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A Mini-History of Computing

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A MINI-HISTORY ᴏꜰ COMPUTING

computing *in* SCIENCE ENGINEERING

Computing in Science & Engineering (CiSE) magazine is the creator of this booklet and the accompanying playing cards. Selections were made by one of our associate editors, who teaches an introductory course on computing history.

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A MINI-HISTORY OF COMPUTING

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TABLE OF CONTENTS

In general, card values were assigned according to relative importance. For example, the Cray computer X-MP, an Ace, was regarded as a bit more important in computing history than the UNIVAC 1, which was a 7.

Ancient Calculating Instruments

From time immemorial, mankind needed to count and find order in the world. While tally sticks, the abacus, and the quipu were used to count quantities and track exchanges and debts, the Antikythera Mechanism computed the movement of stars over time. Time itself is a counting system, developed by the ancient Sumerians and later by the Babylonians. What makes all of these ancient instruments important to computing is their ability to deal with quantity, expressed as place values—a notion later perfected by the Indus Valley civilization with the written number zero that occupies a place. Without the invention of number systems and their corresponding implementation in instruments like these, computing as we know it, where positional binary bits are turned on or off, simply would not exist.
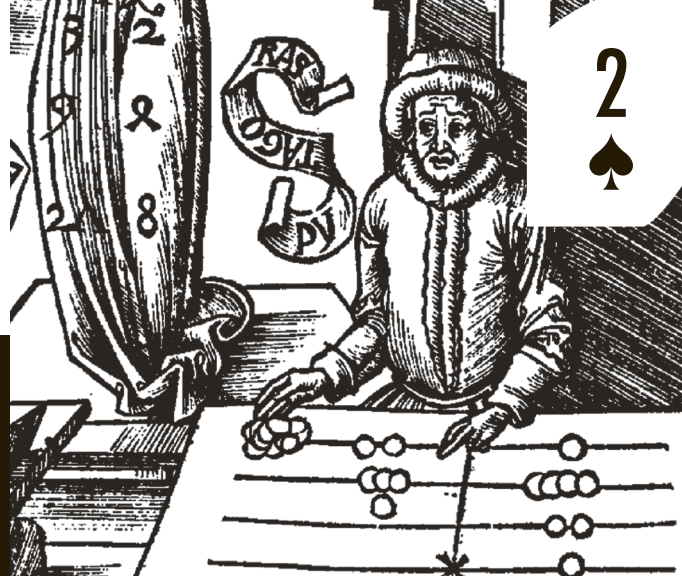
Abacus

2700-2300 BCE, Babylon

The abacus is an ancient calculating tool that enabled commerce in ancient times. The earliest abacus was probably a board or a slab on which Babylonians spread sand and traced letters. Over time, it evolved into a board marked with lines and counters whose positions indicated numerical values such as ones, tens, hundreds, and so on. Though Babylonian in origin, the abacus was also widely used by merchants and traders in Asia, Africa, and medieval Europe long before the modern numeral system was adopted. Today they are often built on bamboo frames with beads sliding on wires.

Antikythera Mechanism

150-100 BCE, Greece

Often regarded as one of the world's first computing devices, the Antikythera Mechanism was an ancient Greek mechanical computer that calculated the movement of the stars and planets. Built from bronze sheets, this clock-like mechanism had more than 30 gear wheels with teeth shaped like equilateral triangles. When a date was entered through a crank, the front dial displayed the date with one hand and showed the positions of the Sun and the Moon with the other two hands. The remains of this ancient computer were recovered in 1901 from a shipwreck near the island of Antikythera in the Mediterranean Sea. Greek inscriptions on the device confirmed its astronomical purpose.
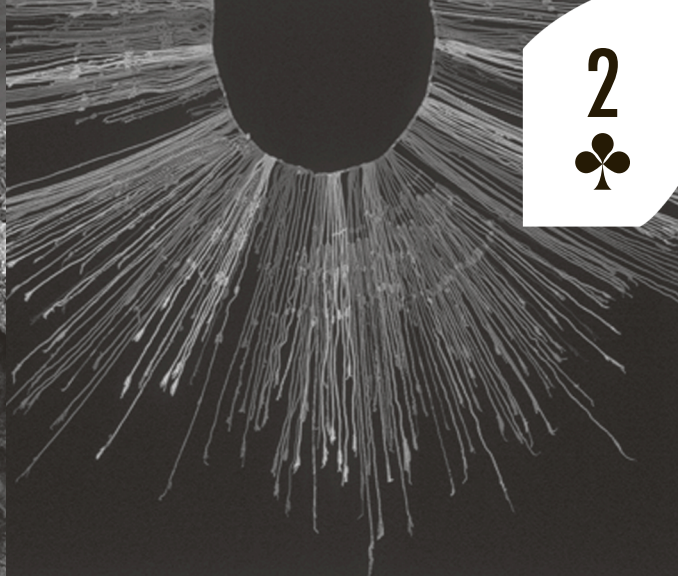
Quipu

3000 BCE, early Incan empire

Quipus were ancient accounting devices used by the Incas and other Andean societies. A quipu was made of colored thread or strings from llama or alpaca hair or cotton cords. The cords contained numeric and other values encoded by knots in a base 10 positional system and could range from a few to more than 2,000 cords. Quipus could carry out simple addition, subtraction, multiplication, and division. Quipus were also used for tracking labor, recording economic output, and telling the history of the Incas.

Pre-Electronic/ Mechanical Calculators, and Computers
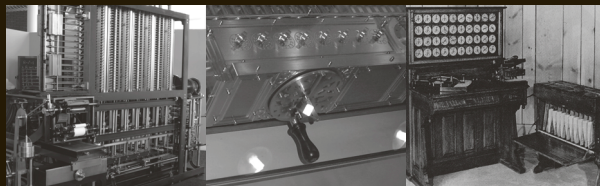
Tally Sticks

Ishango bone discovered in the Upper Paleolithic era, about 8,000 to 20,000 BC, is believed to be the first tally stick; tally sticks were also used widely in medieval Europe.

Tally sticks were long pieces of bone, ivory or wood marked with a system of notches. They were used in ancient times to record counts and keep score. As commerce developed, tallies provided an early method of bookkeeping by recording both physical quantities and money. Transactions were recorded by carving notches on a stick, with the size of the notch indicating the denomination.

The calculating and early computing devices of the late 16th to 19th centuries CE are characterized by their ability to support arithmetic and logic. This period overlaps with the Age of Enlightenment, characterized by intellectual advances in the sciences, mathematics, logic, literature, and the arts. Although Blaise Pascal and Gottfried Leibniz are known for their contributions to logic and mathematics, their work on calculating devices is of paramount importance to their contributions to human thought. Without their ideas and the innovations of Charles Babbage and Herman Hollerith, it is entirely possible that "modern" computing would have arrived much later.

Babbage Analytical Engine

Mid-19th century, England

Charles Babbage's Analytical Engine was designed as an improvement over the Difference Engine's design. Generally considered the first true computer, it was programmable by using punch cards; had a "store" or memory where numbers and intermediate results were held; had a separate "mill" or CPU where the computing took place; and had a reader and printer that were input and output devices. Like the Difference Engine, the Analytical Engine was never successfully completed. Nevertheless, it is considered almost identical to the modern CPU, with the only notable difference being its dependence on mechanical (moving parts) instead of solid state electronics.

