Part 1: Computing Before World War 2

Today's Lecture

- A brief history of computing
  - Major milestones, big ideas
  - The interplay between technological developments and social, political factors.
- Discuss about your experience with Blockly from learn.code.org.
  Used in Programming Assignment 1 and Lab1

Part 1: Computing Before World War 2

Early Devices For Arithmetic

- Abacus: Humans do all the work
- Increase in scientific research in the seventeenth century motivated developments of tools to do arithmetic.
  - Napier's bones for multiplication
  - Pascaline to do addition and subtraction
  - Leibniz's wheel to do all of arithmetic operations

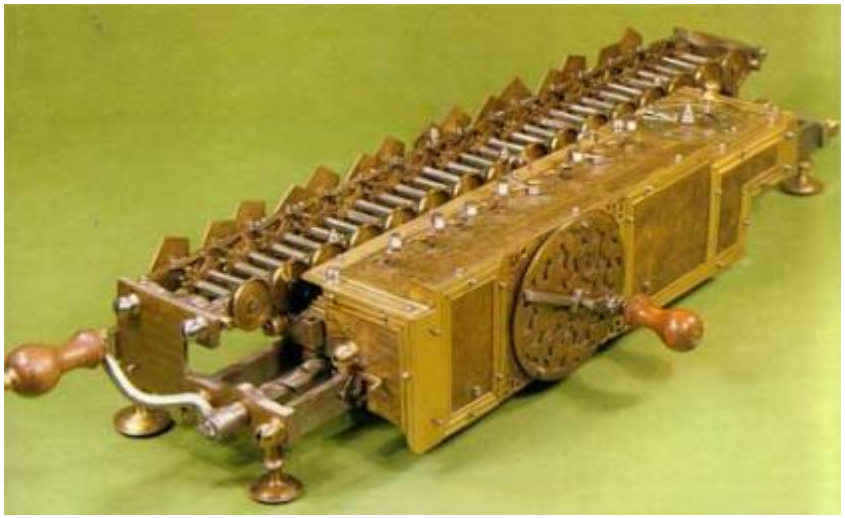
Mechanical Devices for Arithmetic

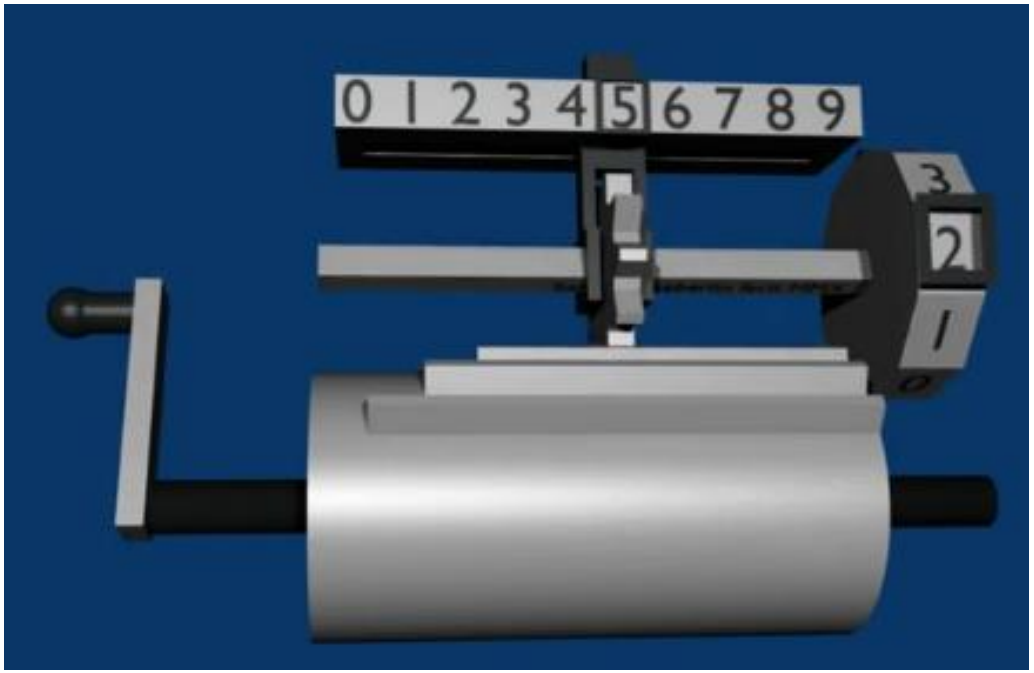
Blaise Pascal's Pascaline (1643)

first successful mechanical calculator (addition and subtraction)

Leibniz's step reckoner (designed in 1673, completed in 1694)

first calculator that could perform all four arithmetic operations: addition, subtraction, multiplication and division.





Key problem:

How to make the carry work reliably in a purely mechanical system?

It's harder than you think!

