1. Computer Architectures

The Management of the Information

Summary

- Raw data
- Information and Knowledge
- The management of the Information
- The management of the Information: Binary Code
- ASCII Code
- Understanding Digital Data Sizes
- Binary Code: Properties
- Converting Binary to Decimal
- Converting Decimal to Binary
- Boolean Algebra
- The Von Neumann Model

ISTITUTO TECNOLOGICO SUPERIORE ACADEMY – INFORMATION AND COMMUNICATIONS TECHNOLOGY
its ICTAcademy
INFORMATION AND COMMUNICATIONS TECHNOLOGY

Raw data

Data refers to **raw**, **unprocessed facts** that are **collected from different sources**. These facts can be **numbers**, **symbols**, **characters**, or even **observations**.

Data on its own does not have any meaning or context until it is processed or interpreted.

Examples of "data" include:

- a value (e.g., 35),
- a series of measurements,
- a name,
- a color,

... and so on.

Key Point:

Data is unorganized and has no direct significance by itself.

Information and Knowledge

Information is what you get when data is **processed** and **organized**, giving **context** to data.

Example of "information":

- a value associated with degrees Celsius (e.g., 35°C) represents a temperature value.

Knowledge is the understanding and insight gained from **interpreting** information, making it useful for decision-making. Knowledge answers questions like "what," "who," "when," and "how much."

Example of "knowledge":

- a temperature value such as 35°C becomes knowledge when it is interpreted as a warm environment.

The Management of the Information: Binary Code/1

Any information **stored** or **retrieved** by a device (such as desktop computers, laptops, or smartphones) must be represented in a language that the device can understand. This language is known as **Binary Code**.

Binary Code is defined as a **coding system** that uses the binary digits **0** and **1** to represent letters, digits, or other characters in a computer or other electronic devices, such as smartphones and tablets.

More specifically, a **BIT (Binary digit)** is the **basic unit of information** used by devices to manage all types of data. A single BIT can exist in one of two states: 0 or 1.

NOTE: With a single BIT, only two elements can be represented.

For example:

1 = “A”

0 = “B”

What about more complex information? BITS COMBINATION.

ICTAcademy
INFORMATION AND COMMUNICATIONS TECHNOLOGY

The Management of the Information: Binary Code/2

Bits and Combinations:

- One bit can have 2 states: 0 or 1.
- With **N bits** we can create $\mathbf{2^N}$ **distinct combinations**.

Examples:

- **1 bit:** $2^1 = 2$ combinations (0, 1)
- **2 bits:** $2^2 = 4$ combinations (00, 01, 10, 11)
- **3 bits:** $2^3 = 8$ combinations (000, 001, 010, 011, 100, 101, 110, 111)

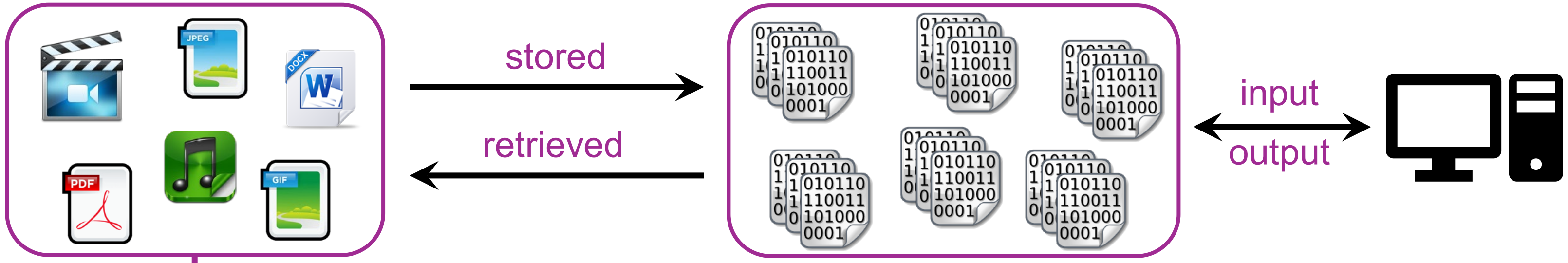
Range of Values:

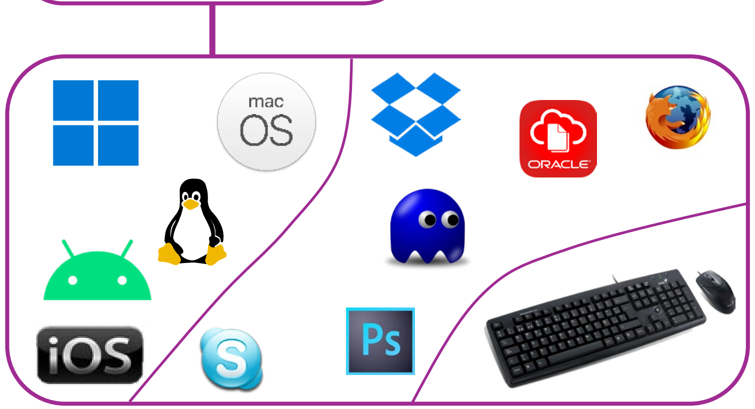
With **N bits**, the representable values range from **0** to $\mathbf{2^N - 1}$.

Examples:

- **1 bit:** $2^1 - 1 = 1$, representable values in range [0,1]
- **2 bits:** $2^2 - 1 = 3$, representable values in range [0,3]
- **3 bits:** $2^3 - 1 = 7$, representable values in range [0,7]

The Management of the Information: Binary Code/3





Inside the device, **everything** is represented by a **set of binary digits**. More specifically:

- Any **Operating System**
(e.g., Windows, Android, Mac OS, Linux)
- Any **Program/Application**
(e.g., Word, Excel, Skype, Firefox)
- Any **Command/Interaction**
(e.g., Keyboard, Mouse, Touchpad)

ASCII Code

ASCII: The American Standard Code for Information Interchange typically uses **7 bits** to represent each character, which allows for **128 unique character** codes.

Extended ASCII: ASCII is sometimes extended to **8 bits**, which enables an **additional 128 characters**, bringing the total to 256. This extension isn't standardized in the same way as the original 7-bit ASCII, and there are various extended ASCII sets, like ISO 8859-1 or Windows-1252, which include characters for **specific languages** or **graphical symbols**.

Types of Characters:

- **Alphanumeric Characters:** This includes all uppercase and lowercase English letters and numbers (0-9).
- **Symbols:** ASCII includes a set of common punctuation symbols and other miscellaneous symbols like @, #, $, etc.
- **Control Characters:** These are non-printable characters that control the flow of text or its processing in some way. Examples include TAB (horizontal tab), LF (line feed), CR (carriage return), and BEL (bell/alert).

ASCII Code - Examples

Standard ASCII Table (7-bit)

Decimal	Hex	Binary	Character	Description
32	20	00100000	(space)	Space
48	30	00110000	0	Digit Zero
65	41	01000001	A	Uppercase A
97	61	01100001	a	Lowercase a
10	0A	00001010	LF	Line Feed
13	0D	00001101	CR	Carriage Return

Extended ASCII Table (8-bit)

Decimal	Hex	Binary	Character	Description
128	80	10000000	Ç	Latin Capital Letter C with Cedilla
165	A5	10100101	¥	Yen Sign
178	B2	10110010	^{2}	Superscript Two
225	E1	11100001	á	Lowercase a with acute
245	F5	11110101	õ	Lowercase o with tilde

Understanding Digital Data Sizes/1

This table provides a comparison of data sizes using different prefixes, their decimal sizes, binary approximations, and practical examples.

- A group of **8 bits** is named **Byte**;

Abbr.	Prefix-Byte	Decimal Size	Size in Thousands	Binary Approximation	An Example
K	Kilo-	10^3	$1,000^1$	$1,024 = 2^{10}$	A text file (e.g., 1 KB)
M	Mega-	10^6	$1,000^2$	$1,024^2 = 2^{20}$	A song (e.g., MP3 file, 4 MB)
G	Giga-	10^9	$1,000^3$	$1,024^3 = 2^{30}$	A HD film (e.g., MP4 file, 1.5 GB)
T	Tera-	10^{12}	$1,000^4$	$1,024^4 = 2^{40}$	A large backup drive (e.g., 1 TB of data)
P	Peta-	10^{15}	$1,000^5$	$1,024^5 = 2^{50}$	Storage of large-scale research data (e.g., climate data, 1 PB)
E	Exa-	10^{18}	$1,000^6$	$1,024^6 = 2^{60}$	Entire data usage of a major tech company (e.g., Google, 1 EB)

Understanding Digital Data Sizes/2

Inside each device, **information** is represented by a fixed set of bytes:

- 16 bits (**2 bytes**)
- 32 bits (**4 bytes**)
- 64 bits (**8 bytes**)

The number of bytes indicates the “power” of a device. The greater the number of bytes:

- The greater the device's ability **to perform complex computations**
- The greater the device's capacity **to manage large amounts of information**
- The greater the device's capability **to process complex instructions**

Binary Code: Properties

Like every numerical system, binary code has its own **intrinsic properties**. One key property, shared with other **positional systems**, is the ability to convert numbers from one numerical base to another.

