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Computer History ENIAC to 2nd Generation

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ENIAC ← heading ↓

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The US-built ENIAC (Electronic Numerical Integrator and Computer) was the first electronic general-purpose computer. It combined, for the first time, the high speed of electronics with the ability to be programmed for many complex problems. It could add or subtract 5000 times a second, a thousand times faster than any other machine. (Colossus couldn't add.) It also had modules to multiply, divide, and square root. High speed memory was limited to 20 words (about 80 bytes.) Built under the direction of John Mauchly and J. Presper Eckert at the University of Pennsylvania, ENIAC's development and construction lasted from 1943 to full operation at the end of 1945. The machine was huge, weighing 30 tons, and contained over 18,000 valves. One of the major engineering feats was to minimize valve burnout, which was a common problem at that time. The machine was in almost constant use for the next ten years.

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ENIAC (Figure 1) was unambiguously a Turing-complete device. It could compute any problem (that would fit in memory). A "program" on the ENIAC, however, was defined by the states of its patch cables and switches, a far cry from the stored program electronic machines that evolved from it. Once a program was written, it had to be mechanically set into the machine. Six women did most of the programming of ENIAC. (Improvements completed in 1948 made it possible to execute stored programs set in function table memory, which made programming less a "one-off" effort, and more systematic.)

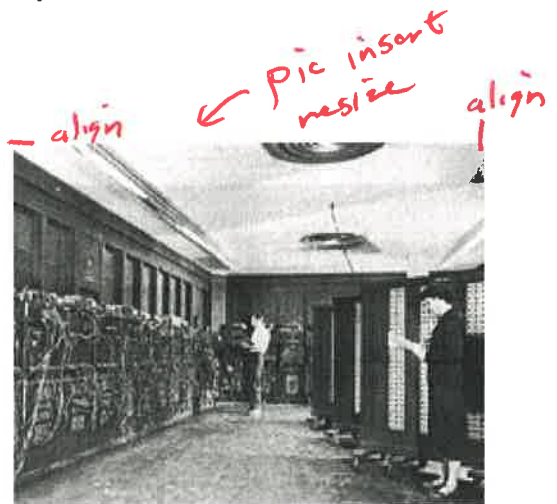


Figure 1-Eniac ← caption

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First-generation von Neumann machines ← heading 2

Even before the ENIAC was recognized its limitations and program computer, EDVAC, credited with a widely the EDVAC design in which working data were stored in a basic design, denoted the von 2), would serve as the development of ENIAC's

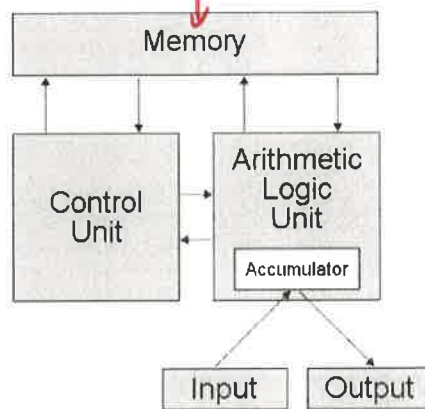


Figure 2 - Von Neumann Architecture

finished, Eckert and Mauchly started the design of a stored- John von Neumann was circulated report describing both the programs and single, unified store. This Neumann architecture (Figure

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foundation for the worldwide successors. In this generation of equipment, temporary or working storage was provided by acoustic delay lines, which used the propagation time of sound through a medium such as liquid mercury (or through a wire) to briefly store data. A series of acoustic pulses is sent along a tube; after a time, as the pulse reached the end of the tube, the circuitry detected whether the pulse represented a 1 or 0 and caused the oscillator to re-send the pulse. Others used Williams tubes, which use the ability of a television picture tube to store and retrieve data. By 1954, magnetic core memory was rapidly displacing most other forms of temporary storage, and dominated the field through the mid-1970s.

EDVAC was the first stored-program computer designed; however it was not the first to run. Eckert and Mauchly left the project and its construction floundered. The first working von Neumann machine was the Manchester "Baby" or Small-Scale Experimental Machine, developed by Frederic C. Williams and Tom Kilburn at University of Manchester in 1948; it was followed in 1949 by the Manchester Mark 1 computer, a complete system, using Williams tube and magnetic drum memory, and introducing index registers. The other contender for the title "first digital stored program computer" had been EDSAC, designed and constructed at the University of Cambridge. Operational less than one year after the Manchester "Baby", it was also capable of tackling real problems. EDSAC was actually inspired by plans for EDVAC (Electronic Discrete Variable Automatic Computer), the successor to ENIAC; these plans were already in place by the time ENIAC was successfully operational. Unlike ENIAC, which used parallel processing, EDVAC

used a single processing unit. This design was simpler and was the first to be implemented in each succeeding wave of miniaturization, and increased reliability. Some view Manchester Mark 1 / EDSAC / EDVAC as the "Eves" from which nearly all current computers derive their architecture. Manchester University's machine became the prototype for the Ferranti Mark 1. The first Ferranti Mark 1 machine was delivered to the University in February, 1951 and at least nine others were sold between 1951 and 1957.

