A **microprocessor** is a computer processor which incorporates the functions of a [computer](https://en.wikipedia.org/wiki/Computer)'s [central processing unit](https://en.wikipedia.org/wiki/Central_processing_unit) (CPU) on a single [integrated circuit](https://en.wikipedia.org/wiki/Integrated_circuit) (IC),[[1]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-Osborne80-1) or at most a few integrated circuits.[[2]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-2) The microprocessor is a multipurpose, clock driven, [register](https://en.wikipedia.org/wiki/Processor_register) based, [programmable](https://en.wikipedia.org/wiki/Computer_program) electronic device which accepts [digital](https://en.wikipedia.org/wiki/Digital_data) or [binary](https://en.wikipedia.org/wiki/Binary) data as input, processes it according to instructions stored in its memory, and provides results as output. Microprocessors contain both combinational logic and [sequential digital logic](https://en.wikipedia.org/wiki/Sequential_logic). Microprocessors operate on numbers and symbols represented in the [binary numeral system](https://en.wikipedia.org/wiki/Binary_numeral_system).

Before microprocessors, small computers had been built using racks of circuit boards with many [medium-](https://en.wikipedia.org/wiki/Medium-scale_integration) and [small-scale](https://en.wikipedia.org/wiki/Small-scale_integration) integrated circuits. Microprocessors combined this into one or a few [large-scale](https://en.wikipedia.org/wiki/Large-scale_integration) ICs. Continued increases in microprocessor capacity have since rendered other forms of computers almost completely obsolete (see [history of computing hardware](https://en.wikipedia.org/wiki/History_of_computing_hardware)), with one or more microprocessors used in everything from the smallest [embedded systems](https://en.wikipedia.org/wiki/Embedded_system) and [handheld devices](https://en.wikipedia.org/wiki/Handheld_device) to the largest [mainframes](https://en.wikipedia.org/wiki/Mainframe_computer) and[supercomputers](https://en.wikipedia.org/wiki/Supercomputer).

## History

The advent of low-cost computers on integrated circuits has transformed modern society. General-purpose microprocessors in [personal computers](https://en.wikipedia.org/wiki/Personal_computer) are used for computation, text editing, multimedia display, and communication over the [Internet](https://en.wikipedia.org/wiki/Internet). Many more microprocessors are part of [embedded systems](https://en.wikipedia.org/wiki/Embedded_system), providing digital control over myriad objects from appliances to automobiles to [cellular phones](https://en.wikipedia.org/wiki/Cellular_phone) and industrial process control.

By the late-1960s, designers were striving to integrate the central processing unit (CPU) functions of a computer onto a handful of MOS LSI chips, called microprocessor unit (MPU) chip sets. Building on [8-bit](https://en.wikipedia.org/wiki/8-bit) arithmetic logic units (3800/3804) he designed earlier at Fairchild, in 1969 Lee Boysel created the Four-Phase Systems Inc. AL-1 an 8-bit CPU slice that was expandable to 32-bits. In 1970, Steve Geller and Ray Holt of Garrett AiResearch designed the MP944 chip set to implement the F-14A Central Air Data Computer on six metal-gate chips fabricated by AMI.

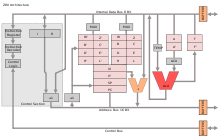
Intel introduced its first [4-bit](https://en.wikipedia.org/wiki/4-bit) microprocessor 4004 in 1971 and its 8-bit microprocessor 8008 in 1972. During the 1960s, computer processors were constructed out of small and medium-scale ICs—each containing from tens of [transistors](https://en.wikipedia.org/wiki/Transistors) to a few hundred.

In the [NASA](https://en.wikipedia.org/wiki/NASA) Apollo space missions to the [moon](https://en.wikipedia.org/wiki/Moon) in the 1960s and 1970s, all onboard computations for primary guidance, navigation and control were provided by a small custom processor called "The [Apollo Guidance Computer](https://en.wikipedia.org/wiki/Apollo_Guidance_Computer)". It used wire wrap circuit boards whose only [logic elements](https://en.wikipedia.org/wiki/Logic_gate) were three-input [NOR gates](https://en.wikipedia.org/wiki/NOR_gate).

