A **microcontroller** (or **MCU**, short for *microcontroller unit*) is a small [computer](https://en.wikipedia.org/wiki/Computer) ([SoC](https://en.wikipedia.org/wiki/System_on_a_chip" \o "System on a chip)) on a single [integrated circuit](https://en.wikipedia.org/wiki/Integrated_circuit) containing a processor core, memory, and programmable [input/output](https://en.wikipedia.org/wiki/Input/output) peripherals. Program memory in the form of [Ferroelectric RAM](https://en.wikipedia.org/wiki/Ferroelectric_RAM), [NOR flash](https://en.wikipedia.org/wiki/NOR_flash) or [OTP ROM](https://en.wikipedia.org/wiki/Programmable_read-only_memory)is also often included on chip, as well as a typically small amount of [RAM](https://en.wikipedia.org/wiki/Random-access_memory). Microcontrollers are designed for embedded applications, in contrast to the [microprocessors](https://en.wikipedia.org/wiki/Microprocessor) used in [personal computers](https://en.wikipedia.org/wiki/Personal_computer) or other general purpose applications consisting of various discrete chips.

History

The first [microprocessor](https://en.wikipedia.org/wiki/Microprocessor) was the [4-bit](https://en.wikipedia.org/wiki/4-bit) [Intel 4004](https://en.wikipedia.org/wiki/Intel_4004) released in 1971, with the [Intel 8008](https://en.wikipedia.org/wiki/Intel_8008) and other more capable microprocessors becoming available over the next several years. However, both processors required external chips to implement a working system, raising total system cost, and making it impossible to economically computerize appliances.

The [Smithsonian Institution](https://en.wikipedia.org/wiki/Smithsonian_Institution) credits [TI](https://en.wikipedia.org/wiki/Texas_Instruments) engineers Gary Boone and Michael Cochran with the successful creation of the first microcontroller in 1971. The result of their work was the[TMS 1000](https://en.wikipedia.org/wiki/TMS_1000), which became commercially available in 1974. It combined read-only memory, read/write memory, processor and clock on one chip and was targeted at embedded systems.[[1]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-1)

Partly in response to the existence of the single-chip TMS 1000,[[2]](https://en.wikipedia.org/wiki/Microcontroller" \l "cite_note-CMoral2008-2) Intel developed a computer system on a chip optimized for control applications, the [Intel 8048](https://en.wikipedia.org/wiki/Intel_8048), with commercial parts first shipping in 1977.[[2]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-CMoral2008-2) It combined [RAM](https://en.wikipedia.org/wiki/Random_access_memory) and [ROM](https://en.wikipedia.org/wiki/Read_only_memory) on the same chip. This chip would find its way into over one billion PC keyboards, and other numerous applications. At that time Intel's President, Luke J. Valenter, stated that the microcontroller was one of the most successful in the company's history, and expanded the division's budget over 25%.

### Volumes

In 2002, about 55% of all [CPUs](https://en.wikipedia.org/wiki/Central_processing_unit) sold in the world were 8-bit microcontrollers and microprocessors.[[4]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-4) Over two billion 8-bit microcontrollers were sold in 1997,[[5]](https://en.wikipedia.org/wiki/Microcontroller" \l "cite_note-5) and according to Semico, over four billion 8-bit microcontrollers were sold in 2006.[[6]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-6) More recently, Semico has claimed the MCU market grew 36.5% in 2010 and 12% in 2011.

n 2012, following a global crisis – a worst ever annual sales decline and recovery and average sales price year-over-year plunging 17% – the biggest reduction since the 1980s, the average price for a microcontroller was US$0.88 ($0.69 for 4-/8-bit, $0.59 for 16-bit, $1.76 for 32-bit).[[8]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-vol-8)

In 2012, worldwide sales of 8-bit microcontrollers were around $4 billion because they were so useful that many companies needed them to be able to progress into better technology. In 2012, [4-bit](https://en.wikipedia.org/wiki/4-bit) microcontrollers also see significant sales.[[9]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-9)

In 2015, 8-bit microcontrollers can be bought for $0.311 (1,000 units),[[10]](https://en.wikipedia.org/wiki/Microcontroller" \l "cite_note-10) 16-bit for $0.385 (1,000 units),[[11]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-11) and 32-bit for $0.378 (1,000 units but at $0.35 for 5,000).

