Digital Electronics and Microprocessors

Class 1

CHHAYADEVI BHAMARE

Scope and Objective of the course:

The course aims at introducing the fundamentals of Digital Electronics and Microprocessor Architecture and programming (8086).

Text Books:

T1: Ronald J. Tocci, Neal S. Widmer and Gregory L. Moss, Digital Systems: Principles and Applications, Pearson Education Pvt. Limited.

T2: Barry B. Brey, The Intel Microprocessors: Architecture, Programming and Interfacing, Pearson Education Pvt. Limited.

Reference Books:

R1: M.Morris Mano, Michael D.Ciletti: Digital Design, Pearson Education

R2: Douglas V. Hall, Microprocessors and Interfacing, Tata Mc-Graw Hill

Evaluation Scheme

Component	Type	Weightage	Duration
Test1	CB	40	1 hr
Test2	CB	40	1 hr
Regular Labs/Lab exam/Online		100	2 hrs/1 hr/1hr
Compree	CB/OB	120	3 hrs

Fundamentals Of Digital Electronics

- Number Systems
- Boolean algebra and logic gates
- Combinational Logic Circuits and their applications
- Sequential circuits and their applications
- Complex digital circuits(Arithmetic circuits Memory Devices etc)
- Integrated Circuit Logic Families
- Finally microprocessor as a complex programmable digital circuits

Fundamentals of Microprocessors

- Introduction to microprocessor
- Microprocessor Architecture (8086)
- Addressing modes of 8086
- Instruction set (Data movement, arithmetic, program control)
- Programming of the microprocessor
- Interfacing(Memory , Basic I/O interfacing)
- Design Example

Number Systems and Codes (T1:-Chapt2)

- A ***number system*** is a set of ***numbers*** together with one or more ***operations*** (e.g. add, subtract).

- Before digital computers, the only known number system is the ***decimal number system***
  - It has a total of ten digits: {0,1,2,….,9}

- **Decimal, Binary, Octal and Hexadecimal Numbers**

Weighted(positional) Number System

$$\mathbf{D} = \mathbf{d}_{n-1}\ \ \mathbf{d}_{n-2}\ \ \ldots\ldots.\ \ \mathbf{d}_2\ \mathbf{d}_1\ \ \mathbf{d}_0$$

Position n-1 | Position 2 | Position 1 | Position 0

- A number **D** consists of *n* digits and each digit has a *position.*
- Every digit *position* is associated with a *fixed weight*.
- If the weight associated with the *i*th. position is w_i, then the value of **D** is given by:

$$D = d_{n-1}\ \ w_{n-1} + d_{n-2}\ \ w_{n-2} + \ldots\ldots + d_1\, w_1 + d_0\, w_0$$

- Also called ***positional number system***

Example

Position Index

First Position Index (0)

Position	3	2	1	0
Number	9	3	7	5
Weight	1000	100	10	1
Value	9 x 1000	3x100	7x10	5x1
Value	9000 +	300 +	70 +	5

9375

- The Decimal number system is a weighted number system.
- For Integer decimal numbers, the weight of the rightmost digit (*at position 0*) is **1**, the weight of *position 1* digit is **10**, that of *position 2* digit is **100**, *position 3* is **1000**, etc.

The Radix (Base)

$$D = d_{n-1}\ d_{n-2}\ \ldots\ldots.\ d_2\ d_1\ d_0$$

Position $n-1$ | Position 2 | Position 1 | Position 0

- A digit d_i, has a weight which is a power of some constant value called **radix (r)** or **base** such that $w_i = r^i$.
- A number system of radix r, has r allowed digits $\{0,1,\ldots (r-1)\}$
- The leftmost digit has the highest weight and called **Most Significant Digit (MSD)**
- The rightmost digit has the lowest weight and called **Least Significant Digit (LSD)**

