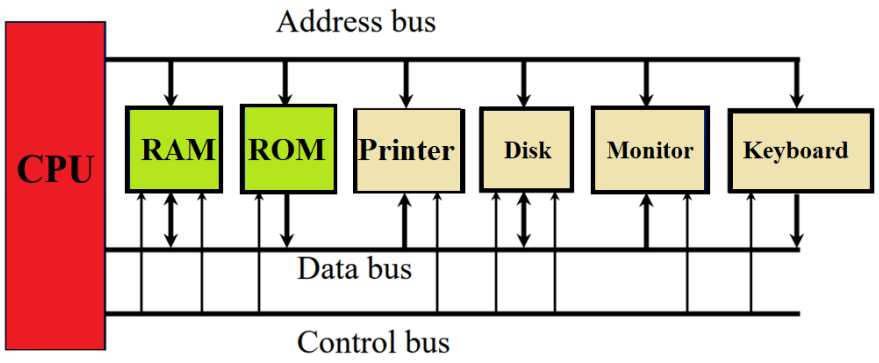
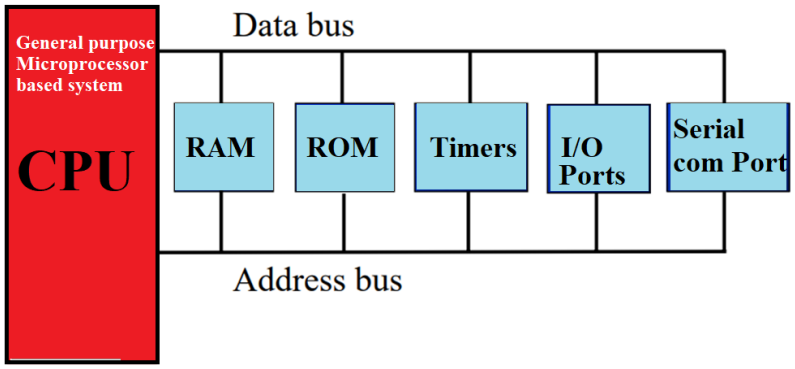
Unit 1

Module: Introduction of Microcontroller / Microprocessor Architecture

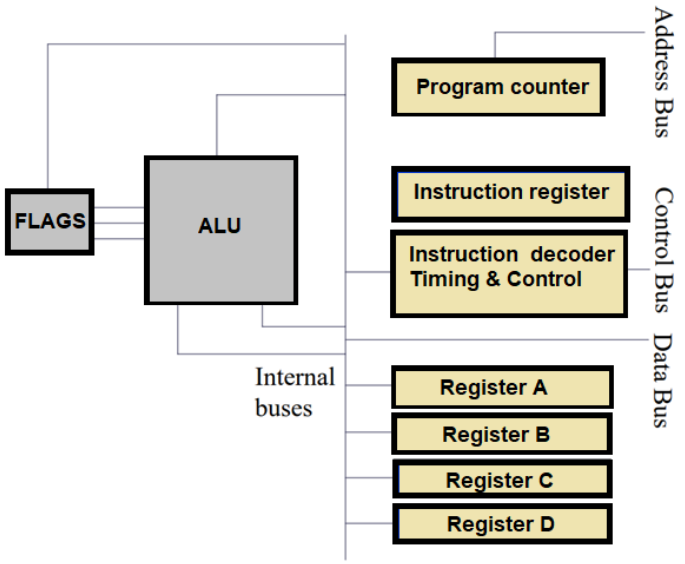
Internal Organization of a Computer



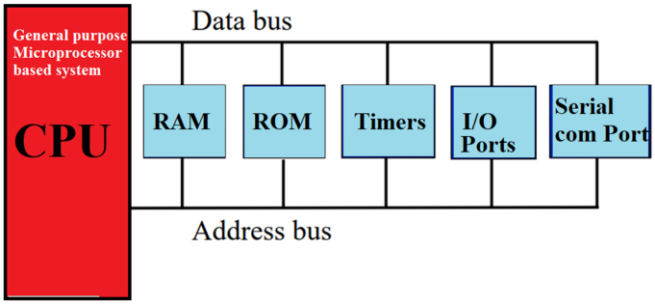
General Purpose microprocessor based system

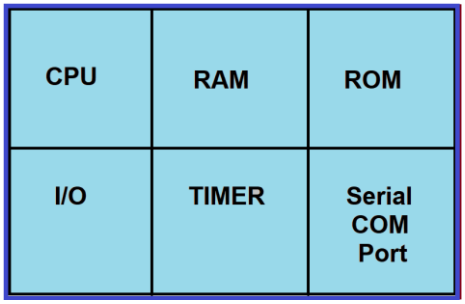


Inside a Microprocessor (CPU)



Microprocessor v/s Microcontrollers





What is a Microcontroller ?

