Gear yourself up for a GREAT History of Computers!

350 Million Years BC The first tetrapods leave the oceans

30,000 BC to 20,000 BC Carving notches into bones

8500 BC Bone carved with prime numbers discovered

1900 BC to 1800 BC The first place-value number system

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1621 AD The invention of the slide rule

1625 AD Wilhelm Schickard's mechanical calculator

1640 AD Blaise Pascal's Arithmetic Machine

1658 AD Pascal creates a scandle

1670 AD Gottfried von Leibniz's Step Reckoner

1714 AD The first English typewriter patent

1726 AD Jonathan Swift writes Gulliver's Travels

1735 AD The Billiard cue is invented

1761 AD Leonhard Euler's geometric system for problems in class logic

1800 AD Jacquard's punched cards

Circa 1800 AD Charles Stanhope invents the Stanhope Demonstrator

1822 AD Charles Babbage's Difference Engine

1829 AD Sir Charles Wheatstone invents the accordion

1829 AD The first American typewriter patent

1830 AD Charles Babbage's Analytical Engine

1834 AD Georg and Edward Scheutz's Difference Engine

1834 AD Tally sticks: The hidden dangers

1837 AD Samuel Morse invents the electric telegraph

1847 AD to 1854 AD George Boole invents Boolean Algebra

1857 AD Sir Charles Wheatstone uses paper tape to store data

1860 AD Sir Joseph Wilson Swan's first experimental light bulb

1865 AD Lewis Carroll writes *Alice's Adventures in Wonderland*

1867 AD The first commercial typewriter

1868 AD First skeletons of Cro-Magnon man discovered

1869 AD William Stanley Jevons invents the Jevons' Logic Machine

1872 AD Lewis Carroll writes *Through the Looking-Glass*

Circa 1874 AD The Sholes keyboard

1876 AD Lewis Carroll writes *The Hunting of the Snark*

1876 AD George Barnard Grant's Difference Engine

1878 AD The first true incandescent light bulb

1878 AD The first shift-key typewriter

1879 AD Robert Harley publishes article on the Stanhope Demonstrator

1880 AD The invention of the Baudot Code

1881 AD Allan Marquand's rectangular logic diagrams

1881 AD Allan Marquand invents the Marquand Logic Machine

1883 AD Thomas Alva Edison discovers the Edison Effect

1886 AD Lewis Carroll writes *The game of Logic*

1886 AD Charles Pierce links Boolean algebra to circuits based on switches

1890 AD John Venn invents Venn Diagrams

1890 AD Herman Hollerith's tabulating machines

Circa 1900 AD John Ambrose Fleming invents the vacuum tube

1902 AD The first teleprinters

1906 AD Lee de Forest invents the Triode

1921 AD Karel Capek's R.U.R. (Rossum's Universal Robots)

1926 AD First patent for a semiconductor transistor

1927 AD Vannevar Bush's Differential Analyser

Circa 1936 AD The Dvorak keyboard

1936 AD Benjamin Burack constructs the first electrical logic machine

1937 AD George Robert Stibitz's Complex Number Calculator

1937 AD Alan Turing invents the Turing Machine

1938 AD Claude Shannon's master's Thesis

1939 AD John Vincent Atanasoff's special-purpose electronic digital computer

1939 AD to 1944 AD Howard Aiken's Harvard Mark I (the IBM ASCC)

1940 AD The first example of remote computing

1941 AD Konrad Zuse and his Z1, Z3, and Z4

1943 AD Alan Turing and COLOSSUS

1943 AD to 1946 AD The first general-purpose electronic computer -- ENIAC

1944 AD to 1952 AD The first stored program computer -- EDVAC

1945 AD The "first" computer bug

1945 AD Johann (John) Von Neumann writes the "First Draft"

1947 AD First point-contact transistor

1948 AD to 1951 AD The first commercial computer -- UNIVAC

1949 AD EDSAC performs it's first calculation

1949 AD The first assembler -- "*Initial Orders*"

Circa 1950 AD Maurice Karnaugh invents Karnaugh Maps

1950 AD First bipolar junction transistor

1952 AD G.W.A. Dummer conceives integrated circuits

1953 AD First TV Dinner

1957 AD IBM 610 Auto-Point Computer

1958 AD First integrated circuit

1962 AD First field-effect transistor

1962 AD The "worst" computer bug

1963 AD MIT's LINC Computer

1970 AD First static and dynamic RAMs

1971 AD CTC's Datapoint 2200 Computer

1971 AD The Kenbak-1 Computer

1971 AD The first microprocessor: the 4004

1972 AD The 8008 microprocessor

1973 AD The Xerox Alto Computer

1973 AD The Micral microcomputer

1973 AD The Scelbi-8H microcomputer

1974 AD The 8080 microprocessor

1974 AD The 6800 microprocessor

1974 AD The Mark-8 microcomputer

1975 AD The 6502 microprocessor

1975 AD The Altair 8800 microcomputer

1975 AD Bill Gates and Paul Allen found Microsoft

1975 AD The KIM-1 microcomputer

1975 AD The Sphere 1 microcomputer

1976 AD The Z80 microprocessor

1976 AD The Apple I and Apple II microcomputers

1977 AD The Commodore PET microcomputer

1977 AD The TRS-80 microcomputer

1979 AD The VisiCalc spreadsheet program

1979 AD ADA programming language is named after Ada Lovelace

1980 AD Danny Cohen writes "*On Holy Wars and a Plea for Peace*"

1981 AD The first IBM PC

1997 AD The first Beboputer Virtual Computer

Further Reading

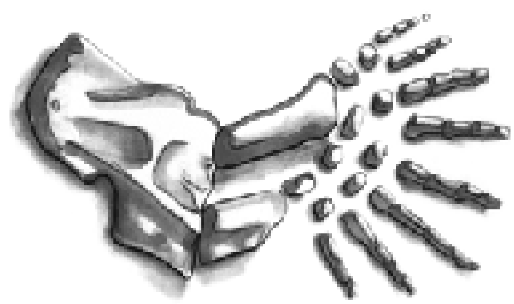
350 Million Years BC
The First Tetrapods Leave the Oceans

The number system we use on a day-to-day basis is the decimal system, which is based on ten digits: zero through nine. The name decimal comes from the Latin decem meaning ten, while the symbols we use to represent these digits arrived in Europe around the thirteenth century from the Arabs who, in turn, acquired them from the Hindus.

As the decimal system is based on ten digits, it is said to be base-10 or radix-10, where the term radix comes from the Latin word meaning "root" . Outside of specialist requirements such as computing, base-10 numbering systems have been adopted almost universally.

This is almost certainly due to the fact that we happen to have ten fingers (including our thumbs). If mother nature had decreed six fingers on each hand we would probably be using a base-twelve numbering system.

In fact this isn't as far-fetched as it may at first seem. The term "*tetrapod*" refers to an animal which has four limbs, along with hips and shoulders and fingers and toes. In the mid-1980s, paleontologists discovered Acanthostega who, at approximately 350 million years old, is the most primitive tetrapod known -- so primitive in fact that these creatures still lived exclusively in water and had not yet ventured onto land.



The first tetrapod had 8 fingers on each hand

After the dinosaurs (who were also tetrapods) exited the stage, humans were one branch of the tetrapod tree that eventually inherited the earth (along with hippopotami, hedgehogs, aardvarks, frogs, ... and all of the other vertebrates). Ultimately, we're all descended from Acanthostega or one of her cousins. The point is that Acanthostega had eight fully evolved fingers on each hand (see the figure above), so if evolution hadn't taken a slight detour, we'd probably have ended up using a base-sixteen numbering system, which would have been jolly handy when we finally got around to inventing computers, let me tell you! (As a point of interest, the Irish hero Cuchulain was reported as having seven fingers on each hand, but this would have been no help in computing whatsoever.)

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30,000 BC to 20,000 BC
Carving Notches Into Bones

The first tools used as aids to calculation were almost certainly man's own fingers, and it is not simply a coincidence that the word "*digit*" is used to refer to a finger (or toe) as well as a numerical quantity.

As the need to represent larger numbers grew, early man employed readily available materials for the purpose. Small stones or pebbles could be used to represent larger numbers than fingers and toes, and had the added advantage of being able to easily store intermediate results for later use. Thus, it is also no coincidence that the word "*calculate*" is derived from the Latin word for pebble.

The oldest known objects used to represent numbers are bones with notches carved into them. These bones, which were discovered in western Europe, date from the Aurignacian period 20,000 to 30,000 years ago and correspond to the first appearance of *Cro-Magnon man*. (The term "Cro-Magnon" comes from caves of the same name in Southern France, in which the first skeletons of this race were discovered in 1868.)

Of special interest is a wolf's jawbone more than 20,000 years old with fifty-five notches in groups of five. This bone, which was discovered in Czechoslovakia in 1937, is the first evidence of the *tally system*.

The tally system is still used to the present day, and could therefore qualify as one of the most enduring of human inventions (see also Tally Sticks: The Hidden Dangers).

The first evidence of the tally system.

Also of interest is a piece of bone dating from around 8,500 BC, which was discovered in Africa, and which appears to have notches representing the *prime numbers* 11, 13, 17, and 19. Prime numbers are those that are only wholly divisible by the number one and themselves, so it is not surprising that early man would have attributed them with a special significance. What is surprising is that someone of that era had the mathematical sophistication to recognize this quite advanced concept and took the trouble to write it down -- not the least that prime numbers had little relevance to everyday problems of gathering food and staying alive.

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1900 BC
The First Place-Value Number System

The decimal system with which we are fated is a place-value system, which means that the value of a particular digit depends both on the digit itself and on its position within the number. For example, a four in the right-hand column simply means four ...... in the next column it means forty ...... one more column over means four-hundred ...... then four thousand, and so on.

For many arithmetic operations, the use of a number system whose base is wholly divisible by many numbers, especially the smaller values, conveys certain advantages. And so we come to the Babylonians, who were famous for their astrological observations and calculations, and who used a sexagesimal (base-60) numbering system (see also The invention of the abacus).

Although sixty may appear to be a large value to have as a base, it does convey certain advantages. Sixty is the smallest number that can be wholly divided by two, three, four, five, and six ...... and of course it can also be divided by ten, fifteen, twenty, and thirty. In addition to using base sixty, the Babylonians also made use six and ten as sub-bases.

The Babylonian's sexagesimal system, which first appeared around 1900 to 1800 BC, is also credited as being *the first known place-value number system,* in which the value of a particular digit depends both on the digit itself and its position within the number. This was an extremely important development, because prior to place-value systems people were obliged to use different symbols to represent different powers of a base, and having unique symbols for ten, one-hundred, one thousand, and so forth makes even rudimentary calculations very difficult to perform (see also The Ancient Egyptians).

Finally, although the Babylonian's sexagesimal system may seem unwieldy to us, one cannot help but feel that it was an improvement on the Sumerians who came before them. The Sumerians had three distinct counting systems to keep track of land, produce, and animals, and they used a completely different set of symbols for each system!

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1000 BC to 500 BC
The Invention of the Abacus

The first actual calculating mechanism known to us is the abacus, which is thought to have been invented by the Babylonians sometime between 1,000 BC and 500 BC, although some pundits are of the opinion that it was actually invented by the Chinese (see also The first place-value number system).

The word abacus comes to us by way of Latin as a mutation of the Greek word *abax*. In turn, the Greeks may have adopted the Phoenician word *abak*, meaning "sand", although some authorities lean toward the Hebrew word *abhaq*, meaning "dust."

Irrespective of the source, the original concept referred to a flat stone covered with sand (or dust) into which numeric symbols were drawn. The first abacus was almost certainly based on such a stone, with pebbles being placed on lines drawn in the sand. Over time the stone was replaced by a wooden frame supporting thin sticks, braided hair, or leather thongs, onto which clay beads or pebbles with holes were threaded.

A variety of different types of abacus were developed, but the most popular became those based on the bi-quinary system, which utilizes a combination of two bases (base-2 and base-5) to represent decimal numbers. Although the abacus does not qualify as a mechanical calculator, it certainly stands proud as one of first mechanical aids to calculation.

See also:

Leonardo da Vinci's mechanical calculator

John Napier and Napier's Bones

The invention of the slide rule

Wilhelm Schickard's mechanical calculator

Blaise Pascal's Arithmetic Machine

Gottfried von Libniz's Step Reckoner

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Logic Diagrams

As we may or may not have previously discused (depending on the way in which you're bouncing around our web pages), these days we are predominantly concerned with computers, but it's worth noting that there has historically been a great deal of fascination in logic in general. This fascination was initially expressed in the form of logic diagrams, and later in the construction of special-purpose logic machines for manipulating logical expressions and representations.

Diagrams used to represent logical concepts have been around in one form or another for a very long time. For example, the Greek philosopher and scientist Aristotle (384 BC to 322 BC) was certainly familiar with the idea of using a stylized tree figure to represent the relationships between (and successive sub-divisions of) such things as different species. Diagrams of this type, which are known as the Tree of Porphyry, are often to be found in medieval pictures.

Following the Tree of Porphyry, there seems to have been a dearth of activity on the logic diagram front until 1761, when the brilliant Swiss mathematician Leonhard Euler introduced a geometric system that could generate solutions for problems in class logic.

Euler's work in this area didn't really catch on, however, because it was somewhat awkward to use, and it was eventually supplanted in the 1890s by a more polished scheme proposed by the English logician John Venn. Venn was heavily influenced by the work of George Boole, and his Venn Diagrams very much complemented Boolean Algebra.

