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Designing the First Stored-Program Electronic Computer at the World's First Electronic Computer Company: The Albert A. Auerbach Collection

Electronic Control Company / Eckert-Mauchly Computer Corp. / Albert A. Auerbach Chronology

May 1945	The world's first electronic computer, the ENIAC, becomes operational at the Moore School at the University of Pennsylvania. It is not a stored-program computer.
February 1946	The existence of the ENIAC is announced to the public.
March 13, 1946	Eckert and Mauchly complete their "Outline of plans for development of electronic computers [sic]," the business plan for the world's first electronic computer company.
March 31, 1946	Eckert and Mauchly leave the University of Pennsylvania's Moore School to start their own electronic computer business, which they call the Electronic Control Company.
September 1, 1947	Herman Lukoff joins the ECC. Albert A. Auerbach, a general circuits engineer with degrees in physics and "several other subjects," is already an employee (Lukoff, *Bits and Dits*, p. 65)
October 1947	Eckert & Mauchly agree to build the BINAC for Northrop Aircraft Company. It will be the first stored-program electronic computer.
1947	Auerbach works on designing a high speed serial binary adder demonstration unit that would work at a 5 MHz rate (Lukoff, p. 69)
December 22, 1947	Eckert and Mauchly incorporate their company and rename it the Eckert-Mauchly Computer Corporation.
1947-48	Auerbach works on a high speed decimal adder (Lukoff, p. 73).
	Marv Jacoby works on a device for reading characters from magnetic tape
December 26, 1947	Auerbach is assigned "full time on Northrop project" (BINAC), working on the accumulator and one word registers (EMCC conference report of 12/29/47).
August-September 1948	First and second modules of the BINAC are completed.
February 7, 1949	Auerbach runs a small test routine for filling memory from the A register (Lukoff, p. 84). This was the very first test routine run

	on the BINAC. Presumably no record of this was issued.
August 22, 1949	BINAC is officially operational; however, work on the machine continues.
February 6, 1950	Eckert-Mauchly Computer Corporation is acquired by Remington Rand
May 15, 1950	Auerbach submits as his thesis for the Master of Science in Electrical Engineering the most comprehensive account of the BINAC ever written. Only a much-abbreviated version will be published in the Trans IEEE.

The BINAC was the first stored-program electronic computer built in the United States. Among stored-program electronic computers, it was preceded in operation only by the British Manchester "Baby" computer, which operated for a very short time. Even though it is recognized that the BINAC included numerous hardware and software innovations, very little about its design and operation is known. Probably because of the scarcity of BINAC documentation, none of the histories of computing discuss it in any detail. One of the only books to include information on its design and engineering is Herman Lukoff's *From Dits to Bits: A Personal History of the Electronic Computer* (1979), cited throughout this description. Apart from the collection in the Sperry-Univac Company Papers at Hagley Museum's Eleutherian Mills Historical Library in Delaware, virtually no primary material on the BINAC is preserved. The *Origins of Cyberspace* Library contained only a very few documents on the BINAC. The Auerbach collection on the development of the BINAC includes documents written and preserved by one of its primary designers—Albert A. Auerbach, designer of the machine's twin CPUs. Most of the material in this collection has never previously been on the market.

The Auerbach Collection is also probably the only collection remaining in private hands of original documents and blueprints from the Electronic Control Company, the world's first electronic computer company. It is a unique opportunity to acquire records of the first significant work by the world's first electronic computer company. Though the world's first electronic computer, the ENIAC designed by Pres Eckert and John Mauchly, was operational in May 1945, its existence was not made public until February 1946. One month later Eckert and Mauchly founded the Electronic Control Company. Their purpose was to manufacture and sell electronic computers; however, at the time hardly anyone could think of a need for electronic computers. Eckert and Mauchly's business concept was so new and radical that they did not even include the word computer in the original company name. At the end of 1947 Eckert and Mauchly renamed their business the Eckert-Mauchly Computer Corporation. No other company would attempt to design and manufacture electronic computers until the early 1950s.

