## **The History of Computing Hardware (1960-Present)**

Read this article to supplement the previous articles. As you see here, the history of computers is split into "generations". This course will primarily focus on the third generation of computers, which began in the 1960s, and the microcomputer technology of today, which has meant that computers are now present in the homes of many people across the world.

The **history of computing hardware** starting at 1960 is marked by the conversion from vacuum tube to solid-state devices such as the transistor and later the integrated circuit. By 1959 discrete transistors were considered sufficiently reliable and economical that they made further vacuum tube computers uncompetitive. Computer main memory slowly moved away from magnetic core memory devices to solid-state static and dynamic semiconductor memory, which greatly reduced the cost, size and power consumption of computers.

## **Third generation**

The mass increase in the use of computers accelerated with 'Third Generation' computers. These generally relied on Jack Kilby's invention of the integrated circuit (or microchip), starting around 1966 in the commercial market.

The first integrated circuit was produced in September 1958, and computers using them began to appear in the early 1960s, for example the 1961 Semiconductor Network Computer (Molecular Electronic Computer, Mol-E-Com), first monolithic integrated circuit general purpose computer (built for demonstration purposes, programmed to simulate a desk calculator) was built by Texas Instruments for the US Air Force.

Some of their early uses were in embedded systems, notably used by NASA for the Apollo Guidance Computer, by the military in the LGM-30 Minuteman intercontinental ballistic missile, the Honeywell ALERT airborne computer, and in the Central Air Data Computer used for flight control in the US Navy's F-14A Tomcat fighter jet.

An early commercial use was the 1965 SDS 92. IBM first used ICs in computers for the logic of the System/360 Model 85 shipped in 1969 and then made extensive use of ICs in its System/370 which began shipment in 1971.

The integrated circuit enabled the development of much smaller computers. The minicomputer was a significant innovation in the 1960s and 1970s. It brought computing power to more people, not only through more convenient physical size but also through broadening the computer vendor field. Digital Equipment Corporation became the number two computer company behind IBM with their popular PDP and VAX computer systems. Smaller, affordable hardware also brought about the development of important new operating systems such as Unix.



1969 Data General Nova

In November 1966, Hewlett-Packard introduced the 2116A minicomputer, one of the first commercial 16-bit computers. It used CTµL (Complementary Transistor MicroLogic) in integrated circuits from Fairchild Semiconductor. Hewlett-Packard followed this with similar 16-bit computers, such as the 2115A in 1967, the 2114A in 1968, and others.

In 1969, Data General introduced the Nova and shipped a total of 50,000 at $8,000 each. The popularity of 16-bit computers, such as the Hewlett-Packard 21xx series and the Data General Nova, led the way toward word lengths that were multiples of the 8-bit byte. The Nova was first to employ medium-scale integration (MSI) circuits from Fairchild Semiconductor, with subsequent models using large-scale integrated (LSI) circuits. Also notable was that the entire central processor was contained on one 15-inch printed circuit board.

Large mainframe computers used ICs to increase storage and processing abilities. The 1965 IBM System/360 mainframe computer family are sometimes called third-generation computers; however their logic consisted primaritly of SLT hybrid circuits, which contained discrete transistors and diodes interconnected on a substrate with printed wires and printed passive components; the S/360 M85 and M91 did use ICs for some of their circuits. IBM's 1971 System/370 used ICs for their logic.

## **Fourth generation**

The basis of the fourth generation was the invention of the microprocessor by a team at Intel.

Third generation minicomputers were essentially scaled-down versions of mainframe computers, whereas the fourth generation's origins are fundamentally different.

Microprocessor-based computers were originally very limited in their computational ability and speed, and were in no way an attempt to downsize the minicomputer. They were addressing an entirely different market.

Processing power and storage capacities have grown beyond all recognition since the 1970s, but the underlying technology has remained basically the same of large-scale integration (LSI) or very-large-scale integration(VLSI) microchips, so it is widely regarded that most of today's computers still belong to the fourth generation.

### **Microprocessors**



1971: Intel 4004

On November 15, 1971, Intel released the world's first commercial microprocessor, the 4004. It was developed for a Japanese calculator company called Busicom as an alternative to hardwired circuitry, but computers were developed around it, with much of their processing abilities provided by one small microprocessor chip. The RAM chip was based on an invention by Robert Dennard of IBM, offering kilobits of memory on one chip. Intel coupled the RAM chip with the microprocessor, allowing fourth generation computers to be smaller and faster than prior computers. The 4004 was only capable of 60,000 instructions per second, but its successors brought ever-growing speed and power to computers, including the Intel 8008, 8080 (used in many computers using the CP/M operating system), and the 8086/8088 family. (The IBM personal computer (PC) and compatibles use processors that are still backwards-compatible with the 8086.) Other producers also made microprocessors which were widely used in microcomputers.

The following table shows a timeline of significant microprocessor development.

