Stored Program Computers

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Early Thoughts about Stored Programming

- **January 1944** Moore School team thinks of better ways to do things; leverages delay line memories from War research
- **September 1944** John von Neumann visits project
  - Goldstine's meeting at Aberdeen Train Station
- **October 1944** Army extends the ENIAC contract research on **EDVAC stored-program concept**
- **Spring 1945** ENIAC working well
- **June 1945** ***First Draft of a Report on the EDVAC***

First Draft Report (June 1945)

- John von Neumann prepares (?) a report on the EDVAC which identifies how the machine could be programmed (unfinished very rough draft)
  - academic: publish for the good of science
  - engineers: patents, patents, patents
- von Neumann never repudiates the myth that he wrote it; most members of the ENIAC team contribute ideas; Goldstine note about "bashing" summer letters together

- 1.0 Definitions
  - The considerations which follow deal with the structure of a *very high speed automatic digital computing system*, and in particular with its *logical control*….
  - The instructions which govern this operation must be given to the device in absolutely exhaustive detail. They include all numerical information which is required to solve the problem….
  - Once these instructions are given to the device, it must be be able to carry them out completely and without any need for further intelligent human intervention….
- 2.0 Main Subdivision of the System
  - First: since the device is a computor, it will have to perform the elementary operations of arithmetics….
  - Second: the logical control of the device is the proper sequencing of its operations (by…a control organ.
  - Third: Any device which is to carry out long and complicated sequences of operations…must have a considerable memory.

PREPARATION OF PROBLEMS FOR EDVAC-TYPE MACHINES, John W. Mauchly (Electronic Control Co.)

Proceedings of a Symposium on Large Scale Digital Computing Machinery, 7-10 Jan. 1947

- The initials stand for "Electronic Discrete Variable Automatic Computer." Such a machine differs from…Mark I, Mark II, the ENIAC, and the Bell Telephone Laboratories' relay computers.
- To begin with, let us consider some of the fundamental characteristics of this type of machine, in particular those points which differ significantly from present machine design. Of these, three have a definite bearing on the handling of problems: (1) an extensive internal memory; (2) elementary instructions, few in number, to which the machine will respond; (3) ability to store instructions as well as numerical quantities in the internal memory, and modify instructions so stored in accordance with other instructions.

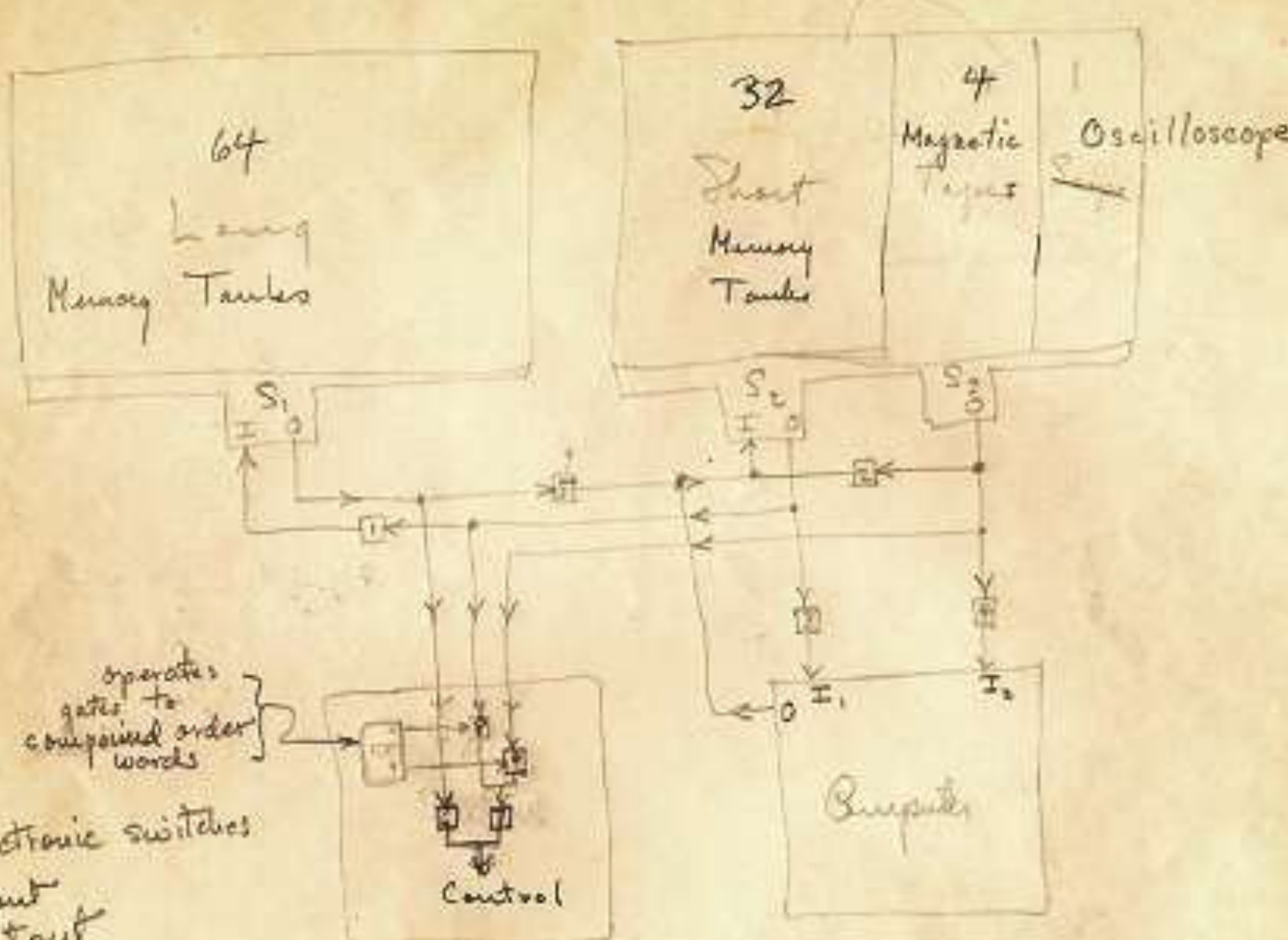
- **March 1947 EDVAC** *delay line memory* working
- **1947 ENIAC converted to an elementary stored-program computer via the use of function tables**
  - *BRL Report No. 673, A Logical Coding System Applied to the ENIAC*, R.F. Clippinger, 29 September 1948
- **1951 Core memory module added to the ENIAC**
  - BRL Memorandum Report No. 582, *Description of the Eniac (sic) Converter Code*, W. Barkley Fritz, December 1961
- **October 1955 ENIAC shut off**
  - *Mina Rees rescues units from a field*

EDVAC Summary (from Stern/Weik)

Applications solution (sic) of ballistic equations, bombing and firing tables, fire control, data reductions, related scientific problems. A general purpose computer which may be used for solving many varieties of mathematical problems.