Eckert and Mauchly's BINAC, a path-breaking parallel machine developed for Northrop Aircraft Company, was also the first electronic computer produced for sale, and the first computer to use solid state components. In design the BINAC was the successor to the ENIAC and the EDVAC, and an important and little understood step on the way to the UNIVAC. As an indication of the rarity of the documents in this collection, only one, the sales brochure for the BINAC, was present in the *Origins of*

Cyberspace library. Most of the other documents in the Auerbach collection were produced for internal use, or issued in very, very few copies. Few, if any other copies of the documents in this collection would have survived. They include some of the earliest programs ever written for a stored-program electronic computer, a collection of original design blueprints showing the evolution of the BINAC design produced by the Electronic Control Co., the original press release for the first stored-program electronic computer ever sold, documents relating to the BINAC patents, and original typescripts describing the logical design and operation of the machine.

Price of the Collection: $40,000.

The BINAC

In order to remain financially solvent while developing the UNIVAC for the United States Census Bureau, Eckert and Mauchly contracted with the Northrop Aircraft Company to develop and construct a binary automatic computer (the BINAC). The contract was signed in October 1947, with Northrop providing $80,000 up front; another $20,000 was due upon delivery of the machine. The contract called for the delivery of the machine on May 15, 1948. Had the BINAC been finished on time, it would have been the world's first operational stored-program electronic computer. However, because of the cutting edge technology reflected in the BINAC's design, and the novelty of producing the world's first electronic computer manufactured for sale, there were inevitable delays. While Eckert-Mauchly was developing the BINAC, a group at the University of Manchester was also developing a much more basic stored-program computer known as the Manchester "Baby." This ran its first program on June 21, 1948. Even though the Manchester "Baby" was operational for only a short time, it preceded the BINAC which did not become operational until February 1949, making the BINAC the first operational stored-program electronic computer in the United States but not the world.

> BINAC was to be a small version of the EDVAC, with some differences. It had a storage capacity of 512 thirty-one-bit words and used delay lines. The machine had two processors, each with 700 tubes, and could perform 3500 additions or subtractions, or 1000 multiplications or divisions per second. The two processors (essentially two computers linked to each other) were unique, because they gave the BINAC the capacity to check itself for accuracy. The two processors performed a function, and if the results agreed, the computer executed the appropriate command. If they did not agree, the computer shut down and awaited further instructions. It was entirely binary, which set it apart from UNIVAC. More important, it was a stored-program computer, the first completed in the United States. It was also the first machine to use a tape input, although the BINAC tape device was quite inferior to later devices for UNIVAC . . . . It contained the best example to date of what is called machine coding, the basic binary instructions that give these machines the instructions to be a computer. Mauchly and Grace Hopper did the coding for BINAC, and Mauchly, Betty Holbertson, and others did the original programming. The part of the machine that handled the logic was made with germanium diodes, probably the first application of the newly invented semiconductors in

computers (Shurkin, *Engines of the Mind: A History of the Computer* [1984], p. 230).

Regarding the operation of the BINAC we quote from the Wikipedia:

> The BINAC ran a test program (consisting of 23 instructions) in March 1949, although it wasn't fully functional at the time. Here are early test programs that BINAC ran:
>
> - February 7, 1949 - Ran a five-line program to fill the memory from register A. [This was the test run by Albert Auerbach as mentioned on the timeline for the collection].
> - February 10, 1949 - Ran a five-line program to check memory.
> - February 16, 1949 - Ran a six-line program to fill memory.
> - March 7, 1949 - Ran 217 iterations of a 23-line program to compute squares. It was still running correctly when it stopped.
> - April 4, 1949 - Ran a fifty-line program to fill memory and check all instructions. It ran for 2.5 hours before encountering an error. Shortly after that it ran for 31.5 hours without error.
>
> Northrop picked up BINAC in September 1949. Northrop employees said that BINAC never worked properly after it was delivered, although it worked at the Eckert-Mauchly workshop. It was able to run some small problems but didn't work well enough to be used as a production machine. The failures were attributed to it not being properly shipped when Northrop picked it up (http://en.wikipedia.org/wiki/BINAC).

