**A Number System**

**(in Context of Computer Science)**

When we type some letters or words, the computer translates them in numbers as computers can understand only numbers. A computer can understand positional number system where there are only a few symbols called digits and these symbols represent different values depending on the position they occupy in the number.

A value of each digit in a number can be determined using

* The digit
* The position of the digit in the number
* The base of the number system (where base is defined as the total number of digits available in the number system).

**Decimal Number System**

The number system that we use in our day-to-day life is the decimal number system. Decimal number system has base 10 as it uses 10 digits from 0 to 9. In decimal number system, the successive positions to the left of the decimal point represent units, tens, hundreds, thousands and so on.

Each position represents a specific power of the base (10). For example, the decimal number 1234 consists of the digit 4 in the units position, 3 in the tens position, 2 in the hundreds position, and 1 in the thousands position, and its value can be written as

(1\*1000)+ (2\*100)+ (3\*10)+ (4\*l)

(1\*103)+ (2\*102)+ (3\*101)+ (4\*l00)

1000 + 200 + 30 + 4

1234

As a computer programmer or an IT professional, you should understand the following number systems which are frequently used in computers.

|  |  |
| --- | --- |
| **S.N.** | **Number System and Description** |
| 1 | **Binary Number System**  Base 2. Digits used : 0, 1 |
| 2 | **Octal Number System**  Base 8. Digits used : 0 to 7 |
| 3 | **Hexa Decimal Number System**  Base 16. Digits used : 0 to 9, Letters used : A- F |

**Binary Number System**

Characteristics of binary number system are as follows:

* Uses two digits, 0 and 1.
* Also called base 2 number system
* Each position of a binary number represents a x power of the base (2), where x is the place value of the digits involved in the binary number.

Example

Binary Number: 101012  So, the place values will be

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **BINARY** | **1** | **0** | **1** | **0** | **1** |
| PLACE VALUE | 4 | 3 | 2 | 1 | 0 |

**Calculating Decimal Equivalent:**

|  |  |  |
| --- | --- | --- |
| **Step** | **Binary Number** | **Decimal Number** |
| Step 1 | 101012 | ((1 \* 24) + (0 \* 23) + (1 \* 22) + (0 \* 21) + (1 \* 20))10 |
| Step 2 | 101012 | (16 + 0 + 4 + 0 + 1)10 |
| Step 3 | 101012 | 2110 |

**Note :** 101012 is normally written as 10101.

**Octal Number System**

Characteristics of octal number system are as follows:

* Uses eight digits, 0,1,2,3,4,5,6,7.
* Also called base 8 number system
* Each position of a binary number represents a x power of the base (8), where x is the place value of the digits involved in the binary number.

Example

Octal Number : 125708 So, the place values will be

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **OCTAL** | **1** | **2** | **5** | **7** | **0** |
| PLACE VALUE | 4 | 3 | 2 | 1 | 0 |

**Calculating Decimal Equivalent:**

|  |  |  |
| --- | --- | --- |
| **Step** | **Octal Number** | **Decimal Number** |
| Step 1 | 125708 | ((1 \* 84) + (2 \* 83) + (5 \* 82) + (7 \* 81) + (0 \* 80))10 |
| Step 2 | 125708 | (4096 + 1024 + 320 + 56 + 0)10 |
| Step 3 | 125708 | 549610 |

**Note :** 125708 is normally written as 12570.

**Hexadecimal Number System**

Characteristics of hexadecimal number system are as follows:

* Uses 10 digits and 6 letters, 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F.
* Letters represents numbers starting from 10. A = 10. B = 11, C = 12, D = 13, E = 14, F = 15.
* Also called base 16 number system
* Each position of a binary number represents a x power of the base (16), where x is the place value of the digits involved in the binary number.