Venn Diagrams were strongly based on the interrelationships between overlapping circles or ellipses. The first logic diagrams based on squares or rectangles were introduced in 1881 by Allan Marquand, a lecturer in logic and ethics at John Hopkins University.

Marquand's diagrams spurred interest by a number of other contenders, including one offering by an English logician and author, the Reverend Charles Lutwidge Dodgson.

Dodgson's diagrammatic technique first appeared in his book *The game of Logic*, which was published in 1886, but he is better known to us by his pen-name, Lewis Carroll, and as being the author of *Alice's Adventures in Wonderland*.

Lewis Carroll

Leaping from one topic to another with the agility of a mountain goat, we might also note that Lewis Carroll enjoyed posing logical conundrums in many of his books, such as *Alice's Adventures in Wonderland* (1865), *Through the Looking-Glass* (1872), and *The Hunting of the Snark* (1876). For example, consider this scene from the Mad Hatter's tea party in Chapter 7 of *Alice's Adventures in Wonderland*:

"*Take some more tea*," the March Hare said to Alice, very earnestly.

"*I've had nothing yet*," Alice replied in an offended tone: "*so I can't take more*."

"*You mean you can't take less*," said the hatter:
"*it's very easy to take more than nothing*."

And we would have to chastise ourselves soundly if we neglected the scene involving Tweedledum and Tweedledee in Chapter 4 of *Through the Looking-Glass*:

"*I know what you're thinking about*," said Tweedledum; "*but it isn't so, nohow*."

"*Contrariwise*," continued Tweedledee, "*if it was so, it might be; and if it were so, it would be; but as it isn't, it ain't. That's logic.*"

You have to admit, these gems of information aren't to be found in your average history of computers, are they? But once again we've wandered off the beaten path ("*No*," you cry, "*tell me it isn't so!*").

Apart from anything else, rectangular logic diagrams as espoused by Allan Marquand and Lewis Carroll are of interest to us because they were the forerunners of a more modern form known as Karnaugh Maps. Karnaugh Maps, which were invented by Maurice Karnaugh, in the 1950s, quickly became one of the mainstays of the digital logic and computer designer's tool-chest.

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300 BC to 600 AD
The First Use of Zero and Negative Numbers

Interestingly enough, the idea of numbers like one, two, and three developed a long time before the concept of zero. This was largely because the requirement for a number "zero" was less than obvious in the context of the calculations that early man was trying to perform.

For example, suppose that a young man's father had instructed him to stroll up to the top field to count their herd of goats and, on arriving, the lad discovered the gate wide open and no goats to be seen. First, his task on the counting front had effectively been done for him. Second, on returning to his aged parent, he probably wouldn't feel the need to say: *"Oh revered one, I regret to inform you that the result of my calculations lead me to believe that we are the proud possessors of zero goats."*

Instead, he would be far more inclined to proclaim something along the lines of: *"Father, some drongo left the gate open and all of our goats have wandered off."*

In the case of the original Babylonian system (see also The first place-value number system), a zero was simply represented by a space. Imagine if, in our decimal system, instead of writing 104 (one-hundred-and-four) we were to write 1 4 (one-space-four).

It's easy to see how this can lead to a certain amount of confusion, especially when there are multiple zeros next to each other. The problems can only be exacerbated if, like the Babylonians, one is using a base-sixty system and writing on clay tablets in a thunderstorm.

After more than 1,500 years of potentially inaccurate calculations, the Babylonians finally began to use a special sign for zero. Many historians believe that this sign, which first appeared around 300 BC, was one of the most significant inventions in the history of mathematics. However, the Babylonians only used their symbol as a place holder and they didn't have the concept of zero as an actual value. Thus, clay tablet accounting records of the time couldn't say something like *"0 fish,"* but instead they had to write out in full: *"We don't have any fish left."*

The use of zero as an actual value, along with the concept of negative numbers, first appeared in India around 600 AD. Although negative numbers appear reasonably obvious to us today, they were not well-understood until modern times. As recently as the eighteenth century, the great Swiss mathematician Leonhard Euler (pronounced "Oiler" in America) believed that negative numbers were greater than infinity, and it was common practice to ignore any negative results returned by equations on the assumption that they were meaningless!

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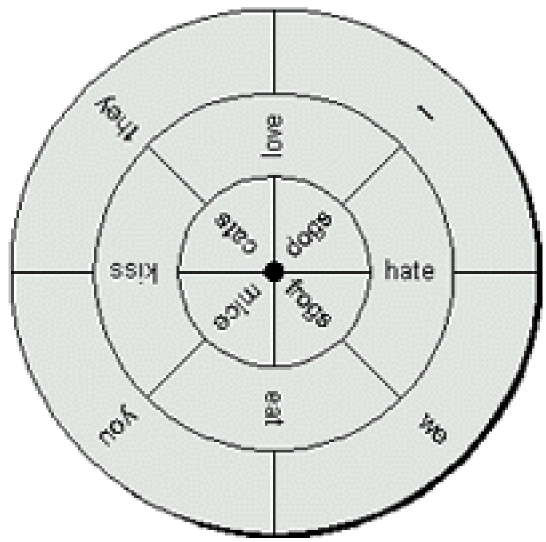
1274 AD
Ramon Lull's Ars Magna

Possibly the first person in the history of formal logic to use a mechanical device to generate (so-called) logical proofs was the Spanish theologian Ramon Lull (see also logic diagrams and logic machines). In 1274, Lull climbed Mount Randa in Majorca in search of spiritual sustenance.

After fasting and contemplating his navel for several days, Lull experienced what he believed to be a divine revelation, and he promptly rushed back down the mountain to pen his famous *Ars Magna*. This magnum opus described a number of eccentric logical techniques, but the one of which Lull was most proud (and which received the most attention) was based on concentric disks of card, wood, or metal mounted on a central axis.



Ramon Lull's disks.

Lull's idea was that each disk should contain a number of different words or symbols, which could be combined in different ways by rotating the disks. In the case of our somewhat jocular example shown above, we can achieve 4 x 4 x 4 = 64 different sentences along the lines of "*I love mice*," "*You hate cats*," and "*They eat frogs*."

Of course, Lull had a more serious purpose in mind, which was to prove the truth of everything contained within the Bible. For example, he used his disks to show that "*God's mercy is infinite*," "*God's mercy is mysterious*," "*God's mercy is just*," and so forth.

Lull's devices were far more complex than our simple example might suggest, with several containing as many as sixteen different words or symbols on each disk. His masterpiece was the *figura universalis*, which consisted of fourteen concentric circles (the mind boggles at the range of combinations that could be generated by this device).

Strange as it may seem to us, Lull's followers (called Lullists) flourished in the late middle ages and the renaissance, and Lullism spread far and wide across Europe.

Why is all of this of interest to us? Well by some strange quirk of fate, Lull's work fired the imagination of several characters with whom we are already familiar, such as Gottfried von Leibniz who invented the mechanical calculator called the Step Reckoner. (See also Jonathan Swift and Gulliver's Travels.)

Although Leibniz had little regard for Lull's work in general, he believed there was a chance it could be extended to apply to formal logic. In a rare flight of fancy, Leibniz conjectured that it might be possible to create a universal algebra that could represent just about everything under the sun, including (but not limited to) moral and metaphysical truths.

In 1666, at the age of 19, Leibniz wrote his *Dissertio de Arte Combinatoria*, from which comes a famous quote describing the way in which he believed the world could be in the future:

"If controversies were to arise," said Leibniz, "there would be no more need of disputation between two philosophers than between two accountants. For it would suffice to take their pencils in their hands, and say to each other: Let us calculate."

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1285 AD to 1349 AD
William of Ockham's Logical Transformations

William of Ockham (also known as William of Occam) was born in 1285 in Surrey, England, and lived until sometime around 1349. Ockham (who entered the Franciscan order and studied and taught at the University of Oxford from 1309 to 1319) was known as *Doctor Invincibilis* (from the Latin, meaning "unconquerable doctor") and *Venerabilis Inceptor* (meaning "worthy initiator").

Ockham was a philosopher and Scholastic theologian, and also won fame as a logician. During the course of his logical investigations, Ockham discovered the foundations for what were to become known as DeMorgan Transformations, which were described by Augustus DeMorgan some 500 years later.

To celebrate Ockham's position in history, the OCCAM computer programming language was named in his honor. (OCCAM is the native programming language for the British-developed INMOS transputer.)

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1434 AD
The First Self-Striking Water Clock

In addition to the Egyptians (see also The ancient egyptians), many other people experimented with water clocks and some interesting variations sprouted forth. For example, in some cases a float was connected to a wheel and, as the float changed its level, the wheel turned to indicate the hour on a dial.

Water clocks were also a standard means of keeping time in Korea as early as the "*Three Kingdoms*" period, and it was here that one of the first known automatic water clocks was devised in 1434. This clock was called *Chagyongnu*, which literally translates as "*self-striking water clock*." When the water reached a certain level, a trigger device released a metal ball which rolled down a chute into a metal drum to "*gong the hour*."

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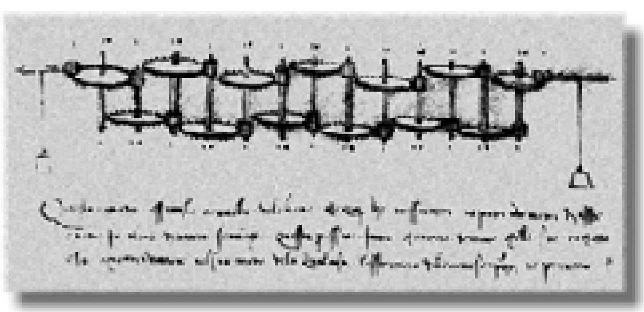
1500 AD
Leonardo da Vinci's Mechanical Calculator

Many references cite the French mathematician, physicist, and theologian, [Blaise Pascal](#) as being credited with the invention of the first operational calculating machine called the [Arithmetic Machine](#).

However, it now appears that the first mechanical calculator may have been conceived by Leonardo da Vinci almost one hundred and fifty years earlier than Pascal's machine.

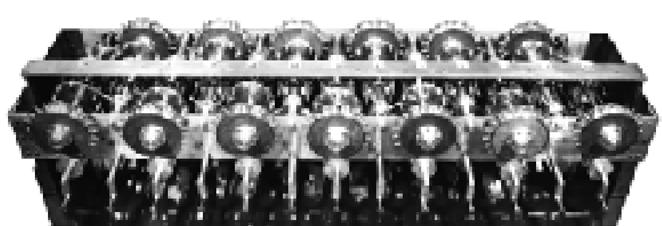
Leonardo da Vinci.



One of da Vinci's original sketches.
Courtesy of IBM

Da Vinci was a genius: painter, musician, sculptor, architect, engineer, and so on. However, his contributions to mechanical calculation remained hidden until the rediscovery of two of his notebooks in 1967.

These notebooks, which date from sometime around the 1500s, contained drawings of a mechanical calculator, and working models of da Vinci's device have since been constructed.



Working model of da Vinci's device.
Courtesy of IBM

See also:

The invention of the abacus

John Napier and Napier's Bones

The invention of the slide rule

Wilhelm Schickard's mechanical calculator

Blaise Pascal's Arithmetic Machine

Gottfried von Libniz's Step Reckoner

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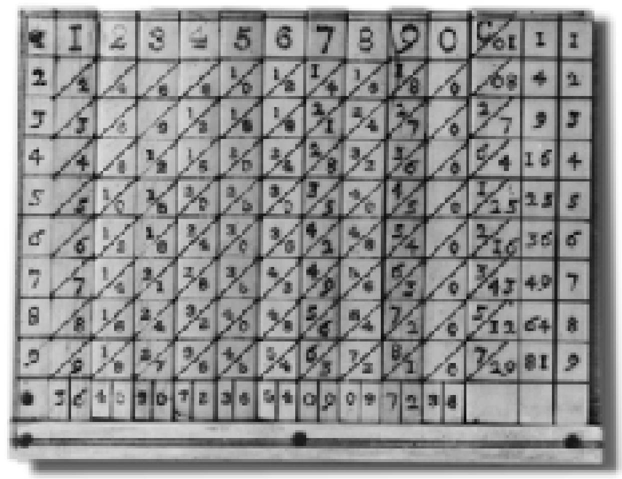
1600 AD
John Napier and Napier's Bones

In the early 1600s, a Scottish mathematician called John Napier invented a tool called Napier's Bones, which were multiplication tables inscribed on strips of wood or bone.

Napier, who was the Laird of Merchiston, also invented logarithms, which greatly assisted in arithmetic calculations.



Napier's Bones.
Courtesy of IBM

John Napier.

In 1621, an English mathematician and clergyman called William Oughtred used Napier's logarithms as the basis for the slide rule (Oughtred invented both the standard rectilinear slide rule and the less commonly used circular slide rule). However, although the slide rule was an exceptionally effective tool that remained in common use for over three hundred years, like the abacus it also does not qualify as a mechanical calculator.

See also:

Leonardo da Vinci's mechanical calculator

The invention of the abacus

Wilhelm Schickard's mechanical calculator

The invention of the slide rule

Blaise Pascal's Arithmetic Machine

Gottfried von Libniz's Step Reckoner

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1625 AD
Wilhelm Schickard's Mechanical Calculator

As was previously noted, determining who invented the first mechanical calculator is somewhat problematical. Many references cite the French mathematician, physicist, and theologian, Blaise Pascal as being credited with the invention of the first operational calculating machine called the Arithmetic Machine.