Babbage Difference Engine

Mid-19th century, England

Charles Babbage, the English mathematician and inventor, designed the Difference Engine. Fueled by an interest in astronomical calculations, Babbage created the device to automate the production of logarithm tables for use in navigation. The Difference Engine operated on discrete digits instead of smooth quantities, and the digits were decimals (0-9) represented by positions on toothed wheels. When one of the toothed wheels turned from 9 to 0, the next wheel advanced one position, carrying the digit. Work was halted on the construction following a dispute between Babbage and one of the engineers, and government funding was withdrawn in 1842. Although the Difference Engine was never completed, the designs were correct, and a replica was successfully built in 1991.

Hollerith Punch Cards

Late 19th century, U.S.A.

Herman Hollerith's tabulating machine counted census data quickly with the use of punch cards. He was inspired by the Jacquard loom and railroad tickets, which, when punched, encoded a description of the passenger. Hollerith designed his punch cards to represent digital information by the presence or absence of holes in set positions. He invented a pantograph "keyboard punch" that allowed the entire card area to be used. The cards used in the 1890 census had round holes, 12 rows, and 24 columns. Electricity allowed the cards to be read, counted and sorted. An expanded punch-card design would later become the standard used in mainframes and minicomputers and were the first on which loadable computer programs were written.

Hollerith Tabulating Machine

Late 19th century, U.S.A.

Herman Hollerith, an American statistician, built a tabulating machine to automate the counting of the 1890 U.S. census. A hand punch recorded the data as holes in a punch card; the tabulating machine contained a spring-loaded pin for each possible hole in the card. The card was then placed in the reader and a handle was pushed down. The pins that passed through the holes closed electrical circuits, causing counters to be incremented and a lid in the sorting box to open. With Hollerith's tabulating machines, it took less than three years to count 62 million people and saved the government $5 million. In 1911, his Tabulating Machine Company was merged into the company that was later renamed IBM.

Leibniz Calculator

17th century, Germany

Gottfried Leibniz was a German philosopher and mathematician famous for inventing differential and integral calculus. Leibniz invented a device called the Stepped Reckoner, a calculator built on the wheels of the Pascaline. The Stepped Reckoner had a cylinder with nine bar-shaped teeth of incremental length parallel to the cylinder's axis. A crank rotates the drum and a regular 10-tooth wheel is rotated zero to nine positions depending on its relative position to the drum. Rotating the stepped drum one way translated into multiplication; the other way translated to division. Although the Leibniz calculator was not developed for commercial production, the stepped drum principle survived for 300 years and was used in many later calculating systems.

Napier's Bones

Early 17th century, Scotland

John Napier, the Scottish mathematician, astronomer and physicist, is best known for developing the concept of logarithms. He also invented Napier's bones (or rods), which helped simplify multiplication and division. Napier's bones were numbered rods used for multiplying, dividing, and finding square roots and cube roots. Napier's bones contained 10 rods corresponding to digits 0 to 9; a special eleventh bone represented the multiplier and listed the digits from 1 to 9, with the digits split by a diagonal line. Multiplication tables were embedded on the rods, thus making multiplication and division as easy as addition and subtraction. Napier published a book in 1617 titled *Rabdologia* explaining how mathematical functions could be performed using numbered rods.
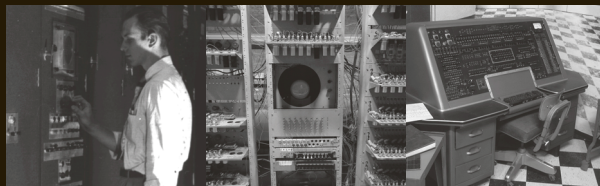
Early Electronic Era


Pascaline

17th century, France

Blaise Pascal, the French mathematician and philosopher, invented a numerical wheel calculator called the Pascaline to help his father, a French tax collector. The Pascaline had eight movable dials that used base 10 and could add up sums to eight digits. When the first dial (one's column) moved 10 notches, the second dial moved 1 notch to represent the 10's column reading of 10 . . . and so on. This principle is still used in car odometers and electricity meters. Subtraction, multiplication, and division could also be performed with the Pascaline, although rather tediously. Pascal's invention launched the development of mechanical calculators in Europe and then, slowly, all over the world.

The Electronic Era of computing was foreshadowed by the Hollerith Tabulating Machine, which employed electric current to detect a punched hole in a punch card but was otherwise mechanical in nature. Computers in this new period are characterized by vacuum tubes, plug boards, and (often) miles of wiring. The machines are subsumed by transistors and integrated circuits, which resulted in greater compactness, larger memories, and significantly more processing power. Most uses of computing during this period are in research and military applications. The UNIVAC-1 marks the transition between research and the advent of the data-processing era.
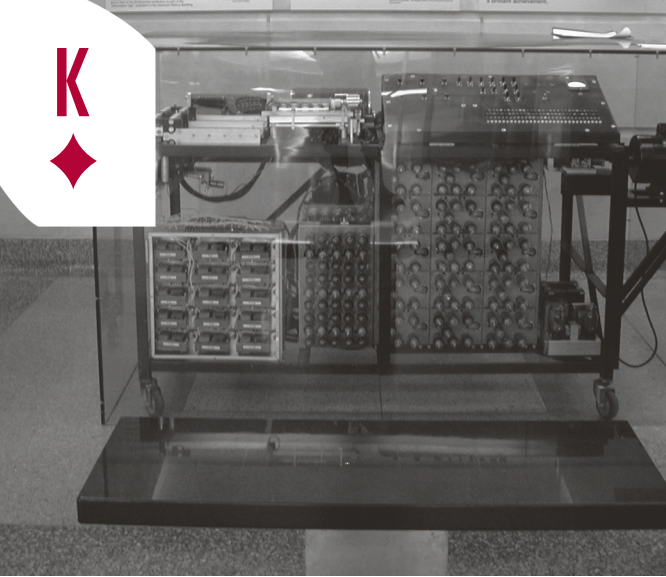
Atanasoff-Berry Computer

Early 1940s, U.S.A.

The Atanasoff-Berry Computer (ABC) was the world's first electronic digital computer. Designed by John Vincent Atanasoff, a mathematics professor at Iowa State University, and his graduate assistant Clifford E. Berry, the ABC featured several innovations that are present in modern computers: It used binary digits to represent all numbers and data; and electronics to perform all calculations, and the computation was separated from the memory. Built between 1939 and 1942, the ABC was the size of a desk, weighed 700 pounds, used a mile of wire, and had more than 300 vacuum tubes that could calculate about one operation every 15 seconds. Development on the ABC was discontinued after World War II began.
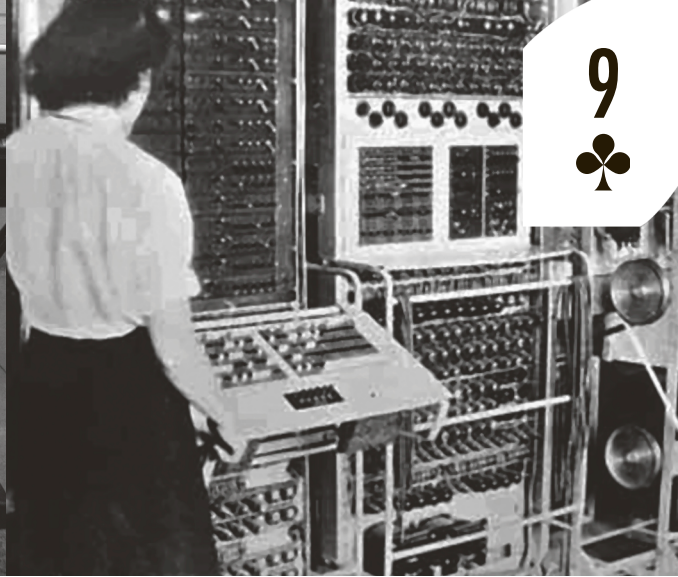
Colossus (UK)

Early 1940s, U.K.