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| **Year** | **Microprocessors** |
| 1971 | Intel 4004 |
| 1972 | Fairchild PPS-25; Intel 8008; Rockwell PPS-4 |
| 1973 | Burroughs Mini-D; National IMP-16; NEC µCOM |
| 1974 | General Instrument CP1600; Intel 4040, 8080; Mostek 5065; Motorola 6800; National IMP-4, IMP-8, ISP-8A/500, PACE; Texas Instruments TMS 1000; Toshiba TLCS-12 |
| 1975 | Fairchild F8; Hewlett Packard BPC; Intersil 6100; MOS Technology 6502; RCA CDP 1801; Rockwell PPS-8; Signetics 2650; Western Digital MCP-1600 |
| 1976 | RCA CDP 1802; Signetics 8X300; Texas Instruments TMS9900; Zilog Z-80 |
| 1977 | Intel 8085 |
| 1978 | Intel 8086; Motorola 6801, 6809 |
| 1979 | Intel 8088; Motorola 68000; Zilog Z8000 |
| 1980 | National Semi 16032; Intel 8087 |
| 1981 | DEC T-11; Harris 6120; IBM ROMP |
| 1982 | Hewlett Packard FOCUS; Intel 80186, 80188, 80286; DEC J-11; Berkeley RISC-I |
| 1983 | Stanford MIPS; Berkeley RISC-II |
| 1984 | Motorola 68020; National Semi 32032; NEC V20 |
| 1985 | DEC MicroVAX 78032/78132; Harris Novix; Intel 80386; MIPS R2000 |
| 1986 | NEC V60; Sun SPARC MB86900/86910; Zilog Z80000 |
| 1987 | Acorn ARM2; DEC CVAX 78034; Hitachi Gmicro/200; Motorola 68030; NEC V70 |
| 1988 | Intel 80386SX, i960; MIPS R3000 |
| 1989 | DEC VAX DC520 Rigel; Intel 80486, i860 |
| 1990 | IBM POWER1; Motorola 68040 |
| 1991 | DEC NVAX; IBM RSC; MIPS R4000 |
| 1992 | DEC Alpha 21064; Hewlett Packard PA-7100; Sun microSPARC I |
| 1993 | IBM POWER2, PowerPC 601; Intel Pentium |
| 1994 | DEC Alpha 21064A; Hewlett Packard PA-7100LC, PA-7200; IBM PowerPC 603, PowerPC 604, ESA/390 G1; Motorola 68060; QED R4600 |
| 1995 | DEC Alpha 21164; HAL Computer SPARC64; Intel Pentium Pro; Sun UltraSPARC; IBM ESA/390 G2 |
| 1996 | AMD K5; DEC Alpha 21164A; HAL Computer SPARC64 II; Hewlett Packard PA-8000; IBM P2SC, ESA/390 G3; MTI R10000; QED R5000 |
| 1997 | AMD K6; IBM PowerPC 620, PowerPC 750, RS64, ESA/390 G4; Intel Pentium II; Sun UltraSPARC IIs |
| 1998 | DEC Alpha 21264; HAL Computer SPARC64 III; Hewlett Packard PA-8500; IBM POWER3, RS64-II, ESA/390 G5; QED RM7000; SGI MIPS R12000 |
| 1999 | AMD Athlon; IBM RS64-III; Intel Pentium III; Motorola PowerPC 7400 |
| 2000 | AMD Athlon XP, Duron; Fujitsu SPARC64 IV; IBM RS64-IV, z900; Intel Pentium 4 |
| 2001 | IBM POWER4; Intel Itanium; Motorola PowerPC 7450; SGI MIPS R14000; Sun UltraSPARC III |
| 2002 | Fujitsu SPARC64 V; Intel Itanium 2 |
| 2003 | AMD Opteron, Athlon 64; IBM PowerPC 970; Intel Pentium M |
| 2004 | IBM POWER5, PowerPC BGL |
| 2005 | AMD Athlon 64 X2, Opteron Athens; IBM PowerPC 970MP, Xenon; Intel Pentium D; Sun UltraSPARC IV, UltraSPARC T1 |
| 2006 | IBM Cell/B.E., z9; Intel Core 2, Core Duo, Itanium Montecito |
| 2007 | AMD Opteron Barcelona; Fujitsu SPARC64 VI; IBM POWER6, PowerPC BGP; Sun UltraSPARC T2; Tilera TILE64 |
| 2008 | AMD Opteron Shanghai, Phenom; Fujitsu SPARC64 VII; IBM PowerXCell 8i, z10; Intel Atom, Core i7; Tilera TILEPro64 |
| 2009 | AMD Opteron Istanbul, Phenom II |
| 2010 | AMD Opteron Magny-cours; Fujitsu SPARC64 VII+; IBM POWER7, z196; Intel Itanium Tukwila, Westmere, Nehalem-EX; Sun SPARC T3 |
| 2011 | AMD FX Bulldozer, Interlagos, Llano; Fujitsu SPARC64 VIIIfx; Freescale PowerPC e6500; Intel Sandy Bridge, Xeon E7; Oracle SPARC T4 |
| 2012 | Fujitsu SPARC64 IXfx; IBM POWER7+, zEC12; Intel Itanium Poulson |
| 2013 | Fujitsu SPARC64 X; Intel Haswell; Oracle SPARC T5 |
| 2014 | IBM POWER8 |
| 2015 | IBM z13 |
| 2017 | IBM POWER9, z14; AMD Ryzen |

