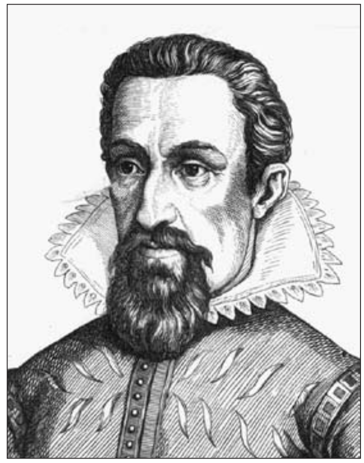
Where Your Computers Really Came From

by Peter Martinson



Johannes Kepler (1571-1630), on the right, and Gottfried Leibniz (1646-1716), were pioneers in the development of calculating machines, which would so lighten the burden of astronomers, in particular.

Kepler and Leibniz: Giving The Astronomer a Hand

It is said that, when Johannes Kepler first saw John Napier's table of logarithms, he wept tears of joy. Kepler spent, literally, years on simple, repetitive calculations, and he even hired a young man for the sole purpose of helping him with calculations. Despite this enormous burden of logistics, Kepler made those crucial breakthroughs upon which all modern science is based. Those are the discoveries of, first, Universal Gravitation, and second, the harmonic ordering of Universal Gravitation throughout the Solar System. Among his unpublished works, two letters were found, that had been exchanged between Kepler and a man named Wilhelm Schickard. Schickard was a close friend of Kepler's at Tübingin University, and both were students of Michael Maestlin. The letters represent a discussion the two had on the construction of a machine that could perform the four routine operations of arithmetic, even with very large numbers. It used a series of sliding windows, buttons, and geared vertical cylinders. It can be surmised that, given Kepler's very clear insight into the importance of scientific discovery, and the enormous impediment created by long series of routine calculations, he must have been very interested in constructing such a machine. A working version was never located.

Blaise Pascal made a calculating machine some time later. Pascal's Pascaline was built on similar principles to Kepler's, but was not as advanced, as it was only designed to add and subtract, and could multiply with repeated additions. He built the machine when he was 18, with the immediate intent of aiding his father in financial arithmetic. It apparently cost more effort to construct than the labor savings involved in its use, but all future calculating machines used its core principles.

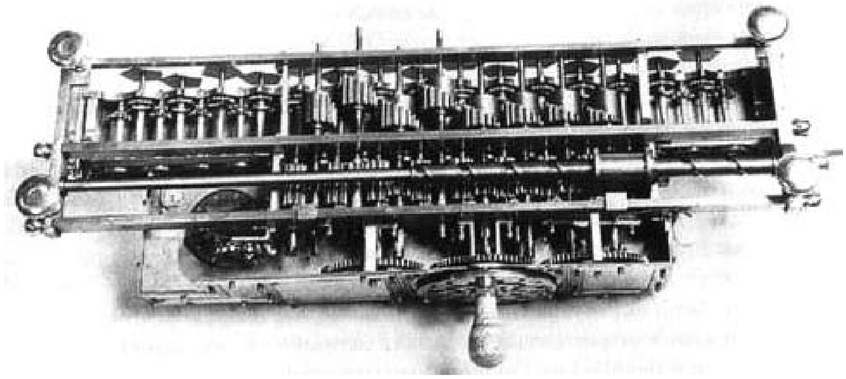
Gottfried Leibniz, the man who discovered the Calculus and launched the science of physical economy, designed his own calculating device, which incorporated Pascal's addition wheels, but added a crucial third row in order to perform multiplication and division. In Leibniz's machine, two sets of wheels performed the additions and multiplications, and they were set at right angles to the set of wheels that displayed the numbers.

In his description of this procedure, Leibniz points out that, by using his machine, scientists will never incur an error in calculation, and huge numbers are just as easy to use as small numbers. What are the uses of this machine? Leibniz says, in conclusion:

"[T]he astronomers surely will not have to continue to exercise the patience which is required for computation. It is this that deters them from computing or correcting tables, from the construction of Ephemerides, from working on hypotheses, and from discussions of observations with each other. For 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 the machine were used."[1]

1. From Leibniz's 1685 description of his machine, as quoted in David Eugene Smith, ed., *A Sourcebook in Mathematics* (New York: Dover Publications, Inc., 1984).