The Colossus machines were electronic computing devices used by British code breakers to help read encrypted German messages during World War II. These machines were among the world's first programmable, digital, electronic, computing devices, and they used vacuum tubes to perform the calculations. The Colossus machines, also known as Mark I, were built at Bletchley Park, a government research center north of London. The Colossus optically scanned a cypher text from a paper tape, gave a programmable logical function to every character, and calculated how frequently the function came back true. With the help of Colossus, the British were able to break the Enigma code, and the Allies knew the Germans' plans in advance of D-day.

EDVAC

1940s, U.S.A.

The EDVAC (Electronic Discrete Variable Automatic Computer) was the "successor" to the ENIAC. The construction of EDVAC began even before the ENIAC was put into service, when the ENIAC team of John Mauchly and J. Presper Eckert, Jr. was joined by John von Neumann. Von Neumann is widely credited for introducing the notion of stored program computing into modern electronic computers; the program is stored in the computer's memory and then executed by the CPU. Although the stored program idea of Alan Turing's imaginary "Turing Machine" and Charles Babbage's never-completed Analytical Engine predates the EDVAC, the EDVAC is the first to support the idea fully. This is considered a turning point in defining the era of modern electronic computing.
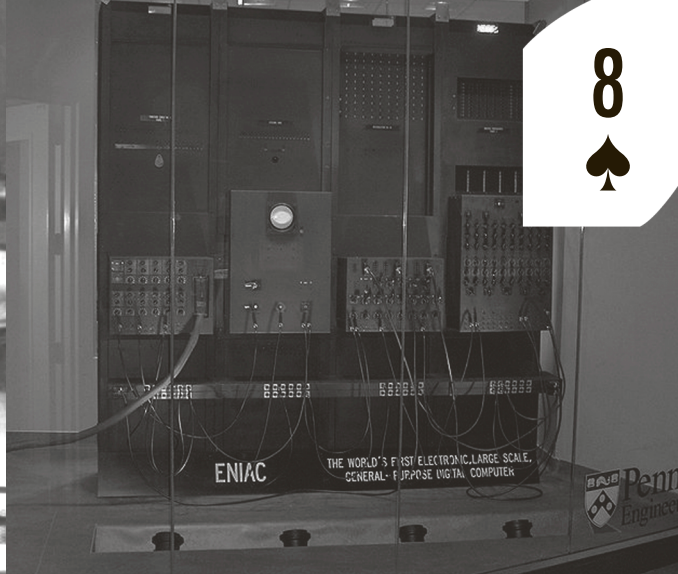
ENIAC

1940s, U.S.A.

The ENIAC (Electronic Numerical Integrator and Computer) was the most powerful computer of its time. Built at the University of Pennsylvania by John Mauchly and J. Presper Eckert, Jr. under the direction of Herman Goldstine, the ENIAC could solve a full range of computing problems. Originally built to compute artillery range tables, it used plug boards to communicate instructions; once instructions were programmed, the machine ran at electronic speed. Its conditional branching feature gave the ENIAC flexibility, which enabled it to solve a wider range of problems. Enormous and complex, the ENIAC ran continuously, generating 150 kilowatts of heat and executing up to 5000 additions per second. It used a decimal system for performing arithmetic — a notable difference from its successor (EDVAC), which made use of binary arithmetic.
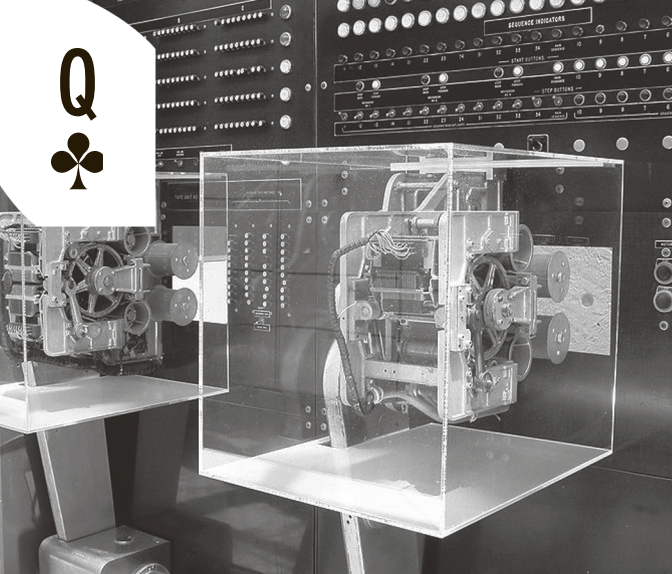
Harvard Mark 1

1939-1944, U.S.A.

Harvard professor Howard Aiken and computer scientist Grace Hopper, in collaboration with IBM, developed a fully functional computer known as the Harvard Mark 1. Inspired by Charles Babbage's Analytical Engine, the 5-ton device contained almost 760,000 separate pieces and was used by the U.S. Navy for gunnery and ballistic calculations. The computer, controlled by prepunched paper tape, could add, subtract, multiply, divide, and reference previous results. It had special subroutines for logarithms and trigonometric functions and used 23 decimal place numbers. Data was stored and counted mechanically using 3000 decimal storage wheels, 1400 rotary dial switches, and 500 miles of wire. The Harvard Mark 1 was classified as a relay computer because of its electromagnetic relays. An electric typewriter "displayed" the output.
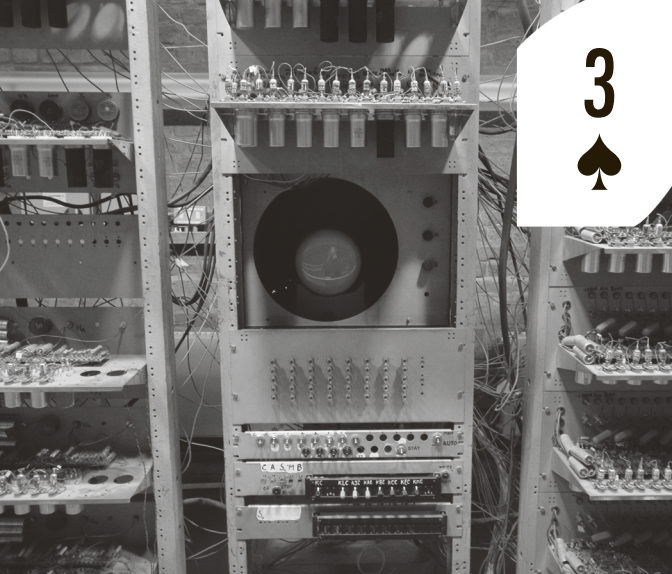
Manchester Mark 1

1949, U.K.

The Manchester Mark 1 was one of the earliest stored-program computers and one of the first to be built with all the components of modern-day basic computers. Its ability to store data and short user programs in electronic memory and process them at electronic speed made it revolutionary for its time. Developed at Victoria University of Manchester from the Small-Scale Experimental Machine (SSEM), it is historically significant because of its inclusion of index registers, an innovative idea that enabled programs to be read sequentially through an array of words in memory. In June 1949, a program designed to search for Mersenne primes ran uninterrupted for nine hours, paving the way for computers to be used for scientific and mathematical research.

UNIVAC 1

1951, U.S.A.

