

# Hardware Systems Definitions & Taxonomies (Part I)

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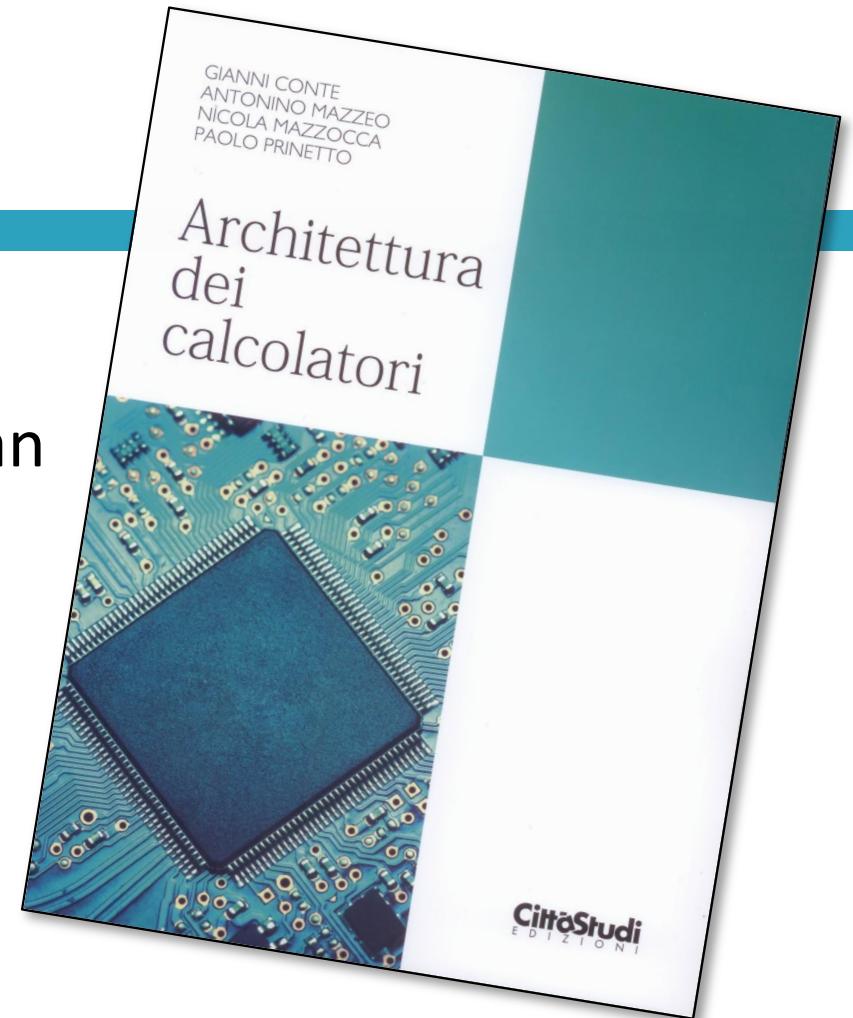
# Goal

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- The lecture first introduces the concept of System
- Four of the most widely used taxonomies for digital systems are then introduced
- Some detailed modellings conclude the lecture.

# Further readings

- Students interested in making a reference to a textbook on the arguments covered in this lecture can refer, for instance, to:
  - G. Conte, A. Mazzeo, N. Mazzocca, P. Prinetto: “Architettura dei calcolatori”, Città Studi, 2015  
(Chapter 1: Classificazioni e Concetti base)  
(In Italian)



# Outline

- The concept of System
- System Taxonomies
  - Information coding
  - Memory capability
  - Functionality
  - Implementation
- Data vs Control vs Timing
- Synchronous Sequential Circuits

# Splitting

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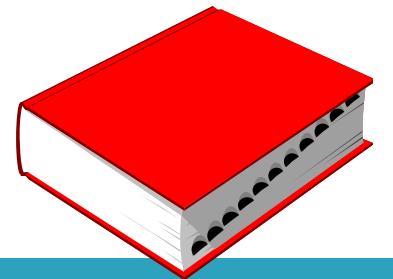
- For sake of usability, the lecture is split in 2 parts:
  - The concept of System
  - System Taxonomies
    - Information coding
    - Memory capability
    - Functionality
  - .....
    - Implementation
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# System

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- Combination of interacting elements organized to achieve one or more stated purposes.

[ISO/IEC/IEEE 15288: 2015]

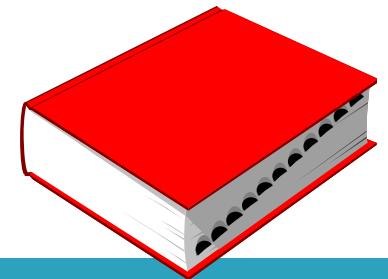
# System

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- Combination of interacting elements organized to achieve one or more stated purposes.
  - Examples include: *general and special-purpose information systems; command, control, and communication systems; crypto modules; central processing units and graphics processor boards; industrial/process control systems; weapons systems; medical devices and treatment systems; financial, banking, and merchandising transaction systems; and social networking systems.*

[ISO/IEC/IEEE 15288: 2015]

# System



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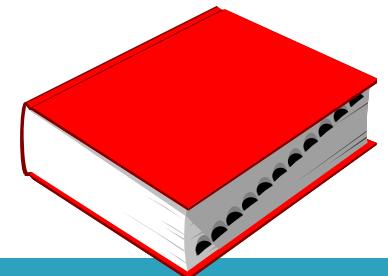
- An entity that interacts with other entities, i.e., other systems, including hardware, software, humans, and the physical world with its natural phenomena

# System

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- Systems are used to deliver (provide) *services*