However, Pascal's claim to fame notwithstanding, the German astronomer and mathematician Wilhelm Schickard wrote a letter to his friend Johannes Kepler about fifteen years before Pascal started developing his Arithmetic Machine. (Kepler, a German astronomer and natural philosopher, was the first person to realize (and prove) that the planets travel around the sun in elliptical orbits.)

In his letter, Schickard wrote that he had built a machine that "...*immediately computes the given numbers automatically; adds, subtracts, multiplies, and divides*". Unfortunately, no original copies of Schickard's machine exist, but working models have been constructed from his notes.

See also:

Leonardo da Vinci's mechanical calculator

John Napier and Napier's Bones

Blaise Pascal's Arithmetic Machine

Gottfried von Libniz's Step Reckoner

The invention of the abacus

The invention of the slide rule

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1640 AD
Blaise Pascal's Arithmetic Machine

As fate would have it, determining who invented the first mechanical calculator is somewhat problematical. Many references cite the French mathematician, physicist, and theologian, Blaise Pascal as being credited with the invention of the first operational calculating machine.

Blaise Pascal.

Pascal's Arithmetic Machine.
Courtesy of IBM

In 1640, Pascal started developing a device to help his father add sums of money. The first operating model, the Arithmetic Machine, was introduced in 1642, and Pascal created fifty more devices over the next ten years. (In 1658, Pascal created a scandal when, under the pseudonym of Amos Dettonville, he challenged other mathematicians to a contest and then awarded the prize to himself!)

However, Pascal's device could only add and subtract, while multiplication and division operations were implemented by performing a series of additions or subtractions. In fact the Arithmetic Machine could really only add, because subtractions were performed using complement techniques, in which the number to be subtracted is first converted into its complement, which is then added to the first number. Interestingly enough, modern computers employ similar complement techniques.

See also:

Leonardo da Vinci's mechanical calculator

John Napier and Napier's Bones

Wilhelm Schickard's mechanical calculator

Gottfried von Libniz's Step Reckoner

The invention of the abacus

The invention of the slide rule

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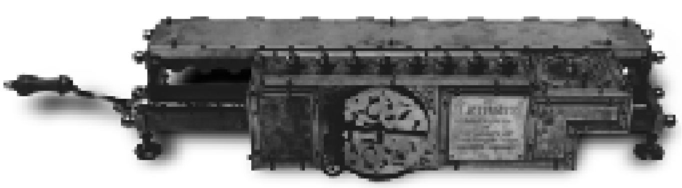
1670 AD
Gottfried von Leibniz's Step Reckoner

In the 1670s, a German Baron called Gottfried von Leibniz (sometimes von Leibnitz) took mechanical calculation a step beyond his predecessors.

Leibniz, who entered university at fifteen years of age and received his bachelor's degree at seventeen, once said: "*It is unworthy of excellent men to lose hours like slaves in the labor of calculation, which could be safely relegated to anyone else if machines were used*."

Gottfried von Leibniz.



Leibniz's Step Reckoner.
Courtesy of IBM

Leibniz developed Pascal's ideas and, in 1671, introduced the *Step Reckoner*, a device which, as well as performing additions and subtractions, could multiply, divide, and evaluate square roots by series of stepped additions.

Leibniz also strongly advocated the use of the binary number system, which is fundamental to the operation of modern computers.

Pascal's and Leibniz's devices were the forebears of today's desk-top computers, and derivations of these machines continued to be produced until their electronic equivalents finally became readily available and affordable in the early 1970s.

See also:

Leonardo da Vinci's mechanical calculator

John Napier and Napier's Bones

Wilhelm Schickard's mechanical calculator

Blaise Pascal's Arithmetic Machine

The invention of the abacus

The invention of the slide rule

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1714 AD
The First English Typewriter Patent

One of the most ubiquitous techniques for interactively entering data into a computer is by means of a keyboard. However, although the fingers of an expert typist leap from key to key with the agility of a mountain goat and the dexterity of a concert pianist, newcomers usually spend the vast bulk of their time desperately trying to locate the next key they wish to press.

It is actually not uncommon for strong words to ensue describing the way in which the keys are laid out, including the assertion that whoever came up with the scheme we employ must have been a blithering idiot. So why is it that a device we use so much is constructed in such a way that anyone who lays their hands on one is immediately reduced to uttering expletives and banging their heads against the nearest wall? Ah, there's the question and, as with so many things, the answer is shrouded in the mists of time ....

The first references to what we would call a typewriter are buried in the records of the British patent office. In 1714, by the grace of Queen Anne, a patent was granted to the English engineer Henry Mill. In a brave attempt towards the longest sentence in the English language with the minimum use of punctuation, the wording of this patent's title was:

"An artificial machine or method for the impressing or transcribing of letters singly or progressively one after another, as in writing, whereby all writing whatever may be engrossed in paper or parchment so neat and exact as not to be distinguished from print."

Unfortunately, after all the labors of the long-suffering patent clerk (a man who could have benefited from access to a typewriter if ever there was one), Mill never got around to actually manufacturing his machine. (See also The first American typewriter patent and The first commercial typewriter.)

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1726 AD
Jonathan Swift writes Gulliver's Travels

In 1274, the Spanish theologian Ramon Lull experienced what he believed to be a divine revelation, in which he invented an eccentric logical technique based on concentric disks mounted on a central axis. Strange as it may seem to us, Lull's followers (called Lullists) flourished in the late middle ages and the renaissance, and Lullism spread far and wide across Europe.

Of course, Lull also has his detractors (which is a kind way of saying that many people considered him to be a raving lunatic). In 1726, the Anglo-Irish satirist Jonathan Swift wrote Gulliver's Travels.

(On the off chance you were wondering, Swift penned his great work nine years before the billiard cue was invented. Prior to this, players used to strike the balls with a small mace.)

Johnathan Swift.

Gulliver's Travels was originally intended as an attack on the hypocrisy of the establishment, including the government, the courts, and the clergy (Swift didn't like to restrict himself unduly), but it was so well written that it immediately became a children's favorite.

In part III, chapter 5 of the tale, a professor of Laputa shows Gulliver a machine that generates random sequences of words. This device was based on a 20 foot square frame supporting wires threaded through wooden cubes, where each face of every cube had a piece of paper bearing a word pasted onto it.

Students randomly changed the words using forty handles mounted around the frame. The students then examined the cubes, and if three or four adjacent words formed part of a sentence that made any sense, they were immediately written down by scribes. The professor told Gulliver that by means of this technique:

"The most ignorant person at a reasonable charge, and with little bodily labor, may write books in philosophy, poetry, law, mathematics, and theology, without the least assistance from genius or study."

The point is that Swift is believed to have been mocking Lull's art when he penned this part of his story. (Having said this, computer programs have been used to create random poetry and music ...... which makes you wonder what Swift would have written about us).

In fact Swift continues to affect us in strange and wondrous ways to this day. When a computer uses multiple bytes to represent a number, there are two main techniques for storing those bytes in memory: either the most-significant byte is stored in the location with the lowest address (in which case we might say it's stored "big-end-first), or the least-significant byte is stored in the lowest address (in which case we might say it's stored "little-end-first).

Not surprisingly, some computer designers favor one style while others take the opposite tack. This didn't really matter until people became interested in creating heterogeneous computing environments in which multiple diverse machines were connected together, at which point many acrimonious arguments ensued.

In 1980, a famous paper written by Danny Cohen entitled "*On Holy Wars and a Plea for Peace*" used the terms *big-endian* and *little-endian* to refer to the two techniques for storing data. These terms, which are still in use today, were derived from that part of Gulliver's tale whereby two countries go to war over which end of a hard-boiled egg should be eaten first -- the little end or the big end!

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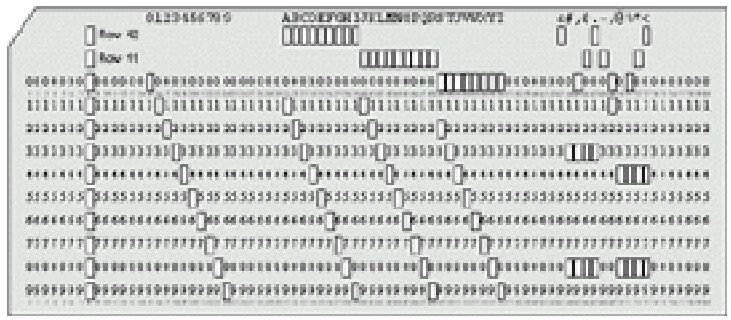
1800 AD
Jacquard's Punched Cards

In the early 1800s, a French silk weaver called Joseph-Marie Jacquard invented a way of automatically controlling the warp and weft threads on a silk loom by recording patterns of holes in a string of cards.

In the years to come, variations on Jacquard's punched cards would find a variety of uses, including representing the music to be played by automated pianos and the storing of programs for computers



IBM 80-column punched card format.

See also:
Charles Babbage's Analytical Engine & Herman Hollerith's tabulating machines

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These notes are abstracted from the book *Bebop BYTES Back (An Unconventional Guide to Computers)*

Logic Machines

As we may or may not have previously discused (depending on the way in which you're bouncing around our web pages), these days we are predominantly concerned with computers, but it's worth noting that there has historically been a great deal of fascination in logic in general. This fascination was initially expressed in the form of logic diagrams, and later in the construction of special-purpose logic machines for manipulating logical expressions and representations.

The world's first real logic machine, in the sense that it could actually be used to solve formal logic problems (as opposed to those described in Ramon Lull's Ars Magna, which tended to create more problems than they solved), was invented in the early 1800s by the British scientist and statesman Charles Stanhope (third Earl of Stanhope). A man of many talents, the Earl designed a device called the *Stanhope Demonstrator*, which was a small box with a window in the top, along with two different colored slides that the user pushed into slots in the sides.

Although Stanhope's brainchild doesn't sound like much it was a start (and there was more to it than we've covered here), but Stanhope wouldn't publish any details and instructed his friends not to say anything about what he was doing. In fact it wasn't until around sixty years after his death that the Earl's notes and one of his devices fell into the hands of the Reverend Robert Harley, who subsequently published an article on the Stanhope Demonstrator in 1879.

Working on a somewhat different approach was the British logician and economist William Stanley Jevons, who, in 1869, produced the earliest model of his famous *Jevons' Logic Machine*.

The Jevons' Logic Machine was notable because it was the first machine that could solve a logical problem faster than that problem could be solved without using the machine! Jevons was an aficionado of Boolean logic, and his solution was something of a cross between a logical abacus and a piano (in fact it was sometimes referred to as a *"Logic Piano"*).

This device, which was about 3 feet tall, consisted of keys, levers, and pulleys, along with letters that could be either visible or hidden. When the operator pressed keys representing logical operations, the appropriate letters appeared to reveal the result.

The next real advance in logic machines was made by Allan Marquand, whom we previously met in connection with his work on logic diagrams. In 1881, by means of the ingenious use of rods, levers, and springs, Marquand extended Jevons' work to produce the *Marquand Logic Machine*. Like Jevons' device, Marquand's machine could only handle four variables, but it was smaller and significantly more intuitive to use. (Following the invention of his logic machine, Marquand abandoned logical pursuits to become a professor of art and archeology at Princeton University.)

Things continued to develop apace. In 1936, the American psychologist Benjamin Burack from Chicago constructed what was probably the world's first electrical logic machine. Burack's device used light bulbs to display the logical relationships between a collection of switches, but for some reason he didn't publish anything about his work until 1949.

In fact the connection between Boolean algebra and circuits based on switches had been recognized as early as 1886 by an educator called Charles Pierce, but nothing substantial happened in this area until Claude E. Shannon published his 1938 paper (as is discussed elsewhere in this history).

Following Shannon's paper, a substantial amount of attention was focused on developing electronic logic machines. Unfortunately, interest in special-purpose logic machines waned in the 1940s with the advent of general-purpose computers, which proved to be much more powerful and for which programs could be written to handle formal logic.

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1822 AD
Charles Babbage's Difference Engine

The first device that might be considered to be a computer in the modern sense of the word was conceived in 1822 by the eccentric British mathematician and inventor Charles Babbage.

In Babbage's time, mathematical tables, such as logarithmic and trigonometric functions, were generated by teams of mathematicians working day and night on primitive calculators. Due to the fact that these people performed computations they were referred to as "*computers*." In fact the term "computer" was used as a job description (rather than referring to the machines themselves) well into the 1940s, but over the course of time this term became associated with machines that could perform the computations on their own.

Charles Babbage

In 1822, Babbage proposed building a machine called the Difference Engine to automatically calculate these tables. The Difference Engine was only partially completed when Babbage conceived the idea of another, more sophisticated machine called an Analytical Engine.

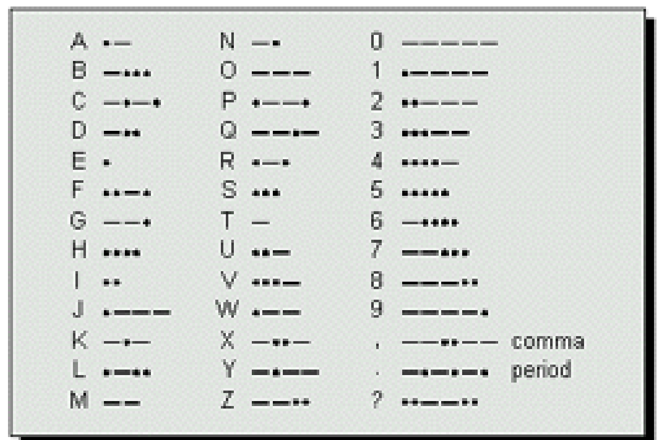
Interestingly enough, more than one hundred and fifty years after its conception, one of Babbage's earlier Difference Engines was eventually constructed from original drawings by a team at London's Science Museum. The final machine, which was constructed from cast iron, bronze and steel, consisted of 4,000 components, weighed three tons, and was 10 feet wide and 6½ feet tall.