Leibniz's Stepping Drum

5 + 2 + 3 = 10

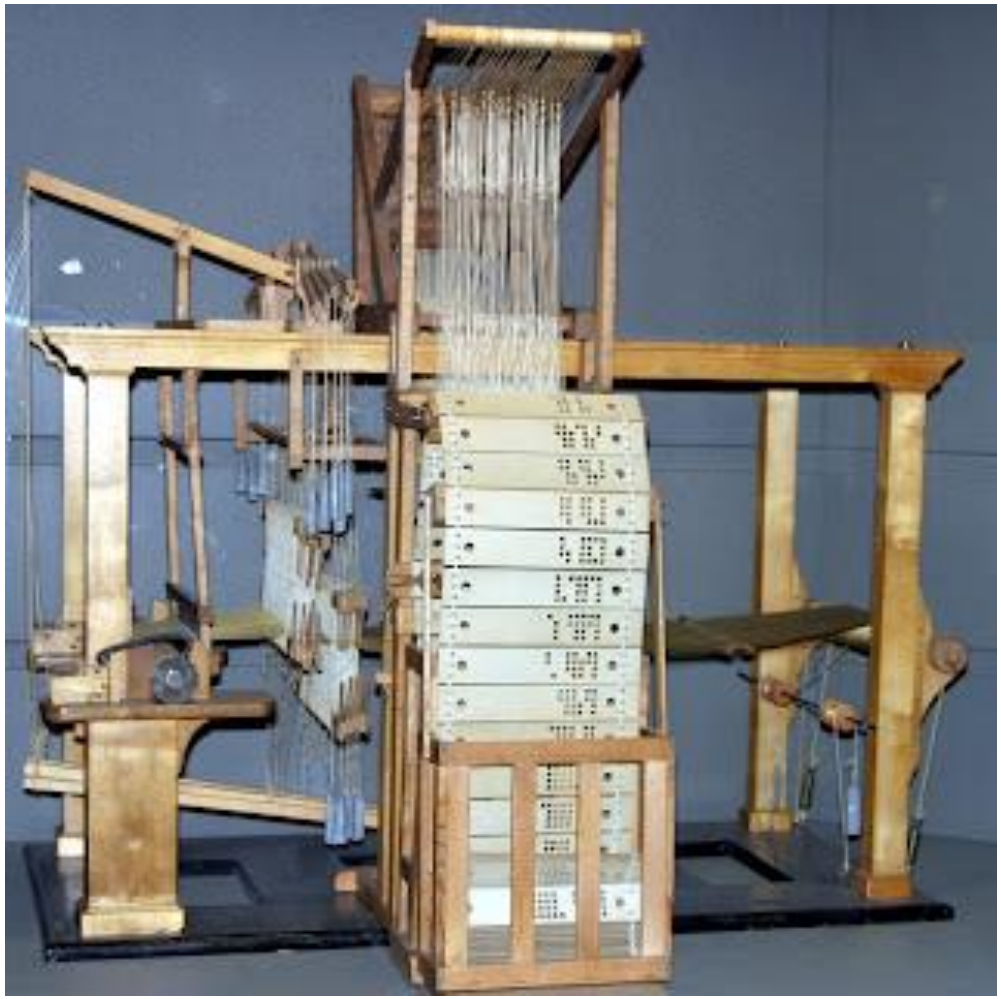
Shortcomings of Early Devices

- They demonstrated how mechanization could simplify and speed up numerical computation.

But

- They did not have memory (storage for data)
- They were not programmable

Jacquard's Loom: First Digital Storage

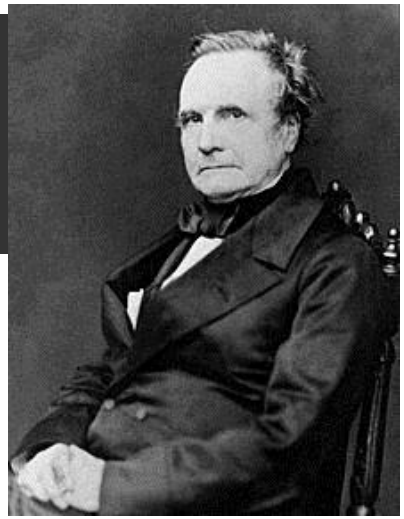


Developed by Joseph-Marie Jacquard (1801). The loom was controlled by a loop of **punched cards**. Holes in the punched cards determined how the knitting proceeded, yielding very complex weaves at a much faster rate.

Technophobia

- Jaquard's loom showed how the knowledge of a human expert could be captured in **machine-readable** form.
- Mobilized craft guilds against this manufacturing technology.

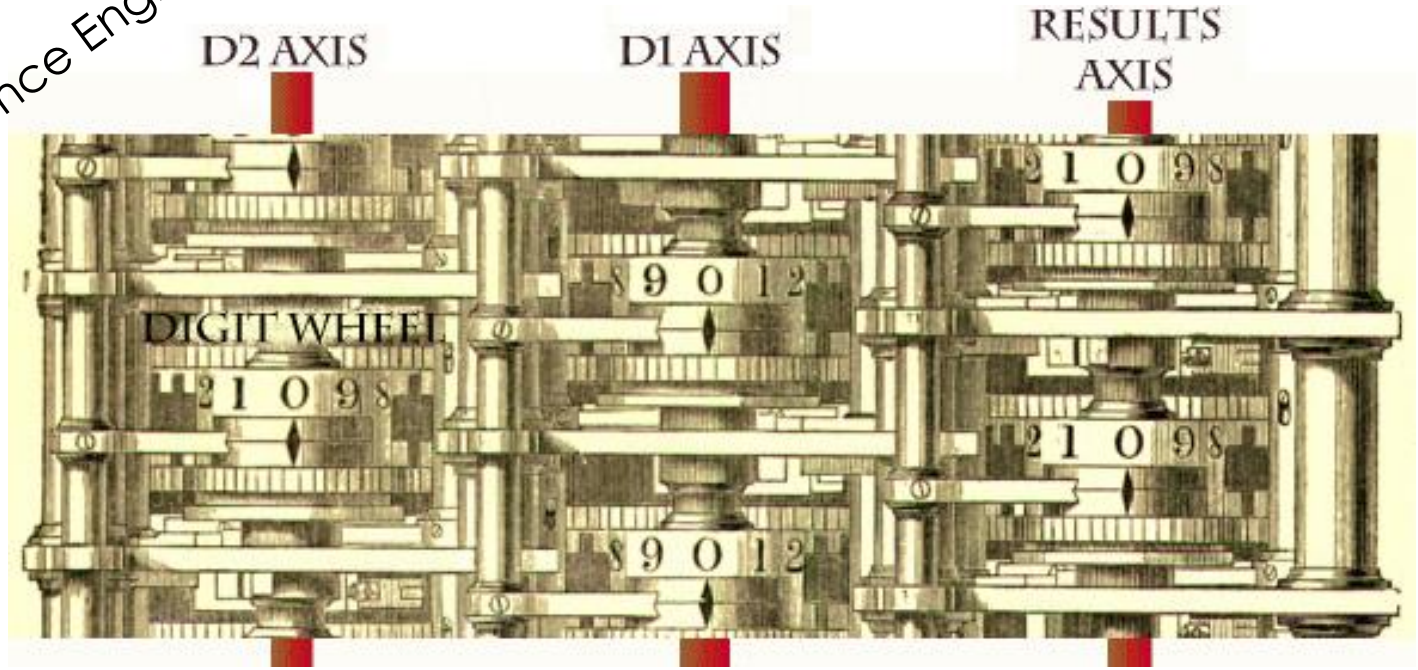
Charles Babbage (1791-1871)



- Mathematician, industrialist, philosopher, politician.
- Frustrated by the many errors in printed mathematical tables (sines, cosines, logs, etc.) used in navigation and engineering.
- Observed that many long computations consist of operations that were regularly repeated.