# Delivered services

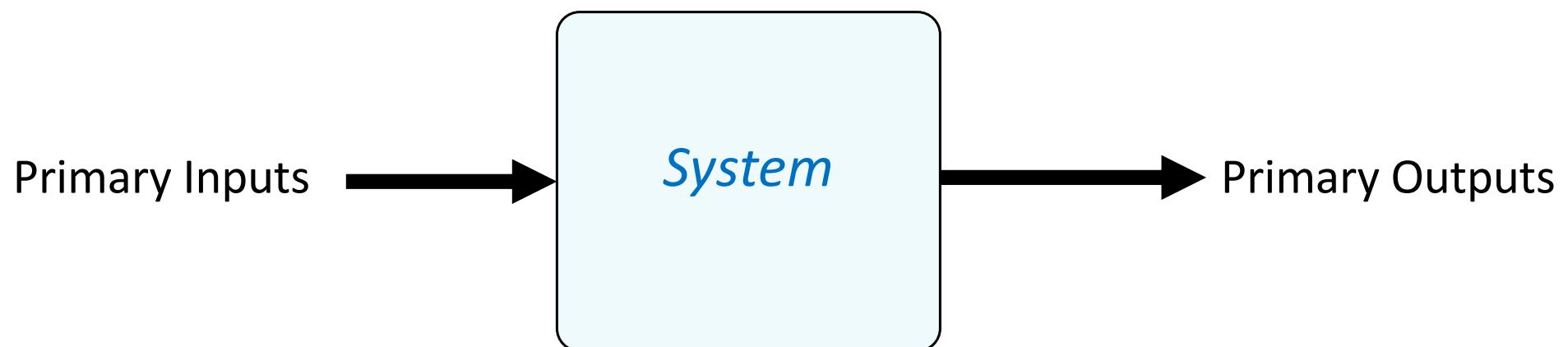


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- The service delivered by a system (in its role as a *provider*) is its behavior as it is perceived by its user(s), i.e., by another system that receives services from the provider

# System I/O signals

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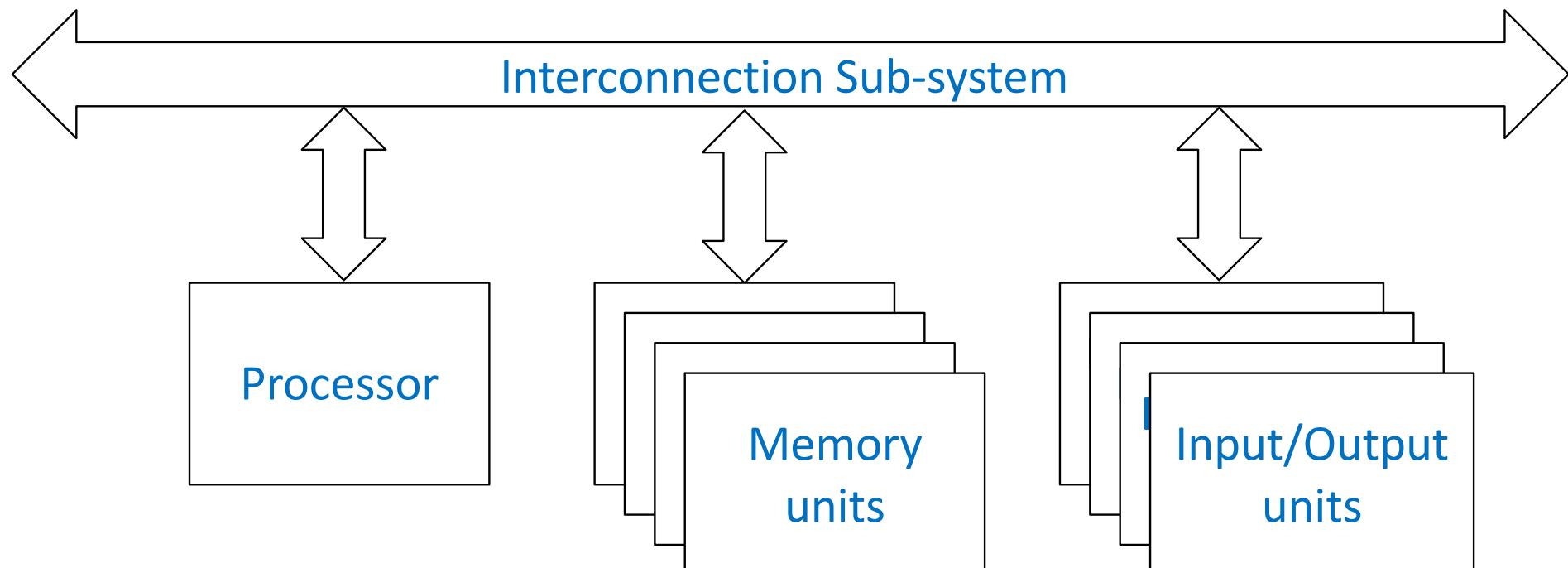
# Typical internal structure

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- Today systems are mostly implemented resorting to one (or more) *Processing Elements*

