The History Of Computers: Part II[1]

You will learn about the computers of the 20th century and the people behind those machines.

1 Part I deals with technologies from an earlier period and while it won't be covered in this class I do talk about them in other classes.

Technology Of 20th Century Computers

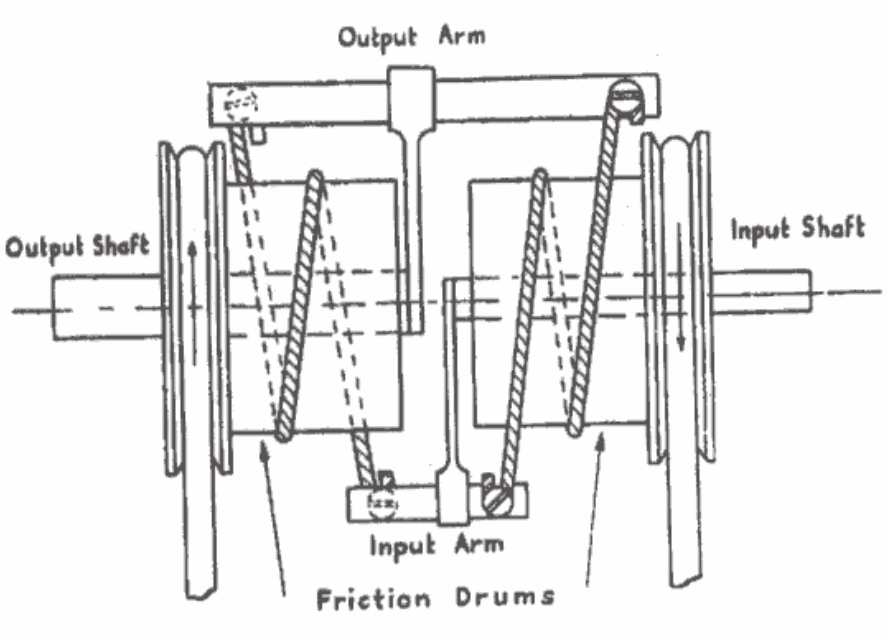
- The mechanical monsters of the twentieth century
  - The machines of Konrad Zuse
  - The Bell telephone models
  - Howard Aiken and the Harvard computers
- The computers of the electronic revolution
  - The ABC
  - The ENIAC
  - The Colossus machines of Bletchley Park

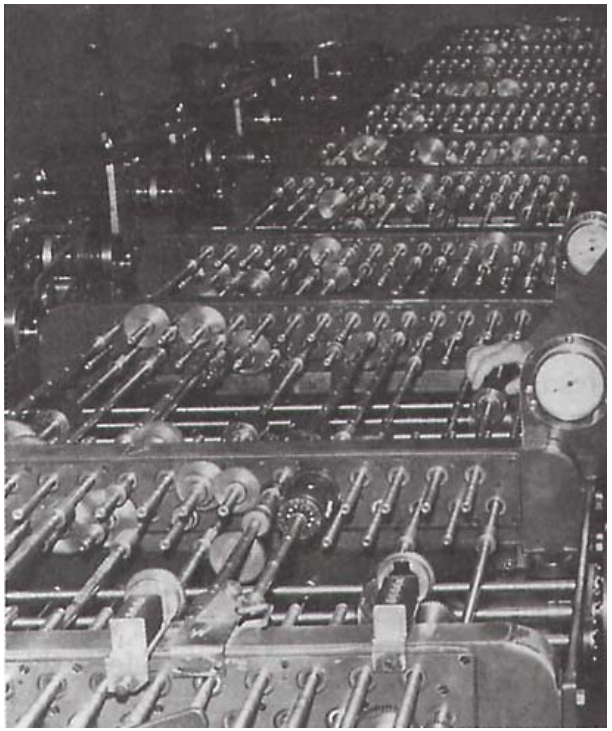
Technology Of 20th Century Computers (2)

- Early forms of computer memory
  - Thermal
  - Mechanical
  - Delay lines
  - Electrostatic
  - Rotary magnetic
  - Stationary magnetic
- The first modern (stored program/memory) computers
  - The Manchester machine
  - The EDSAC
  - The EDVAC
  - The machine of the Institute for Advanced Study (IAS)
  - The BINAC/UNIVAC

The Mechanical Monsters

- Performed calculations using moving mechanical parts rather than using electronics

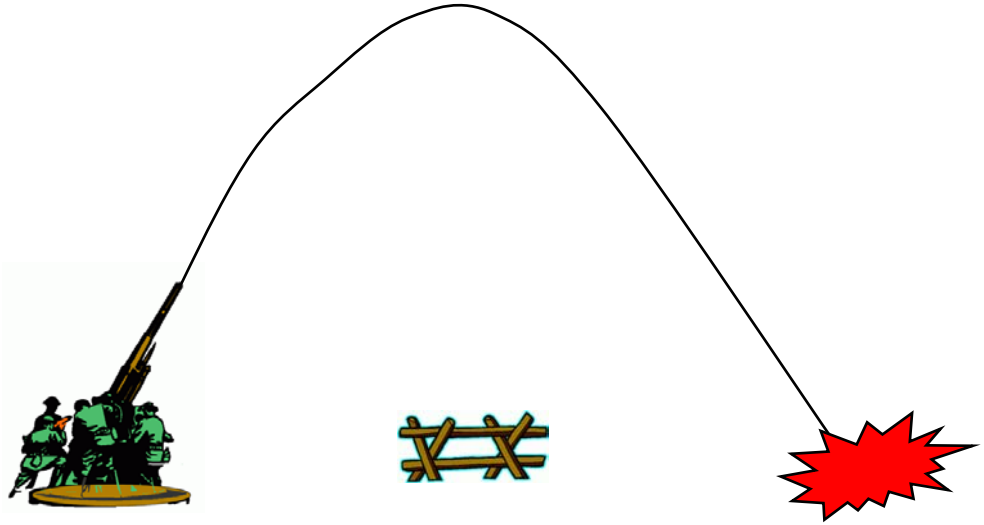




Images from the History of Computing Technology by Michael R. Williams

The Mechanical Monsters

- Many were used to solve equations that were either impossible or very time consuming to solve analytically.
- Often conducting experiments were also impractical.

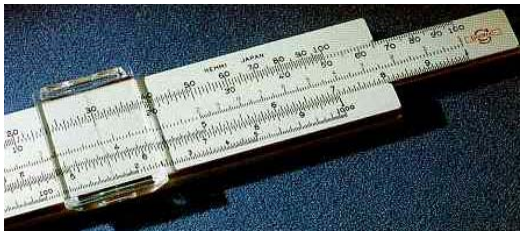


The Mechanical Monsters

- Konrad Zuse
  - Z1 – Z4
- George Stibitz
  - Bell relay based computers Model I - VI
- Howard Aiken
  - Harvard Mark I - IV

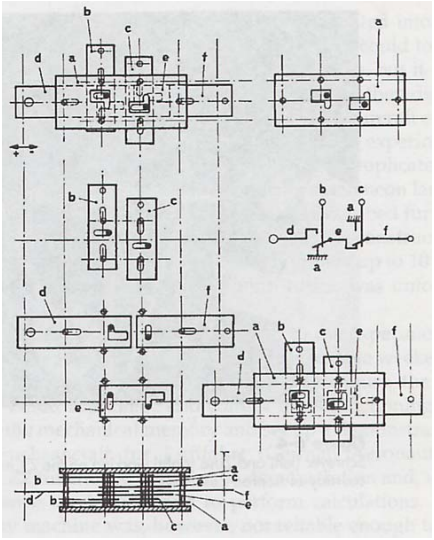
The First Set Of Mechanical Monsters Were Created By Konrad Zuse

- Developed a series of mechanical calculating machines (Z1, Z2, Z3, Z4).
- Motivated by the need to perform complex calculations because current approaches were unsatisfactory.



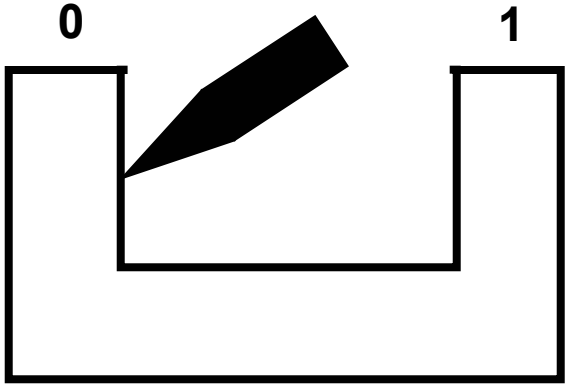
The Z1

- It was entirely mechanical



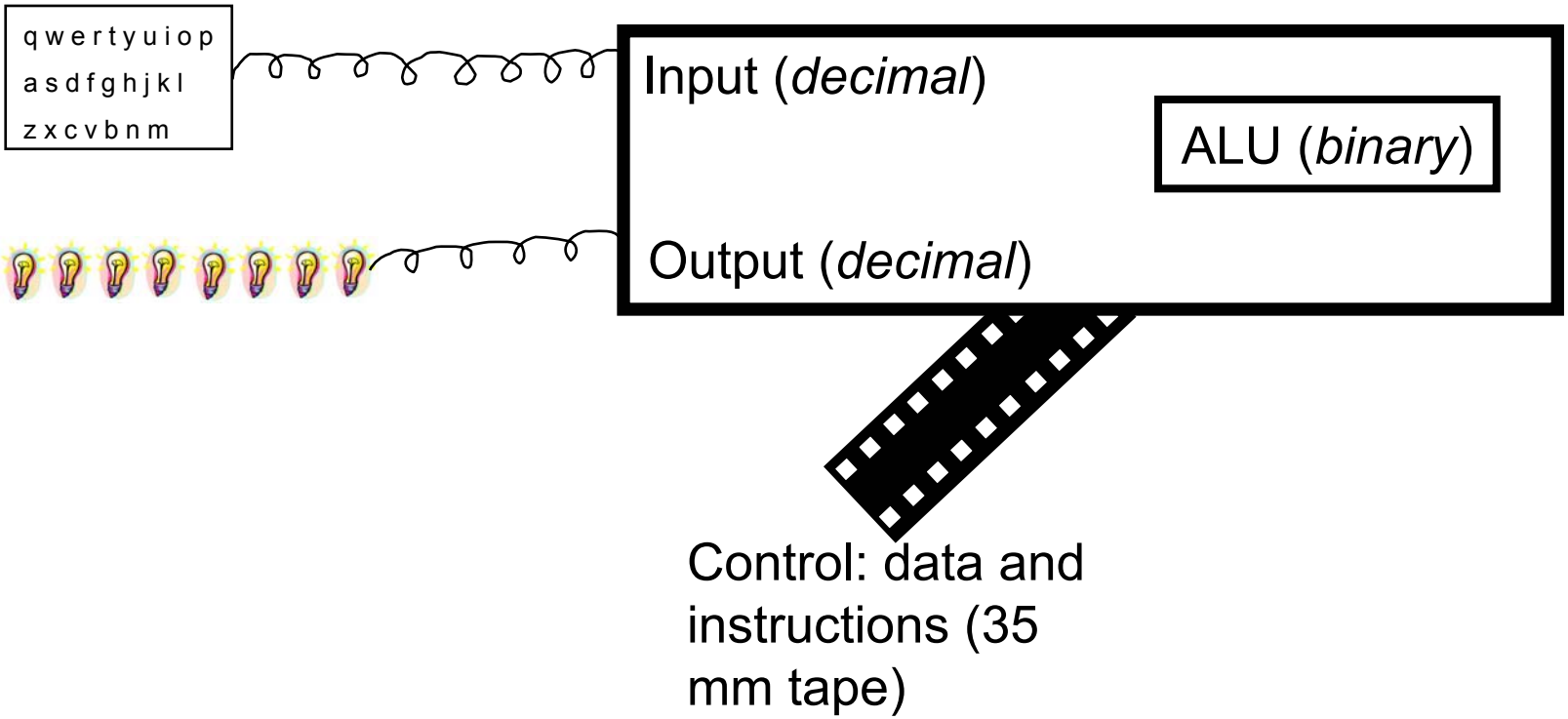
From the History of Computing Technology by Michael R. Williams

- It was used binary as it's basic unit of information storage:



The Z1 (2)

- Overview of the architecture



The Z1 (3)

- This machine was developed in isolation with limited resources in less than ideal conditions and completed in 1938.

