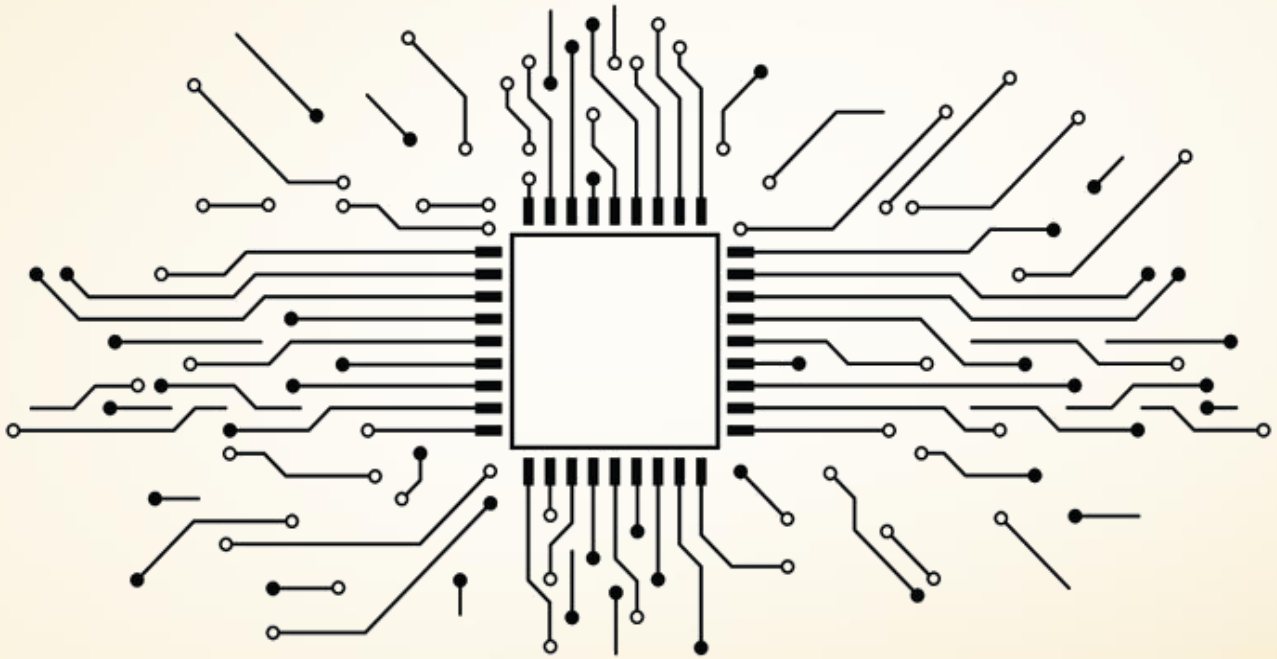
Embedded Systems Concepts



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Main Topics

- Embedded System vs General Computing System
- Definition of Embedded Systems
- Components of Embedded Systems
- Hardware
- Processor
- Instruction cycle
- Memory types
- RAM vs ROM
- Types of RAM
- Types of ROM
- Applications

Main Topics

- MCU architecture
- Clock systems in Embedded Systems
- Memory mapping
- Bus interface unit (BUI)
- Microcontroller unit ports (MCU Ports)
- AMBA

Embedded System vs General Computing System

Criteria	General Computing System	Embedded System
Key factor	Performance and speed	Application specific, time
Power consumption	More since it large system and multipurpose system	Less because it application specific system
Response time	Not critical	Critical
User interface	GUI	May or may not be the
Operating system	General operating system like windows, linux, mac	Real time operating system (RTOS)

Definition of Embedded Systems

An Embedded Systems is one that has computer hardware with software embedded in it as one of its important components, that is designed to perform a dedicated function, either as an independent system or as a part of a large system. At the core is an integrated circuit designed to carry out computation for real-time operations.

