Embedded System Concepts

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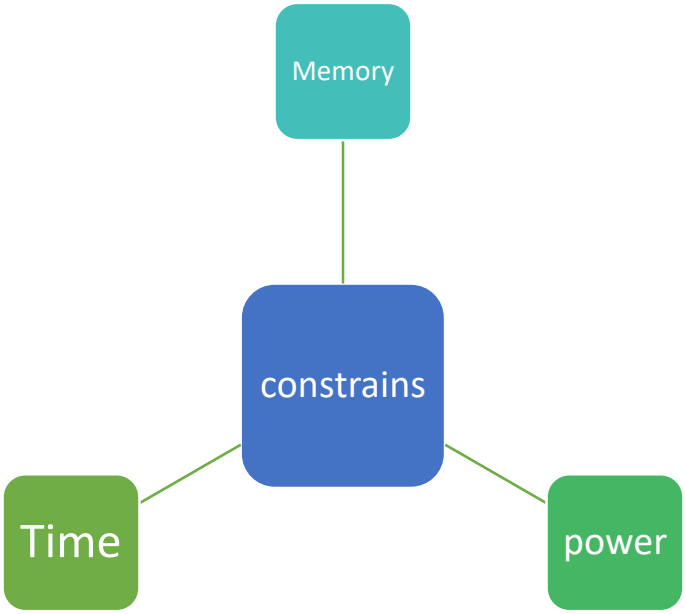
What is the Embedded System?

- It is a combination of hardware and software
- It executes a specific task
- It is a system integrated into a larger system



General purpose systems:

systems that can do many functionalities depending on

1- available hardware

2- installed programs

System Board - System On Chip

Feature	System Board	System on Chip (SoC)
Definition	A main circuit board within a computer	A single integrated circuit that contains most or all components of a computer or other electronic system
Customization	Offers flexibility for customization and upgrades through interchangeable components	Generally less customizable as components are integrated into a single chip
Power Consumption	Low power consumption	Low power consumption
Size	Larger physical size due to separate components and interfaces	Smaller physical footprint due to integration of components onto a single chip
Cost	Expensive	Cheap
Application	Commonly used in traditional desktops, laptops, and servers	Embedded systems

difference between [IC - MPU - MCU - GPU - DSP - SOC – ECU]

1- IC

An electronic circuit that consists of miniaturized electronic components such as resistors, capacitors, and transistors, interconnected on a semiconductor material. [Timer 555]

2- MPU

A central processing unit (CPU) contained on a single integrated circuit (IC) or a few ICs, typically used in general-purpose computing tasks.
[Intel Core processors]

3- MCU

A compact integrated circuit designed to control specific functions within embedded systems, containing a CPU, memory, and peripherals.
[AVR microcontrollers]

4- GPU

A specialized electronic circuit designed to accelerate the creation and rendering of images, videos, and animations [NVIDIA GeForce]