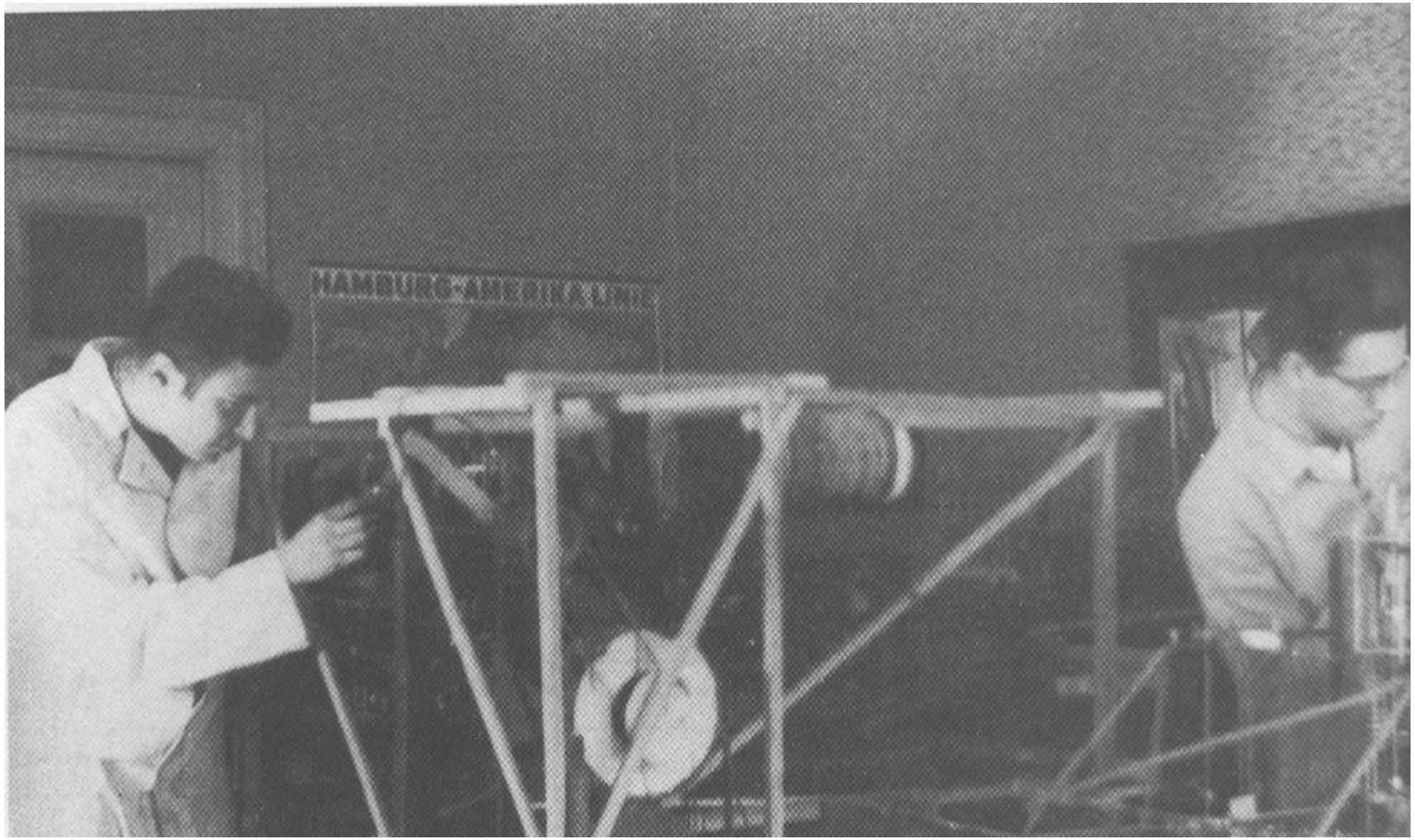


Image from the History of Computing Technology by Michael R. Williams

The Z1 (4)

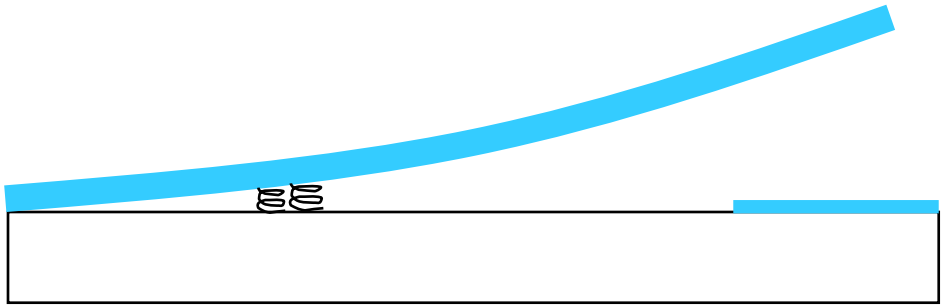
- The memory worked well but the complex routing of the ALU made the transport of information between the parts of the machine problematic:

ALU: Sheets of metal

Location: Cramped Berlin apartment (routing around corners?)

The Z2

- Designed to overcome the signal routing problem using relays
- It was completed in 1939.



- It's one major contribution was to get funding from the Deutsche Versuchsanstalt fur Luftfahrt (German Aeronautical Research Institute) to allow for further work.

The Z3

- Although the work was funded by the German Aeronautical Research Institute, Zuse was not provided with a workspace or technical staff.
- As was the case with the Z1, he completed his work with limited resources (1941).

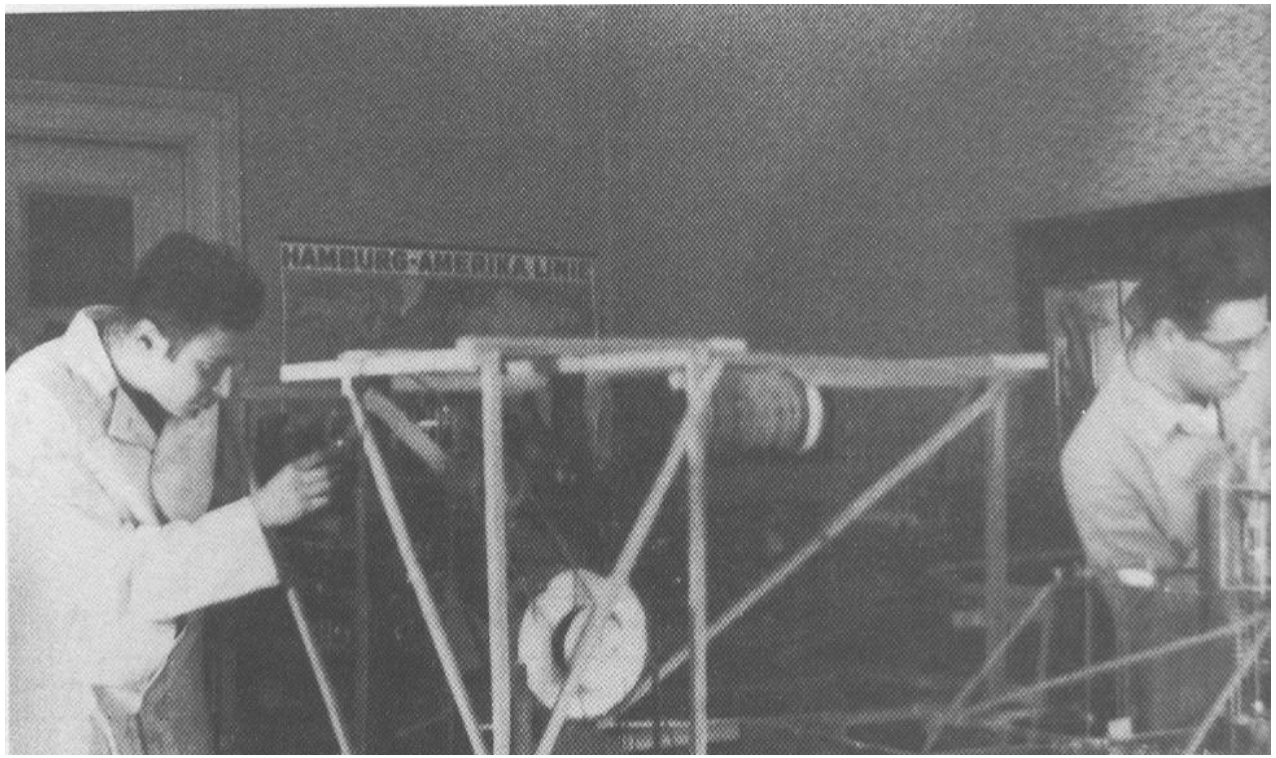
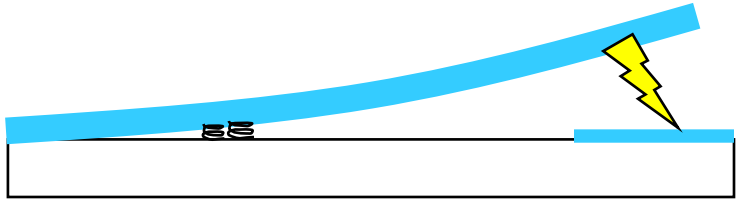


Image from the History of Computing Technology by Michael R. Williams

The Z3 (2)

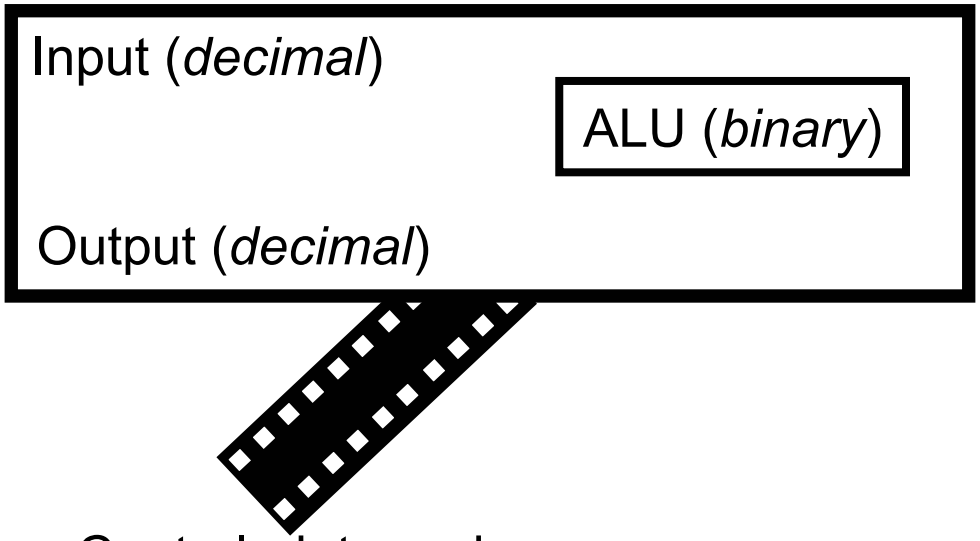
- This machine was similar to the Z1 and Z2 (input, output and control)
- It overcame the reliability problems of the relay-technology



- It was a relatively fast machine (considering the limited resources and relative isolation of Zuse)
  - 3 – 4 additions per second
  - Multiply two numbers every 4 – 5 seconds
  - (Comparable to the speed of the Harvard Mark I which was developed two years later)
- It was developed on a relatively modest budget:
  - 25,000 RM (~$6,500 US)
- But it wasn't practical for large scale problems (limited memory)

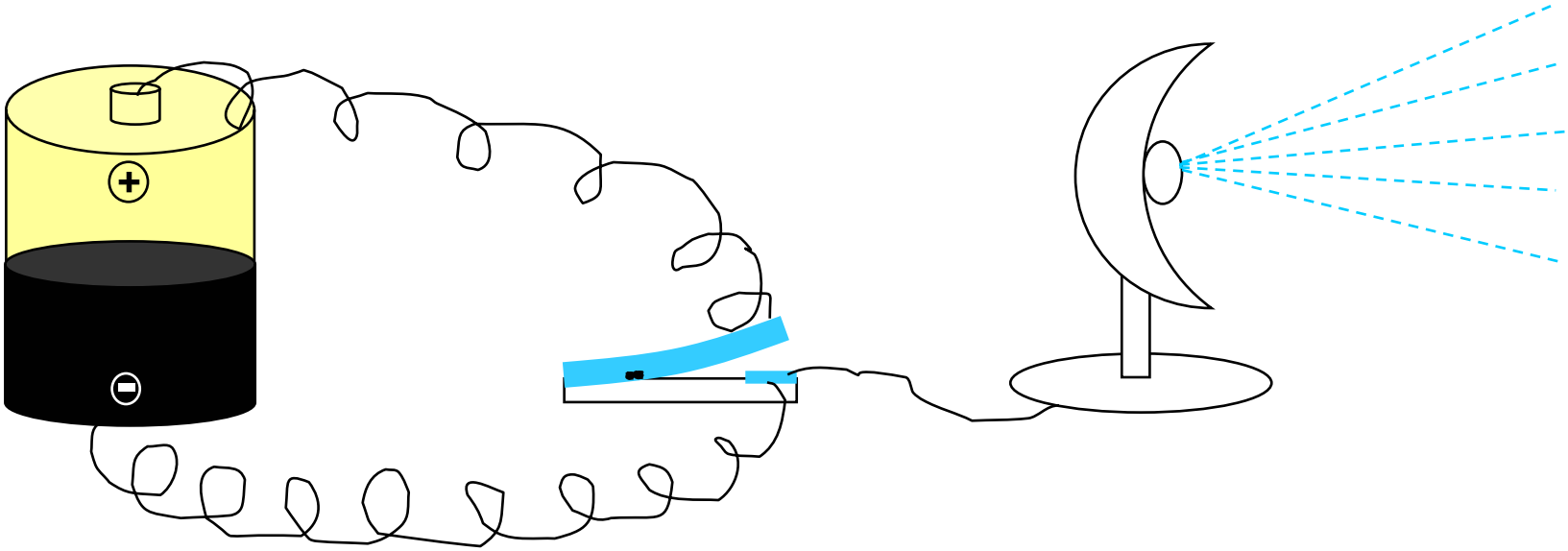
The Z3 (3)

- The main significance was the implementation of the control mechanism.



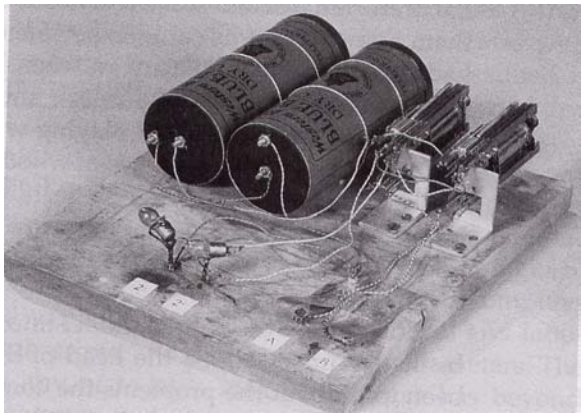
The Second Set Of Mechanical Monsters: The Bell Relay Based Computers

- Motivation: Working with complex numbers on a computing device was problematic.
- George Stibitz, a mathematician at Bell labs, created a prototype relay based computer



The Second Set Of Mechanical Monsters: The Bell Relay Based Computers (2)

- The prototype worked but was somewhat limited.



- But it was enough to enlist the aid of some work colleagues.

The Bell Complex Number Calculator

- The Model I was completed in 1949 at a cost of $20,000.
- The Bell Computer could add, subtract, multiply and divide complex numbers.
- Employed simple switches and flash bulbs.