Furthermore, the **binary system** supports the **four basic operations**:

- Addition;
- Subtraction;
- Multiplication;
- Division.

NOTE:

A number represented using **two digits** is called a **binary number** (**base two**).

A number represented using **ten digits** is called a **decimal number** (**base ten**).

Converting Decimal to Binary

To convert a decimal number (base 10) to a binary number (base 2), follow these steps:

1. **Divide** the number by 2.
2. **Record** the remainder (0 or 1). This will be the least significant bit (LSB).
3. **Continue dividing** the quotient obtained in the previous step by 2, **recording** the remainders.
4. **Repeat** until the quotient is 0.
5. **Write the remainders in reverse order**: from the last obtained to the first.

   This represents the number in binary.

Converting $\mathbf{13_{10}}$ to Binary:

$13 \div 2 = 6$, remainder $= 1$
$6 \div 2 = 3$, remainder $= 0$
$3 \div 2 = 1$, remainder $= 1$
$1 \div 2 = 0$, remainder $= 1$

Result in binary: $\mathbf{1101_2}$

Converting Binary to Decimal

To convert a binary number (base 2) to a decimal number (base 10), follow these steps:

1. **Write down** the binary number.
2. **List the powers of 2** from right to left, starting with 2^0 under the rightmost bit.
3. **Multiply each bit** by the corresponding power of 2.
4. **Sum** the results to get the decimal number.

Converting $\mathbf{1101_2}$ to Decimal:

$$\begin{aligned} 1101 &= 1 \cdot 2^3 + 1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 \\ &= 8 + 4 + 0 + 1 = 13 \end{aligned}$$

Result in decimal: $\mathbf{13_{10}}$

Binary Addition/1

1. **Take** the two binary numbers you want to add.

   NOTE: Make sure both numbers are of the same length.

   If not, add leading zeros to the shorter number until they are of the same length.

2. **Start adding** the bits from the rightmost side (least significant bit) of the two binary numbers, following these rules:

Case	A + B	Sum	Carry
1	0 + 0	0	0
2	0 + 1	1	0
3	1 + 0	1	0
4	1 + 1	0	1

3. **Proceed by adding** the successive bits and considering any carries from the previous columns. If after adding the last bit there remains a carry, write it in the leftmost column of the result.

ICTAcademy
INFORMATION AND COMMUNICATIONS TECHNOLOGY

Binary Addition/2

Example 1 (1011 + 1101):

```
  1011
+ 1101
-----------
 11000 (Result: carry applied)
```

Step-by-step addition with carry:

$1 + 1 = 0$ (carry 1)

$1 + 0 + 1$ (carry) $= 0$ (carry 1)

$0 + 1 + 1$ (carry) $= 0$ (carry 1)

$1 + 1 + 1$ (carry) $= 1$ (carry 1 to a new column)

Example 2 (1011 + 101):

```
  1011
+ 0101
-----------
 10000 (Result: carry applied)
```

Step-by-step addition with carry:

$1 + 1 = 0$ (carry 1)

$1 + 0 + 1$ (carry) $= 0$ (carry 1)

$0 + 1 + 1$ (carry) $= 0$ (carry 1)

$1 + 0 + 1$ (carry) $= 0$ (carry 1 to a new column)

Binary Subtraction/1

1. **Take** the two binary numbers you want to subtract.

   NOTE: Make sure both numbers are of the same length.

   If not, add leading zeros to the shorter number until they are of the same length.

2. **Start subtracting** the bits from the rightmost side (least significant bit) of the two binary numbers, following these rules:

Case	A - B	Difference	Borrow
1	0 - 0	0	0
2	1 - 0	1	0
3	1 - 1	0	0
4	0 - 1	1	1

3. **Proceed by subtracting** the successive bits and considering any borrows from the previous columns. If after subtracting the last bit there remains a borrow, write it in the leftmost column of the result.