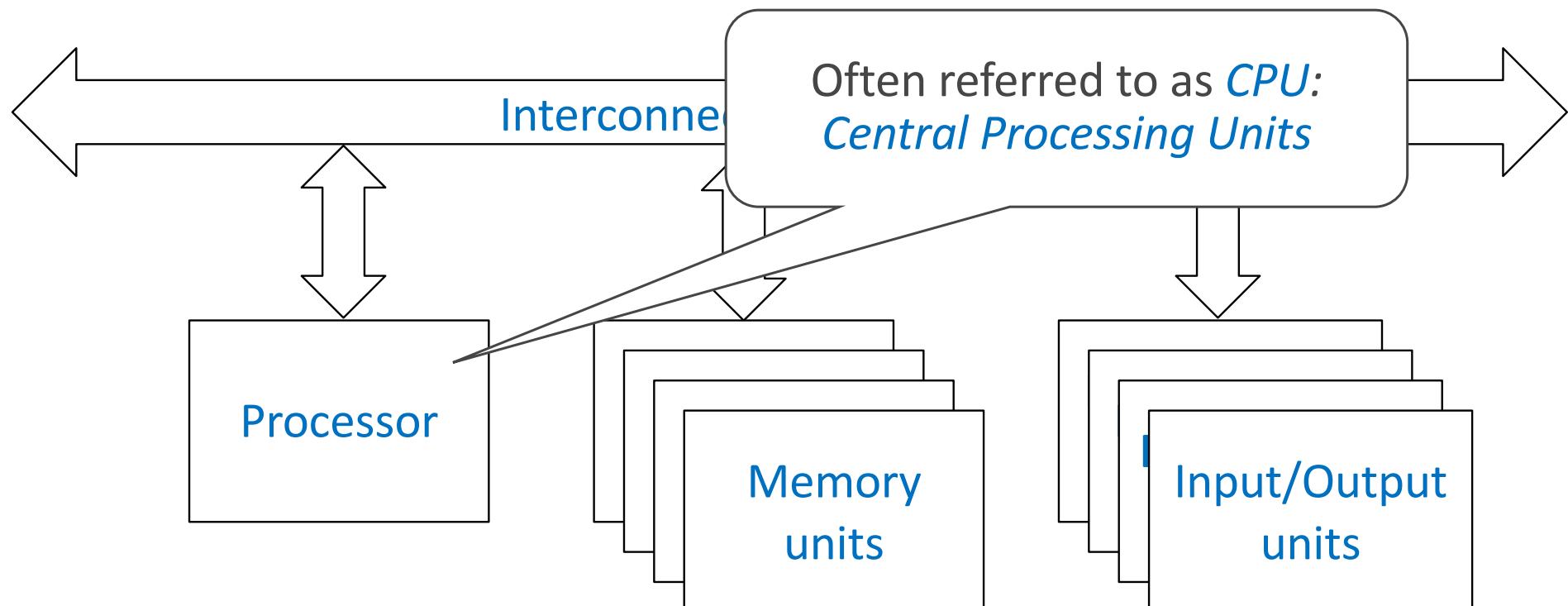
# Processing Element

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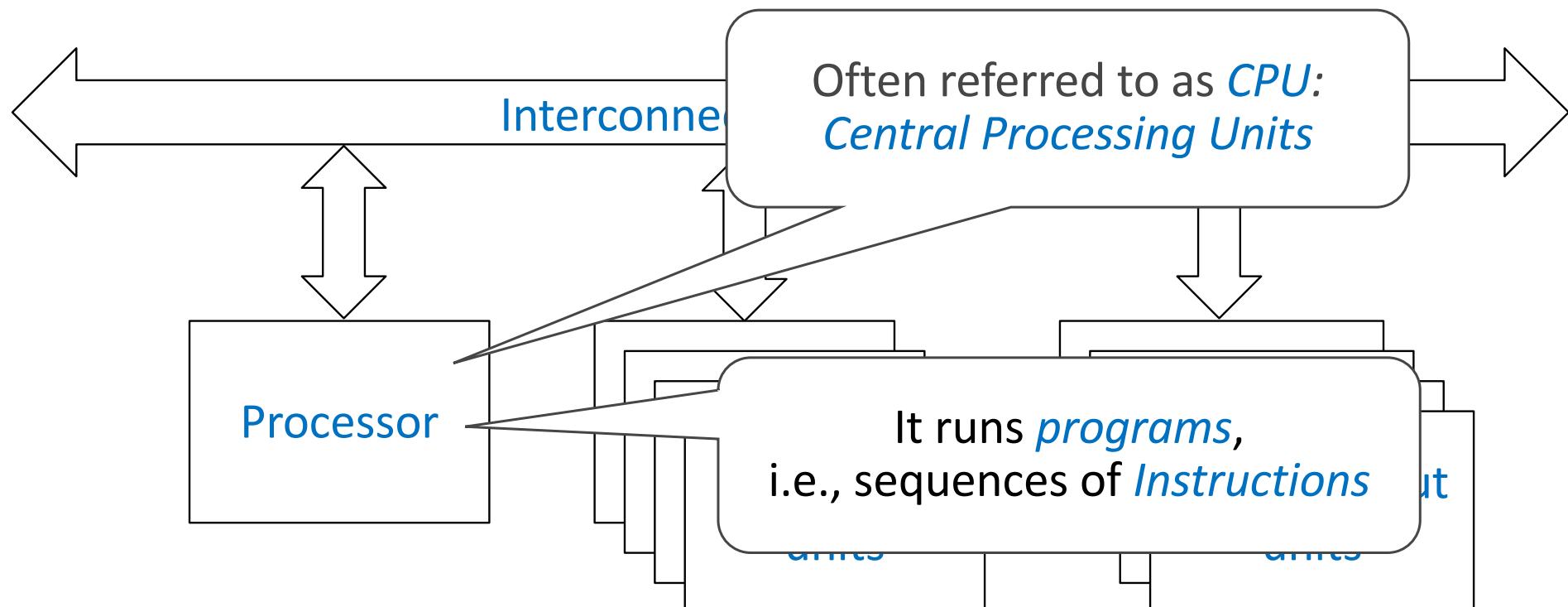
# Processing Element

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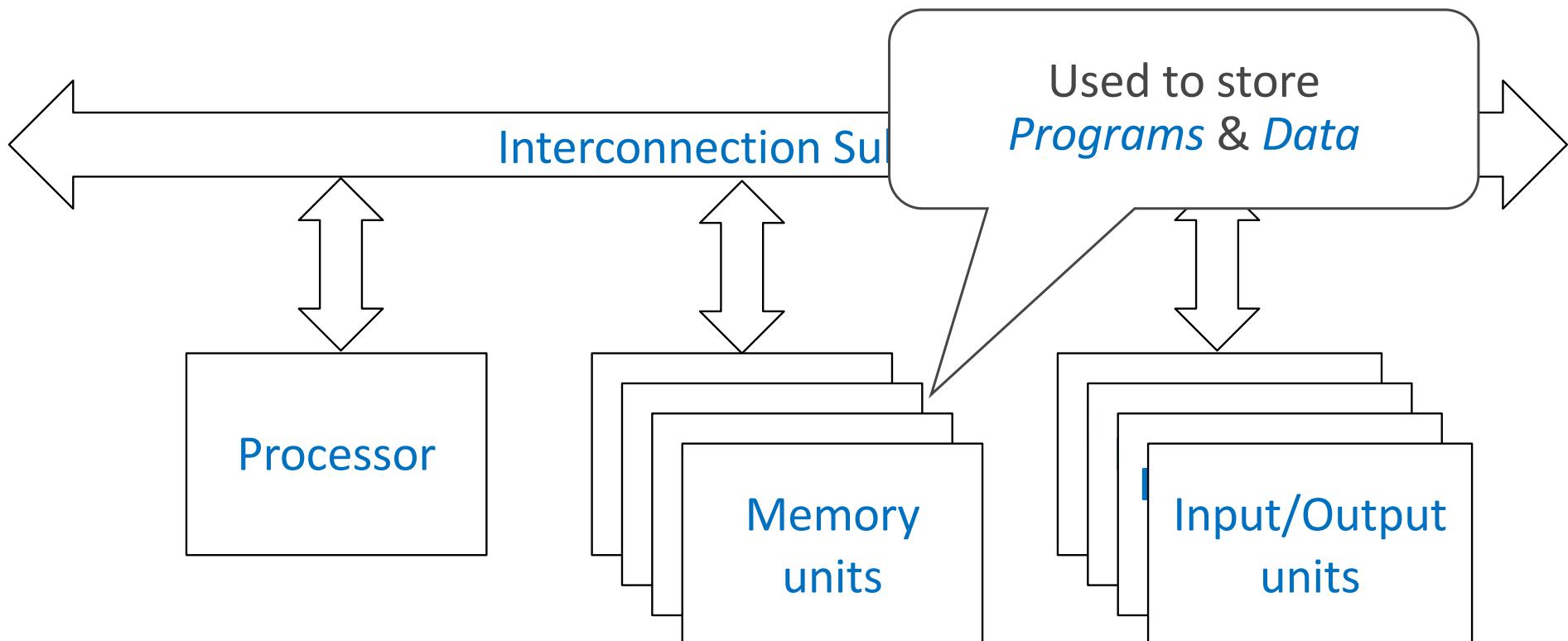
# Processing Element