## Embedded design

[](https://en.wikipedia.org/wiki/File:PIC18F8720.jpg)

A [PIC](https://en.wikipedia.org/wiki/PIC_microcontroller) 18F8720 **microcontroller** in an 80-pin [TQFP](https://en.wikipedia.org/wiki/Quad_Flat_Package) package.

A microcontroller can be considered a self-contained system with a processor, memory and peripherals and can be used as an [embedded system](https://en.wikipedia.org/wiki/Embedded_system).[[13]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-13) The majority of microcontrollers in use today are embedded in other machinery, such as automobiles, telephones, appliances, and peripherals for computer systems.

While some embedded systems are very sophisticated, many have minimal requirements for memory and program length, with no operating system, and low software complexity. Typical input and output devices include switches, [relays](https://en.wikipedia.org/wiki/Relay), [solenoids](https://en.wikipedia.org/wiki/Solenoid), [LEDs](https://en.wikipedia.org/wiki/LED), small or custom [liquid-crystal displays](https://en.wikipedia.org/wiki/Liquid-crystal_display), radio frequency devices, and sensors for data such as temperature, humidity, light level etc. Embedded systems usually have no keyboard, screen, disks, printers, or other recognizable I/O devices of a [personal computer](https://en.wikipedia.org/wiki/Personal_computer), and may lack human interaction devices of any kind.

### nterrupts

Microcontrollers must provide [real-time](https://en.wikipedia.org/wiki/Real-time_computing) (predictable, though not necessarily fast) response to events in the embedded system they are controlling. When certain events occur, an [interrupt](https://en.wikipedia.org/wiki/Interrupt) system can signal the processor to suspend processing the current instruction sequence and to begin an [interrupt service routine](https://en.wikipedia.org/wiki/Interrupt_service_routine) (ISR, or "interrupt handler") which will perform any processing required based on the source of the interrupt, before returning to the original instruction sequence. Possible interrupt sources are device dependent, and often include events such as an internal timer overflow, completing an analog to digital conversion, a logic level change on an input such as from a button being pressed, and data received on a communication link. Where power consumption is important as in batteried devices, interrupts may also wake a microcontroller from a low-power sleep state where the processor is halted until required to do something by a peripheral event.

### Programs

Typically microcontroller programs must fit in the available on-chip memory, since it would be costly to provide a system with external, expandable memory. Compilers and assemblers are used to convert both [high-level](https://en.wikipedia.org/wiki/High-level_programming_language) and [assembly language](https://en.wikipedia.org/wiki/Assembly_language) codes into a compact [machine code](https://en.wikipedia.org/wiki/Machine_code) for storage in the microcontroller's memory. Depending on the device, the program memory may be permanent, [read-only memory](https://en.wikipedia.org/wiki/Read-only_memory) that can only be programmed at the factory, or it may be field-alterable [flash](https://en.wikipedia.org/wiki/Flash_memory) or erasable read-only memory.

Manufacturers have often produced special versions of their microcontrollers in order to help the hardware and [software development](https://en.wikipedia.org/wiki/Software_development) of the target system. Originally these included [EPROM](https://en.wikipedia.org/wiki/EPROM) versions that have a "window" on the top of the device through which program memory can be erased by [ultraviolet](https://en.wikipedia.org/wiki/Ultraviolet) light, ready for reprogramming after a programming ("burn") and test cycle. Since 1998, EPROM versions are rare and have been replaced by [EEPROM](https://en.wikipedia.org/wiki/EEPROM) and flash, which are easier to use (can be erased electronically) and cheaper to manufacture.