The UNIVAC (Universal Automatic Computer) was one of the earliest commercial data-processing computers, and it was at the forefront of the era of large, mass-produced machines. J. Presper Eckert, Jr. and John Mauchly, both of whom had worked on the ENIAC computer, designed the UNIVAC for the U.S. Bureau of the Census in 1951. The UNIVAC used an operator keyboard and console typewriter for limited input and magnetic tape for all other input and output. Primarily a business machine, it merged academic computational research with the office automation trend. The UNIVAC could read 7,200 decimal digits per second—it did not use binary numbers—making it the speediest business machine of its time.

Zuse Z3 Computer

1940s, Germany

Konrad Zuse designed a series of computers in the 1930s and 1940s called the Z1, Z2, and Z3. While his first two computers, the Z1 and Z2, functioned like calculators, his third, the Z3, was an electro-mechanical computer, widely considered the first programmable, fully automatic computing machine. Though it did not support conditional branch operation, it was considered Turing-complete. For the Z3, Zuse developed a complex set of instructions and used binary and floating-point representation that allowed a large range of numbers to be handled, including infinite values and a "no-op" instruction. The Z3 was completed in 1941 and destroyed during an Allied air raid on Berlin.

Minicomputers, Mainframes, and Supercomputers

A ♦
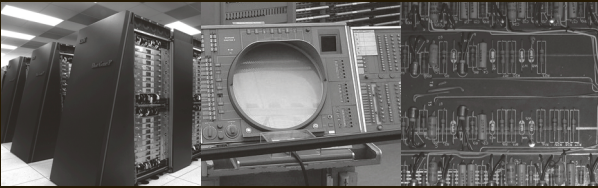
Minicomputers, mainframes, and parallel supercomputers might not appear to have much in common, but all emerged as the first computers for business, military, and academic research tasks. Some of the most significant are included here; they focus on a representative sample from the 1950s to the present era (overlapping with personal computing, mobile devices, and gaming systems). Unlike the earlier electronic computers that preceded them, these were general-purpose programmable computers that marked the true beginning of the industry of computing. They typically avoid plug-board and punched-card designs in favor of editable programs that make programming easier. Although the entire industry has moved toward commodity computing using general off-the-shelf parts (e.g., CPUs, RAM, hard or solid-state disk drives), this era also lives on with modern supercomputing designs such as the IBM Blue Gene.

Cray Computer X-MP

1982, U.S.A.

The Cray X-MP was one of the first supercomputers, touted as the world's fastest computer from 1983 to 1985. With two vector CPUs and 16 MB of memory, multitasking was now possible. The X-MP system included an IOS (Input-Output Subsystem), which allowed the disks to be handled more efficiently, and an SSD (Solid State Disk), which provided facilities for temporary I/O at speeds faster than hard disk storage. The ideas of "multicore" and solid-state drives, now found in today's PC designs, owe a debt to the pioneering ideas of Cray Computer. The vector CPU design, which allowed an operation to apply to an array (or arrays) of data, is now featured in modern graphics processing units for computational and visualization needs.
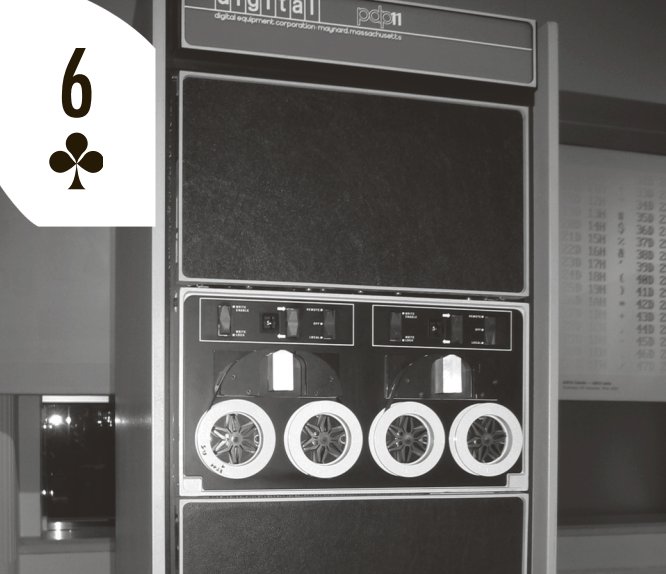
DEC PDP-11

1970, U.S.A.

The DEC PDP-11, sold by Digital Equipment Corporation in the 1970s and 1980s, was the top-selling minicomputer of its time. The 16-bit PDP-11 was easier to program than other computers. It was popular with programmers because of its highly orthogonal and easy-to-memorize instruction set, and machine instructions could be applied uniformly to any kind of data. Unlike earlier computers, the PDP-11 did not have a dedicated bus for I/O; instead, it had a memory bus called the Unibus. This flexible framework made it easier to invent new bus devices, including those that could control the hardware.

IBM Blue Gene/L

2004, U.S.A.

The IBM Blue Gene/L became the fastest supercomputer in the world in November 2004. Its unprecedented performance was achieved in a compact low-power design: it reached operating speeds in the PFLOPS range (peta = 10^{15} floating point instructions per second). The Blue Gene/L was notable for using Linux as its operating system; this marked the beginning of IBM's support of open-source software, especially the operating system software. The Blue Gene/L project was undertaken by IBM with the cooperation of Lawrence Livermore National Laboratory and the U.S. Department of Energy.
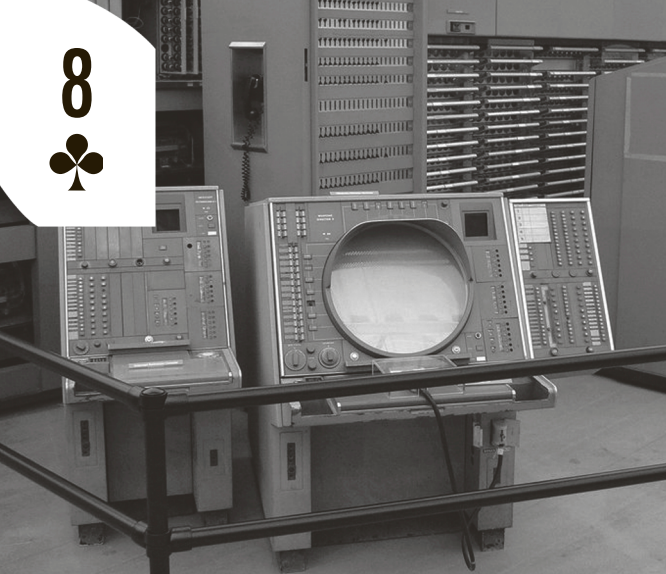
IBM Sage

1956, U.S.A.

The IBM SAGE (Semiautomatic Ground Environment) system was an air defense computer network commissioned by the U.S. military and built in the 1950s. Designed by Jay Wright Forrester and George Valley, two professors at MIT's Lincoln Lab, it was one of the most ambitious computer projects undertaken with more than 800 programmers. Created to detect atomic bomb–carrying Soviet bombers and guide American missiles to intercept and destroy them, it involved building 23 concrete bunkers in the United States and one in Canada. Long-distance telephone lines to more than 100 radar defense sites linked each center across the country, creating one of the first large-scale, wide-area computer networks. Work on SAGE began in the 1950s and was operational from 1963-1983.
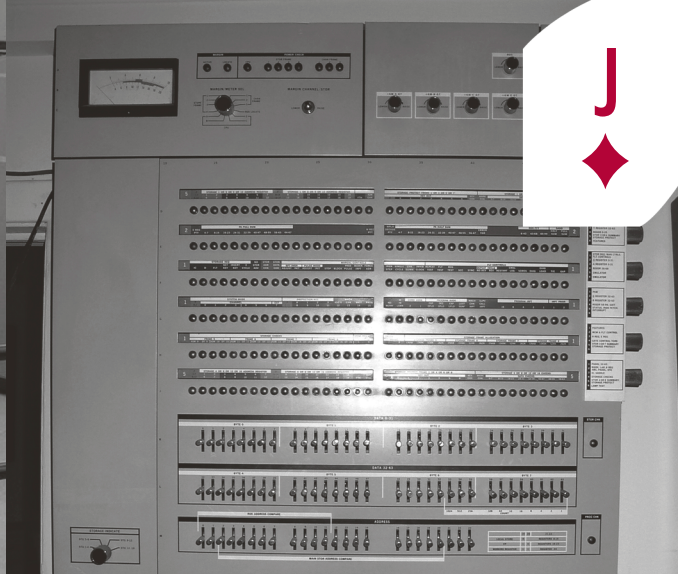
IBM System 360

1964, U.S.A.