Example

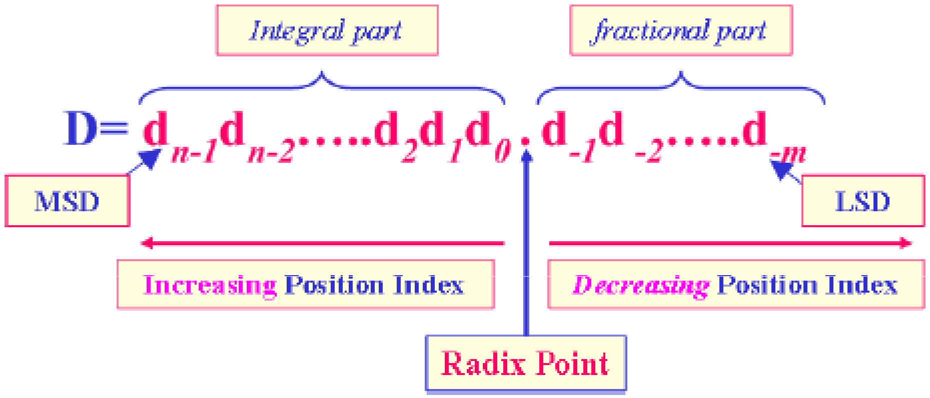
- Decimal Number System
- Radix (base) = 10
- $w_i = r^i$, so
  - $w_0 = 10^0 = 1$,
  - $w_1 = 10^1 = 10$
  - .
  - $w_n = r^n$
- Only 10 allowed digits {0,1,2,3,4,5,6,7,8,9}

MSD LSD

$$9375 = 5 \times 10^0 + 7 \times 10^1 + 3 \times 10^2 + 9 \times 10^3$$
$$= 5 \times 1 + 7 \times 10 + 3 \times 100 + 9 \times 1000$$

Position	3	2	1	0
Weight	1000 $= 10^3$	100 $= 10^2$	10 $= 10^1$	1 $= 10^0$

Fractions (Radix point)



$$D = \sum_{i=-m}^{n-1} d_i r^i$$

- A number D has *n* ***integral*** digits and *m* ***fractional*** digits
- Digits to the left of the radix point (*integral digits*) have ***positive*** position indices, while digits to the right of the radix point (*fractional digits*) have ***negative*** position indices
- The ***weight*** for a digit position *i* is given by $\mathbf{w}_i = \mathbf{r}^i$

Example

- For D = 57.6528
  - n = 2
  - m = 4
  - r = 10 (decimal number)
- The weighted representation for D is:

i = -4	$d_i r^i = 8 \times 10^{-4}$
i = -3	$d_i r^i = 2 \times 10^{-3}$
i = -2	$d_i r^i = 5 \times 10^{-2}$
i = -1	$d_i r^i = 6 \times 10^{-1}$
i = 0	$d_i r^i = 7 \times 10^{0}$
i = 1	$d_i r^i = 5 \times 10^{1}$

D = 5 2 . 9 4 6

d_1 d_0 . d_{-1} d_{-2} d_{-3}

Number	5	2	.	9	4	6
Position	1	0	.	-1	-2	-3
Weight	10^1 = 10	10^0 = 1	.	10^{-1} = 0.1	10^{-2} = 0.01	10^{-3} = 0.001
Value	5 x 10	2 x 1	.	9 x 0.1	4 x 0.01	6 x 0.001
Value	50 +	2 +		0.9 +	~~0.02~~ +	0.006

$D = 5\times10^1 + 2\times10^0 + 9\times10^{-1} + 4\times10^{-2} + 6\times10^{-3}$

0.04

Binary Number System (base-2)

- r = 2
- Two allowed digits {0,1}
- A Binary Digit is referred to as bit
- Examples: 1100111, 01, 0001, 11110
- The left most bit is called the *Most Significant Bit (MSB)*
- The rightmost bit is called the *Least Significant Bit (LSB)*

11110

Most Significant Bit *Least Significant Bit*

Binary to Decimal Conversion

- The decimal equivalent of a binary number can be found by expanding the number into a power series:

Example

- Convert binary to decimal by summing the positions that contain a 1.

- 1 0 0 1 0 1

$$2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0 = 32 + 4 + 1 = 37_{10}$$

Question:

What is the decimal equivalent of $(110.11)_2$?