Components of Embedded Systems

It consists of three parts :

1. Hardware :
   embedded hardware components like processor, timers, interrupt controller, I/O devices, ports

2. Software :
   which may perform the series of tasks or multiple tasks using C language and Embedded C

3. Operating System :
   OP of embedded systems is real time operating system (RTOS) which defines as the way that the system work.Which supervise the application software , it sets the rules during the execution of the application program , Note that a small scale of embedded system programs may not need RTOS

Hardware

- IC
  An integrated circuit (IC) called a chip is made out of a semiconductor material called silicon, in which small electronic components called transistors are formed within the silicon and then wired together with interconnects layered on top of the silicon surface.

- MCU
  Microcontroller unit is a small computer on a single integrated circuit. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals.

- CPU
  Processor is the primary component in a computer that performs most of the processing It executes instruct (ions that are stored in memory and perform basic arithmetic, logic, and input/output operations

Processor

A processor is the heart of the Embedded system , An embedded processor is a micro processor that is used in an embedded system, An embedded system is a computer system that is designed to perform a specific task within a larger system. It is a self-contained system that is embedded within a larger device or system and is used to control the operation of the device. Processor also known as a central processing unit (CPU), is the primary component in a computer that performs most of the processing. It executes instruct (ions that are stored in memory and perform basic arithmetic, logic, and input/output operations . The processor is an essential component of a computer system, as it determines the speed and performance of the system . The processor consists of (ALU , CU , Register files) . The processors employed in the manufacturing of the embedded system can be broadly classified into three types.

Types of processor

1. General Purpose Processor(GPP):
   GPP is used for processing the signal from input to output by controlling the operation of the data bus, address bus, and system bus inside an embedded system. This GPP includes microcontrollers, microprocessors, embedded processors, media, and digital signal processors.

2. Application-Specific System Processor(ASSP):
   This is an application-dependent system processor used for processing the signals involved in the embedded system. Therefore, for performing unique tasks the corresponding processor is required.

3. Application-Specific Instruction Processor(ASIP):
   This is also an application-dependent but instruction driven processor. This is used for processing various instructions set inside a combinational circuit of embedded systems.

Instruction cycle

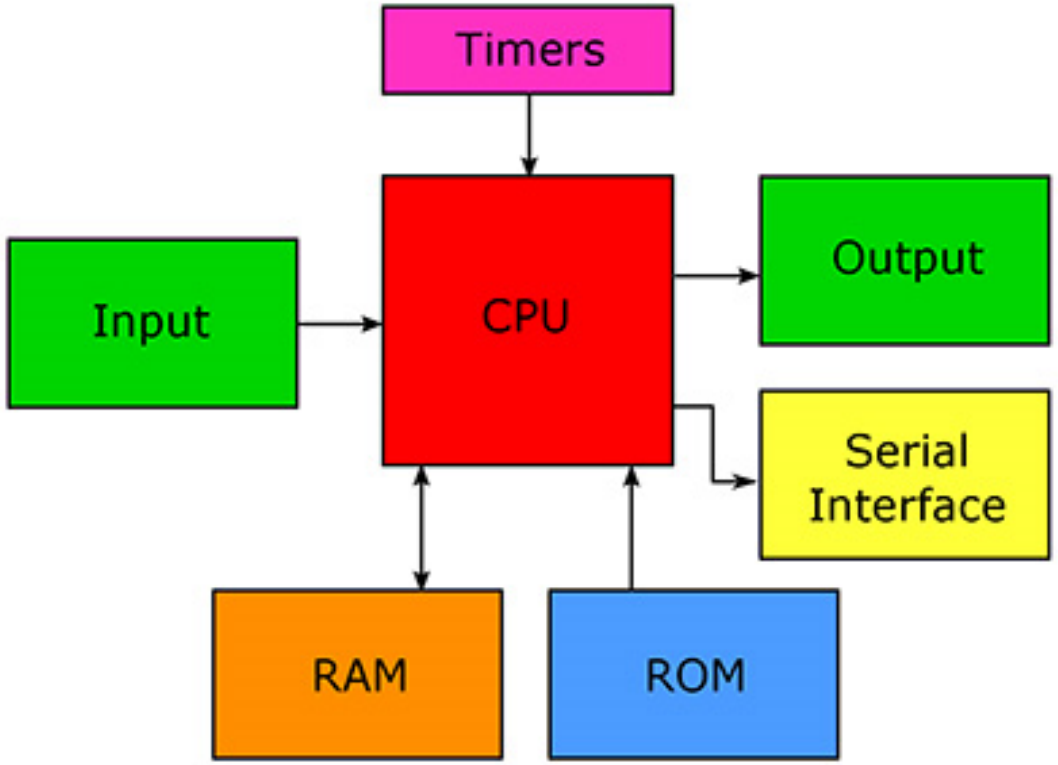
The instruction cycle helps the CPU perform its primary job of expecting tasks. This article will discuss the steps involved in the instruction cycle and an example of the instruction cycle in detail.