A Microcontroller is a programmable digital processor with necessary peripherals.

It incorporates all the features found in microprocessor CPU, such as ALU, PC, SP and registers.

It also has other features needed to make a complete computer. ROM, RAM, Parallel I/O, serial I/O, Counters and clock circuits.

It is a small computer on a single integrated circuit (IC) chip which is dedicated to perform a particular task and execute one specific application.

Components of a Microcontroller

Central processing unit:

- Arithmetic logic unit (ALU), which performs computation.
- Registers needed for the basic operation of the CPU, such as the program counter (PC), stack pointer (SP), and status register (SR).
- Further registers to hold temporary results.
- Instruction decoder and other logic to control the CPU, handle resets, and interrupts, and so on.
- **Memory for the program:**
    - Nonvolatile (read-only memory, ROM), meaning that it retains its contents when power is removed.
    - **Memory for data:** Known as random-access memory (RAM) and usually volatile.
- **Input and output ports:** To provide digital communication with the outside world.
- **Address and data buses:** To link these subsystems to transfer data and instructions.
- **Clock:** To keep the whole system synchronized. It may be generated internally or obtained from a crystal or external source; modern MCUs offer considerable choice of clocks.

Additional Peripherals

Following are additional peripherals those are present in some of the advanced microcontrollers.

- Timers
- Watchdog Timer
- Communication Interfaces such as I2C, USB, SPI, RS232, CAN
- Non-Volatile Memory for data
- Analog to digital converter
- Digital to analog converter

Types of Microprocessors

Important types of Microprocessors are:

- Complex Instruction Set Microprocessors
- The Application Specific Integrated Circuit
- Reduced Instruction Set Microprocessors
- Digital Signal Multiprocessors (DSPs)

Types of Microcontrollers

Microcontrollers are divided into various categories based on memory, architecture, bits and instruction sets. Following is the list of their types

Bit - Based on bit configuration, the microcontroller is further divided into three categories.

- 8-bit microcontroller − This type of microcontroller is used to execute arithmetic and logical operations like addition, subtraction, multiplication division, etc. For example, Intel 8031 and 8051 are 8 bits microcontroller.
- 16-bit microcontroller − This type of microcontroller is used to perform arithmetic and logical operations where higher accuracy and performance is required. For example, Intel 8096, Texas Instruments MSP430 are 16-bit microcontroller.
- 32-bit microcontroller − This type of microcontroller is generally used in automatically controlled appliances like automatic operational machines, medical appliances, etc.

Memory: Based on the memory configuration, the microcontroller is further divided into two categories.

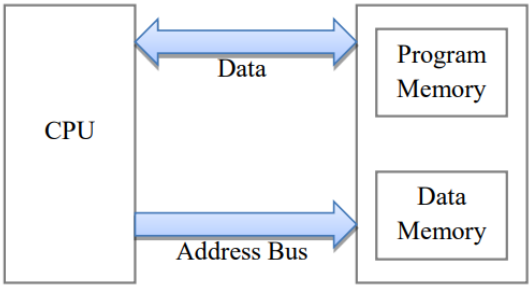
External memory microcontroller − This type of microcontroller is designed in such a way that they do not have a program memory on the chip. Hence, it is named as external memory microcontroller. For example: Intel 8031 microcontroller.

Embedded memory microcontroller − This type of microcontroller is designed in such a way that the microcontroller has all programs and data memory, counters and timers, interrupts, I/O ports are embedded on the chip. For example: Intel 8051 microcontroller.

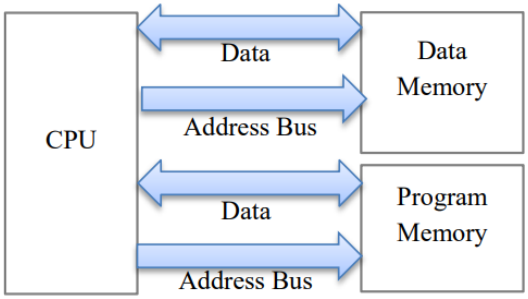
Architecture: Based on Architecture, the microcontroller is further divided into two categories.