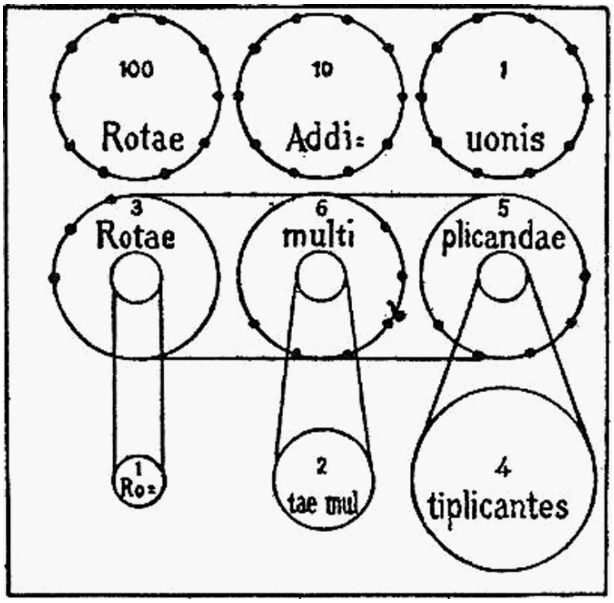
Leibniz's Calculating Machine



Leibniz's general-purpose scientific calculator, and diagram (below).

Gottfried Leibniz, the man who discovered the Calculus, and launched the science of physical economy, designed a device for performing the four basic arithmetic operations, even with huge numbers, and incurring no errors. Here is how Leibniz's calculating machine works:

The first row of wheels displays the digits of the resulting product—the ones, the tens, the hundreds, etc.—and each wheel has ten gear-pins. The second row is organized like the first, but the wheels only have as many pins as that wheel represents. For example, if this number is 365, then the first wheel has five pins, the second has six pins, and the third has three pins. These wheels also have a smaller wheel superimposed upon them, for the multiplication. The third row represents the number being multiplied by the second row, but the wheels are of various sizes, with diameters making a proportion with the smaller wheels of the second row, which is equal to the multiplication factor. For example, if we are multiplying 124 by 365, the second row is organized as stated above, but the smaller wheels are connected by either belts or chains to the wheels in the third row. The wheel representing the number 4 is four times the diameter of the small circle on the 5 wheel; that of the 2 wheel is twice the diameter of the small circle on the 6 wheel; and the 1 wheel is the same diameter of the small circle on the 3 wheel. All the wheels of the second row are connected, so they rotate at the same speed together. Finally, the wheels in the first row are set at right angles to the wheels in the second row, so that the pins catch on each other, like gears.