The device performed its first sequence of calculations in the early 1990's and returned results to 31 digits of accuracy, which is far more accurate than the standard pocket calculator. However, each calculation requires the user to turn a crank hundreds, sometimes thousands of times, so anyone employing it for anything more than the most rudimentary calculations is destined to become one of the fittest computer operators on the face of the planet!

1837 AD
Samuel Morse Invents the Electric Telegraph

In 1837, the British physicist and inventor Sir Charles Wheatstone and the British electrical engineer Sir William Fothergill Cooke invented the first British electric telegraph. (Sir Charles was a busy man. Amongst other things, he also invented the *accordion* in 1829 and three-dimensional photographs in the form of his *stereoscope* in 1838.)

Wheatstone's telegraph made use of five wires, each of which was used to drive a pointer at the receiver to indicate different letters. In the same year, the American inventor Samuel Finley Breese Morse developed the first American telegraph, which was based on simple patterns of "*dots*" and "*dashes*" called Morse Code being transmitted over a single wire (the duration of a "dash" is three times the duration of a "dot").



A	•-	N	-•	0	-----	
B	-•••	O	---	1	•----	
C	-•-•	P	•--•	2	••---	
D	-••	Q	--•-	3	•••--	
E	•	R	•-•	4	••••-	
F	••-•	S	•••	5	•••••	
G	--•	T	-	6	-••••	
H	••••	U	••-	7	--•••	
I	••	V	•••-	8	---••	
J	•---	W	•--	9	----•	
K	-•-	X	-••-	,	--••--	comma
L	•-••	Y	-•--	.	-•-•-•	period
M	--	Z	--••	?	••--••	

Subset of International Morse Code

Morse's system was eventually adopted as the standard technique, because it was easier to construct and more reliable than Wheatstone's. Note that the figure above only shows a subset of the code (although it's quite a large subset), but it's enough to give the general idea. Also note that this table shows International Morse Code, which is a slightly different flavor to American Morse Code.

The Morse Telegraph and Morse code are of interest, because they sparked the first application of paper tapes as a medium for the preparation, storage, and transmission of data, and this technique would eventually be used be the designers of computers.

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1829 AD
The First American Typewriter Patent

Following the first English typewriter patent in 1714 and a few sporadic attempts from different parts of the globe, the first American patent for a typewriter was granted in 1829 to William Austin Burt from Detroit. However, the path of the inventor is rarely a smooth one as Burt was to discover. We may only picture the scene in the patent office:

Clark: "*Hello there, Mr. Burt, I have both good news and bad news. Which would you like first sir?*"

Burt: "*I think I'll take the good news, if it's all the same to you.*"

Clark: "*Well the good news is that you've been granted a patent for the device which you are pleased to call your Typographer*."

Burt: "*Good grief, I'm tickled pink, and the bad news?*"

Clark: "*Sad to relate, the only existing model of your machine was destroyed in a fire at our Washington patent office!*"

To be perfectly honest, the patent office (along with the Typographer) burned down in 1836, seven years after Burt received his patent. But as we all learn at our mother's knee, one should never allow awkward facts to get in the way of a good story.

As fate would have it, the fire probably caused no great loss to civilization as we know it. Burt's first Typographer was notably ungainly, so much so that it was possible to write much faster than one could type with this device.

Undaunted, Burt produced a second model the size of a present-day pinball machine, which, if nothing else, would have made an interesting conversation piece if given to a friend as a Christmas stocking-filler. Perhaps not surprisingly, no one was interested, and Burt eventually exited the stage to make room for younger contenders. (See also The first commercial typewriter.)

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1830 AD
Charles Babbage's Analytical Engine

As was previously noted, the first device that might be considered to be a computer in the modern sense of the word was conceived by the eccentric British mathematician and inventor Charles Babbage.

In 1822, Babbage proposed building a machine called the Difference Engine to automatically calculate mathematical tables. The Difference Engine was only partially completed when Babbage conceived the idea of another, more sophisticated machine called an Analytical Engine.

(Some texts refer to this machine as an "*Analytical Steam Engine*," because Babbage intended that it would be powered by steam).

Charles Babbage

The Analytical Engine was intended to use loops of Jacquard's punched cards to control an automatic calculator, which could make decisions based on the results of previous computations. This machine was also intended to employ several features subsequently used in modern computers, including sequential control, branching, and looping.

Ada Lovelace

Working with Babbage was Augusta Ada Lovelace, the daughter of the English poet Lord Byron. Ada, who was a splendid mathematician and one of the few people who fully understood Babbage's vision, created a program for the Analytical Engine.

Had the Analytical Engine ever actually worked, Ada's program would have been able to compute a mathematical sequence known as Bernoulli numbers. Based on this work, Ada is now credited as being the first computer programmer and, in 1979, a modern programming language was named ADA in her honor.

Babbage worked on his Analytical Engine from around 1830 until he died, but sadly it was never completed. It is often said that Babbage was a hundred years ahead of his time and that the technology of the day was inadequate for the task. Refuting this is the fact that, in 1834, two Swedish engineers called Georg and Edward Scheutz built a small Difference Engine based on Babbage's description. In his book, *Engines of the Mind*, Joel Shurkin stated:

> *"One of Babbage's most serious flaws was his inability to stop tinkering. No sooner would he send a drawing to the machine shop than he would find a better way to perform the task and would order work stopped until he had finished pursuing the new line. By and large this flaw kept Babbage from ever finishing anything."*

Further supporting this theory is the fact that, in 1876, only five years after Babbage's death, an obscure inventor called George Barnard Grant exhibited a full-sized difference engine of his own devising at the Philadelphia Centennial Fair. Grant's machine was 8 feet wide, 5 feet tall, and contained over 15,000 moving parts.

The point is that, although Babbage's Analytical Engine was intellectually far more sophisticated than his Difference Engine, constructing an Analytical Engine would not have been beyond the technology of the day.

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1834 AD
Tally Sticks: The Hidden Dangers

The practice of making marks on, or cutting notches into, things to represent numbers has survived to the present day, especially among school children making tally marks on their desks to signify the days of their captivity (see also Carving notches into bones).

In the not-so-distant past, storekeepers, who often could not read or write, used a similar technique to keep track of their customer's debts. For example, a baker might make cuts across a stick of wood equal to the number of loaves in the shopper's basket. This stick was then split lengthwise, with the baker and the customer keeping half each, so that both could remember how many loaves were owed and neither of them could cheat.

Similarly, the British government used wooden tally sticks until the early 1780s. These sticks had notches cut into them to record financial transactions and to act as receipts. Over the course of time these tally sticks were replaced by paper records, leaving the cellars of the Houses of Parliament full to the brim with pieces of old wood.

Rising to the challenge with the inertia common to governments around the world, Parliament dithered around until 1834 before finally getting around to ordering the destruction of the tally sticks. There was some discussion about donating the sticks to the poor as firewood, but wiser heads prevailed, pointing out that the sticks actually represented "*top secret*" government transactions.

The fact that the majority of the poor couldn't read or write and often couldn't count was obviously of no great significance, and it was finally decreed that the sticks should be burned in the courtyard of the Houses of Parliament. However, fate is usually more than willing to enter the stage with a pointed jape -- gusting winds caused the fire to break out of control and burn the House of Commons to the ground (although they did manage to save the foundations)!

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1847 AD to 1854 AD
George Boole Invents Boolean Algebra

Around the same time that Charles Babbage was struggling with his Analytical Engine, one of his contemporaries, a British mathematician called George Boole, was busily inventing a new and rather cunning form of mathematics.

Boole made significant contributions in several areas of mathematics, but was immortalized for two works in 1847 and 1854, in which he represented logical expressions in a mathematical form now known as *Boolean Algebra*. Boole's work was all the more impressive because, with the exception of elementary school and a short time in a commercial school, he was almost completely self-educated.

In conjunction with Boole, another British mathematician, Augustus DeMorgan, formalized a set of logical operations now known as DeMorgan transformations. As the Encyclopedia Britannica says: *"A renascence of logical studies came about almost entirely because of Boole and DeMorgan."*

In fact the rules we now attribute to DeMorgan were known in a more primitive form by William of Ockham (also known as William of Occam) in the 14th Century. In order to celebrate Ockham's position in history, the OCCAM computer programming language was named in his honor. (In fact, OCCAM is the native programming language for the British- developed INMOS transputer.)

Unfortunately, with the exception of students of philosophy and symbolic logic, Boolean Algebra was destined to remain largely unknown and unused for the better part of a century, until a young student called Claude E. Shannon recognized its relevance to electronics design.

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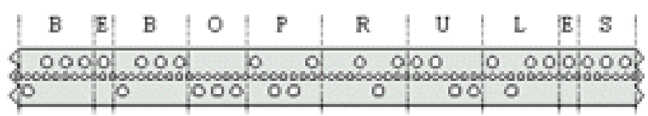
1857 AD
Wheatstone Uses Paper Tape to Store Data

In 1837, the American inventor Samuel Finley Breese Morse developed the first American electric telegraph, which was based on simple patterns of "dots" and "dashes" called Morse Code being transmitted over a single wire.

The telegraph quickly proliferated thanks to the relative simplicity of Morse's system. However, a problem soon arose in that operators could only transmit around ten words a minute, which meant that they couldn't keep up with the public's seemingly insatiable desire to send messages to each other. This was a classic example of a communications bottleneck.

Thus, in 1857, only twenty years after the invention of the telegraph, Sir Charles Wheatstone (the inventor of the accordion) introduced the first application of paper tapes as a medium for the preparation, storage, and transmission of data.

Sir Charles' paper tape used two rows of holes to represent Morse's dots and dashes. Outgoing messages could be prepared off-line on paper tape and transmitted later.

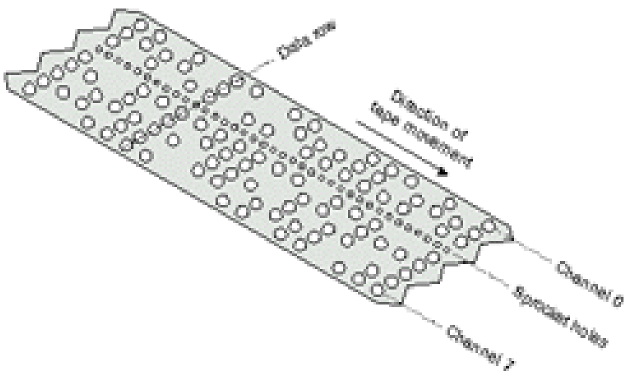


Wheatstone's perforated paper tape

By 1858, a Morse paper tape transmitter could operate at 100 words a minute. Unsuspectingly, Sir Charles had also provided the American public with a way to honor their heroes and generally have a jolly good time, because used paper tapes were to eventually become a key feature of so-called ticker-tape parades.

In a similar manner to Sir Charles' telegraph tape, the designers of the early computers realized that they could record their data on a paper tape by punching rows of holes across the width of the tape. The pattern of the holes in each data row represented a single data value or character. The individual hole positions forming the data rows were referred to as "*channels*" or "*tracks*," and the number of different characters that could be represented by each row depended on the number of channels forming the rows.

The original computer tapes had five channels, so each data row could represent one of thirty-two different characters. However, as users began to demand more complex character sets, including the ability to use both uppercase characters ('A', 'B', 'C', ...) and their lowercase equivalents ('a', 'b', 'c', ...), the number of channels rapidly increased, first to six and later to eight.



1-inch computer paper tape

This illustration represents one of the more popular IBM standards -- a one-inch wide tape supporting eight channels (numbered from 0 to 7) with 0.1 inches between the punched holes.

The first paper tape readers accessed the data by means of springy wires (one per channel), which could make electrical connections to conducting plates under the tape wherever a hole was present. These readers were relatively slow and could only operate at around fifty characters per second.

Later models used opto-electronic techniques, in which a light source was placed on one side of the tape and optical cells located on the other side were used to detect the light and thereby recognize the presence or absence of any holes.

In the original slower-speed readers, the small sprocket holes running along the length of the tape between channels 2 and 3 were engaged by a toothed wheel to advance the tape. The higher-speed opto-electronic models used rubber rollers to drive the tape, but the sprocket holes remained, because light passing through them could be detected and used to generate synchronization pulses.

On the off-chance that you were wondering, the reason the sprocket holes were located off-center between channels 2 and 3 (as opposed to being centered between channels 3 and 4) was to enable the operator to know which side of the tape was which. Of course, it was still necessary to be able to differentiate between the two ends of the tape, so the operators used scissors to shape the front-end into a triangular point, thereby indicating that this was the end to be stuck into the tape reader.

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1867 AD
The First Commercial Typewriter

Following William Austin Burt's attempt at a typewriter, numerous other innovators leapt into the fray with truly Heath Robinson offerings. Some of these weird and wonderful contraptions were as difficult to use as a Church organ, while others printed by keeping the paper stationary and hurling the rest of the machine against it ...... the mind boggles.

The first practical typewriting machine was conceived by three American inventors and friends who spent their evenings tinkering together. In 1867, Christopher Latham Sholes, Carlos Glidden, and Samual W. Soule invented what they called the Type-Writer (the hyphen was discarded some years later).

