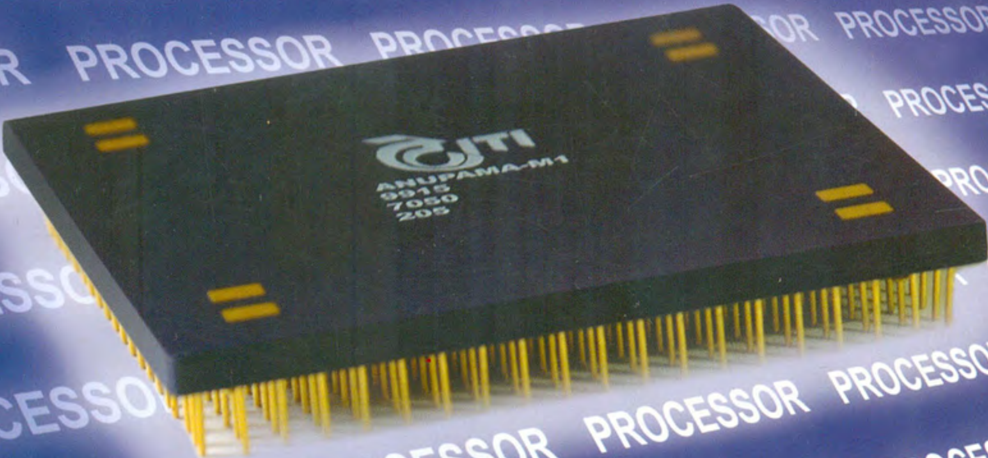
# Anupama PROCESSOR

## Architecture and Applications

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# ANUPAMA PROCESSOR

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# ANUPAMA PROCESSOR
## ARCHITECTURE AND APPLICATIONS

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**ANUPAMA PROCESSOR: ARCHITECTURE AND APPLICATIONS**

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# Contents

# Foreword

I am blissful to write the foreword for this book 'ANUPAMA Processor: Architecture and Applications'. The use of microprocessors has grown fantastically that it is now very common to have processors in every application, be it tiny or giant where thousands of processors work in parallel.

There are numerous books written on processors. Nevertheless, it is my opinion that this book is one of its kind, with the unique feature of being the first text book on indigenous processor. I should congratulate the authors for their untiring efforts in bringing out this book on various aspects of indigenous processor.

Considerable focus has been made by the authors in presenting the first chapter on evolution of processors, starting from the genesis of the processors to latest trends. The second chapter covers the details of architecture of ANUPAMA Processor and authors have made all their efforts in explaining the generation of hex code for ANUPAMA mnemonics. The third chapter consists of assembler details and instruction set simulator which enables the developer to test his code without actually having the processor. In the fourth chapter, the authors have presented the interfaces and circuit diagrams which are practically designed and tested in underwater vehicles. Considerable efforts have been made in presenting the explanation for each component and design.

The authors have endeavored to present the discipline of processors in a logical and concise form – written strictly keeping the academic requirements in view and yet catering to system designers by treating the subject methodically.

The authors have succeeded in bringing out this book in a manner befitting the highest DRDO tradition. I hope that this book will go a long way in meeting the needs and fulfilling the requirements of system designers. I strongly believe that this book will be of immense use to DRDO fraternity.

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# Preface and Acknowledgements

Microprocessors are challenging, fascinating and the field is growing enormously. In the recent years, the growth of the processor technology is far more than expected. Developing countries may face difficulty to get critical components or technology for defence applications. Further, when we use an imported processor, the issue of secure computing also has to be dealt with. Even though the systems are developed indigenously, the heart of the system, the processor, is imported. Also the lifetime of the commercial processors is short, whereas defence applications require the availability of processor for quite a long period. To counter the obsolescence of the processor and to make complete indigenous systems, DRDO has started development of indigenous processors and other ICs.

So we have thought of using one of these indigenous processors 'ANUPAMA' for underwater vehicles which could replace the existing Motorola 68000 processor-based systems. We have started the development of ANUPAMA Processor-based system in 2000 and the system proved successful in underwater vehicle in 2003. Manuals and journals are available on this processor. But a book does not exist. The main intention for initiating the book is to fill up this gap. This book will help the readers to achieve a thorough grasp of the ANUPAMA Processor and will enlighten the implementation concepts. This book is divided into four chapters.