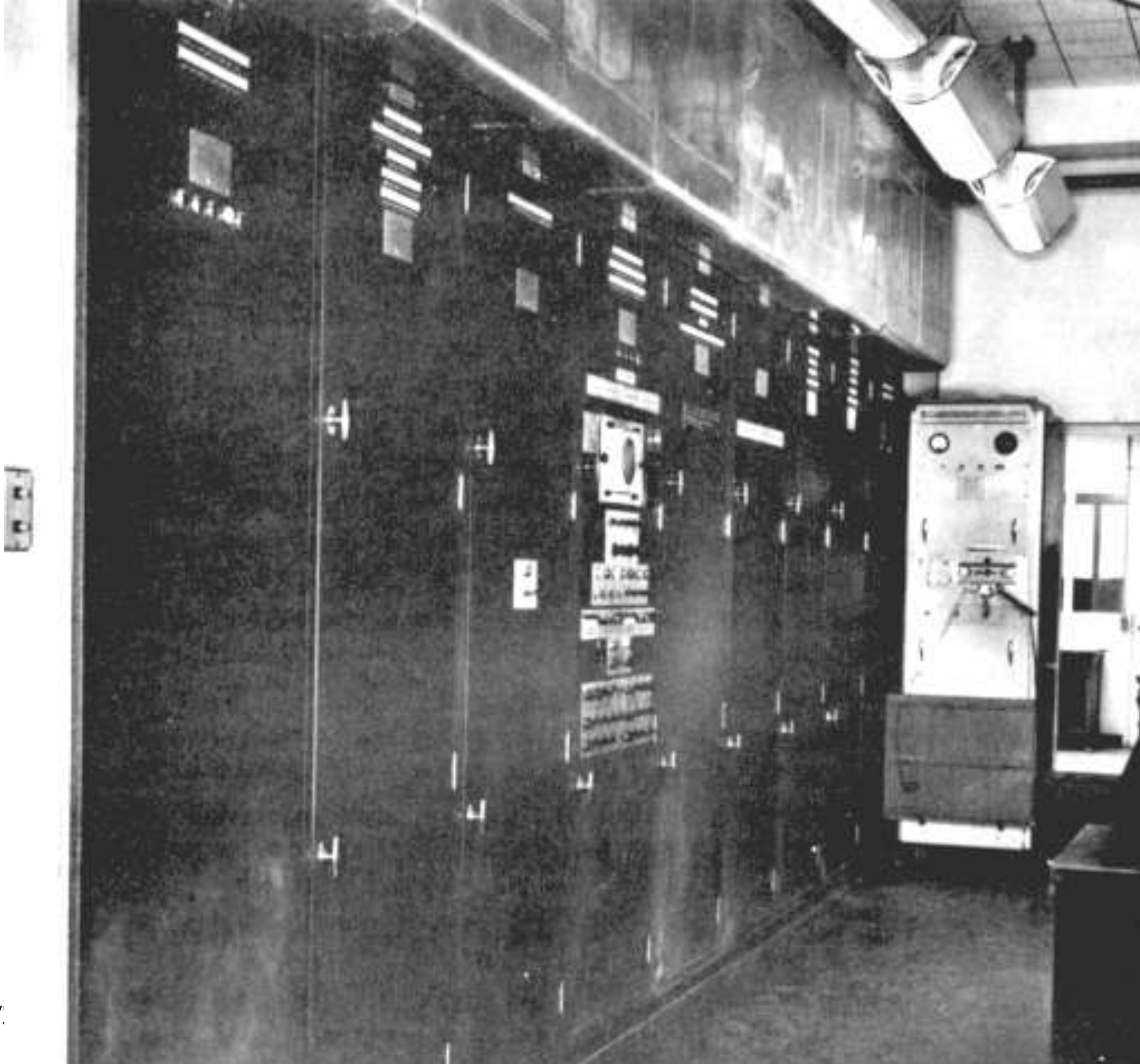
- Internal: binary
- Word: 44 bits
- Instruction:
  - 4 bits operation code
  - 10 bit addresses
- Instructions: 16

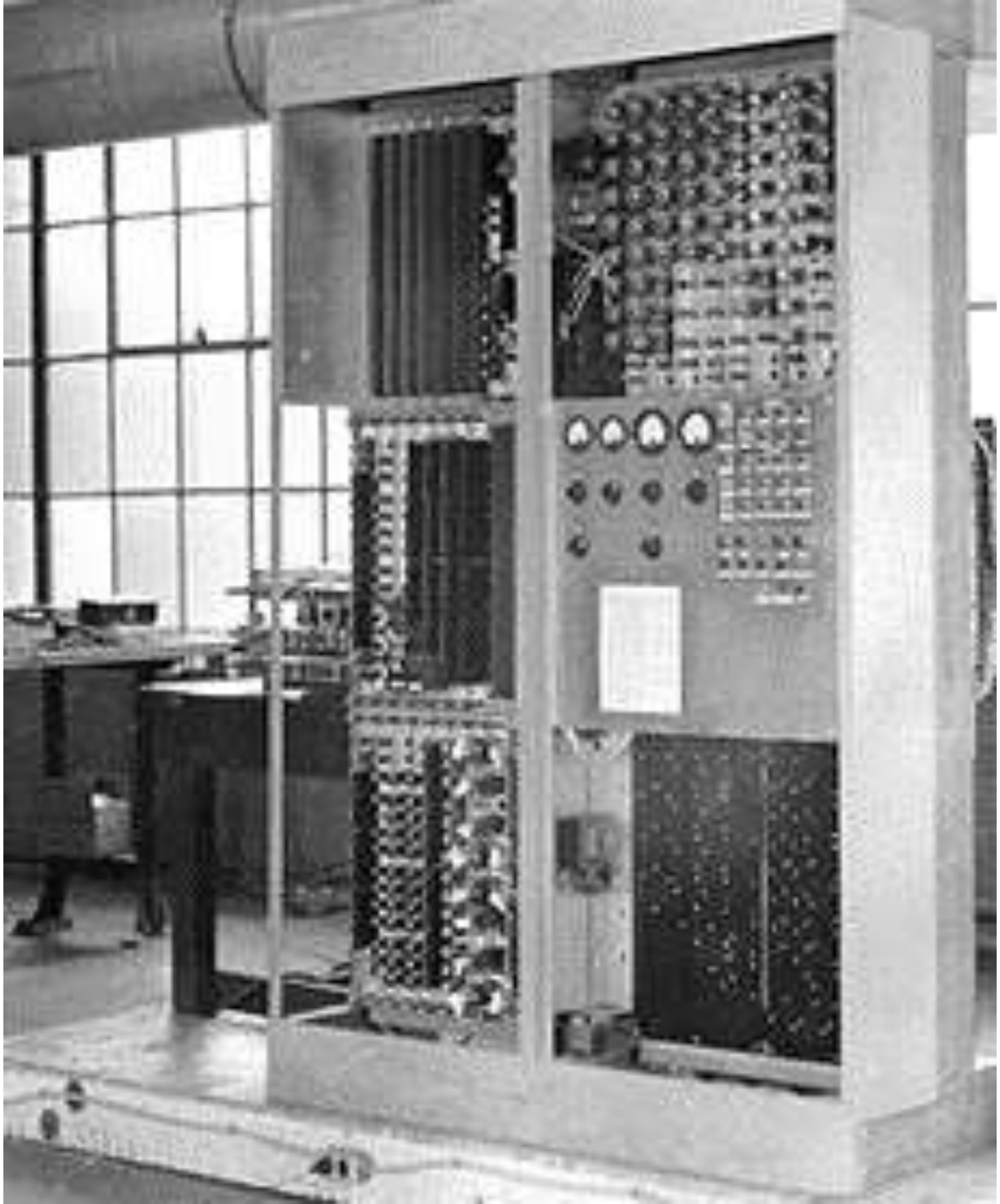
- Add: 864 microseconds
- Multiply: 2880 ms
- Mercury acoustic delay lines: 1024 words
- Mag. drum: 4608 words



S_i electronic switches
I input
O output
gate tube
F.F. flip-flop (switch)

EDVAC
Figure 3.
([illegible] A)
Plan





Other Projects

- April 1943 *Heath Robinson* machine working at Bletchley Park
- December 1943 *Colossus* working
- 1943 *Whirlwind* Project started at MIT as an analog flight simulator
- Fall 1945 Alan Turing arrives at National Physical Laboratory
- Spring 1946 Turing designs the *Automatic Computing Engine (ACE)*

Meanwhile, back at the ranch...