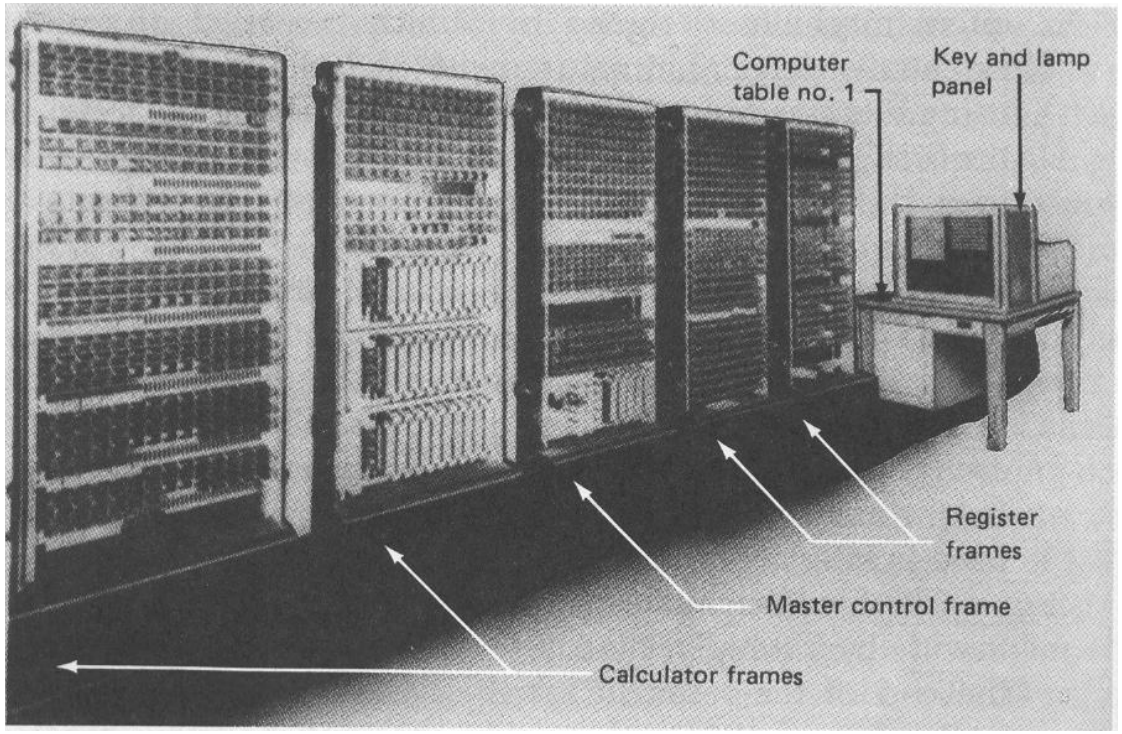
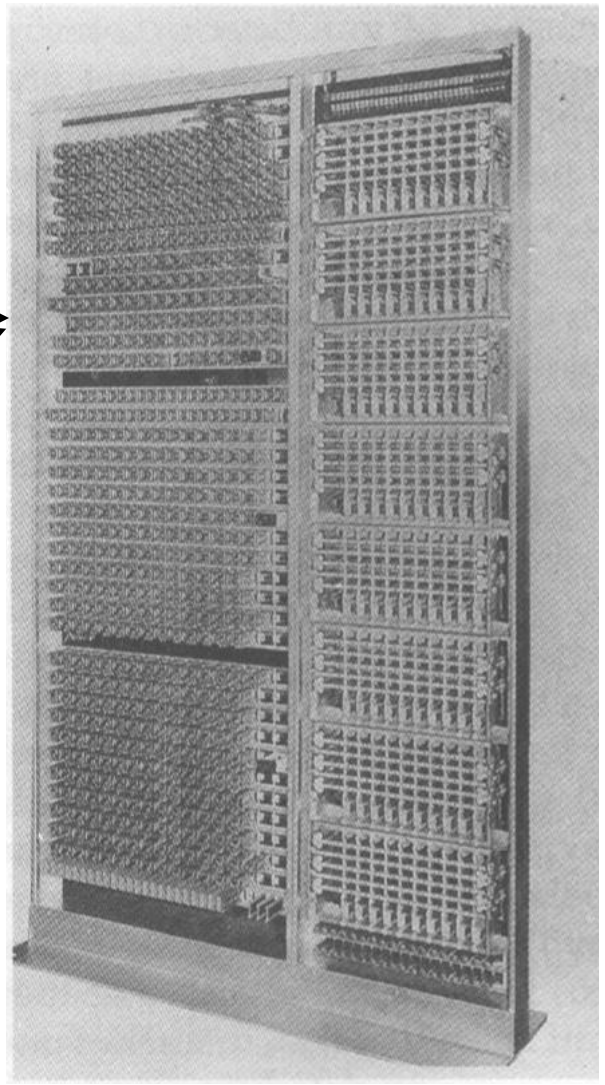


Image from the History of Computing Technology by Michael R. Williams

The Bell Complex Number Calculator (2)



Photos from Bell Technologies Inc.

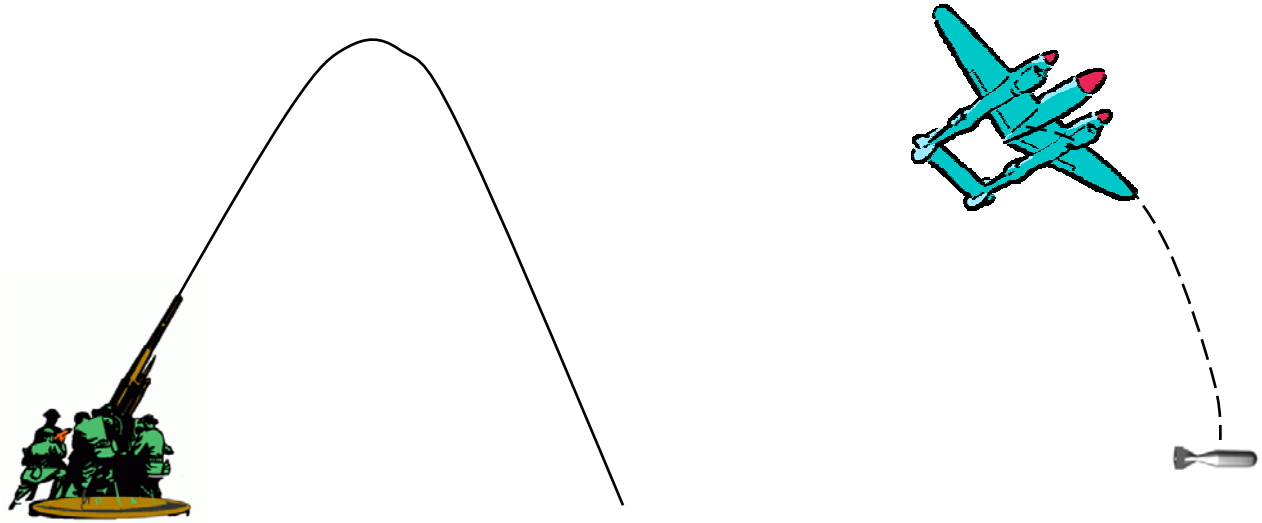
The Bell Complex Number Calculator (3)

- The computer used it's own form of binary, Binary Coded Decimal (BCD).

Decimal value	BCD value
0	0011
1	0100
2	0101
3	0110
4	0111
5	1000
6	1001
7	1010
8	1011
9	1100

Successive Bell Models

- The Model II – V were used in ballistics research.



- The Model VI was developed for the same purpose as the original Model I.

The Third Set Of Mechanical Monsters: The Harvard Machines

- It was developed with the meeting of two men.

- Howard Aiken:

  - A graduate student in the department of Physics at Harvard.
  - Focused on equations that couldn't be solved by standard approaches.
  - These problems were beyond the capabilities of the machines of that era.
  - Unlike most of the developers of the time he was not fixated on a particular technology.

- Thomas J. Watson

  - Head of IBM
  - Aiken convinced Watson to fund the building of a machine to solve these types of problems.

The Harvard Mark I

- It was officially called "The IBM automatic sequence controlled calculator" but it soon became known as the Harvard Mark I.
- It was huge:
  - Size: 51' long x 8' high
  - Wiring required: 500 miles
- It was expensive:
  - ~$400,000 - $500,000.

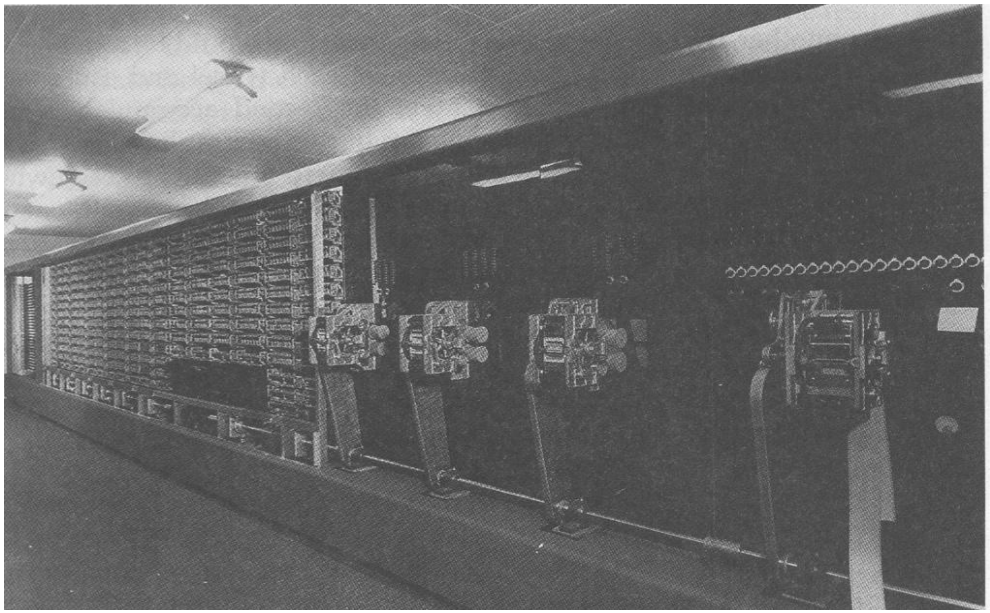
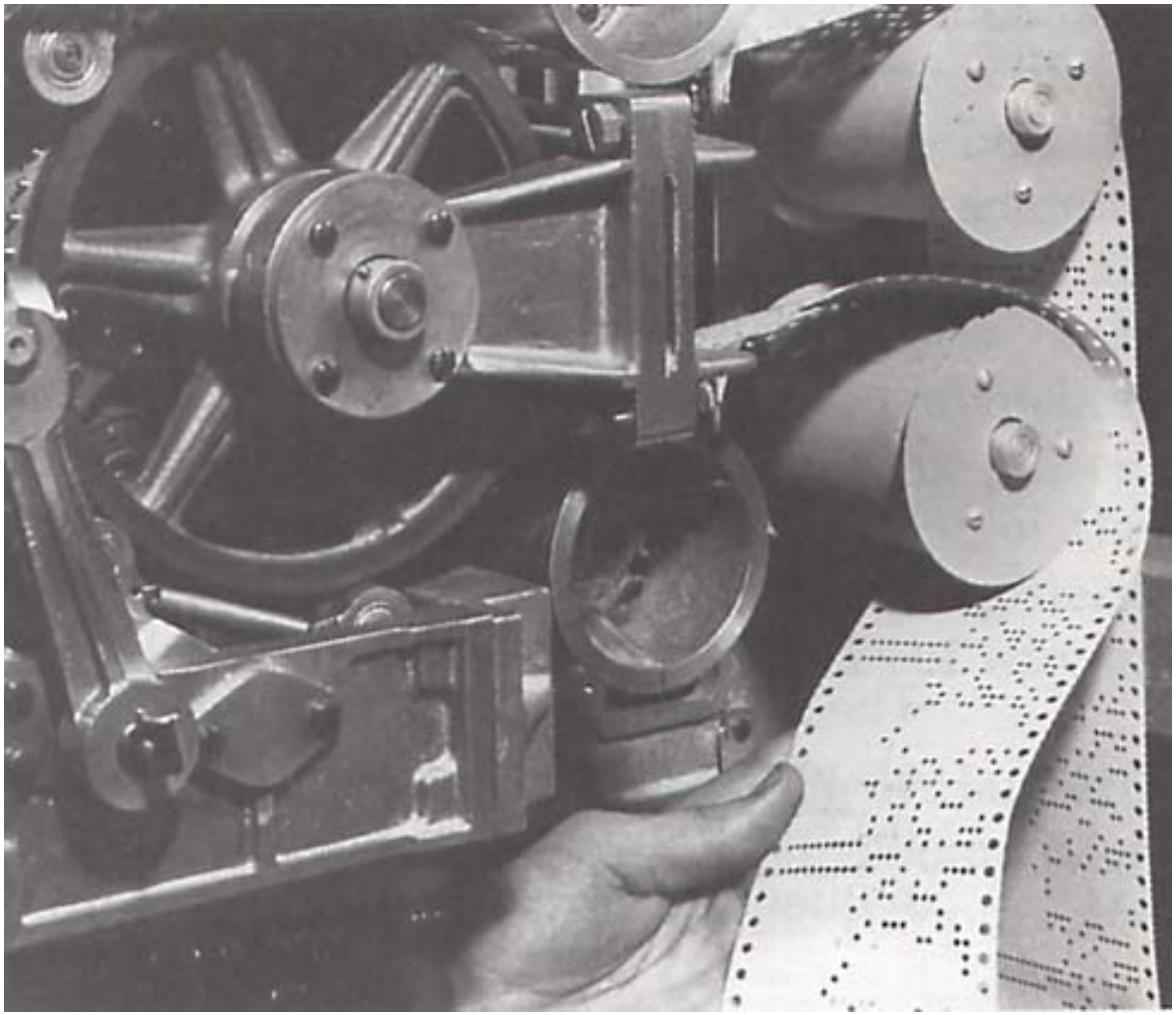


Image from the History of Computing Technology by Michael R. Williams

The Harvard Mark I (2)

- It was built with parts from IBM accounting machines and controlled via punched tape.



Images from the History of Computing Technology by Michael R. Williams

The Harvard Mark I (3)

- It was slow:
  - Multiplications took ~6 seconds
- Extremely accurate
  - 23 digits for a signed number
  - Fixed decimal point: typically 15 or 16 places of precision.
- Used for a number of purposes:
  - The US war effort (the U.S. navy, bureau of ordinance)
  - Solving mathematical problems
- Frequently used as a design model in subsequent machines.