Decimal to Binary Conversion

- Two methods to convert decimal to binary:
  - Reverse process
  - Use repeated division

Decimal to Binary Conversion

- Reverse process
  - Note that all positions must be accounted for

$$37_{10} = 2^5 + 0 \;\; + 0 \;\; + 2^2 + 0 \;\; + 2^0$$

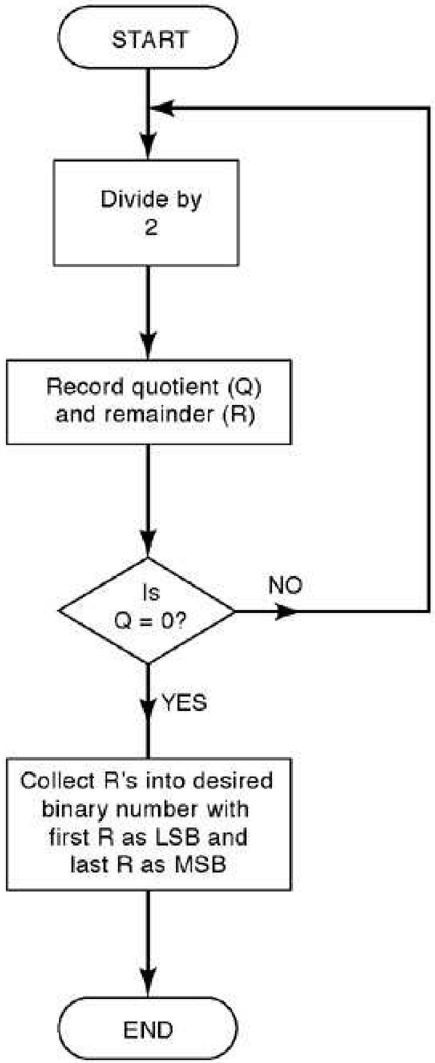
$$1 \quad\;\; 0 \quad\;\; 0 \quad\;\; 1 \quad\;\; 0 \quad\;\; 1_2$$

Decimal to Binary Conversion

- Repeated division steps:
  - Divide the decimal number by 2
  - Write the remainder after each division until a quotient of zero is obtained.
  - The first remainder is the LSB and the last is the MSB

Decimal to Binary Conversion

- Repeated division – This flowchart describes the process and can be used to convert from decimal to any other number system.



Example: Decimal → Binary

53_{10} => 53 / 2 = 26remainder 1 LSB

26 / 2 = 13remainder 0

13/ 2 = 6 remainder 1

6 / 2 = 3 remainder 0

3 / 2 = 1 remainder 1

1 / 2 = 0 remainder 1 MSB

Read from the bottom to the top

= 110101_2 (6 *bits*)

= 00110101_2 (8 *bits*)

$0.81_{10} \rightarrow$ binary???

0.110011_2

0.81_{10} => 0.81 x 2 = 1.62

0.62 x 2 = 1.24

0.24 x 2 = 0.48

0.48 x 2 = 0.96

0.96 x 2 = 1.92

0.92 x 2 = 1.84

= 0.110011_2 (approximately)

Hexadecimal Number System

- Most digital systems deal with groups of bits in even powers of 2.
- Hexadecimal uses groups of 4 bits.
- Base 16
  - 16 possible symbols
  - 0-9 and A-F
- Allows for convenient handling of long binary strings.

Hexadecimal Number to Decimal

- Convert from hex to decimal by multiplying each hex digit by its positional weight.

Example:

$$\begin{aligned} 163_{16} &= 1\times(16^2)+6\times(16^1)+3\times(16^0) \\ &= 1\times256+6\times16+3\times1 \\ &= 355_{10} \end{aligned}$$

Decimal to Hexadecimal

- Convert from decimal to hex by using the repeated division method used for decimal to binary.
- Divide the decimal number by 16
- The first remainder is the LSB and the last is the MSB.

Refer Example 2.4 of text book

Hexadecimal to Binary

Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Binary	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111

- Example of hex to binary conversion:

$$9F2_{16} = \begin{array}{ccc} 9 & F & 2 \\ 1001 & 1111 & 0010 \end{array} = 100111110010_2$$

Binary to Hexadecimal

- Convert from binary to hex by grouping bits in four starting with the LSB.
- Each group is then converted to the hex equivalent
- Leading zeros can be added to the left of the MSB to fill out the last group.

Binary To Hexadecimal Example

Decimal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hexadecimal	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Binary	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111

- Example of binary to hex conversion.

(Note the addition of leading zeroes)

$$1110100110_2 = \boxed{\mathbf{00}11}\ \boxed{1010}\ \boxed{0110}$$

$$= \quad 3 \qquad A \qquad 6$$

$$= 3A6_{16}$$

- Counting in hex requires a reset and carry after reaching F.