- **1946** Eckert and Mauchly leave the Moore School and establish the **Electronic Control Company**
- May 1946 Maurice Wilkes sees a copy of the *First Draft Report*
- *Army sponsors the Moore School Lectures*

Moore School Lectures

- Summer 1946: Under Army funding, the Moore School organizes a series of lectures on computing
- Attended by just about anyone interested in computing, including Maurice Wilkes
- Speakers: Stibitz, Mauchly, Eckert, Aiken, Goldstine, Burks, Chu

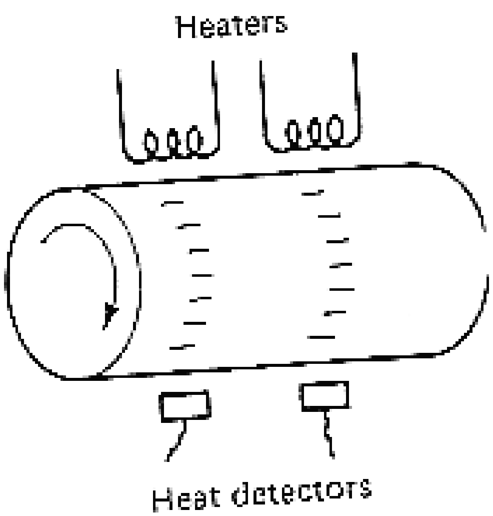
Memories are made of this….

- 1. Thermal devices
- 2. Mechanical devices
- 3. Delay lines
- 4. Electrostatic storage mechanisms
- 5. Rotating magnetic memories
- 6. Stationary magnetic memories

Thermal devices

- A.D. Booth: heated the surface of a drum covered with chalk; used a recycling mechanism to refresh the spots.

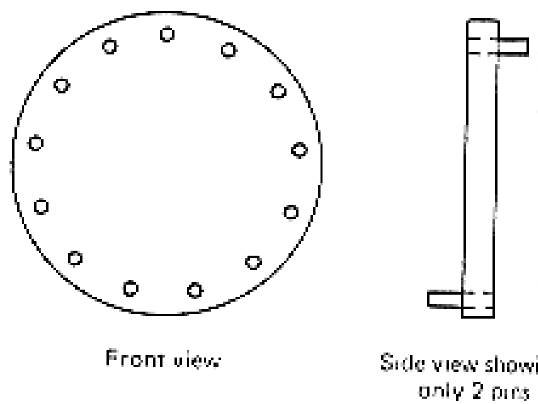
Figure 8-1
A diagram of Booth's experimental thermal memory.

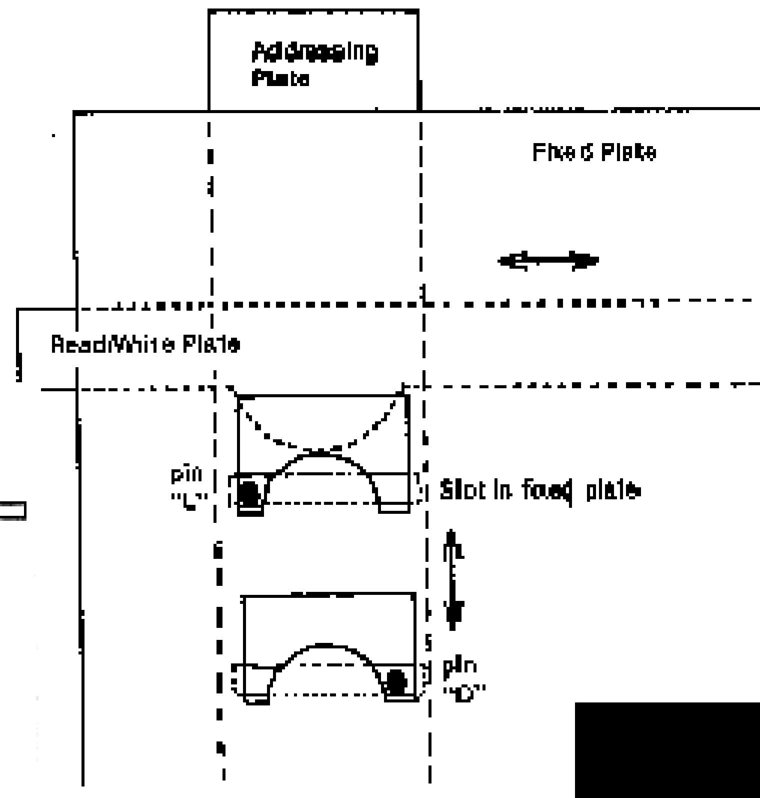


Mechanical devices

- Zuse: sliding elements
- Booth: disk/pin memory, rotating wire mechanical memorv

Figure 8-2
A diagram of a single disk from Booth's disk-pin memory system.

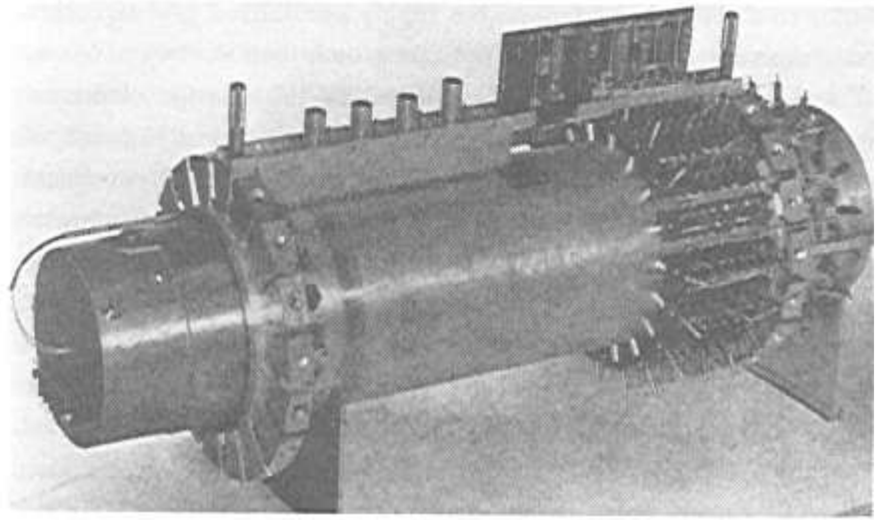


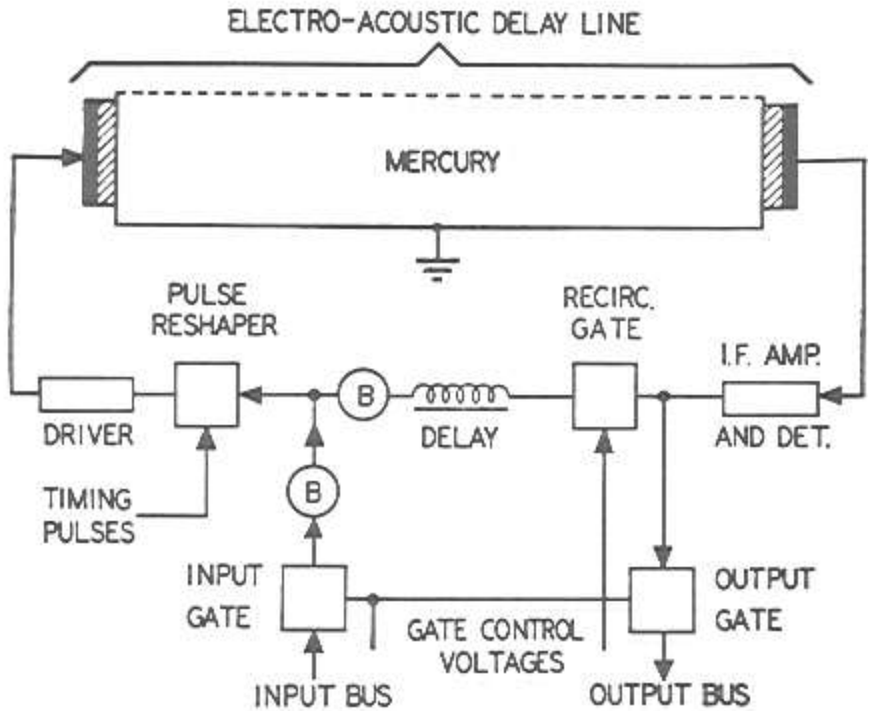


ure 2.4. Binary Memory Device

Delay lines

- Developed by William Shockley of Bell Labs
- Used in radar during the war (Pres Eckert)
- Mercury (acoustic) delay lines (EDVAC)
- Magnetosrictive (Booth and the Ferranti Co.)





