Lesson:

DSA(number system)

Pre Requisites:

- Basic Java

List of concepts involved :

- Number System
- Conversion of Number System
- Bits Manipulation

Number System

A number system is defined as the representation of numbers by consistently using digits or other symbols. The value of any digit in a number can be determined by a digit, its position in the number, and the base of the number system. The numbers are represented in a unique manner and allow us to operate arithmetic operations like addition, subtraction, and division.

There are different types of number systems in which the four main types are as follows.

- **Binary number system (Base - 2)**
- **Octal number system (Base - 8)**
- **Decimal number system (Base - 10)**
- **Hexadecimal number system (Base - 16)**

Binary Number System
The binary number system uses only two digits 0 and 1. The numbers in this system are base 2. The numbers 0 and 1 are called bits, and together 8 bits make up a byte. Computer data is stored in the form of bits and bytes. The binary number system does not work with other numbers like 2,3,4,5 etc.

Example: (10001)base 2, (111101)base , (1010101)base 2 are some examples of numbers in the binary system.

Octal Number System
The octal number system uses 8 digits: 0,1,2,3,4,5,6 and 7 are the base 8. The advantage of this system is that it requires fewer calculations as it has fewer digits compared to other systems. error. Numbers such as 8 and 9 are not included in the octal number system. Like binary, octal is used on minicomputers, but uses the numbers 0 through 7.

Example: (35)base 8, (23)base 8, (141)base 8 are some examples of octal numbers.

Decimal Number System
The decimal number system uses 10 digits: 0,1,2,3,4,5,6,7,8 and 9 and the base digit 10. The decimal number system is the number we usually use to represent numbers in real life. It's a system. . If you see a number with no base, it means the base is 10.

Example: (723)base 10, (32)base 10, (4257)base 10 are some examples of numbers in the decimal number system.

Hexadecimal Number System

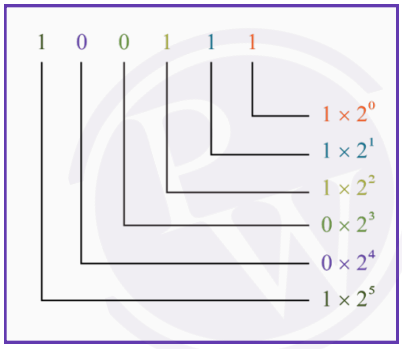
The hexadecimal number system uses 16 numbers/alphabets: 0,1,2,3,4,5,6,7,8,9 and A,B,C,D,E,F (base number 16). Here, A-F of the hexadecimal digits represent the 10-15 decimal number system respectively. This system is used by computers to shorten large binary system strings.

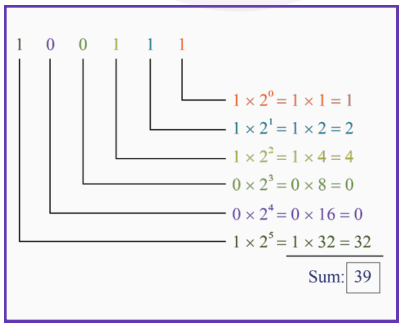
For example, (7B3)base 16, (6F)base 16, and (4B2A)base 16 are some examples of hexadecimal numbers.

Conversion of Number System

1. . Binary to Decimal Conversion

Use the following steps to convert a number from binary to decimal.
Step 1: Starting from the rightmost, multiply each digit of the given number by the exponent at the base.
Step 2: The exponent should start at 0 and increase by 1 each time you move from right to left.
Step 3. Simplify and add each product above. Let's understand the steps with the following example where we need to convert the
number from binary to decimal.
Example: Convert (100111)2 to decimal.
Solution:
Step 1: Determine the base of the given number. The base of (100111)2 is 2.
Step 2: Multiply each digit of the given number, starting from the rightmost, by the exponent at the base. The number should start at 0 and increase by 1 each time you move from right to left.
Here, since the base is 2, the number of digits in the given number is multiplied by 20, 21, 22, and so on from right to left.