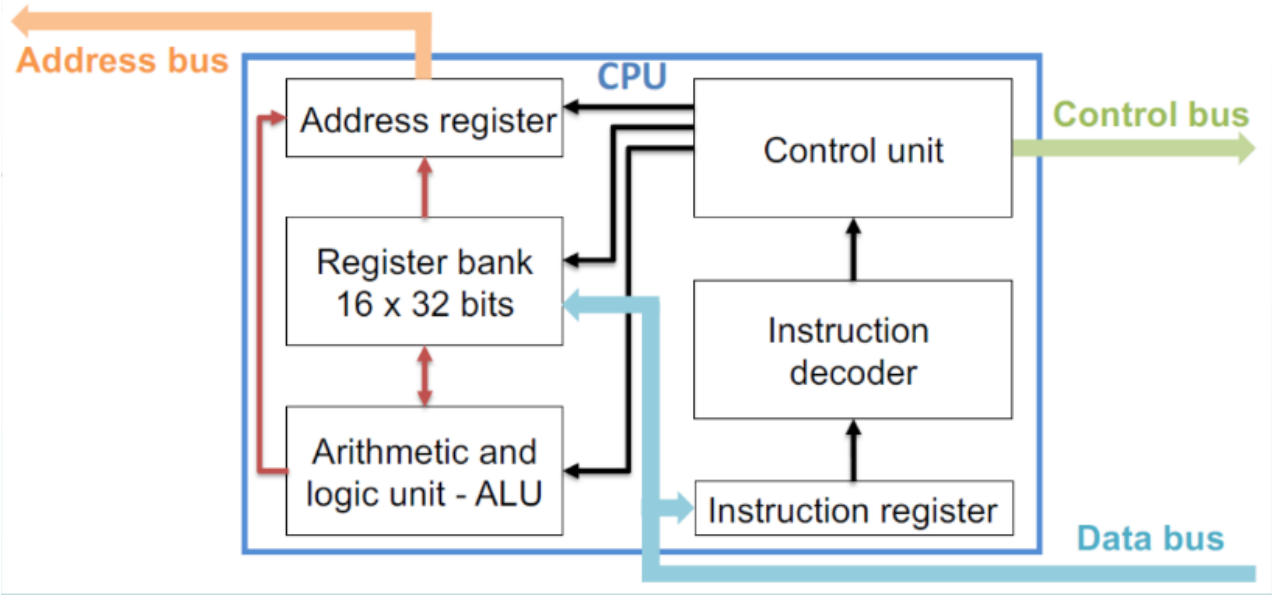
5- DSP

A specialized microprocessor designed specifically for processing digital signals, such as audio signals, video signals, and sensor data.

6- ECU

An embedded system that controls one or more electrical systems or subsystems in a vehicle.

Processor Components



- **Control unit**

  The control unit calculate the address of the instruction.

- **Address register**

  The address register is a small memory inside the CPU to carry the address it needs to send to the memory, either for instruction fetch or data fetch.

- **Instruction register**

  The instruction register (IR) store the instruction being executed now.

- **Instruction decoder**

  The instruction decoder gets the instruction of the instruction register and decode it

- **ALU**

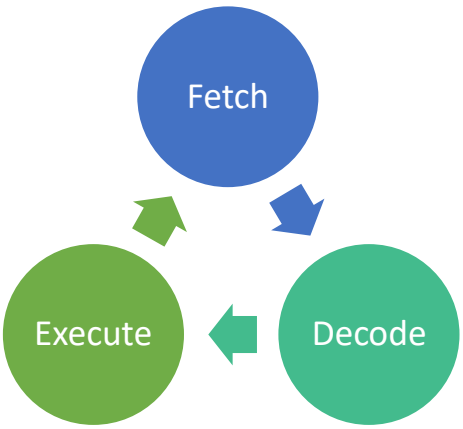
  To execute instructions, we need arithmetic and logic unit (ALU) to performs the mathematical functions

Basic Instruction Cycle

Fetch: get it from the memory to CPU.

Decode: understand it.

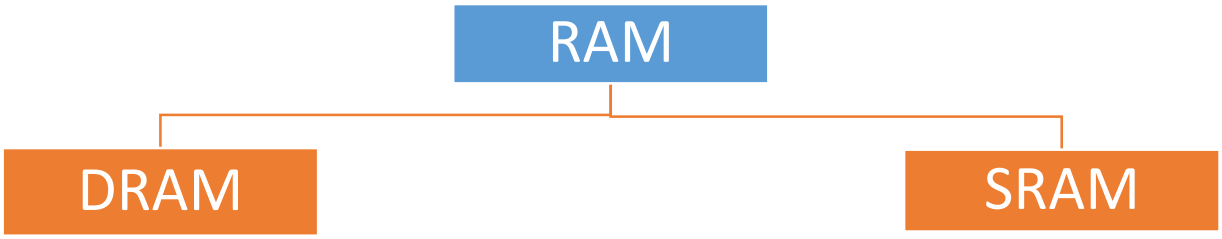
Execute: perform the instruction.



