From Calculators to Computers - A Brief History

by Rex Ungericht

The title of this paper refers to a "brief" history. This document is not intended to be comprehensive; it is simply a recounting of the creation and development of the first computers in the way I wanted to find it when I started reading about the subject.

Most of the images in this paper were pulled from Wikimedia Commons. Every image has a hyperlink back to the source. Much of the information for this paper came from Wikipedia and from History of Computers, although several dozen sources were used in all.

Other than a few observations scattered throughout the text, the information is not original. Only the organization and phrasing is (mostly) my own.

Although I spent many hours researching this paper, I sometimes found conflicting information, and in a couple of instances I found just a single source of information. So although I have striven for accuracy, there may be errors in the text. I appreciate any and all corrections, which can be sent to rex underscore u at hotmail dot com.

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Second draft, September 2013

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Books by Rex Ungericht:

Writing Song Parody Lyrics

The Twelve Parody Carols of Christmas

What Will We Play Next?

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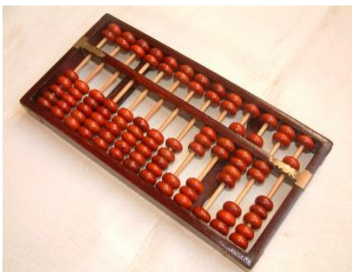
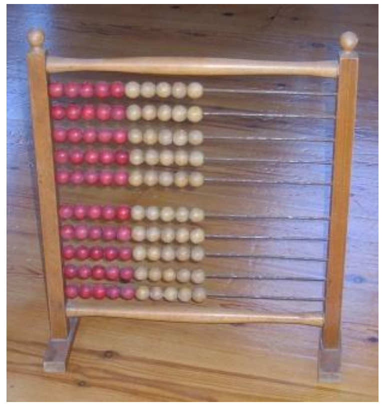
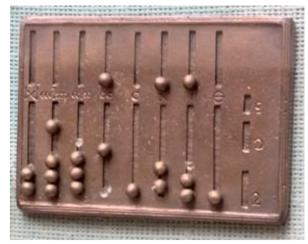
Chapter One: The First Calculator

Ancient humans used sticks, bones, pebbles, and their fingers to help count. But when did someone create an actual device for calculating? This question can have different answers, depending on what you consider to be a "device". Ancient cultures used tally sticks, knots in cords, and counting boards, but the consensus pick for the first calculator is the abacus.

Even though the Greeks didn't invent the abacus, it gets its name from the Greek words for a counting board, abax and abakos.

Many countries created their own versions of the abacus. In 1617, John Napier created a specialized abacus called Napier's bones, to be used to calculate products and quotients of numbers.

In 1946, the U.S. Army newspaper Stars and Stripes sponsored a contest between the Japanese abacus and an electric calculator. The contestants were Kiyoshi Matsuzaki from the Ministry of Postal Administration and a champion operator of the abacus, and Private Thomas Nathan Wood of the 20th Finance Disbursing Section of General MacArthur's headquarters and "the most expert operator of the electric calculator in Japan". After a series of addition, subtraction, multiplication, and division problems, the abacus was declared the winner, 4 to 1.

Since then, other showdowns between the abacus and the calculator have occurred. If you perform a Web search on "abacus vs calculator", you'll find links to several videos showing the capabilities of this ancient tool.

The abacus remains a viable calculating device to this day. In fact, if you want to learn how to use an abacus, you can buy versions that talk and software versions for your computer, tablet, and smartphone. Here are three links. I have not tried any of these apps and do not endorse or guarantee them in any way.

https://play.google.com/store/apps/details?id=maxcom.toolbox.abacus

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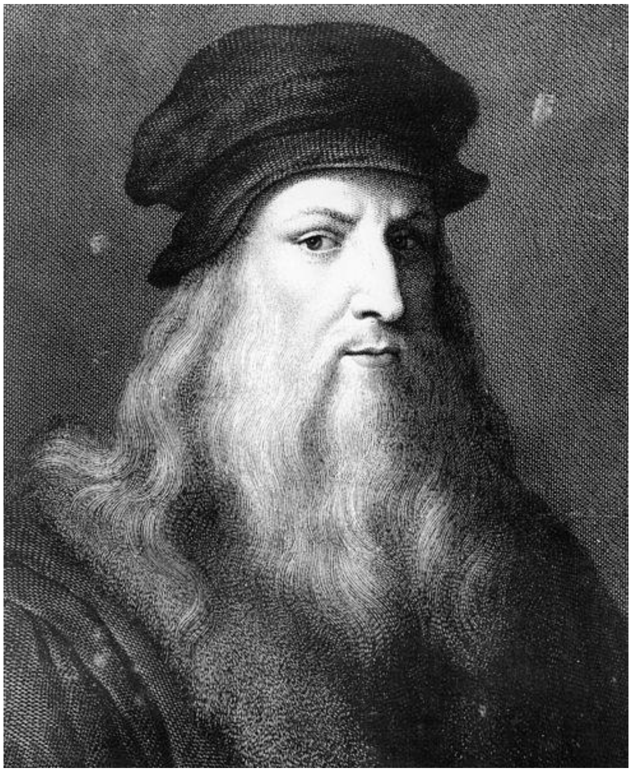
http://hp.vector.co.jp/authors/VA041064/english/index.html

Chapter Two: Leonardo da Vinci and the First Mechanical Calculator - Maybe

In the mid 1400's, the Chinese were putting the last touches on the Forbidden City, and the Incas were building Machu Picchu. Italian architect Leon Battista Alberti invented the anemometer to measure the speed of the wind, and Johannes Gutenberg built the first printing press. The Byzantine Empire was ending, and the Portuguese were sending ships here, there, and everywhere. And on April 15, 1452, in the region of Florence, Italy, Leonardo da Vinci was born - the bastard son of Piero da Vinci and a peasant woman named Catarina (a name fans of Star Trek: Voyager will recognize, although in ST:V it was spelled Katarina).

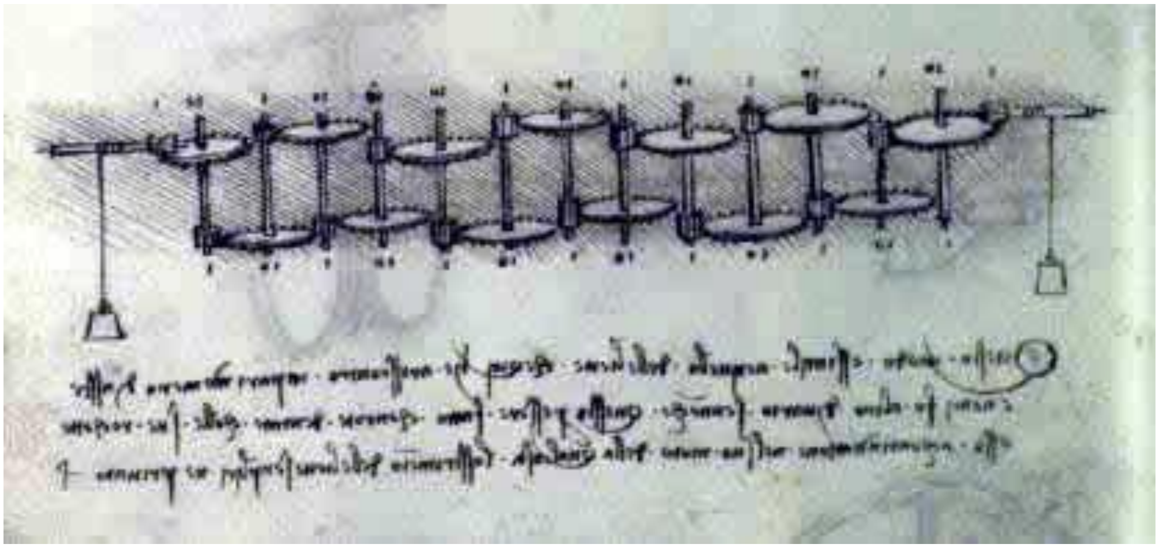


At age 14 Leonardo was apprenticed to the painter Verrocchio, in whose workshop he was likely exposed to drafting, chemistry, metallurgy, plaster casting, leather working, metal working, mechanics, carpentry, drawing, painting, sculpting and modeling. This early exposure to such a variety of skills certainly had some impact on forming Leonardo into the multi-talented creative genius he became. Over the course of his lifetime, Leonardo generated tens of thousands of pages of notes, sketches, and designs.

The painter Francesco Melzi worked for and with Leonardo, and when Leonardo died, Melzi inherited Leonardo's manuscripts. After Melzi's death, the Italian sculptor Pompeo Leoni bought much of Leonardo's work from Melzi's son Orazio. After Leoni's death, the collection was divided and distributed and scattered here and there. One part eventually found its way to the Royal Library in Madrid (later renamed the National Library of Spain).

In the mid to late 1960s (sources say 1964, 1965, and 1967), two of Leonardo's notebooks were rediscovered in the National Library of Spain, having been misplaced for centuries. The notebooks have been dated to 1493.

These notebooks, called the "Codex Madrid", contain drawings of what some think are no more than a gear train, but others think are the mechanism for a mechanical calculator.