Soulé eventually dropped out, but the others kept at it, producing close to thirty experimental models over the next five years. Unfortunately, Sholes and Glidden never really capitalized on their invention, but instead sold the rights to a smooth-talking entrepreneur called James Densmore, who, in 1873, entered into a contract with a gun and sewing machine manufacturer to produce the device.

Strangely, the manufacturers, E. Remington and Sons from the state of New York, had no experience building typewriters. This was primarily because no one had ever produced a typewriter before, but there's also the fact that (let's face it) Remington and Sons made guns and sewing machines.
The first thing they did was to hunt for the best artist-mechanic they could find, and they eventually settled on a man called William K. Jenne.

However, Jenne's expertise was in the design of sewing machines, with the result that the world's first commercial typewriter, released in 1874, ended up with a foot pedal to advance the paper and sweet little flowers on the sides!

See also:
The Sholes keyboard

The Dvorak keyboard

The first printing telegraphs

The first teleprinters

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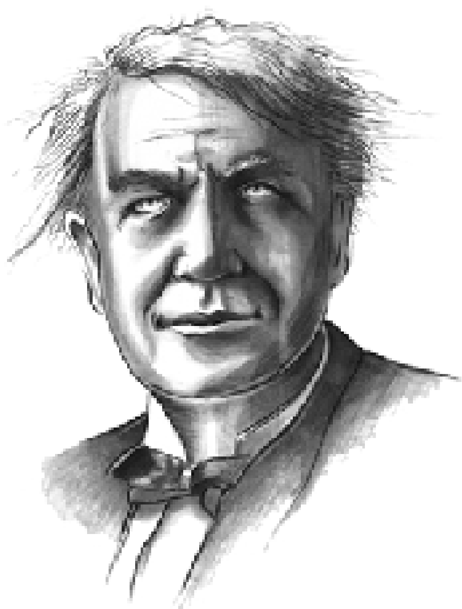
These notes are abstracted from the book *Bebop BYTES Back (An Unconventional Guide to Computers)*

1878 AD
The First True Incandescent Light Bulb

Now here's a bit of a poser for you -- who invented the first electric light bulb? If your immediate response was "*The legendary American inventor, Thomas Alva Edison,*" then you'd certainly be in the majority, but being in the majority doesn't necessarily mean that you're right.



Thomas Alva Edison

It's certainly true that Edison did invent the light bulb (or at least "*a*" light bulb), but he wasn't the first. In 1860, an English physicist and electrician, Sir Joseph Wilson Swan, produced his first experimental light bulb using carbonized paper as a filament. Unfortunately, Swan didn't have a strong enough vacuum or sufficiently powerful batteries and his prototype didn't achieve complete incandescence, so he turned his attentions to other pursuits.

Fifteen years later, in 1875, Swan returned to consider the problem of the light bulb and, with the aid of a better vacuum and a carbonized thread as a filament (the same material Edison eventually decided upon), he successfully demonstrated a true incandescent bulb in 1878 (a year earlier than Edison). Furthermore, in 1880, Swan gave the world's first large-scale public exhibition of electric lamps at Newcastle, England.

So it's reasonable to wonder why Edison received all of the credit, while Swan was condemned to obscurity. The more cynical among us may suggest that Edison was thrust into the limelight (see note below) because many among us learn their history through films, and the vast majority of early films were made in America by patriotic Americans.

However, none of this should detract from Edison who, working independently, experimented with thousands of filament materials and expended tremendous amounts of effort before discovering carbonized thread. It is also probably fair to say that Edison did produce the first commercially viable light bulb.

The reason why this is of interest to us here is that Edison's experiments with light bulbs led him to discover the Edison Effect, which ultimately led to the invention of the vacuum tube.

As one final nugget of trivia, the term "*limelight*" comes from the incandescent light produced by a rod of lime bathed in a flame of oxygen and hydrogen. At the time it was invented, limelight was the brightest source of artificial light known. One of it's first uses was for lighting theater stages, and actors and actresses were keen to position themselves "*in the limelight*" so as to be seen to their best effect.

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1890 AD
Herman Hollerith's Tabulating Machines

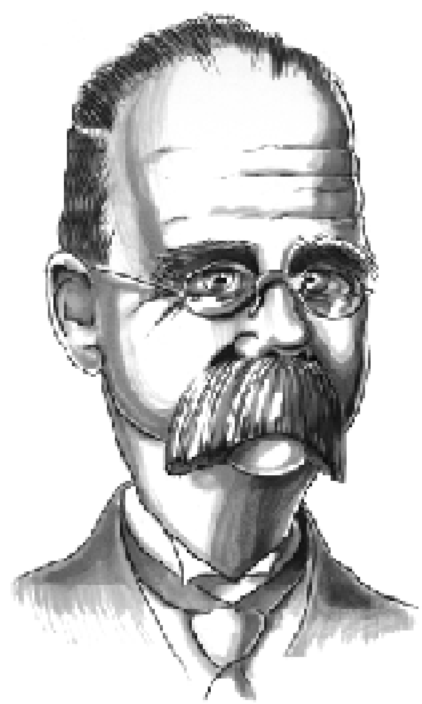
It is often said that necessity is the mother of invention, and this was certainly true in the case of the American census. Following the population trends established by previous surveys, it was estimated that the census of 1890 would be required to handle data from more than 62 million Americans.

In addition to being prohibitively expensive, the existing system of making tally marks in small squares on rolls of paper and then adding the marks together by hand was extremely time consuming. In fact it was determined that, if the system remained unchanged, there was no chance of collating the data from the 1890 census into any useful form until well after the 1900 census had taken place, by which time the 1890 data would be of little value.

The solution to this problem was developed during the 1880s by an American inventor called Herman Hollerith, whose idea it was to use Jacquard's punched cards to represent the census data, and to then read and collate this data using an automatic machine.

While he was a lecturer at MIT, Hollerith developed a simple prototype which employed cards he punched using a tram conductor's ticket punch, where each card was intended to contain the data associated with a particular individual.

From this prototype, he evolved a mechanism that could read the presence or absence of holes in the cards by using spring-mounted nails that passed through the holes to make electrical connections.



Herman Hollerith

Hollerith's final system included an automatic electrical tabulating machine with a large number of clock-like counters that accumulated the results. By means of switches, operators could instruct the machine to examine each card for certain characteristics, such as profession, marital status, number of children, and so on.

When a card was detected that met the specified criteria, an electrically controlled sorting mechanism could gather those cards into a separate container. Thus, for the first time it was possible to extract information such as the number of engineers living in a particular state who owned their own house and were married with two children. Although this may not tickle your fancy, having this capability was sufficient to drive the statisticians of the time into a frenzy of excitement and data collation.

In addition to solving the census problem, Hollerith's machines proved themselves to be extremely useful for a wide variety of statistical applications, and some of the techniques they used were to be significant in the development of the digital computer. In February 1924, Hollerith's company changed its name to *International Business Machines*, or *IBM*. (See also Hollerith's punched cards.)

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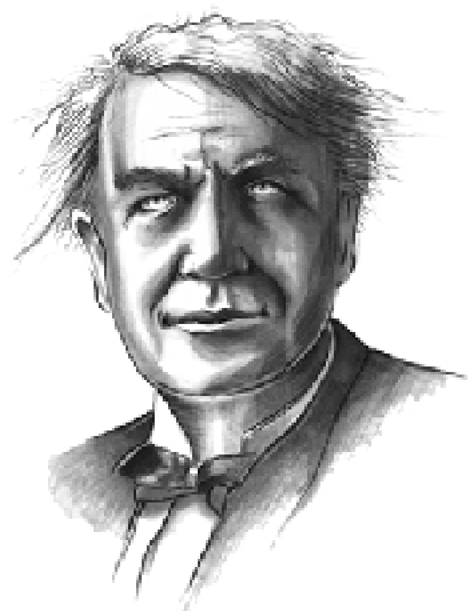
1883 AD to 1906 AD
The Invention of the Vacuum Tube

In 1879, the legendary American inventor Thomas Alva Edison publicly exhibited his incandescent electric light bulb for the first time.

(If you ever happen to be in Dearborn, Michigan, you should take the time to visit the Henry Ford Museum, which happens to contain the world's largest and most spectacular collection of light bulbs.)



Thomas Alva Edison

Edison's light bulbs employed a conducting filament mounted in a glass bulb from which the air was evacuated leaving a vacuum. Passing electricity through the filament caused it to heat up enough to become incandescent and radiate light, while the vacuum prevented the filament from oxidizing and burning up.

Edison continued to experiment with his light bulbs and, in 1883, found that he could detect electrons flowing through the vacuum from the lighted filament to a metal plate mounted inside the bulb. This discovery subsequently became known as the *Edison Effect*.

Edison did not develop this particular finding any further, but an English physicist, John Ambrose Fleming, discovered that the Edison Effect could also be used to detect radio waves and to convert them to electricity. Fleming went on to develop a two-element vacuum tube known as *diode*.

In 1906, the American inventor Lee de Forest introduced a third electrode called the grid into the vacuum tube. The resulting *triode* could be used as both an amplifier and a switch, and many of the early radio transmitters were built by de Forest using these triodes (he also presented the first live opera broadcast and the first news report on radio).

De Forest's triodes revolutionized the field of broadcasting and were destined to do much more, because their ability to act as switches was to have a tremendous impact on digital computing.

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1902 AD
The First Teleprinters

In 1902, a young electrical engineer called Frank Pearne approached Mr. Joy Morton, the president of the well-known Morton Salt Company. Pearne had been experimenting with printing telegraphs and needed a sponsor. Morton discussed the situation with his friend, the distinguished mechanical engineer Charles L. Krum, and they eventually decided they were interested in pursuing this project.

After a year of unsuccessful experiments, Pearne lost interest and wandered off into the sunset to become a teacher. Krum continued to investigate the problem and, in 1906, was joined by his son Howard, who had recently graduated as an electrical engineer. The mechanical and electrical talents of the Krums Senior and Junior complemented each other. After solving the problem of synchronizing the transmitter and receiver, they oversaw their first installation on postal lines between New York City and Boston in the summer of 1910.

These devices, called teleprinters, had a typewriter-style keyboard for entering outgoing messages and a roll of paper for printing incoming messages. The Krums continued to improve the reliability of their systems over the years. By 1914, teleprinters were being used by the *Associated Press* to deliver copy to newspaper offices throughout America, and by the early 1920s they were in general use around the world.

Meanwhile, toward the end of the 1920s and the early 1930s, scientists and engineers began to focus their attentions on the issue of computing. The first devices, such as Vannevar Bush's Differential Analyzer, were predominantly analog, but not everyone was a devotee of analog computing. At a meeting in New Hampshire in September 1940 George Robert Stibitz used a digital machine to perform the first demonstration of remote computing. Leaving his computer in New York City, he took a teleprinter to the meeting which he connected to the computer using a telephone line. Stibitz then proceeded to astound the attendees by allowing them to pose problems which were entered on the teleprinter; within a minute, the teleprinter printed the answers generated by the computer.

By the 1950s, computers were becoming much more complex, but operators were still largely limited to entering programs using a switch panel or loading them from paper tapes or punched cards. Due to the fact that the only way for early computers to be cost-effective was for them to operate twenty-four hours a day, the time-consuming task of writing programs had to be performed off-line using teleprinters with integrated paper tape writers or card punches.

As computers increased in power, teleprinters began to be connected directly to them. This allowed the operators and the computer to communicate directly with each other, which was one of the first steps along the path toward the interactive way in which we use computers today.

By the middle of the 1960s, computers had become so powerful that many operators could use the same machine simultaneously, and a new concept called *time-sharing* was born. The computer could switch between users so quickly that each user had the illusion they had sole access to the machine. (Strangely enough, time-sharing is now only practiced in large computing installations, because computers have become so powerful and so cheap that everyone can have a dedicated processor for themselves).

However, the days of the teleprinter in the computing industry were numbered; they were eventually supplanted by the combination of computer keyboards and video displays, and the sound of teleprinters chuntering away in the back of computer rooms is now little more than a nostalgic memory. (See also The first commercial typewriter and The first printing telegraphs.)

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1921 AD
Karel Capek's R.U.R.

In 1921, the Czech author Karel Capek produced his best known work, the play *R.U.R. (Rossum's Universal Robots),* which featured machines created to simulate human beings.

Some references state that term "*robot*" was derived from the Czech word *robota*, meaning "work", while others propose that *robota* actually means "forced workers" or "slaves." This latter view would certainly fit the point that Capek was trying to make, because his robots eventually rebelled against their creators, ran amok, and tried to wipe out the human race.

However, as is usually the case with words, the truth of the matter is a little more convoluted. In the days when Czechoslovakia was a feudal society, *"robota"* referred to the two or three days of the week that peasants were obliged to leave their own fields to work without remuneration on the lands of noblemen. For a long time after the feudal system had passed away, robota continued to be used to describe work that one wasn't exactly doing voluntarily or for fun, while today's younger Czechs and Slovaks tend to use robota to refer to work that's boring or uninteresting.

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1926 AD to 1962 AD
The First Transistors

The transistor and subsequently the integrated circuit must certainly qualify as two of the greatest inventions of the twentieth century. These devices are formed from materials known as semiconductors, whose properties were not well-understood until the 1950s. However, as far back as 1926, Dr. Julius Edgar Lilienfield from New York filed for a patent on what we would now recognize as an NPN junction transistor being used in the role of an amplifier (the patent title was *"Method and apparatus for controlling electric currents"*).

Unfortunately, serious research on semiconductors didn't really commence until World War II.

At that time it was recognized that devices formed from semiconductors had potential as amplifiers and switches, and could therefore be used to replace the prevailing technology of vacuum tubes, but that they would be much smaller, lighter, and would require less power.

