COMPUTER ARCHITECTURE

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(For the Students of B.Tech Computer Engineering and Information Technology)

By

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This book is dedicated to
my father Mr. L.C. Sharma
and all my family members

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Preface

It gives me a great pleasure in presenting the first edition of the book "Computer Architecture."

This book is based on the latest syllabus prescribed by Rajasthan Technical University, Kota for B.Tech. V semester computer engineering, V semester Information Technology.

The syllabus of RTU is covered in eight chapters as following:

Chapter 1, *Digital Fundamentals,* focuses on the basic knowledge of digital electronics and number systems. This chapter fulfils the requirements up to the mark.

Chapter 2, *Register Transfer Language,* contains concept of bus and timing in register transfer along with the various types of microoperations like arithmetic and logic microoperations.

Chapter 3, *CPU Organisation,* deals with the heart of the computer system—Central processing unit. It includes various types of addressing modes and instruction formats.

Chapter 4, *Pipelining and Parallel Processing,* describes how instructions are executed in parallel manner using the technique pipelining. Various types of techniques to achieve parallelism has been discussed.

Chapter 5, *Computer Arithmetic,* describes the design and implementation of various arithmetic algorithms using various digital components.

Chapter 6, *Microprogrammed Control Unit,* contains the basic organisation of microprogrammed control unit.

Chapter 7, *Memory Organisation,* describes the concept of various types of memories like RAM, ROM, Cache and associative memory. It includes a very interesting concept– Virtual memory organisation.

Chapter 8, *Input-Output Organisation,* deals with the introduction to peripherals and their interfacing. DMA based data transfer is also discussed.

An honest attempt has been made to present each concept in easy and lucid language. Important solved examples have been added for better examination preparations.

All friendly suggestions and criticism for the improvement of the book will be greatly acknowledged and appreciated.

—Author

Acknowledgement

This book has been made possible through the direct and indirect co-operation of various persons, for whom I wish to express my appreciation and gratitude.

I am highly indebited to the authors of various reference books, which I have consulted in giving final shape to this book.

I would like to place on record my gratitude to all of family members whose timely and never failing encouragement has been a great source of inspiration in sustaining our interest in completing this book.

I am also extremely thankful to my publisher for his co-operation and his editorial team to provide excellent layout to the book.

—Author

SYLLABUS

COMPUTER ARCHITECTURE (5 IT 4)/ (5 CS 2)

UNIT-1 : REGISTER TRANSFER LANGUAGE

- Data movement around registers.
- Data movement from/to memory, arithmetic and logic microoperations.
- Concept of bus and timing in register transfer.

UNIT-2 : CPU ORGANISATION

- Addressing Modes.
- Instruction Format.
- CPU organisation with large registers, stacks and handling of interrupts and subroutines instruction pipelining.

UNIT-3 : ARITHMETIC ALGORITHM

- Array multiplier, Booth's algorithm.
- Addition subtraction for signed unsigned numbers and 2's complement numbers.

UNIT-4 : MICROPROGRAMMED CONTROL UNIT

- Basic organisation of microprogrammed controller, Horizontal and Vertical formats, Address sequencer.

UNIT-5 : MEMORY ORGANISATION

- Concept of RAM/ROM, basic cell of RAM, Associative memory, Cache memory organisation, Vertical memory organisation.
- I/O ORGANISATION: Introduction to Peripherals and their interfacing.
- Strobe based and handshake-based communication, DMA based data transfer, I/O processor.

Chapter 1

Digital Fundamentals

1.1 INTRODUCTION

The digital circuits can be classified into two broad categories: Analog system and digital system. Analog systems deal with variables having continuous nature while the digital system defines variables having discrete values. Digital system defines the term digit. The term digital in digital circuits is derived from the way the digital circuit perform operations by counting the digits. A digital circuit operates with binary numbers.

To understand the operation of a digital computer the knowledge of number system, is very essential so in this chapter first we study about number system and methods of conversion from one to another then in next section we discuss about complements that is necessary in arithmetic digital operations.