In 1968, Leonardo expert Robert Guatelli built a working calculator based on Leonardo's design. The calculator was added to a touring collection of Leonardo's work, and the inscription with it reads in part:

"An early version of today’s complicated calculator, Leonardo’s mechanism maintains a constant ratio of ten to one in each of its 13 digit-registering wheels. For each complete revolution of the first handle, the unit wheel is turned slightly to register a new digit ranging from zero to nine. Consistent with the ten to one ratio, the tenth revolution of the first handle causes the unit wheel to complete its first revolution and register zero, which in turn drives the decimal wheel from zero to one. Each additional wheel marking hundreds, thousands, etc., operates on the same ratio."

However, although Leonardo may (or may not) be the father of the mechanical calculator, there's no evidence that a device based on his drawing was developed until 1968, either by Leonardo himself or others.

Chapter Three: Wilhelm Schickard and the Second Mechanical Calculator - Maybe

Seventy-three years after Leonardo's death, Wilhelm Schickard was born in 1592 in Herrenberg, Germany.

At a young age, Wilhelm received a scholarship to a monastery school. From there, he went on to the University of Tubingen, where he received degrees in theology and oriental languages. In 1613, he became a Lutheran minister, and in 1614 he was appointed deacon.

During his years working in the Lutheran church, Schickard met Johannes Kepler (famous to this day for his laws of planetary motion). Kepler had travelled to Tubingen to defend his mother, who had been accused of practicing witchcraft. Kepler was impressed with Schickard's abilities, and asked Schickard to help calculate tables for the book Kepler was working on.

In 1619 Schickard became a professor of Hebrew at the University of Tubingen. As a professor, his research included many subjects such as mathematics, astronomy, and surveying. He began thinking about how he might use a machine to perform astronomical calculations, and in 1623 he wrote to Kepler, saying:

What you have done by calculation I have just tried to do by way of mechanics. I have conceived a machine consisting of eleven complete and six incomplete sprocket wheels; it calculates instantaneously and automatically from given numbers, as it adds, subtracts, multiplies and divides.

Schickard needed a name for his machine. As you might suspect, there weren't a lot of mechanical devices in the early 1600's, but one device that was fairly common to a religious and educated man was the clock. It's my guess that because he was familiar with clocks as mechanical devices, he called his invention a clock -- a "calculating clock" or Rechenuhr.

However, modern scholars have said that Schickard's design was incomplete, and the single-tooth gear he used would not be workable to more than a few places. So if Schickard did indeed manage to build a working Rechenuhr, it would only have been useful for the simplest of calculations. This is supported by the fact that Dr. von Freytag Loringhoff, professor of mathematics at the University of Tubingen, built a model of Schickard's calculator, and had to modify the design to make it work correctly.

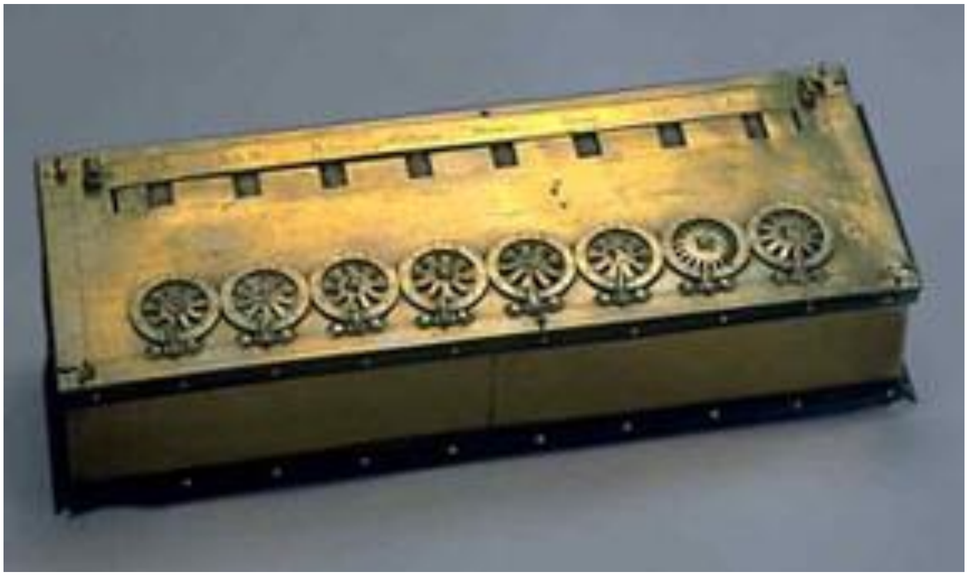
Chapter Four: Blaise Pascal and the Pascaline

Almost 20 years after Schickard wrote to Kepler about his Rechenuhr, Blaise Pascal invented what is generally accepted as the first working mechanical calculator. But before we get to that, let's indulge in a bit of family history.

Sometime in the mid 1500's Martin Pascal was born in Clermont-Ferrand, France, into a family of wealthy merchants. Martin, however, became a bureaucrat, rising through the positions of Receiver General of Taxes at Clermont, Secretary to the Queen, and General of the King's Finances in the Generality of Riom.

In 1588, Martin's son Etienne was born. Etienne was a talented musician and mathematician, and in the early 1600's he went to Paris to study law. He returned to Clermont in 1610 with his law degree. Like his father Martin, he became a tax official. In 1631, five years after the death of his wife Antoinette, he packed up his children and moved to Paris, where he could continue moving up the French hierarchy (becoming Intendant of the Province of Rouen from 1639 - 1648, and receiving the title of Counselor of State in 1645). Etienne also took a great interest in the education of his son Blaise.

Blaise Pascal was a prodigy, especially in the fields of mathematics and science. In 1642, at age 18, in order to help his father with hour after hour of repetitious tax calculations, Blaise invented the Arithmetic Machine (later called Pascal's Calculator and even later the Pascaline).



The Arithmetic Machine could add or subtract two numbers, and by using repeated additions or subtractions it could solve multiplication and division problems.

As you might expect, precision engineering in the 1600's was not anything like we have today. Parts were handmade, and making an Arithmetic Machine was enormously expensive. Only the rich and powerful could afford to have one, and so the Arithmetic Machines that Pascal built in his lifetime (anywhere from 20 to 50, depending on the source) were primarily status symbols instead of a working man's tool.

Chapter Five: Tito Livio Burattini and His Calculating Machine

Sometime around 1650, Blaise Pascal sent a copy of his calculator to Queen Ludwika Maria Gonzaga of Poland. (I don't know if there was a connection between the two, but Pascal was a Frenchman and the Queen was born in Paris.)

Among those at the court in Poland at that time was Tito Livio Burattini. Burattini had been born in 1617 in the northern Italian town of Agordo. In the 1630's he studied at the Universities of Padua and Venice, and then became a travelling scholar, visiting Egypt for a few years and then settling briefly in Germany. In 1642, Burattini was invited by King Wladyslaw IV to serve at the Royal Court in Krakow. Outside of a couple years spent travelling to Italy and Egypt, Burattini spent the remainder of his life in Poland, serving four different Kings as an architect and engineer.

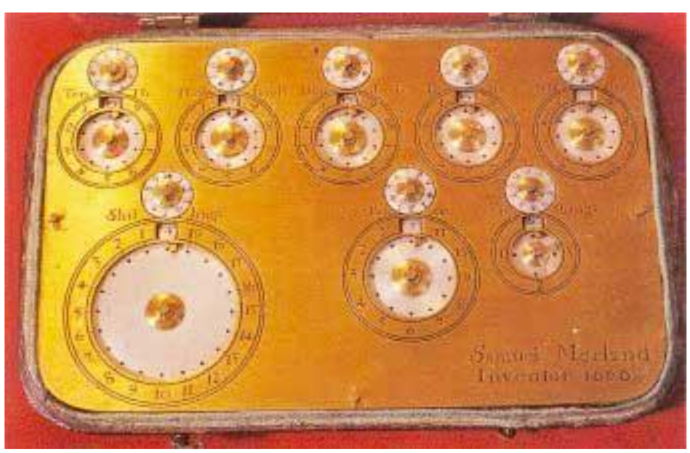
Burattini was at the Polish Court when Pascal's calculator arrived, and he decided to build his own version, called the ciclografo.

Note how thin the device is compared to the Pascaline. Improvements in precision engineering were making it possible to shrink the gears, leading to the creation of Samuel Morland's calculator (next chapter).

Chapter Six: Sir Samuel Morland and the First Pocket Calculator

Samuel Morland was the Buckaroo Banzai of his time -- diplomat, spy, inventor, mathematician, and academic. However, there is no evidence that Morland ever had any adventures in the 8th dimension.

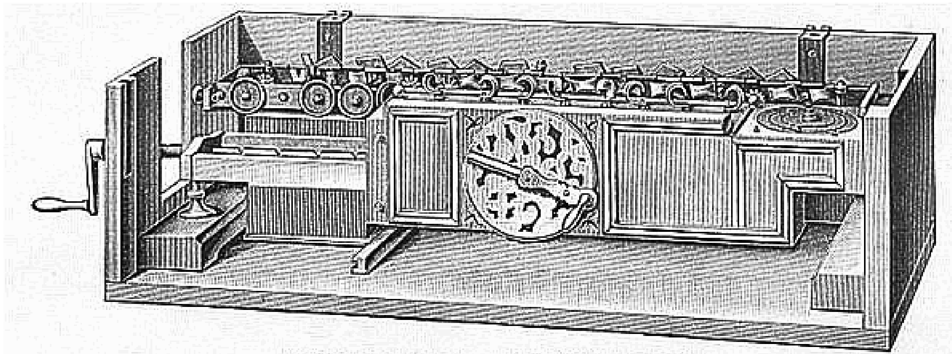
In 1673, in London, Morland published a book titled "The Description and Use of Two Arithmetick Instruments". It is the first of the two that I want to show you, because it is quite possibly the first pocket calculator. Built by clockmaker Humphrey Adamson, it measured 3 x 4 inches and only 8 millimeters thick. It had dials for calculating in decimals and in English currency units. In 1673. Without electronics.