Binary Subtraction/2

Example 1 (1110 – 1001):

```
  1110
- 1001
---------
  0101 (Result: borrow applied)
```

Step-by-step subtraction with borrow:

0 - 1 = 1 (borrow 1)

1 - 0 - 1 (borrow) = 0

1 - 0 = 1

1 - 1 = 0

Example 2 (1011 - 101):

```
   1011
-  0101
-----------
   0110 (Result: borrow applied)
```

Step-by-step subtraction with borrow:

1 – 1 = 0

1 – 0 = 1

0 - 1 = 1 (borrow 1)

1 - 0 - 1 (borrow) = 0

Boolean Algebra/1

Boolean Algebra is a branch of algebra that deals with **true** or **false** values, typically denoted as **1** and **0**, respectively. It is fundamental in the field of **computer science** and **digital electronics** because it is used to design and analyze the **behavior of digital circuits** and **logic gates**.

Key Concepts:

- **Binary Variables:** Represented as 1 (true) and 0 (false).
- **Logical Operations:**

  AND ($\cdot$): Yields true if both operands are true ($1 \cdot 1 = 1$).

  OR ($+$): Yields true if at least one operand is true ($1 + 0 = 1$).

  NOT ($\neg$): Yields the inverse of the operand ($\neg 1 = 0$).

Boolean Algebra/2

TRUTH TABLES

A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

A	NOT A
0	1
1	0

Boolean Algebra/3

- **Commutative:**

A OR B = B OR A

A AND B = B AND A

- **Distributive:**

A OR (B AND C) = (A OR B) AND (A OR C)

A AND (B OR C) = (A AND B) OR (A AND C)

- **De Morgan's Law:**

NOT (A AND B) = (NOT A) OR (NOT B)

NOT (A OR B) = (NOT A) AND (NOT B)

- **Precedence Rules:**

- NOT has the highest precedence;
- followed by AND;
- lastly, OR.

To alter the precedence, use parentheses.

Boolean Algebra/4

Example:

A AND NOT (B OR C)

