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The Invention of the Electronic Digital Computer at Iowa State College, 1930-42

By William Silag

The Prototype, 1939

Progress on the computing machine had thus far been achieved at Atanasoff's desk in Iowa State College's Physics Building rather than in a laboratory or workshop. "All of my work on the capacitor memory and the add-subtract mechanism was entirely theoretical; no experiments were used in deriving the circuits or in checking them." By the end of 1938, however, he was eager to begin building a prototype. "Since the trip to Illinois, I had used more than a year working mostly on jogging. And logic circuits for adding and subtracting. I now felt much more confident that the project would be a success and I knew that I could not go on alone." Early in 1939 Atanasoff applied for financial support for the project in the form of a grant from Robert Buchanan, dean of graduate school at Iowa State College. The requested money, which was to be used for materials and shop work as well as for an assistant's salary, totaled $650. Buchanan approved the request later that spring, and Atanasoff at the start of fall semester 1939.

The two men got along well together from the beginning. "Berry was one of the best things that could have happened to the project," said Atanasoff. "After he had worked for a short time, I knew that he had [not only] the requisite mechanical and electronic skills, but also that he had vision and inventive skills as well."

Diagram of the Prototype

Condensers (2 rings, 25 condensers each)
Switch Points
Bakelite Disk
15 to 1 Worm Gear
Fast Shaft
Slip-Ring and Brush
One- Cycle Switch
Slow Shaft
Scanning Brushes (2 on Each Side)
The prototype of the ABC. (courtesy the Department of Special Collections, ISU library)

Clifford Edward Berry was just beginning his graduate career when he went to work for Atanasoff. He had read through Atanasoff's plans for the computing machine during the summer of 1939, and had a good grasp of Atanasoff's goals when he joined the project in September.

Atanasoff had meticulously worked out designs for some parts of the proposed computer, but he had only rough ideas of the remainder of the machine. There was also the complicated business of perfecting the sequence of mathematical steps the computer would use for solving systems of equations, which was, after all, the machine's principal objective. Atanasoff had been thinking about these steps in the preceding months of planning: "I had begun to consider other problems of mathematics and physics to which the new method [of calculation] could be applied. To this end, I suggested to Clifford that we momentarily forget the 'solution of systems' and build a computer. We of course realized that such a computer should and must be a simple gadget. We did not dare to build everything into our plans. Our skill as inventors depended on how well we chose between these factors, the indispensable and the impossible."

In a few weeks a prototype computer began to take shape in their basement workshop in the Physics Building. It was the size of a breadboard, with electrical components mounted on one surface, and could be moved easily around the workshop. "This prototype was designed to work out all of the aspects which worried us about this kind of a computation," Atanasoff explained. It included the key components of a complete calculating machine in scaled-down form and without many of the accessories needed for practical operation, but it allowed the inventors to see where their ideas were leading them. "Almost as soon as the prototype was completed, it began to work very well. The assembly procedure for the logic circuits which Berry had devised made them perfect." The first demonstrations of the prototype were conducted in October 1939. "Our visitors who understood what was going on were surprised to find so much structure giving additions and subtractions that were correct."

Atanasoff admitted that the prototype was a very crude device. "It could just add and subtract the binary equivalent of decimal numbers having up to eight places. Nevertheless, Clifford Berry and I regarded this machine as a great success. It settled many doubts about how an electronic computer should be built. .... [W]e both knew we could build a machine that could do almost anything in the way of computation." A demonstration of the prototype for college officials in December 1939 resulted in a grant of $810 from the Iowa State College Research Council to build a full-scale machine capable of solving systems of equations. Construction of the larger machine, later named the "Atanasoff Berry Computer" [ABC], began immediately after the winter holidays.

The Atanasoff Berry Computer, 1940-1942

"In order to get started fast, I decided to take a chance and estimate the size of the machine. I knew a few dimensions of the various parts that were to go into it [and] without very much figuring, I made an estimate of the size of the total machine and arrived at roughly the size of an office desk." Soon after Christmas, Atanasoff ordered some angle iron for a frame and asked Clifford Berry to start putting together. "I think I was lucky," he once said, referring to his quick estimates of the size of the frame. "As we progressed we did not often have to redo portions once they were built."

Atanasoff's pioneering vacuum-tube circuitry proved trustworthy in the tests he and Berry conducted with one of the machine's in January 1940.