A customizable microcontroller incorporates a block of digital logic that can be personalized for additional processing capability, [peripherals](https://en.wikipedia.org/wiki/Peripherals) and [interfaces](https://en.wikipedia.org/wiki/Interface_(computer_science)) that are adapted to the requirements of the application. One example is the [AT91CAP](https://en.wikipedia.org/wiki/AT91CAP) from [Atmel](https://en.wikipedia.org/wiki/Atmel).

### Other microcontroller features

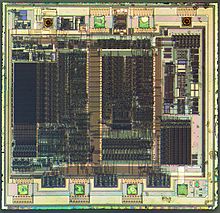
Microcontrollers usually contain from several to dozens of general purpose input/output pins (GPIO). GPIO pins are software configurable to either an input or an output state. When GPIO pins are configured to an input state, they are often used to read sensors or external signals. Configured to the output state, GPIO pins can drive external devices such as LEDs or motors, often indirectly, through external power electronics.

Many embedded systems need to read sensors that produce analog signals. This is the purpose of the [analog-to-digital converter](https://en.wikipedia.org/wiki/Analog-to-digital_converter) (ADC). Since processors are built to interpret and process digital data, i.e. 1s and 0s, they are not able to do anything with the analog signals that may be sent to it by a device. So the analog to digital converter is used to convert the incoming data into a form that the processor can recognize. A less common feature on some microcontrollers is a [digital-to-analog converter](https://en.wikipedia.org/wiki/Digital-to-analog_converter) (DAC) that allows the processor to output analog signals or voltage levels.

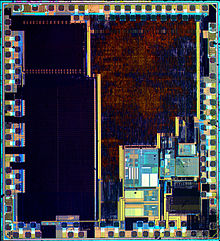
A dedicated [Pulse Width Modulation](https://en.wikipedia.org/wiki/Pulse-width_modulation) (PWM) block makes it possible for the CPU to control [power converters](https://en.wikipedia.org/wiki/Switched-mode_power_supply), [resistive](https://en.wikipedia.org/wiki/Electrical_resistance) loads, [motors](https://en.wikipedia.org/wiki/Electric_motor), etc., without using lots of CPU resources in tight timer [loops](https://en.wikipedia.org/wiki/Program_loops).

[Universal Asynchronous Receiver/Transmitter](https://en.wikipedia.org/wiki/Universal_asynchronous_receiver/transmitter) (UART) block makes it possible to receive and transmit data over a serial line with very little load on the CPU. Dedicated on-chip hardware also often includes capabilities to communicate with other devices (chips) in digital formats such as Inter-Integrated Circuit ([I²C](https://en.wikipedia.org/wiki/I%C2%B2C)), Serial Peripheral Interface ([SPI](https://en.wikipedia.org/wiki/Serial_Peripheral_Interface)), Universal Serial Bus ([USB](https://en.wikipedia.org/wiki/USB)), and [Ethernet](https://en.wikipedia.org/wiki/Ethernet).

Higher integration

[](https://en.wikipedia.org/wiki/File:PIC12C508-HD.jpg)

[Die](https://en.wikipedia.org/wiki/Die_(integrated_circuit)) of a PIC12C508 8-bit, fully static,[EEPROM](https://en.wikipedia.org/wiki/EEPROM)/[EPROM](https://en.wikipedia.org/wiki/EPROM)/[ROM](https://en.wikipedia.org/wiki/Mask_ROM)-based [CMOS](https://en.wikipedia.org/wiki/CMOS" \o "CMOS)microcontroller manufactured by[Microchip Technology](https://en.wikipedia.org/wiki/Microchip_Technology) using a 1200[nanometre](https://en.wikipedia.org/wiki/Nanometre) process.