The first microprocessors emerged in the early 1970s and were used for electronic [calculators](https://en.wikipedia.org/wiki/Calculator), using [binary-coded decimal](https://en.wikipedia.org/wiki/Binary-coded_decimal) (BCD) arithmetic on 4-bit [words](https://en.wikipedia.org/wiki/Word_(data_type)). Other [embedded](https://en.wikipedia.org/wiki/Embedded_system" \o "Embedded system)uses of 4-bit and 8-bit microprocessors, such as [terminals](https://en.wikipedia.org/wiki/Computer_terminal), [printers](https://en.wikipedia.org/wiki/Computer_printer), various kinds of [automation](https://en.wikipedia.org/wiki/Automation) etc., followed soon after. Affordable 8-bit microprocessors with [16-bit](https://en.wikipedia.org/wiki/16-bit) addressing also led to the first general-purpose [microcomputers](https://en.wikipedia.org/wiki/Microcomputer) from the mid-1970s on.

Since the early 1970s, the increase in capacity of microprocessors has followed [Moore's law](https://en.wikipedia.org/wiki/Moore%27s_law); this originally suggested that the number of components that can be fitted onto a chip doubles every year. With present technology, it is actually every two years,and as such Moore later changed the period to two years.

Structure

[](https://en.wikipedia.org/wiki/File:Z80_arch.svg)

A block diagram of the architecture of the [Z80](https://en.wikipedia.org/wiki/Zilog_Z80) microprocessor, showing the arithmetic and logic section, register file, control logic section, and buffers to external address and data lines

The internal arrangement of a **microprocessor** varies depending on the age of the design and the intended purposes of the microprocessor. The complexity of an integrated circuit (IC) is bounded by physical limitations of the number of [transistors](https://en.wikipedia.org/wiki/Transistors) that can be put onto one chip, the number of package terminations that can connect the processor to other parts of the system, the number of interconnections it is possible to make on the chip, and the heat that the chip can dissipate. Advancing technology makes more complex and powerful chips feasible to manufacture.

A minimal hypothetical microprocessor might only include an [arithmetic logic unit](https://en.wikipedia.org/wiki/Arithmetic_logic_unit) (ALU) and a control logic section. The ALU performs operations such as addition, subtraction, and operations such as AND or OR. Each operation of the ALU sets one or more flags in a status register, which indicate the results of the last operation (zero value, negative number, overflow, or others). The control logic retrieves instruction codes from memory and initiates the sequence of operations required for the ALU to carry out the instruction. A single[operation code](https://en.wikipedia.org/wiki/Operation_code) might affect many individual data paths, registers, and other elements of the processor.

As integrated circuit technology advanced, it was feasible to manufacture more and more complex processors on a single chip. The size of data objects became larger; allowing more transistors on a chip allowed word sizes to increase from [4-](https://en.wikipedia.org/wiki/4-bit) and [8-bit](https://en.wikipedia.org/wiki/8-bit) words up to today's [64-bit](https://en.wikipedia.org/wiki/64-bit_computing) words. Additional features were added to the processor architecture; more on-chip registers sped up programs, and complex instructions could be used to make more compact programs. Floating-point arithmetic, for example, was often not available on 8-bit microprocessors, but had to be carried out in software. Integration of the [floating point unit](https://en.wikipedia.org/wiki/Floating_point_unit) first as a separate integrated circuit and then as part of the same microprocessor chip, sped up floating point calculations.

Occasionally, physical limitations of integrated circuits made such practices as a [bit slice](https://en.wikipedia.org/wiki/Bit_slicing) approach necessary. Instead of processing all of a long word on one integrated circuit, multiple circuits in parallel processed subsets of each data word. While this required extra logic to handle, for example, carry and overflow within each slice, the result was a system that could handle, for example, [32-bit](https://en.wikipedia.org/wiki/32-bit) words using integrated circuits with a capacity for only four bits each.

## Embedded applications

Thousands of items that were traditionally not computer-related include microprocessors. These include large and small household [appliances](https://en.wikipedia.org/wiki/Home_appliance), cars (and their accessory equipment units), car keys, tools and test instruments, toys, light switches/dimmers and [electrical circuit breakers](https://en.wikipedia.org/wiki/Arc-fault_circuit_interrupter), smoke alarms, battery packs, and hi-fi audio/visual components (from [DVD](https://en.wikipedia.org/wiki/DVD) players to [phonograph turntables](https://en.wikipedia.org/wiki/Phonograph#Turntable_technology)). Such products as cellular telephones, [DVD video](https://en.wikipedia.org/wiki/DVD_video) system and [HDTV](https://en.wikipedia.org/wiki/HDTV) broadcast systems fundamentally require consumer devices with powerful, low-cost, microprocessors. Increasingly stringent pollution control standards effectively require automobile manufacturers to use microprocessor engine management systems, to allow optimal control of emissions over widely varying operating conditions of an automobile. Non-programmable controls would require complex, bulky, or costly implementation to achieve the results possible with a microprocessor.

A microprocessor control program ([embedded software](https://en.wikipedia.org/wiki/Embedded_software)) can be easily tailored to different needs of a product line, allowing upgrades in performance with minimal redesign of the product. Different features can be implemented in different models of a product line at negligible production cost.