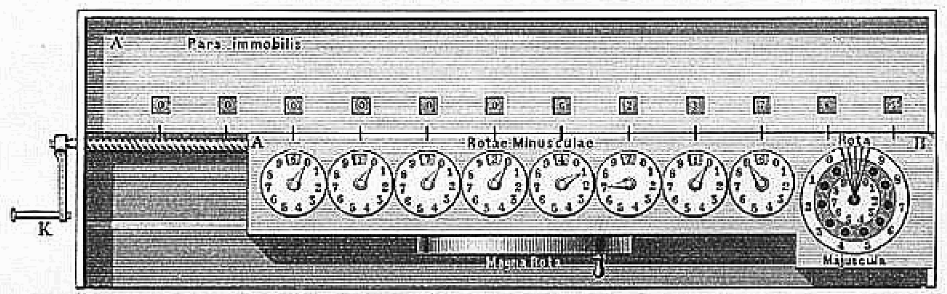
Chapter Seven: Leibniz, His Wheel, and Binary Numbers

In the 1600's Leipzig was an important and prosperous merchant center located between the Parthe, Pleisse and Elster rivers. In 1650 Leipzig became the home of the world's first daily newspaper, the Einkommende Zeitungen. In 1646 Gottfried Wilhelm von Leibniz was born there.

Leibniz was studious and bright, entering university at age 15 and completing both a bachelor's degree and a master's degree in philosophy at age 16, and a bachelor's degree in law at age 18. In 1672, Leibniz went to Paris where he met the Dutch physicist and mathematician Christiaan Huygens. This meeting launched Leibniz on a study of physics and math, including a study of the manuscripts of Blaise Pascal. He started thinking about how to improve the Pascaline, and that led to the invention of the Leibniz Wheel, a cylinder with teeth of incremental lengths which became the basis for a calculating machine of his own design. However, there is no evidence that Leibniz ever made more than two prototypes of his calculator.



2. Rechenmaschine von Leibniz (1673, Hannover).



3. Leibnizsche Rechenmaschine, geometrische Zeichnung.

Among his many interests, Leibniz spent time refining the binary number system, which led him (in 1679) to describe a calculating device that made use of the binary system: "A container shall be provided with holes in such a way that they can be opened and closed. They are to be open at those places that correspond to a 1 and remain closed at those that correspond to a 0. Through the opened gates small cubes or marbles are to fall into tracks, through the others nothing. It [the gate array] is to be shifted from column to column as required." As George Dyson wrote in July 2000, "In the shift registers at the heart of all electronic computers, from mainframes to microprocessors, voltage gradients and pulses of electrons have taken the place of gravity and marbles, but otherwise things are still running exactly as Leibniz envisioned (in Germany) in 1679." So 1679 is the date of the first known concept of a binary computing device. But it would be a long time before such a device was built.

Chapter Eight: Charles Xavier Thomas Makes a Commercial Calculator

During the 1700's, inventors such as Philipp Matthaus Hahn and Charles Stanhope continued the development of calculating machines. But it wasn't until the 1800's that it became possible to create a truly reliable, mass-produced calculator. And the person who did it was Charles Xavier Thomas of Colmar.

In 1785, Charles Xavier Thomas was born in Colmar, the capital of the Alsace wine region in France.

At age 23 or 24, he joined the French army, serving first as Cashier General for supplies in Portugal, then as General Manager of the supply store at army headquarters in Seville, Spain. From that position, he moved on to manage all French army supplies in Spain, and finally he became Inspector of Supply for the entire French army. During this time he realized that a calculating machine would make the job much more efficient.

In 1819, back in civilian life, he co-founded a fire insurance company, but left soon after. Still, he was able to see how the insurance industry could also greatly benefit from a calculating machine. So, in 1820, he invented the Arithmometer, which used a modified and improved version of Leibniz' stepped drum gears.

The initial Arithmometer covered a desk and was so large and heavy it could not be moved by one person. However, Thomas continued to work on the design and was able to reduce the size significantly.

In 1852, he had a reliable model ready for commercialization. And by that time, manufacturing capabilities had reached a point where mass production was possible (relative to the times), and commercial demand for calculating tools was increasing. It was the right product at the right time. And over a span of 90 years, more than 5,000 Arithmometers were produced.

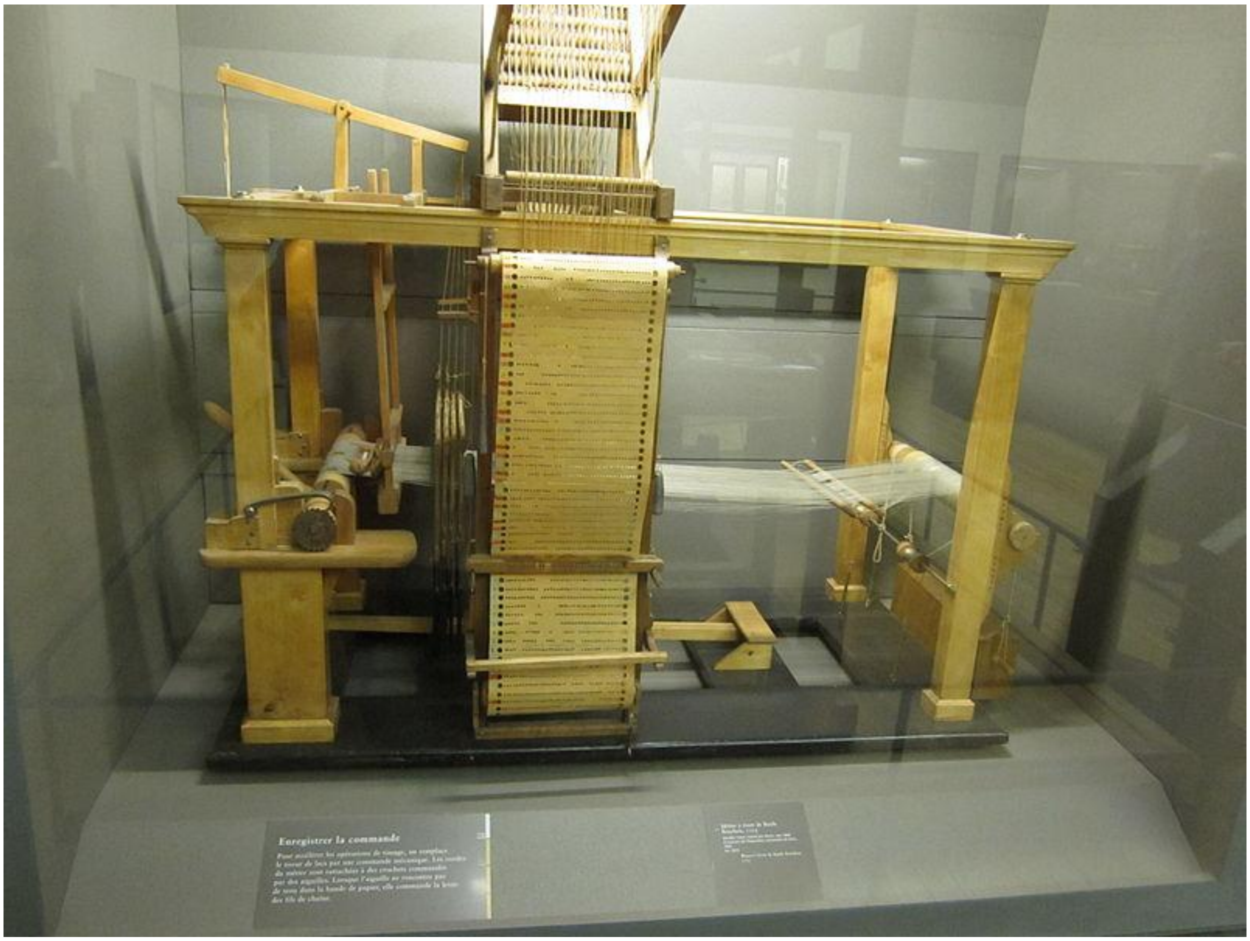
For many years, Thomas was the only commercial manufacturer of calculators, serving as supplier to the entire world. His monopoly ended in 1878 when Arthur Burkhardt founded the calculating machine industry in Germany.

So now let's step back to 1700's and follow the trail of the "super calculators" that eventually led to the creation of computers. As you'll see, while calculators were getting smaller, the predecessors to computers were not.

Chapter Nine: Jean-Baptiste Falcon and Punch Cards

In 1725 Lyon, France, is home to the silk center, where textile workers ply their trade. The looms of the time used cylinders with holes punched in them to control pegs that guided the looms.

To create a cylinder, workers would place a paper template around it that showed where the holes should be punched. Well, a textile worker named Basile Bouchon had an idea -- instead of using the paper templates to punch holes in a cylinder to control the loom, why not just control the loom from the paper template?