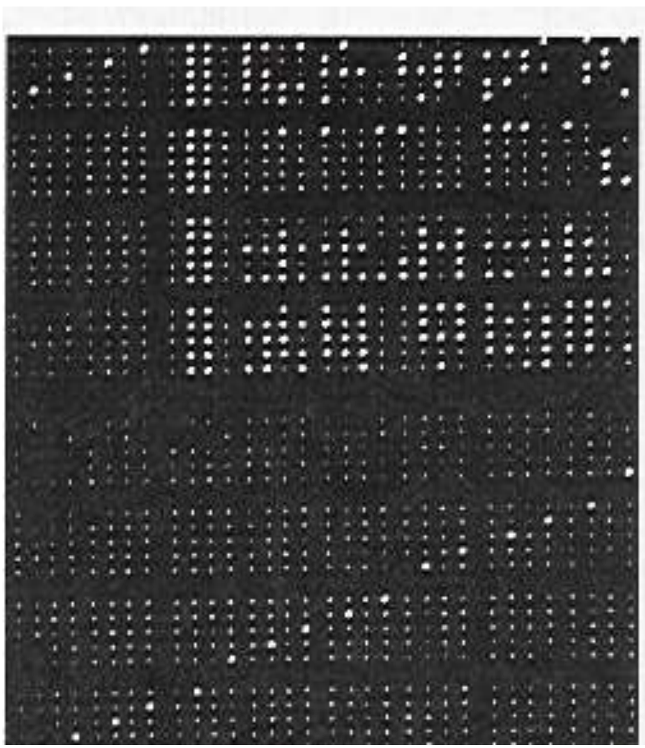
ELECTRO-ACOUSTIC DELAY LINE
MERCURY
PULSE
RESHAPER
RECIRC.
GATE
I.F. AMP.
AND DET.
DRIVER
DELAY
B
B
TIMING
PULSES
INPUT
GATE
OUTPUT
GATE
GATE CONTROL
VOLTAGES
INPUT BUS
OUTPUT BUS

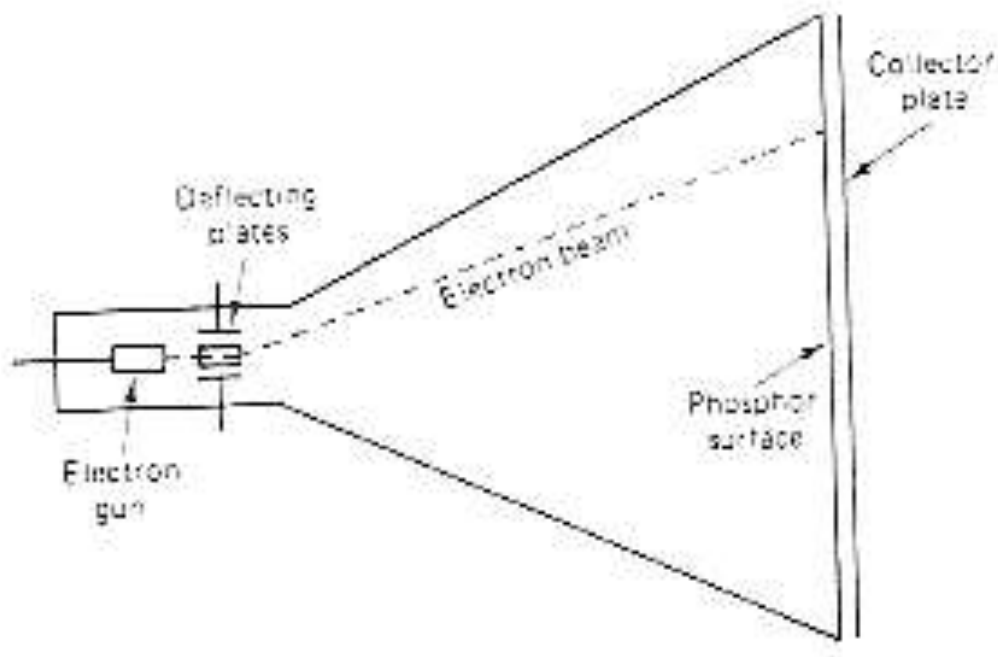
Electrostatic storage mechanisms

- The first truly high-speed random access memory was built by Freddy Williams and Tom Kilburn at Manchester University, UK (another outgrowth of wartime radar research; also mentioned by Pres Eckert during a Moore School lecture)
- 1947: Working model of 1,000 bits (serial system)
- Used in the IAS machine (parallel system)
- Jan Rajchman of RCA Laboratories developed the Selectron tube

Williams tube memory

Figure 8-8
The Williams' tube electrostatic memory system.





Rotating magnetic memories

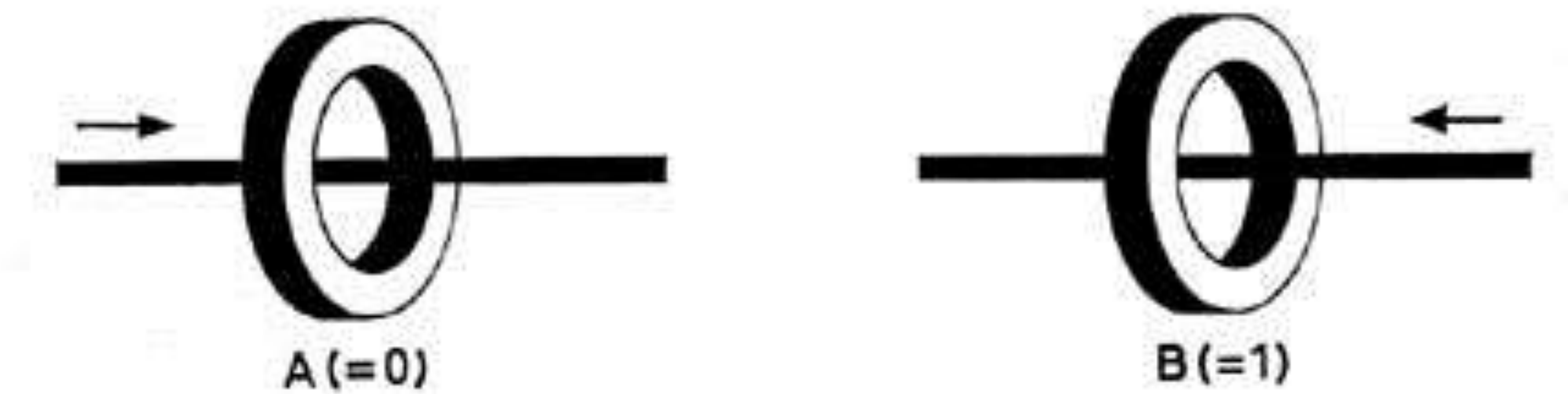
- Existing technology: recording of voice and sound using a ferromagnetic coating: wire, bakelite platters, thin paper, etc.