Other Harvard Machines

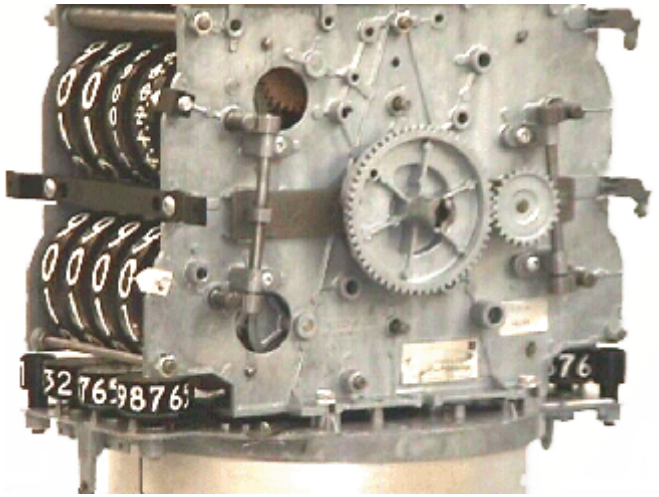
- Mark II:
  - Unlike the Mark I it was built almost entirely with relays.
- Mark III & Mark IV:
  - Development focused on the ease of use over raw speed.
  - Aiken boasted that the Mark IV was the slowest machine in the world because it took 12.75 ms to perform a multiplication.

The Computers Of The Electronic Revolution

- These computers used electronics over mechanical parts.

Electronic vacuum tube

Mechanical "computer"



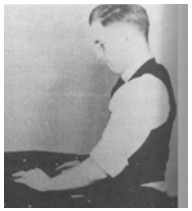
Categories Of Electronic Computers

- The ABC
- The ENIAC
- The Bletchley Park computers

The People Behind The ABC (Atanasoff-Berry Computer)

- John Atanasoff
  - A professor at Iowa State College (now Iowa State university)

- Clifford Berry
  - A graduate student studying under Atanasoff



Motivations For Developing The ABC

- Atanasoff was researching methods of solving complex mathematical equations.

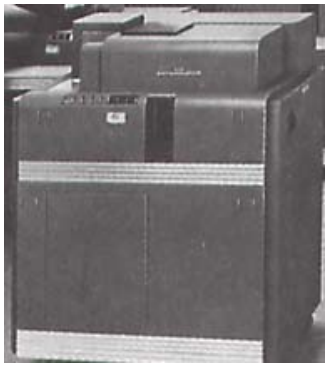
$$\varepsilon_0 \oint E \cdot dA = \sum q$$

$$\oint B \cdot ds = \mu_0 \int J \cdot dA + \mu_0 \varepsilon_0 \frac{d}{dt} \int E \cdot dA$$

$$\oint E \cdot ds = -\frac{d}{dt} \int B \cdot \cdot dA$$

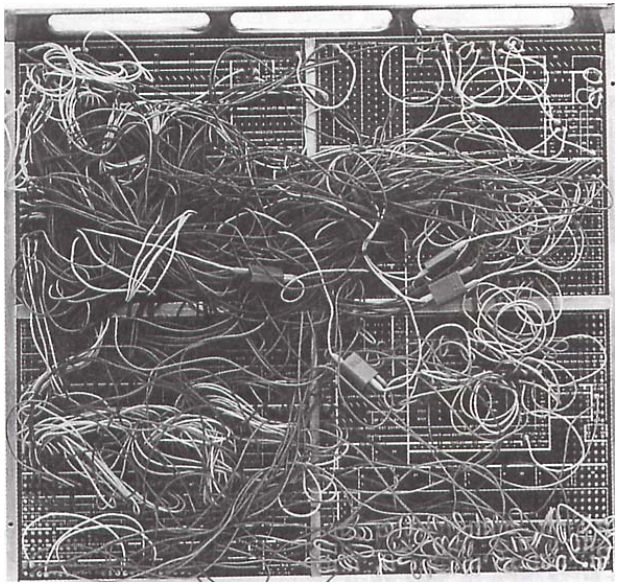
$$\oint B \cdot dA = 0$$

- He started by modifying the small IBM calculator that was leased to the college to see if it could solve these problems.



Motivations For Developing The ABC (2)

- His modifications were extensive



- The folks at IBM weren't happy with the modifications

Motivations For Developing The ABC (3)

- Atanasoff then decided to build his own machine.
- Unfortunately this proved to be more of a daunting task than he first anticipated.

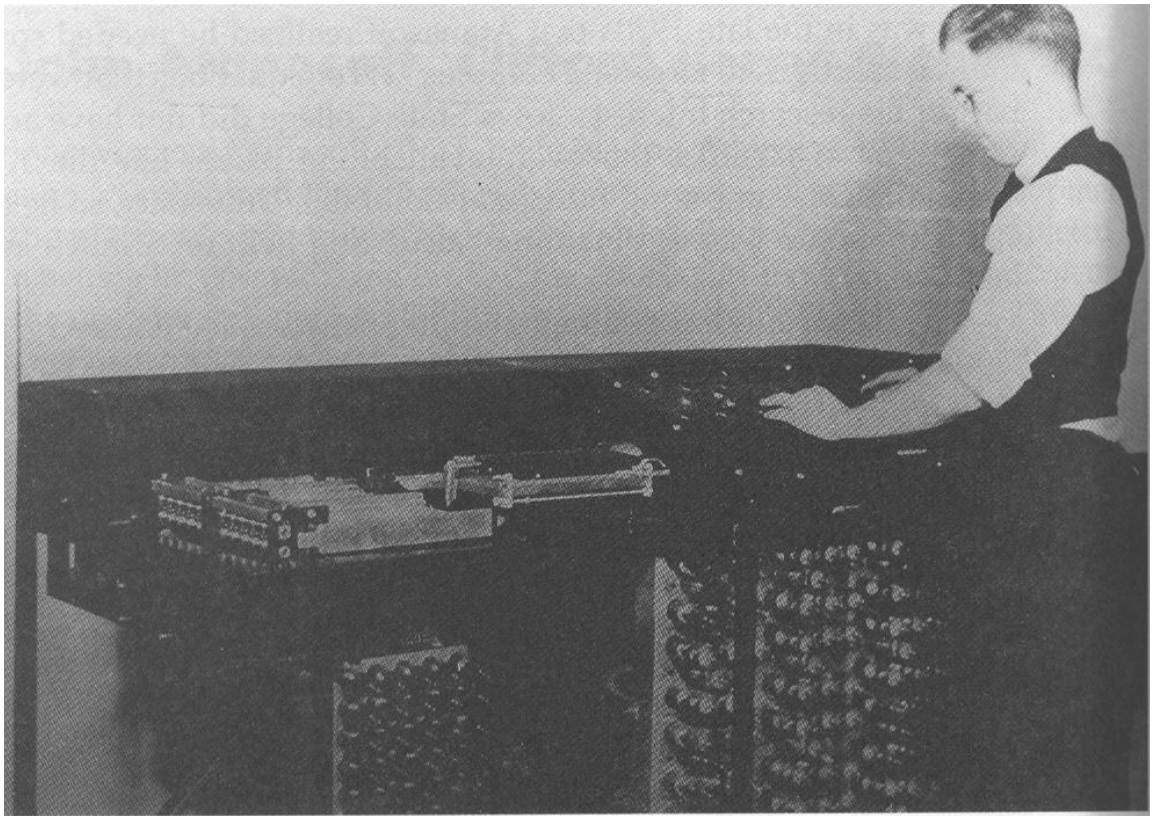
- After a particularly frustrating night he decided to take a break from the lab.

- This lead to an astonishing break through!

Wav file from “The Simpsons”

The First Electronic Computer: The ABC

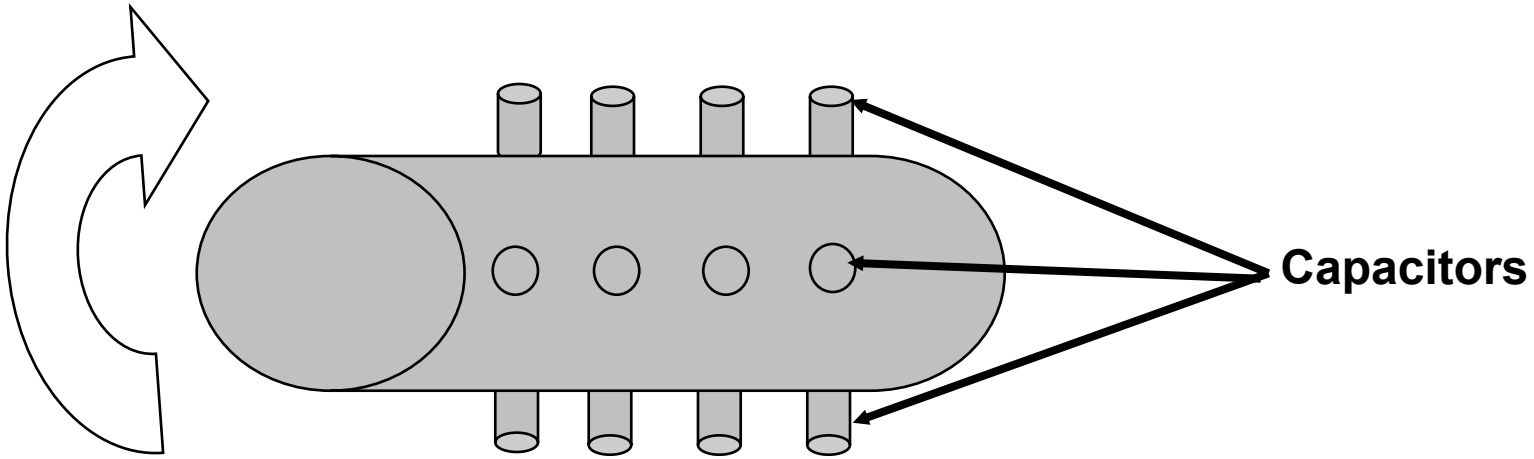
- After enlisting the aid of Berry and several years of hard work the ABC was *nearly* completed at a cost of $6000 (including the $450 paid to Berry) in 1942.
- It was the first *prototype* electronic computer!



A photo of Clifford Berry and the ABC, courtesy of Dr. Atanasoff

The First Electronic Computer: The ABC (2)

- It used a form of regenerative memory that was similar to the kind used in modern D-RAM
- But it was not a stored program computer.



The Moore School Of Electrical Engineering

- It was a major provider of technical and computing resources for the US arm (Ordinance department, ballistics research lab)

- Current approaches to calculate trajectories were too slow and the ENIAC was developed to solve these problems.

The People Behind The ENIAC

- John Mauchly
  - A Physics professor at Ursin College.
  - Developed the designs for the ENIAC

- J. Presper Eckert
  - A lab instructor at the Moore School
  - Designed the individual circuits of the ENIAC

- Joseph Chedaker
  - Supervised the construction team

The Second Electronic Computer: The ENIAC (Electronic Numerical Integrator Calculator)

- It was completed in 1949 at a cost of $500,000
- The machine was huge and required a great deal of resources
  - 8’ high x 3’ deep x 100’ long
  - 30 tons
  - 140,000 watts to power
  - 18,000 vacuum tubes, 1500 relays, 10,000 capacitors

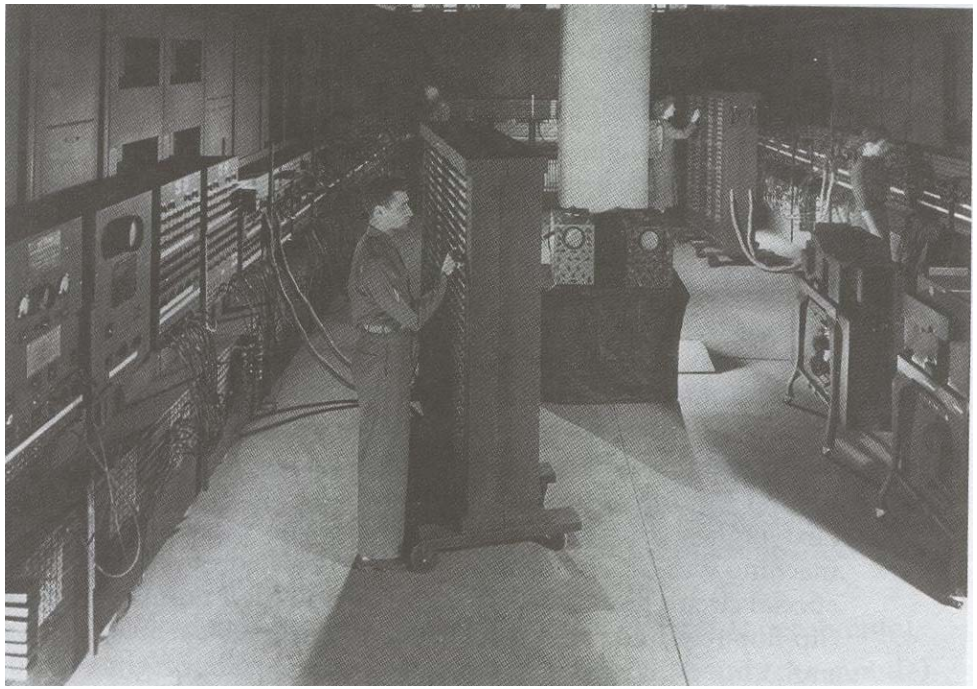
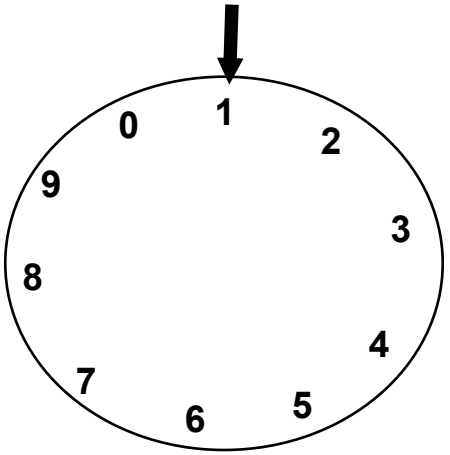