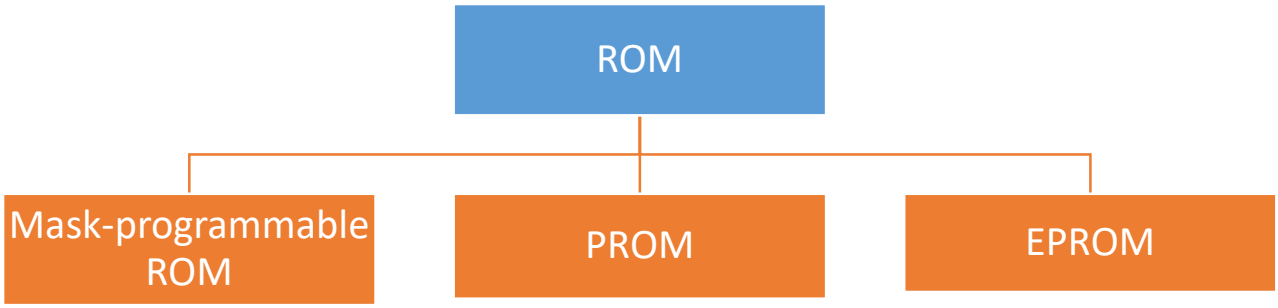
Memory

Types of memories

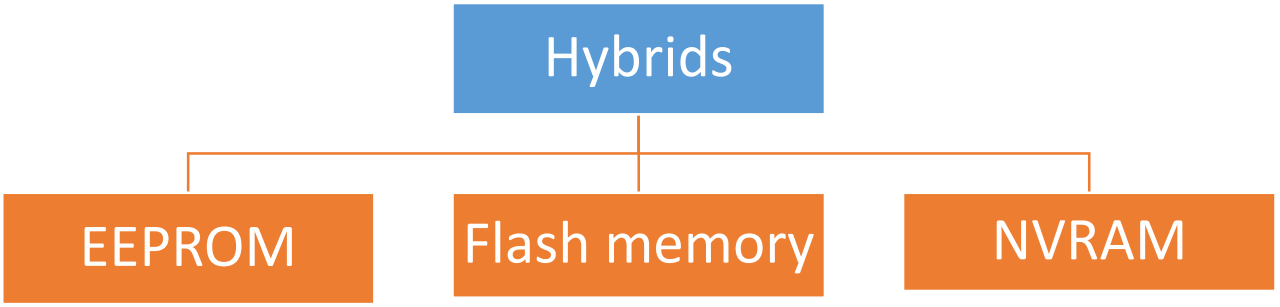
Feature	Volatile Memory	Non-Volatile Memory	Hybrid Memory
Definition	is a type of storage whose contents are erased when the system's power is turned off	Retains stored data even when power is removed	Combines characteristics of both volatile and non-volatile memory
Examples	RAM (Random Access Memory), Cache Memory	ROM (Read-Only Memory), Flash Memory	EEPROM-Flash memory-NVRAM



Feature	DRAM	SRAM
Data Storage Mechanism	Stores data in storage cells consisting of a capacitor and a transistor. Requires periodic refreshing.	Stores data in flip-flops, which do not require refreshing to retain data.
Lifetime of Data	Data has a short lifetime (typically about four milliseconds) and requires periodic refreshing.	Data does not require refreshing and can be retained indefinitely.
Access Time	Slower access times compared to SRAM.	Faster access times (approximately four times faster than DRAM).
Cost	Lower cost per bit compared to SRAM.	Higher cost per bit compared to DRAM.
Usage	Typically used for main memory (RAM) in computers and other digital devices where large capacity is required.	Used in applications where fast access times are crucial, such as CPU caches and high-performance computing.



Feature	Mask Programmable ROM	PROM	EPROM
Reprogram ability	Not reprogrammable.	Can be programmed once by user.	Can be erased and reprogrammed repeatedly.
Programming Method	Data is written into ROM during manufacture.	Data is written into PROM using a device programmer.	Data is written into EPROM using a device programmer.
Erasure Method	N/A	N/A	Exposed to ultraviolet light for erasure.
Data Retention	Data cannot be changed once programmed.	Data cannot be changed once programmed.	Data can be erased and reprogrammed.
Cost	Cheapest type of ROM.	More expensive than Mask ROM.	More expensive than PROM.
Usage	Used in small electronic devices.	Used when some flexibility in programming is needed.	Used when reprogram ability is required.
Advantages	Cheap and suitable for mass production.	Programmable by end-user.	Allows for reprogramming multiple times.
Disadvantages	Data cannot be changed after manufacture.	Can only be programmed once.	More expensive than PROM and Mask ROM.
Example	Traditional ROM chips.	Early versions of BIOS chips.	Early versions of EPROM chips.