The IBM System 360 was the first family of computers designed to host a wide range of applications. Distinguishing architecture from implementation, IBM released a suite of computers that were compatible with each other, even though they had different designs and sold at varying prices. The highly successful venture allowed customers to buy smaller systems with the guarantee that they could migrate to larger systems without having to reprogram software applications. This design approach influenced generations of computers. The chief architect of the IBM System 360 was Gene Amdahl, who represents an important bridge between the mainframe and supercomputer worlds. Amdahl's law describes the maximum speedup that can be expected in a program when multiple CPUs are used.
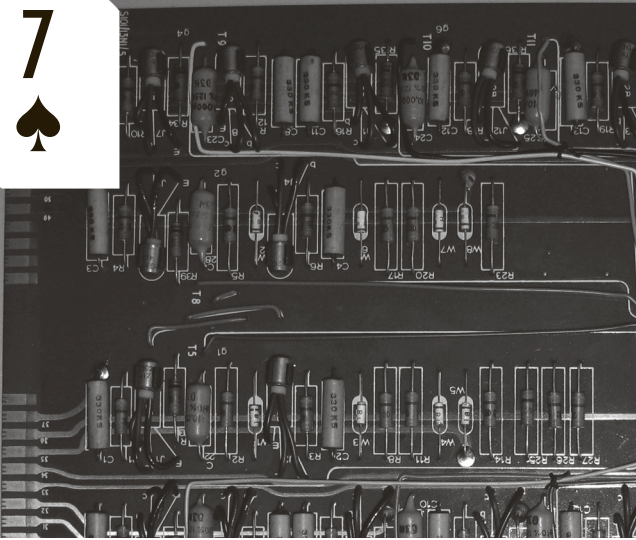
LEO Computer System

1951, U.K.

The LEO (Lyons Electronic Office) was the earliest computer put to commercial use: it estimated the cost of baked goods at J. Lyons and Co., a British catering business. The company sponsored the British computer scientist Maurice Wilkes to work on the first full-sized stored-program computer with the understanding that Wilkes would allow Lyons to build a similar computer. Daniel Caminer, an employee at J. Lyons, created the computer's code with a unique design: it could be easily reconfigured to perform different computing tasks for the business. Lyons was the first company to issue computerized paychecks. Caminer designed two more generations of LEO and helped run LEO Computers, a corporate spin-off.

Thinking Machines CM-1

1983, U.S.A.

The Connection Machine (CM) was a series of supercomputers that grew out of Danny Hillis's research in the early 1980s at MIT. Hillis wanted to find alternatives to the traditional von Neumann computation architecture. Hillis believed that thought processes in humans were the result of millions of neurons interacting and working in different ways—or, as one would say in computer terminology, massively parallel processing. The CM connected commercially available processors to perform operations in parallel. In 1985 the first 65,536-processor (2^{16}) CM was completed. Its computational power was comparable to the Cray-2, then the world's fastest supercomputer, but was much less expensive to build. The CM's cube structure design was visually striking for its time.

PC Era

With the PC era, computers became accessible to the general public. What is commonly associated with the eponymously named IBM PC, the windowed computing environment with a mouse actually began with a humble project at Xerox PARC. Xerox saw little value in a future defined by something other than copiers, yet the computers in this set are all interesting successors to the Xerox Alto. Apple led the revolution in personal computers, followed by Microsoft's Windows. Although some have argued that we are now entering a post-PC era, the PC in one form or another will almost certainly be with us for decades to come, especially for the most demanding business and computational tasks (e.g. graphics/design).
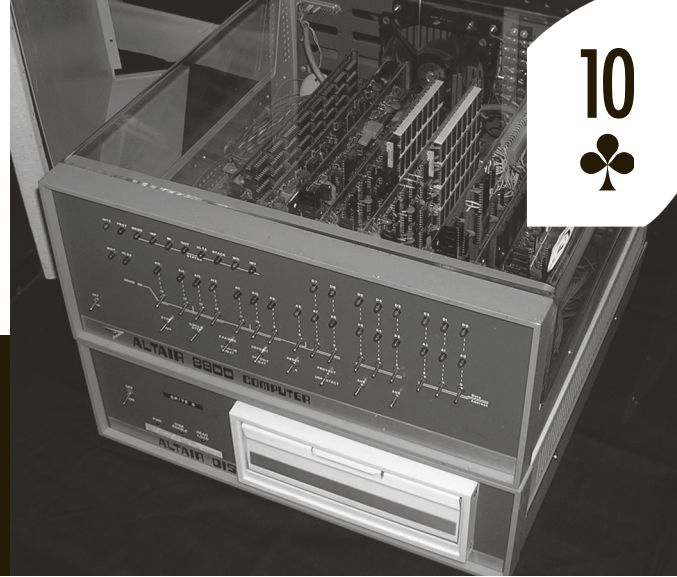
Altair 8800

1975, U.S.A.

The Altair 8800 was the first mail-order minicomputer sold through hobby magazines in the 1970s. Bill Gates and Paul Allen, who went on to found Microsoft Corporation, wrote Altair BASIC, a true programming language, and created the first commercial Microsoft computer product. The Altair, built by Micro Instrumentation and Telemetry Systems, also used the CP/M operating system, which could handle floppy disk drives attached to the machine. CP/M had been written by Gary Kildall in 1973, and by 1976 it was the most popular operating system in the world. With more than 5,000 minicomputers sold by 1975, the Altair 8800 sparked the microcomputer revolution.

Apple II

1977, U.S.A.

Designed by Steve Jobs and Steve Wozniak, the Apple II was an 8-bit home computer and one of the first affordable, mass-produced microcomputer products that Apple Computer manufactured. It was among the most successful personal computers and helped launch the personal computer industry in 1977. The Apple II had color graphics, a modem, its own set of software, and floppy disk drives. It also offered users a unique spreadsheet program, VisiCalc, which was a popular business tool.

Apple Macintosh

1984, U.S.A.

Steve Jobs led the development of the Apple Macintosh and insisted that it be "insanely great." The Mac was the first commercially successful computer to have a mouse and a graphical user interface (GUI) instead of the traditional command-line interface. It led the desktop publishing revolution with its LaserWriter printer (where PDF or Portable Document Format first appeared) and software written specifically for the Mac (for example, Aldus PageMaker). Soon, Macromedia's QuarkXPress, FreeHand, and Adobe's Photoshop and Illustrator reinforced the Mac's position as the premier graphics computer of its time. The Macintosh was introduced to the world in the now iconic 1984 commercial.

Commodore PET

1977, U.S.A.

