

Abstract

A microprocessor is a central part of a modern personal computer (or computer device). It integrates the functions of a central processing unit (the part of a computer that processes the program instructions) onto a single integrated circuit and places a vast amount of processing power in a tiny space.

Intel's invention of the microprocessor in 1971 was a revolution in computing, and it placed the power of a computer on a tiny chip. It was initially developed as an enhancement to allow users to add more memory to their units. However, it soon became clear that the microprocessor had great potential for everything from calculators to cash registers and traffic lights. Its invention made personal computers, tablets and mobile phones possible.

We discuss early microprocessors such as the Intel 4004, the 8-bit Intel 8080 and the 8-bit Motorola 6800. The 16-bit Intel 8086 was introduced in 1978 and the 16/32-bit Motorola 68000 was released in 1979. The 8-bit Intel 8088 (the cheaper 8-bit variant of the Intel 8086) was introduced in 1979, and it was chosen as the microprocessor for the IBM personal computer.

Key Topics

Microprocessor

Intel 4004

Intel 8008

Intel 8080

Intel 8088

Motorola 68000

10.1 Introduction

A *microprocessor* is a central part of a modern personal computer (or computer device). It integrates the functions of a central processing unit (the part of a computer that processes the program instructions) onto a single integrated circuit and places a vast amount of processing power in a tiny space.

Intel's invention of the microprocessor in 1971 was a revolution in computing, and it placed the power of a computer on a tiny chip. It was initially developed as an enhancement to allow users to add more memory to their units. However, it soon became clear that the microprocessor had great potential for everything from calculators to cash registers and traffic lights. Its invention made personal computers, tablets and mobile phones possible.

Computers in the 1960s were large and expensive, and they typically filled an entire room. They were available only to a small number of individuals and government laboratories. The invention of the transistor by Shockley and others at Bell Labs had helped to reduce the size and cost of a computer.

The later invention of the integrated circuit by Jack Kilby of Texas Instruments, and improved upon by Robert Noyce and others at Fairchild Semiconductors, meant that several transistors could now be placed on a chip, leading to further reductions in the size and cost of machines. However, large-scale integration where a large number of transistors could be placed onto a silicon chip was still a long way away.

Several employees left Fairchild Semiconductors in the late 1960s to form their own semiconductor companies in the Silicon Valley area. They formed companies such as Intel, National Semiconductors and Advanced Micro Devices (AMD). Intel began operations making memory chips and it delivered its first product the 64-bit SRAM chip (the 3101) to Honeywell in 1969. It introduced a DRAM chip (the 1103) in 1970, and in 1971, it introduced the microprocessor, an invention that transformed the computing field.

10.2 Invention of the Microprocessor

The invention of the microprocessor (initially called microcomputer) in 1971 was a revolution in computing, with the power of a computer now available on a tiny microprocessor chip.

The microprocessor is essentially a computer on a chip, and its invention made hand-held calculators and personal computers (PCs) possible. Intel's microprocessors are used on the majority of personal computers and laptops around the world.

The invention of the microprocessor happened by accident rather than design. The Nippon Calculating Machine Corporation (later known as Busicom), a Japanese company, requested Intel to design a set of integrated circuits for its new family of high-performance programmable calculators. At that time, it was standard practice to custom design all logic chips for each customer's product, and this clearly limited the applicability of a logic chip to a specialized domain.

The design proposed by *Busicom* required 12 integrated circuits. Ted Hoff, an Intel engineer, studied *Busicom*'s design and he rejected it as unwieldy. He proposed a more elegant solution requiring just four integrated circuits, and his design included a chip that was a general-purpose logic device (microprocessor) that derived its application instructions from the semiconductor memory. *Busicom* accepted his proposed design, and Intel engineers then implemented it.

Hoff's 4004 microprocessor design included a central processing unit (CPU) on one chip. It contained 2300 transistors on a one-eighth by one-sixth inch chip surrounded by three ICs containing ROM, shift registers, input/output ports and RAM.

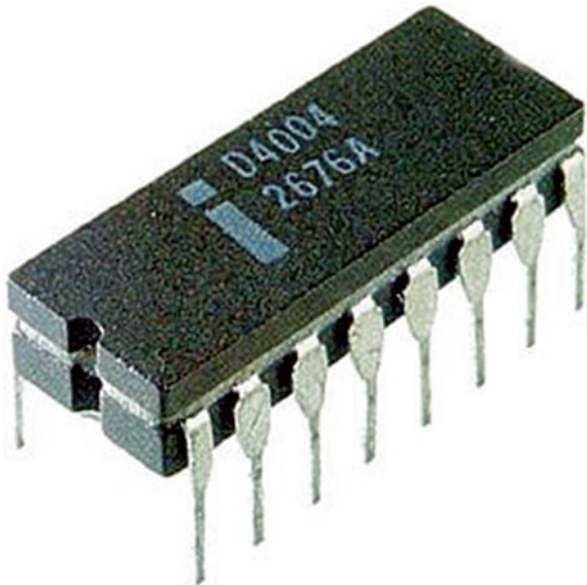
Busicom had exclusive rights to the design and components, but following discussion and negotiations, *Busicom* agreed to give up its exclusive rights to the chips. Intel shortly afterwards announced the availability of the first microprocessor, the Intel 4004 (Fig. 10.1).