Microprocessor control of a system can provide control strategies that would be impractical to implement using electromechanical controls or purpose-built electronic controls. For example, an engine control system in an automobile can adjust ignition timing based on engine speed, load on the engine, ambient temperature, and any observed tendency for knocking—allowing an automobile to operate on a range of fuel grades.

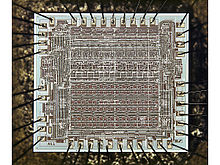
Three projects delivered a microprocessor at about the same time: [Garrett AiResearch](https://en.wikipedia.org/wiki/Garrett_AiResearch)'s [Central Air Data Computer](https://en.wikipedia.org/wiki/Central_Air_Data_Computer) (CADC), [Texas Instruments](https://en.wikipedia.org/wiki/Texas_Instruments) (TI) TMS 1000 (1971 September), and [Intel](https://en.wikipedia.org/wiki/Intel)'s [4004](https://en.wikipedia.org/wiki/Intel_4004) (1971 November).

#### CADC

In 1968, [Garrett AiResearch](https://en.wikipedia.org/wiki/Garrett_AiResearch) (which employed designers [Ray Holt](https://en.wikipedia.org/wiki/Ray_Holt) and Steve Geller) was invited to produce a digital computer to compete with [electromechanical](https://en.wikipedia.org/wiki/Electromechanical) systems then under development for the main flight control computer in the [US Navy](https://en.wikipedia.org/wiki/US_Navy)'s new [F-14 Tomcat](https://en.wikipedia.org/wiki/F-14_Tomcat) fighter. The design was complete by 1970, and used a [MOS](https://en.wikipedia.org/wiki/MOSFET)-based chipset as the core CPU. The design was significantly (approximately 20 times) smaller and much more reliable than the mechanical systems it competed against, and was used in all of the early Tomcat models. This system contained "a 20-bit, [pipelined](https://en.wikipedia.org/wiki/Pipeline_(computing)), [parallel](https://en.wikipedia.org/wiki/Parallel_computing) [multi-microprocessor](https://en.wikipedia.org/wiki/Multiprocessor)".

[Ray Holt](https://en.wikipedia.org/wiki/Ray_Holt) graduated from [California Polytechnic University](https://en.wikipedia.org/wiki/California_Polytechnic_State_University) in 1968, and began his computer design career with the CADC. From its inception, it was shrouded in secrecy until 1998 when at Holt's request, the US Navy allowed the documents into the public domain. Since then people[*[who?](https://en.wikipedia.org/wiki/Wikipedia:Manual_of_Style/Words_to_watch" \l "Unsupported_attributions" \o "Wikipedia:Manual of Style/Words to watch)*] have debated whether this was the first microprocessor. Holt has stated that no one has compared this microprocessor with those that came later.[[15]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-15) According to Parab et al. (2007),*"The scientific papers and literature published around 1971 reveal that the MP944 digital processor used for the F-14 Tomcat aircraft of the US Navy qualifies as the first microprocessor. Although interesting, it was not a single-chip processor, as was not the Intel 4004 – they both were more like a set of parallel building blocks you could use to make a general-purpose form. It contains a CPU,*[*RAM*](https://en.wikipedia.org/wiki/Random-access_memory)*,*[*ROM*](https://en.wikipedia.org/wiki/Read-only_memory)*, and two other support chips like the Intel 4004. It was made from the same*[*P-channel*](https://en.wikipedia.org/wiki/PMOS_logic)*technology, operated at*[*military specifications*](https://en.wikipedia.org/wiki/United_States_Military_Standard)*and had larger chips -- an excellent computer engineering design by any standards. Its design indicates a major advance over Intel, and two year earlier. It actually worked and was flying in the F-14 when the Intel 4004 was announced. It indicates that today’s industry theme of converging*[*DSP*](https://en.wikipedia.org/wiki/Digital_signal_processor)*-*[*microcontroller*](https://en.wikipedia.org/wiki/Microcontroller)*architectures was started in 1971."*[[16]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-16) This convergence of DSP and microcontroller architectures is known as a [digital signal controller](https://en.wikipedia.org/wiki/Digital_signal_controller).