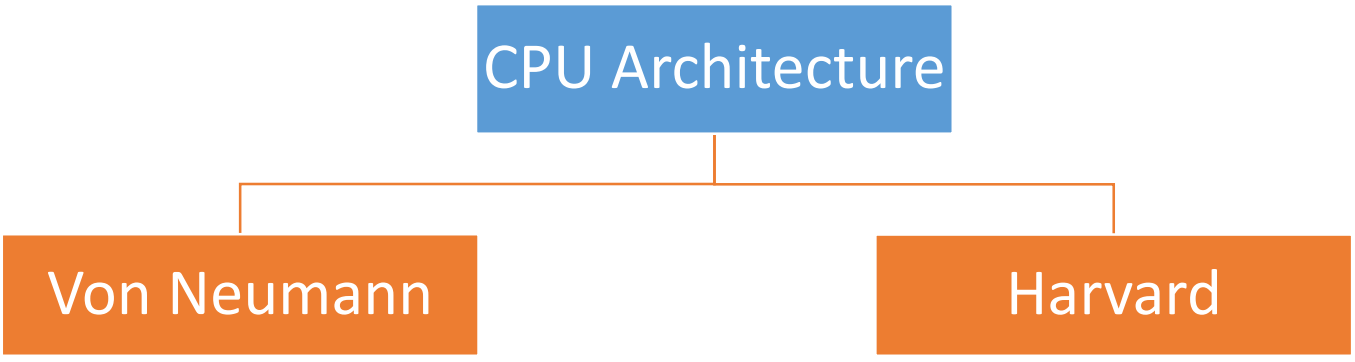
Cache Memory

its acting as a high-speed buffer between the CPU and the main memory. And reducing data retrieval time and relieving the workload on the CPU

- FPU [Floating point unit]
  It is a part of a computer system specially designed to carry out operations on floating-point numbers.

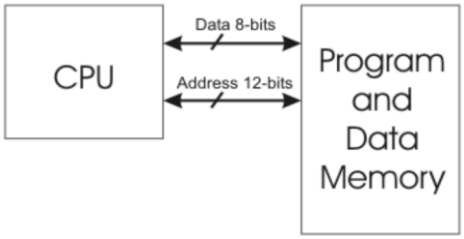
- MPU [memory protection unit]
  Its provides memory protection. It is usually implemented as part of the central processing

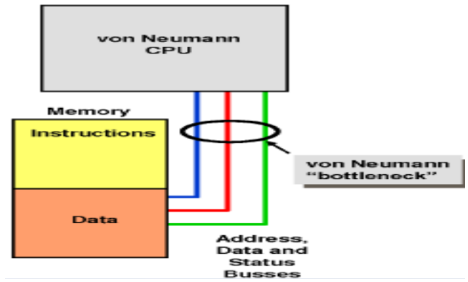
- MMU [memory management unit]
  It is a computer hardware component that handles all memory and caching operations associated with the processor. In other words, the MMU is responsible for all aspects of memory management. It's usually integrated into the processor, although, in some systems, it occupies a separate integrated circuit (IC).



Von Neumann

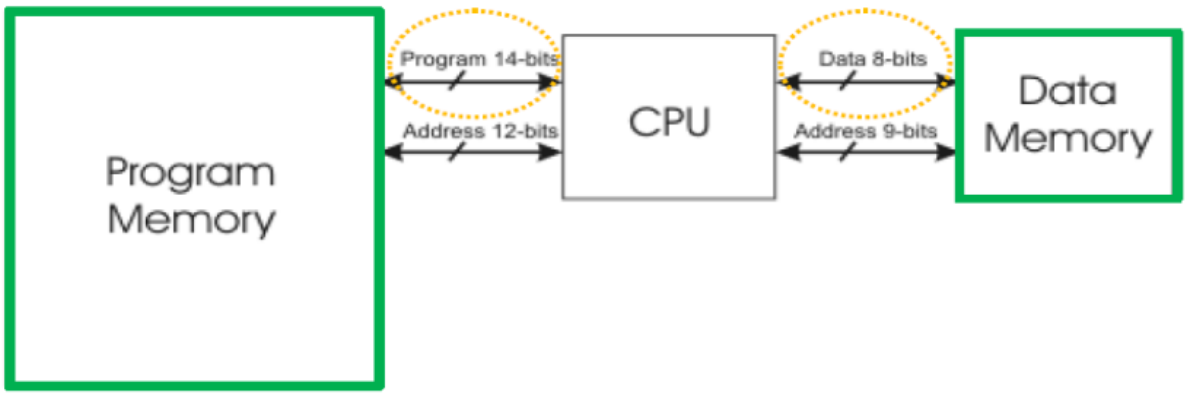
- Processor that uses this architecture has only one block of memory and one data bus
- CPU can read instruction or read/write data from/to memory.
- an instruction fetch and a data operation cannot occur at the same time because they share a common bus.

