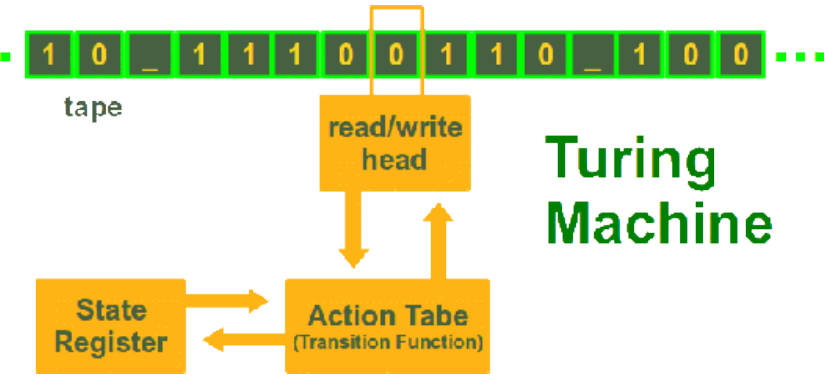
First course of Computer Science

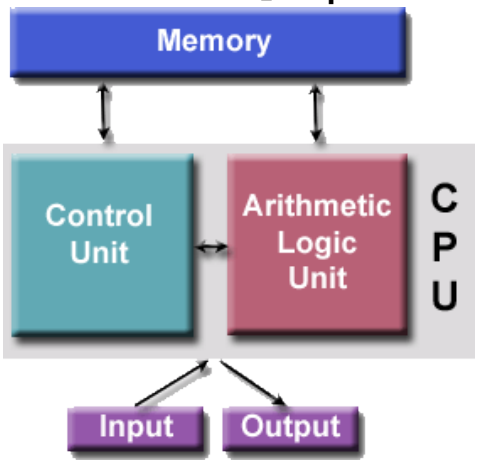
Part V: Computer Architecture

-- A short history of computers

[3 persons + 4 Generations]



Turing Machine



All for Computing faster

- The first use of the word "computer" was recorded in **1613**, referring to a **person** *who carried out calculations, or computations*, (http://en.wikipedia.org/wiki/Computer) such as navigational tables, tide charts, and planetary positions for astronomical almanacs.
- **Inventors have been searching for hundreds of years for a way to mechanize (that is, find a mechanism that can perform) this task**.
  - Imagine you had a job where hour after hour, day after day, you were to do nothing but compute multiplications. Boredom would quickly set in, leading to carelessness, leading to mistakes. And even on your best days you wouldn't be producing answers very fast.

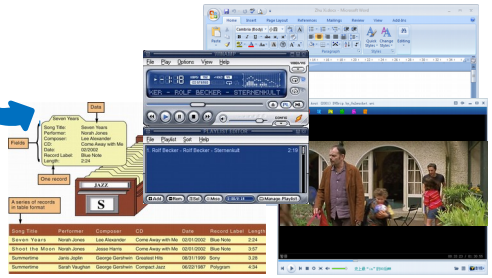
http://www.computersciencelab.com/ComputerHistory/

Big picture now!

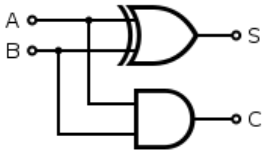
Computers

{0, 1}

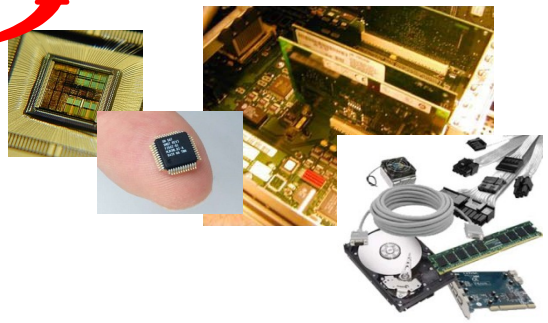
igital
epresentations:
Number,
Character,
Instructions,
V.I.A etc.



Logic
↓
Logic gate
(switch)



IC/VLSI
Components
+
Other peripherals



Computer History

- Early Mathematics & Computation
- Triggered by World War II
  - Three persons
- The Modern Er
  - Four generatio

Early Mathematics & Computation

- Babylonians and Egyptians, > 3000 yrs ago
  - numerical methods for generating tables of square roots, multiplication, trig
  - Applications: navigation, agriculture, taxation
- Greeks, > 3000 yrs ago
  - geometry and logic
- Indians, ~ 600 AD
  - started using placeholders and a decimal number system, similar to modern
  - idea spread to Middle East
- Arabs and Persians ~ 800 AD
  - algorithms

A Famous Arab Mathematician

Abu Jafar Mohammed Ibn Musa Al-Khowarizmi

In early 800s AD worked at center of learning in Baghdad

- Wrote book: *Hisab Al Jabr Wal-Mugabalah*
  - **Described how to compute several practical problems, including linear and quadratic equations**
  - Translated into Latin, spread throughout Europe
- Solidified number system in use now: “Arabic numerals”
- Al-Khowarizmi gives us the word “algorithm”

fig. from Donald Knuth's website

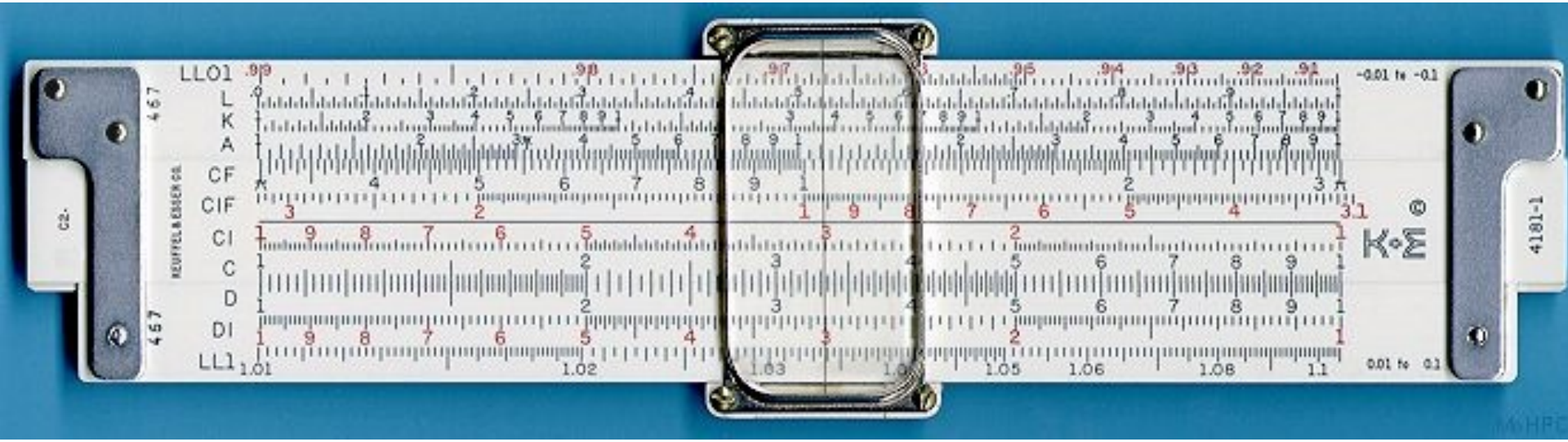
Early Computing Devices

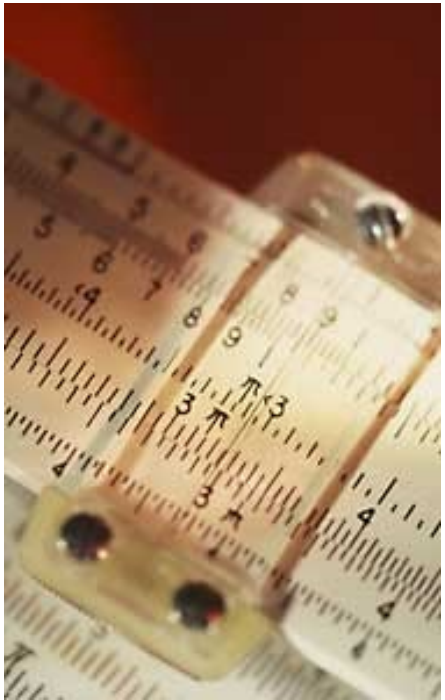
- Abacus
  - About 3000 BC
  - Different types, developed ove
    - Common wire/bead: about 500 B
  - Some still in use today
- John Napier's Bones
  - 1617: Sticks with numbers on them
  - Use to do 4 basic arithmetic operations
- William Oughtred's Slide Rule
  - 1622: Sticks with logarithmic scale, slide along
  - Much more complex calculations
  - Used well into 20th century (replaced by handheld calculator)

fig from http://www.ee.ryerson.ca/~elf/abacus

"A History of Modern Computing" (2nd), Paul E. Ceruzzi, ISBN 0-262-53203-4. MIT Press, 2003.

Slide rule





Human "computers" at work at North American Aviation, Los Angeles, in the early 1950s. The man at the lower left is looking up a number on a **slide rule**. The

More Early Computing Devices

- Blaise Pascal
  - 1642: First numerical calculating machine (addition and subtraction)

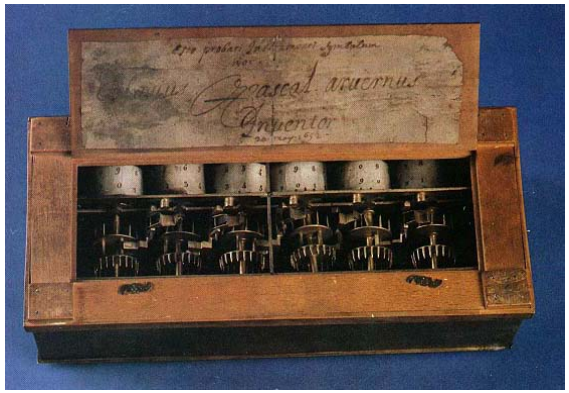
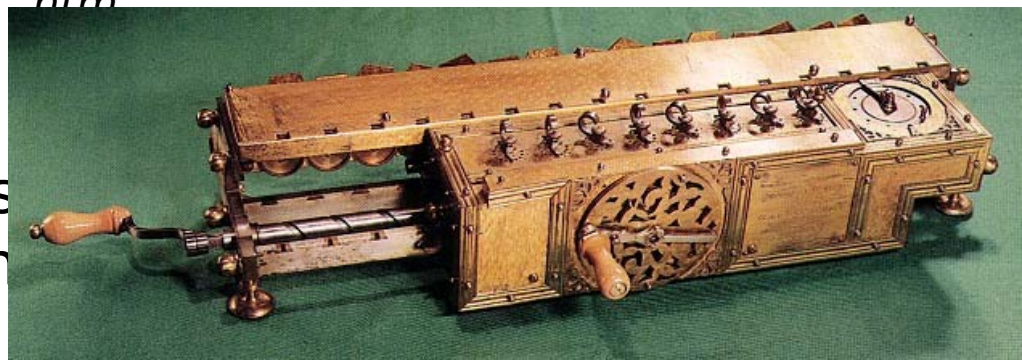


fig from http://www.tcf.ua.edu/AZ/ITHistoryOutline.htm

- Gottfried Leibniz
  - 1673: 4-function mechanical calculator (addition, subtractions multiplication, division



- Used cogs and gears
- Showed mechanization can simplify and speed up numerical calculations

Are These Devices Computers?

