



**Al-Mamoon University**  
**College of Science**  
**Department of Medical Physics**

**lecture (1):**

**Conversion Systems, Decimal and Binary Systems**

**By:**

**Humam A. Arrak**

## Chapter One

### Conversion Systems, Decimal and Binary Systems

- ❖ We previously learned about the Decimal Number System in the principle of counting for numbers, which consists of 10 digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.
- ❖ However, modern computers use Binary Numbers instead of Decimal Numbers, and use only two digits: 0 and 1.
- ❖ There is a problem with Binary Numbers as they are very long when representing larger decimal quantities, making it difficult for people to work with them. As a result, Octal Numbers and Hexadecimal Numbers are now widely used to compress long strings of binary numbers.

**1-Binary-to-Decimal conversion:** Down table lists the binary numbers from 0000 to 1111:

Binary	Decimal
0	0
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8
1001	9
1010	10
1011	11
1100	12
1101	13
1110	14
1111	15

Whenever you look at a binary number, you can find its decimal equivalent as follows:

1. When there is a 1 in a digit position, add weight of that position.
2. When there is a 0 in a digit position, add weight of that position.

#### What is meant by the weight of this position?

In the binary system, each number has a decimal equivalent. This means the weight of the position of each digit (0) or (1) is determined by its position in the

number. The weight of the position means we multiply each rank in the binary number by a multiple starting from (1 - 2 - 4 - 8 - 16 - 32 - ..... ) from the right side. Then we add these numbers normally to get the decimal number result. This can be illustrated by the following examples:

**Ex:**

$$101 \longrightarrow 4 + 0 + 1 = 5$$

The binary number (101) consists of three ranks (units, tens, and hundreds), so we multiply each rank by a multiple from the right side of the binary number, meaning:

- Units rank: 1 multiplied by 1 ( $1 \times 1 = 1$ )
- Tens rank: 0 multiplied by 2 ( $0 \times 2 = 0$ )
- Hundreds rank: 1 multiplied by 4 ( $1 \times 4 = 4$ ) Then we add the results normally ( $4 + 0 + 1 = 5$ ) and so on...

**Ex:**

$$1011 \longrightarrow 8 + 0 + 2 + 1 = 11$$

Binary number                      Decimal equivalent

**Ex:**

$$11001 \longrightarrow 16 + 8 + 0 + 0 + 1 = 25$$

Binary number                      Decimal equivalent

## 2- Streamline Method

We can streamline binary-to-decimal conversion by the following procedure:

1. Write the binary number.
2. Directly under the binary number write 1, 2, 4, 8, 16, 32, 64, etc. working from right to left.
3. If a zero appears in a digit position, cross out the decimal weight for that position.

4. Add the remaining weight to obtain the decimal equivalent. This is considered another method for converting from the binary system to the decimal.

**Ex:**

Step 1: 101

Step 2: 4 2 1

Step 3: 4 ~~2~~ 1

Step 4:  $4 + 1 = 5$

**Ex:**

10101

1 0 1 0 1

16 ~~8~~ 4 ~~2~~ 1

$16 + 4 + 1 = 21$

For fractions, we use the same method but the multiples are denominators for the number (1) and then we convert them to the exponent form of the base (2), such as:

**Ex:**

0.101

.1/2 1/4 1/8

. $2^{-1}$   ~~$2^2$~~   $2^{-3}$

$0.5 + 0 + 0.125 = 0.625$

For mixed numbers (numbers with an integer and fractional part), handle each part according to the rules just developed. The weights for a mixed number are:

etc..... $2^3$   $2^2$   $2^1$   $2^0$  .  $2^{-1}$   $2^{-2}$   $2^{-3}$  .....etc.