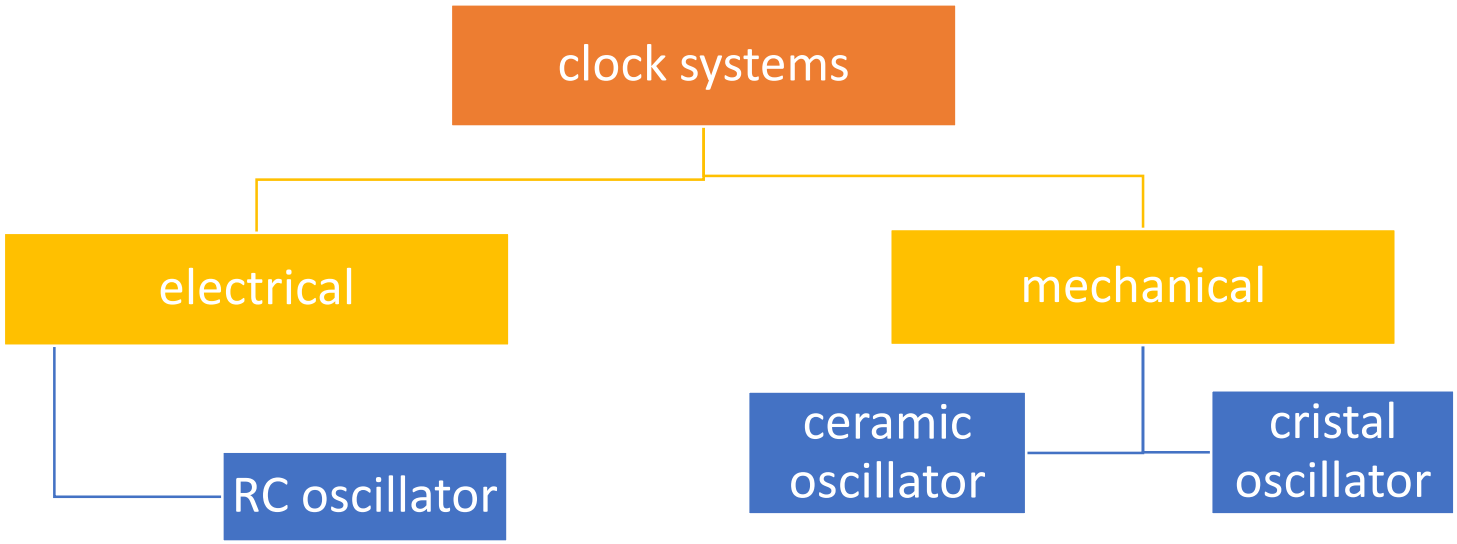




Harvard

- Separate memories for data and instructions.
- Two sets of address/data buses between CPU and memory.





Characteristic	RC Oscillator	Ceramic Oscillator	Crystal Oscillator
Cost	Low	Low-Moderate	Moderate-High
Accuracy	Low	Moderate	High
Setting Time	Fast	Moderate	Slow
Noise Immunity	Low	Moderate	High

Characteristic	Memory Mapping	Port Mapping
Address Space	Maps memory addresses	Maps I/O port addresses
Access Method	Accessed using memory instructions	Accessed using IN/OUT instructions or dedicated I/O instructions
Usage	Suitable for accessing memory-mapped devices such as RAM, ROM, and peripherals	Suitable for accessing I/O ports connected to peripheral devices
Addressing Range	Typically a wide range of addresses, often spanning the entire memory space	Limited address range, typically a smaller subset of the address space
Data Transfer Speed	Generally slower compared to port mapping	Can be faster due to direct access to hardware ports
Interrupt Handling	Usually not specifically designed for interrupt handling	Often used for interrupt handling by reading/writing to specific ports

