



# Computer Fundamentals

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Lecture 5



# Numbering Systems

- Numbering system in common use → decimal
- Numbering system in computers → binary
- Other numbering systems → with different bases
- Conversion from one system to another



# Digits in Numbering Systems

- Binary numbering system (base 2)
  - ❑ 0, 1
- Octal numbering system (base 8)
  - ❑ 0, 1, 2, 3, 4, 5, 6, 7
- Decimal numbering system (base 10)
  - ❑ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- Hexadecimal numbering system (base 16)
  - ❑ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F



# Conversion Table

Binary	Octal	Decimal	Hexadecimal
0	0	0	0
1	1	1	1
10	2	2	2
11	3	3	3
100	4	4	4
101	5	5	5
110	6	6	6
111	7	7	7
1000	10	8	8
1001	11	9	9
1010	12	10	A



# Decimal System

- Decimal (base 10) numbers expressed in positional notation

The right-most is the least significant digit

$$4202 = 4 \times 10^3 + 2 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$$

The left-most is the most significant digit



4202 =  $4 \times 10^3 + 2 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$

↑ ↑

1's multiplier





# Decimal System (cont.)

## ➤ Constituents of a decimal number

$$4202 = 4 \times 10^3 + 2 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$$

Diagram illustrating the expansion of the decimal number 4202 into its constituent powers of 10:

- The number 4202 is shown with the digits 0 and 2 in the tens and units places highlighted in green.
- Below the number, a green bracket spans the entire number, labeled "10's multiplier".
- Each digit is multiplied by a power of 10: 4 (thousands), 2 (hundreds), 0 (tens), and 2 (units).
- The powers of 10 are explicitly shown as  $10^3$ ,  $10^2$ ,  $10^1$ , and  $10^0$ .
- A green bracket above the  $10^1$  term is labeled "10".



# Decimal System (cont.)

## ➤ Constituents of a decimal number

$$4202 = 4 \times 10^3 + 2 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$$

Diagram illustrating the expansion of the decimal number 4202 into its constituent powers of 10. The number 4202 is shown with green arrows pointing to the digits 4 and 2, and a bracket above the 00 indicating the multiplier 100. The equation shows the expansion:  $4202 = 4 \times 10^3 + 2 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$ . A bracket under the 100 in the original image points to the  $10^2$  term in the equation.

100's multiplier





# Decimal System (cont.)

## ➤ Constituents of a decimal number

$$4202 = 4 \times 10^3 + 2 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$$

1000's multiplier

Diagram illustrating the expansion of the decimal number 4202 into its constituent parts based on powers of 10. The number 4202 is shown on the left. A green bracket above the 4 indicates its multiplier is 1000. A green bracket below the 4 and 2 indicates their common multiplier is 1000's multiplier.



# Binary System

- Binary (base 2) numbers also expressed in positional notation

The right-most is the least significant digit

$$1101 = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

The left-most is the most significant digit



# Decimal System (cont.)

## ➤ Constituents of a binary number

$$110\mathbf{1} = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + \mathbf{1} \times 2^0$$

1's multiplier



# Decimal System (cont.)

## ➤ Constituents of a binary number

$$1101 = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

2's multiplier

The diagram illustrates the expansion of the binary number 1101 into its decimal components. The binary digits are 1, 1, 0, and 1 from left to right. The powers of 2 are 3, 2, 1, and 0 respectively. The term  $0 \times 2^1$  is highlighted in green, and a green bracket above it is labeled with a '2'. A green arrow points from the text '2's multiplier' to the powers of 2 in the equation.



# Decimal System (cont.)

## ➤ Constituents of a binary number

$$1101 = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$

4's multiplier

Diagram illustrating the expansion of the binary number 1101 into its decimal components. The binary number 1101 is shown above the equation. A green bracket above the term  $1 \times 2^2$  is labeled with the number 4. A green bracket below the terms  $1 \times 2^3$  and  $1 \times 2^2$  is labeled "4's multiplier".



# Decimal System (cont.)

## ➤ Constituents of a binary number

$$\begin{array}{c} \text{8} \\ \text{1101} = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 \end{array}$$

8's multiplier



# Why Binary?

- Natural for digital computers
- Fundamental building block of a digital computer
  - ❑ Switch - possesses two natural states, ON & OFF
- Easy to represent these states binary system
  - ❑ Only two symbols, 1 and 0
- In some ways, the binary number system is natural to us humans. How?
  
