the MC68000 family characteristics, the assembly language instruction set, and the machine language instruction set for the MC68000, MC68008, and MC68010. Appendix V presents the memory map for Motorola's Design Module.

SUMMARY OF MAJOR TOPICS

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LIST OF ACRONYMS

ACIA	Asynchronous Communications Interface Adapter
ASCII	American Standard Code for Information Interchange
ALU	Arithmetic and Logic Unit
BCD	Binary Coded Decimal
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CPU	Central Processing Unit
CRT	Cathode-Ray Tube
DIP	Dual-in-Line Package
DMA	Direct Memory Address
I/O	Input and Output
MMU	Memory Management Unit
MOS	Metal-Oxide Semiconductor
PIA	Peripheral Interface Adapter
PLA	Programmed Logic Array
PTM	Programmer Timer Module
RAM	Random Access Memory (Read/Write)
ROM	Read Only Memory
SSI	Small Scale Integration
VLSI	Very Large Scale Integration

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ADDITIONAL MATERIAL

The processor manuals provide a more complete treatment of certain characteristics of the processor than is covered in this book. The User's Manual for the MC68000 is available from Prentice-Hall. A manual for the MC68010 can be obtained from Motorola Semiconductor Products Inc., Austin, Texas.

Since development systems vary considerably, the reader should refer to the reference manuals for the specific system on which programs are being developed. These manuals include the Assembly Language Reference Manual for the specific assembler being used, as well as the manuals that describe the use of the system, i.e., how to edit, assemble, and execute programs. Similarly, the hardware manuals for the system and the manufacturer's data sheets for specific components should be used because these documents cover details peculiar to any specific item.

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1

Introduction

A decade of advances in integrated circuit technology was crowned by the announcement in 1980 of the commercial availability of the Motorola MC68000 *microprocessor.* This microprocessor and several others, which are identified as *16-bit microprocessors,* function as the central processing units (CPUs) of computers, but they have been scaled down so that the tens of thousands of circuit elements of the processor fit on a silicon chip about one-fourth of an inch (6.4 millimeters) on a side. When suitably packaged and electrically connected to other integrated circuits, which serve as memory for data and program storage and include input and output circuitry, the processor chip is the central element in a *microcomputer* system. The dimensions of the system may be 12 inches by 12 inches by 0.75 inch (30 by 30 by 1.9 centimeters) before it is enclosed in a cabinet to provide physical protection. The addition of a power supply and suitable peripheral devices such as cathode-ray tube (CRT) terminals yields a computer system capable of being programmed to accomplish a wide variety of tasks. The microprocessor itself controls the detailed operation of the system at the hardware level and performs the arithmetic, logical, or other operations required for the application involved. Figure 1.1 shows the basic hardware elements of a typical microcomputer system useful for personal or small business applications.

The excitement generated by the introduction of the MC68000 and other microprocessors of its class was not caused by the promise of small, low-cost computer systems. Such systems, based on previous microprocessors, were already commercially available. Rather, the greatly enhanced capability of these 16-bit microprocessors caused attention to be focused on the wide variety of potential applications for microcomputers. These processors definitely rival and sometimes exceed the ability of the central processing units of many minicomputers. Their speeds of operation, as an an-