The technique to represent and work with numbers is called number system. **Decimal number system** is the most common number system. Other popular number systems include **binary number system, octal number system, hexadecimal number system**, etc.

1. Decimal Number System

Decimal number system is a **base 10** number system having 10 digits from 0 to 9. This means that any numerical quantity can be represented using these 10 digits. Decimal number system is also a **positional value system**. This means that the value of digits will depend on its position. Let us take an example to understand this.

Say we have three numbers – 734, 971 and 207. The value of 7 in all three numbers is different−

- In 734, value of 7 is 7 hundreds or 700 or 7×100 or 7×10^2
- In 971, value of 7 is 7 tens or 70 or 7×10 or 7×10^1
- In 207, value 0f 7 is 7 units or 7 or 7×1 or 7×10^0

The weightage of each position can be represented as follows −

10^5	10^4	10^3	10^2	10^1	10^0

In digital systems, instructions are given through electric signals; variation is done by varying the voltage of the signal. Having 10 different voltages to implement decimal number system in digital equipment is difficult. So, many number systems that are easier to implement digitally have been developed. Let's look at them in detail.

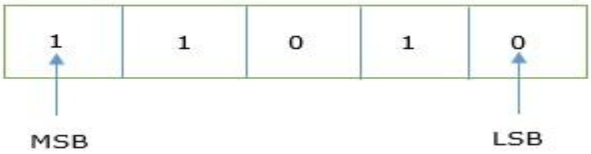
2. Binary Number System

The easiest way to vary instructions through electric signals is two-state system – on and off. On is represented as 1 and off as 0, though 0 is not actually no signal but signal at a lower voltage. The number system having just these two digits – 0 and 1 – is called **binary number system**.

Each binary digit is also called a **bit**. Binary number system is also positional value system, where each digit has a value expressed in powers of 2, as displayed here.

2^5	2^4	2^3	2^2	2^1	2^0

In any binary number, the rightmost digit is called **least significant bit (LSB)** and leftmost digit is called **most significant bit (MSB)**.



And decimal equivalent of this number is sum of product of each digit with its positional value.

$11010_2 = 1\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 0\times2^0$

$= 16 + 8 + 0 + 2 + 0$

$= 26_{10}$

Computer memory is measured in terms of how many bits it can store. Here is a chart for memory capacity conversion.

- 1 byte (B) = 8 bits
- 1 Kilobytes (KB) = 1024 bytes
- 1 Megabyte (MB) = 1024 KB
- 1 Gigabyte (GB) = 1024 MB
- 1 Terabyte (TB) = 1024 GB
- 1 Exabyte (EB) = 1024 PB
- 1 Zettabyte = 1024 EB
- 1 Yottabyte (YB) = 1024 ZB

3. Octal Number System

Octal number system has eight digits – 0, 1, 2, 3, 4, 5, 6 and 7. Octal number system is also a positional value system with where each digit has its value expressed in powers of 8, as shown here −

8^5	8^4	8^3	8^2	8^1	8^0

Decimal equivalent of any octal number is sum of product of each digit with its positional value.

$726_8 = 7\times8^2 + 2\times8^1 + 6\times8^0$

$= 448 + 16 + 6$

$= 470_{10}$

4. Hexadecimal Number System

Octal number system has 16 symbols – 0 to 9 and A to F where A is equal to 10, B is equal to 11 and so on till F. Hexadecimal number system is also a positional value system with where each digit has its value expressed in powers of 16, as shown here −

16^5	16^4	16^3	16^2	16^1	16^0

Decimal equivalent of any hexadecimal number is sum of product of each digit with its positional value.

$27FB_{16} = 2\times16^3 + 7\times16^2 + 15\times16^1 + 10\times16^0$

$= 8192 + 1792 + 240 +10$

$= 10234_{10}$

****Number System Relationship**

The following table depicts the relationship between decimal, binary, octal and hexadecimal number systems.