Babbage's Difference Engine Computed 7th Degree Polynomials to 31 Digits

Difference Engine



http://www.culture.com.au/brain_proj/CONTENT/BABBAGE.HTM

Building the Difference Engine

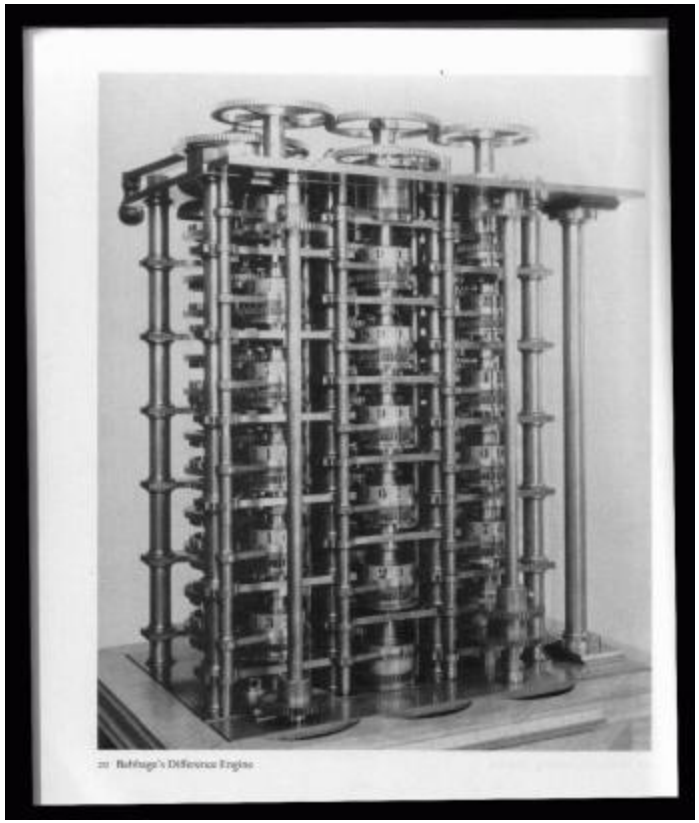


Photo of the
1832 Fragment
of a Difference Engine

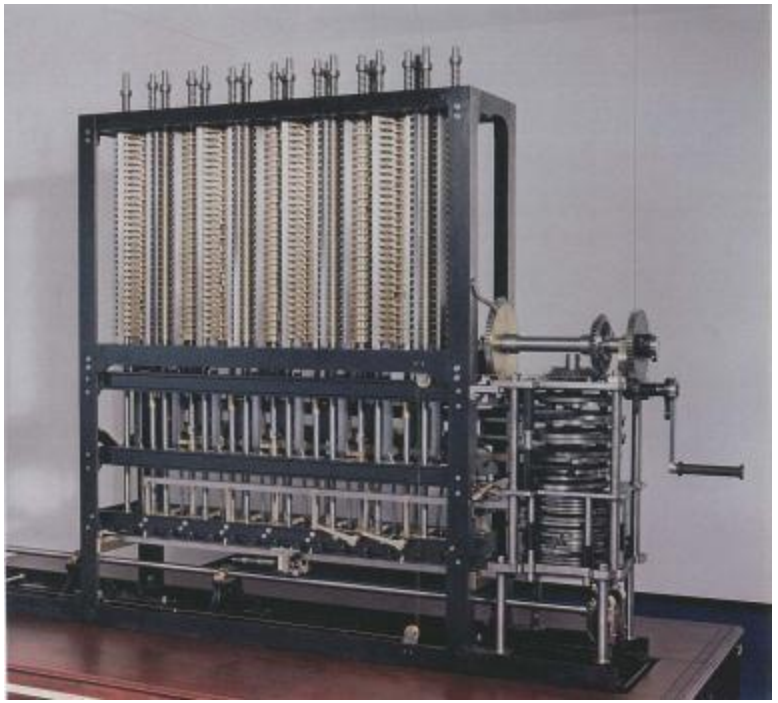


Photo of Babbage Difference Engine No. 2
constructed in 1991

(See video)

6:05 – 12:30

Charles Babbage's Analytical Engine

- **Difference Engine** (1822)
  - Never built (he ran out of money)

- **Analytical Engine** (1834-1836)
  - Babbage's more general "computer"
  - Never built, but its design is considered to be the foundation of modern computing
  - Had all the crucial features:
    - Arithmetic and logical operations
    - Digital data storage
    - Programs stored in memory

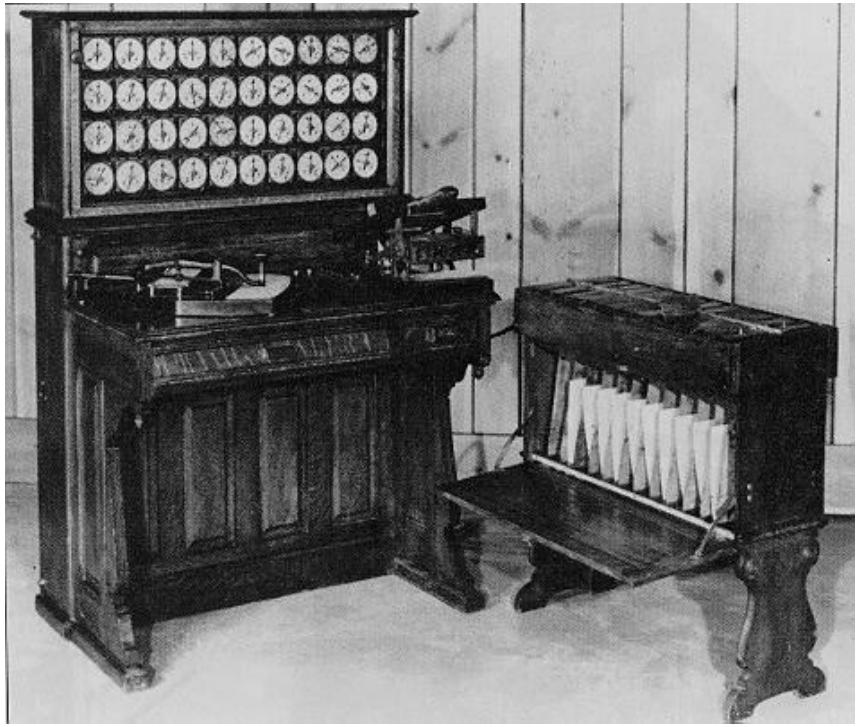
Ada Lovelace

- 1815-1852
- Daughter of poet Lord Byron
- Translated Menabrea's *Sketch of the Analytical Engine* to English
  - Quadrupled its length by adding lengthy notes and detailed mathematical explanations
- Referred to as **the world's first programmer**
  - Described how the machine might be configured (programmed) to solve a variety of problems.