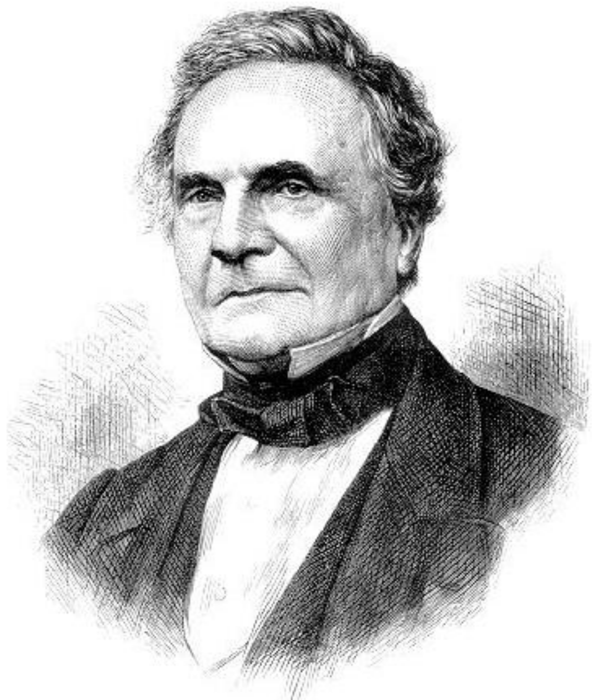
The next year Bouchon's assistant, Jean-Baptiste Falcon, replaced the paper rolls with sturdier cards, and the punch card was born.

(Note: the French inventor and artist Jacques de Vaucanson took Bouchon's and Falcon's ideas and created the first fully automated loom in 1745. Years later, Joseph Marie Jacquard improved on Vaucanson's work and created what is commonly referred to as the "Jacquard Loom", which was first demonstrated in 1801 at the industrial exhibition in Paris.

Jacquard's primary change to the loom was a new type of hook head, which allowed the loom to control enough warp threads to make complex patterns. Jacquard's hook head, along with improvements to the punch card mechanism by Jean Antoine Breton, made the automated loom commercially viable.)

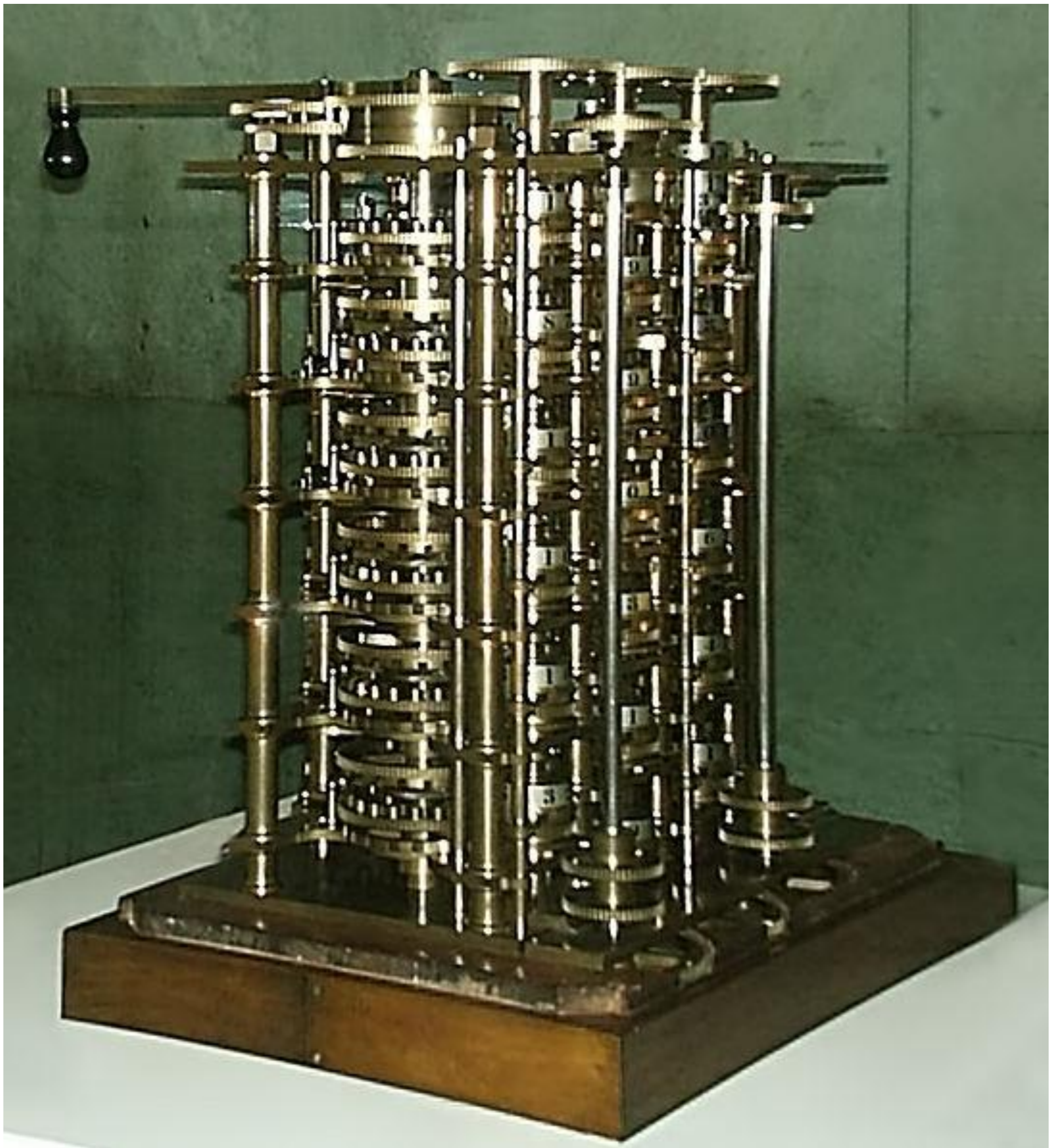
Chapter Ten: Charles Babbage and His "Engines"

In 1811, ten years after the introduction of the Jacquard loom, Charles Babbage entered Trinity College in Cambridge, England.



The son of a wealthy banker, Babbage was well-educated even before reaching college, and indeed, he discovered that he had already advanced beyond the mathematics classes offered at the school. In his studies, he became familiar with the works of Pascal and Leibniz, and decided to create his own mechanical calculator, which he called the "Difference Engine", which gets its name from the method of divided differences, the technique the calculator uses to arrive at results.

The Difference Engine was not a small device. The original plans (Difference Engine Number 1) describe a device eight feet tall with over 25,000 parts and a weight of fifteen tons.



Just one part of the Difference Engine

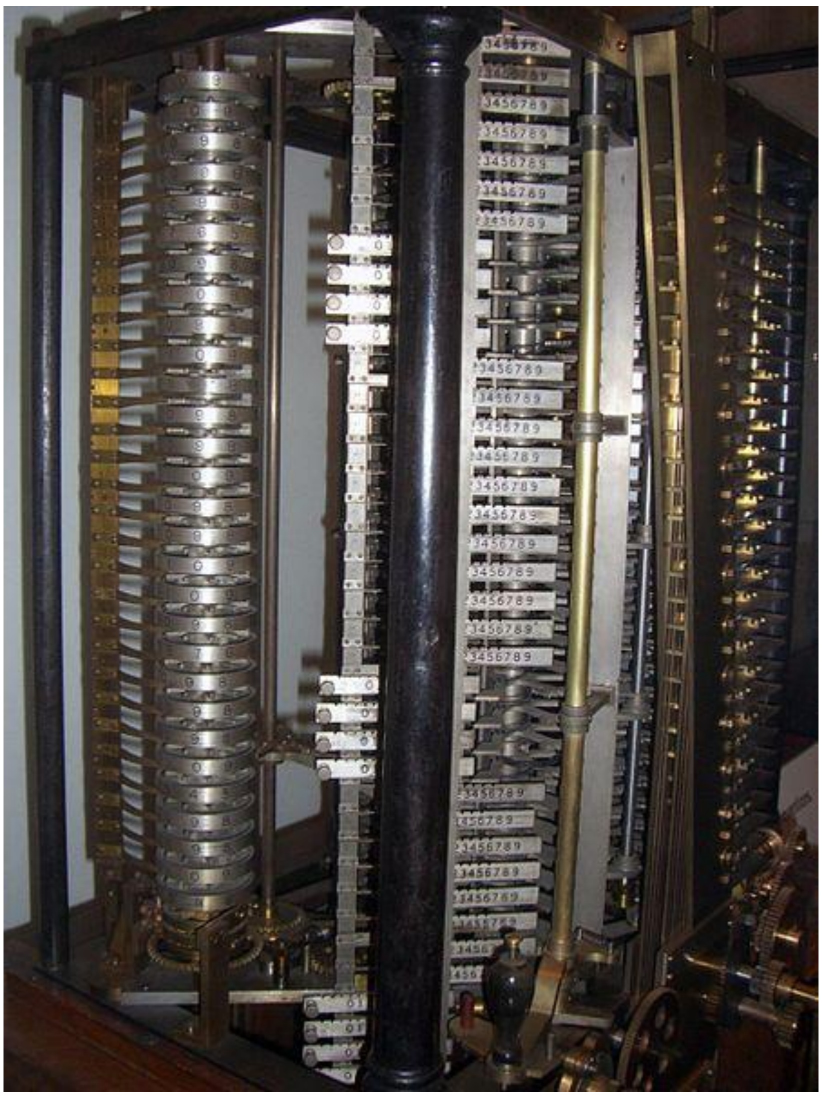
(In 1786, 25 years before Babbage entered college, J.H. Mueller published a description of a difference engine. I haven't found any definitive evidence that Babbage was aware of Mueller's work.)