This was the world's first microprocessor, and although it was initially developed as an enhancement to allow users to add more memory to their units, it soon became clear that the microprocessor could be applied to many other areas.

This small Intel 4004 microprocessor chip was launched in late 1971, and it could execute 60,000 operations per second. The tiny chip had an equivalent computing power as the large ENIAC which used 18,000 vacuum tubes and took up the space of an entire room [ORG:11].

The Intel 4004 sold for \$200 and for the first time affordable computing power was available to designers of all types of products. The introduction of the microprocessor was a revolution in computing, and its invention had applications to everything from traffic lights to medical instruments and to the development of home and personal computers.

Fig. 10.1 Intel 4004 microprocessor



Gary Kildall was one of the early people to recognize the potential of the microprocessor as a computer in its own right, and he began writing experimental programs for the Intel 4004 microprocessor in the early 1970s. Kildall worked as a consultant with Intel on the later 8008 and 8080 microprocessors.

He developed the first high-level programming language for a microprocessor (PL/M) in 1973, which enabled programmers to write applications for microprocessors. He developed the CP/M operating system (Control Program for Microcomputers) in the same year. CP/M allowed the Intel 8080 microprocessor to control a floppy disk drive allowing files to be read and written to and from an 8 inch floppy disk. CP/M made it possible for computer hobbyists and companies to build the first home computers.

Kildall made CP/M hardware independent by creating a separate module called the BIOS (basic input/output system). He added several utilities such as an editor, debugger and assembler, and by 1977, several manufacturers included CP/M with their systems. He set up Digital Research Inc. (DRI) in 1976 to develop, market and sell the CP/M operating system.

10.3 Early Microprocessors

Intel has developed more and more powerful microprocessors since its introduction of the Intel 4004. The Intel 8008 was launched in 1972, and this was a reasonably successful product. It led to the 8-bit Intel 8080 microprocessor, which was released in 1974. The Intel 8080 was the first general-purpose microprocessor, and it was sold for \$360: i.e. a whole computer on one chip was sold for \$360, while conventional computers sold for thousands of dollars. The Intel 8080 soon became the industry standard, and Intel became the industry leader in the 8-bit market. The 8080 played an important role in starting personal computer development, as it attracted the interest of computer developers and engineers.

Motorola introduced its first microprocessor, the 8-bit 6800 microprocessors (Fig. 10.2), in 1974, and this microprocessor was used in automotive, computing and video games. It contained over 4000 transistors. It competed against the Intel 8080 microprocessor, and it was used in some early home computer kits.

Fig. 10.2 Motorola 6800 microprocessor



National Semiconductors introduced its 16-bit IMP-16 in 1973 and an 8-bit version, the IMP-8, in 1974. Texas Instruments introduced the first single-chip microprocessor, the PACE, in 1974, and it introduced its first 16-bit microprocessor, the TMS 9900, in 1976. MOS Technology introduced its 8-bit 6502 in 1975, and Zilog introduced its Z80 in 1976.

The 16-bit Intel 8086 was introduced in 1978, but it soon faced competition from Motorola, which introduced its 16/32-bit 68000 microprocessor in 1979. The Intel 8088 is an 8-bit variant of the 8086, and it was introduced in 1979. The Motorola 68000 was a hybrid 16/32-bit microprocessor that had a 16-bit data bus, but it could perform 32-bit calculations internally. It was used on various Apple Macintosh computers, the Atari ST and the Commodore Amiga.

The first single-chip 32-bit microprocessor was AT&T Bell Labs BELLMAC-32A, which was introduced in 1982. Motorola introduced its 32-bit 68020 microprocessor in 1984, and this microprocessor contained 200,000 transistors on a three-eighths inch square chip.

IBM considered several microprocessors for its IBM PC including the IBM 801 processor, the Motorola 68000 microprocessor and the Intel 8088 microprocessor. IBM chose the Intel 8088 chip (which was cheaper than the 16-bit Intel 8086), and it took a 20% stake in Intel leading to strong ties between both companies.