Herman Hollerith
& The Hollerith Census Machine

- 1880 U.S. Census
  - The amount of data that needed to be analyzed was growing so quickly due to immigration
  - Required almost a decade to compute 1880 Census
- In 1882, Hollerith investigated a suggestion by Dr. John Shaw Billings, head of the division of Vital Statistics for the Census Bureau
  - "There ought to be some mechanical way of [tabulating Census data], something on the principle of the Jacquard loom, whereby holes in a card regulate the pattern to be woven."

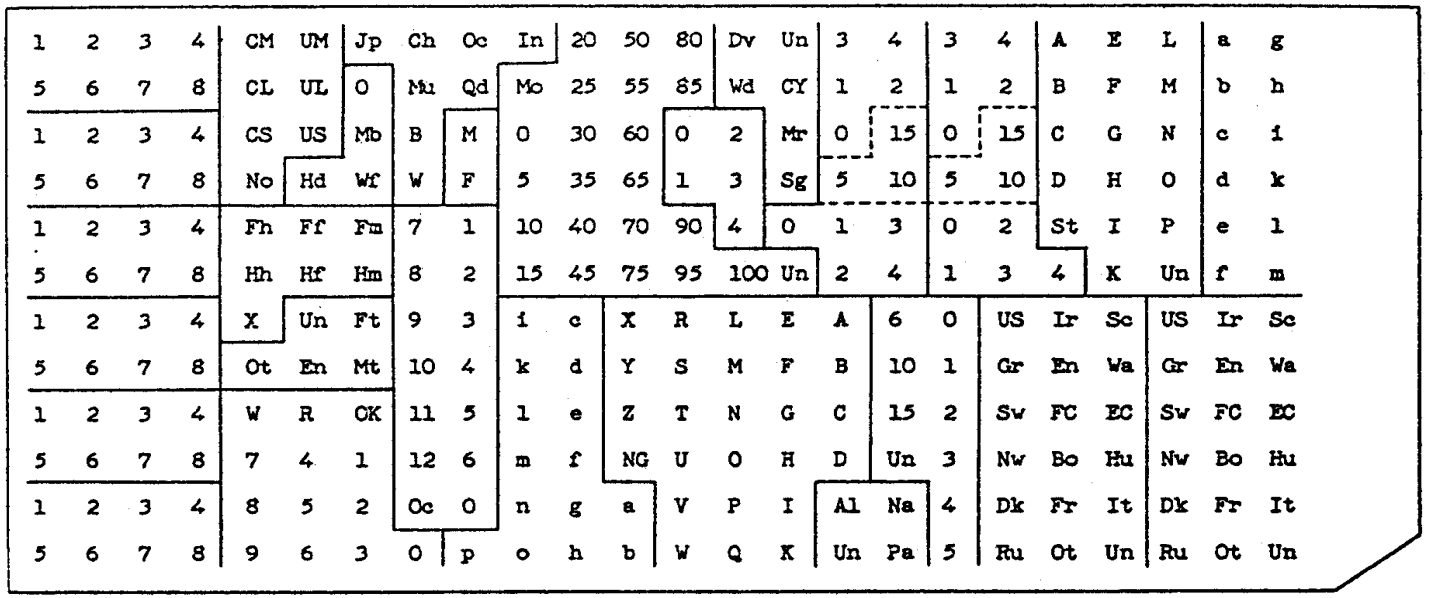
Hollerith's Census Machine



Demonstrated the advantages of automated information processing to solve large real-world problems

