Chapter-3
Number System and Encoding Schemes

In computers, the different number systems that are used are:

- **Decimal Number System:** This number system is composed of 10 digits from 0 to 9, hence is also known as base 10 system. The position of the digits sets its value.
  e.g. : 231 is calculated depending on the position of the digits 2,3 and 1.

  $$2 \times 10^2 \quad + \quad 3 \times 10^1 \quad + \quad 1 \times 10^0$$

  Each digit appearing to the left of the decimal point is representedby raising it to increasing power of ten. Digits appearing to the right of the decimalpoint are representedby raising it to increasing negative power of ten.
  For example, the value 123.456 means:

  $$1x10^2 + 2x10^1 + 3x10^0 + 4x10^{-1} + 5x10^{-2} + 6x10^{-3}$$

- **Binary Number System:** The computer represents values using two voltage levels only by using exactly two different values i.e. zero and one. These two values form the base of the binary numbering system.

  The binary numbering system works just like the decimal numbering system, withtwo exceptions: binary only allows the digits 0 and 1 (rather than 0-9), and binary usespowers of two rather than powers of ten.

  Therefore, it is very easy to convert a binarynumber to decimal. For each “1” in the binary string, add in 2n where “n” is thezero-based position of the binary digit. For example, the binary value $(11001010)_2$is represented in decimal number system as:

  $$1x2^7 + 1*2^6 + 0*2^5 + 0*2^4 + 1*2^3 + 0*2^2 + 1*2^1 + 0*2^0 = 128 + 64 + 8 + 2 = (202)_{10}$$

- **Octal Number System:**This number system has a base 8 with eight unique symbols ranging from 0 to 7. This is also a positional value system, wherein each octal digit is expressed as a power of 8. The places to the left of the decimal are positive powers of 8 and places to the right of decimal are negative powers of 8.

3	7	1	.	0	6	1	2
3×8^2	3×8^1	3×8^0	.	0×8^{-1}	6×8^{-2}	1×8^{-3}	2×8^{-4}

- **Hexadecimal Number System:** This number system uses a base 16 having digits 0 -9 and the letters A to E, where A is used to represent 10, B for 11 and so on.

Like all the other systems, this too is a positional number system where each digit is expressed as increasing power of 16.

A	9	E	0	.	2	B
10×16^{3}	9×16^{2}	15×16^{1}	0×16^{0}	.	2×16^{-1}	11×16^{-2}

Number Conversions:

⇨ **Decimal To Binary Conversions:**

$(56)_{10} = (\,?)_{2}$

	56	Remainder
2	28	0
2	14	0
2	7	0
2	3	1
2	1	1
2	0	1

$(56)_{10} = (111000)_{2}$

⇨ **Binary to Decimal:**

$(111000)_{2}=(?)_{10}$

1×2^{5}	1×2^{4}	1×2^{3}	0×2^{2}	0×2^{1}	0×2^{0}	Sum
32	16	8	0	0	0	56

$(111000)_{2}=(56)_{10}$

⇨ **Decimal to Octal :**

$(561)_{10} = (\,?)_{8}$

	561	Remainder
8	70	1
8	8	6
8	1	0
8	0	1

$(561)_{10} = (1061)_{8}$

⇨ **Octal to Decimal:**

$(1061)_8 = (?)_{10}$

1×8^3	0×8^2	6×8^1	1×8^0	Sum
512	0	48	1	561

$(1061)_8 = (561)_{10}$

⇨ **Decimal to Hexadecimal :**

$(10232)_{10} = (?)_{16}$

	10232	Remainder
16	639	8
16	39	E
16	2	7
16	0	2

$(10232)_{10} = (27E8)_{16}$

⇨ **Hexadecimal to Decimal:**

$(27E8)_{16} = (?)_{10}$

2×16^3	7×16^2	15×16^1	8×16^0	Sum
8192	1792	240	8	10232

$(27E8)_{16} = (10232)_{10}$

⇨ **Octal to Binary:**

$(7645)_8 = (?)_2$

7	6	4	5
111	110	100	101

$(7645)_8 = (111\ 110\ 100\ 101)_2$

⇨ **Binary to Octal :**

(1001010101111011)$_2$ = (?) $_8$

Grouping in threes from right side, and adding zero on the left to make a group of three 001 001 010 101 111011

001	001	010	101	111	011
1	1	2	5	7	3

(1001010101111011)$_2$ = (112573) $_8$

⇨ **Hexadecimal to Binary** :

(7A6D) $_{16}$ = (?) $_2$

7	A	6	D
0111	1010	0110	1001

(7A6D) $_{16}$ = (0111 1010 0110 1001) $_2$

⇨ **Binary to Hexadecimal:**

(11000110110101) $_2$=(?) $_{16}$

Grouping in fours from right side, and adding zero on the left to make a group of four

0011 0001 1011 0101

0011	0001	1011	0101
3	1	11	5

(11000110110101) $_2$=(31B5) $_{16}$

Converting Fractions:

⇨ **Decimal Fractions to Binary:**

(0.425) $_{10}$ = (?)$_2$

0.425 x 2	0.850	0	↓
0.850 x 2	1.700	1	
0.700 x 2	1.400	1	
0.400 x 2	0.800	0	
0.800 x 2	1.600	1	
0.600 x 2	1.200	1	
0.200 x 2	0.400	0	
0.400 x 2	0.800	0	

(0.425) $_{10}$ = (0.01101100)$_2$

- **Binary Fractions to Decimal:**

  $(0.011101)_2 = (\ ?\ )_{10}$

0	.	0	1	1	1	0	1	SUM
0	.	0×2^{-1}	1×2^{-2}	1×2^{-3}	1×2^{-4}	0×2^{-5}	1×2^{-6}	
0.	.	0	0.25	0.125	0.0625	0	0.015	0.453

  $(0.011101)_2 = (0.453)_{10}$

- **Decimal Fractions to Octal:**

  $(0.975)_{10} = (\ ?\ )_8$

0.975 x 8	7.8	7	↓
0.800 x 8	6.4	6	
0.400 X 8	3.2	3	
0.200 X 8	1.6	1	
1.600 X 8	4.8	4	
0.800 X 8	6.4	6	

  $(0.975)_{10} = (763246324)_8$

- **Decimal Fractions to Hexadecimal:**

  $(0.375)_{10} = (\ ?\ )_{16}$

0.375 x 16	6.00	6

  $(0.375)_{10} = (6)_{16}$

Keeping in mind the binary addition rule 1+1=10,1+1+1=11 and one gets carried over.