Babbage received approval from the Royal Society for his design, and that approval (at least in part) helped him obtain government funding in 1823 for construction.

The engineering required to create the Difference Engine proved to be far more difficult than Babbage envisioned. Every part had to be constructed manually using custom tools that Babbage had to design. By 1827 Babbage was on the verge of a breakdown, both from the work on the Difference Engine and from the death of his father, his wife, and his infant son. To recuperate, Babbage embarked on a trip around Europe visiting universities and manufacturing plants. (I wonder if it was on this trip that Babbage came across the Jacquard loom and its punch cards.)

By 1842, time and cost overruns led to the English government abandoning support for the project.

The end of funding for the Difference Engine proved to be an important event in the history of computers. With the Difference Engine behind him, Babbage began work on a base 10 programmable machine that could perform any type of calculation. It is this huge, steam-driven "Analytical Engine" that is considered to be the first design of a general-purpose computer.



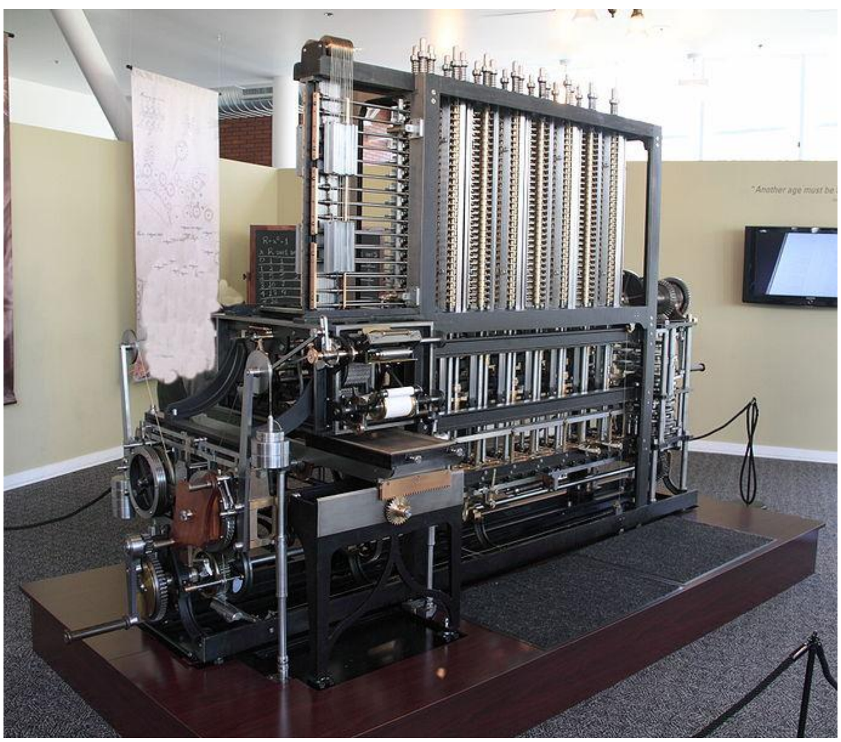
Part of the Analytical Engine

The input was provided via punch cards. The system had memory, an arithmetic unit, and internal procedures. The machine could redirect output to be used as input for further calculation.

However, as with the Difference Engine, construction proved to be too difficult, and Babbage was only able to complete a small part of the Analytical Engine before his death in 1871. However, there is a project underway (at plan28.org) to construct a complete Analytical Engine.

Later in life Babbage redesigned his original Difference Engine as Difference Engine Number 2. Two modified versions of this model were built by Swedish printer Pehr Georg Scheutz in 1853 and 1859. Scheutz' models were smaller and less capable than the full Difference Engine. They were also unreliable. But even so, the same English government that cut off funding for Babbage bought the second of Scheutz' machines. Today, that model is housed at the Science Museum in London.

The Science Museum also finished construction of a complete Difference Engine Number 2 in 1991, using materials and engineering techniques that were available in Babbage's time. It is almost seven feet tall, contains 4000 parts, and weighs over three tons.



Chapter Eleven: Ada Lovelace and the Mental Leap from Calculators to Computers

Augusta Ada King, Countess of Lovelace, was the daughter of the poet Lord Byron.

The month after Ada was born, Byron left the family for good. His wife, Anne Isabella Byron, was bound and determined that her daughter was NOT going to grow up a poet like her father, and so Anne steered Ada's education to mathematics and logic. In 1833, one of her tutors introduced her to Charles Babbage. In 1842, she was commissioned to translate one of Babbage's lectures from French to English -- and in the course of doing so, she added notes which were more voluminous than the lecture. Those notes include two items that are quite relevant in the history of computers:

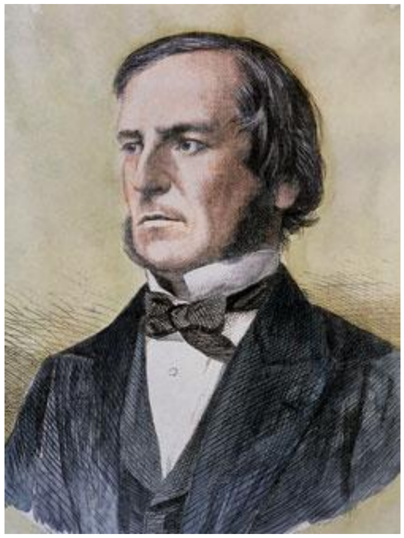
1. She describes an algorithm for using the Analytical Engine to compute Bernoulli numbers. Because of this, Lovelace is often cited as being the first computer programmer.

2. She describes how the Analytical Engine could be used to not only crunch numbers, but also to manipulate anything that could be abstracted to numbers, such as music.

Some researchers claim that Lovelace's notes were not her own and actually originated with Babbage. This is supported from Babbage's own writings, which indicate that he gave Lovelace much of the material for her notes, but that the selection of what to use was "entirely her own". There's no dispute, however, that the notes were published under her name.

Chapter Twelve: George Boole and the Intersection of Math and Logic

George Boole was born the son of a shoemaker and a maid in Lincoln, England in 1815. His father had little more than an elementary school education, and struggled to bring in enough money to support the family. So how in the world did his son George become an educated mathematical genius?



Well, part of it was due to the fact that George's father John, although lacking in formal education, had a great love of science and technology. John spent much of his time with the Lincoln Mechanics' Institution, a social organization that centered around readings, lectures, and discussions of science. In 1834 John was placed in charge of the Institution's library. And it was his father's social network and access to books that allowed George to learn much more than the typical tradesman's son of the time.

And John Boole also motivated George in a second way. You see, John devoted so much attention to his love of science that he neglected his business as a shoemaker. By the time George was 16, John was not earning enough to provide for the family. To bring in money, George had to find employment, and he was able to turn his self-education into a position as a teacher. Then, at age 19, George opened his own school, where he served as headmaster for 15 years.

In 1847 at age 31, while he was still headmaster, he published *The Mathematical Analysis of Logic*. Even though Boole considered the work imperfect, it was impressive enough that it earned him a place on the faculty of Queen's College in Cook, Ireland. And it was there he developed his system of Boolean Logic based on binary processing and the logical operators AND, OR, and NOT.

Then, in 1854, he published his Magnum Opus: "An Investigation of the Laws of Thought, on Which Are Founded the Mathematical Theories of Logic and Probabilities". But it would take the better part of a century before anyone mined the gold in Boole's work.

Chapter Thirteen: Herman Hollerith and the Electric Punch Card Tabulator

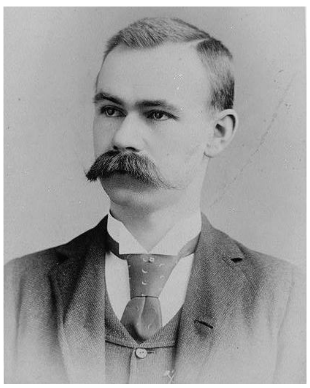
Before we discuss the next step in computing, let's talk about the formation of the United States government, the U.S. Census, and electric power distribution.

When the U.S. Constitution was being drafted, the founding fathers decided that the legislative branch would include a House of Representatives with population-based representation from each state. This meant it was necessary to know each state's population, and so the Constitution requires a census be taken every ten years.

Over the decades, questions were added to the census, so that it became more than a simple headcount; it became a method for the U.S. government to acquire data needed to make decisions for the country. But more and more data meant that the census took longer and longer to tabulate. The census of 1880 wasn't completely hand counted until 1887.

In this same period (1880 - 1887), Thomas Edison founded the Edison Illuminating Company and began building power stations. By 1887, there were 121 Edison power stations in the U.S.

The following year (1888) the Census Bureau sponsored a competition to find a fast and efficient method for tabulating the data collected from almost 63 million (at the time) residents of the United States. There were three entries. Each of the three was used to tabulate a small subset of data from the 1880 census. Last place went to a system that did the job in 144.5 hours. Second place went to a system that did the job in 100.5 hours. And the winning system, submitted by statistician Herman Hollerith, did the job in 5.5 hours.



Hollerith's tabulator **(video link)** used electrically-powered components to read and process punch cards. There are conflicting reports about who came up with the idea of using punch cards, but it was Hollerith who developed the idea into a working system. Using the Hollerith system (which consisted of a Pantograph, or card punch; a card reader; a tabulator; and a sorter) the 1890 census was completely processed in one year, with the population data counted in only six weeks. Hollerith's system showed the world that electricity was the power source of choice for data processing.

