



# 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



# Decimal System (cont.)

## ➤ Constituents of a decimal number

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

1's multiplier

1



# Decimal System (cont.)

## ➤ Constituents of a decimal number

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

10's multiplier

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

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

The diagram illustrates the expansion of the binary number 1101 into its decimal components. The binary digits are 1, 1, 0, and 1, corresponding to the powers of 2 from 3 down to 0. The last digit, 1, is highlighted in green in the original image. A green bracket above the last '1' indicates its multiplier, 2^0. A green bracket below the last '1' and the '0' indicates their multiplier, 2^1. A green bracket below the last '1' and the '0' and the '1' indicates their multiplier, 2^2. A green bracket below the last '1' and the '0' and the '1' and the '1' indicates their multiplier, 2^3. The text '1's multiplier' is centered below the equation.



# Decimal System (cont.)

## ➤ Constituents of a binary number

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

2's multiplier

Diagram illustrating the expansion of the binary number 1101 into its constituent powers of 2. The binary number 1101 is shown above the equation. A green bracket above the 0 in 1101 is labeled with a superscript 2, indicating the power of 2 for that digit. A green bracket below the 1101 is labeled "2's multiplier", indicating the base 2 used in the expansion.



# 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

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