Digital Control

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2025-2026



Introduction

Introduction in microcontrollers

A microcontroller was developed in 1971 by Intel Corporation in the United States.
That is the 4 bit microcontroller called i4004.
It was ordered by a Japanese company BUSICOM for calculators.
Later, the contract was changed and it was sold as a general-purpose microcontroller with success.
After that, Intel Corp. developed a 16 bit microcontroller '8086,' following the 8 bit microcontrollers such as 'i8008', 'i8080A,' and 'i8085.'
After developing several microcontrollers, they continue to develop the CPUs used in current personal computers

Toshiba developed a 12 bit microcontroller TLCS-12 in 1973.
At that time, the United States was considering electronic control units as a countermeasure of the exhaust gas regulation law.
Against this background, Toshiba's 12 bit microcontroller was developed as Ford's in-vehicle engine controller.
After that, Toshiba developed a wide range of high-level microcontrollers from 4 bit to 32 bit or higher.

Definition

A microcontroller (MCU) is a small computer on a single integrated circuit that is designed to control specific tasks within electronic systems. It combines the functions of a central processing unit (CPU), memory, and input/output interfaces, all on a single chip

A microcontroller includes:

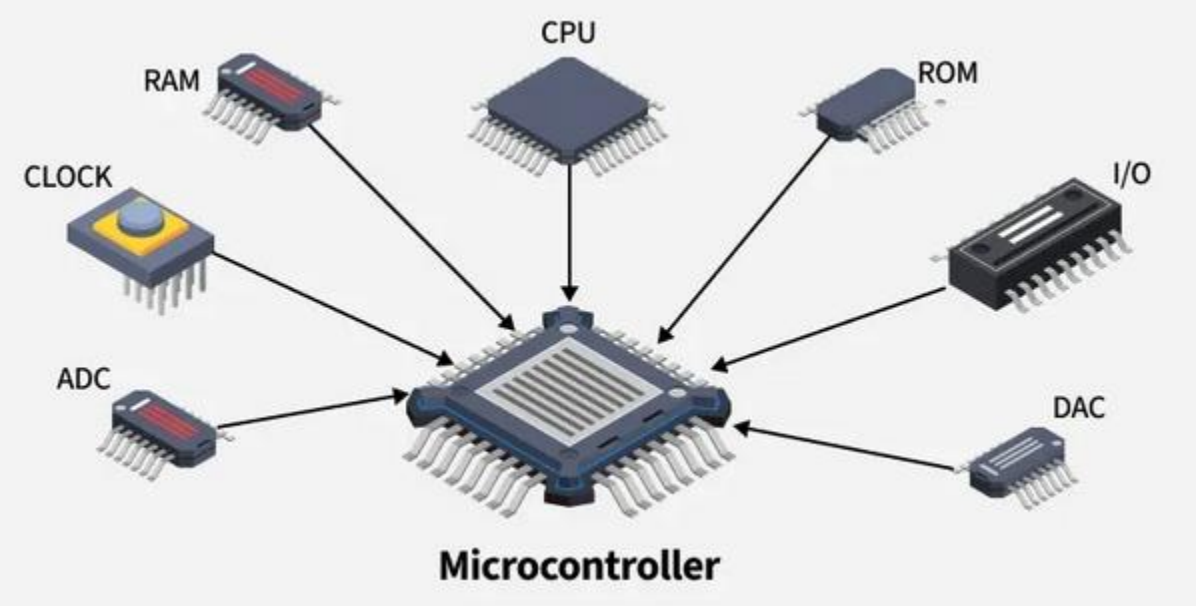
- A processor that runs instructions.
- Memory to store programs and data.
- Input/Output ports to connect with buttons, sensors, screens, etc.
- Communication ports (to connect with other devices).

Why Are Microcontrollers Useful?

- They are programmable, so you can make them do different tasks.
- Common programming languages used are C, C++, and assembly language.

- They are often low-power, which is great for devices that run on batteries.
- They are small, cheap, and perfect for controlling devices over a long time.
- Most microcontrollers are embedded, meaning they are built inside other devices.

The microcontroller used in Embedded System. For example:
• Security Systems
• Laser Printers
• Automation System
• Robotics



Working of Microcontroller

The microcontroller chip is a high-speed device, yet it is slow when compared to a computer. As a result, each command will be executed quickly within the microcontroller. The quartz oscillator is enabled and through control logic register once the supply is powered on. Parasite capacitors will be recharged for a few seconds while the early preparation is taking place.