Text of the Press Release August 22, 1949. This is item 42 in the Auerbach collection:

> ***BINAC DEMONSTRATED,***
>
> ***NEW ELECTRONIC BRAIN***
>
> Philadelphia, August 22—The world's second all-electronic automatic computer was demonstrated hre today at the Eckert-Mauchly Computer Corporation by inventors Dr. John W. Mauchly and J. Presper Eckert, Jr. Named BINAC, it was built to order for Northrop Aircraft, Inc. of Hawthorne, California, [the] first private concern to acquire an "electronic brain." BINAC calculates 12,000 times faster than a human being.
>
> The only other computer like it is ENIAC, built by the same men in 1946 for the U.S. Army. BINAC is tiny in comparison with its 30-ton parent. The computing unit stands only five feet high, four feet long and one foot wide and fits in a medium-sized office. It is the first "giant brain" not gigantic in size, and was designed especially for engineering problems.
>
> "In designing today's advanced military aircraft and guided missiles we constantly encounter mathematical problems which cannot be solved in any reasonable period of time by humans working with pencil and paper or ordinary calculating machines," said John K. Northrop, President of Northrop Aircraft, Inc. "BINAC will be of extraordinary value in reducing preliminary design and test time on most research and development projects."

“In the past it has been practical to carry our analysis of a given design only to a certain point, after which costly and often destructive physical tests were necessary. With this new computer, calculations formerly impossible or impractical of solution can be completed rapidly with savings of hundreds of thousands or possibly even millions of dollars in time and money.”

Actually twin computers, BINAC has duplicate arithmetic channels so it can check itself at every step, and two mercury tube “memories.” Each twin has only 7000 vacuum tubes. ENIAC has 18,000.

The new computer showed its mettle by solving “Poisson’s Equation,” a typical engineering problem. BINAC spent more than two hours of actual computation to obtain 26 solutions. For each solution the computer did 500,000 additions, 200,00 multiplications, and 300,000 transfers of control, all in the space of 5 minutes. A man with an adding machine would have need years to complete the same job.

The audience also got a chance to test the computer. They were asked to select numbers at random. These were typed on a small keyboard having only eight keys. The BINAC used coded instructions from a magnetic tape to deal with these numbers. It calculated the square and cube roots of all the numbers in the fraction of a second.

For each square or cube root, hundreds of arithmetic operations have to be done by the computer. A human being with a scratch pad can find a square root correct to eight or nine digits in six minutes. With a desk calculator he can do it in two minutes. The BINAC does it in one-sixtieth of a second.

The BINAC operates in the binary system instead of the decimal one. In the binary system, it is required only to distinguished between zero and one. The computer has to convert automatically to binary numbers before beginning calculations and to convert answers back again to decimal form before printing them out on an electric typewriter. Actually the computer receives and puts out figures in the octal system, from zero to seven, as this converts more easily to binary than the decimal system does. Decimal numbers may be easily expressed using pairs of octal numbers. The computer sorted them in increasing order from the smallest to the largest. This type of “collation sorting” has never before been done by any computer. It is done only for certain problems.

The audience was able to check results as they came out of the BINAC by consulting a familiar computer’s handbook known as Barlow’s Tables, showing answers to square and cube roots.

For the past month the Eckert-Mauchly Computer Corporation has run a training school for computer operators in the plant, attended by Northrop Aircraft, Inc. engineers and mathematicians who will run the computer when it arrives in California. A typical computer staff consists of several operators and service engineers, one or two mathematicians to program problems, and typists to prepare magnetic instruction tapes.

The main reason for the BINAC’ smaller size is the mercury memory invented by Mr. Eckert. It replaces about 17,000 vacuum tubes and can store 15,000 binary digits. Electrical pulses representing numbers and instructions are sent through it at a rate of 4 million per second. They are held in the column by being rerouted through it for as long as necessary. The tremendous speed of the mercury memory makes it possible for the computer to handle a great volume of data.

Dr. Mauchly stated emphatically that the BINAC will not 'think.' It merely follows instructions given to it in the form of simple arithmetic operations.

"It often takes months and even years to bring a new industrial product from the research laboratory to the factory belt-line. He said. "This time can certainly be shortened through the use of computers such as the BINAC. The new era in industrial design forecast when ENIAC began operating, is now here."

A larger, more general-purpose type of computer named UNIVAC is also being constructed by the Eckert-Mauchly Computer Corporation for customers that include the U.S. Bureau of the Census, the Army Map Service, the Air Comptroller's Office, the Prudential Insurance Company of America, and other private customers.

