COMPUTER ARCHITECTURE

2 The evolution of computing machines

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The evolution of computing machines and other devices for computation can be chronologically divided into five major groups:

- I. Period of mechanics — from about 1600 →
  - Babbage: Analytical Machine
- II. Electro-mechanical computers — from 1939 →
  - Zuse Z3, Harvard Mark
- III. First electronic computers — 1945
  - ENIAC
- IV. Electronic stored program computers — 1945 →
  - EDVAC, the IAS
- V. The rapid development of computers — 1950 →

I. period of mechanics

- first calculators in the 17th century - mechanical, manually operated

Blaise Pascal
1623-1662

Pascal's Calculator
(*Pascaline*, 1652)

- Add
- Subtract

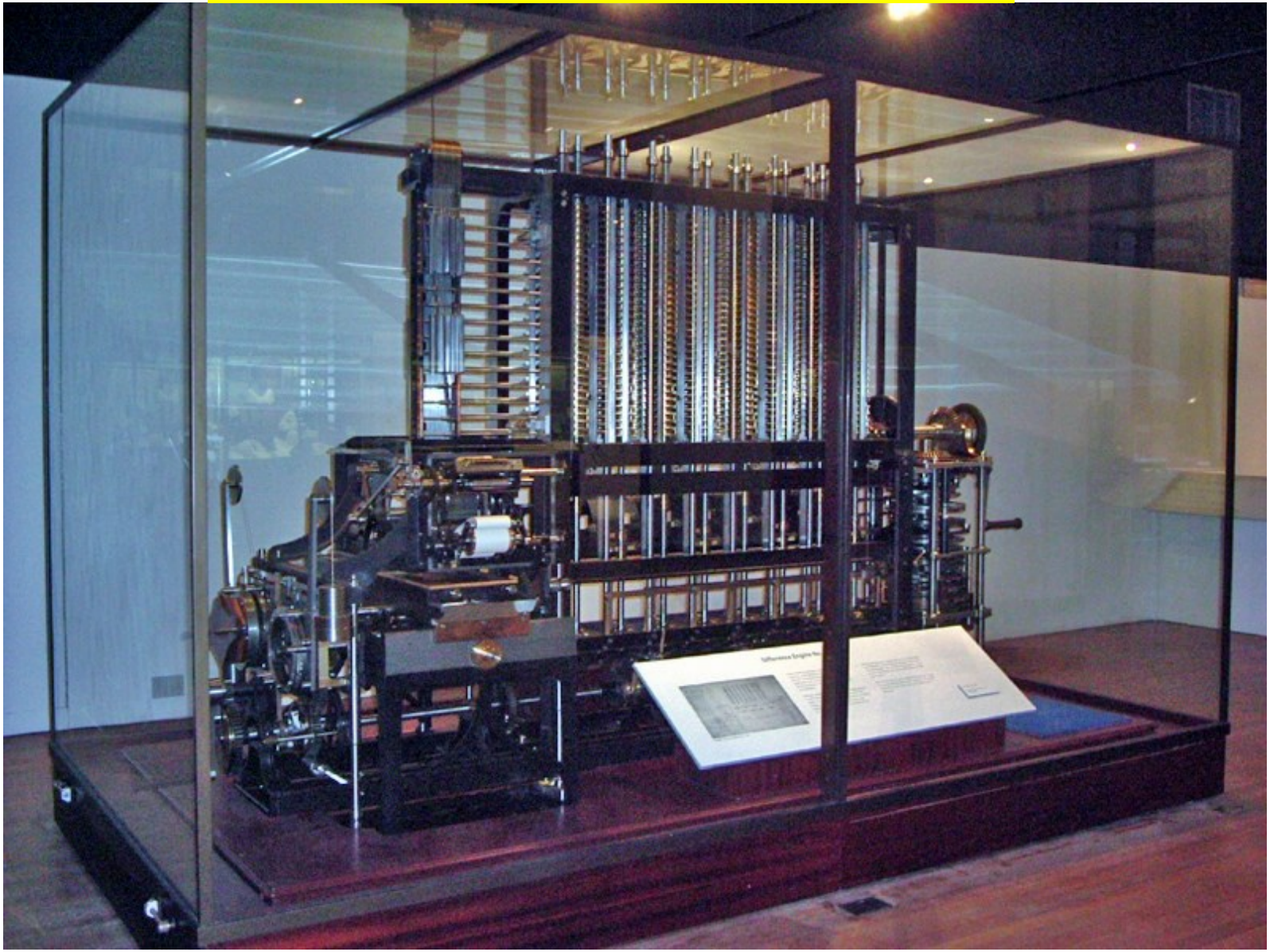
Gottfried Leibniz
1646-1716

Leibniz Calculator (1673)