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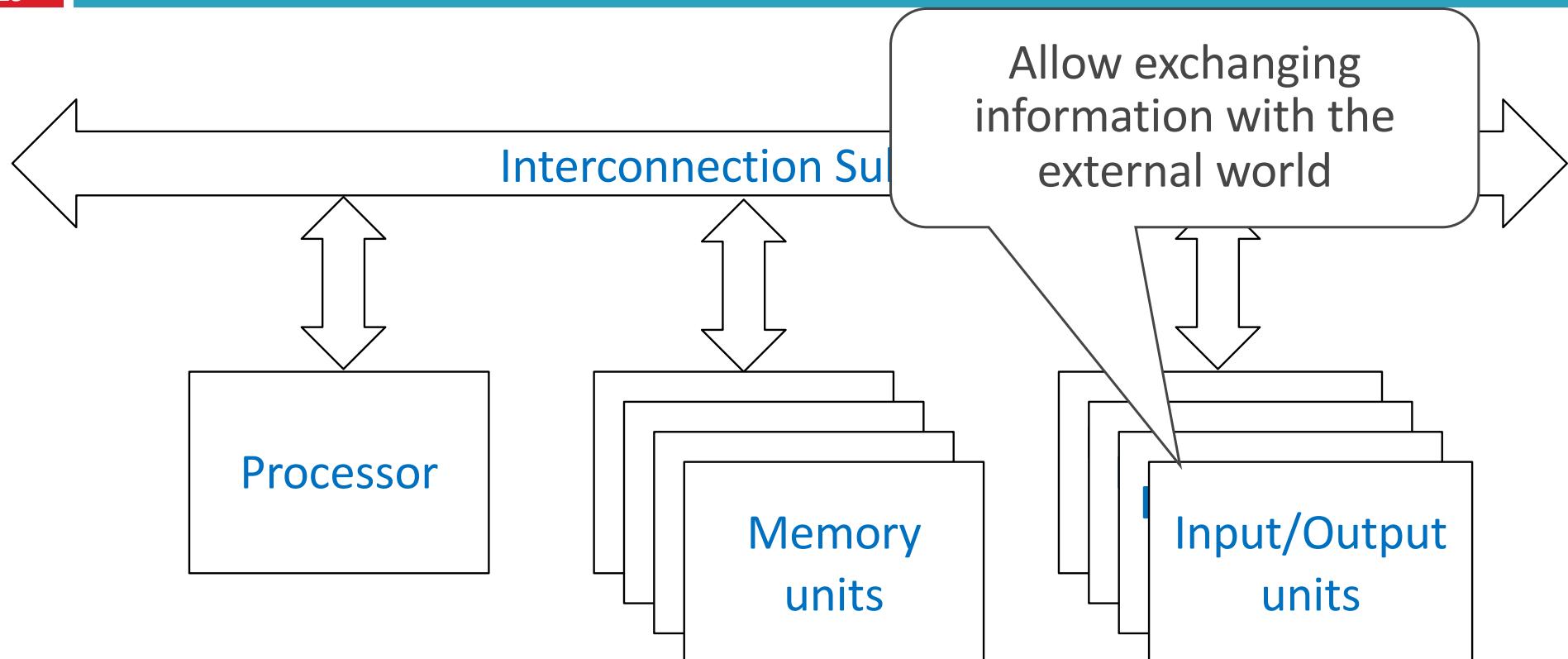
# Processing Element

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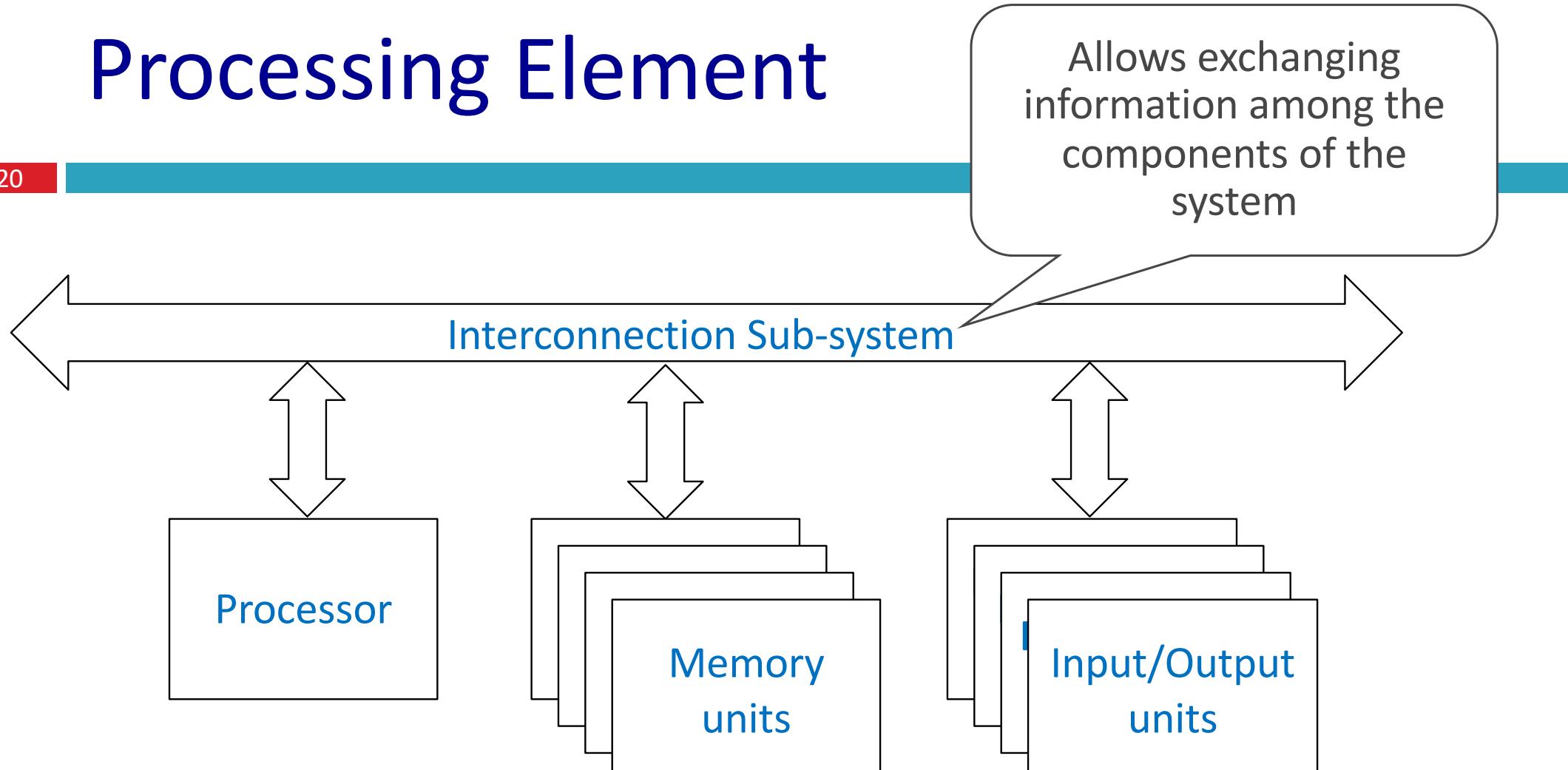
# Processing Element