- Problem was speed:
- wire memories (A.D. Booth and others)
- drum memories became the storage device of choice for early commercial computers

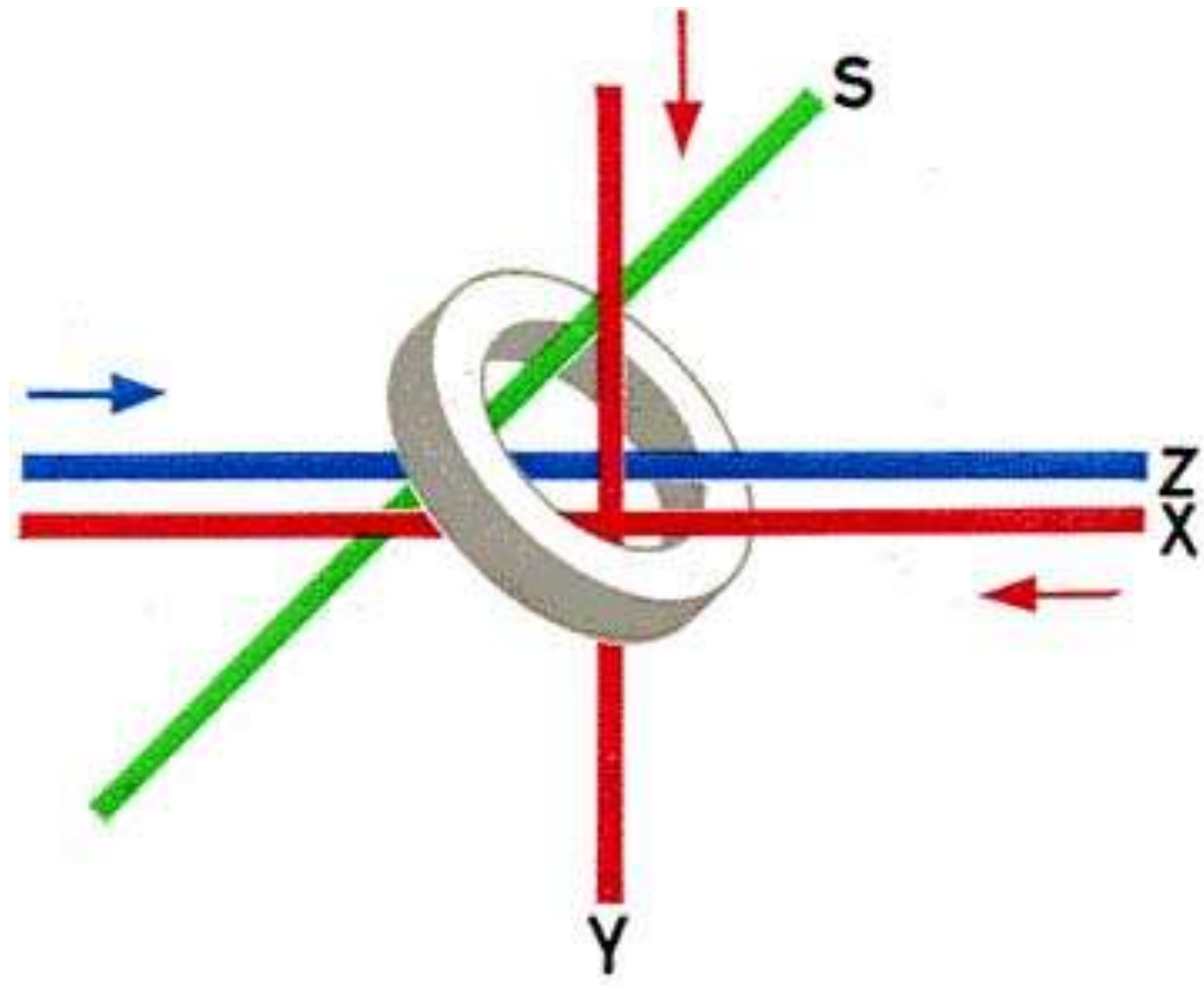
Stationary magnetic memories

- Magnetic core memory: first large-scale reliable memory at reasonable cost.
- Jay Forester experiments with core memory for the Whirlwind Project at MIT
- An Wang began experiments to develop pulse transfer control devices while working with Howard Aiken at Harvard; received a patent in 1949

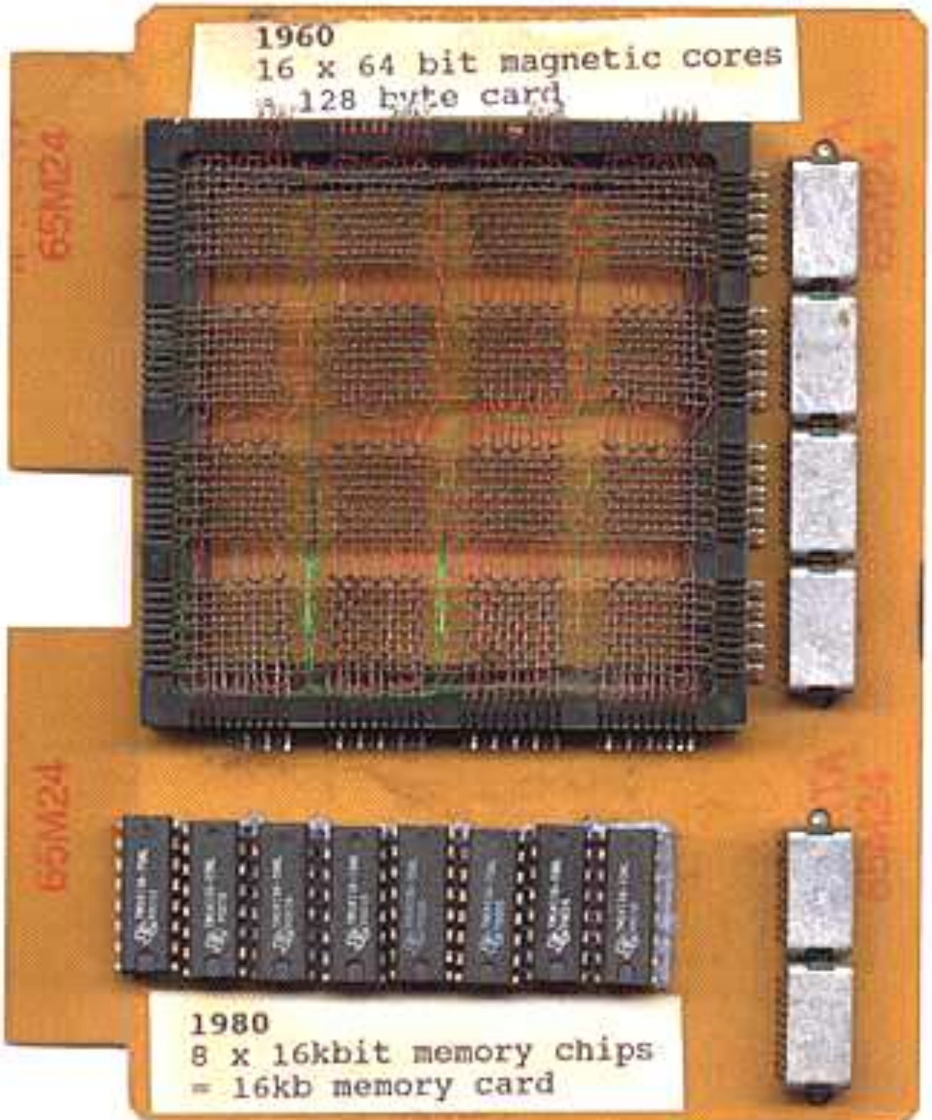
Right hand rule (physics)