All of these factors were of interest to the designers of the radar systems which were to play a large role in the war.

Bell Laboratories in the United States began research into semiconductors in 1945, and physicists William Shockley, Walter Brattain and John Bardeen succeeded in creating the first *point- contact germanium transistor* on the 23rd December, 1947 (they took a break for the Christmas holidays before publishing their achievement, which is why some reference books state that the first transistor was created in 1948).

In 1950, Shockley invented a new device called a bipolar junction transistor, which was more reliable, easier and cheaper to build, and gave more consistent results than point-contact devices. (Apropos of nothing at all, the first TV dinner was marketed by the C.A. Swanson company three years later.)

By the late 1950s, bipolar transistors were being manufactured out of silicon rather than germanium (although germanium had certain electrical advantages, silicon was cheaper and easier to work with). Bipolar junction transistors are formed from the junction of three pieces of doped silicon called the *collector*, *base*, and *emitter*. The original bipolar transistors were manufactured using the mesa process, in which a doped piece of silicon called the mesa (or base) was mounted on top of a larger piece of silicon forming the collector, while the emitter was created from a smaller piece of silicon embedded in the base.

In 1959, the Swiss physicist Jean Hoerni invented the planar process, in which optical lithographic techniques were used to diffuse the base into the collector and then diffuse the emitter into the base. One of Hoerni's colleagues, Robert Noyce, invented a technique for growing an insulating layer of silicon dioxide over the transistor, leaving small areas over the base and emitter exposed and diffusing thin layers of aluminum into these areas to create wires. The processes developed by Hoerni and Noyce led directly to modern integrated circuits.

In 1962, Steven Hofstein and Fredric Heiman at the RCA research laboratory in Princeton, New Jersey, invented a new family of devices called metal-oxide semiconductor *field-effect transistors* (MOS FETs for short).

Although these transistors were somewhat slower than bipolar transistors, they were cheaper, smaller and used less power. Also of interest was the fact that modified metal-oxide semiconductor structures could be made to act as capacitors or resistors.

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1927 AD
Vannevar Bush's Differential Analyser

In 1927, with the assistance of two colleagues at MIT, the American scientist, engineer, and politician Vannevar Bush designed an analog computer that could solve simple equations. This device, which Bush dubbed a Product Intergraph, was subsequently built by one of his students.

Bush continued to develop his ideas and, in 1930, built a bigger version which he called a *Differential Analyzer*. The Differential Analyzer was based on the use of mechanical integrators that could be interconnected in any desired manner. To provide amplification, Bush employed torque amplifiers which were based on the same principle as a ship's capstan. The final device used its integrators, torque amplifiers, drive belts, shafts, and gears to measure movements and distances (not dissimilar in concept to an automatic slide rule).

Although Bush's first Differential Analyzer was driven by electric motors, its internal operations were purely mechanical. In 1935 Bush developed a second version, in which the gears were shifted electro-mechanically and which employed paper tapes to carry instructions and to set up the gears.

In our age, when computers can be constructed the size of postage stamps, it is difficult to visualize the scale of the problems that these early pioneers faced. To provide some sense of perspective, Bush's second Differential Analyzer weighed in at a whopping 100 tons! In addition to all of the mechanical elements, it contained 2000 vacuum tubes, thousands of relays, 150 motors, and approximately 200 miles of wire.

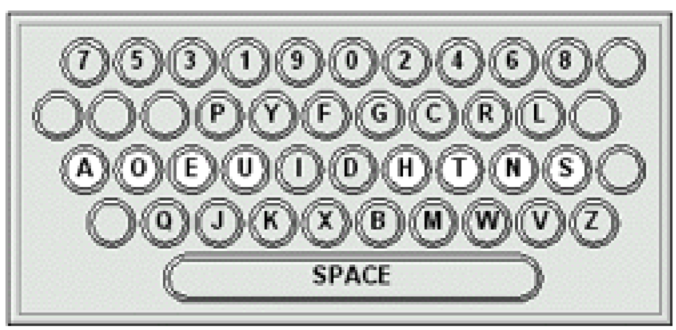
As well as being a major achievement in its own right, the Differential Analyzer was also significant because it focused attention on analog computing techniques, and therefore detracted from the investigation and development of digital solutions for quite some time.

Circa 1936 AD
The Dvorak Keyboard

Almost anyone who spends more than a few seconds working with a QWERTY keyboard quickly becomes convinced that they could do a better job of laying out the keys. Many brave souls have attempted the task, but few came closer than efficiency expert August Dvorak in the 1930s.

When he turned his attention to the typewriter, Dvorak spent many tortuous months analyzing the usage model of the QWERTY keyboard (now there's a man who knew how to have a good time). The results of his investigation were that, although the majority of users were right-handed, the existing layout forced the weaker left hand (and the weaker fingers on both hands) to perform most of the work. Also, thanks to Sholes' main goal of physically separating letters that are commonly typed together, the typist's fingers were obliged to move in awkward patterns and only ended up spending 32% of their time on the home row.

Dvorak took the opposite tack to Sholes, and attempted to find the optimal placement for the keys based on letter frequency and human anatomy. That is, he tried to ensure that letters which are commonly typed together would be physically close to each other, and also that the (usually) stronger right hand would perform the bulk of the work, while the left hand would have control of the vowels and the lesser-used characters. The result of these labors was the *Dvorak Keyboard*, which he patented in 1936.



The Dvorak keyboard (circa 1936)

Note that Dvorak's keyboard had shift keys, but they are omitted from the above figure for reasons of clarity. The results of Dvorak's innovations were tremendously effective. Using his layout, the typist's fingers spend 70% of their time on the home row and 80% of this time on their home keys. Thus, as compared to the approximately 120 words that can be constructed from the home row keys of the QWERTY keyboard, it is possible to construct more than 3,000 words on Dvorak's home row (or 10,000 words if you're talking to someone who's trying to sell you one). Also, Dvorak's scheme reduces the motion of the hands by a factor of three, and improves typing accuracy and speed by approximately 50%, and 20%, respectively.

Unfortunately, Dvorak didn't really stand a chance trying to sell typewriters based on his new keyboard layout in the 1930s. Apart from the fact that existing typists didn't wish to re-learn their trade, America was in the heart of the depression years, which meant that the last thing anyone wanted to do was to spend money on a new typewriter.

In fact, the Dvorak keyboard might have faded away forever, except that enthusiasts in Oregon, USA, formed a club in 1978, and they've been actively promoting Dvorak's technique ever since. (See also The Sholes (QWERTY) keyboard.)

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1937 AD
George Stibitz's Complex Number Calculator

In 1927, the American scientist, engineer, and politician Vannevar Bush designed an analog computer that could solve simple equations. Bush's work was extremely significant, because (quite apart from anything else) it focused attention on analog computing techniques, and therefore detracted from the investigation and development of digital solutions for quite some time.

But not everyone was enamored by analog computing.

In 1937, George Robert Stibitz, a scientist at Bell Laboratories built a digital machine based on relays, flashlight bulbs, and metal strips cut from tin-cans.

Stibitz's machine, which he called the "Model K" (because most of it was constructed on his kitchen table), worked on the principle that if two relays were activated they caused a third relay to become active, where this third relay represented the sum of the operation. For example, if the two relays representing the numbers 3 and 6 were activated, this would activate another relay representing the number 9. (A replica of the Model K is on display at the Smithsonian).

Stibitz later went on to create a machine called the Complex Number Calculator.

Although this device was not sophisticated by today's standards, it was an important step along the way.

In 1940, Stibitz performed a spectacular demonstration at a meeting in New Hampshire. Leaving his computer in New York City, he took a teleprinter to the meeting and proceeded to connect it to his computer via telephone. In the first example of remote computing, Stibitz astounded the attendees by allowing them to pose problems which were entered on the teleprinter; within a short time the teleprinter presented the answers generated by the computer.

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1937 AD
Alan Turing invents the Turing Machine

Many of the people who designed the early computers were both geniuses and eccentrics of the first order, and the English mathematician Alan Turing was first among equals.

In 1937, while a graduate student, Turing wrote his ground-breaking paper *"On Computable Numbers with an Application to the Entscheidungsproblem."* One of the premises of Turing's paper was that some classes of mathematical problems do not lend themselves to algorithmic representations and are not amenable to solution by automatic computers.

Alan Turing

Since Turing did not have access to a real computer (not unreasonably as they didn't exist at the time), he invented his own as an abstract "*paper exercise.*" This theoretical model, which became known as a *Turing Machine*, was both simple and elegant, and subsequently inspired many "*thought experiments.*" A few years later Turing was destined to be a key player in the design and creation of COLOSSUS, which was one of the world's earliest working programmable electronic digital computers.

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1938 AD
Claude Shannon's master's Thesis

Around the 1850s, the British mathematician George Boole was busily inventing a new form of mathematics, in which he represented logical expressions in a mathematical form now known as Boolean Algebra.

Unfortunately, with the exception of students of philosophy and symbolic logic, Boolean Algebra was destined to remain largely unknown and unused for the better part of a century. In fact it was not until 1938 that Claude E. Shannon published an article based on his master's thesis at MIT. (Shannon's thesis has since been described as: *"Possibly the most important master's thesis of the twentieth century."*)

In his paper, which was widely circulated, Shannon showed how Boole's concepts of TRUE and FALSE could be used to represent the functions of switches in electronic circuits. It is difficult to convey just how important this concept was; suffice it to say that Shannon had provided electronics engineers with the mathematical tool they needed to design digital electronic circuits, and these techniques remain the cornerstone of digital electronic design to this day.

Apropos of nothing at all, Shannon is also credited with the invention of the rocket-powered Frisbee, and is famous for riding down the corridors at Bell Laboratories on a unicycle while simultaneously juggling four balls.

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1939 AD
John Vincent Atanasoff's Special-Purpose Electronic Digital Computer

It is said that history is written by the victors. (It is also said that those who fail to learn the lessons of history are doomed to repeat them -- this is particularly true in the case of history courses at high school.)

When one is considering events that occurred only a few decades in the past, however, it would not be unreasonable to expect s aid events to be fairly well-documented, thereby allowing one to report: *"This person definitely invented this thing at this time."*

Sad to relate, this is not always the case as we shall see.....

We now turn our attention to an American mathematician and physicist, John Vincent Atanasoff, who has the dubious honor of being known as the man who either *did* or *did not* construct the first truly electronic special-purpose digital computer.

A lecturer at Iowa State College (now Iowa State University), Atanasoff was disgruntled with the cumbersome and time-consuming process of solving complex equations by hand. Working alongside one of his graduate students (the brilliant Clifford Berry), Atanasoff commenced work on an electronic computer in early 1939, and had a prototype machine by the autumn of that year.

In the process of creating the device, Atanasoff and Berry evolved a number of ingenious and unique features. For example, one of the biggest problems for computer designers of the time was to be able to store numbers for use in the machine's calculations. Atanasoff's design utilized capacitors to store electrical charge that could represent numbers in the form of *logic 0s* and *logic 1s*. The capacitors were mounted in rotating bakelite cylinders, which had metal bands on their outer surface. These cylinders, each approximately 12 inches tall and 8 inches in diameter, could store thirty binary numbers, which could be read off the metal bands as the cylinders rotated.

Input data was presented to the machine in the form of punched cards, while intermediate results could be stored on other cards. Once again, Atanasoff's solution to storing intermediate results was quite interesting -- he used sparks to burn small spots onto the cards. The presence or absence of these spots could be automatically determined by the machine later, because the electrical resistance of a carbonized spot varied from that of the blank card.

Some references report that Atanasoff and Berry had a fully working model of their machine by 1942. However, while some observers agreed that the machine was completed and did work, others reported that it was almost completed and would have worked, while still others stated that it was just a collection of parts that never worked. So unless more definitive evidence comes to light, it's a case of: *"You pays your money and you takes your choice."*

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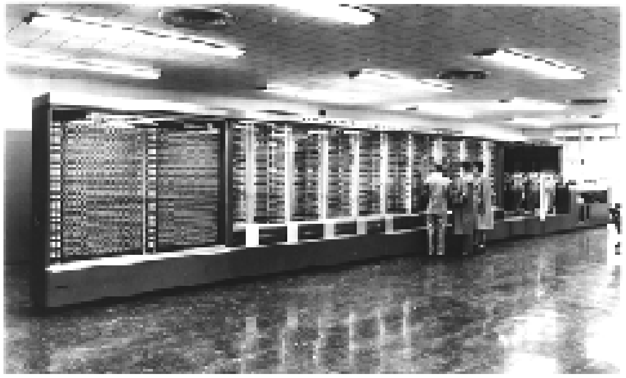
1939 AD to 1944 AD
Howard Aiken's Harvard Mark I (the IBM ASCC)

Many consider that the modern computer era commenced with the first large-scale automatic digital computer, which was developed between 1939 and 1944 (see also Konrad Zuse and his Z3 computer).

This device, the brainchild of a Harvard graduate, Howard H. Aiken, was officially known as the IBM automatic sequence controlled calculator (ASCC), but is more commonly referred to as the Harvard Mark I.

Howard Aiken

The Mark I was constructed out of switches, relays, rotating shafts, and clutches, and was described as sounding like a "roomful of ladies knitting." The machine contained more than 750,000 components, was 50 feet long, 8 feet tall, and weighed approximately 5 tons!



IBM automatic sequence controlled calculator (ASCC) (Courtesy of IBM)

Although the Mark I is considered to be the first digital computer, its architecture was significantly different from modern machines. The device consisted of many calculators which worked on parts of the same problem under the guidance of a single control unit. Instructions were read in on paper tape, data was provided on punched cards, and the device could only perform operations in the sequence in which they were received.