A	B	C	A AND NOT (B OR C)
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0

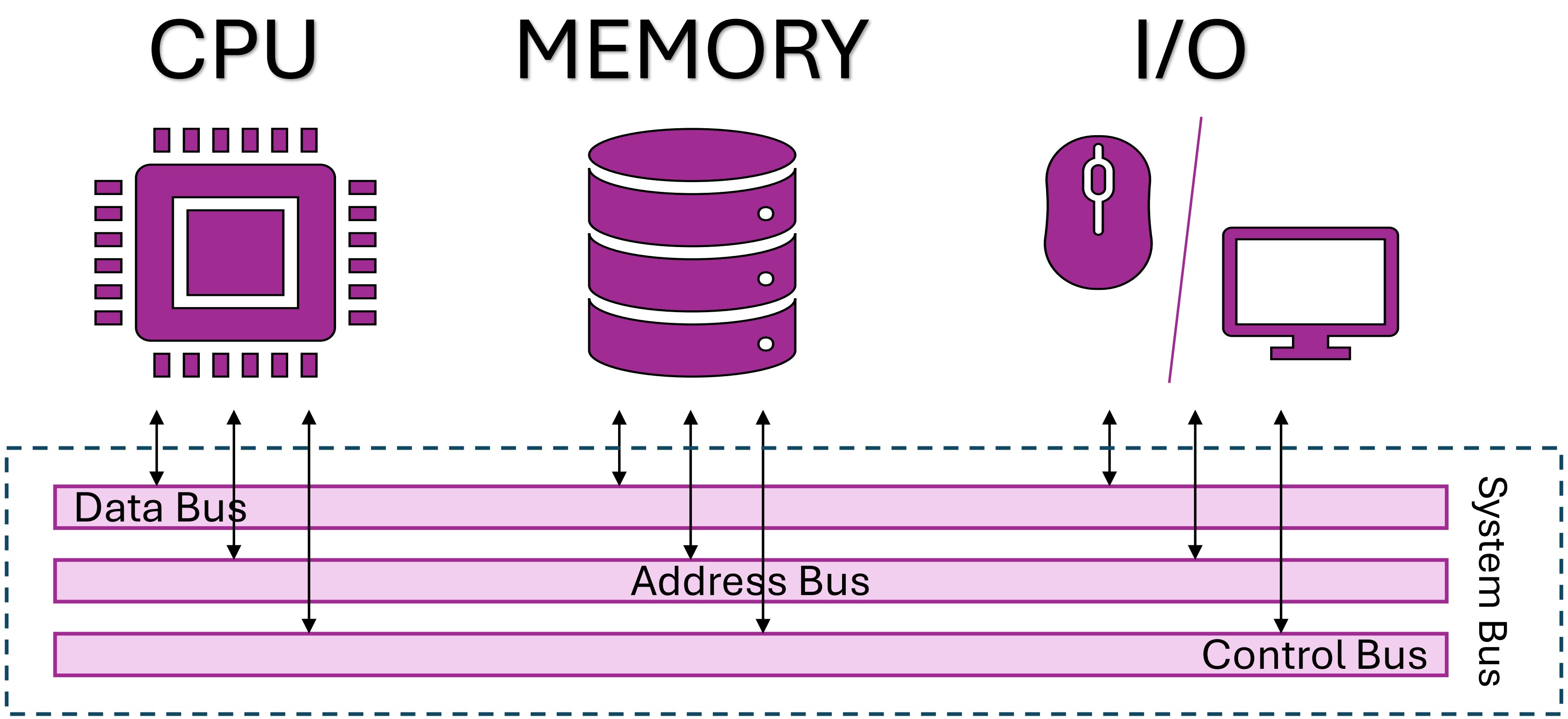
The Von Neumann Model/1

The **Von Neumann Architecture** is a **foundational concept for modern computing systems**, characterized by its structure where data and program code are stored in the same memory space.

The typical **Von Neumann Model** consists of 4 main components:

- **Memory:** Stores both data and instructions.
- **Central Processing Unit:**
  - **Arithmetic Logic Unit (ALU):** Executes all arithmetic and logical operations.
  - **Control Unit (CU):** Decodes program instructions and controls the other components based on these instructions.
- **Input and Output (I/O):** Handle data exchange between the computer system and the external environment.
- **Bus:** Provides a communication system that transfers data between components.

The Von Neumann Model/2



1. Computer Architectures

The Management of the Information

(Additional Resources)

INFORMATION AND COMMUNICATIONS TECHNOLOGY

Two’s Complement

Two's Complement is a method used in computer science and electronics to represent **signed integers** in binary systems. It is particularly useful because it **simplifies arithmetic operations**, such as addition and subtraction, allowing both **positive** and **negative numbers** to be handled by the same logical circuits.

Basics Concepts:

- The most significant bit (MSB) is used as the sign bit:
  - 0: indicates a positive number.
  - 1: indicates a negative number.
- **Negative numbers** are represented by **calculating the two's complement** of their corresponding **positive value**. **Positive numbers** are represented by **calculating the two's complement** of their corresponding **negative value**.

Examples:

+3 in 4-bit binary is $\underbrace{\boxed{0}}_{\text{MSB}}\,011 \longrightarrow$ positive number

-3 in 4-bit binary is $\underbrace{\boxed{1}}_{\text{MSB}}\,101 \longrightarrow$ negative number

How to Calculate Two's Complement 1/2

To find the two's complement of a binary number:

1. **Invert all the bits** of the binary number (one's complement).
2. **Add 1** to the result of the previous step.

Positive -> Negative

Let's assume we are using 4-bit numbers.

Representation of +3:

- The binary representation is: 0011 (4 bits).

Representation of -3:

- **Invert the bits** of +3 (0011): the result is 1100 (one's complement).
- **Add 1 (i.e., 0001)** to 1100.

```
  1100
+ 0001
-------------
  1101 → -3 in 4-bit binary
```

How to Calculate Two’s Complement 2/2

To find the two's complement of a binary number:

1. **Invert all the bits** of the binary number (one's complement).
2. **Add 1** to the result of the previous step.

Negative -> Positive

Let’s assume we are using 4-bit numbers.

Representation of -3:

- The binary representation is: 1101 (4 bits).

Representation of +3:

- **Invert the bits** of -3 (1101): the result is 0010 (one's complement).
- **Add 1 (i.e., 0001)** to 0010.

$$\begin{array}{r} 0010 \\ +\ 0001 \\ \hline 0011 \end{array} \longrightarrow +3 \text{ in 4-bit binary}$$

Two’s Complement Properties

- **Single Zero Representation:** In two's complement, positive zero (`0000`) and negative zero (`0000`) share the same binary representation, avoiding ambiguity.

- **Ease of Addition and Subtraction:** To subtract a number, you simply add its two's complement.

  Examples:

  - “5 – 3” can be performed as “5 + (– 3)” in binary.
  - “-5 – 3” can be performed as “-5 + (-3)” or as “(5 + 3) applying the two's complement to the result” in binary.

  By converting subtraction into addition using two's complement, binary arithmetic becomes simpler and more efficient, particularly in digital systems like computers and calculators.

- **Range of Values:** For an N-bit system, two's complement allows representation of numbers from -2^{N-1} to $2^{N-1} - 1$. For example, with 4 bits, from -8 to +7.