HEXADECIMAL	DECIMAL	OCTAL	BINARY
0	0	0	0000
1	1	1	0001
2	2	2	0010
3	3	3	0011
4	4	4	0100
5	5	5	0101
6	6	6	0110
7	7	7	0111
8	8	10	1000
9	9	11	1001
A	10	12	1010
B	11	13	1011
C	12	14	1100
D	13	15	1101
E	14	16	1110
F	15	17	1111

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 unit's position, 3 in the tens position, 2 in the hundreds position, and 1 in the thousands position. Its value can be written as

(1 x 1000) + (2 x 100) + (3 x 10) + (4 x l)

$(1 \times 10^3) + (2 \times 10^2) + (3 \times 10^1) + (4 \times 10^0)$

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.

Sr.No.	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 the binary number system are as follows −

- Uses two digits, 0 and 1
- Also called as base 2 number system
- Each position in a binary number represents a **0** power of the base (2). Example 2^0
- Last position in a binary number represents a **x** power of the base (2). Example 2^x where **x** represents the last position - 1.

Example

Binary Number: 10101_2

Calculating Decimal Equivalent −

Step	Binary Number	Decimal Number
Step 1	10101_2	$((1 \times 2^4) + (0 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0))_{10}$
Step 2	10101_2	$(16 + 0 + 4 + 0 + 1)_{10}$
Step 3	10101_2	21_{10}

Note − 10101_2 is normally written as 10101.

Octal Number System

Characteristics of the octal number system are as follows −

- Uses eight digits, 0,1,2,3,4,5,6,7
- Also called as base 8 number system
- Each position in an octal number represents a **0** power of the base (8). Example 8^0

- Last position in an octal number represents a **x** power of the base (8). Example 8^x where **x** represents the last position - 1

Example

Octal Number: 12570_8

Calculating Decimal Equivalent –

Step	Octal Number	Decimal Number
Step 1	12570_8	$((1 \times 8^4) + (2 \times 8^3) + (5 \times 8^2) + (7 \times 8^1) + (0 \times 8^0))_{10}$
Step 2	12570_8	$(4096 + 1024 + 320 + 56 + 0)_{10}$
Step 3	12570_8	5496_{10}

Note − 12570_8 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 represent the numbers starting from 10. A = 10. B = 11, C = 12, D = 13, E = 14, F = 15
- Also called as base 16 number system
- Each position in a hexadecimal number represents a **0** power of the base (16). Example, 16^0
- Last position in a hexadecimal number represents a **x** power of the base (16). Example 16^x where **x** represents the last position - 1

Example

Hexadecimal Number: $19FDE_{16}$

Calculating Decimal Equivalent –

Step	Binary Number	Decimal Number
Step 1	$19FDE_{16}$	$((1 \times 16^4) + (9 \times 16^3) + (F \times 16^2) + (D \times 16^1) + (E \times 16^0))_{10}$
Step 2	$19FDE_{16}$	$((1 \times 16^4) + (9 \times 16^3) + (15 \times 16^2) + (13 \times 16^1) + (14 \times 16^0))_{10}$
Step 3	$19FDE_{16}$	$(65536+ 36864 + 3840 + 208 + 14)_{10}$
Step 4	$19FDE_{16}$	106462_{10}

Note − $19FDE_{16}$ is normally written as 19FDE.

***Binary Subtraction using 1's and 2's Complement method:

1's Complement can be obtained by simply altering 1s to 0s and 0s to 1s. For eg, 1's Complement of (1001) is (0110). Similarly, 2's Complement can be obtained by Adding 1 to the 1's complement of a given binary number. For e.g., if (1001) is a given number then, its 1's complement is (0110) and 2's complement is (0110) +(1) = (0111)

Rules in 1s and 2s complement subtraction

Rule using 1s Complement

Step 1: Given numbers must be in the form X-Y with same digits. Extra 0 can be added at the beginning to make same digits.
Step 2: Calculate 1's complement of 'Y'
Step 3: Add result of step 2 with 'X'
Step 4: If there is extra bit, remove that extra bit and add on its remaining bit.
If there is no extra bit, find 1's Complement of result in step 3 and add (-)ve sign.

Rule using 2s Complement

Step 1: Given numbers must be in the form X-Y with same digits. Extra 0 can be added at the beginning to make same digits.
Step 2: Calculate 2's complement of 'Y'
Step 3: Add result of step 2 with 'X'
Step 4: If there is extra bit, remove that and remaining bit will be the answer.
If there is no extra bit, find 2's Complement of result in step 3 and add (-)ve sign.