- von Neumann
- Harvard Architecture

von Neumann and Harvard Architecture



von Neumann Architecture



Harvard Architecture

Harvard Architecture

The volatile (data) and nonvolatile (program) memories are treated as separate systems, each with its own address and data bus. Many microcontrollers use this architecture, including Microchip PICs, the Intel 8051 and descendents, and the ARM9. The principal advantage is efficiency.

It allows simultaneous access to the program and data memories. For instance, the CPU can read an operand from the data memory at the same time as it reads the next instruction from the program memory.

The two systems can be separately optimized. For example, the PIC16 has a data memory with an 8-bit data bus and a 9-bit address bus. On the other hand, the program memory is 14 bits wide, so that each word holds a complete instruction, with a 13-bit address bus.

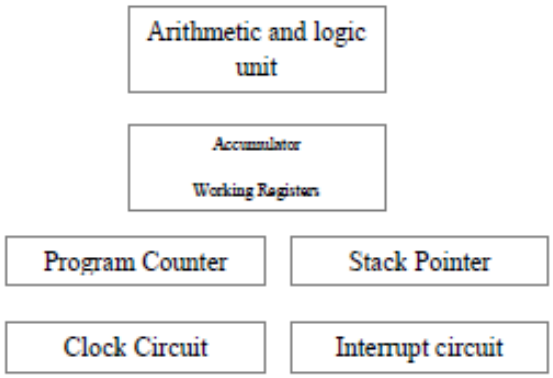
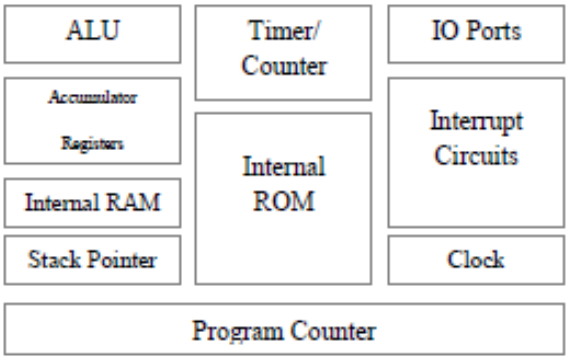
von Neumann Architecture

There is only a single memory system in the von Neumann or Princeton architecture. Only one set of addresses covers both the volatile and nonvolatile memories(data and Program memory). The memory map, which shows the addresses at which each type of memory is located, becomes particularly important. The architecture is intrinsically less efficient because several memory cycles may be needed to extract a full instruction from memory. The system is simpler and there is no difference between access to constant and variable data. Microcontrollers with a von Neumann architecture include the MSP430, the Freescale HCS08, and the ARM7.

Von-Neumann v/s Harvard Architecture

Von-Neumann (Princeton architecture)	Harvard architecture
It uses single memory space for both instructions and data	It has separate program memory and data memory
It is not possible to fetch instruction code and data simultaneously	Instruction code and data can be fetched simultaneously
Execution of instruction takes more machine cycle	Execution of instruction takes less machine cycle
Mainly uses CISC architecture	Mainly uses RISC architecture
Instruction pre-fetching is a main feature	Instruction parallelism is a main feature
Also known as control flow or control driven computers	Also known as data flow or data driven computers
Simplifies the chip design because of single memory space Eg. 8085, 8086, MC6800	Chip design is complex due to separate memory space Eg. General purpose microcontrollers, special DSP chips etc.

MICROPROCESSORS AND MICROCONTROLLERS

Microprocessor	*Microcontroller*
	
Block diagram of microprocessor	*Block diagram of microcontroller*
Microprocessor contains ALU, General purpose registers, stack pointer, program counter, clock timing circuit, interrupt circuit	Microcontroller contains the circuitry of microprocessor, and in addition it has built in ROM, RAM, I/O Devices, Timers/Counters etc.
It has many instructions to move data between memory and CPU	It has few instructions to move data between memory and CPU
Few bit handling instruction	It has many bit handling instructions
Less number of pins are multifunctional	More number of pins are multifunctional
Single memory map for data and code (program)	Separate memory map for data and code (program)
Access time for memory and IO are more	Less access time for built in memory and IO.
Microprocessor based system requires additional hardware	It requires less additional hardwares
More flexible in the design point of view	Less flexible since the additional circuits which is residing inside the microcontroller is fixed for a particular microcontroller
Large number of instructions with flexible addressing modes	Limited number of instructions with few addressing modes

Applications of Microcontrollers

- Automotive Industry
- Consumer Electronics and telecommunication
- Industrial
- Medical devices
- Electronics
- Military and Defence