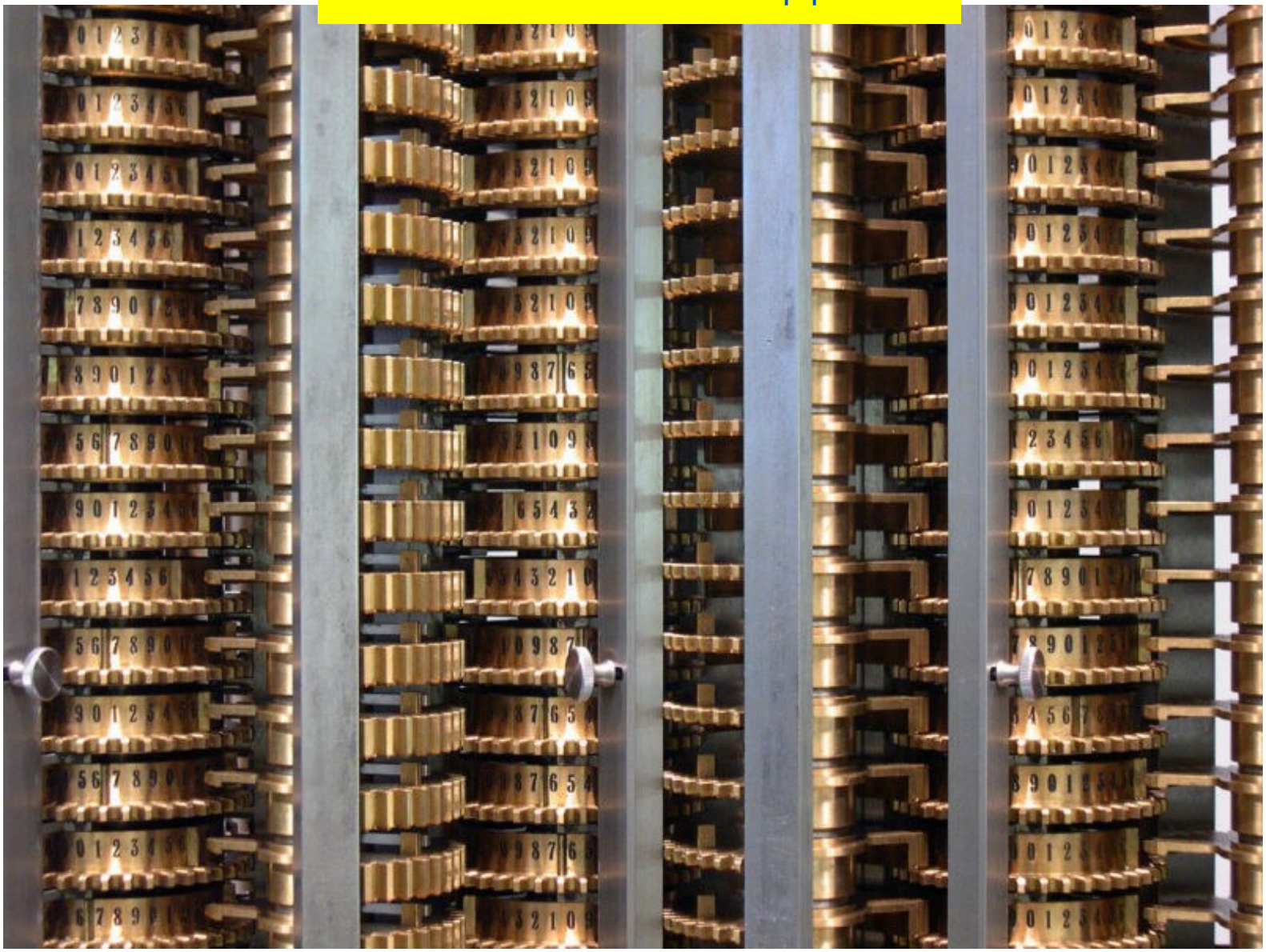
- Add
- Subtract
- Multiply
- Divide.