Hexadecimal Number System

- Hexadecimal is useful for representing long strings of bits.
- Understanding the conversion process and memorizing the 4 bit patterns for each hexadecimal digit will prove valuable later.

Octal Number System (Work for you)

- Assignment1:- Octal to Decimal, Decimal to Octal, Octal to Binary, Binary to Octal
- Assignment2:- convert 724_8 to Decimal

Specific Examples

Question: What is the result of adding 1 to the largest digit of some number system?

- $(9)_{10} + 1 = (10)_{10}$
- $(7)_8 + 1 = (10)_8$
- $(1)_2 + 1 = (10)_2$
- $(F)_{16} + 1 = (10)_{16}$

Conclusion: Adding 1 to the largest digit in any number system always has a result of (10) in that number system.

Examples

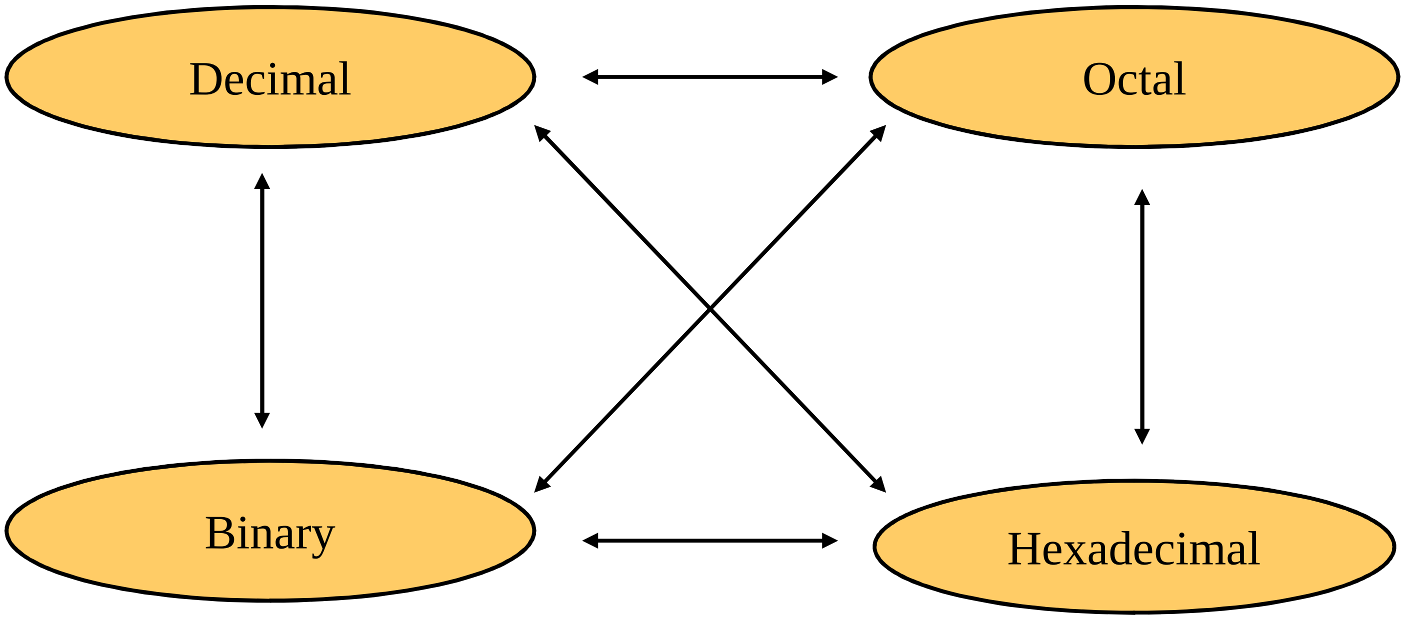
Question: What is the largest value representable using 3 integral digits?

Answer: The largest value results when all 3 positions are filled with the largest digit in the number system.

- **For** the decimal system, it is $(999)_{10}$
- **For** the octal system, it is $(777)_8$
- **For** the hex system, it is $(FFF)_{16}$
- **For** the binary system, it is $(111)_2$

Conversion Among Bases

- The possibilities:



Quick Example

$$25_{10} = 11001_2 = 31_8 = 19_{16}$$

Base