The instruction cycle consists of four phases:

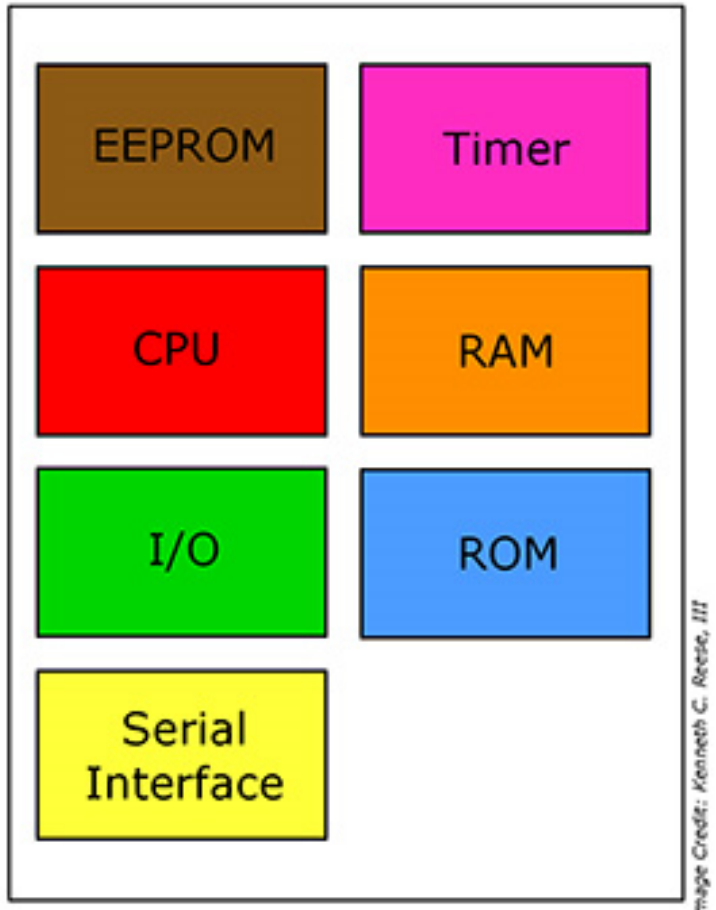
1. Fetching an instruction from memory
2. Decoding the fetched instruction
3. Reading the address from memory,
4. Instruction execution, The computer processor carries it out

Microprocessor	Microcontroller
CPU is stand alone, RAM, ROM, I/O & Timer are separate	CPU, RAM, ROM, I/O & Timer all are on single chip
Designer can decide amount of RAM, ROM, I/O ports	Fixed amount of RAM, ROM, I/O ports on chip
High processing power	Low processing power
High power consumption	Low power consumption
General purpose	Single purpose

Microprocesser: CPU
and several supporting chips.



Microcontroller: CPU
on a single chip.



Memory

Memory in an embedded system is a physical storage embedded device used to store two data types. The embedded system retrieves data from memory, processes it, and outputs data saved in memory. Memory consists of three types :

1. Volatile memory : As long as power is on to the memory device, it will preserve the data. The memory contents will be lose when the power is off. It's where we keep the data and the program instructions like (RAM).
2. Non-Volatile memory : When the power to the memory switches off, the content retains in non-volatile memory. After restarting the machine, the saved data may be recovered using this memory. In most cases, the bootup settings are saved in non-volatile memory. They are slower than volatile memory, but they can store more data for a longer time like (ROM).