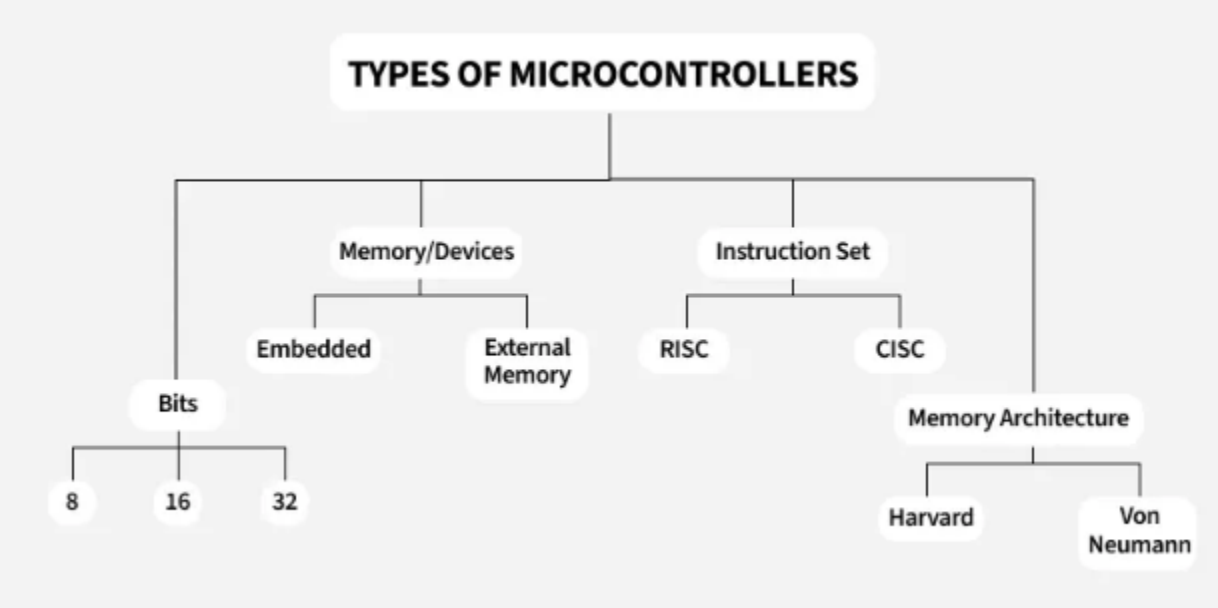
Once the voltage level reaches its maximum value and the oscillator's frequency stabilizes, the operation of writing bits through special function registers becomes stable.

Everything is controlled by the oscillator's CLK, and the whole electronics will begin to function. All of this happens in few nanoseconds.

A microcontroller's major role is that it can be thought of as a self-contained system with a processor memory. Its peripherals can be used in the same way that an 8051 microcontroller can. The bulk of microcontrollers in use today are embedded in other types of machinery such as telephones, appliances, vehicles, and computer system peripherals.

Types of Microcontroller

The types of microcontroller are characterized by thebits, memory architecture, memory/ devices and instruction set.



Classification of Microcontrollers by Number of Bits

- **8-bit Microcontrollers**
    - The internal bus is 8-bits wide.
    - The ALU (Arithmetic Logic Unit) performs operations on 8 bits at a time.
    - Example microcontrollers: Intel 8031/8051, PIC1x, Motorola MC68HC11.

- **16-bit Microcontrollers**
    - The internal bus is 16-bits wide, providing better precision and performance than 8-bit.
    - A 16-bit microcontroller can handle a wider range of numbers (0x0000 to 0xFFFF, or 0 to 65535) compared to the 8-bit range (0x00 to 0xFF, or 0 to 255).
    - Example microcontrollers: Extended 8051XA, PIC2x, Intel 8096, Motorola MC68HC12.
- **32-bit Microcontrollers**
    - These microcontrollers use 32-bit instructions for operations.
    - Used in advanced applications like medical devices, engine control systems, office machines, and other embedded systems.
    - Example microcontrollers: Intel/Atmel 251 family , PIC3x.

Classification of Microcontrollers by Memory Type

- **Embedded Memory Microcontroller**
    - All functional blocks are built into the chip.
    - Includes program memory, data memory, I/O ports, serial communication, counters, timers, and interrupts.
    - Example: 8051 microcontroller (has everything on the chip).
- **External Memory Microcontroller**
    - The microcontroller does not have all functional blocks on the chip.
    - Some components, like program memory, need to be connected externally.
    - Example: 8031 microcontroller (does not have program memory on the chip).

Classification of Microcontrollers by Instruction Set

- **CISC (Complex Instruction Set Computer)**
    - Allows complex instructions that can do multiple tasks in one command.
    - Reduces the need for many simpler instructions.
    - Example: **CISC** systems shorten execution time by reducing the number of instructions in a program.
- **RISC (Reduced Instruction Set Computer)**
    - Simplifies the instruction set, using fewer, simpler commands.
    - Allows instructions to work on any register and access program and data simultaneously.
    - Shortens execution time by reducing clock cycles per instruction.
    - **RISC** systems generally offer better execution performance compared to CISC systems.