Example

Hexadecimal Number : 19FDE16 So, the place values will be

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **HEX** | **1** | **9** | **F** | **D** | **E** |
| PLACE VALUE | 4 | 3 | 2 | 1 | 0 |

**Calculating Decimal Equivalent:**

|  |  |  |
| --- | --- | --- |
| **Step** | **Binary Number** | **Decimal Number** |
| Step 1 | 19FDE16 | ((1 \* 164) + (9 \* 163) + (F \* 162) + (D \* 161) + (E \* 160))10 |
| Step 2 | 19FDE16 | ((1 \* 164) + (9 \* 163) + (15 \* 162) + (13 \* 161) + (14 \* 160))10 |
| Step 3 | 19FDE16 | (65536+ 36864 + 3840 + 208 + 14)10 |
| Step 4 | 19FDE16 | 10646210 |

**Note :** 19FDE16 is normally written as 19FDE.

**Number Conversion:**

There are many methods or techniques which can be used to convert numbers from one base to another. We'll demonstrate here the following:

* Decimal to Other Base System
* Shortcut method - Binary to Octal
* Shortcut method - Octal to Binary
* Shortcut method - Binary to Hexadecimal
* Shortcut method - Hexadecimal to Binary

**Decimal to Other Base System**

* **Step 1 -**Divide the decimal number to be converted by the value of the new base.
* **Step 2 -**Get the remainder from Step 1 as the rightmost digit (least significant digit) of new base number.
* **Step 3 -**Divide the quotient of the previous divide by the new base.
* **Step 4 -**Record the remainder from Step 3 as the next digit (to the left) of the new base number.
* Repeat Steps 3 and 4, getting remainders from right to left, until the quotient becomes zero in Step 3.
* The last remainder thus obtained will be the most significant digit (MSD) of the new base number.

### Example

Decimal Number : 2910

Calculating Binary Equivalent:

|  |  |  |  |
| --- | --- | --- | --- |
| **Step** | **Operation** | **Result** | **Remainder** |
| Step 1 | 29 / 2 | 14 | 1 |
| Step 2 | 14 / 2 | 7 | 0 |
| Step 3 | 7 / 2 | 3 | 1 |
| Step 4 | 3 / 2 | 1 | 1 |
| Step 5 | 1 / 2 | 0 | 1 |

As mentioned in Steps 2 and 4, the remainders have to be arranged in the reverse order so that the first remainder becomes the least significant digit (LSD) and the last remainder becomes the most significant digit (MSD).

Decimal Number : 2910 = Binary Number : 111012.

**Shortcut method - Binary to Octal**

* **Step 1 -**Divide the binary digits into groups of three (starting from the right).
* **Step 2 -**Convert each group of three binary digits to one octal digit.

### Example

Binary Number : 101012

Calculating Octal Equivalent:

|  |  |  |
| --- | --- | --- |
| **Step** | **Binary Number** | **Octal Number** |
| Step 1 | 101012 | 010 101 |
| Step 2 | 101012 | 28 58 |
| Step 3 | 101012 | 258 |

Binary Number : 101012 = Octal Number : 258

**Shortcut method - Octal to Binary**

* **Step 1 -**Convert each octal digit to a 3 digit binary number (the octal digits may be treated as decimal for this conversion).
* **Step 2 -**Combine all the resulting binary groups (of 3 digits each) into a single binary number.

### Example

Octal Number : 258

Calculating Binary Equivalent:

|  |  |  |
| --- | --- | --- |
| **Step** | **Octal Number** | **Binary Number** |
| Step 1 | 258 | 210 510 |
| Step 2 | 258 | 0102 1012 |
| Step 3 | 258 | 0101012 |

Octal Number : 258 = Binary Number : 101012

**Shortcut method - Binary to Hexadecimal**

* **Step 1 -**Divide the binary digits into groups of four (starting from the right).
* **Step 2 -**Convert each group of four binary digits to one hexadecimal symbol.

### Example

Binary Number : 101012

Calculating hexadecimal Equivalent:

|  |  |  |
| --- | --- | --- |
| **Step** | **Binary Number** | **Hexadecimal Number** |
| Step 1 | 101012 | 0001 0101 |
| Step 2 | 101012 | 110 510 |
| Step 3 | 101012 | 1516 |

Binary Number : 101012 = Hexadecimal Number : 1516

**Shortcut method - Hexadecimal to Binary**

* **Step 1 -**Convert each hexadecimal digit to a 4 digit binary number (the hexadecimal digits may be treated as decimal for this conversion).
* **Step 2 -**Combine all the resulting binary groups (of 4 digits each) into a single binary number.