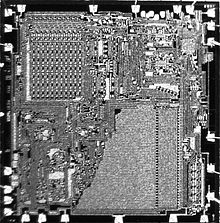
#### Four-Phase Systems AL1

[](https://en.wikipedia.org/wiki/File:AL1_-_Four-Phase_Systems_Inc.jpg)

AL1 by Four-Phase Systems Inc: one from the earliest inventions in the field of microprocessor technology

The [Four-Phase Systems AL1](https://en.wikipedia.org/wiki/Four-Phase_Systems_AL1) was an 8-bit [bit slice](https://en.wikipedia.org/wiki/Bit_slice) chip containing eight registers and an ALU.[[18]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-18) It was designed by Lee Boysel in 1969.At the time, it formed part of a nine-chip, 24-bit CPU with three AL1s, but it was later called a microprocessor when, in response to 1990s litigation by [Texas Instruments](https://en.wikipedia.org/wiki/Texas_Instruments), a demonstration system was constructed where a single AL1 formed part of a courtroom demonstration computer system, together with RAM, ROM, and an input-output device.

#### Pico/General Instrument

[](https://en.wikipedia.org/wiki/File:GI250_PICO1_die_photo.jpg)

The PICO1/GI250 chip introduced in 1971. This was designed by Pico Electronics (Glenrothes, Scotland) and manufactured by General Instrument of Hicksville NY.

In 1971, Pico Electronics and [General Instrument](https://en.wikipedia.org/wiki/General_Instrument) (GI) introduced their first collaboration in ICs, a complete single chip calculator IC for the Monroe/Litton Royal Digital III calculator. This chip could also arguably lay claim to be one of the first microprocessors or microcontrollers having [ROM](https://en.wikipedia.org/wiki/Read-only_memory), [RAM](https://en.wikipedia.org/wiki/Random-access_memory) and a [RISC](https://en.wikipedia.org/wiki/RISC) instruction set on-chip. The layout for the four layers of the [PMOS](https://en.wikipedia.org/wiki/PMOS_logic) process was hand drawn at x500 scale on mylar film, a significant task at the time given the complexity of the chip.

Pico was a spinout by five GI design engineers whose vision was to create single chip calculator ICs. They had significant previous design experience on multiple calculator chipsets with both GI and [Marconi-Elliott](https://en.wikipedia.org/wiki/Elliott_Automation).The key team members had originally been tasked by [Elliott Automation](https://en.wikipedia.org/wiki/Elliott_Automation) to create an 8-bit computer in MOS and had helped establish a MOS Research Laboratory in [Glenrothes](https://en.wikipedia.org/wiki/Glenrothes" \o "Glenrothes), Scotland in 1967.

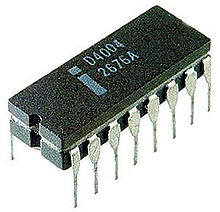
Calculators were becoming the largest single market for semiconductors so Pico and GI went on to have significant success in this burgeoning market. GI continued to innovate in microprocessors and microcontrollers with products including the CP1600, IOB1680 and PIC1650. In 1987 the GI Microelectronics business was spun out into the [Microchip](https://en.wikipedia.org/wiki/Microchip) [PIC microcontroller](https://en.wikipedia.org/wiki/PIC_microcontroller) business.

#### Intel 4004

[](https://en.wikipedia.org/wiki/File:C4004_(Intel).jpg)

The [4004](https://en.wikipedia.org/wiki/Intel_4004) with cover removed (left) and as actually used (right)

The [Intel 4004](https://en.wikipedia.org/wiki/Intel_4004) is generally regarded as the first commercially available microprocessor, and cost US$60 (equivalent to $350.58 in 2015). The first known advertisement for the 4004 is dated November 15, 1971 and appeared in [Electronic News](https://en.wikipedia.org/wiki/Electronic_News). The project that produced the 4004 originated in 1969, when [Busicom](https://en.wikipedia.org/wiki/Busicom" \o "Busicom), a Japanese calculator manufacturer, asked Intel to build a chipset for high-performance [desktop calculators](https://en.wikipedia.org/wiki/Desktop_calculator). Busicom's original design called for a programmable chip set consisting of seven different chips.

[Intel 4004](https://en.wikipedia.org/wiki/Intel_4004), the first commercial microprocessor

#### TMS 1000

The [Smithsonian Institution](https://en.wikipedia.org/wiki/Smithsonian_Institution) says [TI](https://en.wikipedia.org/wiki/Texas_Instruments) engineers Gary Boone and Michael Cochran succeeded in creating the first microcontroller (also called a microcomputer) and the first single-chip CPU in 1971. The result of their work was the TMS 1000, which went on the market in 1974.[[34]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-34) TI stressed the 4-bit TMS 1000 for use in pre-programmed embedded applications, introducing a version called the TMS1802NC on September 17, 1971 that implemented a calculator on a chip.