This machine was based on numbers that were 23 digits wide -- it could add or subtract two of these numbers in three-tenths of a second, multiply them in four seconds, and divide them in ten seconds.

Aiken was tremendously enthused by computers, but like so many others he didn't anticipate the dramatic changes that were to come. For example, in 1947 he predicted that only six electronic digital computers would be required to satisfy the computing needs of the entire United States.

Although this may cause a wry chuckle today, it is instructive because it accurately reflects the general perception of computers in that era. In those days computers were typically only considered in the context of scientific calculations and data processing for governments, large industries, research establishments, and educational institutions. It was also widely believed that computers would only ever be programmed and used by experts and intellectual heroes (if only they could see us now). (Don't forget to check out Konrad Zuse and his Z3 computer.)

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1941 AD
Konrad Zuse and his Z1, Z3, and Z4

In the aftermath of World War II, it was discovered that a program controlled calculator called the Z3 had been completed in Germany in 1941, which means that the Z3 pre-dated Howard Aiken's Harvard Mark I.

The Z3's architect was a German engineer called Konrad Zuse, who developed his first machine, the Z1, in his parents' living room in Berlin in 1938. Although based on relays, the Z3 was very sophisticated for its time; for example, it utilized the binary number system and could handle floating-point arithmetic. (Zuse had considered employing vacuum tubes, but he decided to use relays because they were more readily available, and also because he feared that tubes were somewhat unreliable).

In 1943, Zuse started work on a general-purpose relay computer called the Z4. Sadly, the original Z3 was destroyed by bombing in 1944 and therefore didn't survive the war (although a new Z3 was reconstructed in the 1960s). However, the Z4 did survive (in a cave in the Bavarian Alps) and by 1950 it was up and running in a Zurich bank.

It is interesting to note that paper was in short supply in Germany during to the war, so instead of using paper tape or punched cards, Zuse was obliged to punch holes in old movie film to store his programs and data. We may only speculate as to the films Zuse used for his hole-punching activities; for example, were any first-edition Marlene Dietrich classics on the list? (Marlene Dietrich fell out of favor with the Hitler regime when she emigrated to America in the early 1930s, but copies of her films would still have been around during the war.)

Zuse was an amazing man, who, in many respects, was well ahead of his time. For example, in 1958 he proposed a parallel processor called a field computer, years before parallel computing became well understood. He also wrote (but never implemented) Pkankalkül, which is a strong contender as the first high-level programming language.

To fully appreciate Zuse's achievements, it is necessary to understand that his background was in construction engineering. Also, Zuse was completely unaware of any computer-related developments in Germany or in other countries until a very late stage. In 1957, Zuse received the honorary degree of Dr.techn. in Berlin, and he was subsequently showered with many other honors and awards.

NEW! Discover much more about Konrad Zuse in an Extensive Article written by his eldest son, Horst Zuse, featuring many pictures from Horst's private collection that have never been published before!

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Click Here for info about the book!

These notes are abstracted from the book *Bebop BYTES Back (An Unconventional Guide to Computers)*

1943 AD
Alan Turing and COLOSSUS

During World War II, Alan Turing (inventor of the Turing Machine) worked as a cryptographer, decoding codes and ciphers at one of the British government's top-secret establishments located at Bletchley Park.

During this time, Turing was a key player in the breaking of the German's now-famous *ENIGMA Code*. However, in addition to ENIGMA, the Germans had another cipher that was employed for their ultra-top-secret communications.

This cipher, which was vastly more complicated that ENIGMA, was generated by a machine called a *Geheimfernschreiber* (secret telegraph), which the allies referred to as the "*Fish.*"

Alan Turing

In January 1943, along with a number of colleagues, Turing began to construct an electronic machine to decode the Geheimfernschreiber cipher. This machine, which they dubbed COLOSSUS, comprised 1,800 vacuum tubes and was completed and working by December of the same year!

By any standards COLOSSUS was one of the world's *earliest working programmable electronic digital computers*. But it was a special-purpose machine that was really only suited to a narrow range of tasks (for example, it was not capable of performing decimal multiplications). Having said this, although COLOSSUS was built as a special-purpose computer, it did prove flexible enough to be programmed to execute a variety of different routines.

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1943 AD to 1946 AD
The first general-purpose electronic computer

By the mid-1940s, the majority of computers were being built out of vacuum tubes rather than switches and relays. Although vacuum tubes were fragile, expensive, and used a lot of power, they were much faster than relays (and much quieter).

If we ignore Atanasoff's machine and COLOSSUS, then the first true general-purpose electronic computer was the *electronic numerical integrator and computer (ENIAC)*, which was constructed at the University of Pennsylvania between 1943 and 1946.

ENIAC, which was the brainchild of John William Mauchly and J. Presper Eckert Jr., was a monster.

It was 10 feet tall, occupied 1,000 square feet of floor- space, weighed in at approximately 30 tons, and used more than 70,000 resistors, 10,000 capacitors, 6,000 switches, and 18,000 vacuum tubes. The final machine required 150 kilowatts of power, which was enough to light a small town.

One of the greatest problems with computers built from vacuum t ubes was reliability; 90% of ENIAC's down-time was attributed to locating and replacing burnt-out tubes. Records from 1952 show that approximately 19,000 vacuum tubes had to be replaced in that year alone, which averages out to about 50 tubes a day!

During the course of developing ENIAC, Mauchly and Eckert recognized a variety of improvements and new techniques, which they determined to use in any subsequent machines. For example, one of the main problems with ENIAC was that it was hard-wired; that is, it did not have any internal memory as such, but needed to be physically programmed by means of switches and dials.

Around the summer of 1943, Mauchly and Eckert discussed the concept of creating a stored-program computer, in which an internal read-write memory would be used to store both instructions and data. This technique would allow the program to branch to alternate instruction sequences based on the results of previous calculations, as opposed to blindly following a pre-determined sequence of instructions.

Eckert's idea was to use mercury delay lines (which he already knew a great deal about) for the memory. Around the beginning of 1944, Eckert wrote an internal memo on the subject and, in August 1944, Mauchly and Eckert proposed the building of another machine called the electronic discrete variable automatic computer (EDVAC).

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1944 AD to 1952 AD
The First Stored Program Computer -- EDVAC

As was previously discussed, If we ignore both Atanasoff's machine and COLOSSUS, then the first true general- purpose electronic computer was the ENIAC, which was constructed at the University of Pennsylvania between 1943 and 1946. However, ENIAC's underlying architecture was very different to that of modern computers. During the course of designing ENIAC, it's creators, John William Mauchly and J. Presper Eckert Jr., conceived the concept of stored program computing.

This concept was subsequently documented by Johann (John) von Neumann in his paper which is now known as the First Draft.

(The computer structure resulting from the criteria presented in the "*First Draft*" is popularly known as a von Neumann Machine, and virtually all digital computers from that time forward have been based on this architecture.)

In August 1944, Mauchly and Eckert proposed the building of a new machine called the *electronic discrete variable automatic computer (EDVAC)*. Unfortunately, although the conceptual design for EDVAC was completed by 1946, several key members left the project to pursue their own careers, and the machine did not become fully operational until 1952. When it was finally completed, EDVAC contained approximately 4,000 vacuum tubes and 10,000 crystal diodes. A 1956 report shows that EDVAC's average error-free up-time was approximately 8 hours.

In light of its late completion, some would dispute EDVAC's claim-to-fame as the first stored-program computer.

A small experimental machine (which was based on the EDVAC concept) consisting of 32 words of memory and a 5-instruction instruction set was operating at Manchester University, England, by June 1948.

Another machine called the *electronic delay storage automatic calculator (EDSAC)* performed its first calculation at Cambridge University, England, in May 1949.

EDSAC contained 3,000 vacuum tubes and used mercury delay lines for memory. Programs were input using paper tape and output results were passed to a teleprinter. Additionally, EDSAC is credited as using one of the first assemblers called *"Initial Orders,"* which allowed it to be programmed symbolically instead of using machine code.

Last but not least, the first commercially available computer, the *universal automatic computer (UNIVAC I)*, was also based on the EDVAC design. Work started on UNIVAC I in 1948, and the first unit was delivered in 1951, which therefore predates EDVAC's becoming fully operational.

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1971 AD to 1976 AD
The First Microprocessors

With the benefit of hindsight (the one exact science), the advent of the microprocessor appears to have been an obvious development. But this was less than self-evident at the time for a number of reasons, not the least that computers of the day were big, expensive, and a complete pain to use. Although these arguments would appear to support the development of the microprocessor, by some strange quirk of fate they actually managed to work to its disfavor.

Due to the fact that computers were so big and expensive, only large institutions could afford them and they were only used for computationally intensive tasks. Thus, following a somewhat circular argument, popular opinion held that only large institutions needed computers in the first place. Similarly, due to the fact that computers were few and far between, only the chosen few had any access to them, which meant that only a handful of people had the faintest clue as to how they worked.

Coupled with the fact that the early computers were difficult to use in the first place, this engendered the belief that only heroes (and heroines) with size-16 turbo-charged brains had any chance of being capable of using them at all. Last but not least, computers of the day required many thousands of transistors and the thrust was toward yet more powerful computers in terms of raw number-crunching capability, but integrated circuit technology was in its infancy and it wasn't possible to construct even a few thousand transistors on a single integrated circuit until the late 1960s.

The end result was that the (potential) future of the (hypothetical) microprocessor looked somewhat bleak, but fortunately other forces were afoot. Although computers were somewhat scarce in the 1960s, there was a large and growing market for electronic desktop calculators. In 1970, the Japanese calculator company Busicom approached Intel with a request to design a set of twelve integrated circuits for use in a new calculator.

The task was presented to one Marcian "Ted" Hoff, a man who could foresee a somewhat bleak and never-ending role for himself designing sets of special-purpose integrated circuits for one-of-a-kind tasks. However, during his early ruminations on the project, Hoff realized that rather than design the special-purpose devices requested by Busicom, he could create a single integrated circuit with the attributes of a simple-minded, stripped-down, general-purpose computer processor.

The result of Hoff's inspiration was the world's first microprocessor, the 4004, where the '4's were used to indicate that the device had a 4-bit data path. The 4004 was part of a four-chip system which also consisted of a 256-byte ROM, a 32-bit RAM, and a 10-bit shift register. The 4004 itself contained approximately 2,300 transistors and could execute 60,000 operations per second. The advantage (as far as Hoff was concerned) was that by simply changing the external program, the same device could be used for a multitude of future projects.

Knowing how pervasive micro- processors were to become, you might be tempted to imagine that there was a fanfare of trumpets and Hoff was immediately acclaimed to be the master of the known universe, but such was not to be the case.

The 4004 was so radically different from what Busicom had requested that they didn't immediately recognize its implications (much as if they'd ordered a Chevy Cavalier, which had suddenly transmogrified itself into an Aston Martin), so they politely said that they weren't really interested and could they please have the twelve-chip set they'd originally requested (they did eventually agree to use the fruits of Hoff's labors).

In November 1972, Intel introduced the 8008, which was essentially an 8-bit version of the 4004. The 8008 contained approximately 3,300 transistors and was the first microprocessor to be supported by a high-level language compiler called PL/M. The 8008 was followed by the 4040, which extended the 4004's capabilities by adding logical and compare instructions, and by supporting subroutine nesting using a small internal stack.

However, the 4004, 4040, and 8008 were all designed for specific applications, and it was not until April 1974 that Intel presented the first true general-purpose microprocessor, the 8080. This 8-bit device, which contained around 4,500 transistors and could perform 200,000 operations per second, was destined for fame as the central processor of many of the early home computers.

Following the 8080, the microprocessor field exploded with devices such as the 6800 from Motorola in August 1974, the 6502 from MOS Technology in 1975, and the Z80 from Zilog in 1976 (to name but a few).

Unfortunately, documenting all of the different microprocessors would require an entire web site, so we won't even attempt the task here. Instead, we'll create a cunning diversion that will allow us to leap gracefully into the next topic ......

Good grief! Did you see what just flew past your window?

See also The first personal computers (PCs).

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1973 AD to 1981 AD
The First Personal Computers (PCs)

As is true of many facets in computing, the phrase "*Personal Computer*" can be something of a slippery customer. For example, the IBM 610 Auto-Point Computer (1957) was described as being "*IBM's first personal computer*" on the premise that it was intended for use by a single operator, but this machine was not based on the stored program concept and it cost $55,000! Other contenders include MIT's LINC (1963), CTC's Datapoint 2200 (1971), the Kenbak-1 (1971), and the Xerox Alto (1973), but all of these machines were either cripplingly expensive, relatively unusable, or only intended as experimental projects. So, for our purposes here, we will understand "Personal Computer" to refer to an affordable, general-purpose, microprocessor- based computer intended for the consumer market.

Given that the 8008 microprocessor was not introduced until November 1972, the resulting flurry of activity was quite impressive. Only six months later, in May 1973, the first computer based on a microprocessor was designed and built in France. Unfortunately the 8008-based Micral, as this device was known, did not prove tremendously successful in America. However, in June of that year, the term "*microcomputer*" first appeared in print in reference to the Micral.

In the same mid-1973 time-frame, the Scelbi Computer Consulting Company presented the 8008-based Scelbi-8H microcomputer, which was the first microprocessor-based computer kit to hit the market (the Micral wasn't a kit -- it was only available in fully assembled form). The Scelbi-8H was advertised at $565 and came equipped with 1 K-byte of RAM.

