Preface to the First Edition

With the advent of the first 4-bit microprocessor 4004 from Intel Corporation in 1971, there has been a silent revolution in the domain of digital system design, which has shaken many facets of the current technological progress. In the last 28 years the world has seen an evolution of microprocessors, whose impact on today's technological scenario is phenomenal.

This evolution was possible because of the tremendous advances in the semiconductor process technology. The first microprocessor 4004 contained only ten thousand transistors while the component density increased more than threefold in less than a decade's time. Immediately after the introduction of the 4004, Intel introduced the first eight bit microprocessor 8008 in 1972; these processors were, however, not successful because of their inherent limitations. In 1974, Intel released the first general purpose 8-bit microprocessor 8080. This CPU also was not functionally complete and the first 8-bit functionally complete CPU 8085 was introduced in 1977.

The 8085 CPU is still the most popular one amongst all the 8-bit CPUs. The 8085 CPU houses an on-chip clock generator and provides good performance utilizing an optimum set of registers and a reasonably powerful ALU. The major limitations of these 8-bit microprocessors are their limited memory addressing capacity, slow speed of execution, limited number of scratchpad registers and non-availability of complex instruction set and addressing modes. Another important point to be mentioned here is that 8085 does not support adequate pipelining or parallelism which is so important for enhancing the speed of computation. For example, the non-availability of any instruction queue in an 8085 CPU leads to a situation where the fetching of opcode and operands along with the execution takes place in an absolutely sequential manner.

The first 16-bit CPU from Intel was a result of the designers' efforts to produce a more powerful and efficient computing machine. The designers of 8086 CPU had taken note of the major limitations of the previous generations of the 8-bit CPUs. The 8086 contains a set of 16-bit general purpose registers, supports a 16-bit ALU, a rich instruction set and provides segmented memory addressing scheme. The introduction of a set of segment registers for addressing the segmented memory in 8086 was indeed a major step in the process of evolution. All these features made this 16-bit processor a more efficient CPU.

The development of IBM PC started in July 1980, and precisely after one year, the first machine based on Intel 8088 CPU (which is functionally equivalent to 8086 but supports only 8-bit external data bus) with 1 or 2 floppy disk drives, a keyboard and a monochrome monitor was announced in August 1981. The machine operating system was an early version of operating system MS-DOS from Microsoft. In March 1983, a new version of IBM PC called PC-XT was introduced with ten megabyte hard disk, one double side double density floppy disk drive, keyboard, monitor and asynchronous communication adapter. In fact, the introduction of IBM PCs in 1980s had, to a large extent, produced a profound impact on the evolution of microprocessors. With the introduction of each new generation of microprocessors, the performance of the Personal Computers have also been enriched.

The major limitation in 8086 was that it did not have the memory management and protection capabilities, which was considered an extremely important feature deemed to be an integral part of a

CPU of the eighties. 80286 was the first CPU to possess the ability of memory management, privilege and protection. However, the 80286 CPU also had a limitation on the maximum segment size supported by it (only 64 Kb). Another limitation of 80286 was that, once it was switched into protected mode, it was difficult to get it back to real mode. The only way of reverting it to the real mode was to reset the system.

In the mid eighties the more computationally demanding problems necessitated the development of still faster CPUs. Thus appeared 80386 which was the first 32-bit CPU from Intel. The memory management capability of 80286 was enhanced to support virtual memory, paging and four levels of protection. The design of 80386 circumvented this problem. Moreover, the maximum segment size in 80386 was enhanced and this could be as large as 4 Gb with 80386 supporting as many as 16384 segments. The 80386 along with its math coprocessor 80387, provided a high speed environment. 80486 was designed with an integrated math coprocessor. After getting integrated, the speed of execution of mathematical operations enhanced three folds. Also for the first time an 8 Kb four-way set associative code and data cache was introduced in 80486. A five-stage instruction pipelining was also introduced.

The earlier generation CPUs supported rather crude instruction sets. It was not expected that the programmers those days would write large machine code programs. A single high level instruction might be compiled into ten or even hundred machine code operations. In the course of evolution from the early 8-bit CPUs, the trend was to design CPUs, which could support more and more complex instructions at the assembly language level. Designers of complex instruction set computers (CISC) wanted to reduce this gap.

Since the early days of microprocessor development the designers have tried to make them more powerful by designing more complex instructions. But then some of these powerful instructions and addressing modes were hardly used by the programmers. In fact some of these instructions' logic took up a large part of the microprocessors' silicon chip. The reduced instruction set computer (RISC) designers observed that the data movement type of machine instructions are frequently executed by the CPU. They have optimised the CPUs to execute these instructions rapidly. RISC provided a regular set of instructions having the same format with a lot of pipelining. To improve the processor's performance, the possible ways are suggested below.

(a) Increasing the processor and system clock rate.
(b) Optimising and improving the instruction set.
(c) Executing multiple instructions in one cycle and incorporating parallelism in the CPU architecture.