- BIT = BInary digiT
- BYTE = 8 bits



# Binary - Decimal Conversion

➤ Convert 75 from decimal to binary

2	75	remainder
2	37	1
2	18	1
2	9	0
2	4	1
2	2	0
2	1	0
	0	1

1001011





# Binary - Decimal Conversion (cont.)

➤ Convert 1001011 from binary to decimal

$$\begin{aligned} 1001011 &= 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 \\ &= 64 + 0 + 0 + 8 + 0 + 2 + 1 \\ &= 75 \end{aligned}$$



# Binary - Octal Conversion

- Convert 1001011 from binary to octal
- Make groups of three bits from right
- Add additional zeroes on the left side (if required)
- Convert each group into corresponding number

001 001 011  
└─┘ └─┘ └─┘

- Convert from octal to binary in similar fashion



# Binary - Hexadecimal Conversion

- Convert 1001011 from binary to hexadecimal
- Make groups of four bits from right
- Add additional zeroes on the left side (if required)
- Convert each group into corresponding number

01 00    1011  
    └─┘    └─┘

- Convert from hexadecimal to binary in similar fashion



# Binary Numbers with Fractions

- Decimal numbers have decimal point
  - ❑ E. g. 43.781
- Similarly binary numbers have binary points
  - ❑ E. g. 10111.1011
- Decimal - binary conversion possible



# Binary Numbers with Fractions (cont.)

- Convert 75.56 from decimal to binary up to 5 binary points

2	75	remainder
2	37	1
2	18	1
2	9	0
2	4	1
2	2	0
2	1	0
	0	1

$2 \times 0.56 =$	1.12
$2 \times 0.12 =$	0.24
$2 \times 0.24 =$	0.48
$2 \times 0.48 =$	0.96
$2 \times 0.96 =$	1.92

1001011.10001



# Binary Numbers with Fractions (cont.)

➤ Convert 1011.11 from binary to decimal

$$\begin{aligned} 1011.11 &= 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 + 1 \times 2^{-1} + 1 \times 2^{-2} \\ &= 8 + 0 + 2 + 1 + 0.5 + 0.25 \\ &= 11.75 \end{aligned}$$



# Binary Addition

## ➤ Basic addition

- ❑  $0 + 0 = 0$
- ❑  $0 + 1 = 1$
- ❑  $1 + 0 = 1$
- ❑  $1 + 1 = 10$
- ❑  $1 + 1 + 1 = 11$

## ➤ Add 1011.1101 with 11.001

1 0 1 1 . 1 1 0 1

+ 1 1 . 0 0 1 0

---

= 1 1 1 0 . 1 1 1 1



# Binary Subtraction

## ➤ Basic subtractions

- ❑  $0 - 0 = 0$
- ❑  $1 - 0 = 1$
- ❑  $1 - 1 = 0$
- ❑  $10 - 1 = 1$
- ❑  $11 - 1 = 10$

## ➤ Subtract 11.001 from 1110.1111

1 1 1 0 . 1 1 1 1

- 1 1 . 0 0 1 0

---

= 1 0 1 1 . 1 1 0 1





# Binary Multiplication

## ➤ Basic Multiplications

❑  $0 \times 0 = 0$

❑  $0 \times 1 = 0$

❑  $1 \times 0 = 0$

❑  $1 \times 1 = 1$

## ➤ Multiply 101 by 1110

1 1 1 0

$\times 1 0 1$

---

1 1 1 0

0 0 0 0  $\times$

1 1 1 0  $\times \times$

---

1 0 0 0 1 1 0



# Binary Division

## ➤ Basic Divisions

❑  $0 / 1 = 0$

❑  $1 / 1 = 1$

## ➤ Divide 11010 by 101

$$\begin{array}{r} 101 \\ 101 \overline{) 11010} \\ \underline{101} \phantom{0} \\ 0011 \\ \underline{000} \phantom{0} \\ 0110 \\ \underline{101} \phantom{0} \\ 001 \end{array}$$