The Commodore PET is widely believed to be the world's first "personal" computer. Its arrival was announced at the Consumer Electronics Show in Chicago in 1977, and the PET was usable out of the box. The keyboard came with a separate number pad—revolutionary for its time. The monitor was 9" integrated blue and white, and the main board had powerful new 1-Mhz MOS 6502 processors. Furthermore, it had room for additional RAM or processor boards, 4 KB of memory, a power supply, a cassette tape for storage, and several expansion ports. Notable for its time, PET could create incredible graphics and use uppercase and lowercase text. Its operating system was burned onto the ROM and loaded while the computer booted.

Epson HX-20

1983, U.S.A.

The Epson HX-20 is generally considered the first laptop computer. It came with a full-size keyboard, a printer, a storage device and built-in rechargeable batteries, and Microsoft BASIC. Its LCD screen allowed 4 lines of 20 characters, which was useful for text applications. The Epson HX-20 had an optional cassette recorder for data storage. It sold for $135 (US). The system bus on the left side of the HX-20 allowed for the addition of expansion modules, including additional RAM memory and analog I/O.

IBM 5100 Series

1975, U.S.A.

The IBM 5100 was the company's first microcomputer that was not a mainframe. Often considered the world's first portable computer—though at 55 pounds "portable" was a stretch—it was a complete system with a built-in monitor, keyboard, and data storage. The internal CRT could display 16 lines of 64 characters. A 1/4-inch tape cartridge drive used standard DC300 cartridges to store 204 KB. One drive was installed in the machine, and a second (model 5106) could be added in an attached box. The data formats included several types and were written in 512-byte records. An external video monitor was connected to the IBM 5100 by a BNC connector on the back panel.

IBM PC

1981, U.S.A.

In 1981 IBM Corporation introduced the IBM personal computer, backing its entry into the PC marketplace with its large sales organization. Slightly faster than rival machines, it had about 10 times the memory of its nearest competitor. It had one or two floppy disk drives and an optional color monitor, and it was the host machine for 1-2-3, a popular spreadsheet program. Not surprisingly, it sold more than five million units in its first two years. IBM's entry into the personal computing market energized the computing industry. Software developers set out in scores to write programs for the PC. Even competitors benefited when they realized that they could compete by building IBM PC–compatible machines. This changed the industry forever.
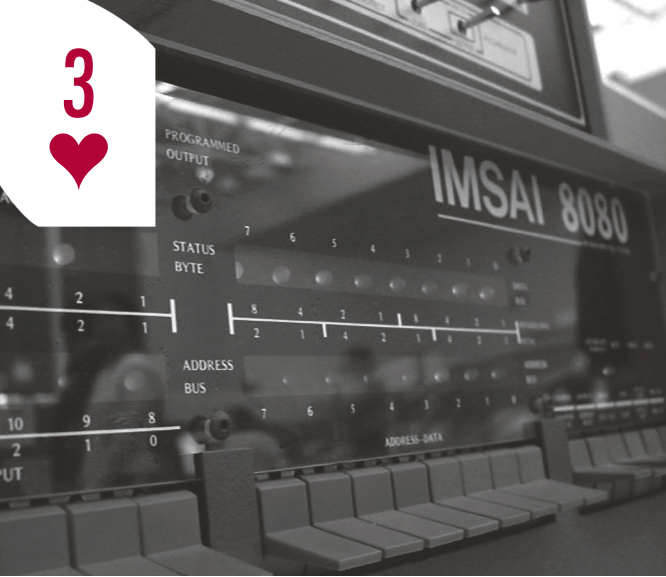
IMSAI 8080

1975, U.S.A.

The IMSAI 8080 is widely regarded as the first "clone" computer; its design is based on the MITS Altair 8800. The IMSAI machine ran on a modified version of the CP/M operating system called IMDOS. IMSAI produced more than 20,000 units between 1975 and 1978. The IMSAI 8080 did not have a keyboard or any display. A programmer had to enter a program using the front panel switches while reading the results on the LED indicator lights. This was slow and tedious; every mistake meant the programmer had to start all over, so only a true hacker could successfully operate it. Nevertheless, the IMSAI 8080 remains important as the first step in the cloning phenomenon, which vaulted the PC to such success.
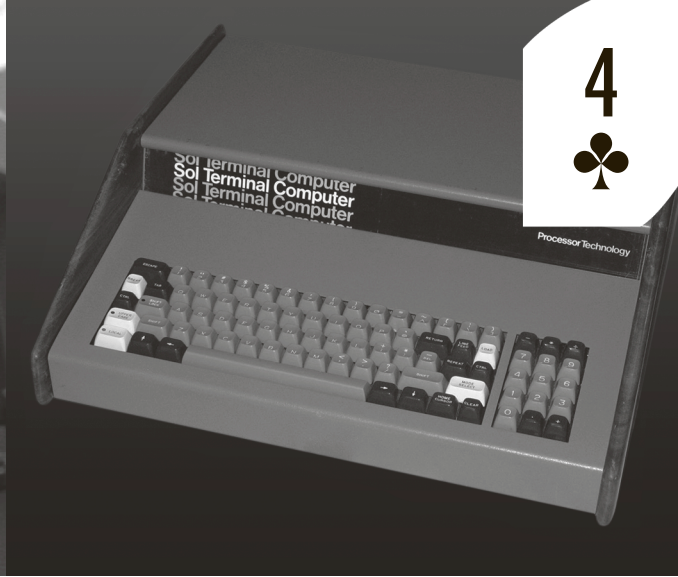
Processor Technology Sol

1975, U.S.A.

Bob Marsh, Lee Felsenstein, and Gordon French designed the Sol-20 in 1975 using the Intel 8080 8-bit microprocessor chip running at 2 MHz. The Sol-20 differed from most other machines of the era, in that it was the first PC to use a keyboard and a built-in video driver, which allowed it to connect to a monitor. The Sol-20's main motherboard was mounted at the bottom of the case and consisted of the CPU, memory, video display, and I/O circuits. The case included a power supply, a fan, and a keyboard; the sides of the case were oiled walnut wood and blue painted steel. Between 1977 and 1979, Process Technology sold more than 10,000 Sol-20 personal computers in electronic kits or fully assembled.

SWTPC 6800

1967-1971, U.S.A.

Founded in 1964 by Daniel Meyer, Southwest Technical Products Corporation (SWTPC) produced a variety of electronic kits and complete computer systems based on the Motorola 6800 micro-processor. Every original computer was built around the Motorola family chips, including the SWTPC 6800, one of the more inexpensive systems of that time. The system was sold in a 2-KB kit version ($395) or 4-KB, 8-KB or 40-KB assembled versions, and it came with complete documentation, including a programming manual with examples. SWTPC also designed the first affordable printers, based on a receipt printer mechanism, for microcomputer users.
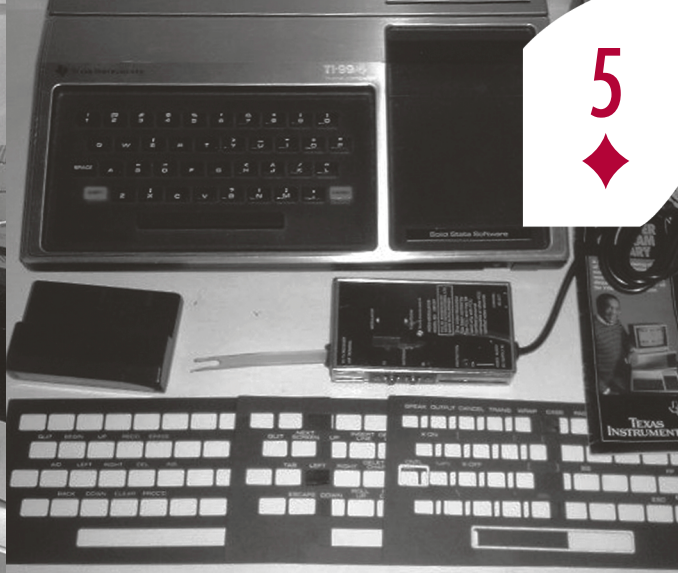
Texas Instruments TI-99/4

1979, U.S.A.