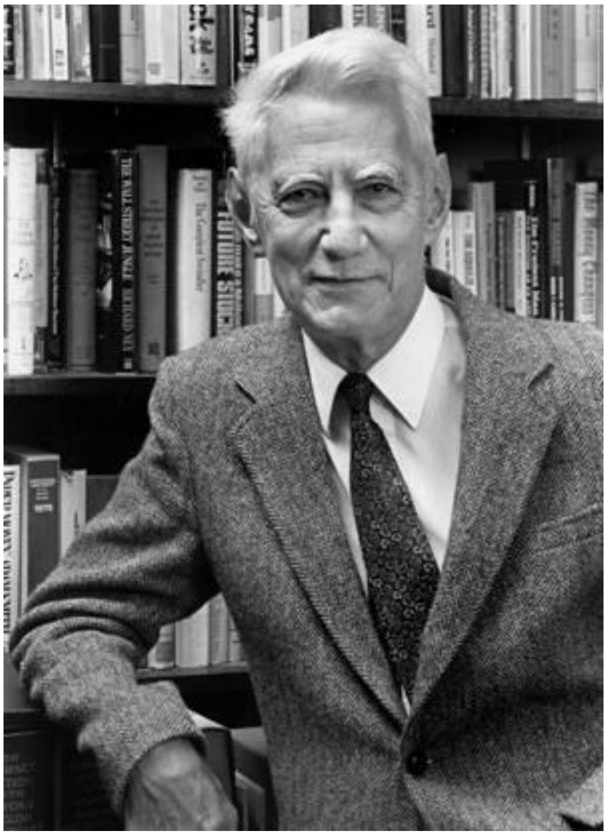
Chapter Fourteen: Claude Shannon and the Theory of Information

In 1930, Vannevar Bush built a differential analyzer at MIT. Unlike previous analog computers, it could be reconfigured to solve other equations and it included electronic valves and relays.

Bush suggested to Claude Shannon **(video link)**, a graduate student and mathematician at MIT, that Shannon have a go at figuring out the underlying principles of the computer. The result (in 1937) is what Howard Gardner called "possibly the most important master's thesis...of the century".

What Shannon realized at this moment in history when electronics were beginning to replace mechanics, was that the on/off states of electronic components meshed perfectly with the binary logic of George Boole, that "on" and "off" could mean "true" and "false" or "1" and "0".

Then, in 1948, Shannon published "A Mathematical Theory of Communication" which cemented the idea that an electronic binary computer wasn't restricted to being just a super calculator; it could be an information processor. This insight has earned Shannon the title of "the father of information theory".



Chapter Fifteen: Konrad Zuse Catches Some Zs

Konrad Zuse was born in 1910 in Berlin-Wilmersdorf, Germany. He majored in civil engineering in college, then went to work at the Henschel Aviation Company. As you might expect, his job required him to perform intensive calculation, and the mechanical calculators available to him were not able to provide the flexibility he needed in his calculations. So he decided to create what he needed. Later in life, Zuse said "You could say that I was too lazy to calculate, and so I invented the computer."

His first attempt -- the Z1 -- was a binary calculator with separate memory storage and program control to perform floating-point arithmetic. It was constructed in his parents' living room using salvaged components. He completed it in 1938.

His second attempt -- the Z2 -- was a revised version of the Z1 that Zuse built after being drafted into the German army. It was completed in 1940.

(Note: Helmut Schreyer, fraternity brother of Konrad Zuse and electronic engineer, had been working with Zuse on the Z computers. When Zuse was drafted, Schreyer started his own project and developed an electronic 10-bit adder that used vacuum tubes for processing and neon lamps for memory.)

When Zuse was discharged from the army, he and Schreyer built the Z3, partly with a grant from the German government. It was completed in 1941, was the size of a large SUV, and was the first program-controlled electromechanical digital computer, incorporating loops but not jumps.

The Z1, Z2, and Z3 were all destroyed during the Allied bombing raids in the latter years of WWII. A reconstructed Z1 is on display at the German Technical Museum in Berlin. A reconstructed Z3 is on display at the Deutsches Museum in Munich.

The Z3

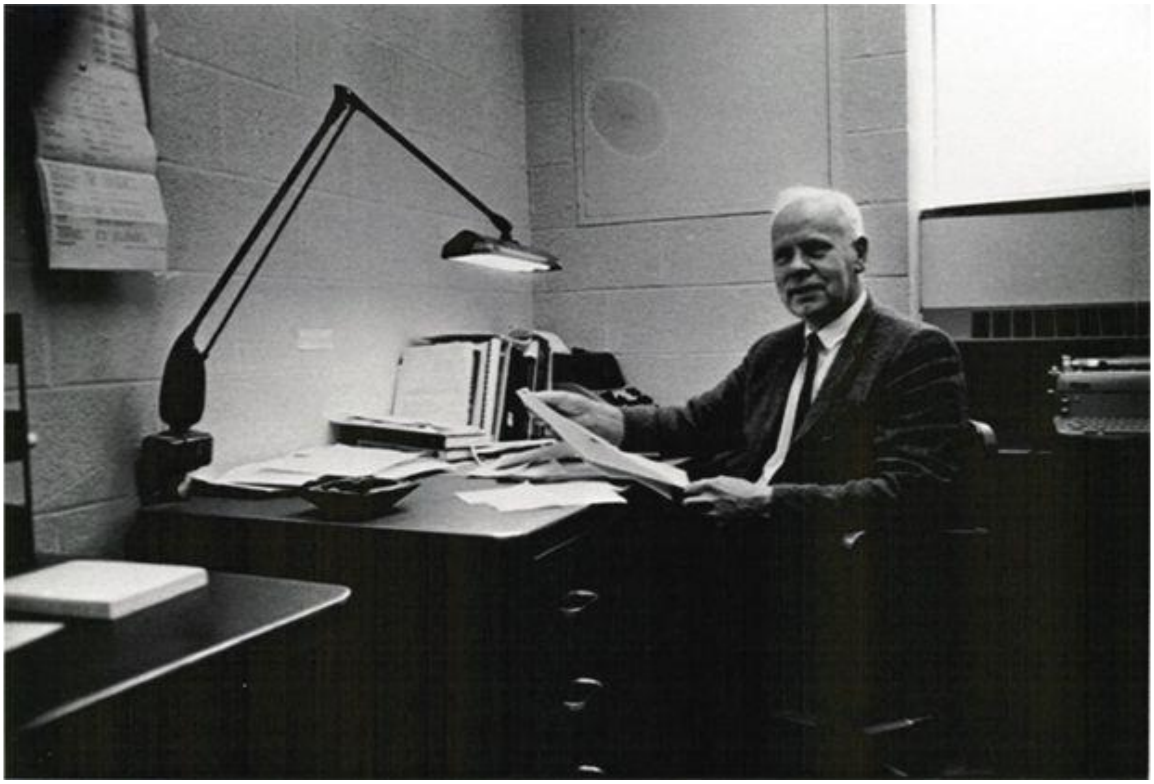
In 1942, with the war still raging, Zuse began work on the Z4. Due to the continued bombing, and particularly the "Berlin Blitz", he had to keep moving the computer from place to place, finally winding up in a Hinterstein, in the southernmost part of Germany close to the border with Austria and up in the Alps. As a result, and probably fortuitously for the allies, he was not able to complete the computer until after the war had effectively been decided in 1945. Along with the hardware, Zuse created the first higher-level programming language: Plankalkuel (plain calculus).

Zuse went on to create many more Z-series computers.

(Note: You can view a history of computers on YouTube that includes several of the people mentioned up to this point: Charles Babbage, Konrad Zuse, and the Computer.)

Chapter Sixteen: George Stibitz and the Complex Number Computer

While Zuse was working on his Z models in Germany, George Stibitz **(video link)** was doing similar work in New York.

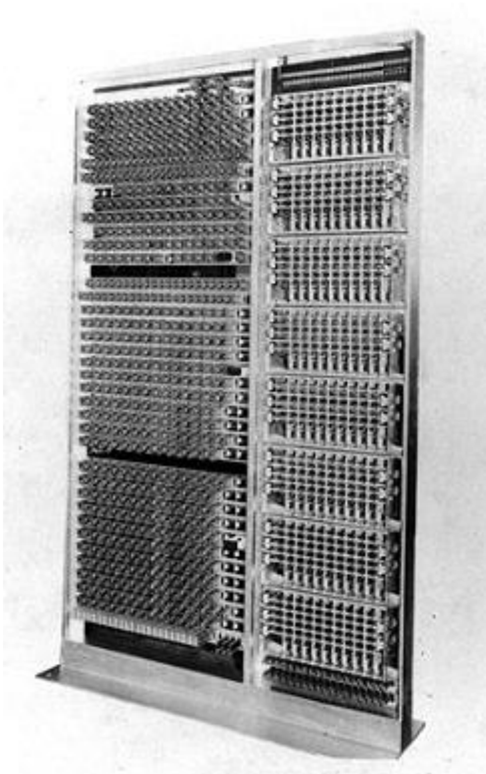


The son of a college professor, Stibitz showed an aptitude for science and engineering at an early age. In 1930, he received a PhD in mathematical physics from Cornell, and then went to work at the Bell Telephone Laboratories. While there, he observed the repetitious manual calculating going on (sound familiar?) and started thinking about methods to automate the process. In November 1937 he grabbed a couple of spare relays (which used an electromagnet to operate a mechanical switch) and a few other parts from the Bell stockroom and went home to tinker. The result was a binary adder with two lights: a lit bulb represented 1 and an unlit bulb represented 0.