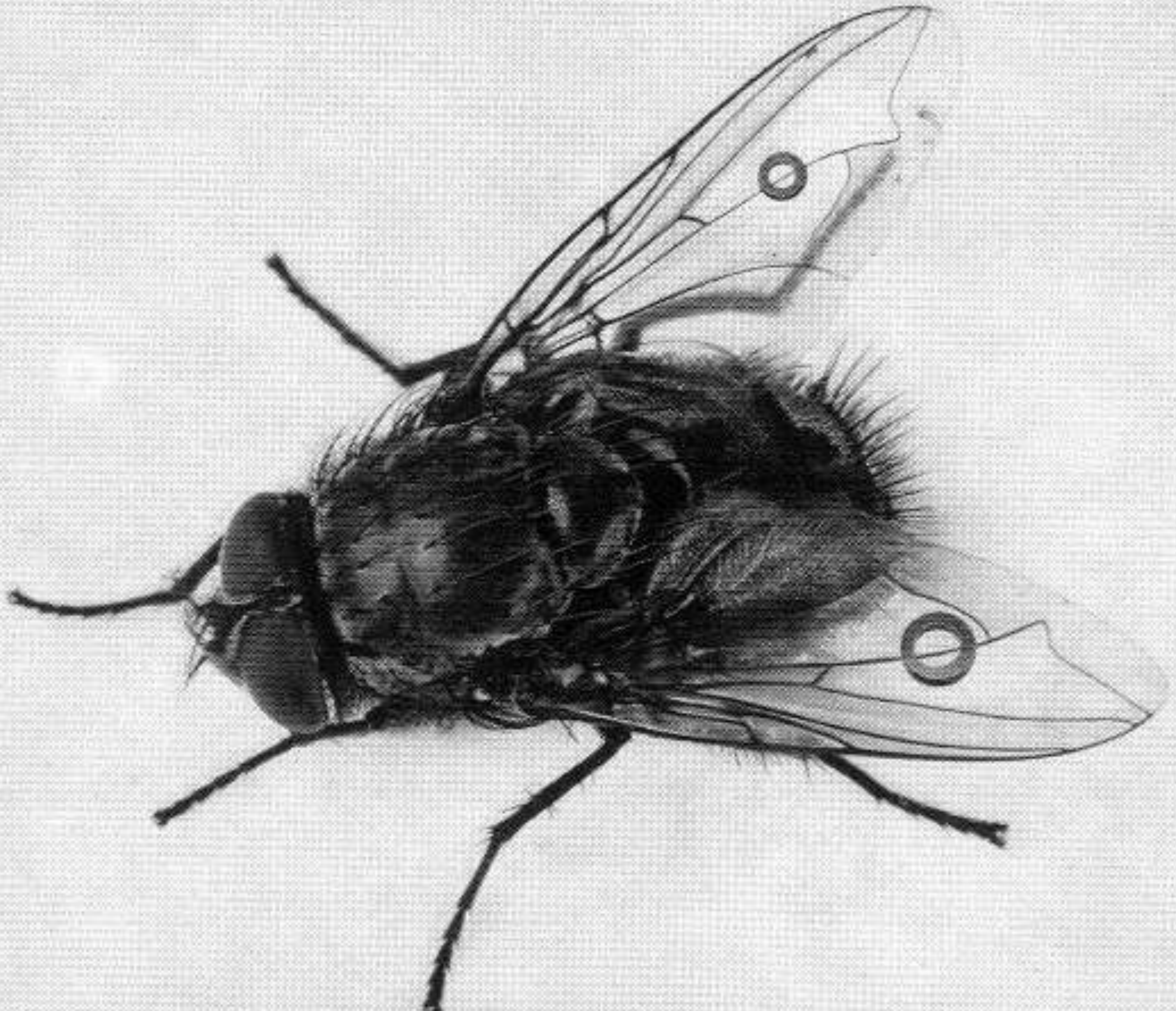


Coincident current core memory

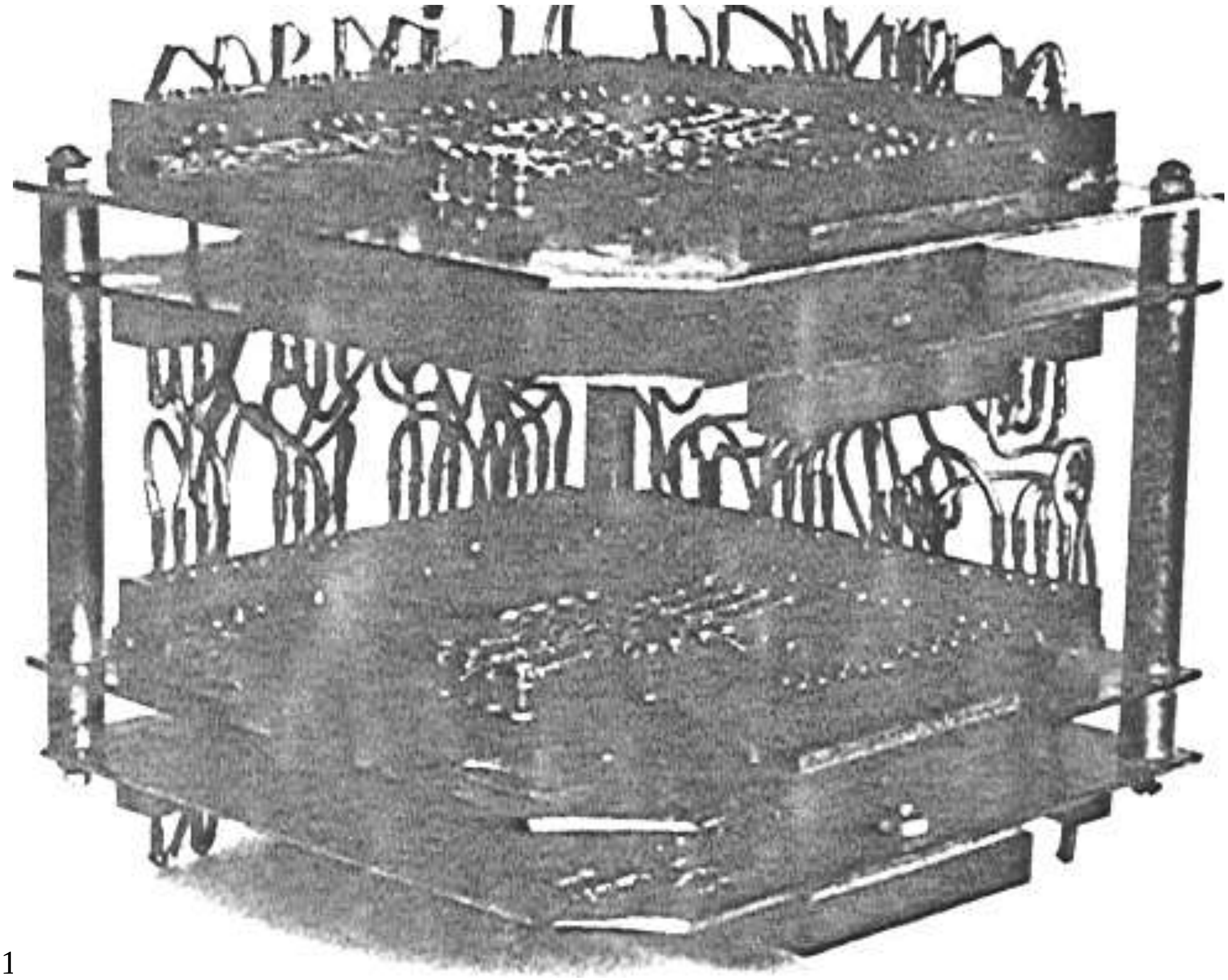