The first chapter is "Introduction to Microprocessors". In this chapter, a description on how a computer is evolved from a microprocessor, is given. Also described is the hierarchy of different microprocessors and the constituents of microprocessors. The second chapter "Architecture of ANUPAMA Processor" is about the architecture of indigenously developed ANUPAMA Processor. This chapter describes the functional block diagrams, state transition diagram of microprocessor operation, timing diagrams, instruction set details, opcode generation, and interrupts. The third chapter is "ANUPAMA Assembly Language Programming". It deals with assembly language programming and tools required for programming like assembler, instruction set simulator, programming exercises, etc. Fourth chapter is "Case Studies with ANUPAMA Processor". It is mostly related to practical approach. It deals with block diagrams of different I/O's and memory interface to ANUPAMA Processor. This chapter also furnishes the test program and test data of these interfaces.

This book is mainly useful to professionals in electronics and communication engineering, electrical engineering, and who want to study an indigenous RISC processor with built-in peripherals. The students can easily attempt their projects based

on ANUPAMA Processor, as this book details many interfaces, test programs and test data. Authors would like to record their deep sense of gratitude to Ms Nirmala, Scientist, NSTL for her contribution. They would also like to express their thanks to Shri Abraham Varughese, Scientist, NSTL.

Authors are indebted to Dr V Bhujanga Rao, Director, NSTL, Vishakhapatnam, for his valuable comments and encouragement.

The authors would like to thank Dr KD Nayak, Director, ANURAG, Hyderabad, and Shri K Santeppa, Associate Director, ANURAG, Hyderabad for their support and guidance.

Authors

# Chapter 1

# Introduction to Microprocessors

## 1.1 INTRODUCTION

### 1.1.1 Genealogy of Computers

A computer is a machine that manipulates data according to a list of instructions. Figure 1.1 shows the block diagram of a computer.

Computers have evolved in numerous physical forms. The first device that resemble modern computers date back to the mid-20th century (around 1940-1945). Modern computers are based on comparatively tiny integrated circuits and are million to billion times faster while the size has shrunk to a fraction of their original size. Today, computers may be made small enough to fit into a wristwatch and powered by a watch battery. However, the most common form of computer in use today is the embedded computer. Embedded computers are small, simple devices that are used to control other devices, for e.g., machines ranging from fighter aircraft to industrial robots, and digital cameras to children's toys. Therefore, computers with capability and complexity ranging from that of a personal digital assistant to a supercomputer perform the same computational tasks given enough time and storage capacity.

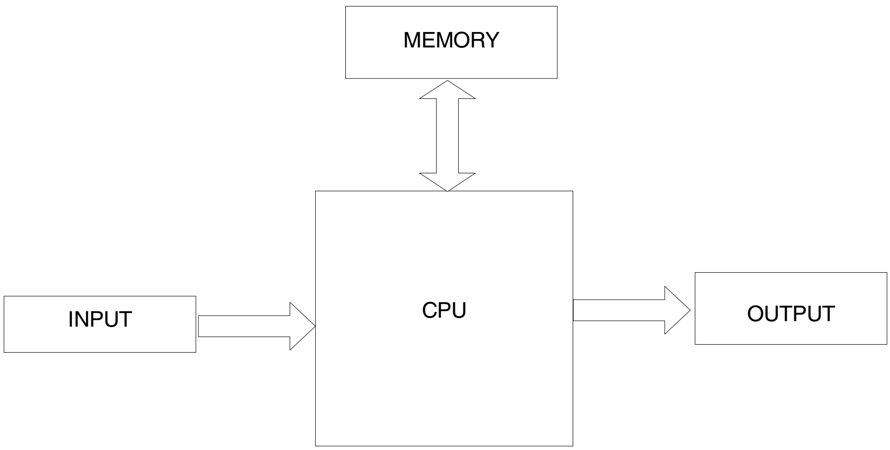


**Figure 1.1. Block diagram of a computer.**

## 1.2 TYPES OF COMPUTERS

There are two fundamental types of computers; analog and digital (hybrid computers combine elements of both types). In our everyday use, the term computer refers to digital computers, with a typical example being the common personal computer (PC). Digital computers are essentially simple machines that can understand and manipulate only series of elementary symbols: 0's and 1's (yes or no, true or false).