The first universal programmable computer in the Soviet Union was created by a team of scientists under direction of Sergei Alekseyevich Lebedev from Kiev Institute of Electrotechnology, Soviet Union (now Ukraine). The computer MESM (MESM, Small Electronic Calculating Machine) became operational in 1950. It had about 6,000 vacuum tubes and consumed 25 kW of power. It could perform approximately 3,000 operations per second. Another early machine was CSIRAC, an Australian design that ran its first test program in 1949. CSIRAC is the oldest computer still in existence and the first to have been used to play digital music.

Commercial computers

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In October 1947, the directors of J. Lyons & Company, a British catering company famous for its teashops but with strong interests in new office management techniques, decided to take an active role in promoting the commercial development of computers. By 1951 the LEO I computer was operational and ran the world's first regular routine office computer job. On 17 November 1951, the J. Lyons company began weekly operation of a bakery valuations job on the LEO (Lyons Electronic Office). This was the first business application to go live on a stored program computer.

In June 1951, the UNIVAC I (Universal Automatic Computer) was delivered to the U.S. Census Bureau. Remington Rand eventually sold 46 machines at more than \$1 million each (\$8.2 million as of 2009). UNIVAC was the first "mass produced" computer; all predecessors had been "one-off" units. It used 5,200 vacuum tubes and consumed 125 kW of power. It used a mercury delay

line capable of storing 1,000 words of 11 decimal digits plus sign (72-bit words) for memory. A key feature of the UNIVAC system was a newly invented type of metal magnetic tape, and a high-speed tape unit, for non-volatile storage. Magnetic media is still used in almost all computers.

In 1952, IBM publicly announced the IBM 701 Electronic Data Processing Machine, the first in its successful 700/7000 series and its first IBM mainframe computer. The IBM 704, introduced in 1954, used magnetic core memory (Figure 3), which became the standard for large machines. The first implemented high-level general purpose programming language, Fortran, was also being developed at IBM for the 704 during 1955 and 1956 and released in early 1957. (Konrad Zuse's 1945 design of the high-level language Plankalkül was not implemented at that time.) A volunteer user group, which exists to this day, was founded in 1955 to share their software and experiences with the IBM 701.

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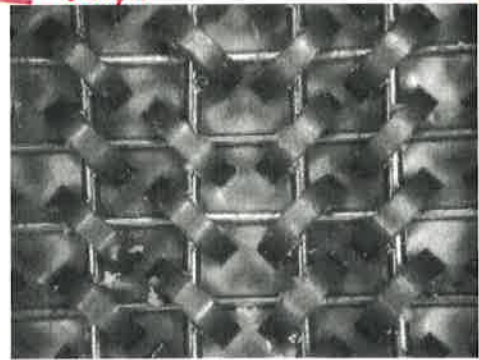


Figure 3 - Core Memory

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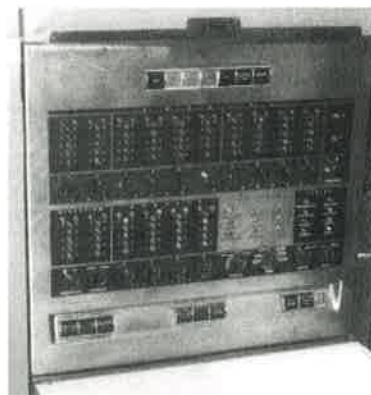


Figure 4 - IBM 650 Front Pannel

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IBM introduced a smaller, more affordable computer in 1954 that proved very popular. The IBM 650 (Figure 4) weighed over 900 kg, the attached power supply weighed around 1350 kg and both were held in separate cabinets of roughly 1.5 meters by 0.9 meters by 1.8 meters. It cost \$500,000 (\$3.96 million as of 2009) or could be leased for \$3,500 a month (\$30 thousand as of 2009). Its drum memory was originally 2,000 ten-digit words, later expanded to 4,000 words. Memory limitations such as this were to dominate programming for decades afterward. Efficient execution

using drum memory was provided by a combination of hardware architecture: the instruction format included the address of the next instruction; and software: the Symbolic Optimal Assembly Program, SOAP, assigned instructions to optimal address (to the extent possible by static analysis of the source program). Thus many instructions were, when needed, located in the next row of the drum to be read and additional wait time for drum rotation was not required.

In 1955, Maurice Wilkes invented microprogramming, which allows the base instruction set to be defined or extended by built-in programs (now called firmware or microcode). It was widely used in the CPUs and floating-point units of mainframe and other computers, such as the IBM 360 series.