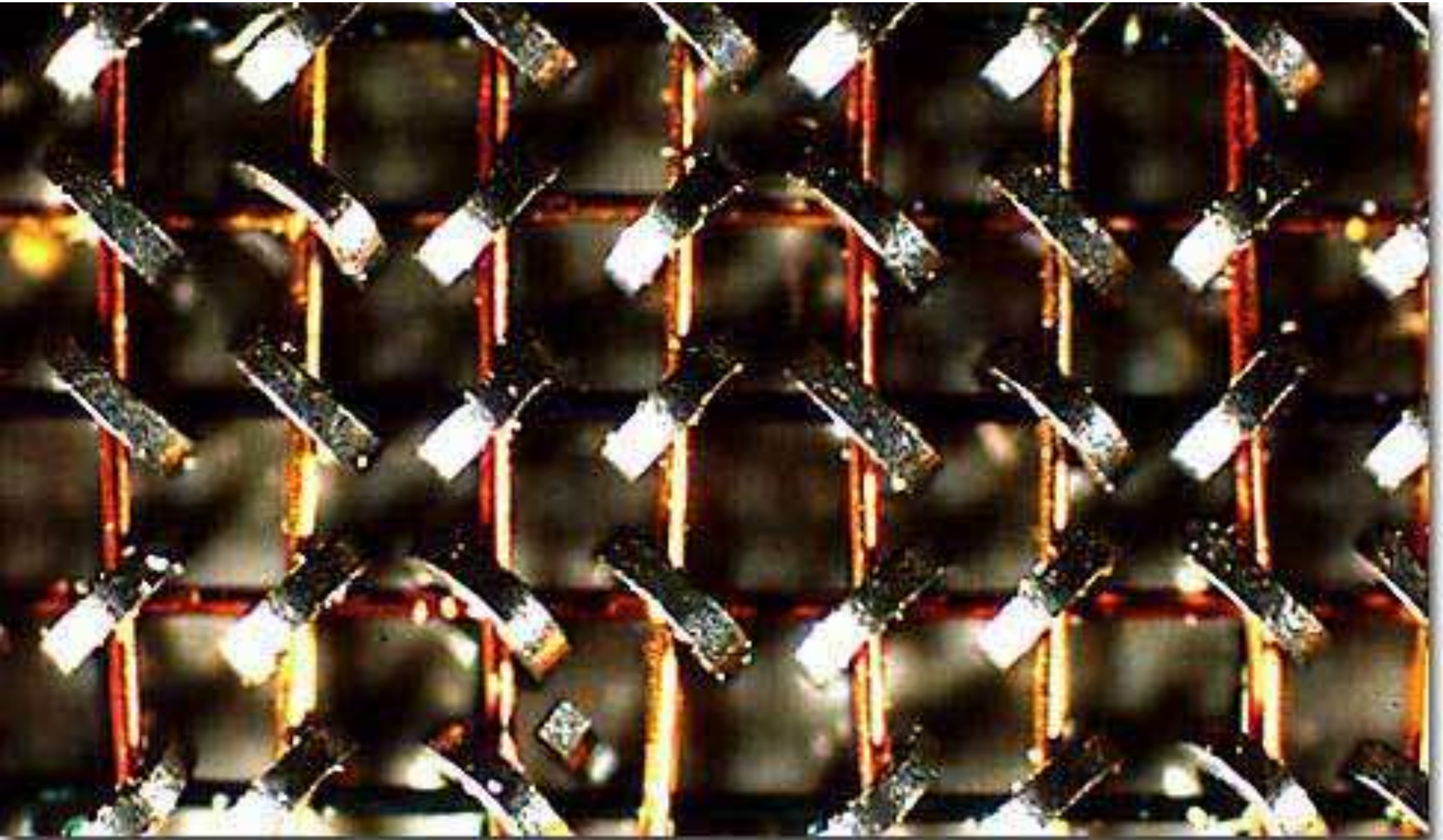
Memory card (c1960)



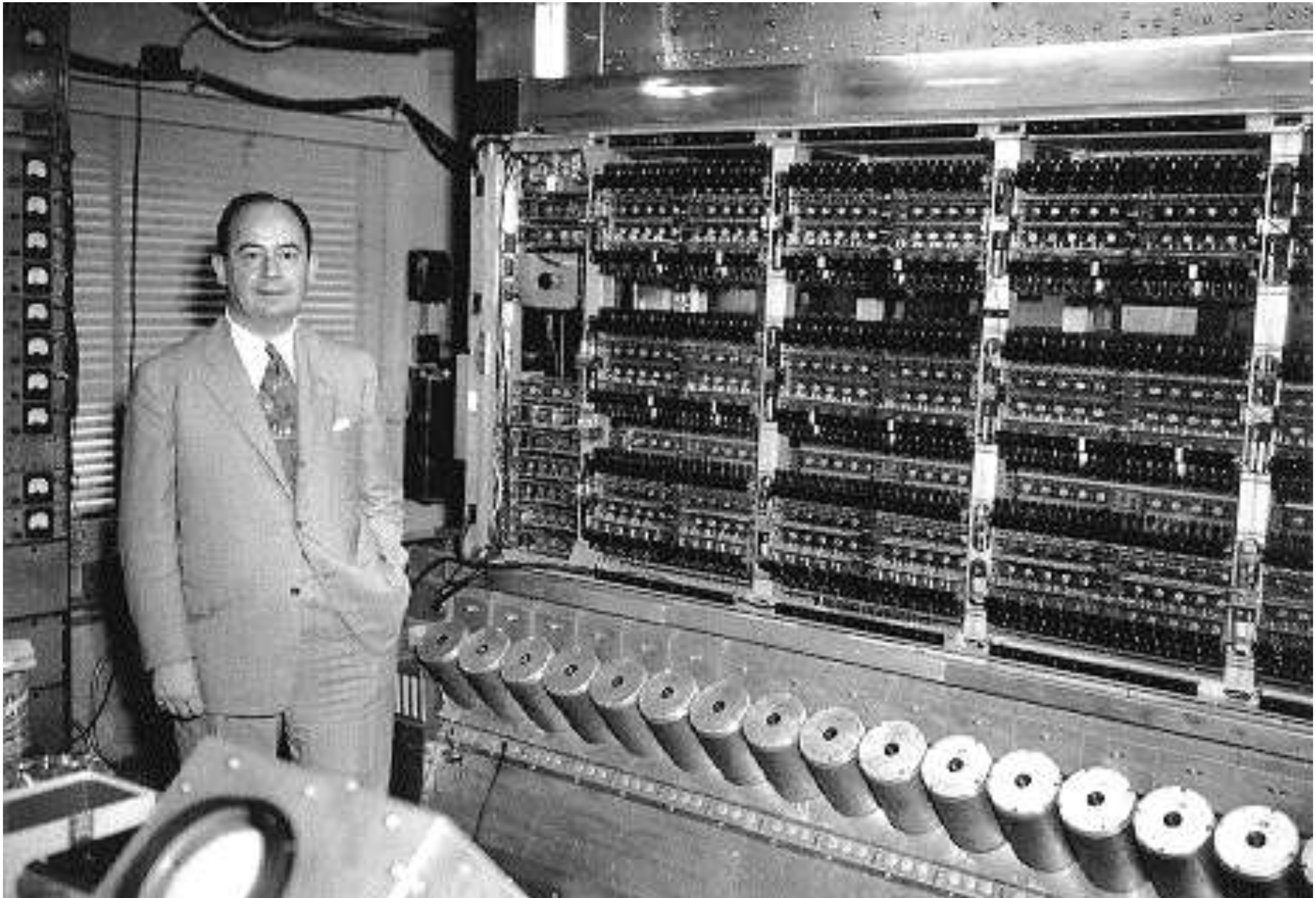


First 4 X 4 Core Memory (IBM 1952)