- Not considered general-purpose computers
- They lack
  - **memory**
  - **ability to be programmed**

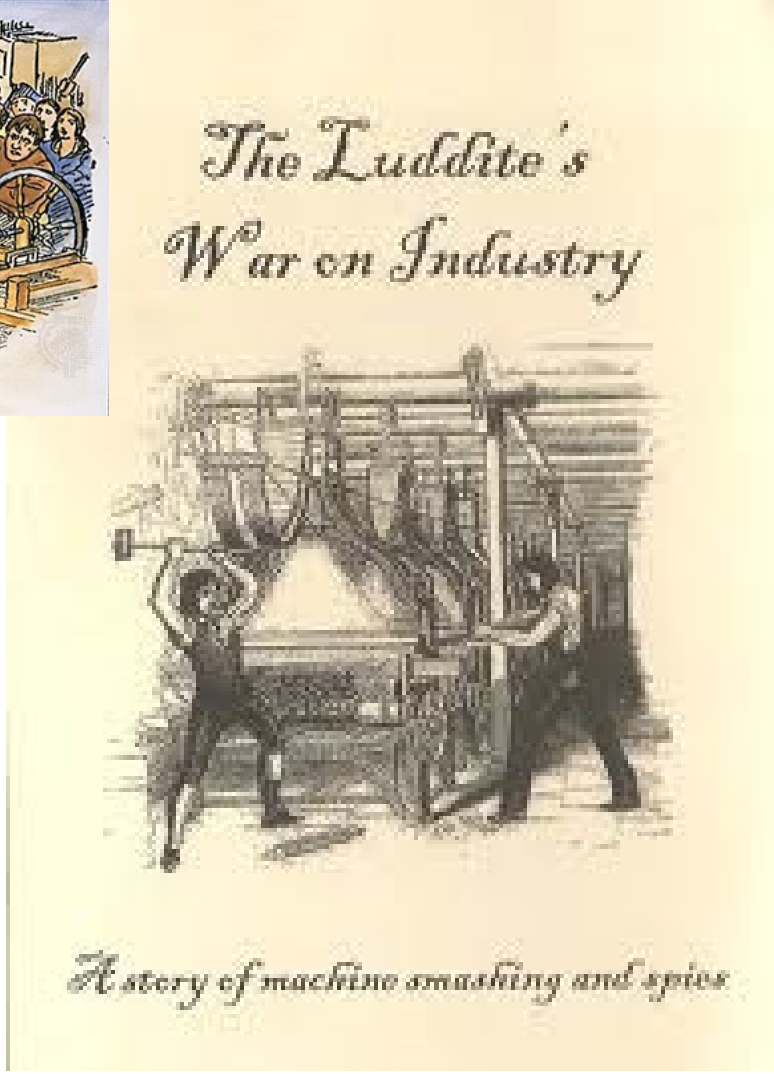
First Programmable Device with Memory

- A loom [织布机]!
- Used to weave cloth with patterns
- Invented by Joseph Jacquard, France, 1804
- Automated loom using **punched cards** to create pattern
  - hole in card at a certain place causes change in the weave at corresponding place in the fabric

fig from Wikipedia, Jacquard loom entry

Jacquard Loom

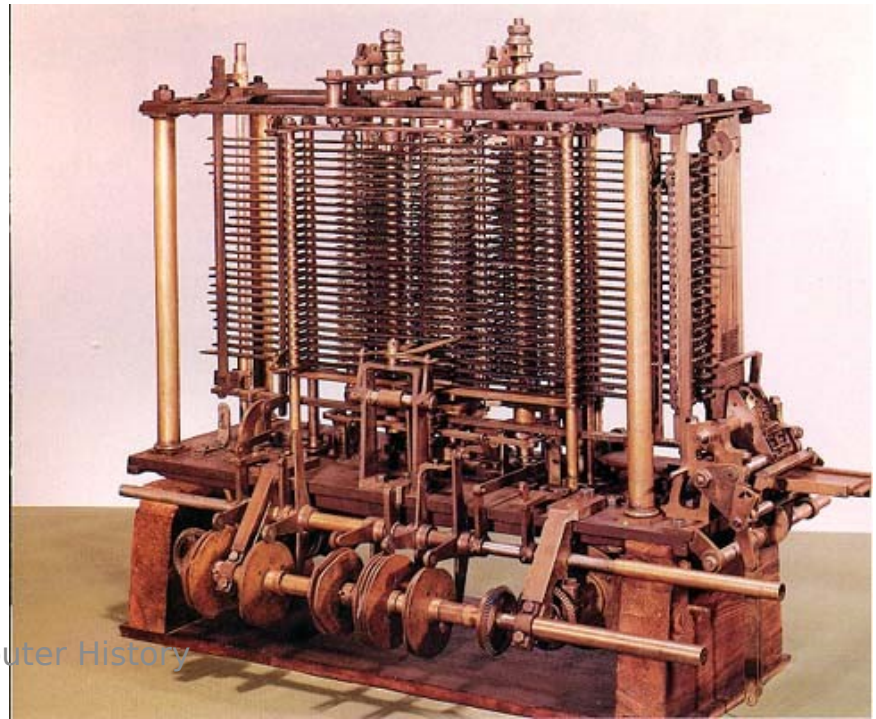
- **Memory**: the cards
- **Programmable**: change the cards
- Capture human expertise in a machine
- Target of Luddite movement [勒德运动]
  - riots against Industrial Revolution
  - threatened craft guilds



英国工人以破坏机器为手段反对工厂主压迫和剥削的自发工人运动。首领称为卢德王，故名。

Charles Babbage & Analytical Engine

- 1833: Designed the “Analytical Engine”
  - Could not get funding, since never finished first machine, but fully designed
    - to be steam-powered
  - This was the **first general computational device**!
- Separate storage from calculation
- Familiar parts:
  - mill <=> **ALU**
  - store <=> **memory**
  - operator <=> control unit
  - Output [**Punch cards**. (打孔机)] <=> input/output
- Used punched cards



Ada Lovelace

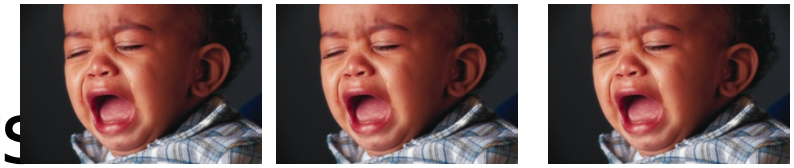
http://brideswell.com/content/audio-production/ada-lovelace-day-delia-derbyshire/

fig from women.cs.cmu.edu/ada

- Augusta Ada Byron, Countess of Lovelace
  - Daughter of poet Lord Byron
  - Friend of Charles Babbage

- Translated, edited, and commented on document describing Babbage's Analytical Engine
- Realized its potential as a general purpose computer
  - Wrote "programs" that could be run on it. As a result, she is often considered the world's first computer programmer.

U.S. Census & Computer



- Taken every 10 years
- By late 1800s, was becoming more difficult
  - 1880 census not tabulated until 1888
  - Serious doubt that 1890 census could be finished before time for following census
  - Competition held to develop automatic enumeration and tabulation of census data
- A fundamental need for "large-scale" computing

Herman Hollerith

- Herman Hollerith developed tabulating machine
  - Developed machines for encoding information on punched cards
  - Cards could be sorted and tabulated
- 1890 census completed in 2 years with Hollerith's machines
  - Also saved millions of dollars

fig from www.columbia.edu/acis/

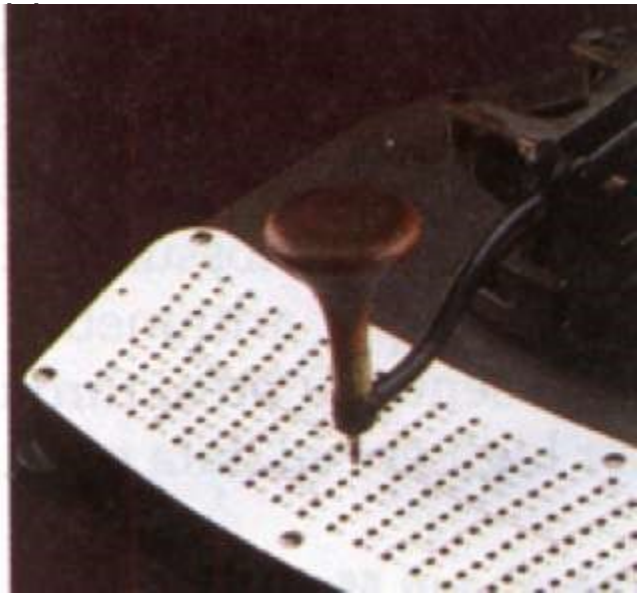


fig from www-03.ibm.com

Further Developm

Need faster automatically computing machine ℗ Electro-s(electric and electronic)

- Work continued on m
  tabulate, record.
  - Charles Flint: Computi
    Recording (**CTR**) compa
    Hollerith's work.
  - Thomas J. Watson renames CTR to International Business Machines (**IBM**) in 1924.
- Individual machines were created for *each* stage of a process
  - For example, separate machines to count, sort.
  - Most machines encoded information on

Computer History

- Early Mathematics & Computation
- Triggered by World War II
  - Three persons
- The Modern Era
  - Four generations

Impact of World War II

- Applications of the 1940's:
  - ballistics tables
  - troop deployment data
  - secret codes
- Several research projects, funded by military, focused on developing computers
  - on both sides

fig from www.diggerhistory.info

War-Time Projects

- Colossus: England, **Alan Turing**
  - cracked German Enigma code
  - shrouded in secrecy until 1970's
- ABC: Iowa State, **John Atanasoff** & Clifford Berry
  - solve systems of linear equations
- MARK I & Howard Aiken
  - used binary values (0/1) instead of decimal (0 to 9), learned from Atanasoff
- ENIAC
  - Electronic Numerical Integrator and Computer

Alan Mathison Turing

(1912-1954):
the Brilliant Mind

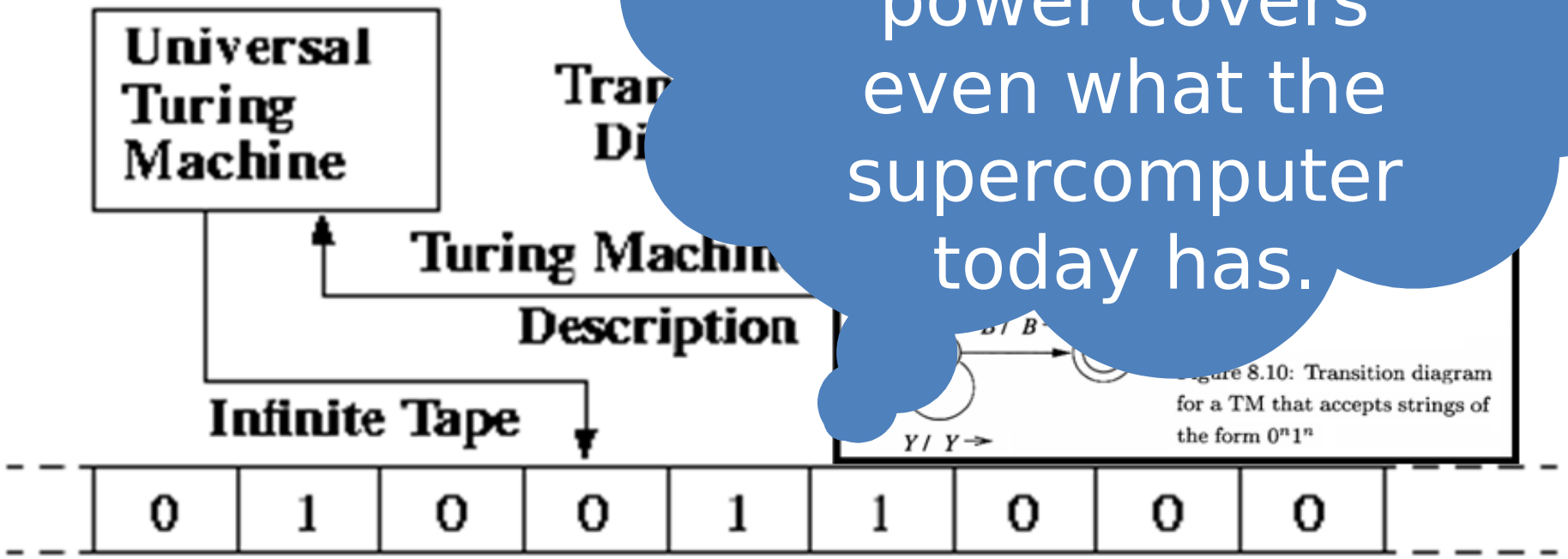
- Alan Mathison Turing was one of the great pioneers of the computer field. He inspired the now common terms of "The Turing Machine" and "Turing's Test."
  - The test (written at 1950) consisted of a person asking questions via keyboard to both a person and an intelligent machine. He believed that if the person could not tell the machine apart from the person after a reasonable amount of time, the machine was somewhat intelligent. This test has become the "holy grail" [圣杯] of the **artificial intelligence** community.
- His intelligence and foresight

tp://ei.cs.vt.edu/~history/Turing.html
http://www.shela-

Turing machine

- **Control unit**
-
-

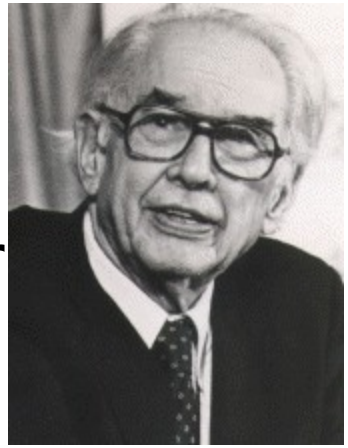
The theoretical model of the computers, whose power covers even what the supercomputer today has.