List of Items in the Auerbach Collection:

1. **[Auerbach].** E. E. 622. Mid-year examination. Mimeographed typescript. 2ff. N.p., Jan. 30, 1947. Creased horizontally.

   Examination in electrical engineering taken by Auerbach who was continuing his education at the University of Pennsylvania while he was working at the Electronic Control Co. The first question deals with Poisson's equation, an equation Auerbach later programmed the BINAC to solve.

2. **Auerbach, Albert A.** et al. BINAC application (cover title). 59 blueprints containing 76 numbered diagrams. N.p., n.d. In cardboard binder with typed label. Printed label reading "Minn. C.A. 4-67 Civ. 138. Plaintiff's trial exhibit no. 7641.5" in lower right corner of front cover. Blueprints browned. [1 949].

   A collection of schematic diagrams of the BINAC submitted as part of an application for a patent on the BINAC. The patent was never granted.. The inventors listed are: J. P. Eckert, Jr.; J. W. Mauchly; A. A. Auerbach; R. F. Shaw; J. R. Weiner; H. F. Welsh; L. D. Wilson. Each sheet signed in the blueprint by George V. Eltgroth, attorney. Together these 76 engineering diagrams probably represent a complete set of engineering diagrams for the design and operation of the BINAC.

   The legal markings indicate that this collection of documents was used as evidence in the famous ENIAC patent trial. This case, in which Eckert and Mauchly's patent for the stored-program electronic computer was disallowed, was decided in 1973. See *Origins of Cyberspace* 1380.

3. **Auerbach.** Delay line divider and test word generator. Photograph of a blueprint. Philadelphia: Electronic Control Company, 10/20/47. Approved 11-4-47.

   The earliest blueprint in the collection.

4. **[Auerbach?].** Introduction to the description of logical operation. [14]ff., variously numbered. 31 full-page diagrams / charts, mostly blueprint, one folding. [Philadelphia: Eckert-Mauchly Computer Corporation], n.d. [post December 22, 1947]. Blueprints browned. Corrections in ink on one or two blueprints.

   Auerbach probably wrote this in the preliminary planning stages of the project. Most of the blueprints are captioned "Eckert-Mauchly Computer Corp.," indicating that they were produced after the Electronic Control Company's incorporation and renaming on December 22, 1947. The purpose of this document would presumably have been to explain the theoretical operations of the BINAC to its customer, Northrop Aircraft. However, it could also have been used to inform Eckert-Mauchly's other customer, the U.S. Census Bureau, about the planned operations of the machine, and perhaps to educate other potential customers at the time. It appears that portions of the present document were included in the Eckert-Mauchly Computer Corporation's *Engineering Report on the BINAC Built for Northrop Aircraft Corporation* (1949), a copy of which is preserved at Eleutherian Mills.

5. **Auerbach.** High speed counter for alg. adder. Mechanical drawing in pencil, initialed "AAA." Single sheet. Philadelphia, n.d. [post December 22, 1947]. "Eckert-Mauchly Computer Corp." printed in lower right corner.

6. **Smoliar, Gerry.** Timing pulse generator with AVC. A 52-1205. Blueprint diagram. [Philadelphia:] Electronic Control Company, 12/31/47. Light browning.9

7. **Eckert.** Flip-flop circuits. Blueprint diagram, drawn by "G.S." (George Smoliar]. Single sheet. Folded. Philadelphia: Electronic Control Company, 28 Feb. 1948. Light browning.

   Eckert designed numerous "flip-flops" for various computers. Auerbach has drawn in his own pencil addition to the design in an empty panel of the blueprint.

8. **Sheppard, C. B.** Input-output synchronizer block—block diagram. Blueprint diagram. Single sheet. [Philadelphia:] Electronic Control Company, 4/2/48. Light browning. Date stamp and pencil annotations (presumably Auerbach's) on the verso.

9. **Sheppard.** Program generator chassis "J" input-output synchronizer. Blueprint diagram. Single sheet. Philadelphia: Electronic Control Company, 4/6/48. Light browning.

10. **Sheppard.** Program generator synchronizer unit. Blueprint diagram. Single sheet. Philadelphia: Electronic Control Company, 4/6/48. Browned, a few stains on verso.

11. **Sheppard.** Amplifiers synchronizer unit. Large blueprint diagram. Single sheet. Philadelphia: Electronic Control Company, 4/8/48. Light browning.