**Ex:**

Convert 110.001 to a decimal number.

$$1 \quad 1 \quad 0 \quad . \quad 0 \quad 0 \quad 1$$

$$4 \quad 2 \quad \cancel{1} \quad . \quad \cancel{0.5} \quad \cancel{0.25} \quad 0.125$$

$$4 + 2 + 0.125 = 6.125 \quad \text{So, } (110.001)_2 = (6.125)_{10}.$$

**Ex:**

What is the decimal value of binary 1011.11?

$$1 \quad 0 \quad 1 \quad 1 \quad . \quad 1 \quad 1$$

$$8 \quad \cancel{4} \quad 2 \quad 1 \quad . \quad 0.5 \quad 0.25$$

$$8 + 2 + 1 + 0.5 + 0.25 = 11.75$$

**3- Decimal - to - Binary conversion (Double – Dabble Method):**

In double - dabble method you progressively divide the decimal number by 2, writing down the remainder after each division. The remainders, taken in inverse order, form the binary.

(Meaning we take the decimal number, divide it by 2, and write next to it the quotient and the remainder. As for the quotient, we take it and also divide it by 2, while the remainder represents the rank of the binary number. This process continues every time until the quotient reaches (0) meaning dividing downwards, and to write the binary number we take the remaining numbers and write them starting from bottom to top).

**Ex:** How to convert decimal 13 to its binary equivalent?

Dividing by 2	Dividing	Remaining
$13 \div 2$	6	1
$6 \div 2$	3	0
$3 \div 2$	1	1
$1 \div 2$	0	1

So, binary 1101 is equivalent to decimal 13

For fractions are concerned, we multiply by 2 and record a carry in the integer position. The carries read downward are the binary fraction.

Meaning we take the decimal fraction and multiply it by 2 and write the result next to it. As for the remainder of the result without the integer part, we take it and multiply it by 2 each time. As for the integer part of the result (the carry), it represents the rank of the binary fraction, and we repeat this process at least 5 times to get an approximate value. To write the binary number we take the integer parts and write them starting from top to bottom.

**Ex:** Convert 0.85 to binary equivalent?

Multiply by 2	The result	Fraction	Integer
$0.85 \times 2$	1.7	0.7	1
$0.7 \times 2$	1.4	0.4	1
$0.4 \times 2$	0.8	0.8	0
$0.8 \times 2$	1.6	0.6	1
$0.6 \times 2$	1.2	0.2	1

So, binary 0.11011 is equivalent to decimal 0.85.

**Ex:** Convert decimal 23.6 to a binary number?

**A:** Split decimal 23.6 into an integer of 23 and a fraction of 0.6.

Dividing by 2	Dividing	Remaining
$23 \div 2$	12	1
$11 \div 2$	5	1
$5 \div 2$	2	1
$2 \div 2$	1	0
$1 \div 2$	0	1

Multiply by 2	The result	Fraction	Integer
$0.6 \times 2$	1.2	0.2	1
$0.2 \times 2$	0.4	0.4	0
$0.4 \times 2$	0.8	0.8	0
$0.8 \times 2$	1.6	0.6	1
$0.6 \times 2$	1.2	0.2	1

The binary number is 10111.10011.

#### 4- Useful Equivalents:

The down table shows some decimal - binary equivalents. Whenever a binary number has all 1's (consists of only 1's), you can find its decimal equivalent by using this formula:

$$\text{Decimal} = 2^n - 1$$

where n is the number of bits.

Ex: 1111 has 4 bits; therefore, its decimal equivalent is:

$$\text{Decimal} = 2^4 - 1 = 16 - 1 = 15$$

Ex: 11111111 has 8 bits, so

$$\text{Decimal} = 2^8 - 1 = 256 - 1 = 255$$

Q: The Macintosh computer process binary numbers that are 32 bits long. If a 32 bit number has all 1's, what is its decimal equivalent?

$$\text{A: Decimal} = 2^{32} - 1$$

$$= (2)^8 (2)^8 (2)^8 (2)^8 - 1$$

$$= (256) (256) (256) (256) - 1$$

$$= 4294967295$$