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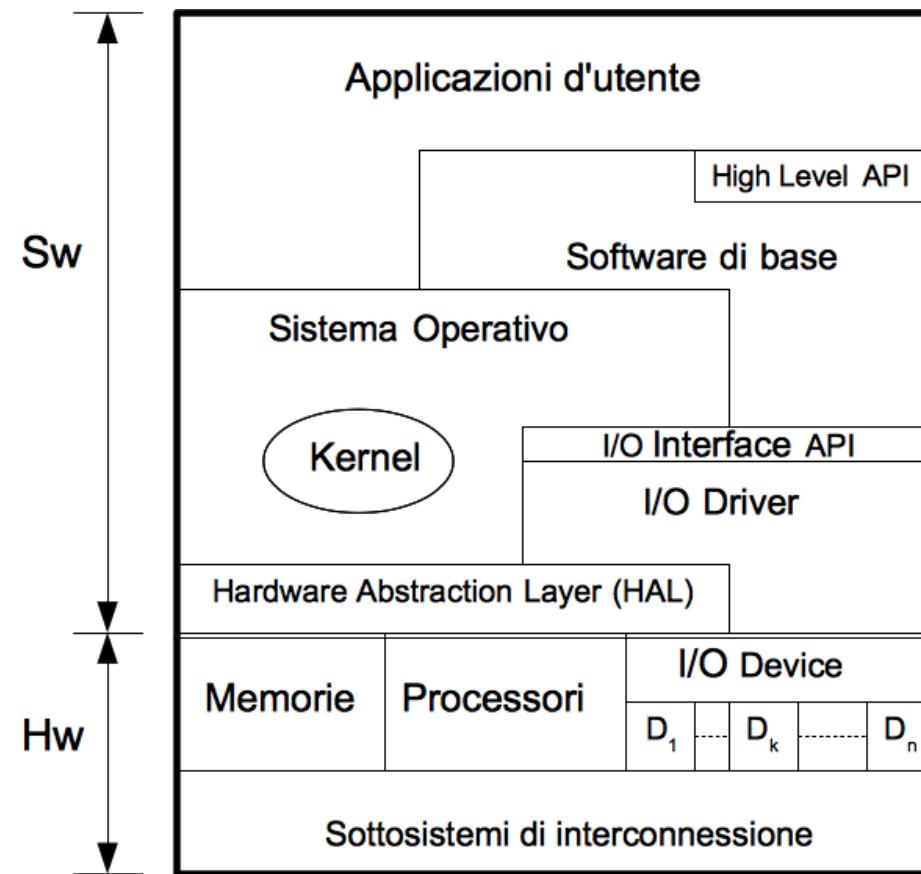
# Processing Element

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# Processing Element

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# Outline

- The concept of System
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  - Functionality
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- Synchronous Sequential Circuits

# System Taxonomies

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- A plenty of possible taxonomies exists about hardware systems.
- In the sequel we shall focus just on the following ones:
  - Information coding
  - Memory capability
  - Functionality
  - Implementation

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# Information coding

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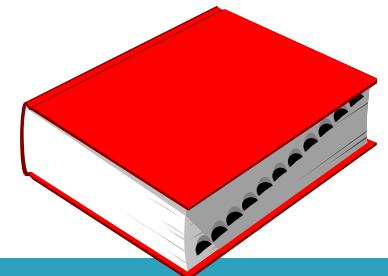
- Analog System
- Digital System



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# Digital System



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- A proper assembly of electronic devices, designed to store, transform, and communicate information items in digital form, i.e., as a proper sequence of *bits*.