Image from the History of Computing Technology by Michael R. Williams

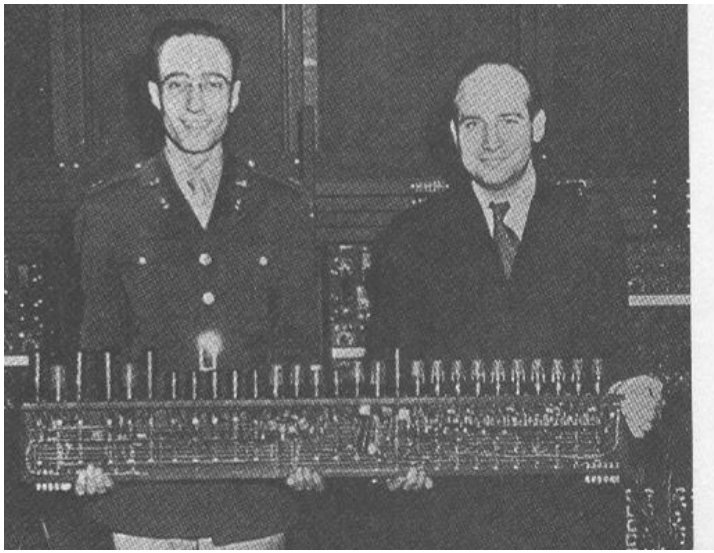
The Second Electronic Computer: The ENIAC (2)

- Many of the components were just electronic equivalents of the mechanical version.
- E.g., to store a single digit:

Mechanical approach



The approach used in the ENIAC

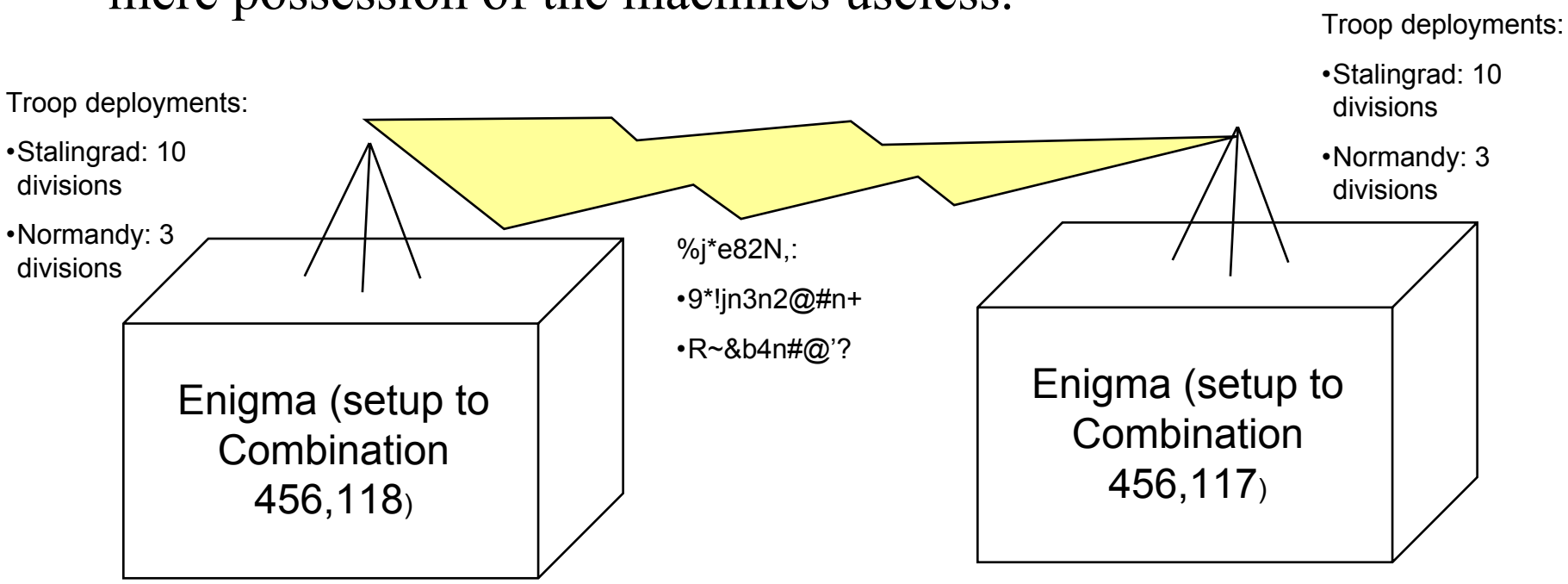


The ABC And The ENIAC

- The ABC was the first *prototype* electronic computer (not quite completed): 1942.
- The ENIAC was the first *fully operational* electronic computer (finished): 1949.

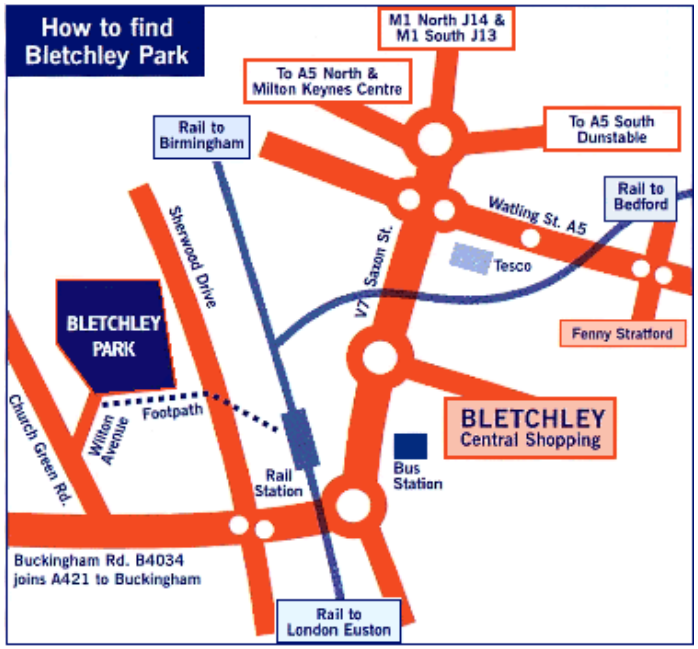
The Machines At Bletchley Park: Colossus Machines

- The Enigma machines: used before and during WWII by Germany as an encryption device.
- There were two version: one for the military and one for business.
- The sheer number of possible combinations (100 billion!) made mere possession of the machines useless.



The Machines At Bletchley Park: Colossus Machines (2)

- The British code breaking group, the Code and Cipher School worked on deciphering the German codes at Bletchley Park outside of London:



- Intelligence work involved a great deal of secrecy:
  - Information was strictly on a "need to know basis" for the people working there.
  - Even now much of the information is still classified

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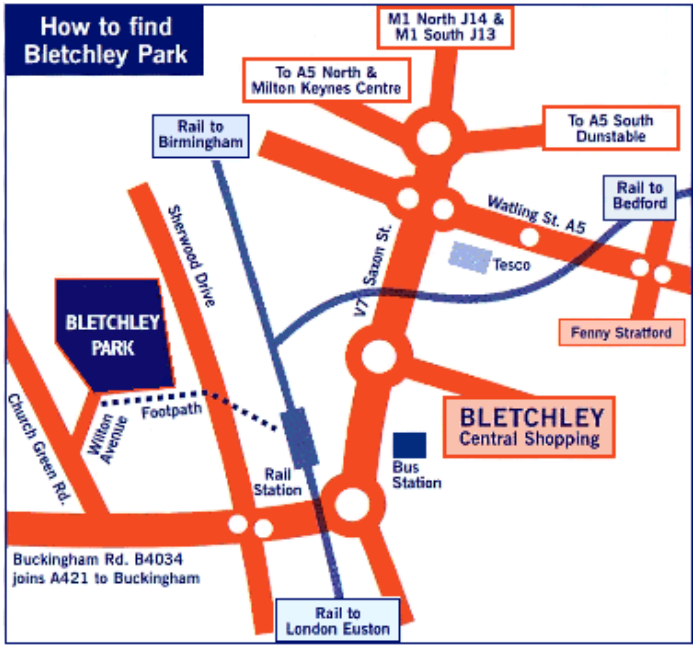

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Top secret

Alan Turing

- A distinguished British Mathematician from Cambridge
- He worked at Bletchley Park as a code-breaker (contributed to the design of the machinery as well as applying his Mathematical knowledge)

Image from the History of Computing Technology by Michael R. Williams

The Third Set Of Electronic Computers: The Machines At Bletchley Park

- Heath Robinson machines (1942)
  - Used a combination of mechanical relays and electronic vacuum tubes
  - Their exact function is still unknown but they were probably used for deciphering the German codes
  - Unreliable
- The Colossus (1943)
  - Developed to replace the Heath Robinson machines
  - Addressed the reliability problem by replacing the relays with vacuum tubes
  - The produced a remarkable increase in speed over the previous machines.
  - Miraculously the first one was completed in less than a year.

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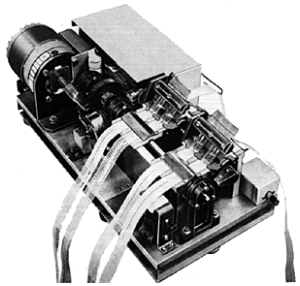
Top secret

Top secret

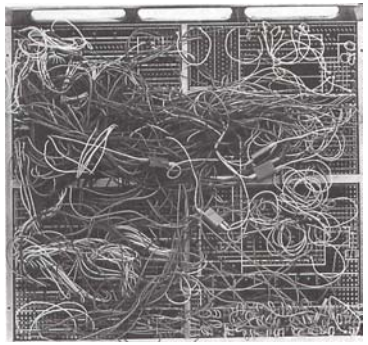
Before The First Stored Program Computers

- Before these computers were developed existing machines received their instructions from:
  - Punch card

  - Punch tape



  - Complex wiring and rewiring techniques.



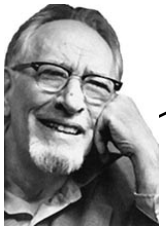
Who Came Up With The Concept Of The Stored Program Computer?

- The answer
  - It's shrouded in a great deal of controversy.
- The location where the idea was developed
  - The Moore School (the team that developed the ENIAC: Eckert and Mauchly) near the end of the second World War ~late 1943 – early 1944.
- The person most widely credited with coming up with the idea
  - John Von Neumann
  - Starting Sept. 1944 he became a regular visitor in the Moore school

  - Based on the ideas being discussed he wrote "*The First Draft of a Report on the EDVAC*".
  - He received so much notoriety that modern computers are sometimes referred to as "Von Neumann machines".

Who Came Up With The Concept Of The Stored Program Computer? (2)

- Finally in 1947 a judge made a ruling on the case



Early Forms Of Computer Memory

- Thermal
- Mechanical
- Delay line
- Electrostatic
- Rotary magnetic
- Stationary magnetic

Thermal Memory

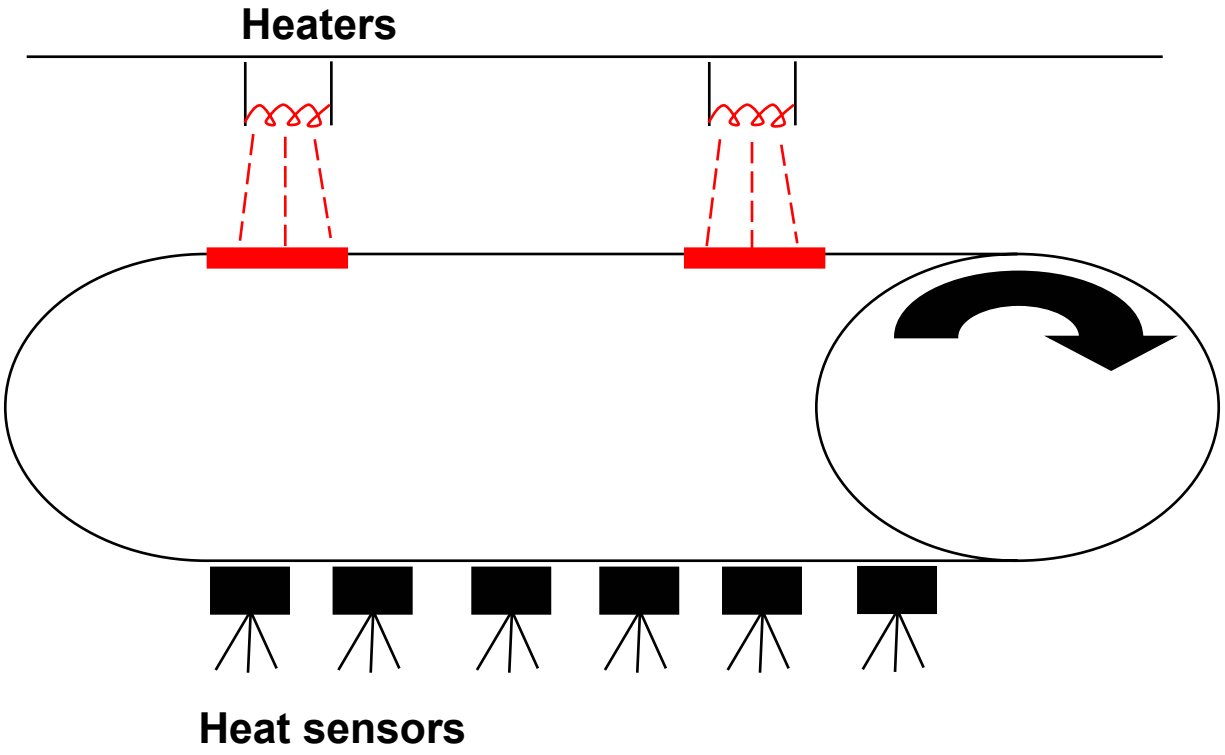
- In Britain after WWII Andrew Donald Booth experimented with creating a practical form of computer memory

Picture from the School of Computer Science and Information Systems at Birkbeck College.