Photo: IBM

Hollerith's Census Machine



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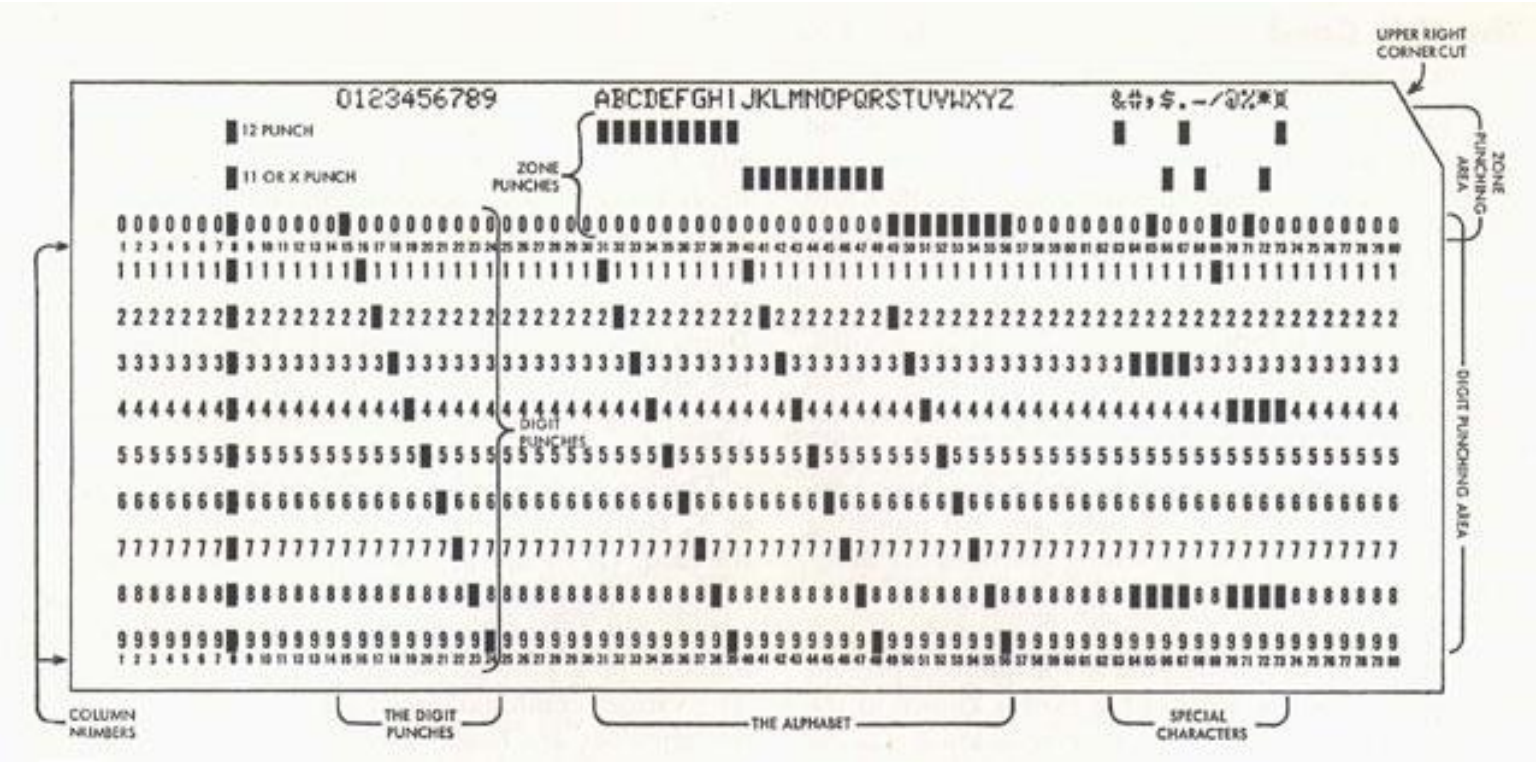
5	6	7	8	CL	UL	O	Mu	Qd	Mo	25	55	85	Wd	CY	1	2	1	2	B	F	M	b	h
1	2	3	4	CS	US	Mb	B	M	0	30	60	0	2	Mr	0	15	0	15	C	G	N	c	i
5	6	7	8	No	Hd	Wf	W	F	5	35	65	1	3	Sg	5	10	5	10	D	H	O	d	k
1	2	3	4	Fh	Ff	Fm	7	1	10	40	70	90	4	0	1	3	0	2	St	I	P	e	l
5	6	7	8	Hh	Hf	Hm	8	2	15	45	75	95	100	Un	2	4	1	3	4	K	Un	f	m
1	2	3	4	X	Un	Ft	9	3	i	c	X	R	L	E	A	6	0	US	Ir	Sc	US	Ir	Sc
5	6	7	8	Ot	En	Mt	10	4	k	d	Y	S	M	F	B	10	1	Gr	En	Wa	Gr	En	Wa
1	2	3	4	W	R	CK	11	5	l	e	Z	T	N	G	C	15	2	Sw	FC	EC	Sw	FC	EC
5	6	7	8	7	4	1	12	6	m	f	NG	U	O	H	D	Un	3	Nw	Bo	Hu	Nw	Bo	Hu
1	2	3	4	8	5	2	Oc	0	n	g	a	V	P	I	Al	Na	4	Dk	Fr	It	Dk	Fr	It
5	6	7	8	9	6	3	0	p	o	h	b	W	Q	K	Un	Pa	5	Ru	Ot	Un	Ru	Ot	Un

Photo of a punch card for the Hollerith machine, from *John McPherson, Computer Engineer*, an oral history conducted in 1992 by William Aspray, IEEE History Center, Rutgers University, New Brunswick, NJ, USA.

- The entire 1890 census data was processed in 3 months and complete 1890 data was published in 1892.
- Total population of the U.S.: 62,622,250



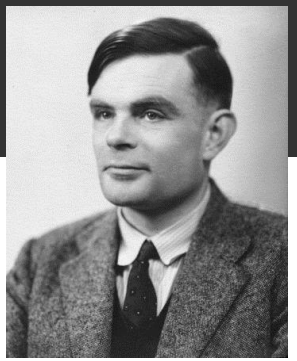
An IBM punch card used from 1928 until the 1970s.

- Hollerith forms the Tabulating Machine Company in 1896 which eventually becomes IBM in 1924 through a merger and several name changes.

Effect of World War 2

- World War 2 gave rise to new information-based concerns
  - Ballistic tables, troop deployment data, secret codes
  - Military started funding projects to build automatic machines

Alan Turing



- Considered the **"father"** of modern computer science.
- Presented formalisms for the **notions of computation and computability** in the 1930's.
- Worked at Bletchley Park in Great Britain during WW 2 to develop Collossus to help break the German Enigma Code.
- Developed the notion in 1950 of a test for machine intelligence now called the **Turing Test**.
- **The Turing Award**, the highest award in computing, is named in honor of Alan Turing.

Computing from WW2 to Present

Across the Atlantic in the US

Harvard Mark I
(IBM Archives)

Harvard Mark I
(IBM Automatic Sequence Controlled Calculator)
Developed by Howard Aiken