TI filed for a patent on the microprocessor. Gary Boone was awarded [U.S. Patent 3,757,306](https://www.google.com/patents/US3757306) for the single-chip microprocessor architecture on September 4, 1973. In 1971 and again in 1976, Intel and TI entered into broad patent cross-licensing agreements, with Intel paying royalties to TI for the microprocessor patent. A history of these events is contained in court documentation from a legal dispute between Cyrix and Intel, with TI as inventor and owner of the microprocessor patent.

A computer-on-a-chip combines the microprocessor core (CPU), memory, and I/O ([input/output](https://en.wikipedia.org/wiki/Input/output)) lines onto one [chip](https://en.wikipedia.org/wiki/Integrated_circuit). The computer-on-a-chip patent, called the "microcomputer patent" at the time, [U.S. Patent 4,074,351](https://www.google.com/patents/US4074351), was awarded to Gary Boone and Michael J. Cochran of TI. Aside from this patent, the standard meaning of [microcomputer](https://en.wikipedia.org/wiki/Microcomputer) is a computer using one or more microprocessors as its CPU(s), while the concept defined in the patent is more akin to a microcontroller.

### 8-bit designs

The Intel 4004 was followed in 1972 by the [Intel 8008](https://en.wikipedia.org/wiki/Intel_8008), the world's first [8-bit](https://en.wikipedia.org/wiki/8-bit) microprocessor.

The 8008 was the precursor to the successful [Intel 8080](https://en.wikipedia.org/wiki/Intel_8080) (1974), which offered improved performance over the 8008 and required fewer support chips. Federico Faggin conceived and designed it using high voltage N channel MOS. The [Zilog Z80](https://en.wikipedia.org/wiki/Zilog_Z80" \o "Zilog Z80) (1976) was also a Faggin design, using low voltage N channel with depletion load and derivative Intel 8-bit processors: all designed with the methodology Faggin created for the 4004. [Motorola](https://en.wikipedia.org/wiki/Motorola) released the competing [6800](https://en.wikipedia.org/wiki/Motorola_6800) in August 1974, and the similar [MOS Technology 6502](https://en.wikipedia.org/wiki/MOS_Technology_6502) in 1975 (both designed largely by the same people). The 6502 family rivaled the Z80 in popularity during the 1980s

Another early 8-bit microprocessor was the [Signetics 2650](https://en.wikipedia.org/wiki/Signetics_2650" \o "Signetics 2650), which enjoyed a brief surge of interest due to its innovative and powerful [instruction set](https://en.wikipedia.org/wiki/Instruction_set) architecture.

### 12-bit designs

The [Intersil 6100](https://en.wikipedia.org/wiki/Intersil_6100" \o "Intersil 6100) family consisted of a [12-bit](https://en.wikipedia.org/wiki/12-bit) microprocessor (the 6100) and a range of peripheral support and memory ICs. The microprocessor recognised the DEC [PDP-8](https://en.wikipedia.org/wiki/PDP-8)[minicomputer](https://en.wikipedia.org/wiki/Minicomputer) instruction set. As such it was sometimes referred to as the **CMOS-PDP8**. Since it was also produced by Harris Corporation, it was also known as the **Harris HM-6100**. By virtue of its CMOS technology and associated benefits, the 6100 was being incorporated into some military designs until the early 1980s.

### 16-bit designs

The first multi-chip [16-bit](https://en.wikipedia.org/wiki/16-bit) microprocessor was the [National Semiconductor](https://en.wikipedia.org/wiki/National_Semiconductor) [IMP-16](https://en.wikipedia.org/wiki/IMP-16), introduced in early 1973. An 8-bit version of the chipset was introduced in 1974 as the IMP-8.

Other early multi-chip 16-bit microprocessors include one that [Digital Equipment Corporation (DEC)](https://en.wikipedia.org/wiki/Digital_Equipment_Corporation) used in the [LSI-11](https://en.wikipedia.org/wiki/LSI-11) OEM board set and the packaged [PDP 11/03](https://en.wikipedia.org/wiki/PDP-11)[minicomputer](https://en.wikipedia.org/wiki/Minicomputer)—and the [Fairchild Semiconductor](https://en.wikipedia.org/wiki/Fairchild_Semiconductor) MicroFlame 9440, both introduced in 1975–76. In 1975, National introduced the first 16-bit single-chip microprocessor, the[National Semiconductor PACE](https://en.wikipedia.org/wiki/National_Semiconductor_PACE), which was later followed by an [NMOS](https://en.wikipedia.org/wiki/NMOS_logic) version, the [INS8900](https://en.wikipedia.org/wiki/INS8900).