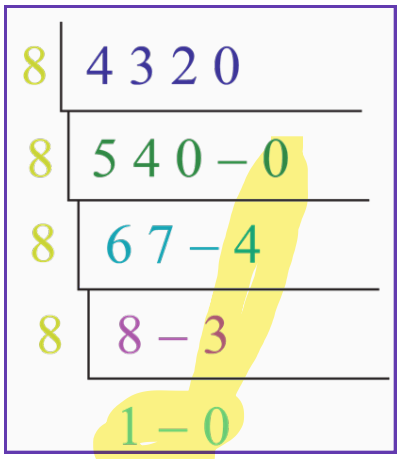


Thus, 1001112 = 3910.

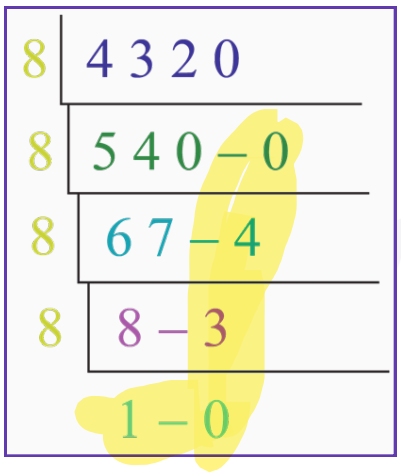
Decimal to Binary/Octal/hexadecimal

Use the following steps to convert a number from decimal to binary/octal/hexadecimal. Shows step by step how to convert a number from decimal to octal.

Example: Converts 432010 to octal.
Solution:
Step 1: Determine the base of the desired number. We need to convert this number to base 8, so the base of the number we want is 8.
Step 2: Divide the given number by the base of the desired number and write the quotient and remainder in quotient-remainder format. Repeat this process until you get a quotient less than the base (redivide the quotient by the base).



Step 3: The given number in the octal number system is obtained just by reading all the remainders and the last quotient from bottom to top.



yeh Base hai

Therefore, 432010 = 103408

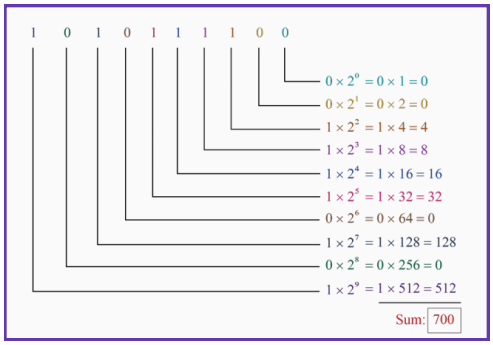
Any Number System to any other Number System

To convert a number from one of the binary/octal/hexadecimal systems to one of the others, first convert to decimal, then use the process above to convert to the required system.

Example: Convert 10101111002 to hexadecimal.

Solution:

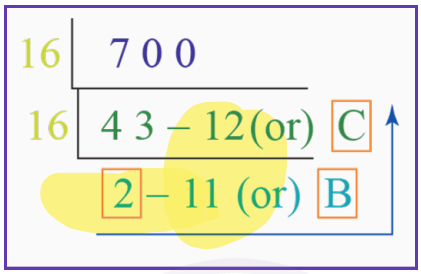
Step 1: Convert this number to decimal as described above.



Thus, 10101111002 = 70010 → (1)

Step 2: Convert the above number (which is in the decimal system), into the required number system (hexadecimal).

Here, we have to convert 70010 into the hexadecimal system using the above-mentioned process. It should be noted that in the hexadecimal system, the numbers 11 and 12 are written as B and C respectively.



Thus, 70010 = 2BC16 → (2)
From the equations (1) and (2), 10101111002 = 2BC16

Bit manipulation:

This can be defined as the process of applying logical operations on sequence of bits where bits is the smallest form of data which is used to store information in a computer.
Broadly bits are either 0 or 1. Combination of these two digits is the foundation of bit manipulation.
Bit manipulation is used because it nearly consumes constant time for operations and is very efficient on all systems.
The most useful bits operator that we will cover in the lecture are as follows:

- AND (&)
- OR (|)
- NOT (!)
- XOR (^)
- Left shift (<<)
- Right shift (>>)

1. AND operator:
Symbol : &
This is a binary operator that operates on two operands. The numbers are converted in their binary format and corresponding bits of both the operands are operated.
This results in 1 if both the bits are 1. Otherwise if any of the bit in both operands is 0 the resultant of this AND

operator is 0.