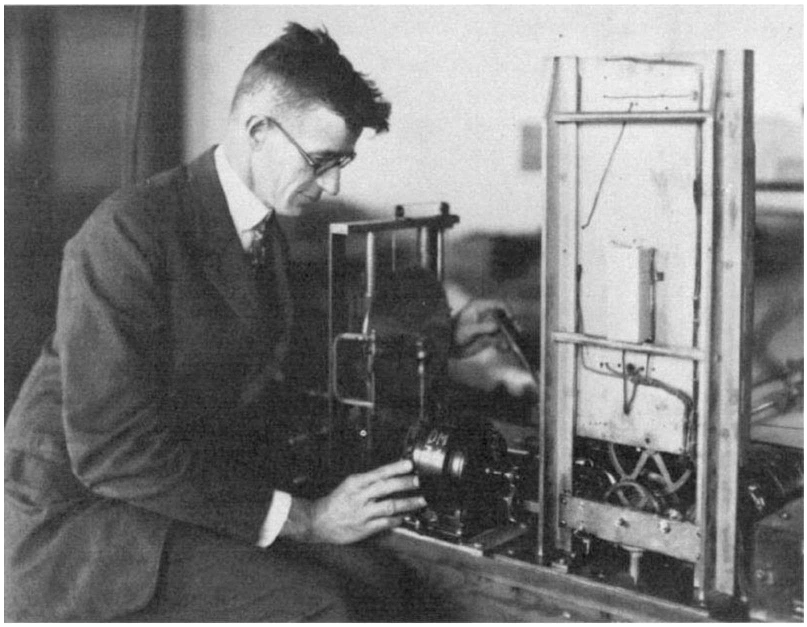


To perform the multiplication, first rotate the 4 wheel once, which rotates all the wheels of 365 four times. This rotation advances the first row to represent 365 times 4, or 1,460. Now, the first row is slid to the right, so that the 5 in the second row is above the tens digit in the first row. Now, the 2 wheel is rotated, rotating the 365 wheels twice, which rotate the first set of wheels (not including the ones digit wheel), effectively adding 7,300 to 1,460, and the first row then displays 8,760. Last, the two rows are slid over again, and the 1 wheel is rotated. This adds 36,500 to 8,760, resulting in 45,260. All of the motions, after the initial set up, can then be automated by a simple hand crank, or a steam powered engine. —*Peter Martinson*

Leibniz clearly wanted everybody to know how his machine worked, so that knowledge could be spread as far as possible. He even tried to convince the Russian Czar, Peter the Great, to give one of his calculators to the Emperor of China. He did not want the mechanical calculating machine to be a hidden black box that kept the knowledge of the operations from the operator, as Paolo Sarpi and Bill Gates have done. He wanted science to be open to everybody. This ideal of Leibniz made him hated by the agents of the new Venetian Party seated in London, who deployed the hoax of the "Wicked Witch of the West," Isaac Newton, against the great German scientist.

Charles Babbage: Saving English Science From the British Empire

There was virtually no advance in mechanical computing technology between the death of Leibniz in 1716, and the work of Charles Babbage (1791-1871), in the early 19th Century. Babbage, working at Cambridge, recognized, along with his collaborator, England's leading astronomer John Herschel, that their country had become the intellectual backwater of Europe, and was lagging disastrously behind the growing economic and industrial power of the new U.S.A. In 1812, they attacked this problem, by adopting Leibniz as their champion, and they published an attack, titled *The Principles of Pure Deism in Opposition to the Dotage of the University*, referring to the political decision of the Royal Society to push Newton's not-Calculus over Leibniz's Calculus. This attack prompted the creation of the Cambridge Analytical Society.[2]



Vannevar Bush, correcting calculations on his Product Integraph, 1927.

In the aftermath of Carl F. Gauss's discovery of the orbit of Ceres, Babbage saw the immediate need to improve the accuracy and error reduction in astronomical observational data, which had become a limiting factor in further breakthroughs. In 1823, he convinced the British government to grant him the money to build a machine capable of improving the astronomical tables used by maritime navigators for determining longitude. His *Difference Engine* was able to take a small number of manually performed calculations, and then mechanically generate a fully completed nautical almanac, all based on the initial principles of Leibniz's original calculating engine. The construction of the machine was slow, and ran into many problems, which Babbage blamed on the lack of precision in machine-tool design in England.

Before completing his Difference Engine, Babbage moved on to his more advanced *Analytical Engine*, which would be able to solve virtually any set of algebraic relationships. He was inspired by the use of punch-card programming of mechanical looms in France, designed by Joseph Marie Jacquard, and decided to also use punch cards for his engine. He used two sets of cards:

"[T]he first to direct the nature of the operations to be performed—these are called operation cards; the other to direct the particular variables on which those cards are required to operate—these latter are called variable cards.

"Every set of cards made for any formula will at any future time, recalculate that formula with whatever constants may be required.