Thermal Memory (2)

- His first attempt involved a heat transfer process

Cooling fan

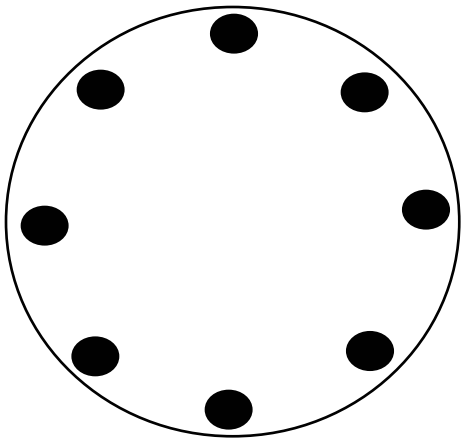


Thermal Memory (3)

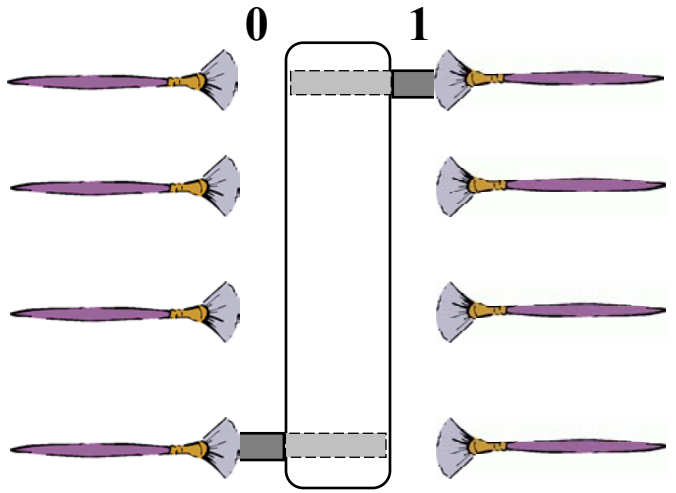
- Thermal-based memory technology never proceeded past the experimental stage.
- It was abandoned by Booth in favor of mechanically based memories.

Mechanical Memory

- Because of the reliability problems of the heat based memory Booth then experimented with various forms of mechanically based memories.
- The first version employed brushes and pin (*the disk-pin memory system*)



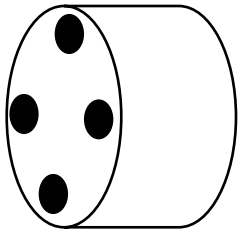
Front view



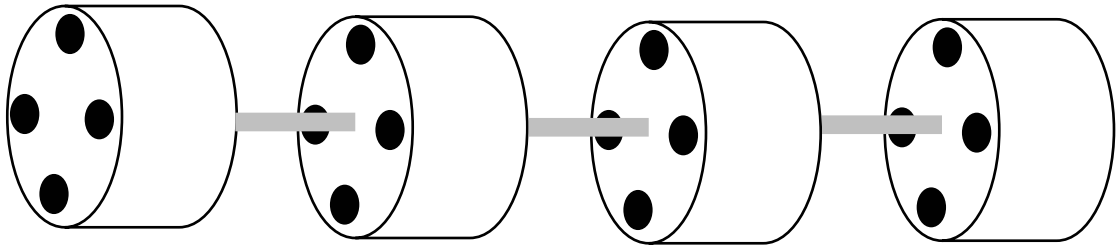
Side view

Mechanical Memory (2)

- The first form of mechanical memory could either be used in a serial computer or a parallel one.
- Serial: Single disk



- Parallel: Multiple disks



Mechanical Memory (3)

- The problems of constructing the first form of mechanical memory resulted in Booth creating a second form of mechanical memory (*rotating wire mechanical memory*).

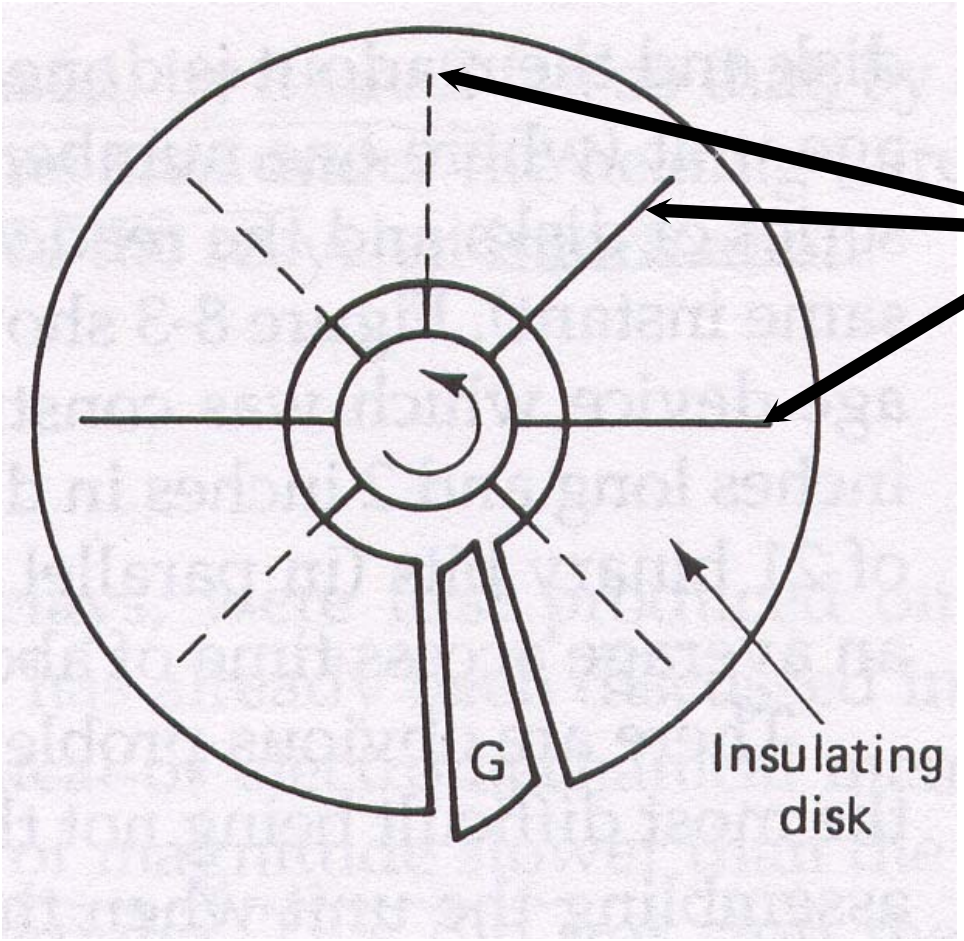


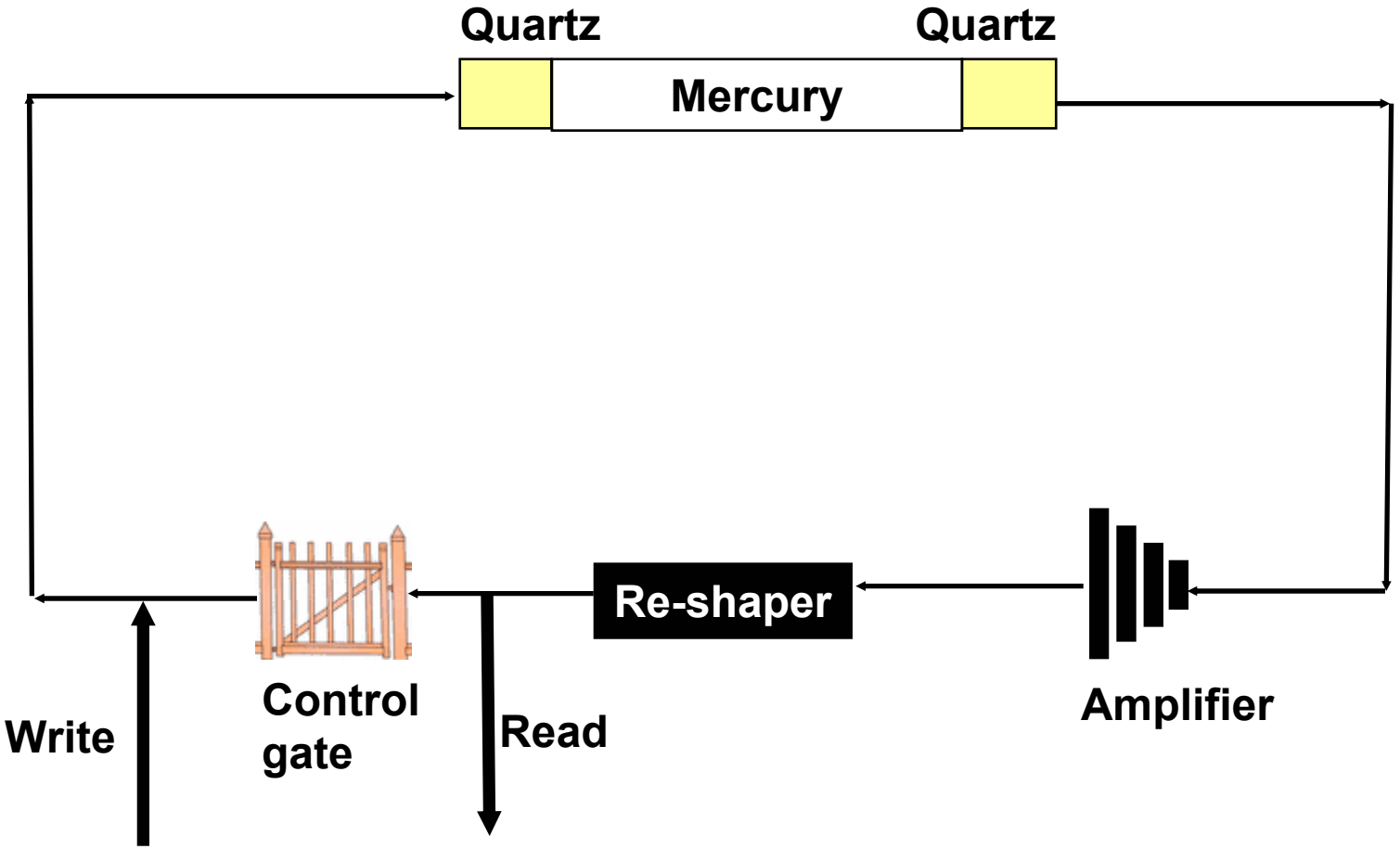
Image from the History of Computing Technology by Michael R. Williams

Mechanical Memory (4)

- While the disk-pin and rotating wire mechanical memory were fairly ingenious given the lack of raw experimental materials in post WWII they were too slow to be of practical value.
  - e.g., memory refresh rate of 100 – 200 / second vs. 1,000,000 for vacuum tube processors.

Delay Line Memory

- Developed by William Shockley and refined by Presper Eckert near the end of WW II
- It was not very compact but it worked (tube ~1 – 2 meters)

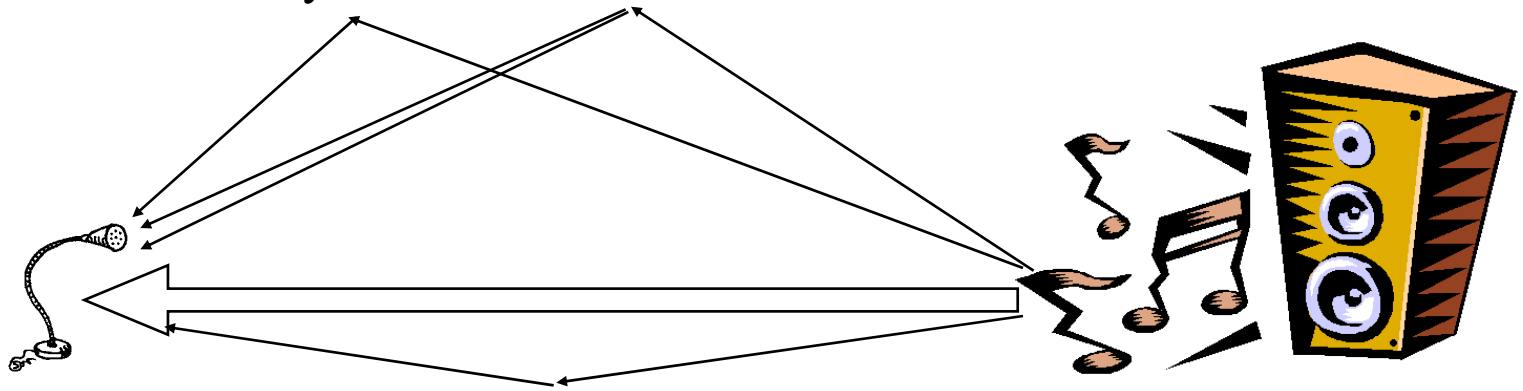


Delay Line Memory (2)

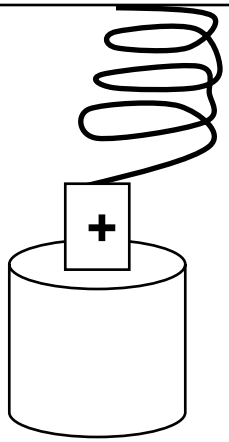
- It was the first type of memory to gain widespread acceptance (it was more reliable than earlier technologies).
- Used in many machines:
  - EDSAC, EDVAC, UNIVAC, NPL pilot ACE, SEAC, LEO..
- However there were still some problems (signal interference) so alternatives to mercury were proposed by different researchers:
- Alan Turing:
  - Alcohol based delay line

Delay Line Memory (3)

- Andrew Donald Booth
  - Air based delay line



  - A ‘slinky’ delay line



Delay Line Memory (4)

- Nickel based delay line
  - Nickel: a good carrier of sound and temperature was not as critical as with the mercury based version.