The table for AND operator is shown below:

a	b	a&b
0	0	0
0	1	0
1	0	0
1	1	1

For example : let a = 5 and b = 7
Let's perform a&b
a = 101
b = 111
———————
101 which is equivalent to 5 in decimal.

2. OR operator:
Symbol : |
This is a binary operator that operates on two operands. The numbers are converted in their binary format and corresponding bits of both the operands are operated.
This results in 0 if both the bits are 0. Otherwise if any of the bits in both operands is 1 the resultant of this OR operator is 1.

The table for OR operator is shown below:

Input A	Input B	OR Operator A | B
0	0	0
0	1	1
1	0	1
1	1	1

For example : let a = 5 and b = 7
Let's perform a|b
a = 101
b = 111
———————
111 which is equivalent to 7 in decimal.

3. NOT operator:
Symbol : !
This is a unary operator which negates the effect of the input bit. If the bit inputted is 0 it is converted to 1, if the

bit inputted is 1 it is converted to 0.

x	x'
0	1
1	0

Example : let a = 4,
Let's find out !a
4 in binary would be 100, its complement / not would be to convert every 0 to 1 and every 1 to 0.
!a = 011 = 3 in decimal.

4. XOR operator:
Symbol : ^
This is a binary operator that operates on two operands. The numbers are converted in their binary format and corresponding bits of both the operands are operated.
This results in 0 if both the bits are same i.e either both the bits are 0 or both the bits are 1. Otherwise if the bits in both operands are different the resultant of this XOR operator is 1.

The table for XOR operator is shown below:

A	B	A **XOR** B
0	0	0
0	1	1
1	0	1
1	1	0

For example : let a = 5 and b = 7
Let's perform a|b
a = 101
b = 111
———————
010 which is equivalent to 2 in decimal.

5. Left shift operator:
Symbol : <<
This is a binary operator that works on two operands and left shifts the bits of the first operand, the second operand decides the number of places to shift.
For example, let num = 1100110010 and we want to left shift it by 1 bit.
The num after shift will be 11001100100
If we want to left shift it by 2 bits. Then num would be 110011001000
Observation: 1100110010 = 818 in decimal
And after left shift by 1 bit, 11001100100 = 1636 in decimal = 818 *(2^1)
After left shift by 2 bits, 110011001000 = 3272 = 818 * (2^2)

From here we can conclude, shifting an integer “x” with an integer “y” denoted as ‘(x<<y)’ is equivalent to multiplying x with 2^y (2 raised to power y).

For example : 4 << 3 = 4 * 2^3 = 4 * 8 = 32

Note: In an arithmetic shift, the sign bit is extended to preserve the signedness of the number as to prevent overflow

6. Right shift operator:
Symbol : >>
This is a binary operator that works on two operands and right shifts the bits of the first operand, the second operand decides the number of places to shift.
For example, let num = 1100110010 and we want to right shift it by 1 bit.
The num after shift will be 110011001
If we want to right shift it by 2 bits. Then num would be 11001100
Observation: 1100110010 = 818 in decimal
And after right shift by 1 bit, 0110011001 = 409 in decimal = 818 *(2^(-1))
After left shift by 2 bits, 0011001100 = 204= 818 * (2^(-2))

From here we can conclude, shifting an integer “x” with an integer “y” denoted as ‘(x>>y)’ is equivalent to multiplying x with 1/(2^y)(2 raised to power negative y).

Another point of observation here will be to continue right shifting each time on the right end we are getting the bit of the number and one bit from the number is removed. That indicates, if we want to get each bit of the number one by one we can continually right shift till the number does not become 0.

For example : 40 << 3 = 40 * 1/(2^3) = 40 * 1/8 = 5

We will solve some problems using bits manipulation in assignment.

Next Class teasers:

- Introduction to Recursion
- Factorial & Fibonacci problems
- Power of number using bits
- Count number of stairs