"Thus the *Analytical Engine* will possess a library of its own. Every set of cards once made will at any future time reproduce the calculations for which it was first arranged."[3]

This machine was also never completed. Babbage had designed a yet more efficient machine, for which he believed "... it will take less time to construct it altogether than it would have taken to complete the Analytical Machine from the stage in which I left it."[4] Lyndon LaRouche has noted that the principles established by Leibniz, then by Babbage, are the core of all modern digital computers.[5] The only advances made in this domain were in the types of materials and the technology used in manufacturing. Besides that, no principled advance has been made in digital computing. Of course, that does not include the development of *Analog Computers*, which are more analogous to the designs of machine tools, than digital systems.

The Typical American Scientist: Vannevar Bush

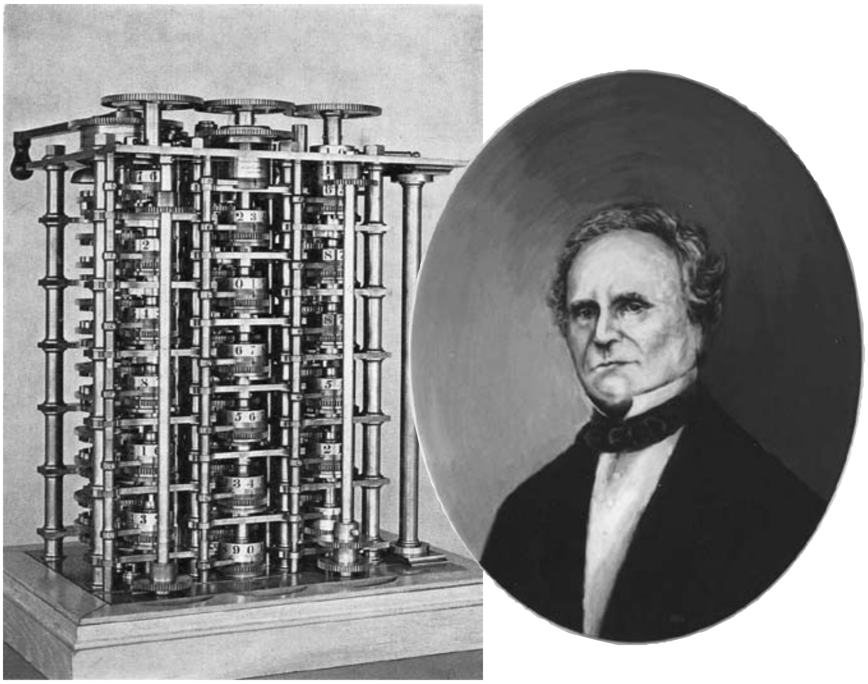
"Two centuries ago," wrote Vannevar Bush, "Leibniz invented a calculating machine which embodied most of the essential features of recent keyboard devices, but it could not then come into use. The economics of the situation were

2. Lyndon H. LaRouche, Jr., "I Don't Believe in Signs," *EIR*, July 21, 2006.

3. Charles Babbage, *Passages from the Life of a Philosopher*; cited in Herman A. Goldstine, "A Brief History of the Computer," *Proceedings of the American Philosophical Society,* Vol. 121, No. 5, October 1977.

4. Lord Moulton, "The Invention of Logarithms, Its Genesis and Growth," Napier Tercentenary Memorial Volume, ed. C.G. Knott (London: 1915); Goldstine, *ibid*.

5. LaRouche, *op cit*.



Charles Babbage and his Difference Engine. Lyndon LaRouche has noted that the principles established by Leibniz, then by Babbage, are the core of all modern digital computers.

against it: the labor involved in constructing it, before the days of mass production, exceeded the labor to be saved by its use, since all it could accomplish could be duplicated by sufficient use of pencil and paper. Moreover, it would have been subject to frequent breakdown, so that it could not have been depended upon; for at that time and long after, complexity and unreliability were synonymous.

"Babbage, even with remarkably generous support for his time, could not produce his great arithmetical machine. His idea was sound enough, but construction and maintenance costs were then too heavy. Had a Pharaoh been given detailed and explicit designs of an automobile, and had he understood them completely, it would have taxed the resources of his kingdom to have fashioned the thousands of parts for a single car, and that car would have broken down on the first trip to Giza.