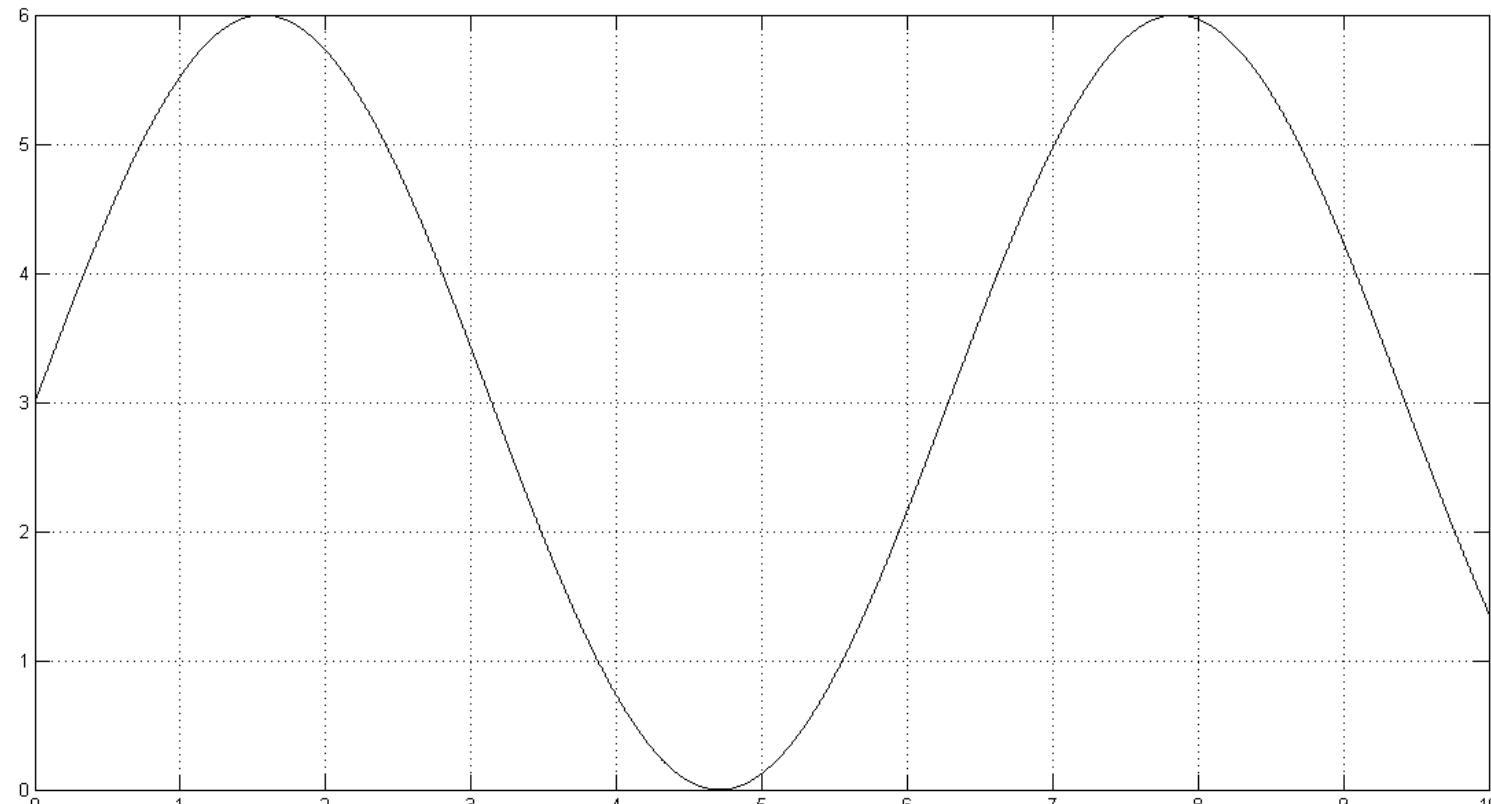
# Analog System



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- When we say something is analog, we often simply mean that it's not digital: the job it does, or the information it handles, doesn't involve processing numbers electronically

# Analog signal

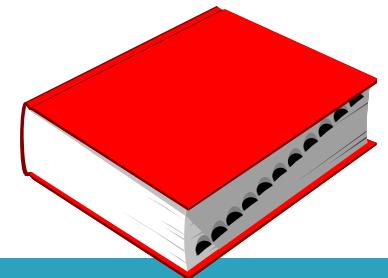


# A2D conversion

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- Requires:
  - Sampling
  - Digitalization

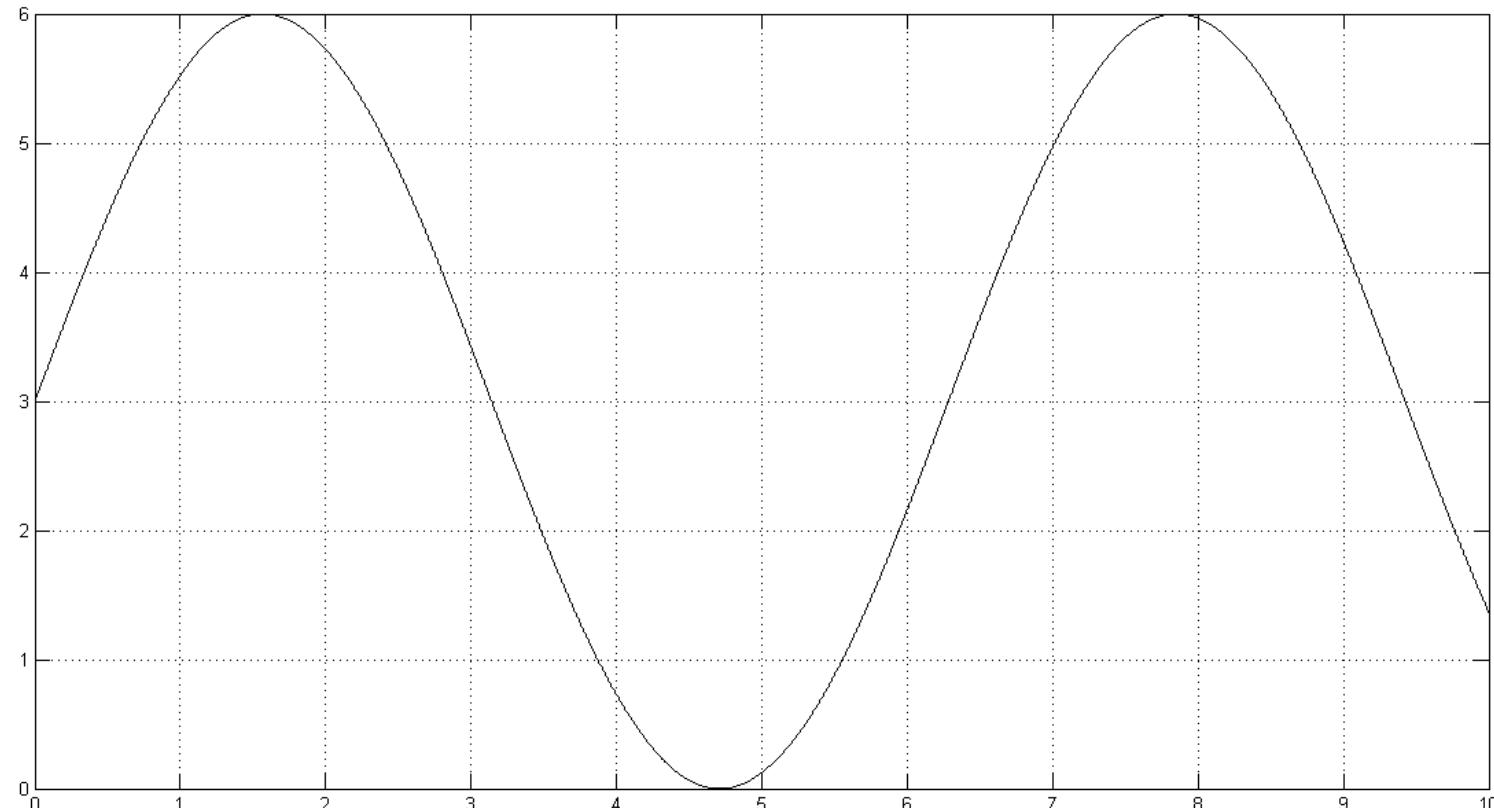
# Sampling



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- The process of converting a signal (for example, a function of continuous time and/or space) into a numeric sequence (a function of discrete time and/or space)

# Sampling



# Sampling frequency

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- Q:
  - How many samples are needed not to loose information?