Stibitz realized that by using relays, a calculator could perform a sequence of calculations. In addition, relay circuits could manage the order of calculations and store interim results.

Initially, Bell Labs was not willing to finance Stibitz' relay calculator. But over the next year, as the demands of the company required greater and greater ability to perform complex calculations, the company allowed Stibitz to go ahead. Construction of the "Complex Number Calculator" (later called the Bell Labs Model Relay Computer) began in April 1939 and finished in January 1940. The device used over 400 binary relays in addition to ten multiposition relays (used for temporary storage of numbers). It was not programmable, however.

One of the more interesting design choices for the Complex Number Computer was the separation of the computing device from the input/output device. The computer itself was tucked away in a back room somewhere...

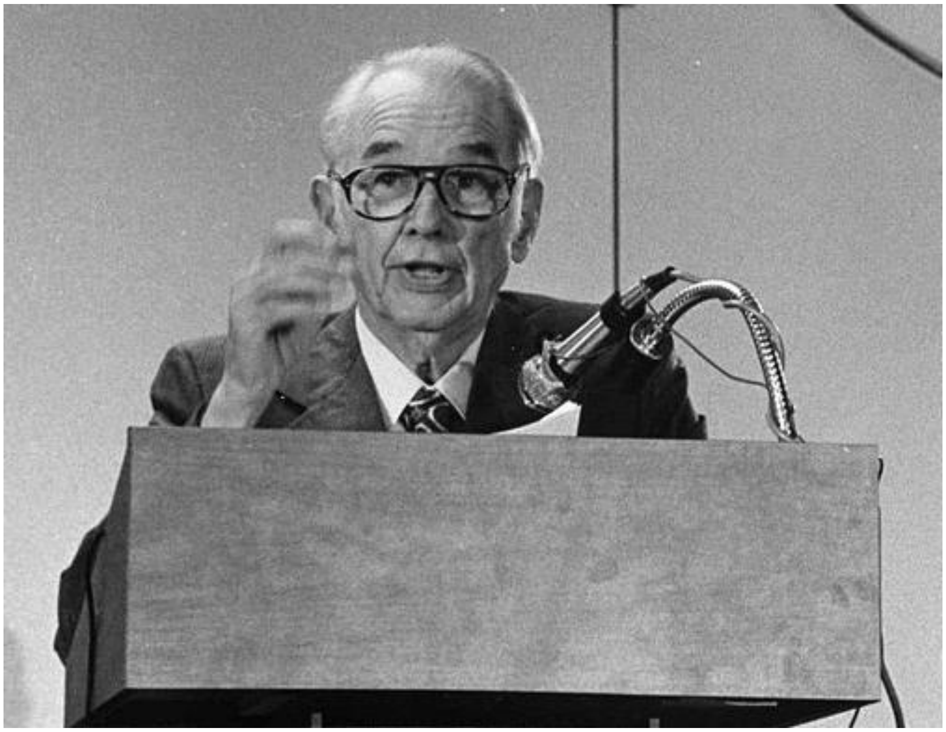


...and an operator accessed it via a modified teletype machine connected to the computer via wires.

This "remote access" was pushed even further when on September 11, 1940, Stibitz operated his computer via phone lines from Dartmouth College in Hanover, New Hampshire -- approximately 250 miles north and east of Bell Labs.

Chapter Seventeen: John Atanasoff knows his ABC

In 1889, a Bulgarian named Ivan Atanasov arrived at Ellis Island in New York. During the immigration process, Ivan Atanasov the Bulgarian became Ivan Atanasoff the American. Ivan was an electrical engineer, and after arriving in America he married a schoolteacher named Iva Purdy. In 1903, Ivan and Iva welcomed John Vincent Atanasoff into the world.



John Atanasoff **(video link)** was a quick learner and a good student, but pretty normal for his age -- until the day his father purchased a Dietzgen slide rule. Young John was fascinated by the device, and wanted to know the concepts behind it. At age nine, with his mother's help, he began diving into advanced mathematics, reading college-level texts. His fascination with mathematics and science never waned, and eventually he wound up at Iowa State, which was famous for its science and engineering program.

He completed a Master's degree in mathematics in 1926, then went to the University of Wisconsin, where he received a PhD in theoretical physics. In 1930 he returned to Iowa State to accept a position as a professor of physics and mathematics.

While at Iowa State, he collaborated with colleague Glen Murphy to create an analog calculator to analyze surface geometry. In doing so, he decided that analog devices were too slow and problematic, with results dependent on all parts of the device working in tandem. This started him thinking about a digital device. And as the story goes, two things then led him to an inspiration: speed and booze.

One winter night in 1937, frustrated with trying to come up with a workable plan for a digital computer, he jumped in his car and started driving (up to 100MPH or more according to some accounts). Two hours later, he found himself in Illinois, where he pulled into a roadhouse and ordered bourbon. And he then began scribbling ideas on cocktail napkins, and those ideas formed the basis of his computer.

After more than a year of planning, Atanasoff received a grant from Iowa State to begin construction. He hired a bright grad student, Clifford Berry, and working from 1939 to 1941 they constructed the Atanasoff-Berry Computer **(video link),** or ABC.

The ABC was a specific-purpose computer, created to resolve differential equations. It could not be programmed, and it did not have a central processing unit. It was, however, the first computer to separate data processing from memory, the first to use vacuum tubes, and the first to use rotating drums containing capacitors holding the electrical charge for memory.

(Note: After constructing his computer, Atanasoff was recruited to work on projects for national defense. When he was finally cleared to return to Iowa State University, he discovered that the staff had disassembled and scrapped the ABC.)

Chapter Eighteen: Howard Aiken and the ~~ASCC~~ Harvard Mark I

The invention of an all-electronic computer did not mean that electromechanical engineering was dead yet. In 1944, Howard Aiken completed the Harvard Mark I.

Howard Aiken was born in 1900 in Hoboken, New Jersey, and for the first twelve years of his life, he lived in a household with an alcoholic father. At age twelve, big and strong for his years, he had had enough. When his father once again began to physically abuse his mother, young Howard grabbed a fireplace poker and chased his father out of the house, never to be seen again.

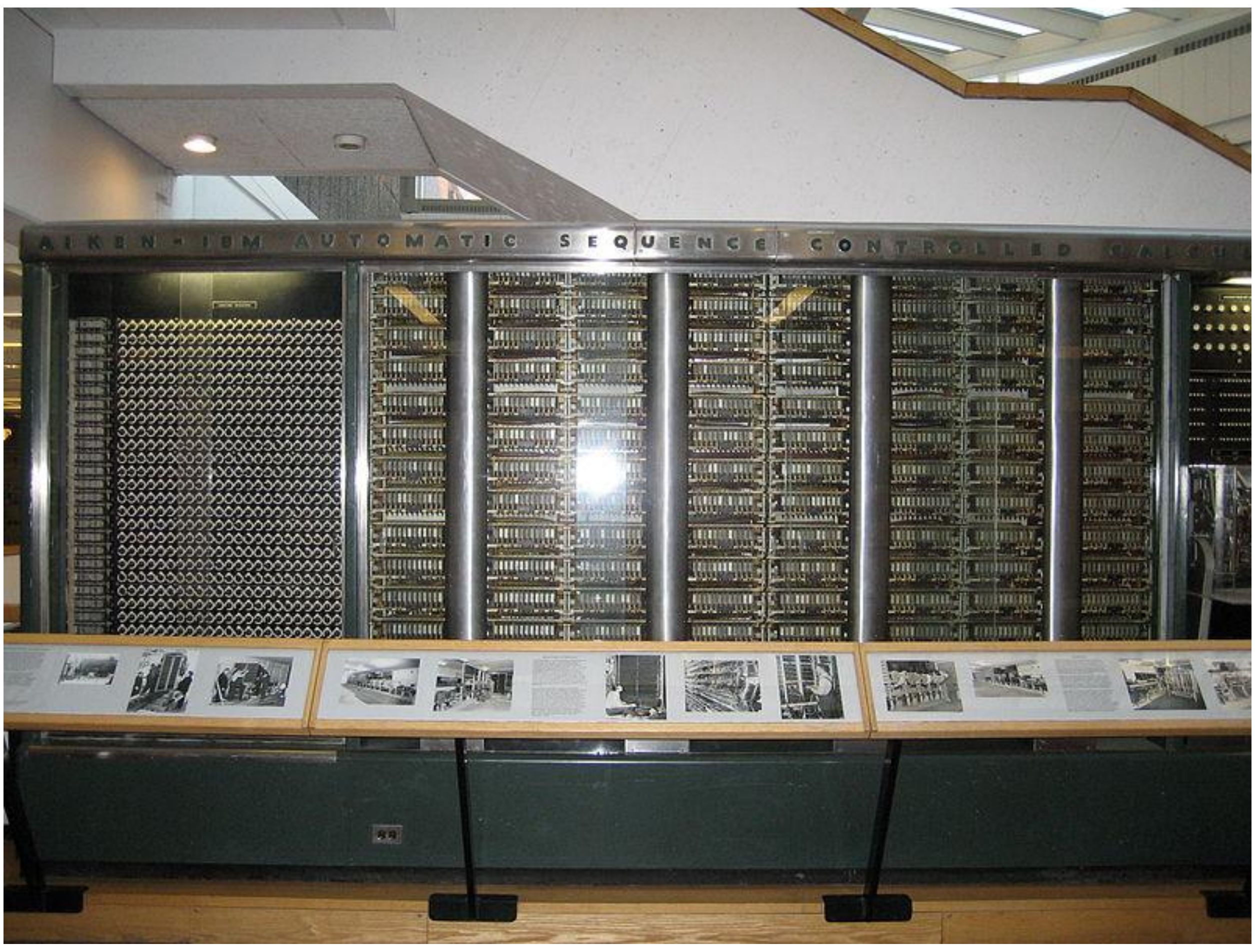
By the time he reached ninth grade, Aiken had to become a breadwinner for the family. He found a job installing telephones and continued his education via correspondence courses. He showed enough brilliance that one of his teachers found Aiken a night job as an electrician's helper, which allowed him to return to classes during the day. In 1919 he graduated high school and decided to continue his education at the University of Wisconsin. Again, he worked during the night (as a switchboard operator for the Madison Gas and Electric Company) and attended classes during the day. After his graduation in 1923 with a B.S. in electrical engineering, the Madison Gas and Electric Company promoted him to chief engineer.