"Machines with interchangeable parts can now be constructed with great economy of effort. In spite of much complexity, they perform reliably. Witness the humble typewriter, or the movie camera, or the automobile. Electrical contacts have ceased to stick when thoroughly understood. Note the automatic telephone exchange, which has hundreds of thousands of such contacts, and yet is reliable. A spider web of metal, sealed in a thin glass container, a wire heated to brilliant glow, in short, the thermionic tube of radio sets, is made by the hundred million, tossed about in packages, plugged into sockets—and it works! Its gossamer parts, the precise location and alignment involved in its construction, would have occupied a master craftsman of the guild for months; now it is built for thirty cents. The world has arrived at an age of cheap complex devices of great reliability; and something is bound to come of it."[6]

Franklin Delano Roosevelt understood the necessity of scientific advancement for national security. During World War II, the involvement of science in the war effort was not only required in the development of new, more powerful, and longer range weaponry, but also in aiming the new ordnance. Accurate trajectory charts for the various ballistic weapons, including underwater weaponry, were in high demand, but they required astronomical scales of calculation to produce.

Vannevar (sounds like "achiever") Bush (1890-1974) had already been concerned about producing number crunchers, in the tradition of Leibniz and Babbage. Just before the war broke out, the Army Ordnance Department had commissioned Bush to apply his machine shop at MIT (Massachusetts Institute of Technology) to the calculations of ballistics trajectories. He had been working on improving his *Differential Analyzer* since 1931, and was assembling a new, more powerful version. This machine was an advance over both Leibniz's and Babbage's, in that, instead of calculating using only discrete steps of integers, it could perform continuous calculations. This analog computer, which performed calculations by physically *acting out* the principles, opened up the prospect of applying mechanical calculation to problems involving the integral calculus.

The Differential Analyzer used principles similar to Leibniz's engine, but, instead of displaying a set of digits representing the solution to the problem, it could be set up to draw a smooth curve on a drawing board, and it could even take as input a curve traced on a piece of paper by a person. To accomplish this, he replaced Leibniz's orthogonal gears with smooth disks, one rotating to turn the other. The greatest source of error, initially, was transmitting the small, precise rotations through yards of machinery to the output table.[7] This technical problem was solved by the machine-tool designers at Baltimore's Bethlehem Steel, who designed the *Torque Amplifier*, which amplified the smallest, weakest ro-

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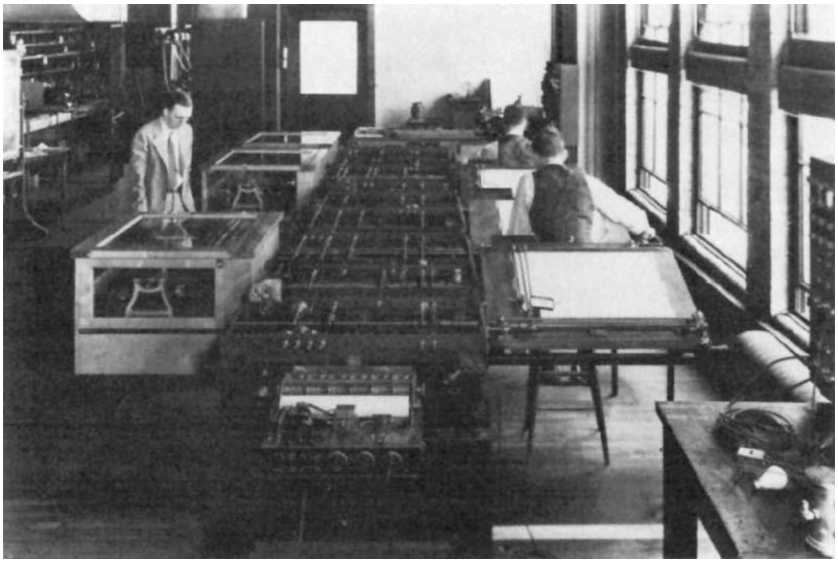
6. Vannevar Bush, "As We May Think," *Atlantic Monthly*, July 1945.