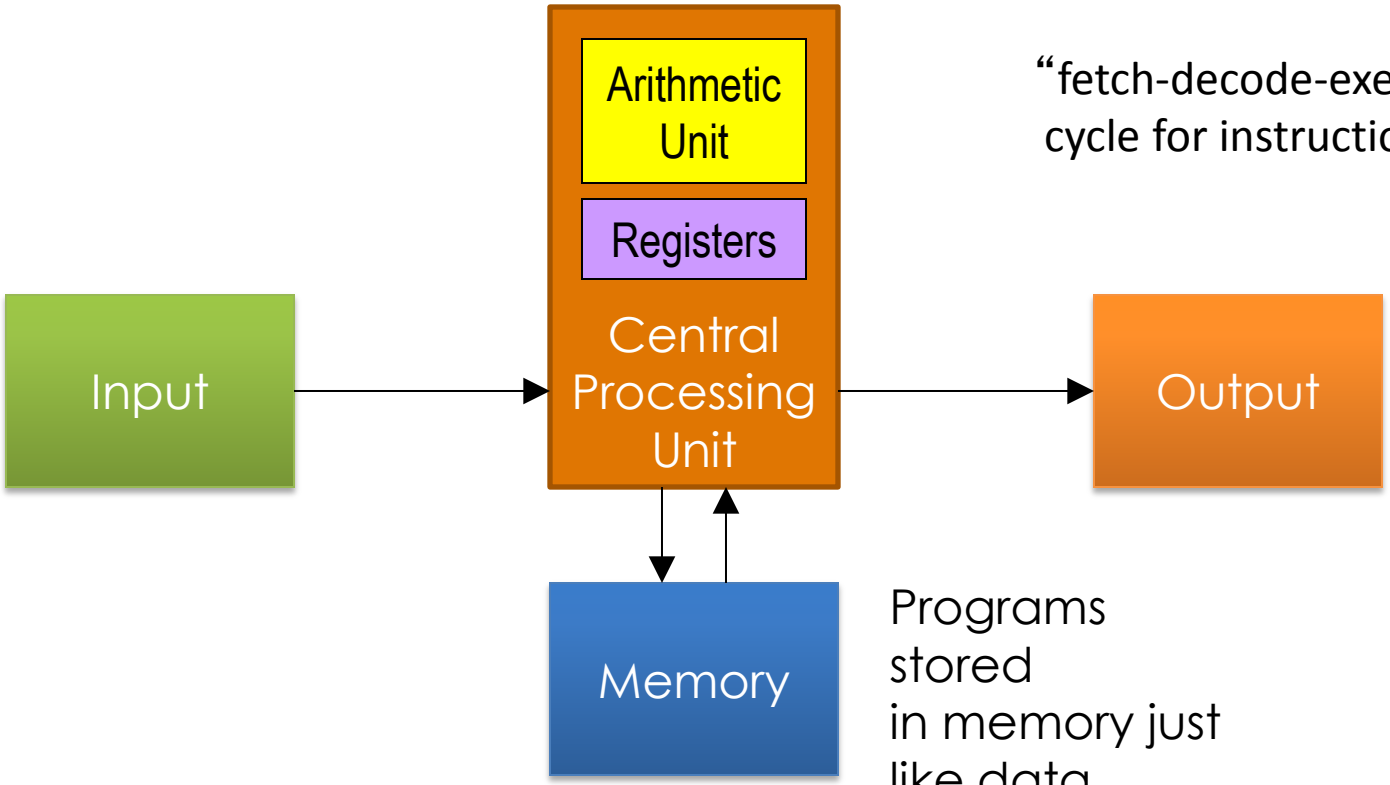
- Contained more than 750,000 components
  - over 50 feet long
  - 8 feet tall
  - weighed ~5 tons
- Sounded like a "roomful of ladies knitting"

Early Electronic Computers

- Electromechanical – Harvard Mark I
- Purely electronic – ENIAC, Colossus, Atanasoff-Berry Computer (ABC), Z1 all had memory and were programmable.
- But they were not ***stored program computers.***

  They were programmed externally.

Von Neumann Architecture

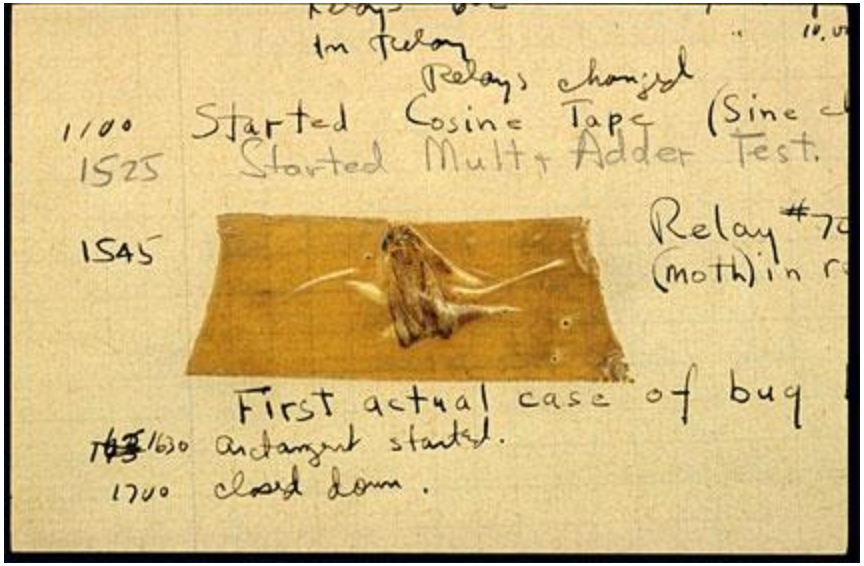


"fetch-decode-execute" cycle for instructions in programs

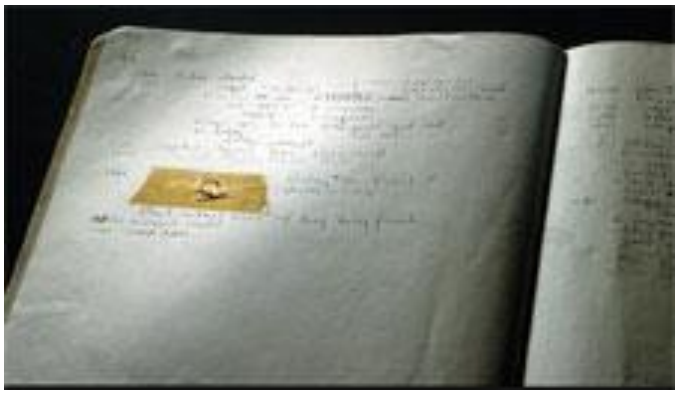
Programs stored in memory just like data

The First Debugger

- Grace Hopper, working on the Harvard Mark II computer in 1947, found the first actual computer "bug" and coined the term "debugging".



- The "Grace Hopper Celebration of Women in Computing" is an annual conference named in her honor.