### 1.2.1 Digital Computer

A digital computer stores data in terms of digits (numbers) and proceeds in discrete steps from one state to the next. The states of a digital computer typically involve binary digits which are represented by the presence or absence of magnetic markers in a storage medium, on-off switches or relays. In digital computers, even letters, words, and whole texts are represented digitally. Unlike analog computers, digital computers can only approximate a continuum by assigning large number of digits to a state description and by proceeding in arbitrarily small steps.

### 1.2.2 Analog Computer

An analog computer measures continuous physical quantities such as electrical, mechanical, or hydraulic phenomena to model the problem being solved. Computations are carried out by measuring rather than counting.

## 1.3 ADVANTAGES OF DIGITAL COMPUTERS

The advantages of digital computers are:

- Digital systems can be interfaced well with digital computers and are easy to control with software. New features can often be added to a digital system without changing hardware. Often this can be done outside the factory by updating the product's software. So the product's design errors can be corrected after the product is in a customer's hands.
- It is easy to store information in digital systems than in analog ones. The noise-immunity of digital systems permits data to be stored and retrieved without degradation. In analog system, noise from ageing and wear degrade the information stored. In digital system, as long as the total noise is below a certain level, the information can be recovered perfectly.
- They can store the results of its calculations for later use, can compare results with other data, and on the basis of such comparisons can change the series of operations it performs. Digital computers are used for reservation systems, scientific investigation, data-processing and word processing applications, desktop publishing, electronic games, and many other purposes.
- One of the primary advantages of digital electronics is its robustness. Digital electronics are robust because if the noise is less than the noise margin then the system performs as if there were no noise at all. Therefore, digital signals can be regenerated to achieve lossless data transmission, within certain limits. Analog signal transmission and processing, by contrast, always introduces noise.

## 1.4 TYPES OF DIGITAL COMPUTERS

Today's computers are of three main types: mainframes, minicomputers, and microcomputers. They differ in size, speed of operation, amount of data that can be stored, and the number of simultaneous users.

### 1.4.1 Mainframes

These allow many simultaneous users, handle typically huge databases, and can perform complex mathematical operations. We find them mainly in industry, research, and university computing centres.

### 1.4.2 Minicomputers

These can support a small number of simultaneous users, typically 50 to 100. These machines are primarily used by large businesses to handle accounting, billing, and inventory records.

### 1.4.3 Microcomputers

The microcomputer is essentially a personal or desktop computer. These desktop PCs, which dwarf the capabilities of the huge early computers, are used extensively in the home (entertainment, communication, personal databases, and spreadsheets) and in all types of businesses (word processing, accounting, inventory control, research).

A general purpose computer has four main sections: the arithmetic/logic unit (ALU), the control unit, the memory, and the input and output devices (collectively termed I/O). These parts are interconnected by buses, often made of groups of wires. The control unit, ALU, registers, and basic I/O (and often other hardware closely linked with these) are collectively known as central processing unit (CPU). Early CPUs were composed of many separate components but since the mid-1970s CPUs have typically been constructed on a single integrated circuit called a microprocessor.

#### *1.4.3.1 Control Unit*

The control unit directs the various components of a computer. It reads and interprets (decodes) instructions in the program one by one. The control system decodes each instruction and turns it into a series of control signals that operate other parts of the computer. Control systems in advanced computers may change the order of some instructions so as to improve performance.

A key component common to all CPUs is the program counter, a special memory cell (a register) that keeps track of location in memory to read the next instruction.

The control system's function is as follows – read the code for the next instruction from the cell indicated by the program counter.

- Step 1 Decode the numerical code for the instruction into a set of commands or signals for each of the other systems
- Step 2 Increment the program counter so that it points to the next instruction
- Step 3 Read whatever data the instruction requires from cells in memory. The location of this required data is typically stored within the instruction code
- Step 4 Provide the necessary data to an ALU or register
- Step 5 If the instruction requires an ALU or specialised hardware to complete, instruct the hardware to perform the requested operation
- Step 6 Write the result from the ALU back to a memory location or to a register or perhaps an output device
- Step 7 Jump back to step 1.

It is noticeable that the sequence of operations that the control unit goes through to process an instruction is in itself like a short computer program – and indeed, in some more complex CPU designs, there is another yet smaller computer called a microsequencer that runs a microcode program that causes all of these events to happen.