In June 1974, Radio Electronics magazine published an article by Jonathan Titus on building a microcomputer called the Mark-8, which, like the Micral and the Scelbi-8H, was based on the 8008 microprocessor. The Mark-8 received a lot of attention from hobbyists, and a number of user groups sprang up around the US to share hints and tips and disseminate information.

Around the same time that Jonathan Titus was penning his article on the Mark-8, a man called Ed Roberts was pondering the future of his failing calculator company known as MITS (which was located next to a laundromat in Albuquerque, New Mexico). Roberts decided to take a gamble with what little funds remained available to him, and he started to design a computer called the Altair 8800 (the name "Altair" originated in one of the early episodes of Star Trek). (The authors don't have the faintest clue why the Altair 8800 wasn't named the Altair 8080, but we would be delighted to learn the answer to this conundrum if anyone out there knows -- feel free to email us at info@maxmon.com.)

Roberts based his Altair 8800 system on the newly-released 8080 microprocessor, and the resulting do-it-yourself kit was advertised in Popular Electronics magazine in January 1975 for the then unheard-of price of $439. In fact, when the first unit shipped in April of that year, the price had fallen to an amazingly low $375. Even though it only contained a miserly 256 bytes of RAM and the only way to program it was by means of a switch panel, the Altair 8800 proved to be a tremendous success. (These kits were supplied with a steel cabinet sufficient to withstand most natural disasters, which is why a remarkable number of them continue to lurk in their owner's garages to this day).

Also in April 1975, Bill Gates and Paul Allen founded Microsoft (which was to achieve a certain notoriety over the coming years), and in July of that year, MITS announced the availability of BASIC 2.0 on the Altair 8800. This BASIC interpreter, which was written by Gates and Allen, was the first reasonably high-level computer language program to be made available on a home computer. MITS sold 2,000 systems that year, which certainly made Ed Roberts a happy camper, while Microsoft had taken its first tentative step on the path toward world domination.

In June 1975, MOS Technology introduced their 6502 microprocessor for only $25 (an Intel 8080 would deplete your bank account by about $150 at that time). A short time later, MOS Technology announced their 6502-based KIM-1 microcomputer, which boasted 2 K-bytes of ROM (for the monitor program), 1 K-byte of RAM, an octal keypad, a flashing LED display, and a cassette recorder for storing programs. This unit, which was only available in fully-assembled form, was initially priced at $245, but this soon fell to an astoundingly $170.

The introduction of new microcomputers proceeded apace. Sometime after the KIM-1 became available, the Sphere Corporation introduced its Sphere 1 kit, which comprised a 6800 microprocessor, 4 K-bytes of RAM, a QWERTY keyboard, and a video interface (but no monitor) for $650.

In March 1976, two guys called Steve Wozniak and Steve Jobs (who had been fired with enthusiasm by the Altair 8800) finished work on a home-grown 6502-based computer which they called the Apple 1 (a few weeks later they formed the Apple Computer Company on April Fools day).

Although it was not tremendously sophisticated, the Apple 1 attracted sufficient interest for them to create the Apple II, which many believe to be the first personal computer that was both affordable and usable. The Apple II, which became available in April 1977 for $1,300, comprised 16 K-bytes of ROM, 4 K-bytes of RAM, a keyboard, and a color display. Apple was one of the great early success stories. In 1977 they had an income of $700,000 (which was quite a lot of money in those days), and just one year later this had soared tenfold to $7 million! (which was a great deal of money in those days).

Also in April 1977, Commodore Business Machines presented their 6502-based Commodore PET, which contained 14 K-bytes of ROM, 4 K-bytes of RAM, a keyboard, a display, and a cassette tape drive for only $600. Similarly, in August of that year, Tandy/Radio Shack announced their Z80-based TRS-80, comprising 4 K-bytes of ROM, 4 K-bytes of RAM, a keyboard, and a cassette tape drive for $600.

One point that may seem strange today is that there were practically no programs available for the early microcomputers (apart from the programs written by the users themselves). In fact it wasn't until late in 1978 that commercial software began to appear. Possibly the most significant tool of that time was the VisiCalc spreadsheet program, which was written for the Apple II by a student at the Harvard Business School and which appeared in 1979.

It is difficult to overstate the impact of this VisiCalc, but it is estimated that over a quarter of the Apple machines sold in 1979 were purchased by businesses solely for the purpose of running this program. In addition to making Apple very happy, the success of VisiCalc spurred the development of other applications such as wordprocessors.

When home computers first began to appear, existing manufacturers of large computers tended to regard them with disdain ("*It's just a fad ..... it will never catch on*"). However, it wasn't too long before the sound of money changing hands began to awaken their interest. In 1981, IBM launched their first PC for $1,365, which, if nothing else, sent a very powerful signal to the world that personal computers were here to stay.

Unfortunately, we've only been able to touch on a few systems here, but hopefully we've managed to illustrate both the public's interest in, and the incredible pace of development of, the personal computer. The advent of the general-purpose microprocessor heralded a new era in computing -- microcomputer systems small enough to fit on a desk could be endowed with more processing power than monsters weighing tens of tons only a decade before.

The effects of these developments are still unfolding, but it is not excessive to say that digital computing and the personal computer have changed the world more significantly than almost any other human invention, and many observers believe that we've only just begun our journey into the unknown!

See also Further Reading.

For your interest ...... In 1975, an IBM mainframe computer that could perform 10,000,000 instructions per second cost around $10,000,000. In 1995 (only twenty years later), a computer video game capable of performing 500,000,000 million instructions per second was available for approximately $500!

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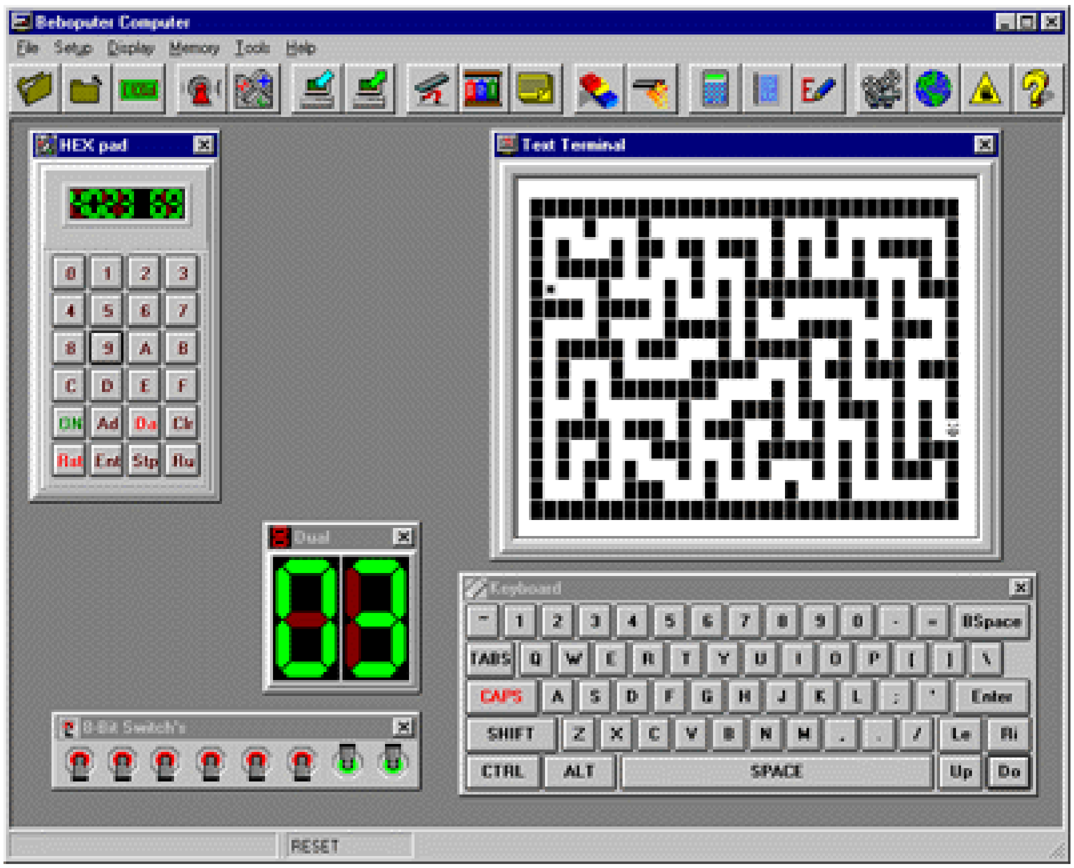
1997 AD
The First Beboputer Virtual Computer

In 1997, [Maxfield & Montrose Interactive Inc.] introduced the *Beboputer*(TM). The *Beboputer* (pronounced *"bee-bop-you-ter"*) is a fully-functional virtual computer which accompanies the book [*Bebop BYTES Back*] (An Unconventional Guide to Computers).

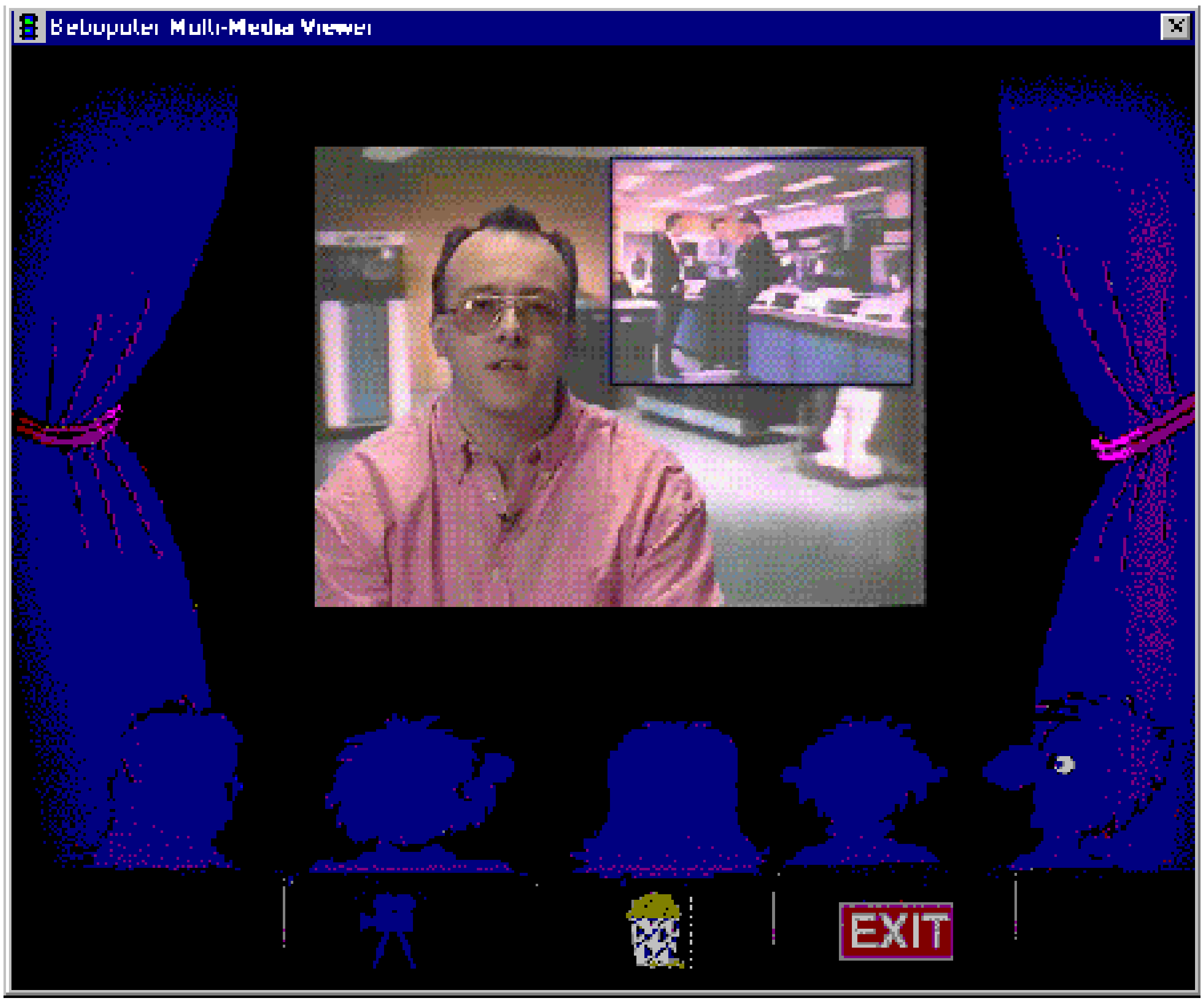


The screenshot above shows the hexadecimal keypad in the upper-left. This device can be used to enter and run programs. Also shown are a set of 8 switches, which are plugged into one of the *Beboputer's* input ports, and a dual 7-segment LED display, which is plugged into one of the *Beboputer's* output ports

Also shown are a typewriter-style keyboard and the Beboputer's virtual computer screen.

In fact the screen shows a maze, and solving this maze is one of the competitions that are posted on a set of special *Beboputer* Web pages (that you access from the *Beboputer*).

In addition to creating your own experiments, the *Beboputer* comes equipped with a series of interactive laboratories. Building on simple concepts, these educational laboratories will guide you through a unique learning experience, providing you with an in-depth understanding of how computers work.



As is illustrated above, each laboratory comes equipped with a multimedia introduction to reinforce your educational experience. In fact, the *Beboputer* comes equipped with more than 200 megabytes of multimedia content, including archive videos of early computers.

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