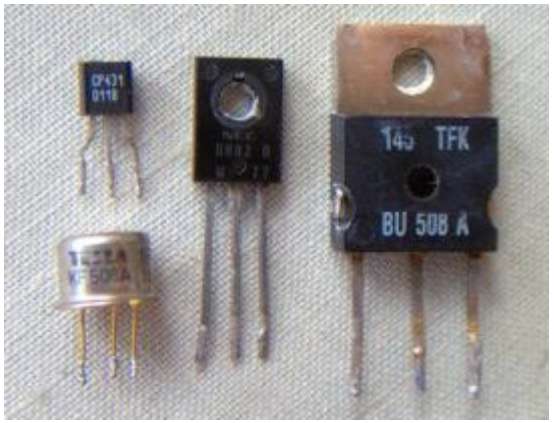


From Vacuum Tubes to Transistors

unreliable
bulky

Before the transistor was invented,
we used vacuum tubes: 2-3 inches tall;
equivalent to 1-3 transistors

reliable
smaller



(See video)
20:47 – 24:30

Integrated Circuit

- A network of transistors and other electronic components incorporated on a single silicon chip
- Mass production capability
- Miniaturization of computers was desirable
  - Essential for the space race

Noyce and Kilby

- Robert Noyce and Jack Kilby are credited with the invention of **the integrated circuit** (IC) or **microchip**.
  - Robert Noyce co-founded Intel in 1968.
  - Kilby won the Nobel Prize in Physics in 2000.
- By the mid 1970s, ICs contained tens of thousands of transistors per chip.
  - In 1970, Intel created the 1103--the first generally available DRAM (memory) chip.
  - Today, you would need more than 65,000 of them to put 8 MB of memory into a PC.

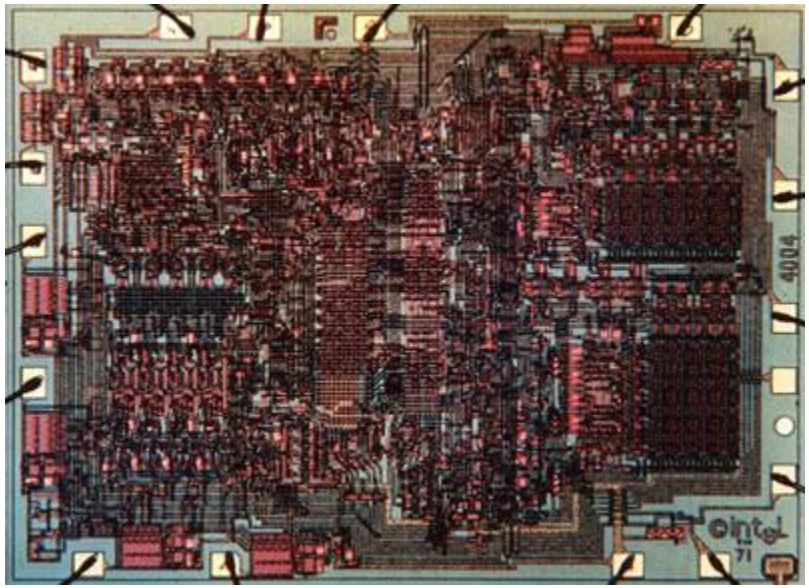
Mainframes

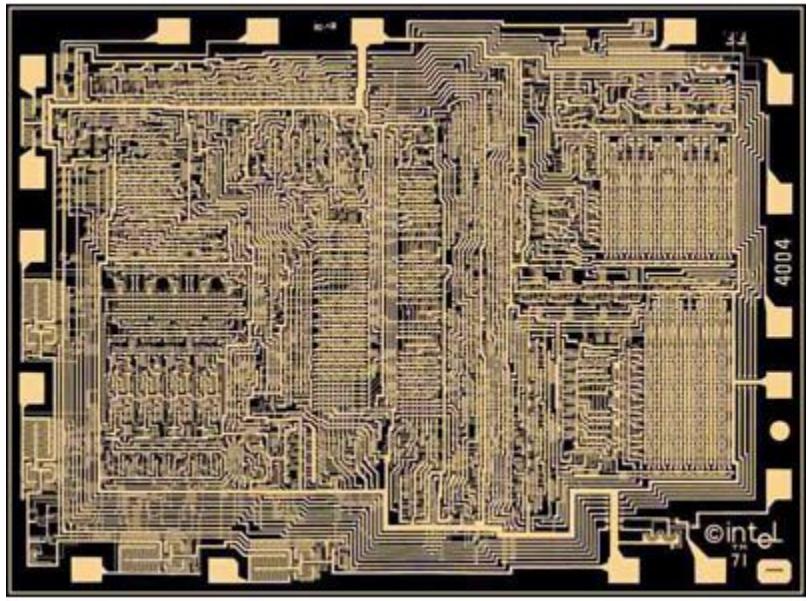
- In the 1960s and 1970s, large computers called "**mainframes**" became widespread in businesses and universities. IBM was the largest computer maker.

IBM System/360

The Microprocessor

- In 1971 Intel released the first **microprocessor**: the 4004, shown below.
- A microprocessor is an entire CPU on a chip.
- **The personal computer revolution began shortly thereafter.**





A Modern Inexpensive Personal Computer

1.4GHz dual-core Intel Core i5
4GB memory
500GB hard drive1
Intel HD Graphics 5000
OS X Yosemite

$499.00

Units of Memory

Byte	B	8 bits (8b)		
Kilobyte	KB	1024 B	$= 2^{10}$ Bytes	$\approx 10^3$ Bytes
Megabyte	MB	1024 KB	$= 2^{20}$ Bytes	$\approx 10^6$ Bytes
Gigabyte	GB	1024 MB	$= 2^{30}$ Bytes	$\approx 10^9$ Bytes
Terabyte	TB	1024 GB	$= 2^{40}$ Bytes	$\approx 10^{12}$ Bytes
Petabyte	PB	1024 TB	$= 2^{50}$ Bytes	$\approx 10^{15}$ Bytes

If one byte weighed 1 ounce, how many tonnes would 1 GB weigh? Note that 1 ounce is 30 grams. One tonne is 1 million grams.

30 thousand tonnes!

Examples

- How many bytes can be stored in a 4GB flash drive?

$$4 \times 2^{30} \text{ Bytes} \approx 4 \times 10^{9} \text{ Bytes}$$

- How many bytes/second is a 16Mbps cable modem connection?