Encoding of Characters

Along with the numbers discussed above, the computer has to deal with characters and alphanumeric data. The different methods used to represent these characters on computer are:

- **ASCII Codes:**The American Standard Code for Information Interchange (ASCII) is a character-encoding scheme based on the ordering of the English alphabet. ASCII codes represent text in computers, communications equipment, and other devices that use text.

  ASCII reserves the first 32 codes (numbers 0–31 decimal) for control characters: codes originally intended not to represent printable information, for example, character 10 represents the "line feed" function (which causes a printer to advance its paper), and character 8 represents "backspace". The printable characters i.e. letters, digits, punctuation marks, and a few miscellaneous symbols are represented by the next set.

- ⇨ **ISCII Codes:** Indian Standard Code for Information Interchange (ISCII) is a coding scheme for representing various writing systems of India. It encodes the main Indic scripts and a Roman transliteration. The supported scripts are: Assamese, Bengali, Devanagari, Gujarati, Gurmukhi, Kannada, Malayalam, Oriya, Tamil, and Telugu.

- ⇨ **UNICODE:**Unicode is a computingindustry standard for the consistent encoding, representation and handling of text expressed in most of the world's writing systems. Unicode consists of a range of more than 109,000 characters covering 93 scripts.

  It consist a set of code charts for visual reference, an encoding methodology for characters like upper and lower case. It helps in the correct display of text containing both right-to-left scripts, such as Arabic and Hebrew, and left-to-right scripts.

THE UNICODE CONSORTIUM

The Unicode Consortium develops the Unicode Standard. Their goal is to replace the existing character sets with its standard Unicode Transformation Format (UTF).

The Unicode Standard has become a success and is implemented in HTML, XML, Java, JavaScript, E-mail, ASP, PHP, etc. The Unicode standard is also supported in many operating systems and all modern browsers.

THE UNICODE CHARACTER SETS

Unicode can be implemented by different character sets. The most commonly used encodings are UTF-8 and UTF-16:

- UTF-8

  A character in UTF8 can be from 1 to 4 bytes long. UTF-8 can represent any character in the Unicode standard. UTF-8 is backwards compatible with ASCII. UTF-8 is the preferred encoding for e-mail and web pages

- UTF-16
  16-bit Unicode Transformation Format is a variable-length character encoding for Unicode, capable of encoding the entire Unicode repertoire. UTF-16 is used in major operating systems and environments, like Microsoft Windows, Java and .NET.

THE DIFFERENCE BETWEEN UNICODE AND UTF-8
Unicode is a **character set**. UTF-8 is **encoding**.
Unicode is a list of characters with unique decimal numbers (code points). A = 65, B = 66, C = 67.
This list of decimal numbers represent the string "hello": 104 101 108 108 111
Encoding is how these numbers are translated into binary numbers to be stored in a computer:

UTF-8 encoding will store "hello" like this (binary): 01101000 01100101 01101100 01101100 01101111

1 Mark Questions:

1. Expand

a) ISCII b) ASCII

2. Write short note on:

a) ASCII b) ISCII c) UNICODE

3. What is number system?

4. What is meant by the base of number system? Give examples to illustrate this concept.

2 Mark Questions:

1. Express the following Decimal number into their equivalent binary number.

a. 359 b. 236

2. Express the following octal number into their equivalent binary number.

a. 111 b. 214

3. Convert the following decimal numbers to binary:-

a. 13 c. 106

b. 3. 84 d. 200

4. Convert the following binary numbers to decimal:-

a. 10010 b. 101010

5. Convert to hexadecimal

a. 423 b. 72905

6. Convert to octal

a. 11111011110101

b. 1011110100011000111

7. Convert hexadecimal to decimal

a. 1A6 b. 7FF

8. Convert the following decimal numbers to their binary equivalent:

a. (252.25)10 b. (125.500)10

9. Convert the following numbers to their equivalent decimal:

a. (6214)8 b. (14EA)16

10. Represent the following negative numbers in their two's complement form:

a. 45 b. 24

11. Convert the following decimal numbers to their binary equivalent:

a. (4348.0245)10 b. (1256.075)10

12. Convert the following binary numbers to their octal and hexadecimal equivalents:

a. $(1100011101)_2$ b. $(1000011000)_2$

13. Convert the following numbers to their equivalent decimal:

a. (6342)8 b. (1EA9)16

14. Represent the following negative numbers in their two's complement form:

a. 27 b. 34

15. Convert the following numbers to their equivalent decimal:

a. (7235)8 b. (AE87)16

16. Represent the following negative numbers in their two's complement form:

a. 82 b. 18

17. Convert $(1958.345)_{10}$ to its equivalent octal and binary.

18. Convert the following numbers into their Binary equivalent:

a. (6789)10 c. (7652)8

b. (A10E)16

19. Convert the following binary numbers to their octal and hexadecimal equivalents:

a. (1100010101)2 b. (1001011001011)2