    Revisions by Auerbach in pencil.

12. **Sheppard.** Precessor chassis H & I of input-output synchronizer. Blueprint diagram with pencil corrections on the blueprint and additions on the verso by Auerbach. Single sheet. Philadelphia: Electronic Control Company, 4/19/48. Light browning.

13. **Sheppard.** Distributor and memory chassis D, E & F of input-output synchronizer. Large blueprint diagram with pencil additions, presumably by Auerbach. Philadelphia: Electronic Control Company, 4/20/48.

14. **Sheppard.** Synchronizer & counter chassis "G" of input-output's synchronizer. Large blueprint diagram with pencil revisions and corrections by Auerbach. Includes use of semi-conductors in circuitry. Single sheet. Philadelphia: Electronic Control Company, 4/27/48. "May 26, 1948" stamped on back in red ink.

15. **Sheppard.** Drivers & head relay input-output synchronizer. Blueprint diagram with extensive additions in pencil on recto and verso, by Auerbach. Single sheet. Philadelphia: Electronic Control Company, 5/12/48. Browned, a few stains on verso.

16. **[Auerbach].** Filling station. Positive photostat of Auerbach's rough draft for the diagram professionally drawn as the following item. Single folding sheet. Numbered D-45-1360. N.p., n.d. [June 1948]. Stamp reading "This document and information property of Eckert-Mauchly Computer Corporation" on recto and verso.

    Appears to be a rough draft of the blueprint listed below.

17. **Auerbach.** Filling station block diagram—Binary computer. Blueprint diagram (2 copies). Single folding sheet. Philadelphia: Electronic Control Company, 6/26/48. Light browning.

    See Lukoff, p. 84: "February 7, 1949—Al Auerbach ran a small routine (five lines of coding) for filling memory from the A register."

18. **[BINAC].** Decimal Adder Demonstration. Confidential. Mimeograph typescript. 4ff.; 3rd leaf stamped "Suppress." Diagrams on ff. 3-4. Philadelphia: Eckert-Mauchly Computer Corp., 7/20/1948. Light browning.

    An early attempt to describe the way the BINAC would perform this operation before the machine was actually built. "The decimal adder demonstrates the addition of two decimal numbers, expressed in the 'excess three' pulse code, at a rate of 4,000,000 pulses per second." "The machine, of course, reaches it conclusion faster than the operator, since the two decimal numbers are added in 3.75 microseconds—or at the rate of approximately one billion additions an hour."

19. **[Jacoby, Marv].** Checking of addition in a binary adder. Carbon typescript. 7, [1]ff. Philadelphia: Eckert-Mauchly Computer Corp., 1948. Initials MJ/vh, dated 12/17/48, at foot of f. 7. Light browning.

    Marv Jacoby was a member of the EMCC Engineering Group; see Lukoff, p. 87.

20. **The Binac.** Series of photostats of charts, each punched for a three ring binder:

The Binac

Acoustic Delay Register for Binac memory System

Binac Memory Temperature Control System

Binac Converter Panel

Binac Operational Speeds

Example of Assignment of memory Locations for a Computation of a Problem

Mercury memory Channels

Binac – Remote Control Box

Binac Keyboard

21. **[BINAC].** Decimal adder demonstration. Mimeograph typescript. 3ff. Diagram on f. 3. Philadelphia: Eckert-Mauchly Computer Corp., 1948. Light browning.

Later version, without the suppressed leaf.

22. **[BINAC].** Generation of squares. Blueprint typescript. Single sheet. [Philadelphia], 3/7/49. Light browning.

"March 7, 1949—Dick Baker, the Northrop Aircraft representative on site, wrote that Machine #2 [of the BINAC, a parallel machine] performed 217 iterations of the routine on P90 (23 lines of coding for generation of squares) correctly and it was still computing correctly when stopped. This test was worked up to furnish information for John Mauchly for his paper for the IRE conference. Only one memory tank was used" (Lukoff, p. 84). Northrop Aircraft had contracted to purchase the BINAC. *These programs, written in the machine language of the BINAC, and those in items 37-40 below are among the earliest extant programs for a stored-program electronic computer.*

23. **[BINAC].** Program using all instructions (BINAC). Generation of squares no. III. Blueprint typescript. 2ff. [Philadelphia], 3/9/49 – 3/11/49. Light browning.