For constructing the digital circuit knowledge of logic gates, combinational circuits, sequential circuits and digital components are required. These all are covered in this chapter. Computer codes are the format in which input and output are specified so we take brief idea about computer codes. All these are the basic digital fundamentals.

So we are going to cover the following topics:

1. Number system
2. Complements
3. Logic gates
4. Computer codes
5. Combinational circuits
6. Sequential circuits
7. Digital components.

1.1.1 Decimal Number System

The most familiar number system is decimal number system. To represent any number this system uses 10 digits (0 to 9). Thus, decimal number system is said to have a Base or Radix of 10. The weight of each digit depends upon the relative position of that digit in the number.

Let the number is $(678)_{10}$. This can be represent as: 600 + 70 + 8

$$= 6 \times 10^2 + 7 \times 10^1 + 8 \times 10^0$$

The weight of I^{st} digit 8 $= 8 \times 10^0$

The weight of II^{nd} digit 7 $= 7 \times 10^1$

The weight of III^{rd} digit 6 $= 6 \times 10^2$.

The above expression can be generalised as the weight of n^{th} digit of the number

$$= n^{th} \text{ digit} \times (10)^{n-1}$$

$$= n^{th} \text{ digit} \times (\text{Base})^{n-1}$$

digit is considered from right hand side.

1.1.2 Binary Number System

To understand the operation of a digital computer the knowledge of binary system is essential.

Binary number system deals with two digits 0 and 1, so the base or radix of the binary number system is 2. In short a binary digit is known as a bit. All computer systems use binary number system for their internal operation and manipulation.

Let the binary number is $(1011)_2$. This can be represented as: $1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$

The weight of I^{st} digit 1 $= 1 \times 2^0$

The weight of II^{nd} digit 1 $= 1 \times 2^1$

The weight of III^{rd} digit 0 $= 0 \times 2^2$

The weight of IV^{th} digit 1 $= 1 \times 2^3$.

So the weight of n^{th} bit of the number considering from right hand side is

$$= n^{th} \text{ bit} \times (2)^{n-1}$$

$$= n^{th} \text{ bit} \times (\text{Base})^{n-1}$$

The weight of each bit depends upon the relative position of that bit in the number.

1.1.3 Octal Number System

The base of the octal number system is 8. It uses eight digits 0, 1, 2, 3, 4, 5, 6 and 7. Octal number system is also positional number system, the weight of each digit depends upon the relative position of that digit in the number.

Let the number is $(534)_8$. This can be represented as: $5 \times 8^2 + 3 \times 8^1 + 4 \times 8^0$

The weight of the I^{st} digit 4 $= 4 \times 8^0$

The weight of the II^{nd} digit 3 $= 3 \times 8^1$

The weight of the III^{rd} digit 5 $= 5 \times 8^2$.

This can be generalised as weight of n^{th} digit of number from right hand side is

$$= n^{th} \text{ digit} \times (8)^{n-1}$$

The octal number system is the most popular number system in digital circuit. This system is also used in computer industry.

1.1.4 Hexadecimal Number System

Hexadecimal number system use 16 digits to represent a number. Its radix (base) is 16. Its digits 0 to 9 are same as decimal number system. The alphabets A, B, C, D, E, F are used to represent 10, 11, 12, 13, 14 and 15 respectively.

Let the number $(A49)_{16}$. This can be represented as: $A \times 16^2 + 4 \times 16^1 + 9 \times 16^0$

The weight of the I^{st} digit 9 $= 9 \times (16)^0$

The weight of the II^{nd} digit 4 $= 4 \times (16)^1$

The weight of the III^{rd} digit A $= A \times (16)^2$

So the weight of n^{th} digit of a number can be represented as

$$= n^{th} \text{ digit} \times (16)^{n-1}$$

$$= n^{th} \text{ digit} \times (\text{Base})^{n-1}$$

Again hexadecimal number system is positional number system, weight of each digit depends upon the relative position of the digit in the number.

Table 1.1

Decimal Number	*Hexadecimal Number*
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F

1.1.5 Conversions

Each and every positional number system is having its own application. There is requirement for converting a given number system into another number system for the internal processing of a computer system.

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