[](https://en.wikipedia.org/wiki/File:STM32F100C4T6B-HD.jpg)

[Die](https://en.wikipedia.org/wiki/Die_(integrated_circuit)) of a STM32F100C4T6B [ARM Cortex-M3](https://en.wikipedia.org/wiki/ARM_Cortex-M) microcontroller with 16[kilobytes](https://en.wikipedia.org/wiki/Kilobyte) [flash memory](https://en.wikipedia.org/wiki/Flash_memory), 24 [MHz](https://en.wikipedia.org/wiki/Hertz) [Central Processing Unit](https://en.wikipedia.org/wiki/Central_Processing_Unit) (CPU), [motor control](https://en.wikipedia.org/wiki/Motor_controller)and [Consumer Electronics Control](https://en.wikipedia.org/wiki/HDMI#CEC)(CEC) functions. Manufactured by[STMicroelectronics](https://en.wikipedia.org/wiki/STMicroelectronics).

Micro-controllers may not implement an external address or data bus as they integrate RAM and non-volatile memory on the same chip as the CPU. Using fewer pins, the chip can be placed in a much smaller, cheaper package.

Integrating the memory and other peripherals on a single chip and testing them as a unit increases the cost of that chip, but often results in decreased net cost of the embedded system as a whole. Even if the cost of a CPU that has integrated peripherals is slightly more than the cost of a CPU and external peripherals, having fewer chips typically allows a smaller and cheaper circuit board, and reduces the labor required to assemble and test the circuit board, in addition to tending to decrease the defect rate for the finished assembly.

A micro-controller is a single [integrated circuit](https://en.wikipedia.org/wiki/Integrated_circuit), commonly with the following features:

* [central processing unit](https://en.wikipedia.org/wiki/Central_processing_unit) - ranging from small and simple [4-bit](https://en.wikipedia.org/wiki/4-bit) processors to complex [32-bit](https://en.wikipedia.org/wiki/32-bit) or [64-bit](https://en.wikipedia.org/wiki/64-bit) processors
* volatile memory ([RAM](https://en.wikipedia.org/wiki/RAM)) for data storage
* [ROM](https://en.wikipedia.org/wiki/Read-only_memory), [EPROM](https://en.wikipedia.org/wiki/EPROM), [EEPROM](https://en.wikipedia.org/wiki/EEPROM) or [Flash memory](https://en.wikipedia.org/wiki/Flash_memory) for [program](https://en.wikipedia.org/wiki/Computer_program) and operating parameter storage
* discrete input and output bits, allowing control or detection of the logic state of an individual package pin
* serial [input/output](https://en.wikipedia.org/wiki/Input/output) such as [serial ports](https://en.wikipedia.org/wiki/Serial_port) ([UARTs](https://en.wikipedia.org/wiki/UART))
* other [serial communications](https://en.wikipedia.org/wiki/Serial_communications) [interfaces](https://en.wikipedia.org/wiki/Network_interface_controller) like [I²C](https://en.wikipedia.org/wiki/I%C2%B2C), [Serial Peripheral Interface](https://en.wikipedia.org/wiki/Serial_Peripheral_Interface) and [Controller Area Network](https://en.wikipedia.org/wiki/Controller_Area_Network) for system interconnect
* [peripherals](https://en.wikipedia.org/wiki/Peripheral) such as [timers](https://en.wikipedia.org/wiki/Timer), event counters, [PWM generators](https://en.wikipedia.org/wiki/Pulse-width_modulation), and [watchdog](https://en.wikipedia.org/wiki/Watchdog_timer)
* [clock generator](https://en.wikipedia.org/wiki/Clock_generator) - often an oscillator for a quartz timing crystal, resonator or [RC circuit](https://en.wikipedia.org/wiki/RC_circuit)
* many include analog-to-digital converters, some include digital-to-analog converters
* [in-circuit programming](https://en.wikipedia.org/wiki/In-circuit_programming) and [in-circuit debugging](https://en.wikipedia.org/wiki/In-circuit_debugging) support

Some microcontrollers use a [Harvard architecture](https://en.wikipedia.org/wiki/Harvard_architecture): separate memory buses for instructions and data, allowing accesses to take place concurrently. Where a Harvard architecture is used, instruction words for the processor may be a different bit size than the length of internal memory and registers; for example: 12-bit instructions used with 8-bit data registers.