The TI-99/4 was Texas Instruments' first entrant into the home computer market. It came with a Zenith monitor and sold for a little more than $1,000, which was expensive at that time. The TI-99/4 had the BASIC programming language built in. On boot-up, the user had the option of running TI-BASIC, an equation calculator, or the ROM cartridge, if one had been inserted. Its central processor was TI's 16-bit TMS9900 microprocessor, designed to make it better than other 8-bit home computers in the market. Equipped with a 13-inch video color monitor, it was designed to use plastic plug-in modules of read-only memory, and contained programs such as games, personal finance, and educational software. The reaction was mostly favorable, although the price tag put it beyond the reach of many home users.

Timex Sinclair 1000

1982, U.S.A

The Timex Sinclair (TS) 1000 was the least expensive home computer of its time, selling for only $99.95. Produced by a joint venture between Timex Corporation and Sinclair Research, it was launched in July 1982 and best known for its pioneering use of one-letter "keywords" for most commands (for example, typing the letter "p" in keyword mode would generate the keyword "PRINT"). The TS 1000 had several limitations: a small keyboard, limited memory, and minimal storage. Third-party add-ons for the TS 1000 became popular, and soon full-size keyboards, speech synthesizers, sound generators, disk drives, and memory expansions flooded the market. Languages such as Forth and Pascal, as well as BASIC compilers and assemblers, increased the TS 1000's programming capabilities.

TRS-80 Models I–IV

1977, U.S.A.

The TRS-80 was Tandy Corporation's desktop microcomputer model line. Tandy's Radio Shack stores sold them in the late 1970s and early 1980s, and the first units were popular with hobbyists, home users, and small businesses. The original TRS-80 had a full-stroke QWERTY keyboard, 4 KB of memory, a Z80 microprocessor, the BASIC programming language, and a monitor. It first sold for $399, fully assembled and tested. The mainboard and keyboards were combined into one unit. The next iteration of the TRS-80 Model II was popular as a small business computer. Later models incorporated disk drives and more memory. The Model III, housed in one case, became the most popular personal computer in schools and homes, rivaling the Apple II.
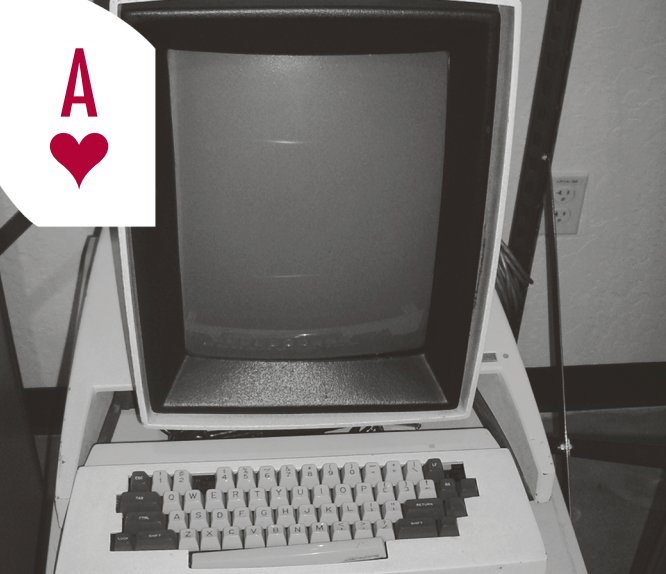
Xerox Alto

1973, U.S.A.

The Xerox Alto was the first personal computer to use a mouse-driven graphical user interface and influenced the design of personal computers to come, such as the Apple Macintosh and the first Sun workstations. Developed at Xerox PARC in 1973, it was used widely at universities for several years. The Alto popularized the use of raster graphics for all output, even text. Many innovative computer programs were written for the Alto, including the first WYSIWYG document preparation systems, Bravo and Gypsy; the early paint program, the Markup bitmap editor; and the first versions of the Smalltalk environment.

Zenith Z89

1979-1985, U.S.A.

The Z89 was a personal computer produced by Zenith Data Systems in the early 1980s. Using the Zilog Z80 microprocessor, the Z89 was integrated in a terminal-like structure with a non-detachable keyboard, 12-inch monochrome CRT, hard-sectored controller, and a 5.25 diskette drive. The Z89 was sold assembled and came with 16-KB of memory; later versions had up to 48-KB on the main CPU board. Several extension boards were available for it, including 64-KB memory boards, hard-disk controller cards, three-port serial I/O boards, and H19 terminal boards. A third-party small upgrade card was also offered to double the processor speed to 4 MHz. Microsoft adapted its various programming languages (BASIC, FORTRAN, COBOL) for the Z89.

Devices

9 ♠

Smart devices represent the convergence of portable computing and telephony with the arrival of mobile computing. While convergence continues and is likely to change gaming systems as well, devices will continue to play a major role in computing history. Devices have already been successfully used in national emergencies and revolutions around the world; often they are people's only connection to the internet. This category represents a subset of smart devices, beginning with the devices that truly started it all—the Apple Newton, followed shortly by some members of the same team who went on to create the PalmPilot. The most recent devices are those that appear to have the most traction among consumers, notably devices running the popular Apple iOS and Android operating systems.
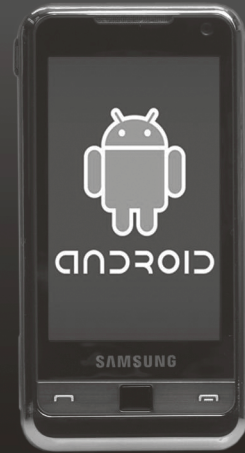
Android Phones

2007, U.S.A.

The Android mobile operating system is the world's bestselling smartphone platform. Originally developed by Android, it was bought by Google in 2005 and developed further by Google and other members of the Open Handset Alliance. Today more than 200,000 applications are available for Android, most of them sold through the Android Market. Android itself is available under a free and open-source software license, and the entire source code has been published under the Apache open source license.

Apple iPad

2010, U.S.A.

The Apple iPad is a popular tablet computer designed and developed by Apple as a platform for books, movies, music, games, and web content. Smaller and lighter than a typical laptop computer, it is controlled by a multitouch display and a virtual onscreen keyboard (instead of a physical keyboard). The iPad was released in April 2010 and sold more than 3 million devices in 80 days. It runs on the same operating system as the iPod Touch and iPhone devices and can run iPad-specific applications as well as most iPhone ones.

Apple iPhone

2007, U.S.A.

The iPhone is an incredibly popular line of Internet and multimedia-enabled smartphones from Apple. More than just a cell phone, the iPhone comes with a camera for video and stills, text messaging, visual voicemail, an internet client with email, web browser, and both 3G and WiFi connectivity. It also comes with a virtual keyboard and interface that is intuitive to most users. Another reason for its popularity is the more than 300,000 Apple applications available, including GPS navigation, games, publications, and social networking.
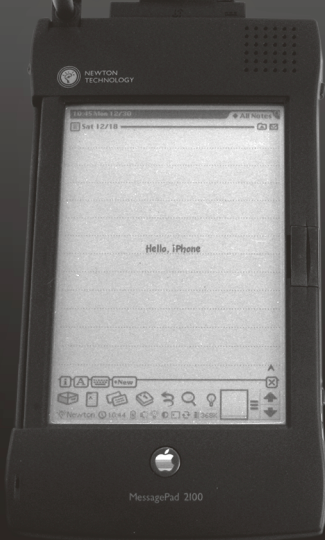
Apple Newton

1987, U.S.A.