John Vincent Atanasoff [阿塔纳索夫]

The other precursor to combine the electronics and binary to

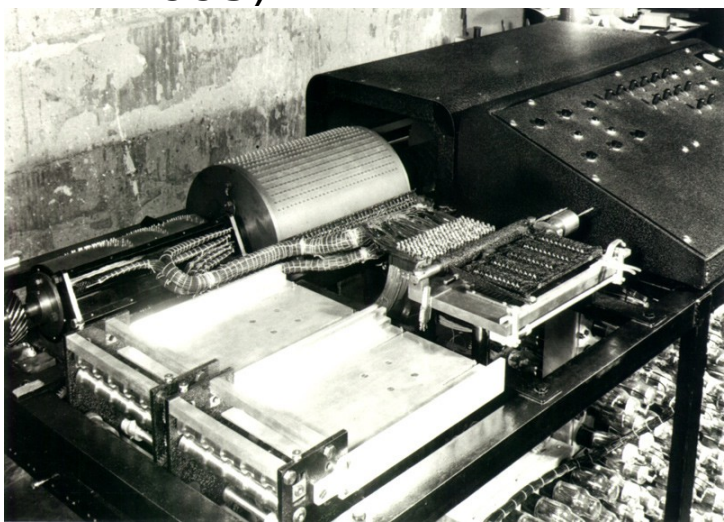
- 1937, one of the earliest researchers who thought to use resistant [电阻], amplifier [放大器] and capacitor [电容器] etc. to build the **electronic computer**.
- He found that it's quite convenient to implement the calculation components based on binary system
  - Switches, just on and off



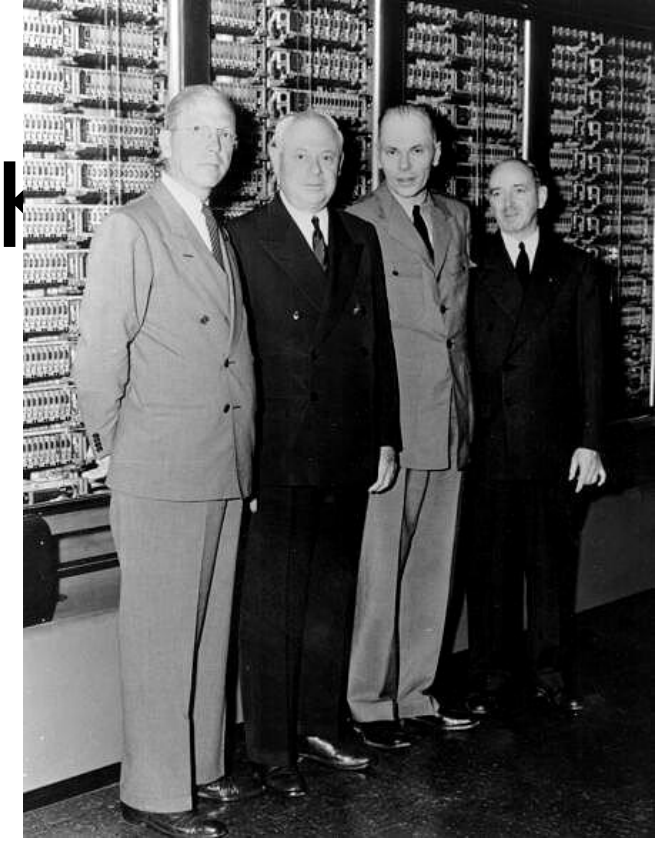
John Atanasoff (1903 – 1995)

Clifford Berry (1918 – 1963)

Atanasoff-Berry Computer (

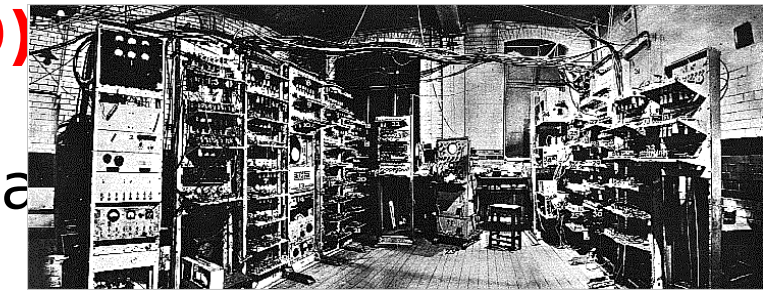


Howard Aiken & MARK



- Funded by Navy and IBM, at Harvard
- 1943
- **general-purpose programmable computer**
  - used **relays**, **magnets** and **gears**
  - **used binary values (0/1) instead of decimal (0 to 9)**
  - used **vacuum tubes** and electric current (on/off) instea of 10-toothed gears
- memory: 72 numbers
- speed: 23-digit multiplication

fig from www-03.ibm.com/ibm/history/



Grace Murray Hopp

- Joined Naval Reserve in 194
  - As Lieutenant, became **one of the first programmers of the Mark I**
- Noted difficulty of programming in machine language
  - Wanted way of specifying programming more naturally
  - Created **the *first* compiler**, A-O
  - Subsequently created other compilers, became
  - strong proponent of compilers/prograr
  - ges, r

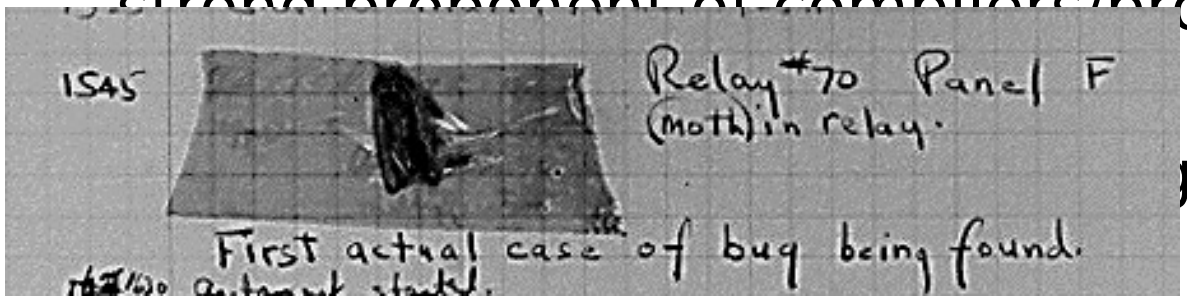
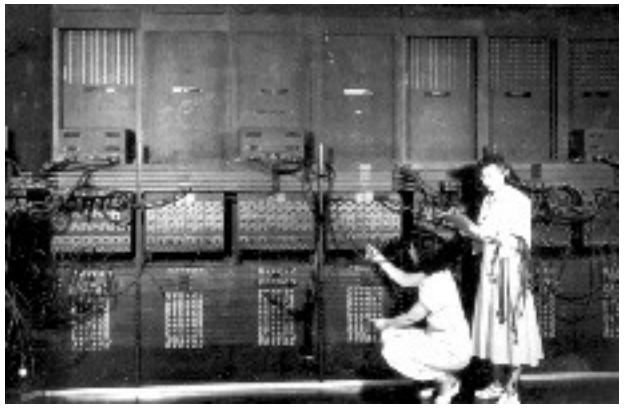


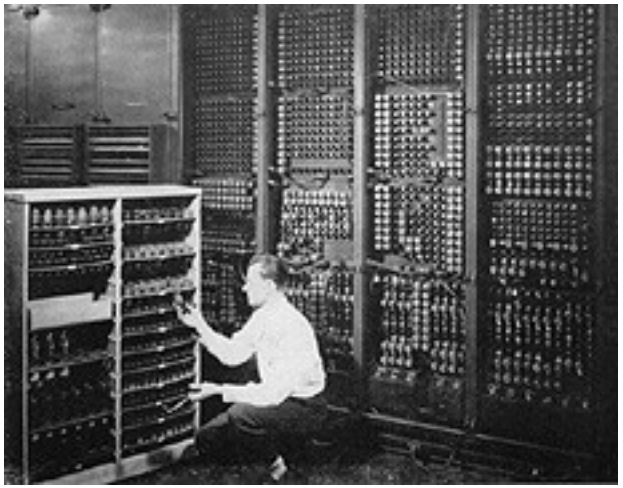
fig from cs.vassar.edu/history/hopper

fig from computerhistory.o

ENIAC "Electronic Numerical Integrator and Computer"

- 1946
- Motivating application: calculate firing tables (how to aim gun depending on distance, wind speed, temp, etc.)
- Funded by Army at Univ. of Penn.
- John Mauchly & Presper Eckert lead designers
- **First *fully electronic* general-purpose computer**
- **Vacuum-tube** based
- **Required rewiring to change program originally**
- 100 feet long, 10 feet high, 30 tons