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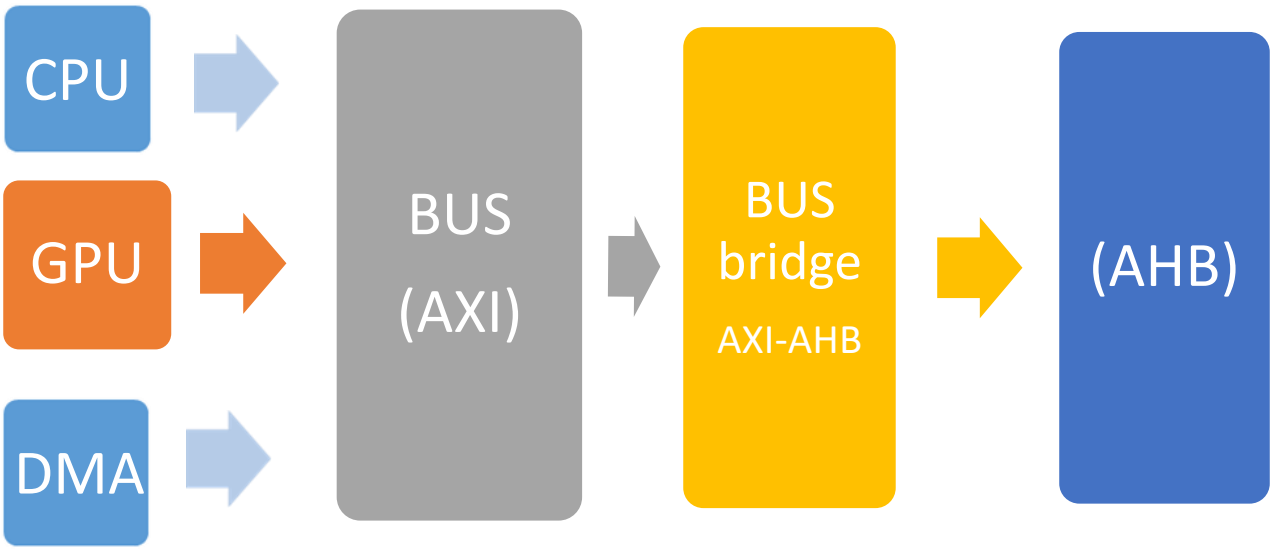
Bus bridge

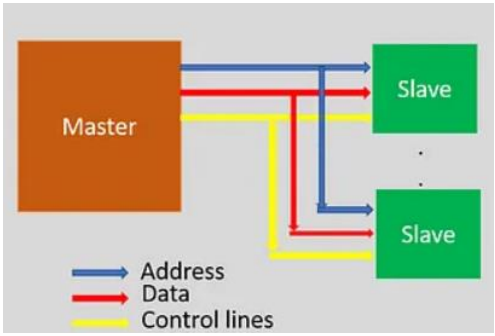
used in computer systems to connect two or more buses that operate at different speeds, have different architectures, or use different protocols.



Hardware ports

Master

- The master device/port typically initiates and controls the communication or data transfer process.
- It often has the authority to issue commands, request data, or send instructions to other devices or ports.



Slave

- The slave device/port typically responds to commands, requests, or instructions issued by the master device/port.
- It often has limited control over the communication process and relies on the master device/port for direction

Transactions

Read Transaction

- A read transaction involves retrieving data from a specific location, such as memory, a register, or an I/O device.
- The process typically begins with the requester, often a CPU or another device, sending a read request to the target location.
- The target location then responds to the read request by transmitting the requested data back to the requester.

Write Transaction

- A write transaction involves storing or updating data at a specific location, such as memory, a register, or an I/O device.
- Similar to a read transaction, the process begins with the requester sending a write request to the target location, along with the data to be written.
- The target location receives the write request and updates its contents with the provided data.

AMBA [the ARM Advanced Bus Architecture]

It's a widely-used standard for on-chip interconnect in System-on-Chip (SoC) designs, providing specifications like AXI, AHB, and APB for efficient connection and management of IP cores