Subsequent work on the ABC proceeded with only a few minor difficulties during 1940 and 1941. In May 1942 Atanasoff and Berry completed construction of the machine and began demonstrations and troubleshooting. THey had spent about $5,000 on the project, with Berry's salary accounting for much of the money spent.The mathematical processes and most of the engineering features of the Atanasoff Berry Computer seemed faultless: "during the construction of the computer, we had tested and corrected each subsystem, and so the shakedown did not require much time except for one flaw." The flaw had to do with the reliability of the ABC's electric-spark method of punching holes in binary cards. "We had tested the base-two card system rather carefully, but the number of tests was sufficient to find an error which occurred once in 10,0000 or 100,000 times. This meant that when we tested the complete machine, in the spring of 1942, we discovered that the card system was rather good, but not good enough." Determined to establish an error-free computing operation, neither had any inclination to return to work in Ames. Back at Iowa State College, where the ABC had been stored, the machine was finally dismantled.

Meanwhile, the computer industry had begun to develop and in the mid-1950s patent controversies arose that caused corporate lawyers to begin tracing the ancestry of the electronic digital computer. Several lawyers, working independently, and on different cases, "discovered Atanasoff, Berry, and the ABC. The first discovery was made by an IBM lawyer in 1954 but Atanasoff did not become a major center of attention in the patent controversies until the mid-1960s, when lawyers for the Honeywell Corporation began building a case that challenged the legitimacy of a patent by which the Sperry Rand Company (manufacturer of the UNIVAC computer) was collecting royalties from its competition, including Honeywell.

The case went to trial in Minneapolis, home of the Honeywell Corporation, in the late 1960s and a decision invalidating the Sperry Rand Company patent was made by the Federal Judge Earl Larson in 1973. Judge Larson's decision named John Vincent Atanasoff as the originator of several of the major engineering concepts on which the rise of the electronic computer, and the computer industry, had taken place in the late 1940s and 1950s. While the court did not grant Atanasoff or anybody else either monetary reward or reassignment of patent rights, the court destroyed all other claims pertaining to the invention of the electronic digital computer, including those advanced by Sperry Rand.

Atanasoff is happy enough with the court's decision. "What each man accomplishes depends on his brains and energy," Atanasoff remarked in an interview a few years ago, "but also on the surroundings in which he works. In this, timing is important." And about the timing of the ABC, he said simply, "I am very grateful that fate should have placed me at the beginning of this great adventure."

Analog computer: *A computer that operates by converting numbers in measurable physical quantities, such as the lengths of rod, rotations, or voltages. [A conventional watch offers an example of analog measurement. Time is measured by the relative positions of the hands on the face of the watch. For example, 1.17 is represented by the hour hand between 1 and 2, and the minute hand between 3 and 4.]*

Binary: A number system using two digits, usually 1 or 0. It is the most common system used in computers. The value of a number is determined by the relative position of 1's and 0's. For example/:

Decimal number	*binary equivalent*
1	*00000001*
2	*00000010*
3	*00000011*
4	*00000100*
5	*00000101*
6	*00000110*
7	*00000111*
8	*00001000*
9	*00001001*
10	*00001010*

Binary system counting: *Blocks of 1, 2, and powers of 2 (2x2=4, 2x2x2=8, 2x2x2x2=16, etc.) are used to build numbers that we associate with the decimal number system. A binary number is built from the* *right column to the left: a 0 in a column indicates that no block of that number is needed, while a 1 in a column indicates that a block of that power of 2 is needed to build the desired number. Thus, the number 3 is built from 1 1-block, and 1 2-block (or 1+2=3). The number four is built from 0 1-block, 0 2-block, and 1 2-block (of 0+0+4=4) The number seven is built from 1 1-block, 1 2-block, and 1 2-block (or 1+2+4=7). The number 10 is built from 0 1-block, 1 2-block, and 1 2-block (or 0+2+0+8=10). Large numbers can thus be simply represented for computers using only a system of 1's and 0's.*

Bit: *A single binary digit, a 1 or 0. A bit is one-eighth of a byte.*

Byte: *A cluster of eight binary digits. A byte is composed of eight bits.*

Capacitor: *A device for storing an electrical charge, also called a condenser.*

Decimal: *The number system using ten digits, 0 through 9. It is the most common system used by people for counting.*

Digital Computer: *A computer that operates with numbers expressed in digits, whether in a decimal, binary, or other number system. [A digital watch indicates time directly in numbers, such as 1:17.]*

The Atanasoff Berry Computer

The Atanasoff Berry Computer embodied four complementary ideas: digital electronic logic circuits, binary enumeration, serial calculation, and regenerative memory. Atanasoff's memory component included a pair of electrical recording devices he called "abaci" elements, one called a keyboard abacus and the other a counter abacus (see illustration of the ABC on page 177). The ABC computed by adding a number on the keyboard abacus to a number on the counter abacus. "The numbers on the two abaci thus play different roles," Atanasoff wrote in 1940. "One is left unchanged, the other is enhanced or diminished by the first in the course of the operation." Atanasoff and Berry planned their machine to operate on thirty abaci of each type (2x30), each containing fifty (50) binary digits, for a total of three thousand bits of memory (2x30x50=3000).