RAM	ROM
Temporary storage	Permanent storage
Volatile	Non-volatile
High speed	Low speed
High power consumption	Low power consumption
General purpose	Single purpose

Types of RAM

- Types of RAM

1. SRAM :
   It's a sort of RAM that stores each bit with latching circuitry, which is made up of flip-flops. As a result, there is no need to refresh the memory.
2. DRAM :
   which refers to "Dynamic RAM." It uses more energy, which results in more incredible heat. DRAM is packed more densely than SRAM.

Types of ROM

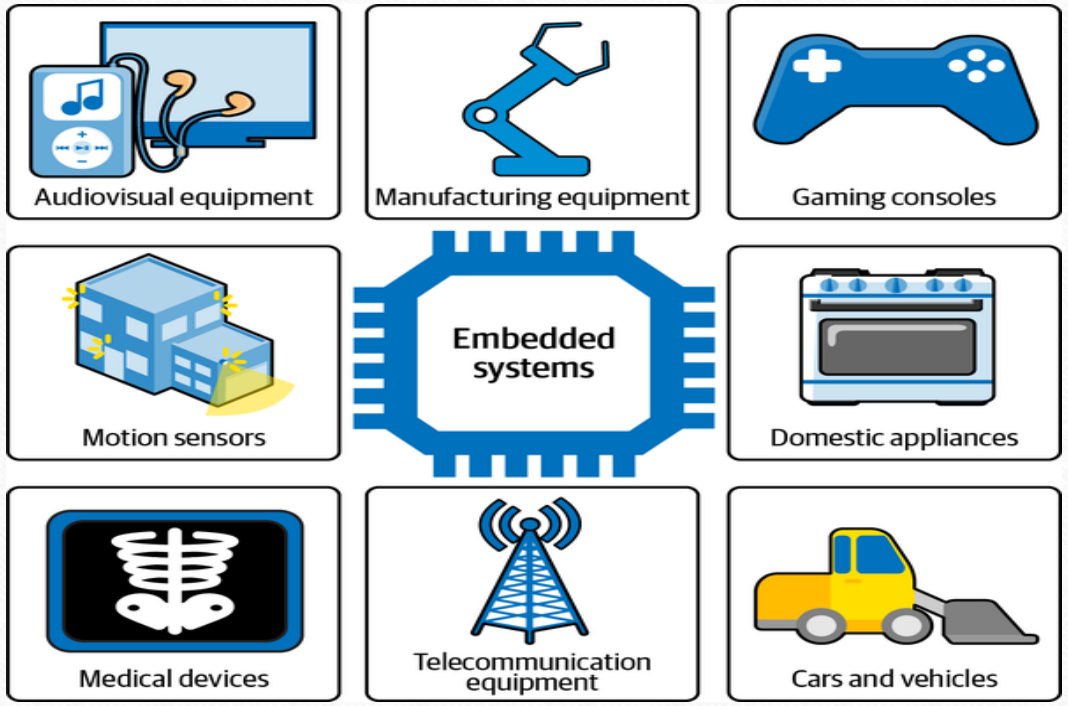
- Types of ROM

1. PROM :
   It's a logic gate-based programmable memory. The programmer can save data in PROM. Once the information holds in the gadget, it cannot be programed.
2. EPROM :
   stands for Erasable Programmable Memory, and it is made up of floating gate transistors. The end-user can save, wipe, and reprogram the data. To wipe the contents of an EPROM, it must be removed from the computer. It deletes by exposing the data to a UV light source.

Applications

Embedded systems are commonly found in :

- Automation
- Industrial
- Automotive
- Home appliances
- Medical
- Telecommunication
- Robotics
- Security systems
- Military applications.



MCU architecture

Von-Neuman	Harvard
First digital computer architecture. Introduced stored program concept	Computer architecture based on Harvard Mark 1
One memory module for data and instructions	Have different memory modules for data and instructions.
common bus for data and instructions	Individual buses for data and instructions
CPU takes 2 clocks to execute one instruction. Because fetch data before executing an instruction.	Can execute instruction one clock cycle.
CPU can not fetch instructions and data read/write at the same time.	CPU can not fetch instructions and data read/write at the same time.
Slow	Fast