# Nyquist–Shannon sampling theorem

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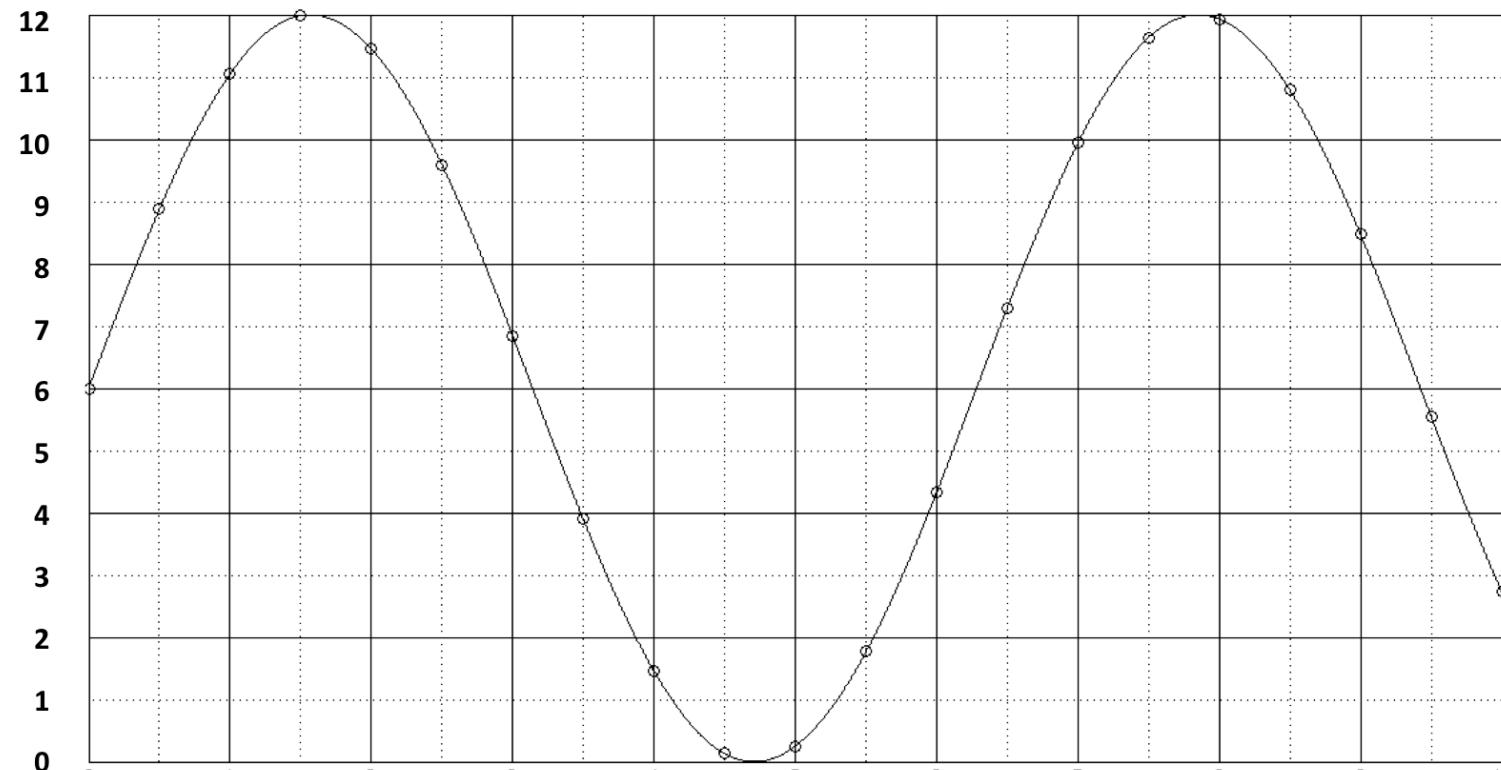
- If a function  $x(t)$  contains no frequencies higher than  $B$  Hz, it is completely determined by giving its ordinates at a series of points spaced  $1/(2B)$  seconds apart

# Sampling frequency

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- Q:
  - How many samples are needed not to loose information?
- A:
  - A sufficient sample-rate is  $2B$  samples/s, or anything larger
  - Equivalently, for a given sample rate  $fs$ , perfect reconstruction is guaranteed possible for a bandlimit  $B < fs/2$ .

# Digitalization



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# Memory capability

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- In information technology and computer engineering, systems can be designed to *remember* preceding events (or user interactions), or not.
- The remembered information is called the *state* of the system
- Systems are thus classified as:
  - *Stateful*: designed to remember preceding events (or user interactions)
  - *Stateless*: designed to NOT remember preceding events (or user interactions).

# Stateful vs Stateless systems

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## Stateful system

- At any time, its outputs are completely determined by its current inputs and its state.
- It must somehow “store” data & information items

## Stateless system

- At any time, its outputs are completely determined by its current inputs, only
- It doesn’t “store” any data or information item

# Combinational vs. Sequential Devices

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- When dealing with digital networks:
  - *Stateful* systems are usually referred to as *Sequential* devices
  - *Stateless* systems are usually referred to as *Combinational* devices

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# Functionality

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- *General purpose processor*
- *DSP* (Digital Signal Processor)
- *GPU* (Graphics Processing Unit)
- *GPGPU* (General Purpose GPU)
- *Smart Card*

# General purpose processor

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- *General purpose processor*
- *DSP* (Digital Signal Processor)
- *GPU* (Graphics Processing Unit)
- *GPGPU* (General Purpose GPU)
- *Smart Card*

➤ General purpose processors designed to efficiently execute any kind of programs



# DSP (Digital Signal Processor)

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- *General purpose processor*
- **DSP** (Digital Signal Processor)
- **GPU** (Graphics Processing Unit)
- **GPGPU** (General Purpose GPU)
- *Smart Card*

- Design to efficiently perform signal processing oriented operations (FFT, DFFT, filters, convolutions, ...)