Another early single-chip 16-bit microprocessor was TI's [TMS 9900](https://en.wikipedia.org/wiki/Texas_Instruments_TMS9900), which was also compatible with their [TI-990](https://en.wikipedia.org/wiki/TI-990) line of minicomputers. The 9900 was used in the TI 990/4 minicomputer, the [TI-99/4A](https://en.wikipedia.org/wiki/TI-99/4A) home computer, and the TM990 line of OEM microcomputer boards. The chip was packaged in a large ceramic 64-pin [DIP package](https://en.wikipedia.org/wiki/Dual_in-line_package), while most 8-bit microprocessors such as the Intel 8080 used the more common, smaller, and less expensive plastic 40-pin DIP.

Intel "upsized" their 8080 design into the 16-bit [Intel 8086](https://en.wikipedia.org/wiki/Intel_8086), the first member of the [x86](https://en.wikipedia.org/wiki/X86) family, which powers most modern [PC](https://en.wikipedia.org/wiki/IBM_PC_compatible) type computers. [Intel](https://en.wikipedia.org/wiki/Intel) introduced the 8086 as a cost-effective way of porting software from the 8080 lines, and succeeded in winning much business on that premise.

The [8088](https://en.wikipedia.org/wiki/Intel_8088), a version of the 8086 that used an 8-bit external data bus, was the microprocessor in the first [IBM PC](https://en.wikipedia.org/wiki/IBM_PC).

 Intel then released the [80186](https://en.wikipedia.org/wiki/Intel_80186) and [80188](https://en.wikipedia.org/wiki/Intel_80188), the [80286](https://en.wikipedia.org/wiki/Intel_80286) and, in 1985, the 32-bit [80386](https://en.wikipedia.org/wiki/Intel_80386), cementing their PC market dominance with the processor family's backwards compatibility. The 80186 and 80188 were essentially versions of the 8086 and 8088, enhanced with some onboard peripherals and a few new instructions. Although Intel's 80186 and 80188 were not used in IBM PC type designs, second source versions from NEC, the [V20](https://en.wikipedia.org/wiki/NEC_V20) and V30 frequently were.

 The 8086 and successors had an innovative but limited method of [memory segmentation](https://en.wikipedia.org/wiki/Memory_segmentation), while the 80286 introduced a full-featured segmented [memory management unit](https://en.wikipedia.org/wiki/Memory_management_unit) (MMU). The 80386 introduced a flat 32-bit memory model with paged memory management.

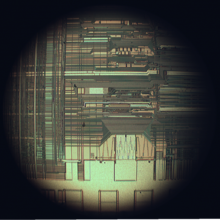
The 16-bit Intel x86 processors up to and including the 80386 do not include [floating-point units (FPUs)](https://en.wikipedia.org/wiki/Floating-point_unit). Intel introduced the [8087](https://en.wikipedia.org/wiki/Intel_8087), [80187](https://en.wikipedia.org/wiki/Intel_80187), [80287](https://en.wikipedia.org/wiki/Intel_80287) and [80387](https://en.wikipedia.org/wiki/Intel_80387) math coprocessors to add hardware floating-point and transcendental function capabilities to the 8086 through 80386 CPUs.

The 8087 works with the 8086/8088 and 80186/80188, the 80187 works with the 80186 but not the 80188 , the 80287 works with the 80286 and the 80387 works with the 80386. The combination of an x86 CPU and an x87 coprocessor forms a single multi-chip microprocessor; the two chips are programmed as a unit using a single integrated instruction set.

The 8087 and 80187 coprocessors are connected in parallel with the data and address buses of their parent processor and directly execute instructions intended for them.

The 80287 and 80387 coprocessors are interfaced to the CPU through I/O ports in the CPU's address space, this is transparent to the program, which does not need to know about or access these I/O ports directly; the program accesses the coprocessor and its registers through normal instruction opcodes.

### 32-bit designs

[](https://en.wikipedia.org/wiki/File:80486DX2_200x.png)

Upper interconnect layers on an [Intel 80486](https://en.wikipedia.org/wiki/Intel_80486)DX2 die

16-bit designs had only been on the market briefly when [32-bit](https://en.wikipedia.org/wiki/32-bit) implementations started to appear.

The most significant of the 32-bit designs is the [Motorola MC68000](https://en.wikipedia.org/wiki/Motorola_68000), introduced in 1979. The 68k, as it was widely known, had 32-bit registers in its programming model but used 16-bit internal data paths, three 16-bit Arithmetic Logic Units, and a 16-bit external data bus (to reduce pin count), and externally supported only 24-bit addresses (internally it worked with full 32 bit addresses). In [PC-based IBM-compatible mainframes](https://en.wikipedia.org/wiki/PC-based_IBM-compatible_mainframes) the MC68000 internal microcode was modified to emulate the 32-bit System/370 IBM mainframe.Motorola generally described it as a 16-bit processor. The combination of high performance, large (16 [megabytes](https://en.wikipedia.org/wiki/Megabyte) or 224 bytes) memory space and fairly low cost made it the most popular CPU design of its class. The [Apple Lisa](https://en.wikipedia.org/wiki/Apple_Lisa) and [Macintosh](https://en.wikipedia.org/wiki/Apple_Macintosh) designs made use of the 68000, as did a host of other designs in the mid-1980s, including the [Atari ST](https://en.wikipedia.org/wiki/Atari_ST) and [Commodore Amiga](https://en.wikipedia.org/wiki/Commodore_Amiga).