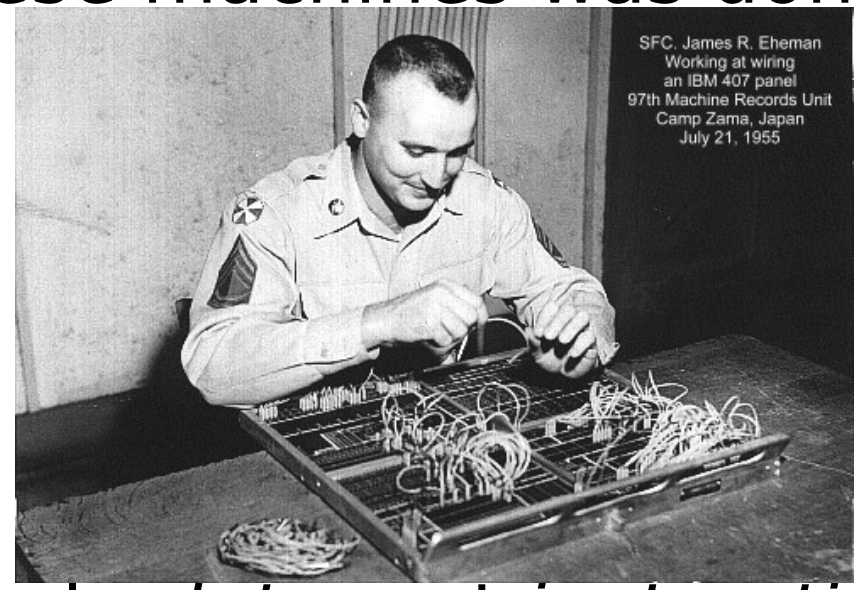




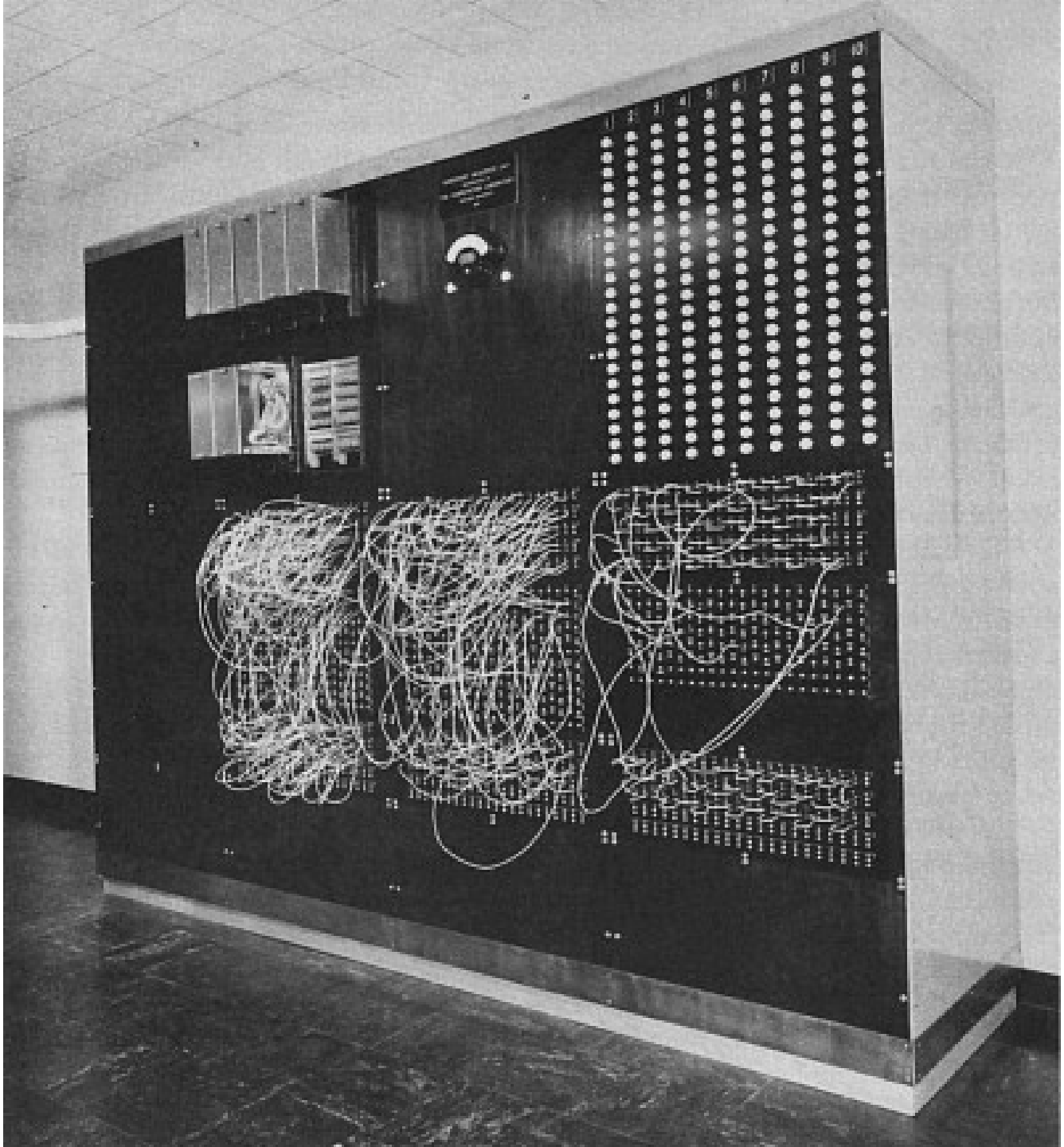
figs from www.library.upenn.edu/exhibits/rbm/mauchly/jwm8b

Aspect Still Missing…

- All these projects still missing a key feature of modern computers
- Programming these machines was done externally with
  - Wires
  - Connectors
  - Plug-boards



- Memory stored only *data,* not *instructions*
- To change the program, need to rewire
  - Ex: 6000 switches on ENIAC



Von Neumann Architecture

- John Von Neumann, mathematician, physicist, chemist, computer scientist,... at Princeton
- worked on ENIAC
- realized shortcoming
- Key idea:
  - **encode instructions as binary values and store in memory along with data**
  - **To change program, rewrite sequence of instructions**

fig from mathdl.maa.org

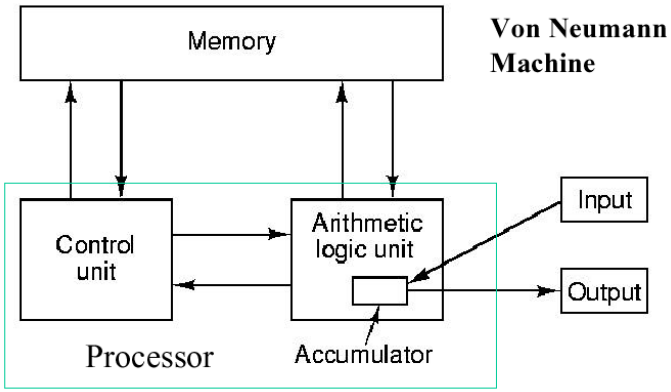
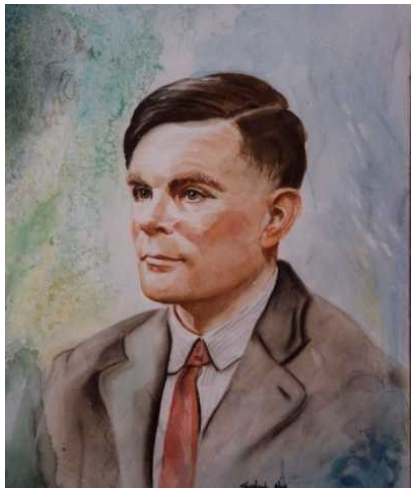


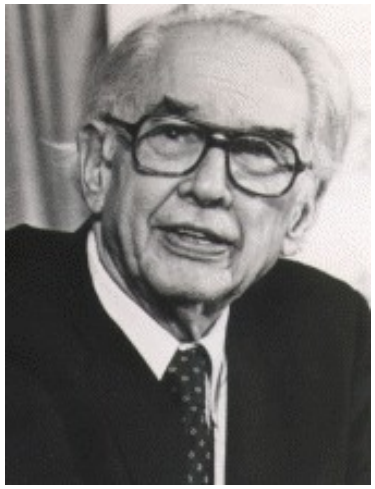
fig from cs.cmu.edu/ref/pgss/lecture

Three persons



Alan Mathison Turing

Theoretical model of modern computer



John Vincent Atanasoff

Combine the electronics and binary together

John Von Neumann

Common architecture of modern computers

Computer History

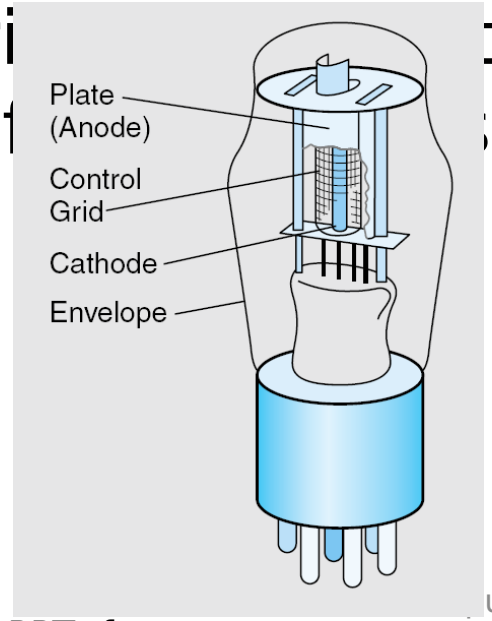
- Early Mathematics & Computation
- Triggered by World War II
  - Three persons
- The Modern Era
  - Four generations

The Modern Era, 1950 - Present

- Changes more evolutionary than revolutionary
- Focused on making con
  - faster
  - smaller
  - cheaper
  - more reliable
  - easier to use
- Conventionally divided into rough "generations"

First Generation (1940-1956) Vacuum Tubes

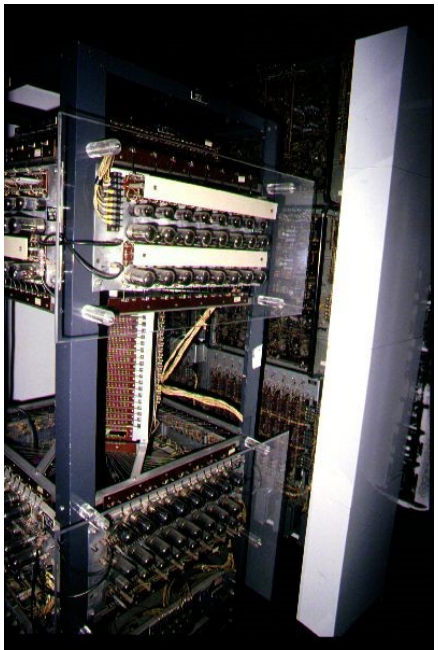
- The first computers used **vacuum tubes** for circuitry and magnetic drums for memory, and were often enormous, taking up entire rooms.
  - They were very expensive to operate and in addition to using a great deal of electri[illegible]ed a[illegible]eat, which was of[illegible]se of [illegible]tions.

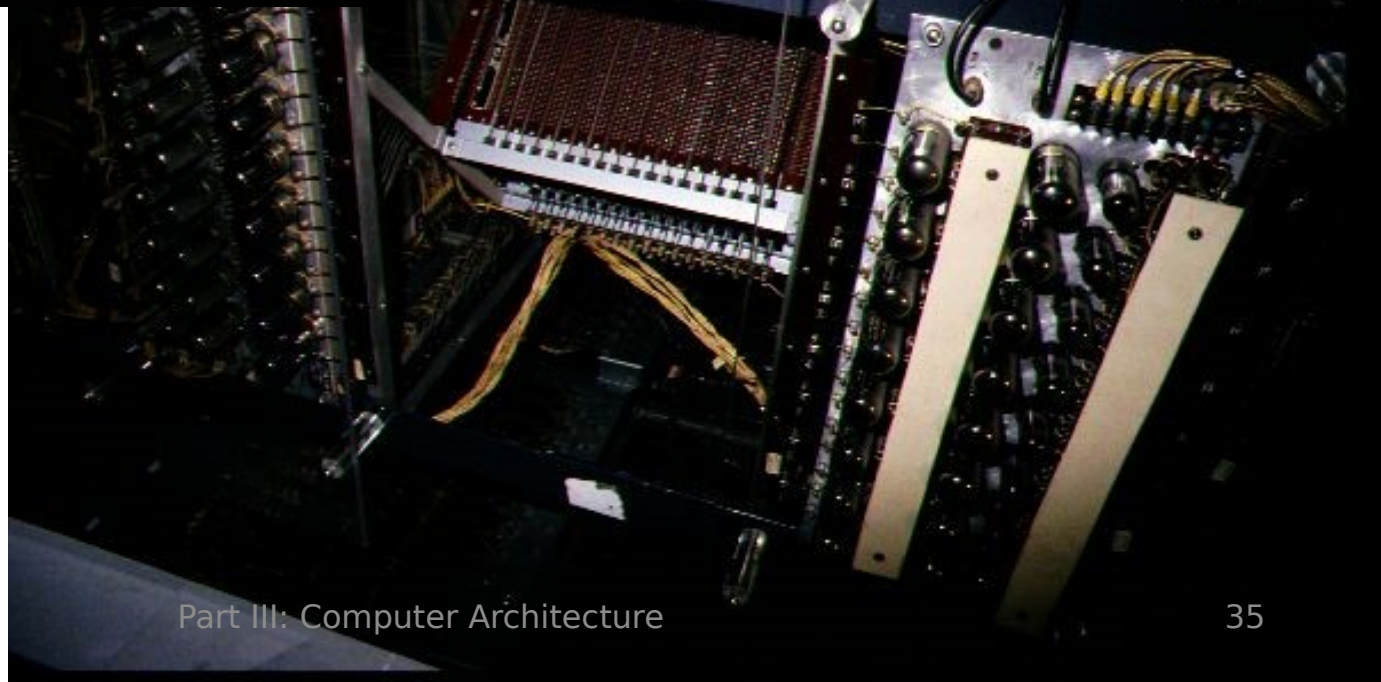


Vacuum Tubes [真空管]