Microcontrollers typically do not have a [math coprocessor](https://en.wikipedia.org/wiki/Math_coprocessor), so [floating point](https://en.wikipedia.org/wiki/Floating_point) arithmetic is performed by software.

## Programming environments

Microcontrollers were originally programmed only in [assembly language](https://en.wikipedia.org/wiki/Assembly_language), but various [high-level programming languages](https://en.wikipedia.org/wiki/High-level_programming_language), such as [Python](https://en.wikipedia.org/wiki/Python_(programming_language)) and [JavaScript](https://en.wikipedia.org/wiki/JavaScript), are now also in common use to target [microcontrollers](https://en.wikipedia.org/wiki/Microcontrollers) and [embedded systems](https://en.wikipedia.org/wiki/Embedded_systems)[[16]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-16). These languages are either designed specially for the purpose, or versions of general purpose languages such as the[C programming language](https://en.wikipedia.org/wiki/C_(programming_language)). [Compilers](https://en.wikipedia.org/wiki/Compiler) for general purpose languages will typically have some restrictions as well as enhancements to better support the unique characteristics of microcontrollers. Some microcontrollers have environments to aid developing certain types of applications. Microcontroller vendors often make tools freely available to make it easier to adopt their hardware.

[Simulators](https://en.wikipedia.org/wiki/Logic_simulation) are available for some microcontrollers. These allow a developer to analyze what the behavior of the microcontroller and their program should be if they were using the actual part. A [simulator](https://en.wikipedia.org/wiki/Simulator) will show the internal processor state and also that of the outputs, as well as allowing input signals to be generated. While on the one hand most simulators will be limited from being unable to simulate much other hardware in a system, they can exercise conditions that may otherwise be hard to reproduce at will in the physical implementation, and can be the quickest way to debug and analyze problems.

Recent microcontrollers are often integrated with on-chip [debug](https://en.wikipedia.org/wiki/Debug) circuitry that when accessed by an [in-circuit emulator](https://en.wikipedia.org/wiki/In-circuit_emulator) via [JTAG](https://en.wikipedia.org/wiki/JTAG), allow debugging of the firmware with a [debugger](https://en.wikipedia.org/wiki/Debugger). A real-time ICE may allow viewing and/or manipulating of internal states while running. A tracing ICE can record executed program and MCU states before/after a trigger point.

Types of microcontrollers

As of 2008, there are several dozen microcontroller architectures and vendors including:

* [ARM](https://en.wikipedia.org/wiki/ARM_architecture) core processors (many vendors)
  + [ARM Cortex-M](https://en.wikipedia.org/wiki/ARM_Cortex-M) cores are specifically targeted towards microcontroller applications
* [Atmel AVR](https://en.wikipedia.org/wiki/Atmel_AVR) (8-bit), [AVR32](https://en.wikipedia.org/wiki/AVR32) (32-bit), and [AT91SAM](https://en.wikipedia.org/wiki/AT91SAM) (32-bit)
* [Cypress Semiconductor](https://en.wikipedia.org/wiki/Cypress_Semiconductor)'s M8C Core used in their [PSoC (Programmable System-on-Chip)](https://en.wikipedia.org/wiki/PSoC" \o "PSoC)
* [Freescale ColdFire](https://en.wikipedia.org/wiki/Freescale_ColdFire) (32-bit) and [S08](https://en.wikipedia.org/wiki/Freescale_S08) (8-bit)
* [Freescale 68HC11](https://en.wikipedia.org/wiki/Freescale_68HC11) (8-bit), and others [based on the Motorola 6800 family](https://en.wikipedia.org/wiki/List_of_Freescale_products)
* [Intel 8051](https://en.wikipedia.org/wiki/Intel_8051), also manufactured by [NXP Semiconductors](https://en.wikipedia.org/wiki/NXP_Semiconductors), Infineon and many others
* [Infineon](https://en.wikipedia.org/wiki/List_of_common_microcontrollers#Infineon): [8-bit XC800](https://en.wikipedia.org/wiki/XC800), [16-bit XE166](https://en.wikipedia.org/wiki/XE166_family), [32-bit XMC4000](https://en.wikipedia.org/wiki/Infineon_XMC4000) (ARM based Cortex M4F), [32-bit TriCore](https://en.wikipedia.org/wiki/TriCore) and, [32-bit Aurix](https://en.wikipedia.org/wiki/Aurix) Tricore Bit microcontrollers[[19]](https://en.wikipedia.org/wiki/Microcontroller#cite_note-19)
* [MIPS](https://en.wikipedia.org/wiki/MIPS_architecture)
* [Microchip Technology](https://en.wikipedia.org/wiki/Microchip_Technology) [PIC](https://en.wikipedia.org/wiki/PIC_microcontroller), (8-bit PIC16, PIC18, 16-bit dsPIC33 / PIC24), (32-bit PIC32)
* [NXP Semiconductors](https://en.wikipedia.org/wiki/NXP_Semiconductors) LPC1000, LPC2000, LPC3000, LPC4000 (32-bit), LPC900, LPC700 (8-bit)
* [Parallax Propeller](https://en.wikipedia.org/wiki/Parallax_Propeller)
* [PowerPC](https://en.wikipedia.org/wiki/PowerPC) ISE
* [Rabbit 2000](https://en.wikipedia.org/wiki/Rabbit_2000) (8-bit)
* [Renesas Electronics](https://en.wikipedia.org/wiki/Renesas_Electronics): [RL78 16-bit MCU](https://en.wikipedia.org/wiki/RL78); [RX 32-bit MCU](https://en.wikipedia.org/wiki/RX_Microcontroller_Family); [SuperH](https://en.wikipedia.org/wiki/SuperH" \o "SuperH); [V850 32-bit MCU](https://en.wikipedia.org/wiki/V850); [H8](https://en.wikipedia.org/wiki/H8_Family); [R8C 16-bit MCU](https://en.wikipedia.org/wiki/R8C)
* [Silicon Laboratories](https://en.wikipedia.org/wiki/Silicon_Laboratories) Pipelined 8-bit 8051 Microcontrollers and mixed-signal ARM-based 32-bit microcontrollers
* [STMicroelectronics](https://en.wikipedia.org/wiki/STMicroelectronics) [STM8](https://en.wikipedia.org/wiki/STM8) (8-bit), [ST10](https://en.wikipedia.org/wiki/ST10) (16-bit) and [STM32](https://en.wikipedia.org/wiki/STM32) (32-bit)
* [Texas Instruments](https://en.wikipedia.org/wiki/Texas_Instruments#Microcontrollers) [TI MSP430](https://en.wikipedia.org/wiki/MSP430) (16-bit), [MSP432](http://www.ti.com/msp432) (32-bit), [C2000](https://en.wikipedia.org/wiki/TMS320) (32-bit)
* [Toshiba TLCS-870](https://en.wikipedia.org/wiki/Toshiba_TLCS) (8-bit/16-bit)

Many others exist, some of which are used in very narrow range of applications or are more like applications processors than microcontrollers. The microcontroller market is extremely fragmented, with numerous vendors, technologies, and markets. Note that many vendors sell or have sold multiple architectures.

### \Advantages of Microcontroller:

            Microcontroller's use increased rapidly. Now these are used in almost every electronic equipment like Washing Machines, Mobile Phones and Microwave Oven. Following are the most important facts about Microcontrollers, which causes rapid growth of their use:

* Microcontrollers are cheap and very small in size, therefore they can be embedded on any device.
* Programming of Microcontrollers is simple to learn. Its not much complicated.
* We can use simulators on Computers to see the practical results of our program. Thus we can work on a Embedded project without even buying the required Components and Chips. Thus we can virtually see the working of our project or program

### Applications of Microcontrollers:

Microcontrollers are mostly used in following electronic equipments :

* Mobile Phones
* Auto Mobiles
* CD/DVD Players
* Washing Machines
* Cameras
* In Computers-> Modems and Keyboard Controllers
* Security Alarms
* Electronic Measurement Instruments.
* Microwave Oven.