Hexadecimal Number : 1516

Calculating Binary Equivalent:

|  |  |  |
| --- | --- | --- |
| **Step** | **Hexadecimal Number** | **Binary Number** |
| Step 1 | 1516 | 110 510 |
| Step 2 | 1516 | 00012 01012 |
| Step 3 | 1516 | 000101012 |

Hexadecimal Number : 1516 = Binary Number : 101012

**Sign and Magnitude Representation:**

In this method, first bit is considered as a sign bit. Here positive number starts with 0 and negative number starts with 1.

Example:

2510  = (?)2

Division Result Remainder

25/2 = 12 1

12/2 = 6 0

6/2 = 3 0

3/2 = 1 1

1/2 = 0 1

So the binary number is (11001)2. If we take the size of the word is 1 byte, then the number 25 will be represented as

00011001.

Suppose, if the number is -25, and then it will be represented as

10011001

**Complement Method:**

Complements are used in the digital computers in order to simplify the subtraction operation and for the logical manipulations.

For each radix-r system (radix r represents base of number system).

There are two types of complements.

|  |  |  |
| --- | --- | --- |
| **S.N.** | **Complement** | **Description** |
| 1 | Radix Complement | The radix complement is referred to as the r's complement |
| 2 | Diminished Radix Complement | The diminished radix complement is referred to as the (r-1)'s complement |

**Method to find r’s and (r-1)’s complement:**

Formula to find r's complement of any number N.

rn - N

Where r is the base (redix) of N.

n is the number of digits involve in N.

N is the number.

Example: r's complement of 3610 is ?.

3610 = r’s complement.

N=36, r=10 n=2

102 – 36 = 100 - 36 = 64 ans.

Formula to find r's complement of any number N.

(rn – 1) -N

Where r is the base (redix) of N.

n is the number of digits involve in N.

N is the number.

Example: r's complement of 3610 is ?.

3610 = r’s complement.

N=36, r=10 n=2

(102 – 1) - 36 = 99 - 36 = 63 ans.

So, (r-1)’s complement of any decimal number can be obtained by subtracting each digit of the Number N by 9.

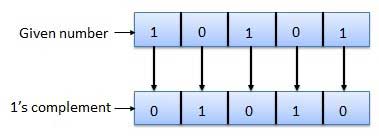
**Conclusion:** r’s complement of any number can be obtained by adding 1 to the resultant of (r-1)’s complement of the number.

**Binary system complements**

As the binary system has base r = 2. So the two types of complements for the binary system are 2's complement and 1's complement.

1's complement

The 1's complement of a number is found by changing all 1's to 0's and all 0's to 1's. This is called as taking complement or 1's complement. Example of 1's Complement is as follows.

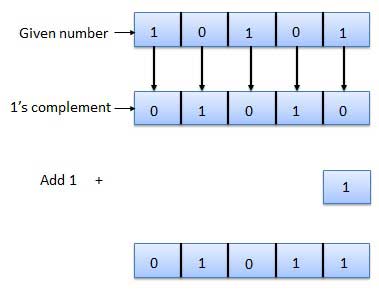


2's complement

The 2's complement of binary number is obtained by adding 1 to the Least Significant Bit (LSB) of 1's complement of the number.

2's complement = 1's complement + 1

Example of 2's Complement is as follows.



**ASCII**

ASCII stands for American Standard Code for Information Interchange. ASCII-7 can represent 128 characters. Out of 7 bits, 3 are zone bits and 4 are numeric bits. ASCII-8 can represent 256 characters. It is an extended form of ASCII-7.

**ISCII: (Indian Standard Code for Information Interchange)**

A lot of efforts have gone into facilitating the use of Indian languages on computers. In 1991, the Bureau of Indian Standards adopted the ISCII. It is an 8 bit code which allows English and Indian Scripts alphabets to be used simultaneously. Characters coded in ISCII need 8 bits for each character.

**Unicode**

Unicode is a new universal coding standard adopted by all new platforms. It is promoted by Unicode Consortium which is a non profit organization. Unicode provides a unique number for every character irrespective of the platform, program and the language. It is a character coding system designed to support the worldwide interchange, processing, and display of the written texts of the diverse languages.