# GPU (Graphics Processing Unit)

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- *General purpose processor*
  - *DSP* (Digital Signal Processor)
  - **GPU** (Graphics Processing Unit)
  - *GPGPU* (General Purpose GPU)
  - *Smart Card*
- Design to efficiently perform mathematical calculations, primarily for the purpose of image rendering and graphic oriented operations

# GPGPU (General Purpose GPU)

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- *General purpose processor*
  - *DSP* (Digital Signal Processor)
  - *GPU* (Graphics Processing Unit)
  - ***GPGPU* (General Purpose GPU)**
  - *Smart Card*
- GPU designed to performs non-specialized calculations that would typically be conducted by the CPU

# GPGPU today

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- Over the past decade that's proven key to a growing range of applications.
- GPUs perform much more work for every unit of energy than CPUs. That makes them key to HPC.
- In AI, GPUs have become key to deep learning, pouring vast quantities of data through neural networks.

# Smart Card

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- *General purpose processor*
  - *DSP* (Digital Signal Processor)
  - *GPU* (Graphics Processing Unit)
  - *GPGPU* (General Purpose GPU)
  - *Smart Card*
- Device providing different security solutions, like authentication mechanisms based on something the user has.

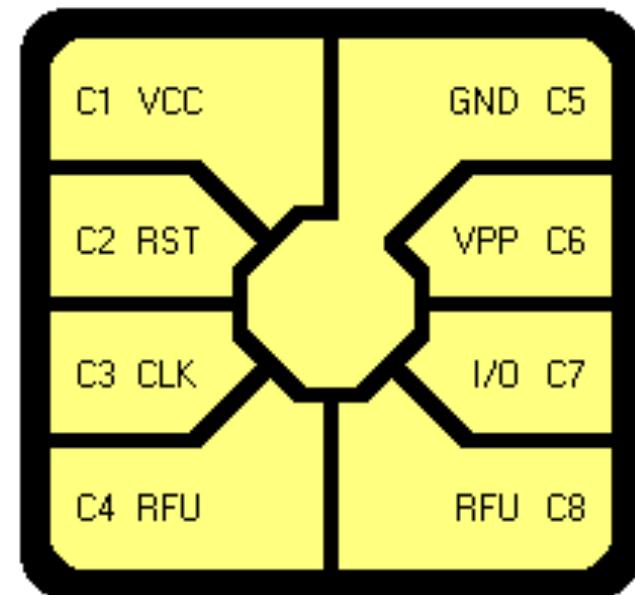


# Smart Card

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- Is comprised of a CPU linked to an I/O system

## ISO 7816 Standards



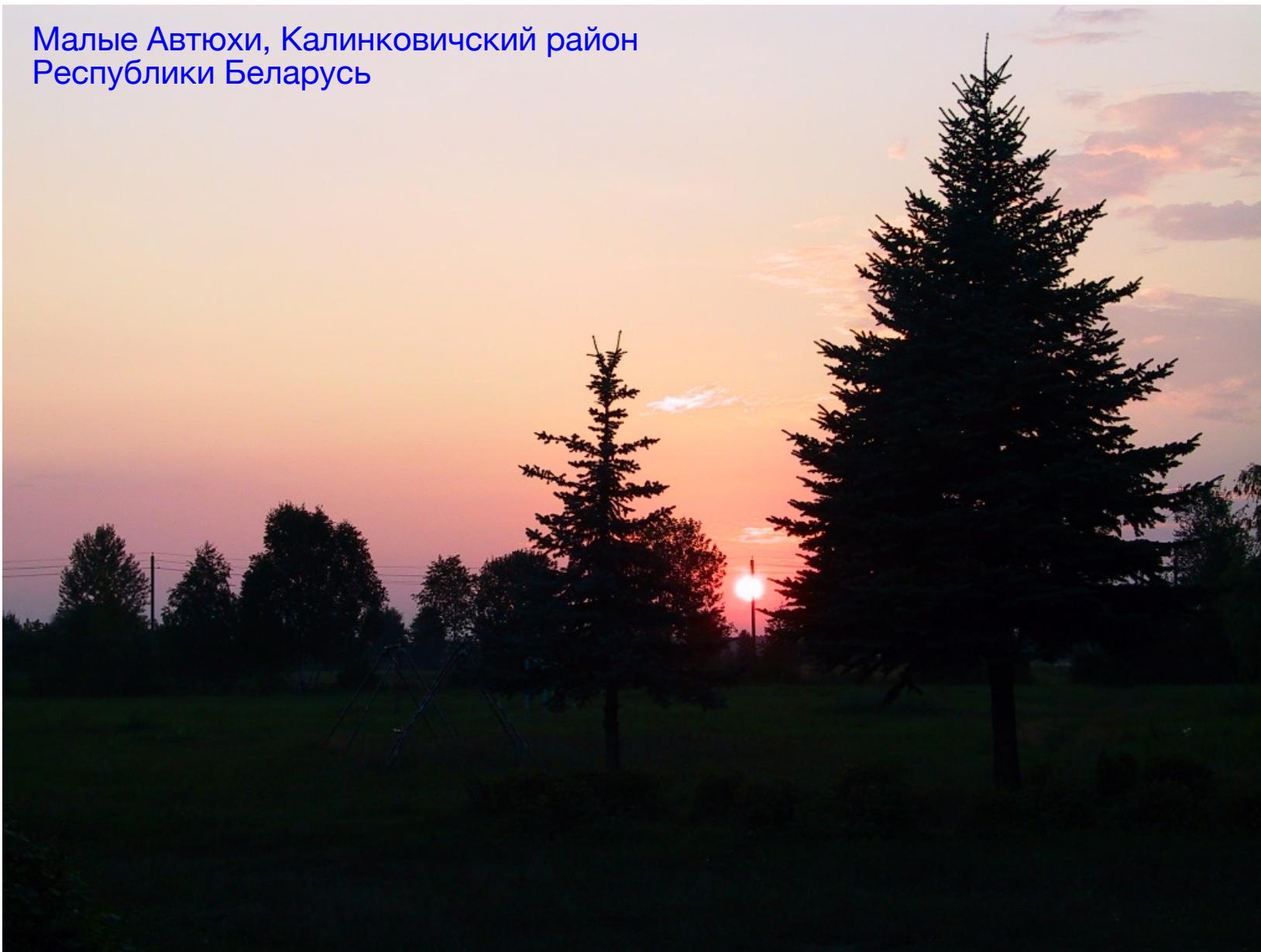
# SIM Card

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A *Subscriber Identity Module* or *Subscriber Identification Module* (SIM), widely known as a *SIM card*, is also a type of Smart Card



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