IBM introduced its first magnetic disk system, RAMAC (Random Access Method of Accounting and Control) in 1956. Using fifty 24-inch (610 mm) metal disks, with 100 tracks per side, it was able to store 5 megabytes of data at a cost of \$10,000 per megabyte (\$80 thousand as of 2009). (As of 2009, magnetic storage, in the form of hard disks, cost less than 1/100 of one cent per megabyte). To put it another way, \$80,000 would buy you 1.15 Petabytes of magnetic disk space in 2009. That is an increase of 1,227,133,513,142 times the space in just 53 years.

Second generation: transistors ← heading 2

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CPU → By the early 1950s transistors started to become available, offering the possibility of building cheaper and faster computers. Initially the only devices available were germanium point-contact transistors, which although less reliable than the vacuum tubes they replaced had the advantage of consuming far less power. The first transistorised computer was built at the University of Manchester and was operational by 1953; a second version was completed there in April 1955. The later machine used 200 transistors and 1,300 solid-state diodes and had a power consumption of 150 watts. However, it still required valves to

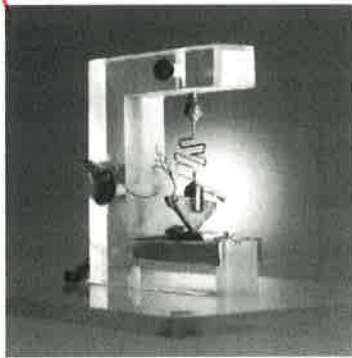


Figure 5- First Transistor

generate the clock waveforms at 125 kHz and to read and write on the magnetic drum memory, whereas the Harwell CADET operated without any valves by using a lower clock frequency, of 58 kHz when it became operational in February 1955. Problems with the reliability of early batches of point contact and alloyed junction transistors meant that the machine's mean time between failures was about 90 minutes, but this improved once the more reliable bipolar junction transistors became available.

The bipolar junction transistor (BJT) was invented in 1947 (Figure 5). If no electrical current flows through the base-emitter path of a bipolar transistor, the transistor's collector-emitter path blocks electrical current (and the transistor is said to "turn full off"). If sufficient current flows through the base-emitter path of a transistor, that transistor's collector-emitter path also passes current (and the transistor is said to "turn full on"). Current flow or current blockage represent binary 1 (true) or 0 (false), respectively. From 1955 onwards bipolar junction transistors replaced vacuum tubes in computer designs, giving rise to the "second generation" of computers. Compared to vacuum tubes, transistors have many advantages: they are less expensive to manufacture and are much faster, switching from the condition 1 to 0 in millionths or billionths of a second. Transistor volume is measured in cubic millimeters compared to vacuum tubes' cubic centimeters. Transistors' lower operating temperature increased their reliability, compared to vacuum tubes. Transistorized computers could contain tens of thousands of binary logic circuits in a relatively compact space.

Initially, it was believed that very few computers would ever be produced or used. This was due in part to their size, cost, and the skill required to operate or interpret their results. Transistors greatly reduced computers' size, initial cost, and operating cost.

Typically, second-generation computers were composed of large numbers of printed circuit boards such as the IBM Standard Modular System each carrying one to four logic gates or flip-flops. A second generation computer, the IBM 1401, captured about one third of the world market. IBM

installed more than one hundred thousand 1401s between 1960 and 1964— This period saw the only Italian attempt: the Olivetti ELEA, produced in 110 units.



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Figure 6 - IBM 350 Disk Drive

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Transistorized electronics improved not only the CPU (Central Processing Unit), but also the peripheral devices. The IBM 350 RAMAC (Figure 6) was introduced in 1956 and was the world's first disk drive. The second generation disk data storage units were able to store tens of millions of letters and digits. Multiple Peripherals can be connected to the CPU, increasing the total memory capacity to hundreds of millions of characters. Next to the fixed disk storage units, connected to the CPU via high-speed data transmission, were removable disk data storage units. A removable disk stack can be easily exchanged with another stack in a few seconds. Even if the removable disks' capacity is smaller than fixed disks, their interchangeability guarantees a nearly unlimited quantity of data close at hand. But magnetic tape provided archival capability for this data, at a lower cost than disk.

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Many second generation CPUs delegated peripheral device communications to a secondary processor. For example, while the communication processor controlled card reading and punching, the main CPU executed calculations and binary branch instructions. One databus would bear data between the main CPU and core memory at the CPU's fetch-execute cycle rate, and other databusses would typically serve the peripheral devices. On the PDP-1, the core memory's cycle time was 5 microseconds; consequently most arithmetic instructions took 10 microseconds (100,000 operations per second) because most operations took at least two memory cycles; one for the instruction, one for the operand data fetch.

During the second generation remote terminal units (often in the form of teletype machines like a Friden Flexowriter) saw greatly increased use. Telephone connections provided sufficient speed for early remote terminals and allowed hundreds of kilometers separation between remote-terminals and the computing center. Eventually these stand-alone computer networks would be generalized into an interconnected network of networks—the Internet.