The first option is applicable both to CISC and RISC processors. The second option is primarily for CISC but is applicable to RISC as well. The third option is more suited to RISC CPUs. Ever since the appearance of commercially available RISC CPUs, there has been a debate over the performance of RISC versus CISC. The RISC architects argue that their instructions may be executed in a single cycle and thus take less time than is taken by a CISC CPU. This is because of pipelining, reduction of instructions to a simple operation and synthesis of complex operations with compiler generated code sequences. When RISC machines first arrived in the market, CISC processors were performing at 6–10 cycles per instruction, while the RISC CPUs could execute a set of simpler instructions in one cycle and offer better performance. Many of the CISC processors have subsequently used many features of RISC.

This book is intended as a textbook on 'Advanced Microprocessors' which is a compulsory course at graduate and postgraduate levels in many science and engineering branches of studies, specially in

Electronics, Electrical, Instrumentation, Physics and Computer Science disciplines. The book is suitable for a one-semester course on advanced microprocessor—their architectures, programming, hardware interfacing and applications. The purpose of our book is to provide the readers with a good foundation on microprocessors, their principles and practices. We have tried to keep an appropriate balance between the basic concepts and practical applications related to microprocessors technology. Thus we have aimed at the following:

- To present the fundamental concepts of advanced microprocessors and their architectures.
- To enable the students to write efficient programs in assembly level language of the 8086 family of microprocessors.
- To make the students aware of the techniques of interfacing between the processors and peripheral devices so that they themselves can design and develop a complete microprocessor based system.
- To present in a lucid manner the basic concepts of systems programming, viz, operating systems, assemblers, compilers, etc. to enable the students to understand the entire space of microprocessor technology and specially the software aspects related to microprocessing.
- To present to the students the utility of faster modes of data transfer and techniques.
- To present a host of interesting applications involving microprocessors.

Some of the salient features of the book are listed below.

1. The book covers a wide range of microprocessors from 16-bit 8086 to Pentium in a lucid manner. The evolution from one processor architecture to another is evident as one goes through the chapters. A detailed description of each microprocessor has been presented in individual Chapters. Chapter 1 covers 8086/8088 architecture in adequate detail. Chapter 9 covers 80286 along with its coprocessor. Chapter 10 covers the microprocessor 80386 and its coprocessor 80387. This chapter also covers in sufficient detail 80486, the integrated CPU with built-in math coprocessor. Pentium, the latest in the Intel microprocessor family, has been briefly presented in Chapter 11.
2. An important feature of the book is the inclusion of a number of interesting applications of microprocessors. An adequate account of each one of these applications has been presented in the book. An interesting application of microprocessors for controlling an Aluminium Smelter has been presented in Chapter 13. Chapter 14 presents another interesting application in the area of Pattern Scanner Design. Design of a microprocessor-based Electronic Weighing Bridge has been elaborated in Chapter 15.
3. One of the major problems encountered by students is the difficulty in writing assembly language programs. In this book, a large number of assembly language programs have been presented. Which will enable the students to write efficient codes on 16-bit or 32-bit platforms. Chapter 2 covers the 8086 family instruction set and the assembler directives with necessary examples. The art of programming in 8086 Assembly language has been elaborated with a large number of program examples in Chapter 3. A very important spectrum of programs involving stacks, subroutines, interrupts, macros and time delays has been discussed in adequate detail in Chapter 4.
4. A good account of a number of general peripheral devices like I/O ports, keyboards, displays, ADCs, DACs, stepper motors, etc. has been elaborated in Chapter 5.

5. Some special dedicated peripherals like interrupt controllers, DMA controllers, CRT controllers, floppy disk controllers, etc. have been discussed elaborately along with interfacing examples and programs in Chapters 6 and 7. The detailed knowledge about these peripherals is extremely important for interfacing these devices with advanced CPUs and also for designing standalone microprocessor-based systems.
6. Usually the students look for separate books for understanding the system programs' concepts. In this book a complete chapter (Chapter 12) has been devoted to explaining the concepts of assemblers, loaders, linkers, compilers and the operating systems. The understanding of systems programming concepts are extremely important for an integrated understanding of a microcomputer system.
7. The importance of multiprocessor based system design cannot be underestimated in today's world. A full chapter has been devoted to presenting issues related to the multiprocessor based system design. The co-processor like 8087, 8089, etc. along with their interfacing strategies have been presented in Chapter 8 of the book. Design of an 8088 based multimicroprocessor system has been described in adequate detail in this chapter with an example.
8. Microcontrollers are being extensively used in today's industrial environments. An introductory chapter on microcontrollers has been included for the benefit of the students. Intel's 8-bit microcontroller 8051 and 16-bit microcontroller 80196 have been presented in sufficient detail in Chapter 16 along with an 8031 based application design example.

   On the whole, the book is intended to provide adequate support to the reader for acquiring an integrated understanding of the subject.

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