Internals with lots of vacuum tubes

http://davewhitmore.net/Images/computer_history.htm





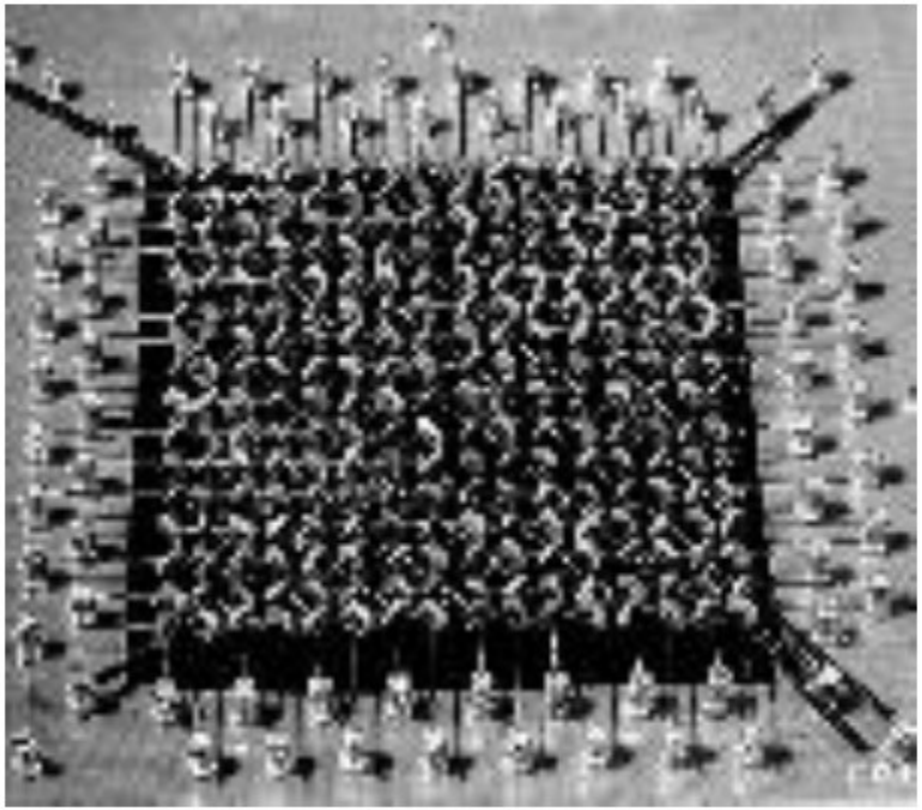
http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

Whirlwind(1951)

Jay Forrester, Bob Everett and others at MIT began work on a simulator for the Air Force in late 1946, but changed their minds about the use of analog techniques, deciding instead to use digital processing to produce the **first real-time processing computer** -- the Whirlwind. This work is also well known for the development of core memory.

http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

Cores on a Matrix of Wires



The basic concept for core memory had been patented by An Wang, Harvard University, in 1949, but his technique involved using the cores on single wires to form delay lines. The Whirlwind Project conceived the technique of stringing the cores onto a matrix of wires and thus producing a random access memory.

The IBM 650 Magnetic Drum Data Processing Machine was announced 2 July **1953** (as the "Magnetic Drum Calculator", or MDC), but not delivered until December 1954.

- IBM pioneered the arrangement of vacuum tubes in pluggable modules such as IBM 650.

Left to right:
Type 650 Power Supply
Type 650 Console Unit
Type 533 Read-Punch Unit

http://www.columbia.edu/acis/history/650.ht

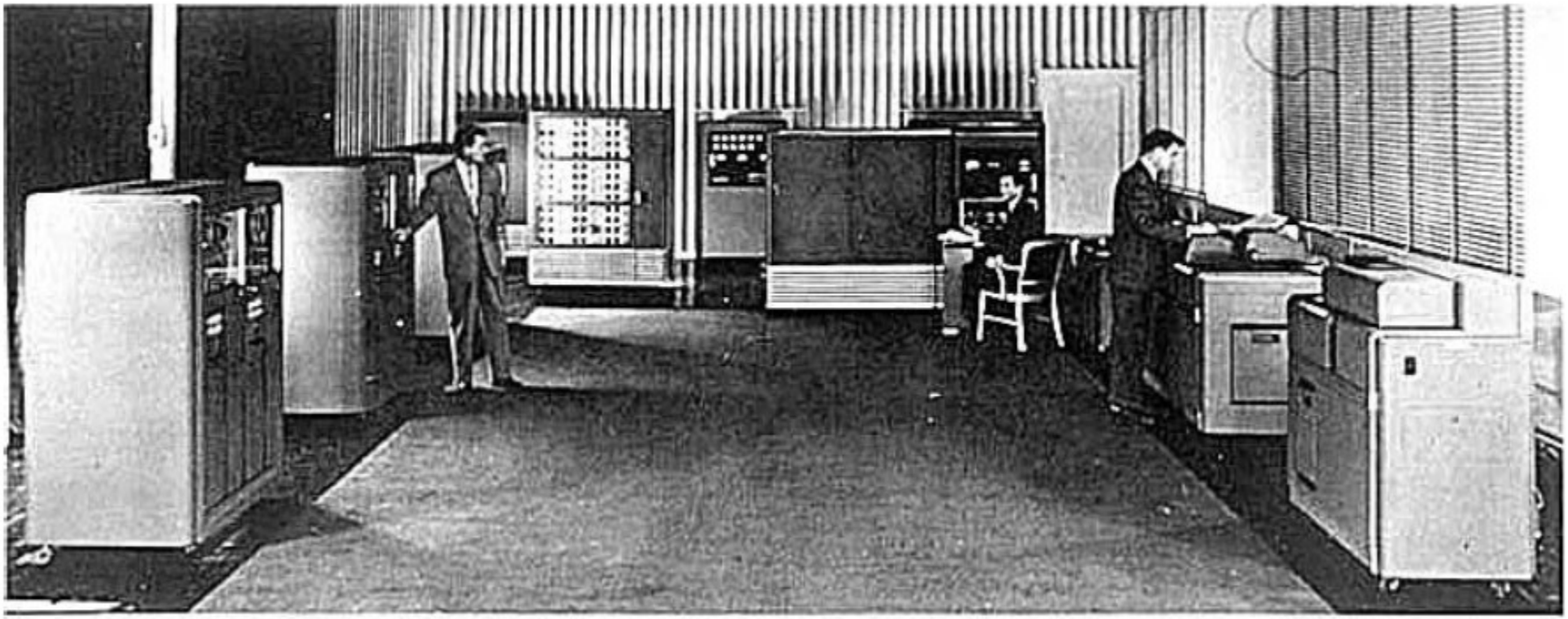
http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

1952年，IBM公司推出了它的第一台机器------IBM701，在这台机器中使用了威廉管(William's tube)存储器。

这种机器一共生产了19套;租金为$15,000/月。

http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

IBM 701 (1952)



IBM ELECTRONIC DATA PROCESSING MACHINES—TYPE 701

http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

1953, In the midst of the first "police action" on the part of the United Nations in Korea, IBM took the opportunity to contribute to the war effort by providing a "Defense Calculator" that was in fact their first true entry into the computer business. The IBM "Type 701 EDPM" was built as a result of the conviction of T.J.Watson, Jr. that IBM had to take a step into this field and his convincing his father that computers would not immediately destroy the card processing business. The 700 series of machines, including the 704, 709, and eventually the 7090 and 7094, dominated the large mainframe market for the next decade, and brought IBM from computer obscurity to first place in that same time period.

First Generation (1940-1956) Vacuum Tubes

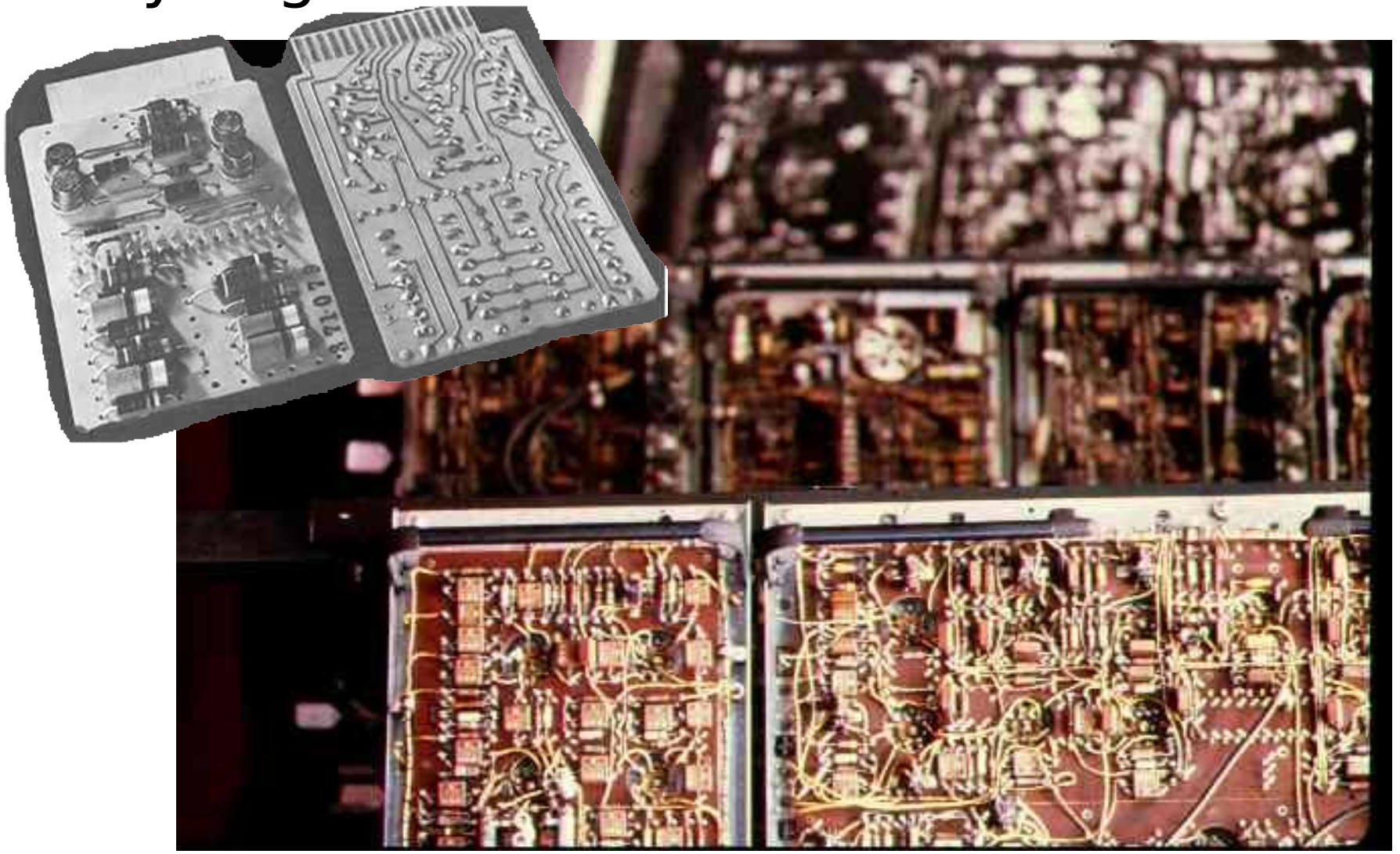
- First generation computers relied on **machine language**, **the lowest-level programming language understood by computers**, to perform operations, and they could only solve one problem at a time.
- Input was based on **punched cards** and **paper tape**, and output was displayed on printouts.

Second Generation (1956-1963) Transistors [晶体管]

- **Transistors** replaced vacuum tubes and ushered in the second generation of computers.
  - The transistor was invented in 1947 but did not see widespread use in computers until the late 1950s.
  - The transistor was far superior to the vacuum tube, allowing computers to become smaller, faster, cheaper, more energy-efficient and more reliable than their first-generation predecessors.
  - Though the transistor still generated a great deal of heat that subjected the computer to damage, it was a vast improvement over the vacuum tube.