Clock systems in Embedded Systems

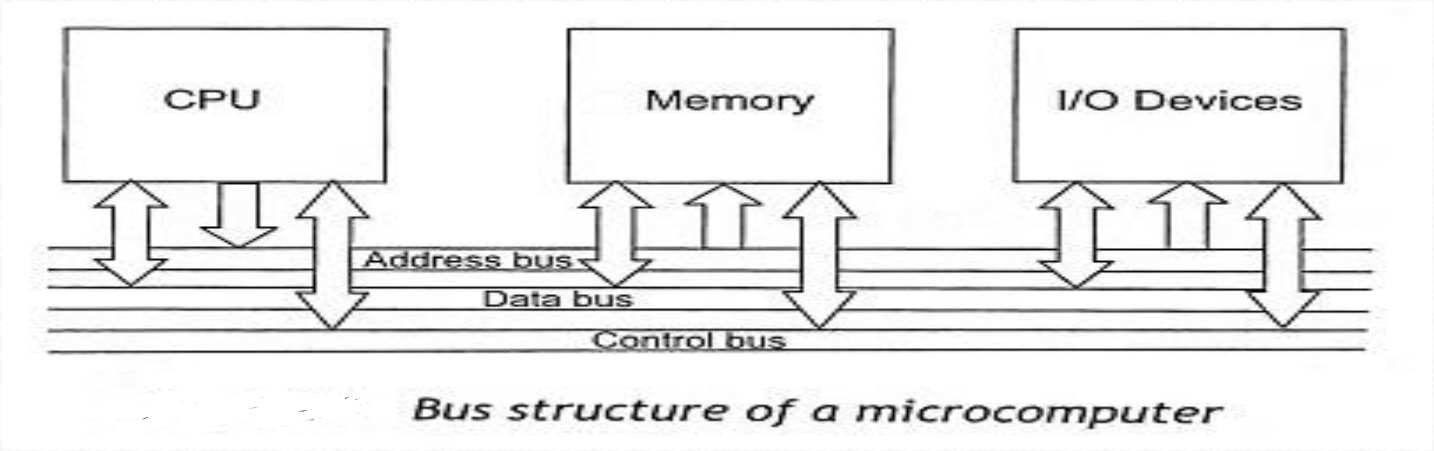
- It consist of :
  Electrical → RC oscillator
  Mechanical → Ceramic oscillator – crystal oscillator
- A real-time clock (RTC) :
  RTC is used in embedded systems to keep track of the precise time and date even when the device is not connected to the network or the main power is off.
- RTC is powered by its own internal lithium battery, and even if the power of the system is turned off, the RTC clock keeps running.
- Oscillator is like the heart and the clock pulse is like the heartbeat. They are used for the synchronous function of the components inside the embedded system.

Memory mapping

- Memory-mapping is a mechanism that maps a portion of a file, or an entire file, on disk to a range of addresses within an application's address space. The application can then access files on disk in the same way it accesses dynamic memory
- Memory-mapped I/O allows the CPU to control hardware by reading and writing specific memory addresses. Usually, this would be used for low-bandwidth operations such as changing control bits.
- DMA allows hardware to directly read and write memory without involving the CPU

Bus Interface Unit

- Bus interface unit (BIU) takes care of all data and addresses transfers on the buses for the EU like sending addresses, fetching instructions from the memory, reading data from the ports and the memory as well as writing data to the ports and the memory. BIU is responsible for fetching instructions from memory and decoding them, while the EU executes the instructions. BIU also manages data transfer between the microprocessor and memory or I/O devices



Bus structure of a microcomputer

MCU Ports

- Port refers to a group of pins on a microcontroller which can be accessed simultaneously, or on which we can set the desired combination of zeros and ones, or read from them an existing status.
- Port is a register inside a microcontroller which is connected by wires to the pins of a microcontroller
- Types of ports are → (UART, SPI, I2C, Ethernet, and USB) all of them are communication ports
- I/O ports are used to transfer data to and from the processor and the external environment

AMBA

- Arm Advanced Bus Architecture (AMBA) is a bus protocol specifically designed for high-performance, on-chip communication in microcontroller systems.
- It provides a hierarchical structure that allows multiple masters to access multiple slaves, which significantly speeds up data transfer while maintaining low power consumption.
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