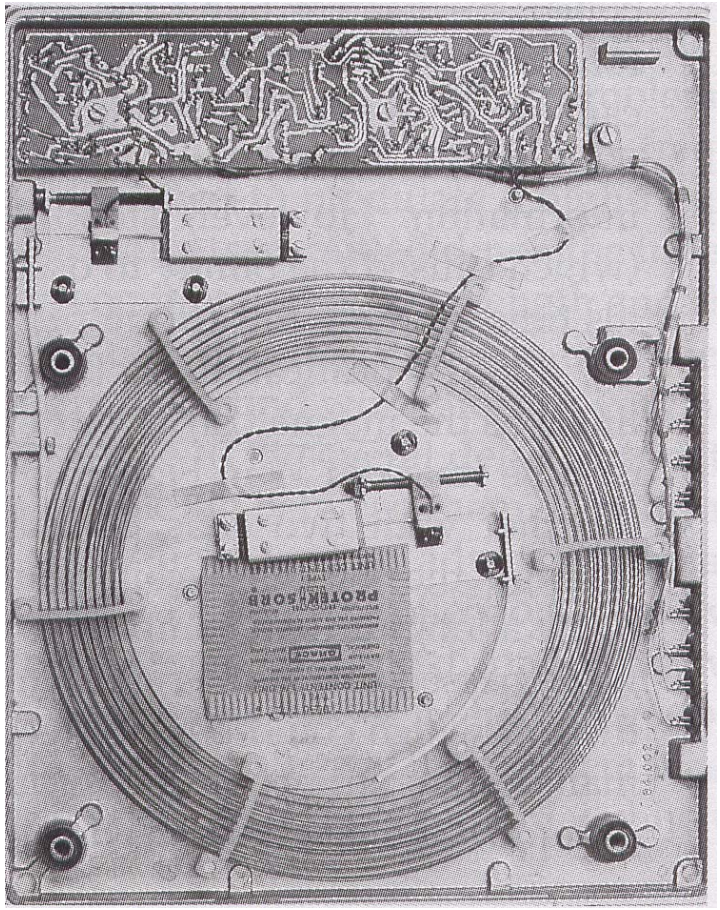
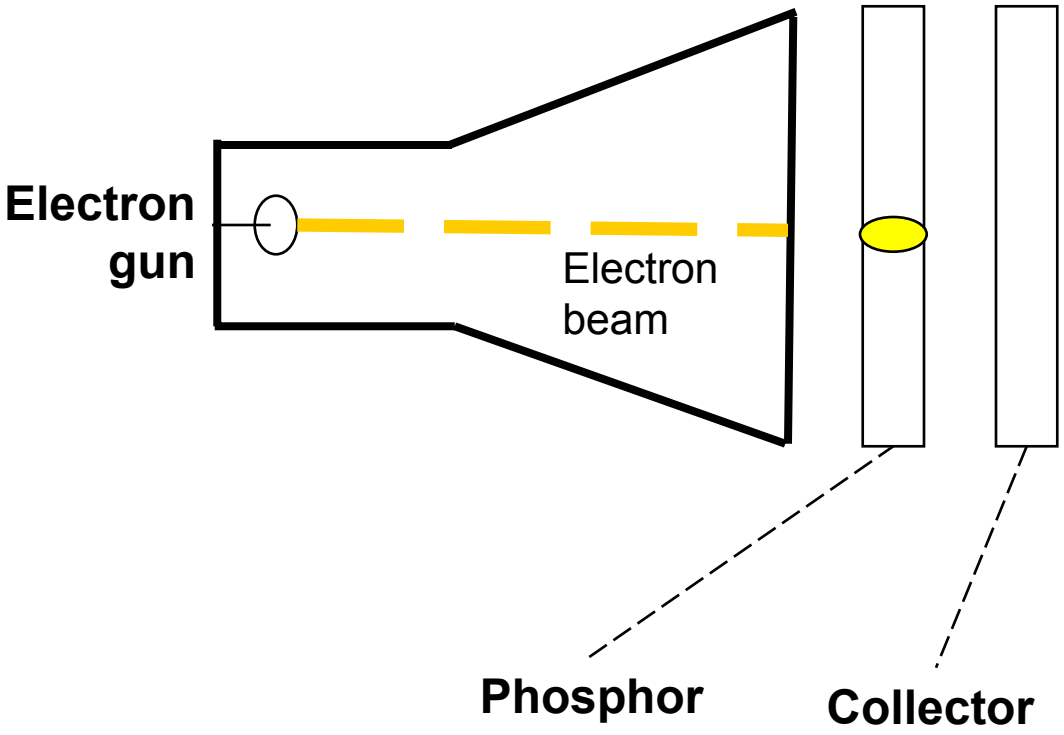


Image from the History of Computing Technology by Michael R. Williams

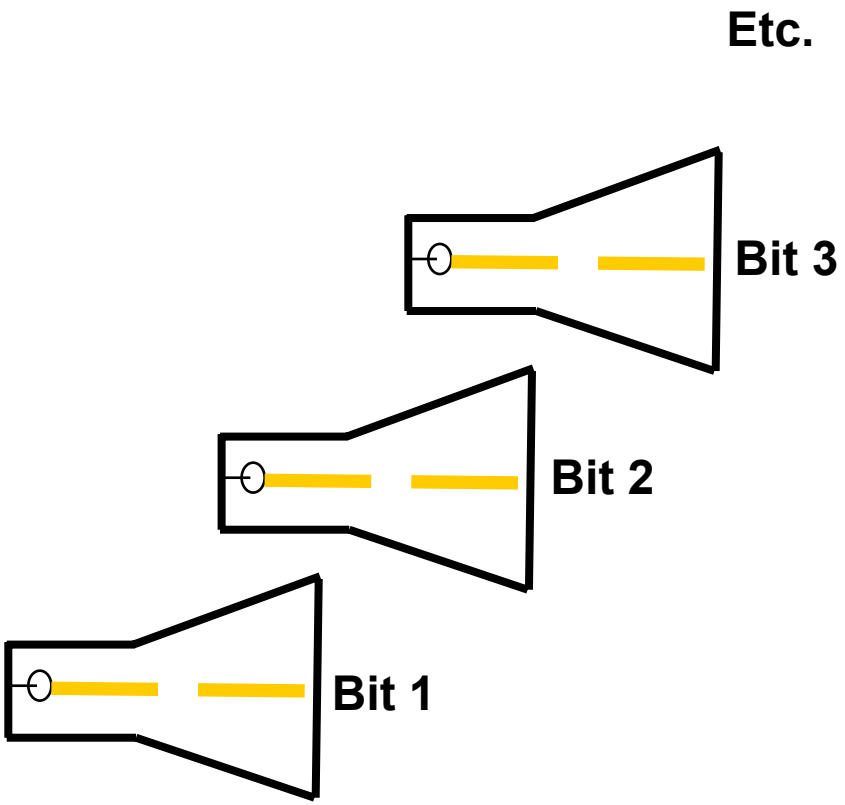
Electrostatic Memory (Williams' Tube)

- It was developed in the late 1940's by Frederic C. Williams using a cathode ray tube (CRT) as a memory storage mechanism.



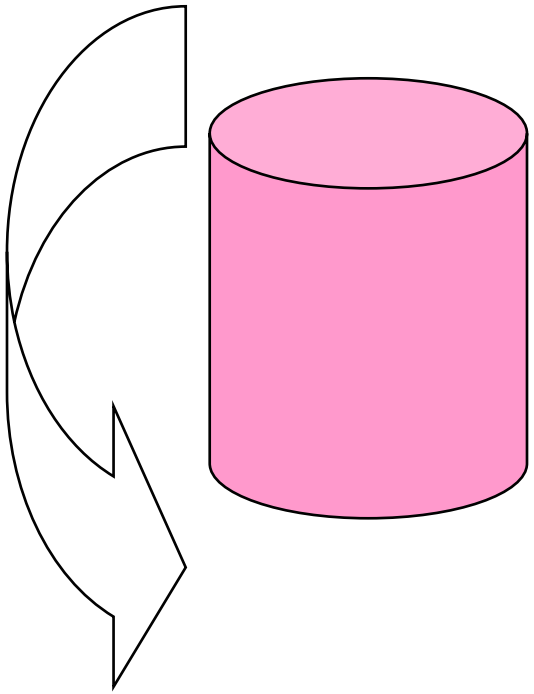
Electrostatic Memory (Williams' Tube: 2)

- For parallel machines each bit of a word was stored on separate CRTs.



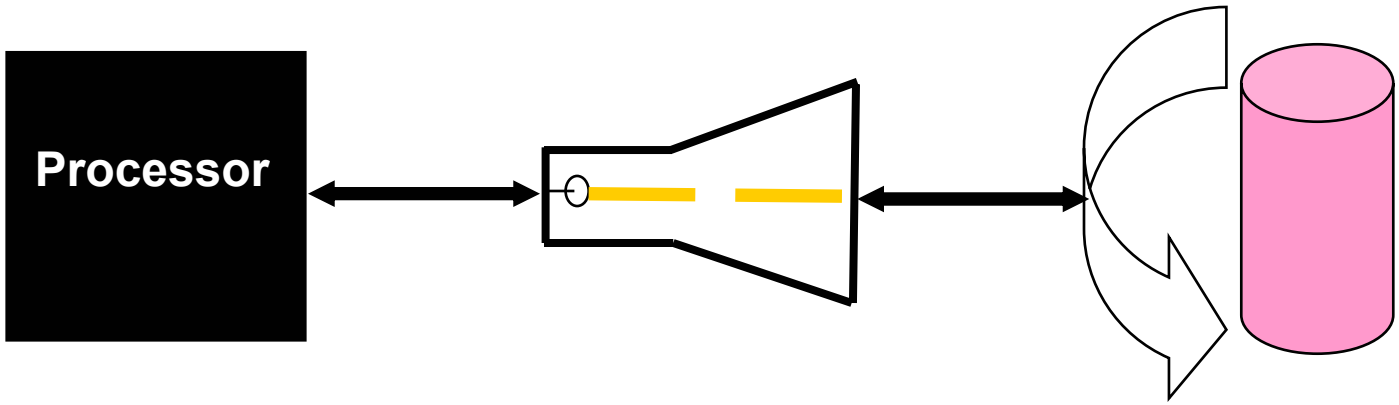
Rotating Magnetic Memory

- The concept was based on the technology of magnetic voice recording.
- Tapes were too slow to act as memory so in the late 1940's the idea of using a rotating drum was conceived by many different people.



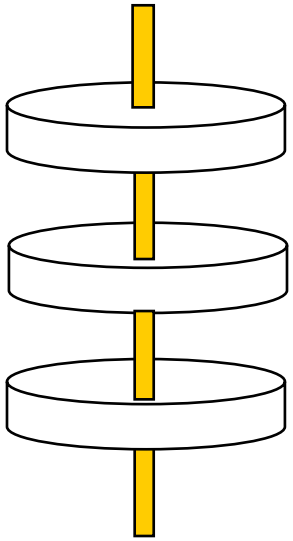
Rotating Magnetic Memory (2)

- Even rotating at a high rate of speed this form of memory was slow.
- A two level memory concept was often employed:



Stationary Magnetic memory ("Core Memory")

- It was developed in the late 1940's – early 1950's by several developers J. Forrester, Dudley Buch, Jan Rajchman, An Wang and Frederick Viehe:



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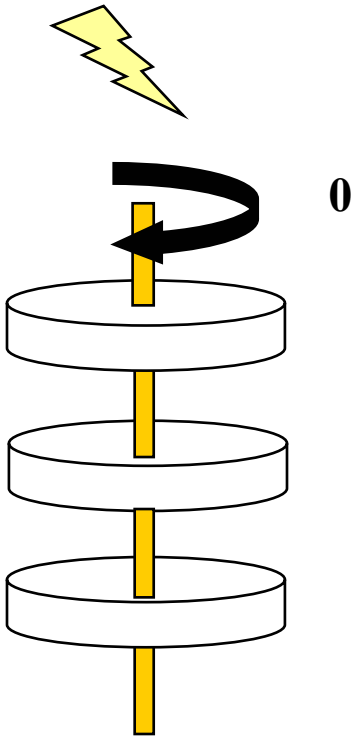

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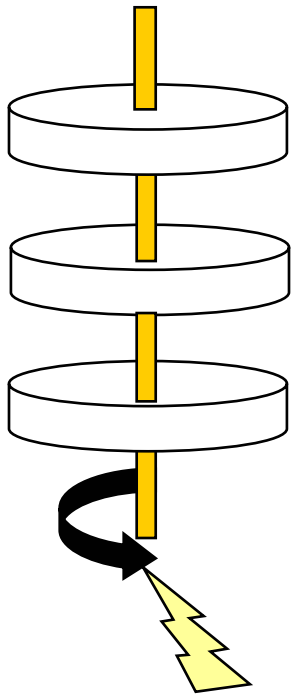


1

The First Stored Program Computers

- The Manchester Machine
- EDSAC
- EDVAC
- The machine of the Institute for Advanced Study (IAS)
- The BINAC/UNIVAC

The Manchester Machine

- After the end of the war many of the people who worked at Bletchley Park obtained jobs at Manchester university.
- In 1948 it was the first fully electronic machine that operated based on the instructions stored in it's memory.
- However the initial machine was extremely limited in it's capabilities:
  - It had a serial "word size"
  - The instruction set consisted of subtractions, conditional branches and a 'stop' instruction.