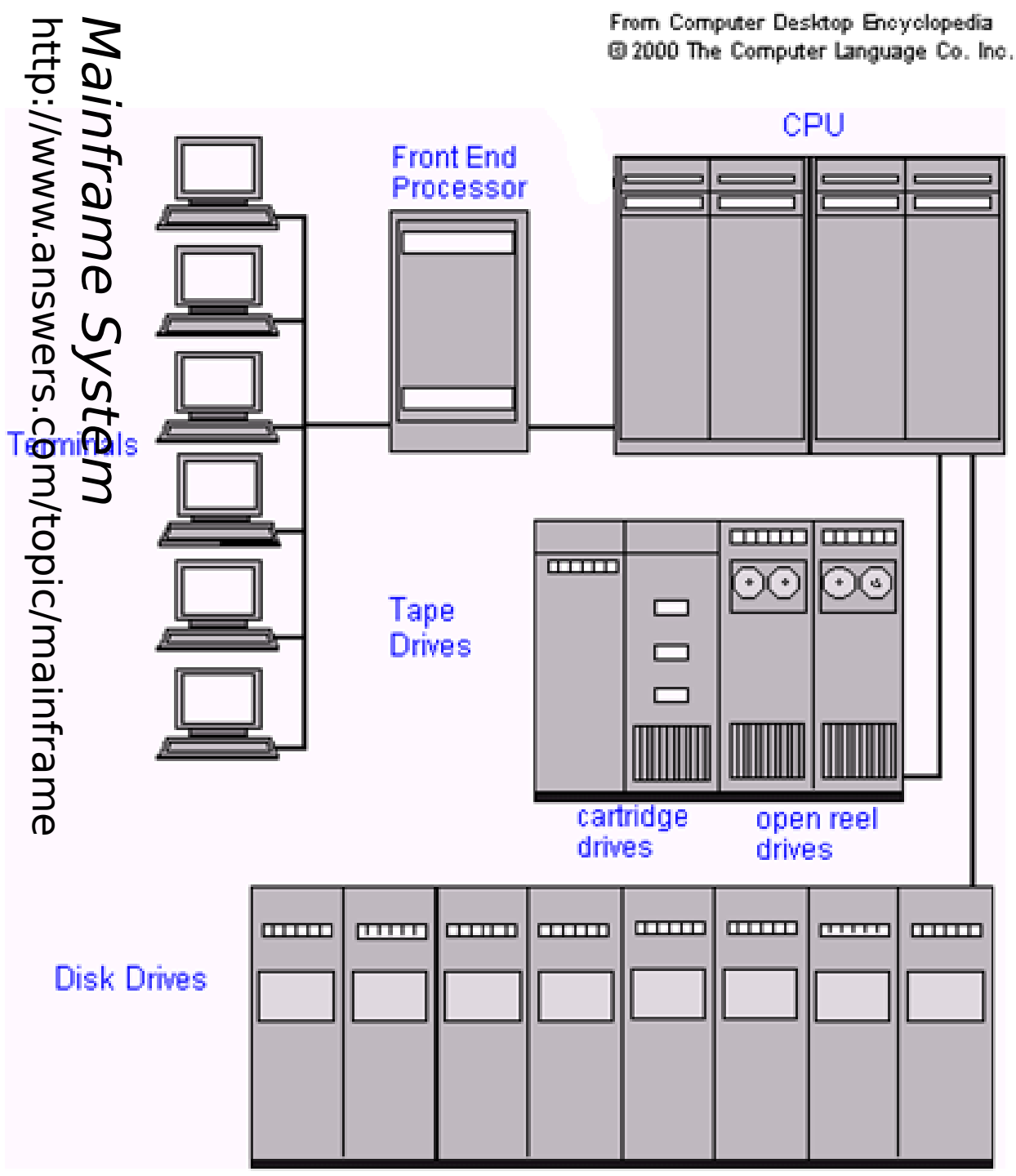
some historians claim the transistor was the most important invention of the 20th century

Early Logic Modules: Circuit board with transistors



http://davewhitmore.net/Images/computer_history.htm

Computer - Mainframe



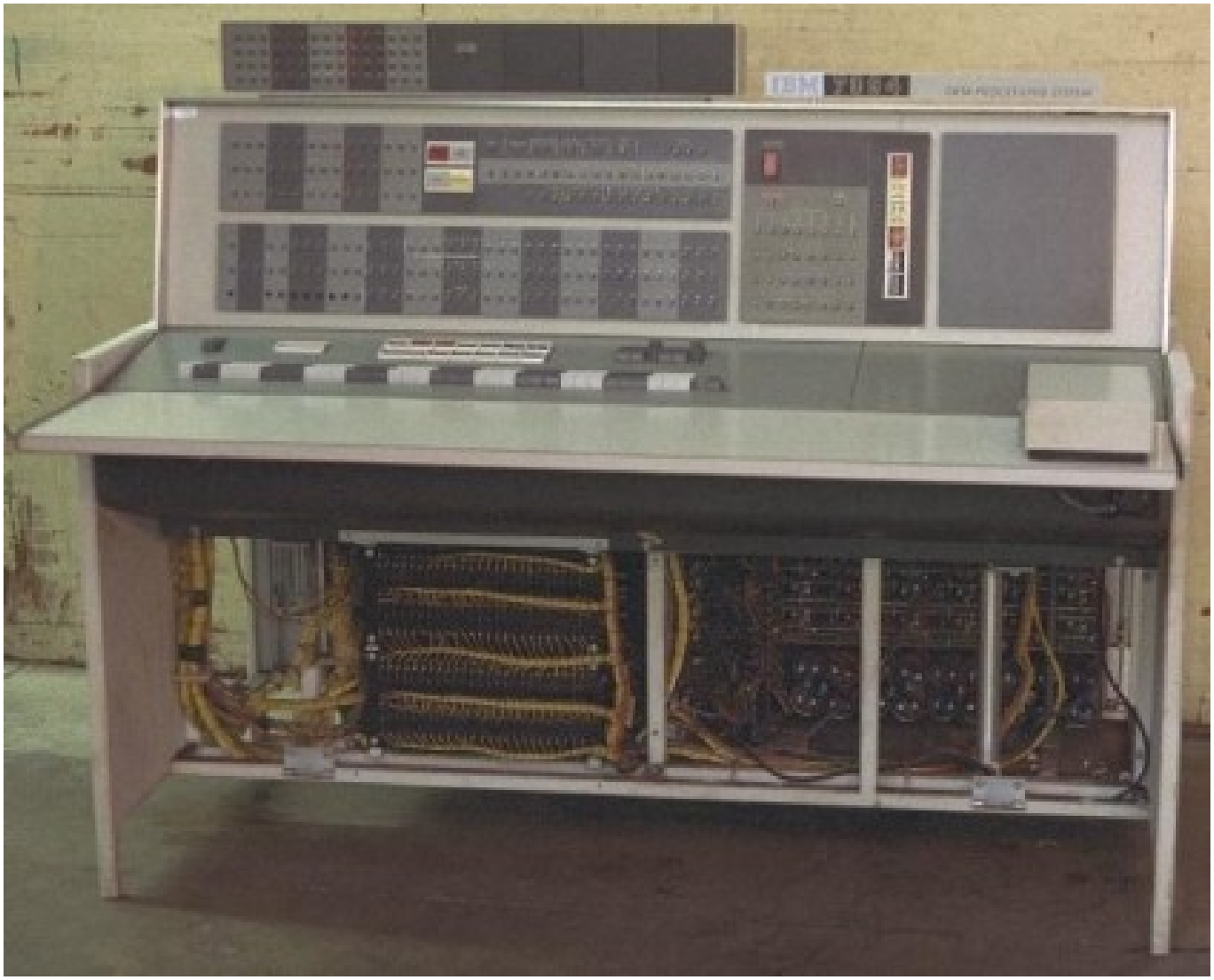
- In the "ancient" mid-1960s, all computers were mainframes, since the term referred to the main CPU cabinet. Today, it refers to a class of ultra-reliable medium and large-scale servers designed for enterprise-class and carrier-class operations.
- Mainframes support symmetric multiprocessing (SMP) with several dozen central processors in one system. They are highly scalable. Built with multiple ports into high-speed caches and main memory, a mainframe can address thousands of gigabytes

IBM 7094

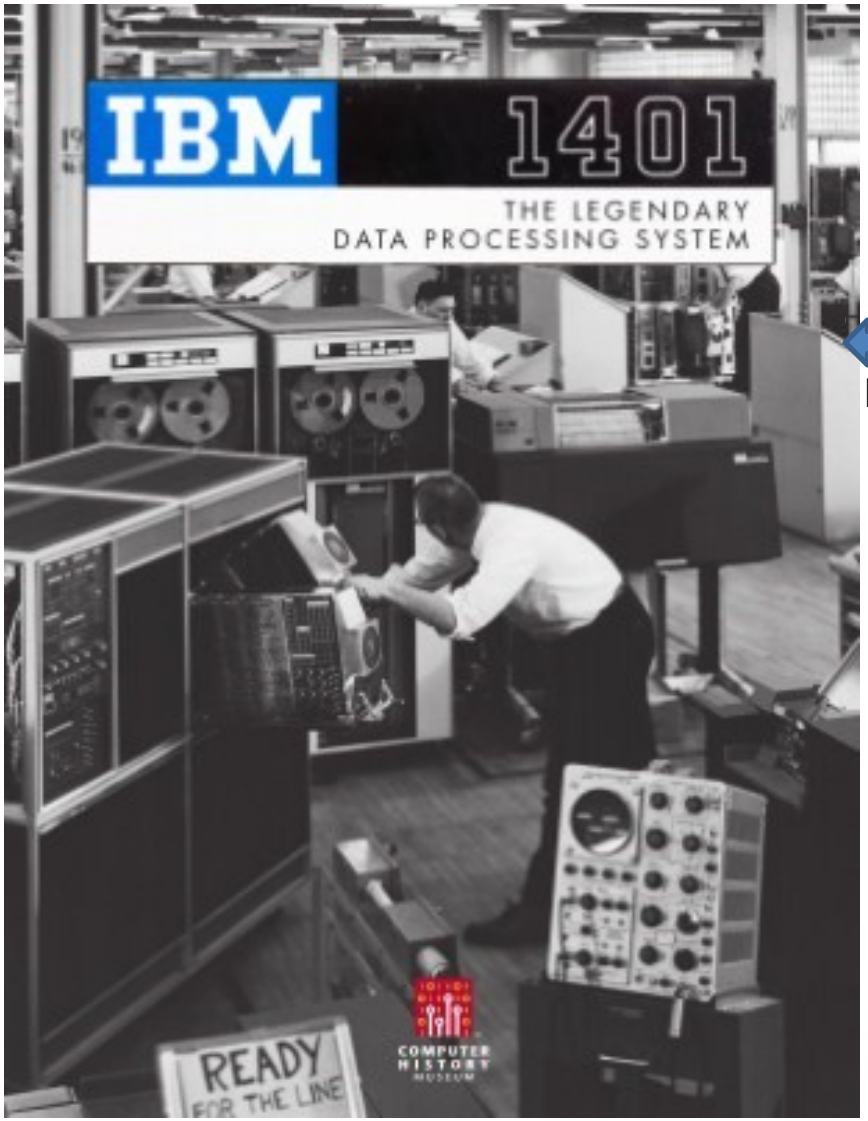
- 700 series in 1952 last member of 7000 in 1964
- Memory 2K to 32K of 36 bit words
- Memory Cycle time fell from 30 micro sec to 1.4 micro sec
- Number of Opcodes grew from 24 to 185
- Use of data channels
- Multiplexor to which all channels are connected

IBM 7094

IBM 7094



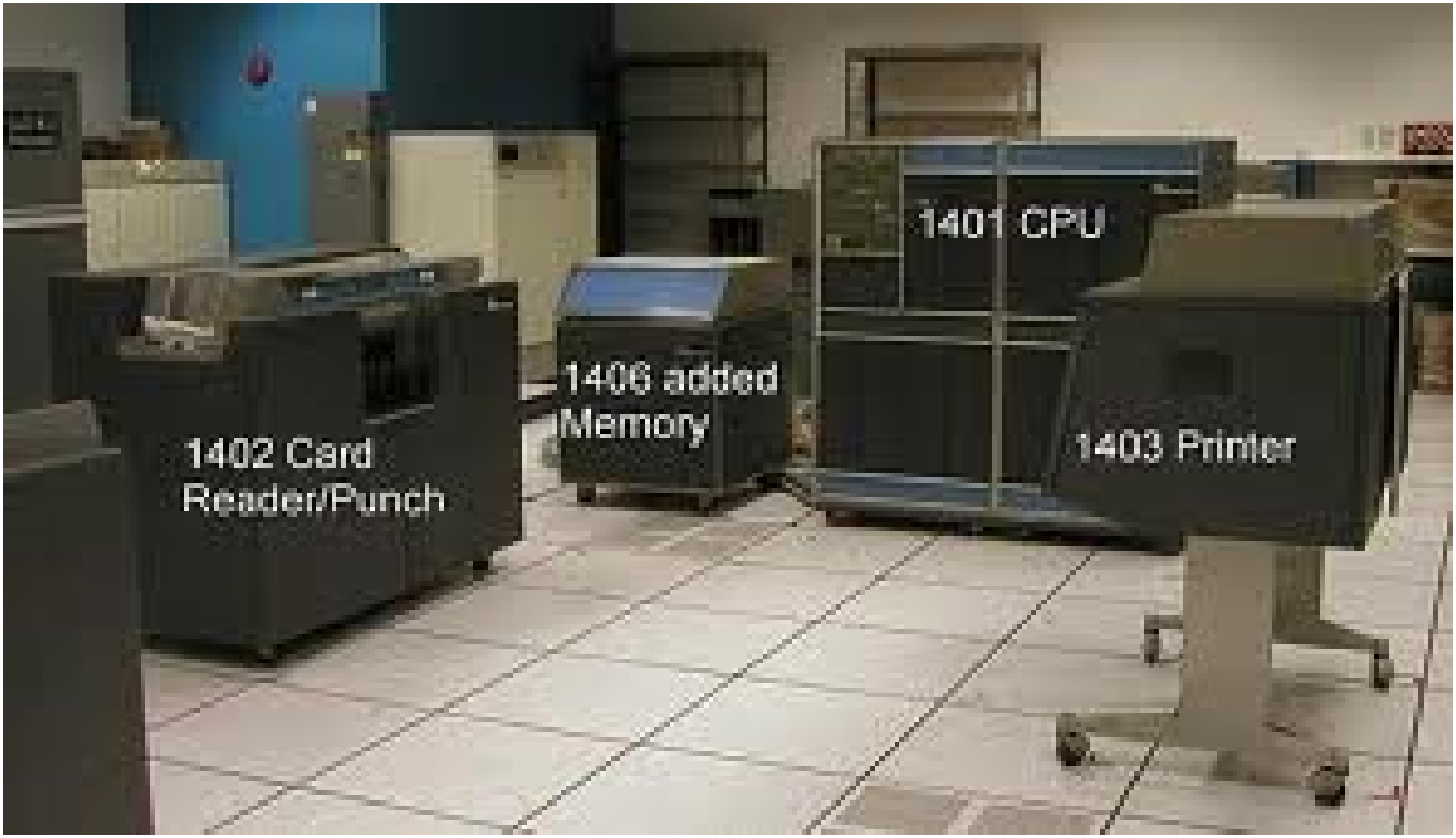
IBM 1401 – The legendary Data processing system