One of the first test routines run on the BINAC prior to the machine's official completion in August of that year. See Lukoff, p. 84. See *Origins of Cyberspace* 1143 & 1144 for BINAC test routines developed at the U.S. Census Bureau on 3/14/49 and 3/21/49.

24. **[BINAC].** Generation of sine and cosine on BINAC. File 160-3B. Blueprint typescript. 3ff. Light browning.

More BINAC test routines.

25. **[BINAC].** Square root routine for BINAC. File 100-3B. Blueprint typescript. 3ff. [Philadelphia], 3/11/49. Light browning.

Another extremely early program for the BINAC.

26. **[BINAC].** Test of multiply and divide instructions (BINAC). Blueprint typescript. Single sheet. [Philadelphia], 3/11/49. Light browning. Signed "Auerbach" in pencil ms. at the upper right.

Still another extremely early program for the BINAC.

27. **[BINAC].** The BINAC. A product of the Eckert-Mauchly Computer Corp. Reproduced typescript, stapled. 8 sheets, including full-page illustration. N.p.: Eckert-Mauchly Computer Corp., ©1949. Toned, a few edges frayed.

The sales brochure for the BINAC. Published the year BINAC was delivered, the flyer contains the computer's statistics, a brief outline of its elements and general characteristics, coding instructions, and a conversion table comparing decimal, coded decimal, binary, and octal numbers. A full-page illustration shows the various components of the system. *Origins of Cyberspace* 1145.

28. **[BINAC].** BINAC demonstrated, new electronic brain. Mimeograph typescript. 7ff. New York, August 22, 1949. Light browning.

"Corrected release for press conference at the Eckert-Mauchly Computer Corp., 3747 Ridge Avenue Phila., Pa., on August 17, 1949, 2:30 p.m. Release date: August 22, 1949." The press release describes the BINAC's successful solution of "Poisson's equation" and calculation of square and cube roots. It included an Addenda of Useful Information and a Bibliography. The full text of the Press Release is transcribed in the introduction to this listing.

29. **Auerbach.** The Arithmetic Circuits of the BINAC. Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Electrical Engineering at the Moore School of Electrical Engineering. Carbon typescript illustrated with tipped-in blueprint-type diagrams, full-page blueprints (some folding) and photographs. Philadelphia, May 15, 1950. [5], 131, 131a, 132-133, 133a, 134-135, 135a, 136-137, 137a, 138-141, 141a, 142-144, 144a, 145-146ff. 2 photocopies of the BINAC and its central control unit laid in. In cardboard binder with typed label on the front cover. A few photographs detached, corner of binder repaired with clear tape.

An unpublished and possibly unique early treatise on the design and operation of the BINAC CPU. As Auerbach writes, "The Binac, successor, historically, to the Eniac and the Edvac, is a high speed, automatic, digital computer, operating in serial fashion on numbers expressed in binary form. The digits occur at a repetition rate of four million per second, considerably faster than any computer thus far built. In this sense, it may truly be called "high speed". It is automatic in the sense that, properly instructed, the Binac will perform a complicated calculation by itself. This is in contrast to a desk calculator, for instance, which merely assists the human operator in performing a calculation." (p. 1). This copy may be unique, or unique except for a copy that might have been preserved at the Moore School. The thesis includes dozens of block diagrams of the logical design and operation of the machine reproduced from Auerbach's own drawings, as well as photographs of oscillograms taken at various points in the arithmetic processes.

30. **Auerbach; J. Presper Eckert; Robert F. Shaw; James R. Weiner; Louis D. Wilson.** The BINAC. Philadelphia: Eckert-Mauchly Computer Corp., [1951]. Carbon / blueprint typescript. [3], 76ff. In cardboard binder, typed label on front cover indicating that this is "Copy III." Blueprint leaves browned.

Though this paper is signed by Auerbach and the other co-inventors of the machine it is obvious through comparison with this text and that of Auerbach's thesis above that the paper is merely a condensation of Auerbach's much more comprehensive Master's Thesis (the previous item). It was published in 1952 in the Transactions of the RIEE with perhaps half the text and illustrations.

Price of the Collection: $40,000.