Classification of Microcontrollers by Memory Architecture

- **Harvard Memory Architecture Microcontroller**
    - Has separate memory for program and data.
    - Allows simultaneous access to both program and data memory, improving efficiency.
    - Common in microcontrollers that require faster data processing.
- **Von Neumann Memory Architecture Microcontroller**
    - Uses shared memory for both program and data.
    - Simplifies design but can be slower since the program and data share the same bus.

Microcontroller Properties

- Microcontroller devices are capable of having words longer than 64 bits.
- Microcontroller consist of RAM , ROM , Timer , I/O Ports.
- Microcontroller ROM is used for program storage and RAM is used for data storage.
- It is designed by using CISC architecture.
- The power consumption of modern microcontrollers is significantly lower and have operating voltage range from 1.8V to 5.5V
- The latest feature of microcontroller is flash memory like EPROM and EEPROM.
- The most recent feature of a microcontroller is flash memory, such as EPROM and EEPROM.

Uses of Microcontroller

Microcontrollers are used in a wide range of electronic devices and systems given below:

Everyday Uses of Microcontrollers:

- Devices that detect and control light (like automatic street lights).
- Devices that monitor and adjust temperature (like smart thermostats).
- Fire detection and safety systems (like smoke alarms).
- Tools used in factories to measure and monitor things.
- Systems that control industrial processes automatically.

Uses of Microcontrollers in Industrial Control:

- Devices that measure and track industrial data.
- Systems that manage and control production processes.

Uses of Microcontrollers in Measuring Devices:

- Voltage meters.
- Devices that count rotating parts (like in motors).
- Current meters.
- Portable measuring tools (like digital multimeters).

Issues in Microcontroller

Some of the most common issues that can arise with microcontrollers:

- **Timing Issues**
    - Microcontrollers need precise timing to run tasks correctly.
    - Any timing errors can cause malfunctions that are often hard to detect and fix.
- **Power Issues**
    - They need a stable power supply.
    - Power fluctuations or drops can cause the microcontroller to stop working or behave unpredictably.
- **Heat Issues**
    - Microcontrollers generate heat during use.
    - Too much heat can damage the chip or cause it to fail.
    - Caused by poor design, bad cooling, or high room temperatures.
- **Noise Issues**
    - Can be affected by electromagnetic interference (EMI) and radio frequency interference (RFI) from nearby devices.
    - This can lead to errors or unexpected behavior.

- **Code Issues**
    - The software or code running on the microcontroller may have bugs or errors.
    - This can lead to malfunctions or failure of the system.
- **Security Issues**
    - Microcontrollers can be hacked or infected with malware.
    - Risks include unauthorized access, data theft, or system control by attackers.
- **Compatibility Issues**
    - May not work well with other hardware or components.
    - Can result in errors or system failures.

What is a microprocessor?

Microprocessor is a type of computer ***processor*** in which both the data processing logic and control are included on a single integrated circuit or on small numbers of integrated circuits. These processors consist of logic, control and arithmetic circuits. Its integrated circuit is capable of interpreting and executing program instructions. These are multiple-purpose, clock-driven and register-based digital integrated circuits that accept input in binary data and process it as per the instruction stored in its memory.

Difference between Microprocessor and Microcontroller

proprocessor	**Microcontroller**
Since memory and I/O are connected externally, the circuit becomes large in size	Since memory and I/O are present together, the internal circuit is small in size
It cannot be used in compact systems	It can be used in compact systems
Cost is high	Cost is low
It is not suitable for devices that run on stored power since total power consumption is high due to external components	It can be used on devices that use stored power since total power consumption is low due to less external components

RAM, ROM, I/O units, and other peripherals are not embedded on a single chip	RAM, ROM, CPU and other peripherals are embedded on a single chip
Do not have power saving mode	Have a power-saving mode
Used in personal computers	Used in embedded systems
Less number of registers	More number of registers
Uses an external bus	Uses an internal controlling bus
Based on the Von Neumann model	Based on the Harvard architecture
It is a central processing unit on a single silicon-based integrated chip	It is a byproduct of the development of microprocessors with a CPU along with other peripherals
Complex and expensive due to a large number of instructions to process	Simple and inexpensive due to less number of instructions to process
Can run at a very high speed	Can run up to 200MHz or more

Microcontrollers vs Microprocessors: Similarities Between Microcontrollers and Microprocessors

While there are several difference between microprocessor and microcontroller, the two have a few similarities as well. The following points highlight the similarities between microcontrollers and microprocessors:

1. Both microprocessor and microcontroller are semiconductor components that are built on IC.
2. These are used in different modern electronic equipment to automate processes.
3. Microcontroller and microprocessor both have a CPU through which both components process instructions and perform calculations.
4. Both consist of ALU, CPU, registers, address bus, data bus and control bus.
5. Both microprocessors and microcontrollers are built with internal registers. However, the number of registers is higher in microcontrollers as compared to microprocessors.