7. For a pedagogical example of this, see Sky Shields's construction of the catenary curve, in the December issue of *Dynamis*, http://wlym.com/~seattle/dynamis.



Vannevar Bush's Differential Analyzer, 1931.

tations into powerful cranks.

Bush built his first machine, called the *Profile Tracer*, to obtain his doctorate in engineering. This machine was slung between two bicycle tires and pushed like a lawnmower. As it moved, a pen inside would continuously draw the changing elevation of the land onto a rotating drum of paper, producing a virtual photograph of the cross section of the land traversed. The mechanism inside the Profile Tracer formed the basis for his next machine, made purely for calculation—the *Product Integraph*. This device, built with his student Herbert Stewart, was the key to performing integral calculus using an array of rotating wheels. Stewart's plan had been to observe the output at specific time intervals, but Bush recommended attaching a pen to it, to draw a smooth curve that represented the integral itself. The Differential Analyzer used more than a dozen of these Product Integraphs, in a structure half the size of Bush's laboratory. By the end of the war, it was the most important calculating machine in the United States, as it was the fastest and most accurate producer of trajectory tables.

The development of the principles governing the functioning of analog computers lost all funding after the death of Roosevelt. At that point, the new program of Cybernetics, driven by London through Columbia University, had virtually taken over. Norbert Wiener, Bush's former student,[8] had been installed as the head of MIT's Research Laboratory for Electronics (RLE), and all research was now directed towards development of the digital computer. In his new recommendations for development of the computer, he specified:

"That the central adding and multiplying apparatus of the computing machine should be numerical, as in an ordinary adding machine, rather than on a basis of measurement, as in the Bush differential analyzer."[9]

Today, Bush's Differential Analyzer sits in a museum case in the basement of MIT, while the digital computer, operating with no advance over Babbage's Difference Engine, has become the false symbol of "technological advance." Each somewhat faster component is advertised as a great breakthrough, although the principles remain the same.

To sharpen the point about computing machines, it should be sufficient here to state, once again, the difference between Man, on the one side, and both animals and computers on the other. The great hoax, is the promotion of the idea that Man can be studied as either a social animal, or an advanced computer. As any of the scientists just described knew, since humans are not computers, computers cannot perform science. Inverting this, any operation that can be performed by a machine, cannot be attributed to a human trait. Mathematical calculations are purely logical deductive procedures, which humans can, of course, do. But, human scientific discovery is not an epiphenomenon of calculations. For example, Carl Gauss was known for his titanic calculating abilities, yet his work was not an outgrowth of his calculations. He knew that calculations were merely a useful, necessary, albeit mechanical tool, for precisely locating those paradoxes which lie between measurements taken from various senses.

The human mind was not modeled on the design for the digital computer, therefore the mind cannot be assumed to follow the rules of those machines. But, Lyndon LaRouche has demonstrated that true economic growth must proceed from an increasing density of discoveries, per person. There are principles bounding the creative abilities of the human mind, and they are knowable principles. But, they are not found by looking at how computers or animals work. So, get your sticky hands off that computer keyboard or joystick, and go use your creativity! For starters, begin with Kepler's discovery of Universal Gravitation, followed by his discovery of the harmonic ordering of the whole Solar System, at http://www.wlym.com/~animations. And get political—it's more fun being creative during a renaissance, than during a dark age.

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8. Wiener, who got his start when Vannevar Bush appointed him to head up the anti-aircraft ordnance department, faced the problem of targeting a German Luftwaffe dive bomber, which moved just as fast as the bullets used to shoot it down. He made some unique innovations, including his concept of feedback loops, in modeling the targeting of a weapon after the mind's control over the human body. He then went off the deep end, when he started modeling the mind after weaponry control systems.

9. Norbert Wiener, *Cybernetics* (New York: MIT Press, 1961).