http://www.magcloud.com/browse/Issue

http://www.irishtimes.com/newspaper/finance/2009/1113/1224258713702.html

IBM 140x: 1401, 1402, 1403, and 1406



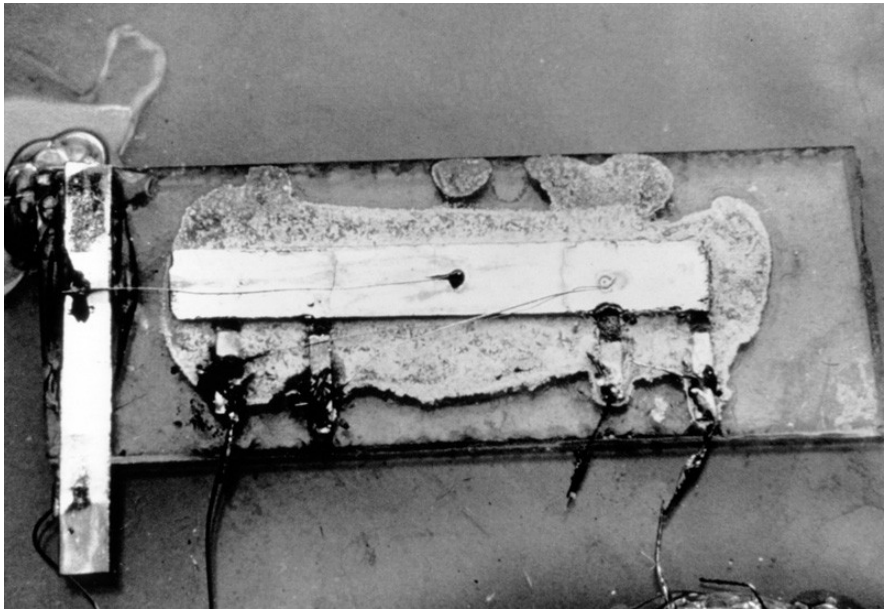
http://ibm-1401.info/1401-CHM-Left-Labeled-.jpg

Second Generation (1956-1963) Transistors [晶体管]

- Second-generation computers still relied on punched cards for input and printouts for output.
- Second-generation computers moved from cryptic binary machine language to symbolic, or **assembly languages**, which allowed programmers to specify instructions in words.
- **High-level programming languages** were also being developed at this time, such as early versions of **COBOL** and **FORTRAN**.
- These were also the first computers that stored their instructions in their memory, which moved from a magnetic drum to magnetic core technology.

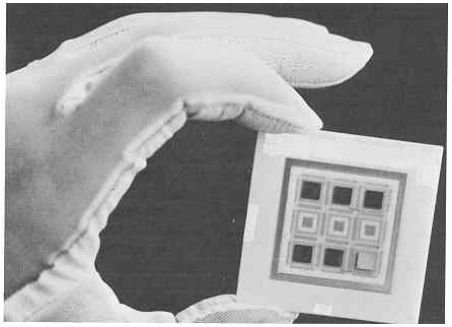
Third Generation (1964-1971) Integrated Circuits [集成电路]

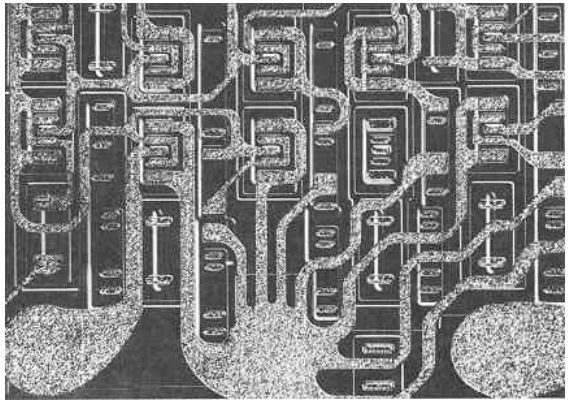
- The development of the **integrated circuit** was the hallmark of the third generation of computers.
  - Transistors were miniaturized and placed on silicon chips, called **semiconductors**, which drastically increased the speed and efficiency of computers.



1958

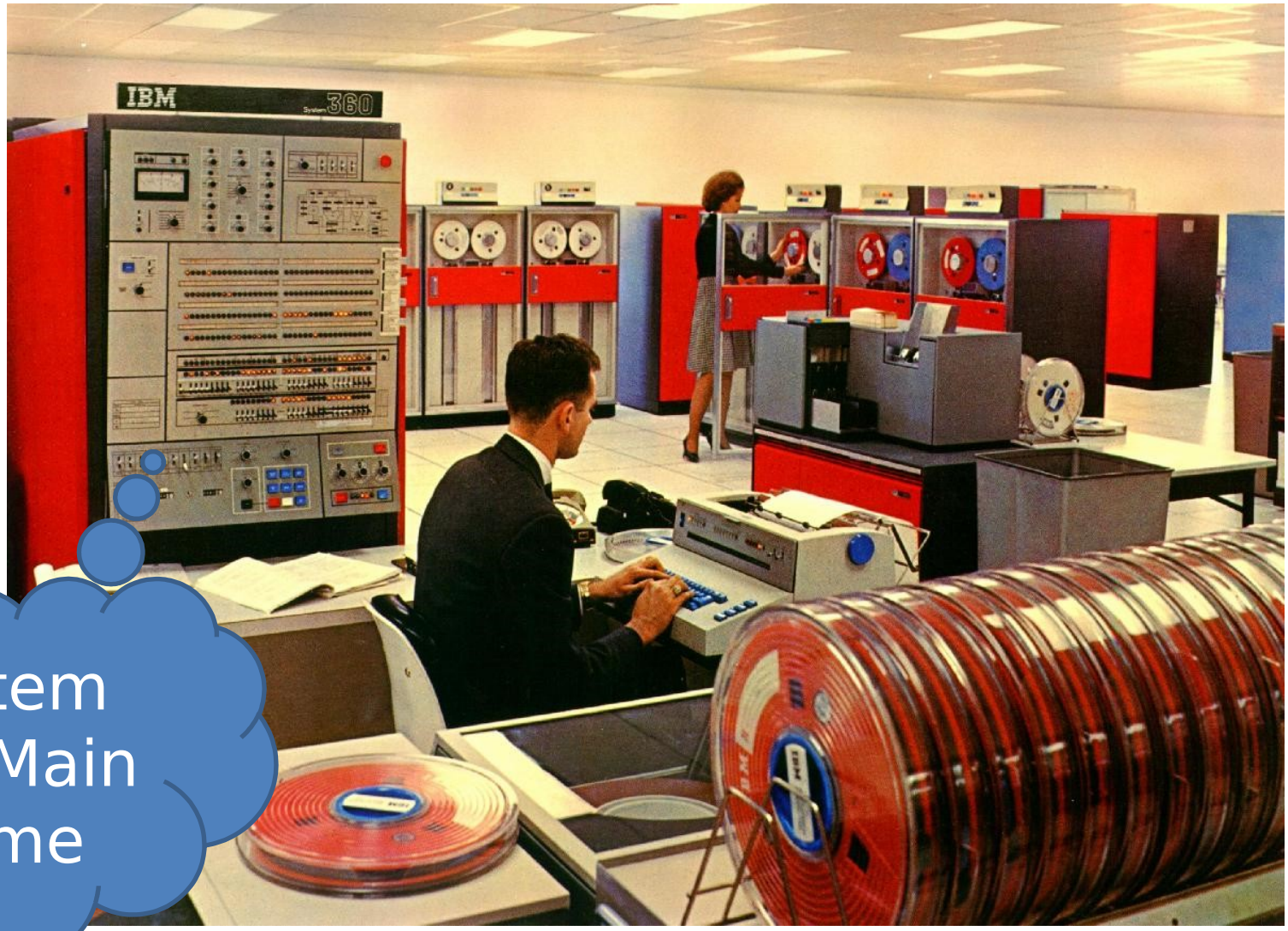
Kilby integrated circuit





IBM 360

The whole system – mainframe (IBM360), input/output machine, and tape machine etc.



System unit/Main frame

http://www.techcn.com.cn/index.php?doc-view-140320.html

IBM 360: Initial Implementations

	Model 30	. . .	*Model 70*
Storage	8K - 64 KB		256K - 512 KB
Datapath	8-bit		64-bit
Circuit Delay	30 nsec/level		5 nsec/level
Local Store	Main Store		Transistor Registers
Control Store	Read only 1μsec		Conventional circuits

IBM 360 instruction set architecture (ISA) completely hid the underlying technological differences between various models.

Milestone: The first true ISA designed as portable hardware-software interface!

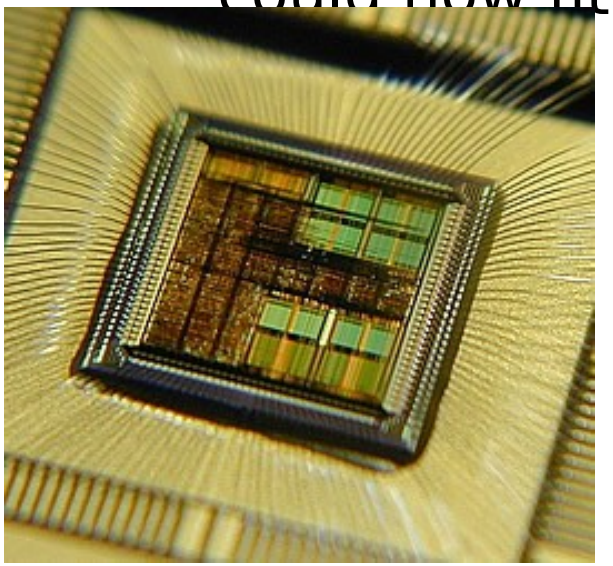
With minor modifications it still survives today!