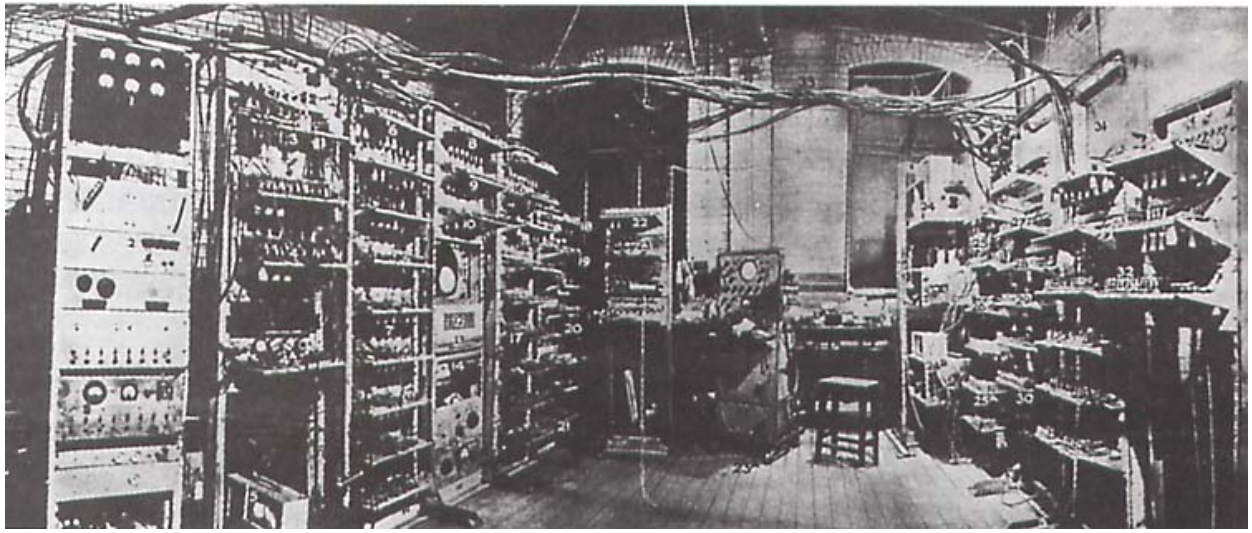
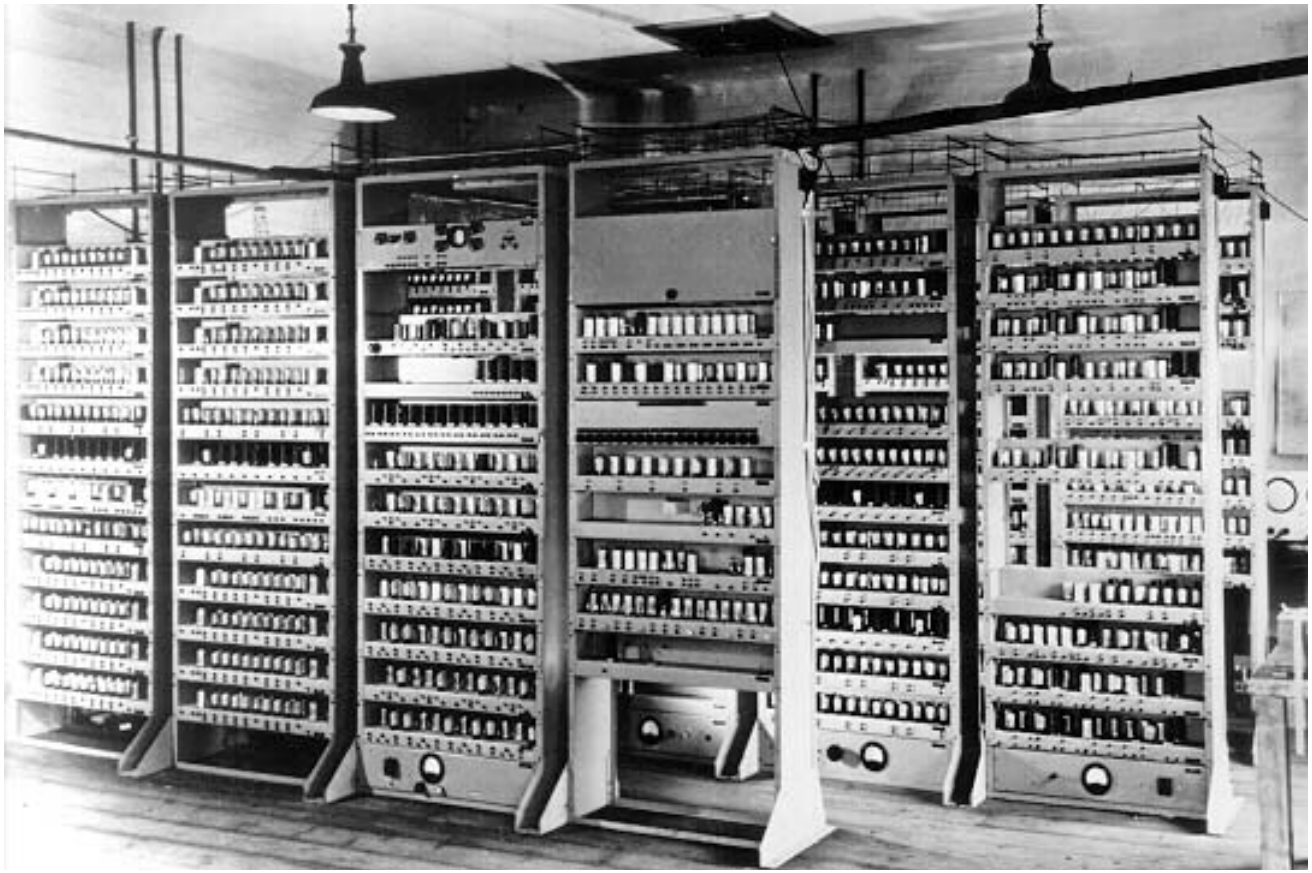


Image from the History of Computing Technology by Michael R. Williams

The EDSAC

- The Electronic Delay Storage Automatic Calculator (EDSAC) was completed in 1949 at Cambridge.
- It named after the theoretical machine (The EDVAC) written about in Von Neumann's paper.



EDSAC (2)

- First demonstrated in 1949 (ran at 500,000 Hz / 0.5 MHz)!
- A spin-off of the EDSAC (called LEO / Lyons Electric Office) was the first computer to be used for commercial data processing.

The EDVAC

- The Electronic Discrete Variable Arithmetic Computer (EDVAC) was the first stored program computer to have been conceived (although it was completed after the Manchester Machine and the EDSAC).
- Von Neumann first wrote a paper describing the theory behind a stored program machine "The First Draft of a report on the EDVAC"
- The project suffered from many problems: Many of the original people behind the idea of the SPC left the Moore School.
- The actual machine was not completed until 1952.

Picture from the Ballistic Research Laboratories

The Institute For Advanced Study (IAS) Machine

- After leaving the Moore School Von Neumann and Goldstein accepted positions at the IAS (Princeton) to develop the IAS machine (1951).

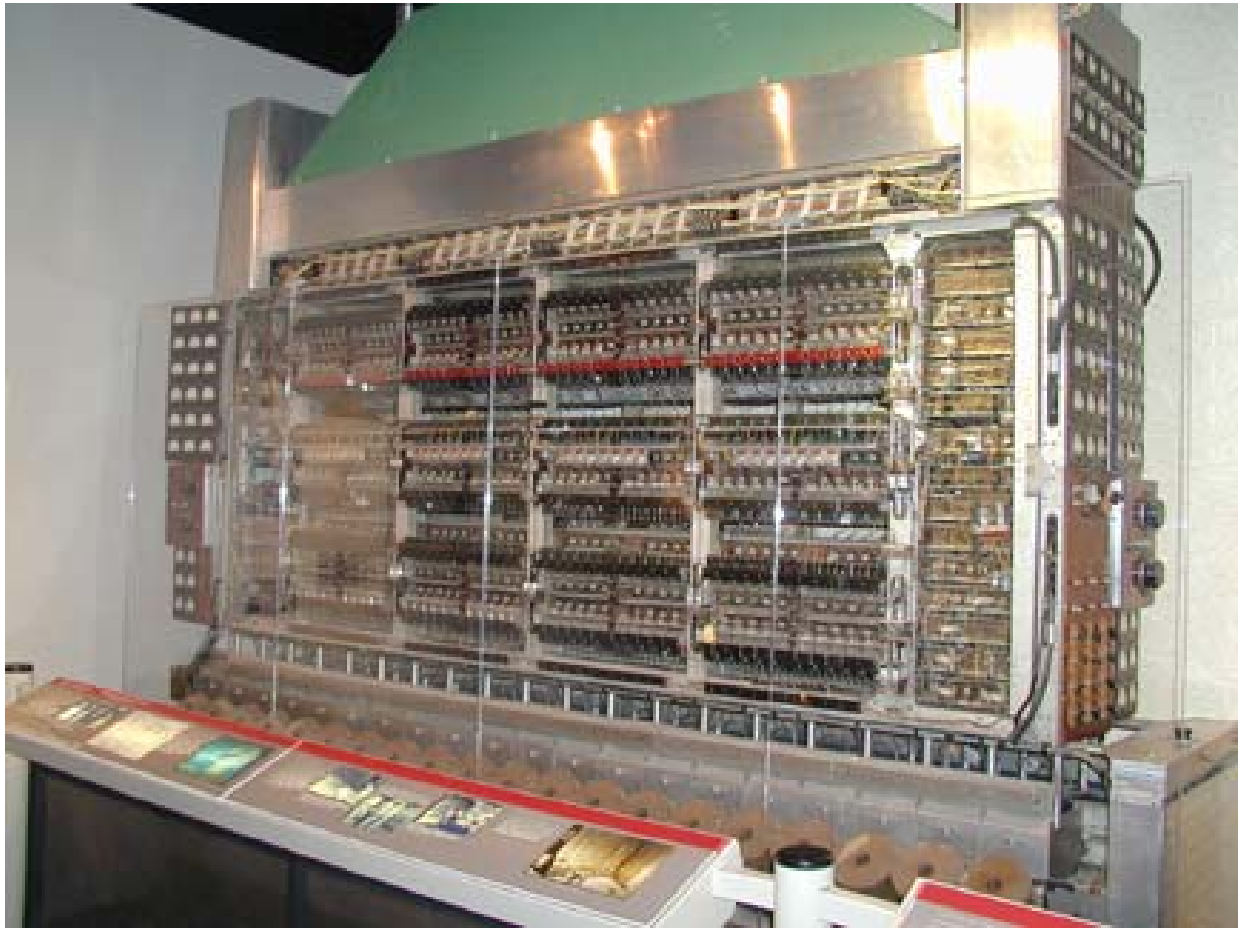


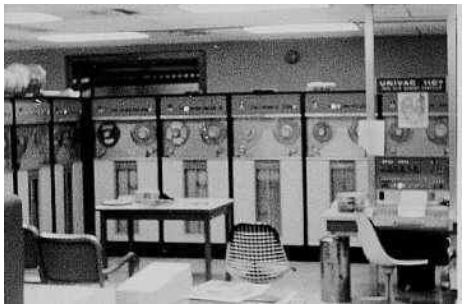
Image from the Smithsonian Collection

The Institute For Advanced Study (IAS) Machine (2)

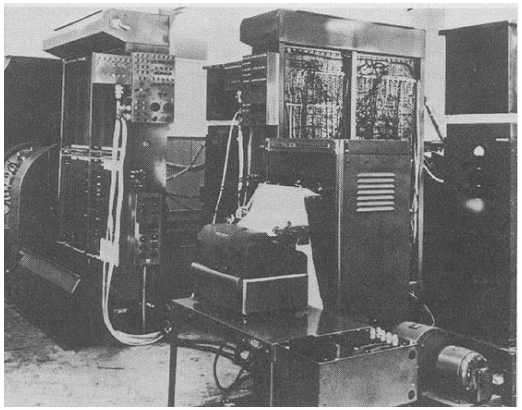
- The machine processed data in parallel and it was very fast:
  - Additions ~60 microseconds.
  - Multiplications ~ 300 microseconds.
- The performance set the design standard for fast parallel computers:
  - Von Neumann architecture of the modern computer refers to the IAS machine

The BINAC / UNIVAC

- When Eckert and Mauchly left the Moore School they founded the Electronic Control Company.
- The first project was for the US Census Bureau to produce the UNIVAC (*Univ*ersal *A*utomatic *C*omputer): 1949

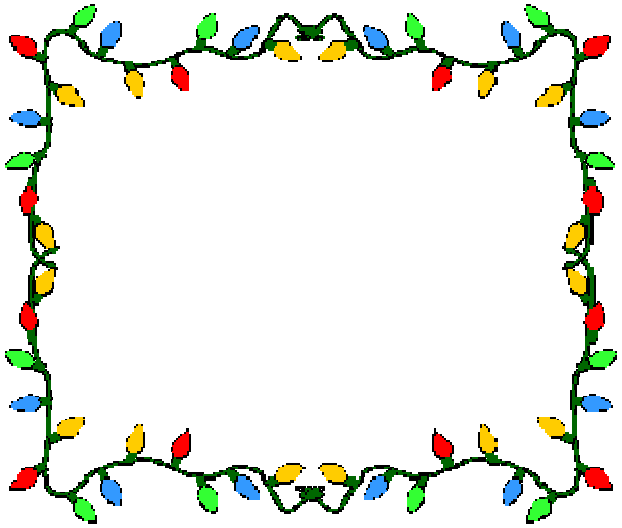


- The next project was for Northrop Aircraft BINAC (*Bin*ary *A*utomatic *C*omputer): 1949



The BINAC / UNIVAC (2)

- The computer was reasonably fast
  - Addition ~ 0.5 milliseconds
  - Multiplication ~ 2 milliseconds
- UNIVAC was synonymous with computer for several years:
  - CBS used one to predict a US presidential election



The "UNIVAC" on TV

The real UNIVAC

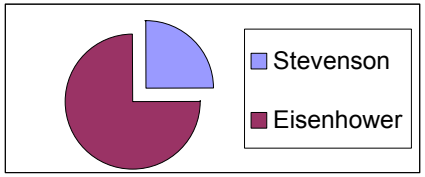
The BINAC / UNIVAC (3)

- CBS used one to predict the 1952 U.S. presidential election.

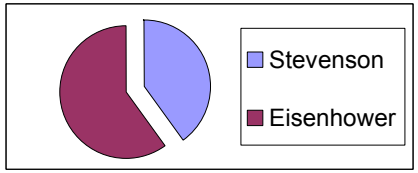
Eisenhower

Stevenson

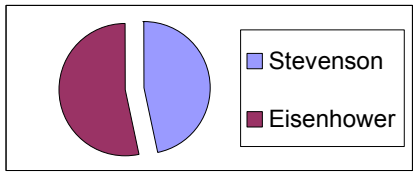
- Results after first run



- Results after second run



- Broadcast results



You Should Now Know

- When were the different categories of computers and what were some of their distinguishing features:
  - The mechanical monsters
  - The computers of the electronic revolution
  - The first SPC's (stored program computers) and the technology of behind the memory used.
- Who were the people who were involved in the creation of these technologies.