Bits per second

$$16 \times 2^{20} \text{ bps} = 16/8 \times 2^{20} \text{ Bps}$$
$$\approx 2 \times 10^{6} \text{ bps}$$

Bytes per second

How Time Flies…

Commodore 64 (1982)

64KB of IC memory

$595

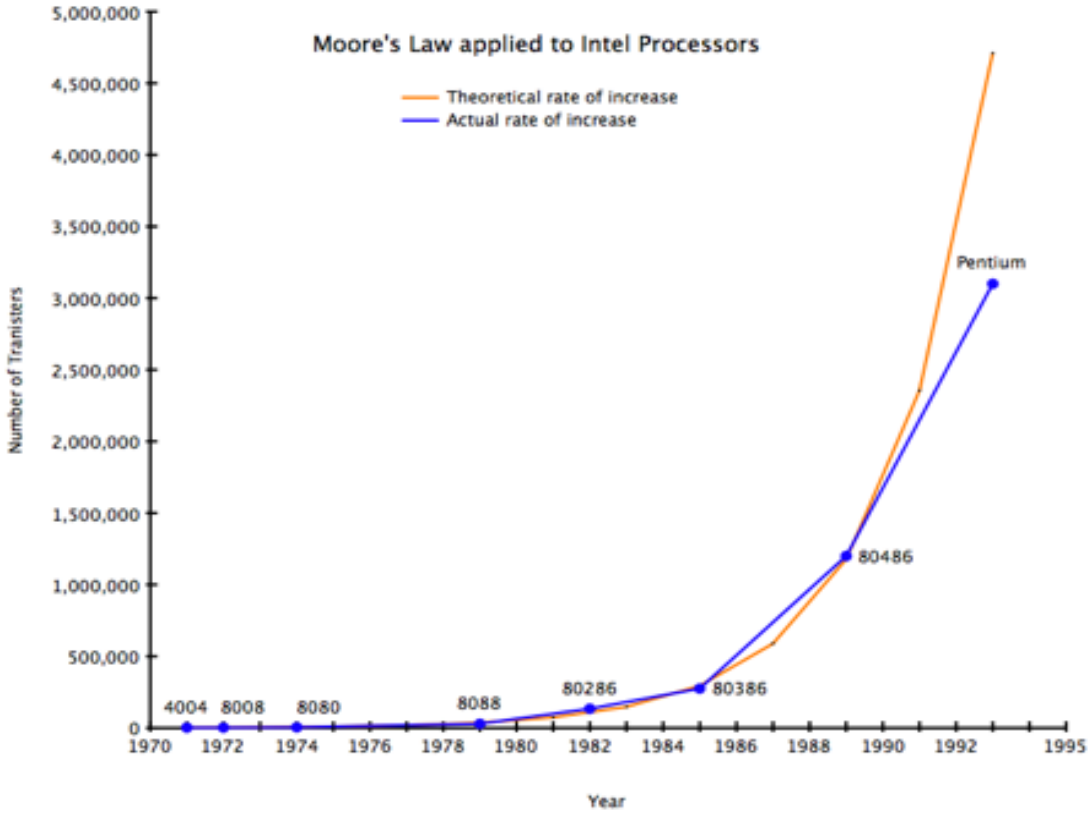
Apple Mac mini(2015)

4GB memory, 500GB Hard Drive

$499

Moore's Law

- Gordon Moore co-founded Intel Corporation in 1968.
- Famous for his prediction on the growth of the semiconductor industry: **Moore's Law**
  - An empirical observation stating in effect that the **complexity of integrated circuits doubles every 18 months.** ("complexity" generally means number of transistors on a chip)


Moore's Law applied to Intel Processors
Theoretical rate of increase
Actual rate of increase
Number of Tranisters
Year
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1970
1972
1974
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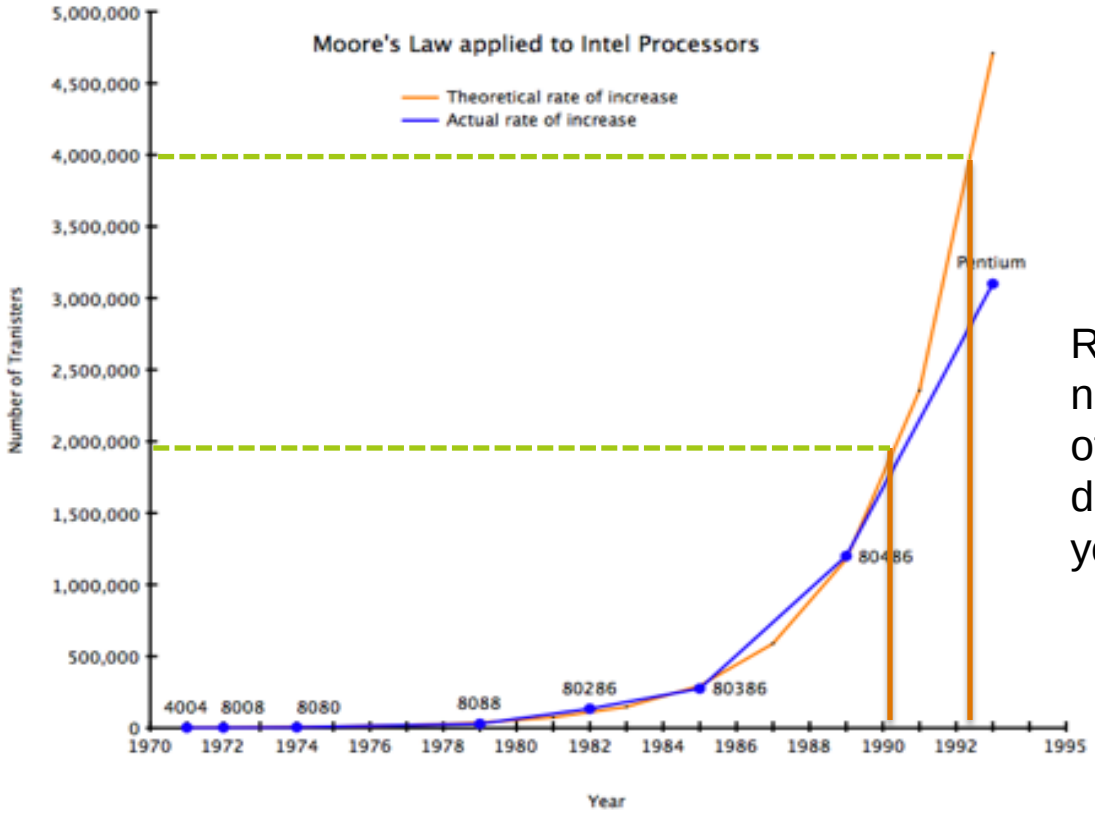
4004
8008
8080
8088
80286
80386
80486
Pentium



Roughly, the number of transistors doubled in 2 years