For abacus elements Atanasoff used small tubular paper condensers, fifty per element. The condenser elements occupied radical positions at six-degrees intervals within a hollow cylinder of bakelite measuring eleven inches long by eight inches in diameter. Each cylinder held thirty-two fifty-condenser abacus elements (two of the thirty-two were idle by design), arranged in rings along the inner wall of the bakelite cylinder. The condensers' inner terminals connected to a common lead; their outer terminals connected to contacts poking out through the wall of the cylinder. As the cylinder rotated on its horizontal axis, once per second, these contacts were read and recharged by brushed extending from the circuits of the add-subtract mechanism.

At the heart of the logic circuitry, a set of thirty add-subtract mechanisms did the actual computing. The add-subtract mechanism governing the coaction of the two abaci embodied the most significant electrical circuit developed by Atanasoff and Berry. Each add-subtract mechanism consisted of seven twin triode vacuum tubes interconnected to perform binary addition. Berry developed circuits in which the grids of the input tubes floated on small capacitors charged by momentary contact with a storage capacitor. Each add-subtract mechanism had three inputs, two for the digits being added and one to handle the carry-over from the previous place, and two outputs, one for the result in that place and one for the carry-over to the next place. The thirty computing units were identical in structure and rested

on individual chassis piled in a five-by-six array within the larger angle-iron frame. The machine looked like a big office desk covered with wires and electrical hardware.
The add-subtract mechanism arranged the abacus elements in a specific correspondence, added or subtracted one from the other, and took care of carry-over or borrowing as necessary in the mathematical procedure. Able to recharge its data source continually, an add-subtract mechanism conducted its routine serial operations at a fixes pace, one operation per second as the cylinder completed its electrically-powered rotation.

The logic circuits could calculate binary numbers serially with impressive speed. Addition and subtraction could be accomplished in a single operation, while multiplication and division, which were carried out by successive additions or subtractions, took a series of operations. Base-two calculation demanded only about a third the number of separate operations as base-ten calculation would have demanded on the same machinery. The prototype of 1939 suggested the potential of the circuitry by calculating pi (the ratio of the circumference of a circle to its diameter) to a thousand decimal places with ease, but its was the full-scale ABC that demonstrated the superiority of electrical calculation over mechanical calculation. For example, where MIT's differential analyzer took at least a few hours to set up and arrive at a solution for a variable in two complex equations, the ABC did the same work in no more than ninety seconds.

The ABC provided the results of intermediate steps in a mathematical operation on cards, issued by an auxiliary punching device receiving electrical signals from the add-subtract mechanism. The machine's operator could reinser hese card slater if they were needed in the operation. The ABC reported all such intermediate results in binary code (since the add-subtract mechanism did its work in base-two numbers, translation to base-ten in the midst of the mathematical operation made little sense.) Moreover, the punched cards themselves (like the abaci elements) permitted the expression of thirty fifty-place base-two numbers, nearly triple the capacity of the same equipment using base-ten numbers. Atanasoff's desire to maximize the quantitative potential of the ABC thus reinforced his decision to adopt binary notation for the actual task of electronic calculation.

For loading information into the computer, Atanasoff and Berry devised a system of cards that could be read by passing an electrical charge through through punched holes. Clifford Berry engineered the card-handling apparatus, which featured a novel method of initially punching cards by burning holes in them electrically. He geared this apparatus to the abaci shaft, thereby synchronizing the movement of the cards with the calculating operation. When a negatively charged contact touched a reading brush, an arc five thousand volts strong burned a hole through the card and then extinguished itself within a quarter of a second. All of this action took place as the card-handling mechanism whisked the cards along its steel rollers at the rate of one per second.

Subsequent readings of the data thus recorded on cards repeated several steps of the punching procedure. Cards to be read passed between electrodes-- the same ones used for punching — which tested in proper sequence each possible hole position on a card. The electrode's card-reading voltage was low enough to force a current through any point already broken down, and ranged from one-fourth to one-third of the card-punching voltage. When a hole on a card passed between the electrodes, a negative impulse — representing a number value of "one" — entered the input section of the add-subtract mechanism. Card positions bearing no hole were read as the number value "zero".

In order to make the results of the binary calculation readable to the person operating the ABC. an auxiliary device changed base-two numbers to base-ten by means of a conversion drum. Atanasoff estimated that five fifteen-place binary numbers could be transferred simultaneously in a total time of fifteen seconds, with faster rates of conversion possible for smaller numbers.

From the operator's point of view, the ABC was a streamlined affair. Manual controls included power switches and a keyboard, switches for starting card punching and reading operations, and switches to route numbers to a specific abacus. A flexible arrangement of plugs and jacks permitted special set-ups. Once a computing procedure was programmed, the operator fed in data cards and the results were reported on the ABC's output dials.