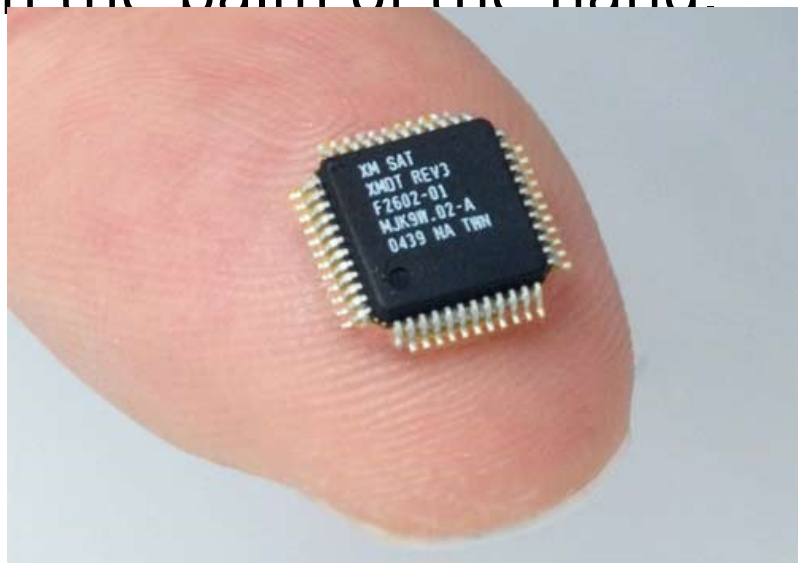
Third Generation (1964-1971) Integrated Circuits [集成电路]

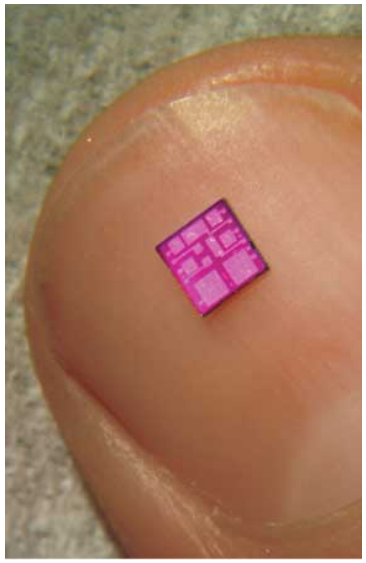
- Instead of punched cards and printouts, users interacted with third generation computers through **keyboards** and **monitors** and interfaced with an **operating system**, which allowed the device to run many different applications at one time with a central program that monitored the memory.
- Computers for the first time became accessible to a mass audience because they were smaller and cheaper than their predecessors.

Fourth Generation (1971-Present) Microprocessors

- The **microprocessor** brought the fourth generation of computers (at first, **VLSI** -- very large-scale integration: 大规模集成电路), as thousands of integrated circuits were built onto a single silicon chip.
  - What in the first generation filled an entire room could now fit in the palm of the hand.





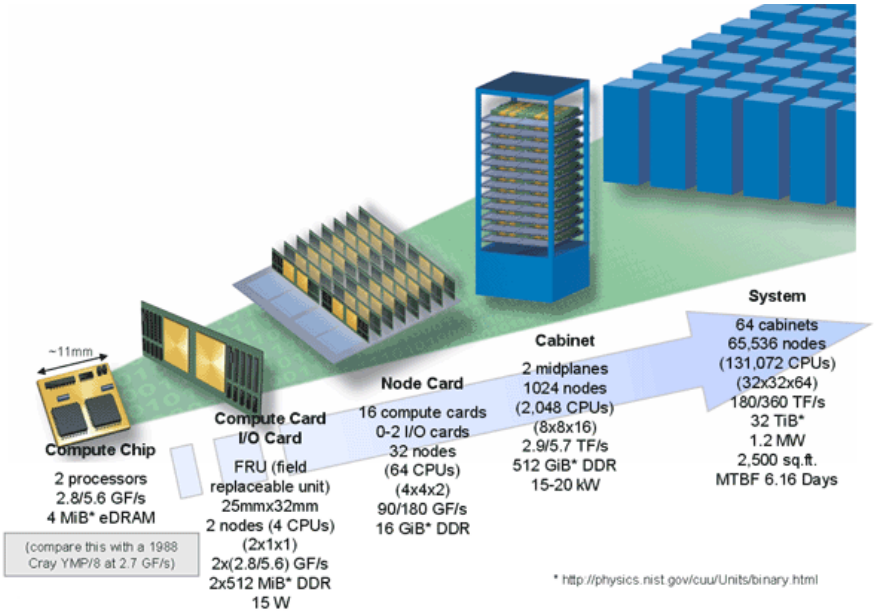


Trends & Classes

· As these small computers became more powerful, they could be linked together to form networks, which eventually led to the development of the Internet.
·Fourth generation computers also saw the development of GUIs, the mouse and handheld devices.

These are also computers

A videogame console

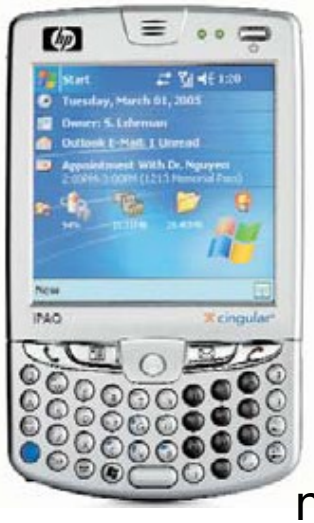


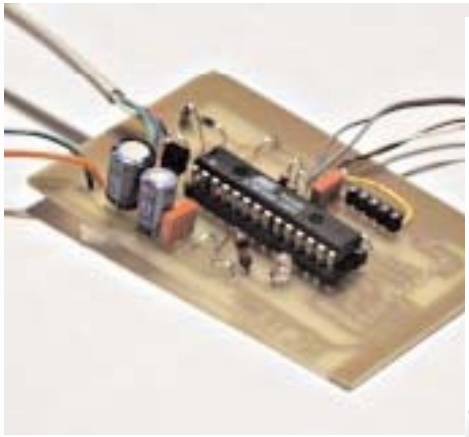
supercomputer

FIGURE 1-21

The iPod and other portable media players work with music, videos, and photos.

PDAs, Portable Players, and Smart

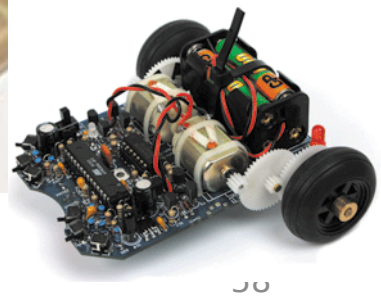




microcontroller

FIGURE 1-22

A microcontroller is usually mounted on a circuit board and then installed in a machine or appliance using wires to carry input and output signals.



http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

Desktop Supercomputing

	Dell Precision 610 Workstation	1989 Cray Y-MP8/4128
CPUs	2 Xeon 550MHz	4 166MHz
Max RAM	2 GB	1 GB
Peak Mflops	1333	1333
Weight	< 50 lbs	> 5,000 lbs
Cost	< $15K	> $13M
	www.dell.com	3/20/89 Electronic News

http://mprc.pku.edu.cn/courses/organization/autumn2011/slide11/CHX11_org02_history.pdf

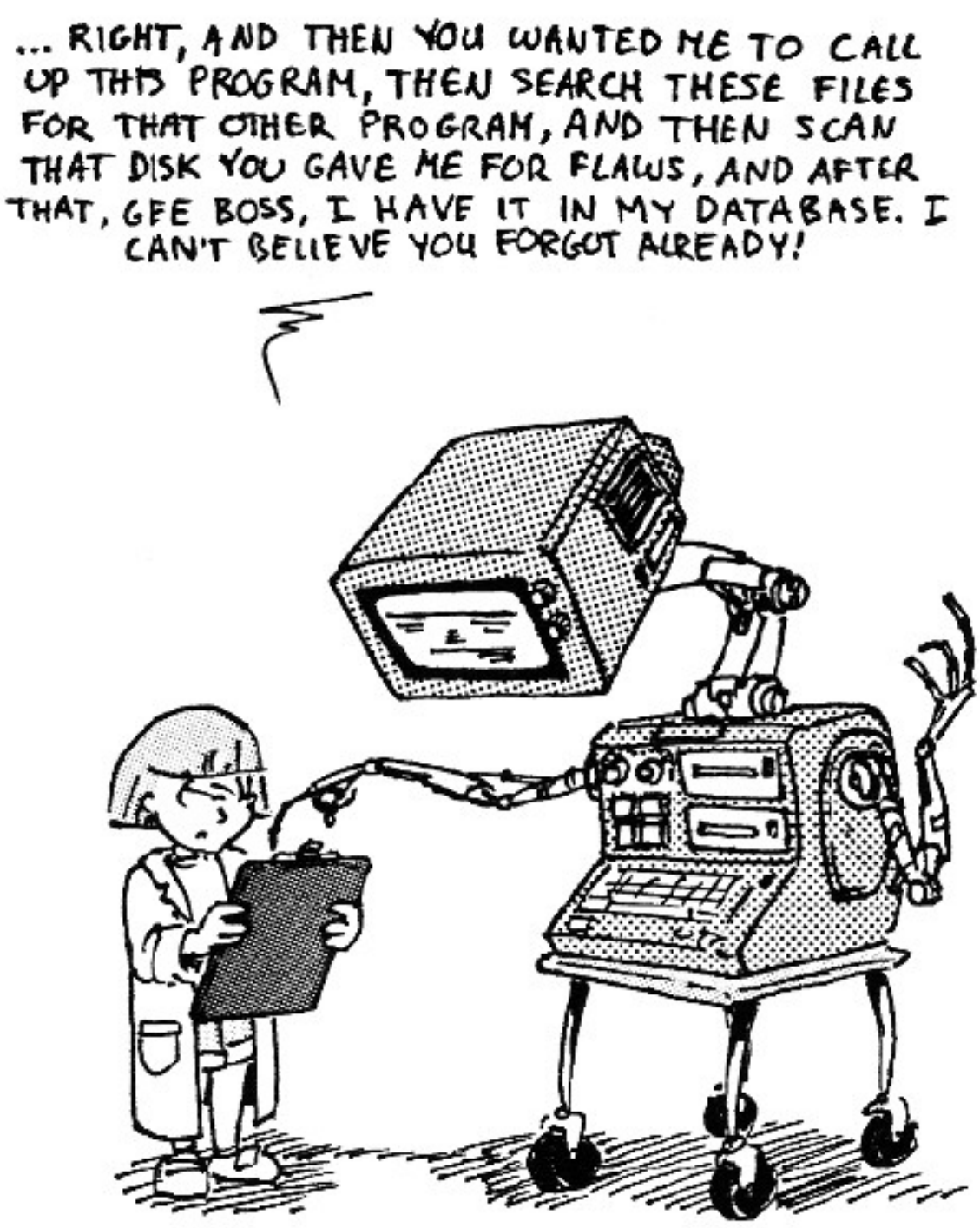
PPR of computers of 1951 - 1996

Year	Name	Size (in^3)	Power (watt)	Performance (add/sec)	MM (kb)	Price ($)	PPR with UNIVAC	Modified Price (1996 $)	PPR with UNIVAC
1951	UNIVAC I	1000	124,500	1,900	48	1,000,000	1	4,996,749	1
1964	IBM S/360-50	60	10,000	500,000	64	1,000,000	263	4,140,257	318
1965	PDP-8	8	500	330,000	4	16,000	10,855	66,071	13,135
1976	Cray-1	58	60,000	166,000,000	32,768	4,000,000	21,842	8,459,712	51,604
1981	IBM PC	1	150	240,000	256	3,000	42,105	4,081	154,673
1991	HP 9000/750	2	500	50,000,000	16,384	7,400	3,556,188	8,156	16,122,356
1996	Intel PPro/200	2	5000	400,000,000	16,384	4,400	47,846,890	4,400	239,078,908

Present and Beyond: Artificial Intelligence?

- Fifth generation computing devices (?), based on **artificial intelligence** [人工智能], are still in development, though there are some applications, such as voice recognition, that are being used today
  - Its goal is to develop devices that respond to natural language [自然语言] input and are capable of learning and self-organization [自组织].
  - The use of **parallel processing** [并行处理] and **superconductors** [超导] is helping to make artificial intelligence a reality.
  - **Quantum computation** [量子计算] and **molecular** [分子] and **nanotechnology** [纳米技术] will radically change the face of computers in years to come.

http://www.webopedia.com/DidYouKnow/Hardware_Software/2002/FiveGenerations.asp



往右一点，然后，你会想让我调用这个程序，
之后为另一个程序搜索这些文件，再然后，扫描那个磁盘，最后，老板你看，我就已经将它放到我的数据库里了。
但是，真不敢相信：你自己竟然已经忘了！

"Great Ideas in Computer Science with Java", Alan W. Biermann and Dietolf Ramm, Massachusetts Institute of Technology,