Aiken moved on to positions at the Westinghouse Electrical and Manufacturing Company and the Line Material Company before deciding to return to academia. In 1932 he began graduate studies at the University of Chicago. After two semesters he decided to leave what he later called a "lousy institution" and transfer to Harvard, where he received a Master's degree in physics in 1937 and a PhD in physics in 1939.

Like many of his predecessors in this history, the idea for his computer was a result of having to do hours of manual calculations. In 1936 he discussed his idea for a computer with the physics department at Harvard, but the size and weight requirements made the department heads reluctant to approve giving up so much space in their building. But eventually they said he could have the space -- on the condition that he build the machine first.

So, in 1937, the same year he received his Master's degree, he turned to private industry. He took his idea to the Monroe Calculating Machine Company. They turned him down, but suggested he make his pitch to Thomas Watson, president of IBM. Watson agreed to fund the project. However, to save money, Watson stipulated that the computer be built from the same mechanical parts that IBM used in its accounting machines.

With Aiken leading an IBM construction team at the IBM laboratories in Endicott, NY, the ASCC (Automatic Sequence Controlled Calculator) was completed at the end of 1943. It weighed five tons and contained over 750,000 components, including 530 miles of wire. It ran at the blazing speed of three calculations per second. After completion, it was moved to Harvard where it was renamed the Harvard Mark I.



Two years before the Mark I was finished, the Japanese attacked Pearl Harbor and the U.S. entered World War II. In 1942 Aiken joined the Naval Reserve, attaining the rank of Commander by the time of his discharge in 1946. He remained at Harvard, where he headed a computation project for the Navy's Bureau of Ordinance (performing gunnery and ballistics calculations).

When the Mark I became available in 1943 it was employed for those naval calculations. The Navy sent Lieutenant and PhD in Mathematics Grace Hopper (more on her next chapter) to assist Aiken. When she arrived at the project, Aiken greeted her with "Where the hell have you been? Here, compute the coefficients of the arc tangent series by next Tuesday."

After the Mark I, Aiken went on to produce the Mark II, Mark III, and Mark IV.

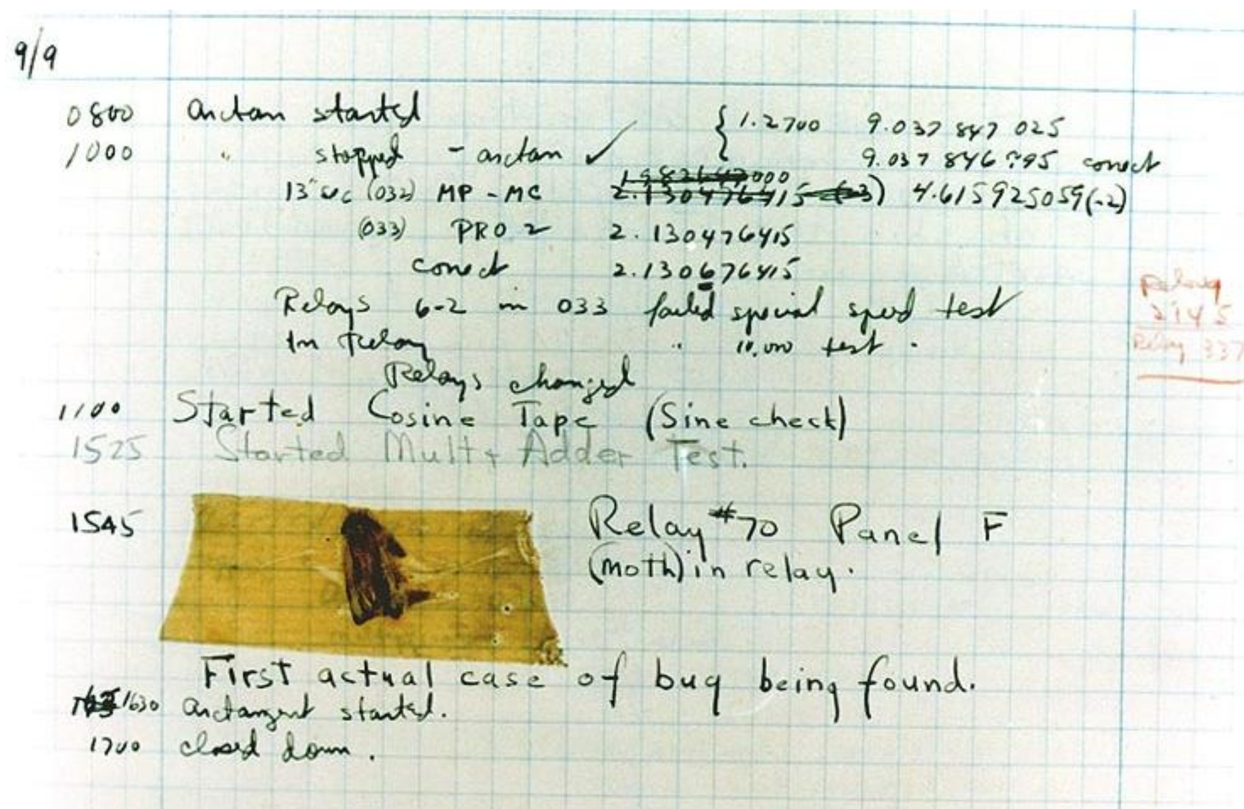
- The Mark II was completed in 1947. It used electromagnetic relays instead of electromechanical ones, and it was the second computer to have floating-point hardware. Like the Mark I, it read instructions from tape. It also had several functions (square root, etc.) built into the hardware.
- The Mark III was completed in 1949. It used magnetic drums and 16-bit words.
- The Mark IV was completed in 1952. It was all electronic.

Chapter Nineteen: Amazing Grace Hopper

In 1928, [Grace Hopper](#) **(video link)** earned her bachelor's degree in mathematics, graduating Phi Beta Kappa from Vassar College. She then moved on to Yale, where she continued her study of mathematics, receiving a Master's degree in 1930 and a Ph.D. in 1934. While she was working on her Ph.D., she was also teaching mathematics at Vassar, and by 1941 she was an associate professor.

She might have remained a teacher for the rest of her life. But on December 7, 1941, the Japanese attacked Pearl Harbor and brought America into World War II. In 1943, Hopper took a leave of absence from Vassar and enlisted in the U.S. Navy Reserve, although she needed an exemption to get in: she weighed 105 pounds, and the Navy minimum weight was 120 pounds.

The Navy took one look at her degrees and, after her basic training, put her in the Bureau of Ships Computation Project at Harvard University, where she worked with Howard Aiken on the Mark I, Mark II, and Mark III. While working on the Mark II she found the first real computer bug -- a moth.



Hopper was also put in charge of writing the operator manuals for the Mark I. Perhaps it was during this task, when she had to document using binary arithmetic to program the computer, that she started thinking about easier ways to program.

In 1946, Hopper went on inactive duty and remained at Harvard as a research fellow until 1949, when she joined the Eckert-Mauchly Computer Corporation as a senior mathematician. J. Presper Eckert and John Mauchly had formed their company after a patent rights dispute with the University of Pennsylvania, where they had built ENIAC (Electronic Numerical Integrator and Computer) between 1943 and 1946. When Hopper joined them, they were working on creating their Universal Automatic Computer, or UNIVAC, for the U.S. Census Bureau.

Grace Hopper and UNIVAC

While working on UNIVAC, Hopper developed the first compiler, called A-O. It could turn symbolic mathematical code into machine binary code. She followed that with B-O, later known as FLOW-MATIC. This compiler "understood" twenty statements in English. From there, she went on to lead the creation of the first English programming language: COBOL, or **Co**mmon **B**usiness-**O**riented **L**anguage. (Although not without resistance: when she initially proposed an English-language compiler, she was told in no uncertain terms that computers didn't understand English.)

Chapter Twenty: To Infinity and Beyond

So we've reached the point where computers are becoming all-electronic, with higher level languages and compilers. It is at this point that I end this history.

There is, of course, much more development -- in both hardware and software -- after UNIVAC. But the foundation of the modern electronic computer was firmly in place by the late 1940's and early 1950's. Computers were beginning to move out of the realm of specialized machines that could only be operated by highly-educated mathematicians and engineers, and were moving toward general-purpose machines for business, and later for individual consumers.

But at the end of the 1940's that future was still hazy. I leave you with a quote from the March 1949 edition of Popular Mechanics Magazine: "Where a calculator like ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1000 vacuum tubes and perhaps weigh only 1½ tons."

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