### *1.4.3.2 Arithmetic/Logic Unit*

The arithmetic/logic unit (ALU) is capable of performing two classes of operations, arithmetic, and logic. The set of arithmetic operations that a particular ALU supports may be limited to adding and subtracting or might include multiplying or dividing, trigonometric functions (sine, cosine, etc.,) and square roots. Some can only operate on whole numbers (integers) whilst others use floating point to represent real numbers – however, any computer that is capable of performing just the simplest operations can be programmed to break down the more complex operations into simple steps that it can perform. Therefore, any computer can be programmed to perform any arithmetic operation although it will take more time to do so, if its ALU does not directly support the operation. Superscalar computers contain multiple ALUs so that they can process several instructions at the same time.

### *1.4.3.3 Memory*

Magnetic core memory was popular main memory for computers through the 1960s until it was completely replaced by semiconductor memory. A computer's memory can be viewed as a list of cells into which numbers can be placed or read. Each cell has a numbered address and can store a single number. The information stored in memory may represent practically anything. Letters, numbers, even computer instructions can be placed into memory with equal ease. Since the CPU does not differentiate between different types of information, it is up to the software to give significance to what the memory sees as nothing but a series of numbers.

In almost all modern computers, each memory cell is setup to store binary numbers in groups of eight bits (called a byte). Each byte is able to represent 256 different numbers; either from 0 to 255 or –128 to +127. To store large numbers, several consecutive bytes may be used (typically, two, four, or eight). When negative numbers are required, they are usually stored in two's complement notation. Other arrangements are possible, but are usually not seen outside of specialised applications or historical contexts. A computer can store any kind of information in memory as long as it can somehow be represented in numerical form. Modern computers have billions or even trillions of bytes of memory.

The CPU contains a special set of memory cells called registers that can be read out of and written into them much more rapidly than the main memory area. There are typically between two and one hundred registers depending on the type of CPU. Registers are used for the most frequently needed data items to avoid having to access main memory every time data is needed. Since data is constantly being worked on, reducing the need to access main memory (which is often slow compared to the ALU and control units) greatly increases the computer's speed.

Computer main memory comes in two principal varieties: random access memory or RAM and read-only memory or ROM. RAM can be read and written to as and when the CPU commands it but ROM is preloaded with data and software that never changes, so the CPU can only read from it. ROM is typically used to store the computer's initial start-up instructions. In general, the contents of RAM are erased

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## ABOUT THE AUTHORS

**O Subrahmanyam** completed BE (Electronics and Communication) from College of Engineering, Kakinada and MTech in 1981 from IIT, Delhi. He joined Defence Electronics Research Laboratory in 1971 and presently heading Instrumentation Division, Naval Science and Technological Laboratory.

He has developed 8-bit processor-based systems for programmable deep mobile targets, 16-bit processor-based instrumentation systems for light weight torpedoes. He has also developed 32-bit ANUPAMA processor based Instrumentation systems for advanced torpedoes for which scientist of the year award is conferred. He has published several papers in international and reputed Indian journals and is member of reputed professional bodies.

**Prof P Seetha Ramaiah** completed his BTech (Electronics and Communication Engineering) and ME (Instrumentation and Control) and is presently working as Professor in Andhra University. He obtained his PhD in 1990.

He has received Best Researcher Award from Andhra University in 1998. He has published many articles in international and national journals. He was a visiting professor at Illinois State University, USA (1999-2000). His major research projects include Four Fingered Robotic Hand, Active Noise Control system for DUCT and Robot Hand-Eye Coordination System.

**ChNAB Sankar** completed his MSc and joined DRDO in 1996. Thereafter, he completed MS (Software Systems) from BITS, Pilani. He is presently working as Scientist E in ANURAG, DRDO. He is instrumental in the design, development and user orientation of the software development tools like compilers, assembler, linker and other binary utilities, libraries, debuggers, instruction set simulators and integrated development environment for Anupama and Abacus processors.
He obtained three copyrights connected with the various components of Anupama software development tools.

## ABOUT THE BOOK

The book gives a detailed account of development of indigenous Anupama processor. The first chapter details evolution of computer from a microprocessor. The second chapter describes the architecture of Anupama processor, its functional block diagrams, state transition diagram, timing diagrams, instruction set details, opcode generation and interrupts. The third chapter deals with assembly language programming and development tools like assembler, instruction set simulator, programming exercises. The final chapter describes practical approach to coding. It deals with block diagrams of different input/output devices, memory interface to processor and also furnishes the test program and test data of these interfaces.

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