Today, Intel's microprocessors are used on most personal computers around the world, and the contract to supply the Intel 8088 microprocessor was a major turning point for the company. Intel had been focused more on the sale of dynamic random access memory chips, with sales of microprocessors in thousands or in tens of thousands. However, sales of microprocessors rocketed following the introduction of the IBM PC, and soon sales were in tens of millions of units.

The introduction of the IBM PC was a revolution in computing, and there are hundreds of millions of computers in use around the world today. It placed computing power in the hands of ordinary users, and today's personal computers are more powerful than the mainframes that were used to send man to the moon. The cost of computing processing power has fallen exponentially since the introduction of the first microprocessor, and Intel has played a key role in squeezing more and more transistors onto a chip leading to more and more powerful microprocessors and personal computers.

10.4 A Selection of Semiconductor Companies

Robert Noyce and Gordon Moore founded Intel (Integrated Electronics) in 1968. Today, it is an American semiconductor giant with headquarters at Santa Clara in California. It is one of the largest semiconductor manufacturers in the world, with plants in the United States, Europe and Asia. It has played an important role in shaping the computing field with its invention of the microprocessor in 1971. It is the inventor of the x86 series of microprocessors that are used in most personal computers, and the company is renowned for its leadership in the microprocessor industry and for its excellence and innovation in microprocessor design and manufacturing.

Noyce and Moore left Fairchild Semiconductors to set up Intel, and the initial focus of the company was on semiconductor memory products and to make semiconductor memory practical. Its goal was to create large-scale integrated (LSI) semiconductor memory, and it introduced a number of products including the Intel 1103, which was a one-kilobit (KB) dynamic random access memory (DRAM) integrated circuit.

Motorola set up a research lab in 1952 to take advantage of the potential of semiconductors, and by 1961 it was mass-producing semiconductors at a low cost. It introduced a transistorized walkie-talkie in 1962 as well as transistors for its Quasar televisions. Its microprocessors have played an important role in the computing field. These include the influential 68000 and PowerPC architecture, which were used in the Apple Macintosh and Power Macintosh personal computers. Motorola's semiconductor business was spun off to become a separate company called Freescale Semiconductor Inc. in 2004.

Advanced Micro Devices was formed by Jerry Sanders and several of his colleagues from Fairchild Semiconductors in 1969. It initially acted as a second-source supplier of microchips designed by Fairchild and National Semiconductors, and it later acted as second supplier for the x86 chips produced by Intel. AMD produces microprocessors, motherboards and chipsets, and it is the second largest supplier of x86-based microprocessors.

National Semiconductors was founded in Connecticut by Bernard Rothlein and several of his colleagues from Sperry Rand Corporation. It introduced the 16-bit IMP-16 microprocessor in 1973 and the 8-bit version, the IMP-8, in 1974. National Semiconductors was taken over by Texas Instruments in 2011.

Texas Instruments (TI) is an American electronics company that was formed in 1951, and its headquarters are in Dallas. It is one of the largest manufacturers of semiconductors in the world, and it produces a wide range of semiconductor products including chips for mobile phones, calculators, microcontrollers, digital signal processors, analog semiconductors and multicore processors.

It commenced research on transistors in the early 1950s, and it introduced one of the first transistor radios in 1954. It invented the integrated circuit in 1958; PACE, the first single-chip microprocessor, was introduced in 1974; and the TMS 9900, its first 16-bit microprocessor, was released in 1976.

MOS Technology was formed in 1969 initially as a second supplier of calculator chips for Texas Instruments. Several Motorola designers of the Motorola 6800 microprocessor joined the company in 1975, and their knowledge allowed MOS to develop the 6501 and 6502 microprocessors. MOS Technology was taken over by Commodore in 1976.

10.5 Review Questions

1. What is a microprocessor?
2. What is the significance of the Intel 4004?
3. Why is the invention of the microprocessor considered a revolution in computing?
4. What are the main contributions made by Motorola to the semiconductor field?
5. Why did so many employees leave Fairchild Semiconductors to set up companies in Silicon Valley? What companies did they form?
6. What are the main contributions made by Intel to the semiconductor field?
7. Explain the significance of PL/M and CP/M?

10.6 Summary

A microprocessor is a central part of a modern personal computer (or computer device), and it places a vast amount of processing power on a tiny chip. Intel's invention of the microprocessor in 1971 changed computing forever, and it placed the power of a computer on a tiny chip.

The microprocessor was initially developed as an enhancement to allow users to add more memory to their units. However, it soon became clear that the microprocessor had applications to many other areas. Its invention led to personal computers, tablets and mobile phones.

The invention of the microprocessor happened by accident rather than design, and it was initially developed as part of the design to allow users to add more memory to their units. The design solution included a general-purpose chip that derived its application instructions from the semiconductor memory. This was the Intel 4004 microprocessor.