The Apple Newton was an early personal digital assistant and the first tablet platform known for its handwriting recognition software. Development of the Newton platform started in 1987 and ended in 1998, after Steve Jobs returned to Apple. Most Newton devices were developed and marketed by Apple, but other companies such as Sharp, Motorola, and Digital Ocean released similar devices running the Newton OS. None were as successful as Apple's devices. The need for handwriting recognition dropped off quickly, giving the Newton a quirky position in computing history.

PalmPilot

1997, U.S.A.

The PalmPilot was one of the earliest handheld devices that cornered the market for personal digital assistants. Easy to use and carry, it was the size of a deck of cards and sold for close to $400. The PalmPilot came with a stylus that let users "write" on the green screen. Although it did not replace computers, the PalmPilot made it easy to carry useful information everywhere. Features included a calendar, phonebooks, memo pads, and expense-tracking software. Most importantly, the PalmPilot could link to desktop computers, enabling users to synch their information easily. At its peak, more than 2 million units were sold. Jeff Hawkins and Donna Dubinsky developed the PalmPilot in the mid-1990s.

Gaming Consoles/Computers

Gaming consoles are computers designed primarily for interactive entertainment. Although the development of computer games goes back to the 1950s, the arrival of the Magnavox Odyssey in 1972 marks the beginning of this era. The set includes Commodore and Amiga, which some might remember as personal computers. The early systems from Atari and Nintendo had cartridge systems, in which games were "plugged in" (and difficult to copy). Recent offerings from the three major console makers—Nintendo, Microsoft, and Sony—all use the same commodity components found in today's personal computers, including DVD and internet-based distribution. It is anybody's guess what will come next, but there is widespread belief that convergence with smart devices will continue to be the norm, which is evident in the popularity of handheld offerings (e.g., Nintendo DS) and gaming apps on the iPad and other tablets.

Amiga

1985, U.S.A.

The Amiga was the heir apparent to the Commodore 64 and was particularly popular among computer enthusiasts and gamers. It was a notable advancement over the Commodore 64, owing to a more "modern" OS (Amiga DOS) and support for the graphical demands of game developers and multitasking. The best-selling model was the Amiga 500, which achieved greater success in Europe than in the United States. Compared with the Commodore 64, Amiga sales were more modest at 6 million units. New Amiga systems followed in 1992; however, by that time, PCs were no longer competitive with the new gaming consoles.

Atari Video Computer System

1977, U.S.A.

The Atari Video Computer System, released in 1977 in North America, featured full-color graphics and sound. The system came with two joysticks, two paddle controllers, and one game cartridge. Sales of Atari VCS skyrocketed in 1980 after Atari released a home version of the video game Space Invaders. Over three decades, more than 30 million units were sold, making the Atari gaming systems among the most popular in history.

Commodore VIC-20

1980, U.S.A.

The Commodore VIC-20 was an 8-bit computer that was the first to sell more than 1 million units. (VIC stands for video interface chip.) Sold at retail stores, the VIC-20 came with programmable function keys, full-size typewrite-style keys, and a display that showed 22 characters of text per line. Its use for business applications was limited, but it was wildly popular with players of video games. It had a good color display and a joystick port, and many video games were made for it. The VIC-20 grew so popular that its production was up to 9,000 units a day, with sales eventually reaching $305 million. Soon, the price of a VIC-20 dropped under $100, the first color computer to do so.
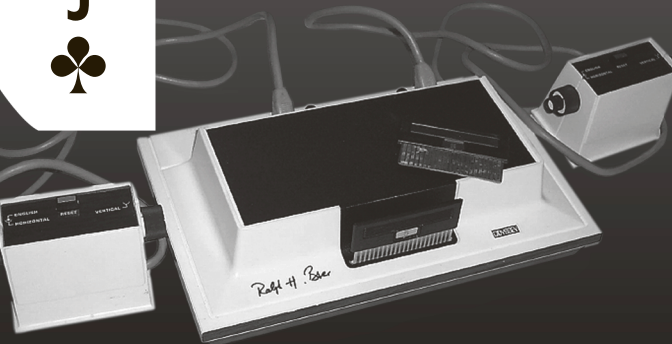
Magnavox Odyssey

1972, U.S.A.

The Magnavox Odyssey was the first video game system designed for consumers. Introduced in stores in 1972, it came with six cartridges to play 12 different games, including pong (or tennis), hockey, football, roulette, and states, a game designed to help children learn the names of the 50 American states. The Magnavox Odyssey system came with translucent plastic overlays that players placed on their TV screen to simulate color graphics. Included with the system were dice, poker chips, and score sheets the same way traditional board games were sold. Player controls came with two knobs for vertical and horizontal movement. By 1978 more than 300,000 units were sold.

Microsoft Xbox 360

2001, U.S.A.

The Xbox gaming console was Microsoft's entry into the fast-moving gaming console market at the beginning of the 2000s. It is viewed primarily as a competitor to Playstation, which appealed to hard-core gamers. Xbox was the first platform to offer a "live" service to play games interactively online. It is also distinguished by being a relatively developer-friendly console that makes it easy for just about any third-party developer to create games for the platform. The Xbox 360 platform is notable for its addition of supercomputer-like capabilities (dual CPU and a GPU) and being the first console to have a hard drive. The recent addition of the Kinect camera allows for a player to interact with the game without using a controller, resulting in a system more attractive to casual gamers.

Nintendo Entertainment System

1983, Japan

The Nintendo Entertainment System (NES), known as the Family Computer (Famicom) in Japan, was an 8-bit video game console that became the best-selling gaming console of its time. It is widely credited with helping to revitalize the market for gaming consoles after the gaming crash of 1983. It launched in the United States in 1985 with 18 titles, including Super Mario Brothers, which is still sold today in the Nintendo Wii system. Perhaps the most notable aspect of the NES is its controller design, which has stood the test of time in a market where technology changes frequently.

Nintendo Wii

2006, Japan

The Nintendo Wii is the world's bestselling video game console (32-bit), having outsold Microsoft's Xbox 360 and Sony's Playstation 3. Distinguished by its revolutionary remote controller, it operates as a handheld pointing device that detects movement in three dimensions. The Wii remote serves as a racket in a tennis game or a steering wheel in driving games, making it an attractive platform for casual gameplay. Built-in WiFi delivers free online services and downloadable games, and the nunchuck adds analog thumbstick and trigger buttons. The system allows for up to four controllers to be linked at the same time using standard Bluetooth wireless technology. The price of Wii gaming systems was reduced in 2011 in response to the new Kinect technology in the Xbox 360.

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Sony Playstation

1994, Japan

The Sony Playstation is a 32-bit video game console first released in 1994. Significant features included a unified online gaming service, the PlayStation Network, where players from around the world could play against each other using the internet. Its multimedia capabilities were robust, and it was the only gaming console to use Blu-ray as its primary storage medium. It has since been replaced by the highly successful PS/2 and PS/3 systems. Before the arrival of GPU computing, many researchers were using Playstation hardware and Linux to run high-performance computing codes. Its multicore computing architecture and the ability to support data-parallel computing were quickly embraced on other platforms.

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