The first commercial, single chip, fully 32-bit microprocessor available on the market was the [HP FOCUS](https://en.wikipedia.org/wiki/HP_FOCUS).

Intel's first 32-bit microprocessor was the [iAPX 432](https://en.wikipedia.org/wiki/Intel_iAPX_432" \o "Intel iAPX 432), which was introduced in 1981, but was not a commercial success. It had an advanced [capability-based](https://en.wikipedia.org/wiki/Capability-based_security) [object-oriented](https://en.wikipedia.org/wiki/Object_(computer_science))architecture, but poor performance compared to contemporary architectures such as Intel's own 80286 (introduced 1982), which was almost four times as fast on typical benchmark tests. However, the results for the iAPX432 was partly due to a rushed and therefore suboptimal [Ada](https://en.wikipedia.org/wiki/Ada_(programming_language)) [compiler](https://en.wikipedia.org/wiki/Compiler).

Motorola's success with the 68000 led to the [MC68010](https://en.wikipedia.org/wiki/Motorola_68010), which added virtual memory support. The [MC68020](https://en.wikipedia.org/wiki/Motorola_68020), introduced in 1984 added full 32-bit data and address buses. The 68020 became hugely popular in the [Unix](https://en.wikipedia.org/wiki/Unix) supermicrocomputer market, and many small companies

The [ARM](https://en.wikipedia.org/wiki/ARM_architecture) first appeared in 1985.[[45]](https://en.wikipedia.org/wiki/Microprocessor#cite_note-45) This is a [RISC](https://en.wikipedia.org/wiki/RISC) processor design, which has since come to dominate the 32-bit [embedded systems](https://en.wikipedia.org/wiki/Embedded_systems) processor space due in large part to its power efficiency, its licensing model, and its wide selection of system development tools. Semiconductor manufacturers generally license cores and integrate them into their own[system on a chip](https://en.wikipedia.org/wiki/System_on_a_chip) products; only a few such vendors are licensed to modify the ARM cores. Most [cell phones](https://en.wikipedia.org/wiki/Cell_phones) include an ARM processor, as do a wide variety of other products. There are microcontroller-oriented ARM cores without virtual memory support, as well as [symmetric multiprocessor](https://en.wikipedia.org/wiki/Symmetric_multiprocessor_system) (SMP) applications processors with virtual memory.

### 64-bit designs in personal computers

While [64-bit](https://en.wikipedia.org/wiki/64-bit_computing) microprocessor designs have been in use in several markets since the early 1990s (including the [Nintendo 64](https://en.wikipedia.org/wiki/Nintendo_64) [gaming console](https://en.wikipedia.org/wiki/Gaming_console) in 1996), the early 2000s saw the introduction of 64-bit microprocessors targeted at the PC market.

With AMD's introduction of a 64-bit architecture backwards-compatible with x86, [x86-64](https://en.wikipedia.org/wiki/X86-64) (also called **AMD64**), in September 2003, followed by Intel's near fully compatible 64-bit extensions (first called IA-32e or EM64T, later renamed **Intel 64**), the 64-bit desktop era began. Both versions can run 32-bit legacy applications without any performance penalty as well as new 64-bit software. With operating systems [Windows XP x64](https://en.wikipedia.org/wiki/Windows_XP_Professional_x64_Edition), [Windows Vista](https://en.wikipedia.org/wiki/Windows_Vista) x64, [Windows 7](https://en.wikipedia.org/wiki/Windows_7) x64, [Linux](https://en.wikipedia.org/wiki/Linux), [BSD](https://en.wikipedia.org/wiki/BSD), and [Mac OS X](https://en.wikipedia.org/wiki/Mac_OS_X) that run 64-bit native, the software is also geared to fully utilize the capabilities of such processors. The move to 64 bits is more than just an increase in register size from the IA-32 as it also doubles the number of general-purpose registers.

In 2011, ARM introduced a new 64-bit ARM architecture.