### **Supercomputers**



1976: Cray-1 supercomputer

The powerful supercomputers of the era were at the other end of the computing spectrum from the microcomputers, and they also used integrated circuit technology. In 1976, the Cray-1 was developed by Seymour Cray, who had left Control Data in 1972 to form his own company. This machine was the first supercomputer to make vector processing practical. It had a characteristic horseshoe shape to speed processing by shortening circuit paths. Vector processing uses one instruction to perform the same operation on many arguments; it has been a fundamental supercomputer processing method ever since. The Cray-1 could calculate 150 million floating point operations per second (150 megaflops). 85 were shipped at a price of $5 million each. The Cray-1 had a CPU that was mostly constructed of SSI and MSI ECL ICs.

## **Mainframes and minicomputers**



Time-sharing computer terminals connected to central computers, such as the TeleVideo ASCII character mode smart terminal pictured here, were sometimes used before the advent of the PC.

Computers were generally large, costly systems owned by large institutions before the introduction of the microprocessor in the early 1970s — corporations, universities, government agencies, and the like. Users were experienced specialists who did not usually interact with the machine itself, but instead prepared tasks for the computer on off-line equipment, such as card punches. A number of assignments for the computer would be gathered up and processed in batch mode. After the jobs had completed, users could collect the output printouts and punched cards. In some organizations, it could take hours or days between submitting a job to the computing center and receiving the output.

A more interactive form of computer use developed commercially by the middle 1960s. In a time-sharing system, multiple teleprinter terminals let many people share the use of one mainframe computer processor. This was common i

A different model of computer use was foreshadowed by the way in which early, pre-commercial, experimental computers were used, where one user had exclusive use of a processor. Some of the first computers that might be called "personal" were early minicomputers such as the LINC and PDP-8, and later on VAX and larger minicomputers from Digital Equipment Corporation (DEC), Data General, Prime Computer, and others. They originated as peripheral processors for mainframe computers, taking on some routine tasks and freeing the processor for computation. By today's standards, they were physically large (about the size of a refrigerator) and costly (typically tens of thousands of US dollars), and thus were rarely purchased by individuals. However, they were much smaller, less expensive, and generally simpler to operate than the mainframe computers of the time, and thus affordable by individual laboratories and research projects. Minicomputers largely freed these organizations from the batch processing and bureaucracy of a commercial or university computing center.

## **Timeline of computer systems and important hardware**

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| **Year** | **Hardware** |
| 1959 | Transistors: IBM 7090; IBM 1401 |
| 1960 | DEC PDP 1 |
| 1961 | Fairchild resistor transistor logic |
| 1962 | NPN transistor |
| 1963 | Mouse; CMOS patented |
| 1964 | CDC 6600; IBM Data Cell Drive |
| 1965 | DEC PDP 8; IBM 1130 |
| 1966 | Integrated circuits: HP 2116A;[14] Apollo Guidance Computer |
| 1967 | Fairchild built first MOS; Englebart applies for mouse patent |
| 1969 | Data General Nova |
| 1969 | Honeywell 316 |
| 1970 | DEC PDP 11 |
| 1971 | 8" floppy disk; ILLIAC IV |
| 1972 | Atari founded; Cray Research founded |
| 1973 | Micral first microprocessor PC |
| 1974 | Altair 8800; Data General Eclipse |
| 1975 | Olivetti P6060; Cray-1 |
| 1976 | Tandem Computers |
| 1977 | Apple II; TRS-80 Model 1; Commodore PET; 5.25" floppy |
| 1978 | DEC VAX 11 |
| 1979 | Atari 400, 800 |
| 1980 | Sinclair ZX80, Seagate hard disk drive |
| 1981 | IBM PC, Acorn BBC Micro |
| 1982 | Commodore 64, Sinclair ZX Spectrum |
| 1983 | Apple Lisa; 3.5" floppy |
| 1984 | Apple Mac; Apple Lisa 2 |
| 1985 | PC's Limited (renamed Dell Computer Corporation in 1988); Amiga 1000 |
| 1986 | Tandem Nonstop VLX |
| 1987 | Thinking Machine CM2; Tera Computer Founded |
| 1988 | Dell |
| 1989 | NeXT |
| 1990 | ETA10; CD-R |
| 1991 | Apple Switches to PowerPC |
| 1992 | HP 95LX; Palmtop PC |
| 1993 | Intel PPGA |
| 1994 | VESA Local Bus |
| 1995 | IBM Deep Blue chess computer |
| 1996 | USB 1.0 |
| 1997 | Compaq buys Tandem; CD-RW |
| 1998 | iMac |
| 1999 | First BlackBerry device (850) |
| 2000 | USB 2 |
| 2003 | Arduino |
| 2005 | Mac Mini; World's first desktop dual-core CPU Athlon 64 X2 |
| 2006 | Apple transition to Intel |
| 2007 | iPhone 1 |
| 2008 | USB 3.0 |
| 2010 | Apple iPad |
| 2012 | IBM zEnterprise System; Raspberry Pi |
| 2015 | HoloLens |