IAS Machine



Institute for Advanced Study

- March 1946 John von Neumann attempts to set up a computer project at Institute for Advanced Study in Princeton, NJ
- June 1946 Julian Bigelow joins von Neumann and Herman Goldstine; later Arthur Burks
- Summer 1951 IAS machine: limited operation
- **June 1952 IAS fully operational**
  - copies: ADIVAC, ORDVAC, MANIAC, ILLIAC, JOHNNIAC, WEIZAC, etc

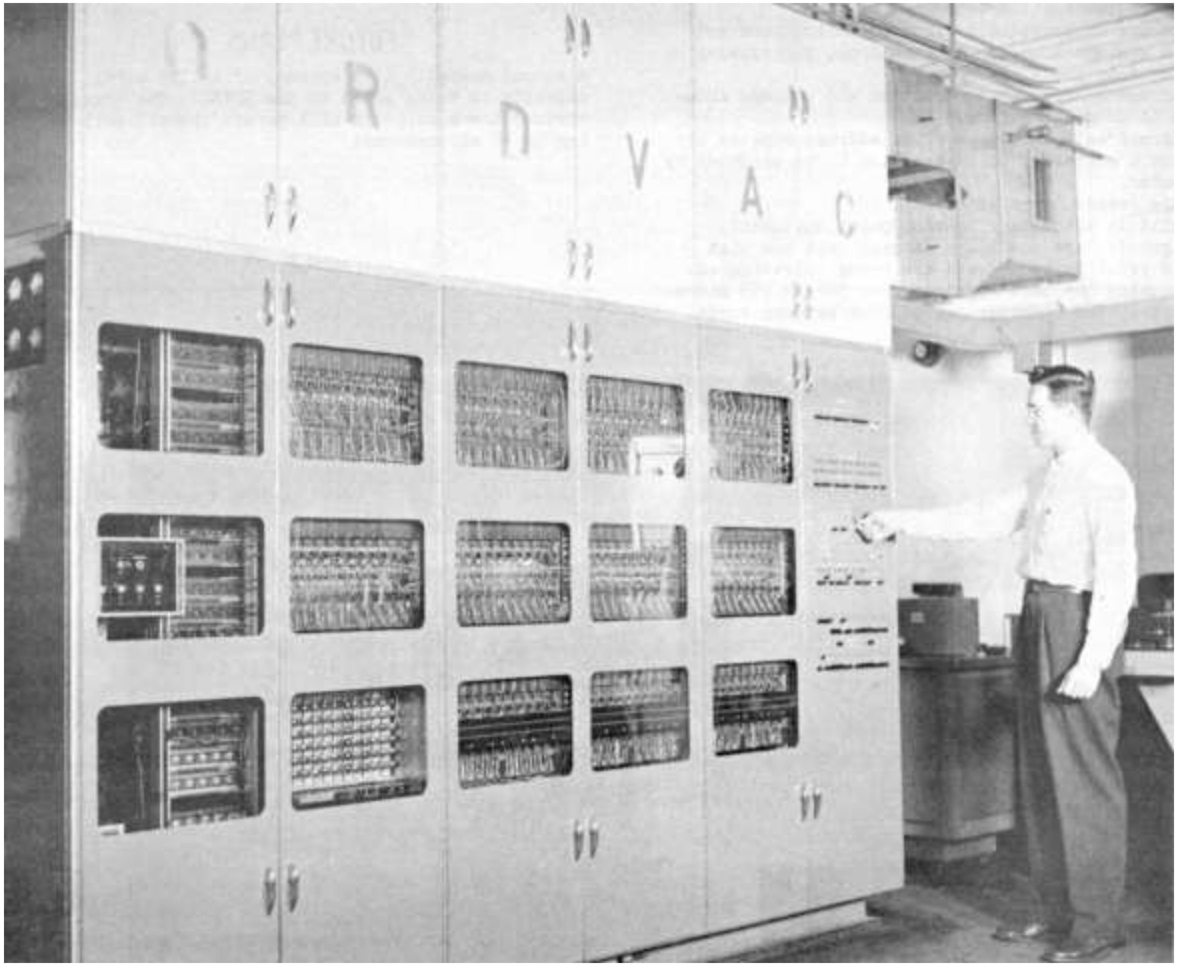
PRELIMINARY DISCUSSION OF THE LOGICAL DESIGN OF AN ELECTRONIC COMPUTING INSTRUMENT by Arthur Burks, Herman H. Goldstine, and John von Neumann

Institute for Advanced Study, Princeton, N.J. (28 June 1946)

- 1.1 Inasmuch as the completed device will be a general purpose computing machine, it should contain certain main organs relating to arithmetic, memory-storage, control….
- 1.2 It is evident that the machine must be capable of storing in some manner not only the digital information needed in given computation…but also the instructions which govern the actual routine to be performed….
- 1.3 Conceptually we have discussed two different forms of memory: storage of numbers and storage of orders. If however, the orders…are reduced to a numerical code…the memory organ can…store... numbers and orders.

Rand Corporation: Johnniac

ORDVAC at ARL



British efforts...

- August 1946 Maurice Wilkes considers building a computer at Cambridge University
- September 1946, F.C. Williams and T. Kilburn join computer project at Manchester University
- January 1947 Harry Huskey arrives at National Physical Laboratory (NPL)
- January 1947 Construction starts on Electronic Discrete Serial Automatic Computer (EDSAC)
- June 1947 Manchester prototype limited operation
- May 1948 EDSAC fully operational

Other Efforts

- 1948 Standards Eastern Automatic Computer (SEAC) started at NBS (operational April 1950)
- 1949 Standards Western Automatic Computer (SWAC) started at the Institute for Numerical Analysis, NBS (@ UCLA)


NBS WESTERN AUTOMATIC COMPUTER

Whirlwind (MIT)

- Operational: 1950
- Word Length: 16 bits (8 bit character)
- Speed: 16 microseconds (max)
- Memory: 2048 word addressable core
- Storage: revolving drums, tapes
- Instruction set: 32 instructions
- Assembly/machine language (OCTAL)
- Size: 50’ X 50’ X 20’
- Technology: 15,000 vacuum tubes
- Power: 150,000 watts
- Begun in 1947, completed in 1957

Some Whirlwind Innovations

- magnetic-core memory
- graphical output terminal to display results
- light pen for operator interaction
- software aids
- diagnostic routines
- data communications over telephone lines
- computer-run air-traffic control (SAGE)
- automatic control of machine tools
- time sharing

References

- Nancy B. Stern, *From ENIAC to UNIVAC, An Appraisal of the Eckert-Mauchly Computers*, Digital Press, 1981
- Kathleen R. Mauchly, "John Mauchly's Early Years, *Annals*, Vol.6, No.2 (April 1984)
- Herman Goldstine, *From Pascal to von Neumann*, Princeton University Press, 1972
- Emerson Pugh, *Memories that Shaped an Industry*, MIT Press, 1984

- Redmond & Smith, *Project Whirlwind*, *The History of A Pioneer Computer*, Digital Press, 1980.

Show and Tell

- delay line memory, core memory plane(s), drum
- Photographs: Electronic Control Company: BINAC construction team, etc.
- *The Moore School Lectures*
- Wheeler, Wilkes and Gill, *The Preparation of Programs for an Electronic Digital Computer*
- Project Whirlwind *Report R-166*