### RISC

In the mid-1980s to early 1990s, a crop of new high-performance reduced instruction set computer ([RISC](https://en.wikipedia.org/wiki/RISC)) microprocessors appeared, influenced by discrete RISC-like CPU designs such as the [IBM 801](https://en.wikipedia.org/wiki/IBM_801) and others. RISC microprocessors were initially used in special-purpose machines and [Unix](https://en.wikipedia.org/wiki/Unix) [workstations](https://en.wikipedia.org/wiki/Workstation), but then gained wide acceptance in other roles.

The first commercial RISC microprocessor design was released in 1984 by [MIPS Computer Systems](https://en.wikipedia.org/wiki/MIPS_Computer_Systems), the 32-bit [R2000](https://en.wikipedia.org/wiki/R2000_(microprocessor)) (the R1000 was not released). In 1986, HP released its first system with a [PA-RISC](https://en.wikipedia.org/wiki/PA-RISC) CPU. In 1987 in the non-Unix [Acorn computers](https://en.wikipedia.org/wiki/Acorn_computers)' 32-bit, then cache-less, [ARM2](https://en.wikipedia.org/wiki/ARM2)-based [Acorn Archimedes](https://en.wikipedia.org/wiki/Acorn_Archimedes) became the first commercial success using the [ARM architecture](https://en.wikipedia.org/wiki/ARM_architecture), then known as Acorn RISC Machine (ARM); first silicon [ARM1](https://en.wikipedia.org/wiki/ARM_architecture) in 1985. The R3000 made the design truly practical, and the [R4000](https://en.wikipedia.org/wiki/R4000) introduced the world's first commercially available 64-bit RISC microprocessor. Competing projects would result in the IBM [POWER](https://en.wikipedia.org/wiki/IBM_POWER_Instruction_Set_Architecture) and [Sun](https://en.wikipedia.org/wiki/Sun_Microsystems) [SPARC](https://en.wikipedia.org/wiki/SPARC) architectures. Soon every major vendor was releasing a RISC design, including the [AT&T CRISP](https://en.wikipedia.org/wiki/AT%26T_CRISP), [AMD 29000](https://en.wikipedia.org/wiki/AMD_29000), [Intel i860](https://en.wikipedia.org/wiki/Intel_i860) and [Intel i960](https://en.wikipedia.org/wiki/Intel_i960), [Motorola 88000](https://en.wikipedia.org/wiki/Motorola_88000), [DEC Alpha](https://en.wikipedia.org/wiki/DEC_Alpha).

In the late 1990s, only two 64-bit RISC architectures were still produced in volume for non-embedded applications: [SPARC](https://en.wikipedia.org/wiki/SPARC) and [Power ISA](https://en.wikipedia.org/wiki/Power_Architecture), but as ARM has become increasingly powerful, in the early 2010s, it became the third RISC architecture in the general computing segment.

### Multi-core designs

A [multi-core processor](https://en.wikipedia.org/wiki/Multi-core_processor) is a single chip that contains more than one microprocessor core. Each core can simultaneously execute processor instructions in parallel. This effectively multiplies the processor's potential performance by the number of cores, if the software is designed to take advantage of more than one processor core. Some components, such as bus interface and cache, may be shared between cores. Because the cores are physically close to each other, they can communicate with each other much faster than separate (off-chip) processors in a multiprocessor system, which improves overall system performance.

In 2005, AMD released the first native dual-core processor, the Athlon X2. Intel's Pentium D had beaten the X2 to market by a few weeks, but it used two separate CPU dies and was less efficient than AMD's native design. As of 2012, dual- and quad-core processors are widely used in home PCs and laptops, while quad-, six-, eight-, ten-, twelve-, and sixteen-core processors are common in the professional and enterprise markets with workstations and servers.

Modern desktop computers support systems with multiple CPUs, but few applications outside of the professional market can make good use of more than four cores. Both Intel and AMD currently offer fast quad, hex and octa-core desktop CPUs, making multi-CPU systems obsolete for many purposes. The desktop market has been in a transition towards quad-core CPUs since Intel's Core 2 Quad was released and are now common, although dual-core CPUs are still more prevalent.

## Market statistics

In 1997, about 55% of all [CPUs](https://en.wikipedia.org/wiki/Central_processing_unit) sold in the world are 8-bit [microcontrollers](https://en.wikipedia.org/wiki/Microcontroller), over two billion of which were sold.

In 2002, less than 10% of all the CPUs sold in the world were 32-bit or more. Of all the 32-bit CPUs sold, about 2% are used in desktop or laptop personal computers.

In 2003, about US$44 (equivalent to $56.6 in 2015) billion worth of microprocessors were manufactured and sold.

in 2004–10, and the rate of improvement slowed to -15% to -25% per year in 2010–13.