Q1) Subtract (1010) from (1111) using 1's and 2's complement.
Ans. Given question is (1111) - (1010)

A) Using 1's Complement,
First calculating 1's complement of (1010) is (0101)
Adding (0101) with (1111) we get
(0101) + (1111) = (10100)
Since, there is extra bit i.e. 4 digits added with 4 digits and gives 5 digits result
Removing that extra bit and adding on it
(0100) + (1) = (0101)
Hence, result is (0101)

B) Using 2's Complement,
First calculating 2's complement of (1010) is (0101) + (1) = (0110)
Adding (0111) with (1101) we get
(0110) + (1111) = (10101)
Since, there is extra bit i.e. 4 digits added with 4 digits and gives 5 digits result
Removing that extra bit, we get (0101)
Hence, result is (0101)

Q2) Subtract (100) from (11) using 1's and 2's complement.
Ans. Given question is (11) - (100), making same digits we have (011) - (100)

A) Using 1's Complement,
First calculating 1's complement of (100) is (011)
Adding (011) with (011) we get
(011) + (011) = (110)
Since, there is no extra bit i.e. 3 digits added with 3 digits and gives 3 digits result
Calculating 1's complement of (110) we get (001) and putting (-)ve sign
Hence, result is -(001)

B) Using 2's Complement,
First calculating 2's complement of (100) is (011) + (1) = (100)
Adding (100) with (011) we get
(100) + (011) = (111)
Since, there is no extra bit i.e. 3 digits added with 3 digits and gives 3 digits result
Calculating 2's complement of (111) we get (000) + (1) = (0001) and putting (-)ve sign
Hence, result is -(001)

Q3) Subtract (1001) from (1101) using 1's and 2's complement.
Ans. Given question is (1101) - (1001)

A) Using 1's Complement,
First calculating 1's complement of (1001) is (0110)
Adding (0110) with (1101) we get
(0110) + (1101) = (10011)
Since, there is extra bit i.e. 4 digits added with 4 digits and gives 5 digits result
Removing that extra bit and adding on it
(0011) + (1) = (0100)
Hence, result is (0100)

B) Using 2's Complement,
First calculating 2's complement of (1001) is (0110) + (1) = (0111)
Adding (0111) with (1101) we get
(0111) + (1101) = (10100)
Since, there is extra bit i.e. 4 digits added with 4 digits and gives 5 digits result
Removing that extra bit, we get (0100)
Hence, result is (0100)

Q4) Perform (111100) - (1011) using 1's and 2's complement.
Ans.Given question is (111100) - (1011), making same digits we have (111100) - (001011)

A) Using 1's Complement,
First calculating 1's complement of (001011) is (110100)
Adding (110100) with (111100) we get
(110100) + (111100) = (1110000)
Since, there is extra bit i.e. 6 digits added with 6 digits and gives 7 digits result
Removing that extra bit and adding on it
(110000) + (1) = (110001)
Hence, result is (110001)

B) Using 2's Complement,
First calculating 2's complement of (001011) is (110100) + (1) = (110101)
Adding (110101) with (111100) we get
(110101) + (111100) = (1110001)
Since, there is extra bit i.e. 6 digits added with 6 digits and gives 7 digits result
Removing that extra bit, we get (110001)
Hence, result is (110001)

Q5) Perform (1010) - (101111) using 1's and 2's complement.
Ans. Given question is (1010) - (101111), making same digits we have (001010) - (101111)

A) Using 1's Complement,
First calculating 1's complement of (101111) is (010000)
Adding (010000) with (001010) we get
(010000) + (001010) = (011010)
Since, there is no extra bit i.e. 6 digits added with 6 digits and gives 6 digits result
Calculating 1's complement of (011010) we get (100101) and putting (-)ve sign
Hence, result is -(100101)

B) Using 2's Complement,
First calculating 2's complement of (101111) is (010000) + (1) = (010001)
Adding (010001) with (001010) we get
(010001) + (001010) = (011011)
Since, there is no extra bit i.e. 6 digits added with 6 digits and gives 6 digits result
Calculating 2’s complement of (011011) we get (100100) + (1) = (100101) and putting (-)ve sign
Hence, result is -(100101)