- Charles Babbage (1792 - 1871)
  - Differential machine (1823 - 1833)
  - ***Analytical Machine (1834 - 1836)***
    - "The first real precursor of today's computers" ([Kodek])
    - It combines two important features:
      - Operation run by a program
      - It is designed to solve arbitrary problems
    - Never fully completed.

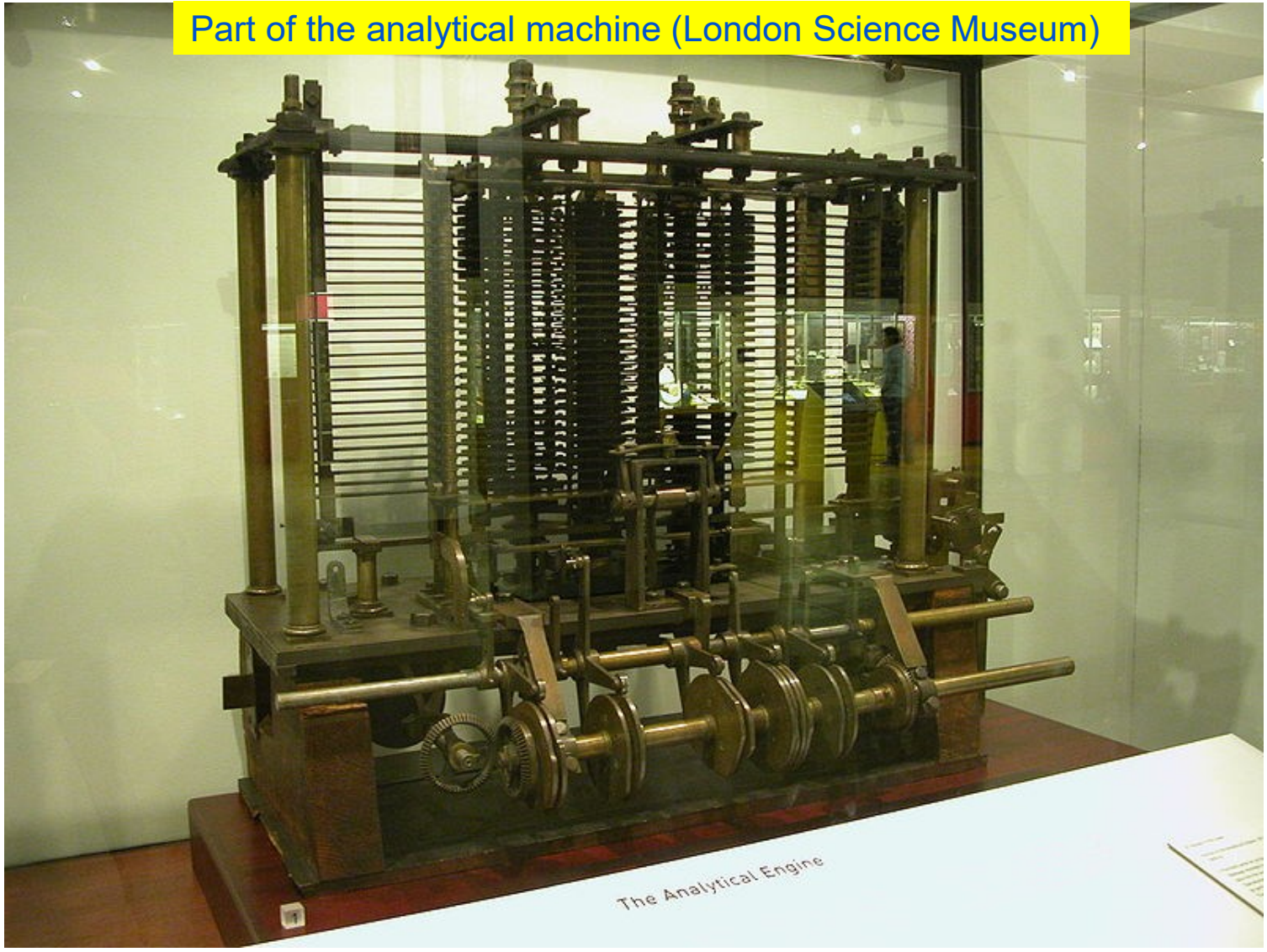
Differential machine 2 (London Science Museum)



Differential machine 2 close-up picture



Part of the analytical machine (London Science Museum)



Babbage: Analytical Machine

YT Video: False Dawn: The Babbage Engine

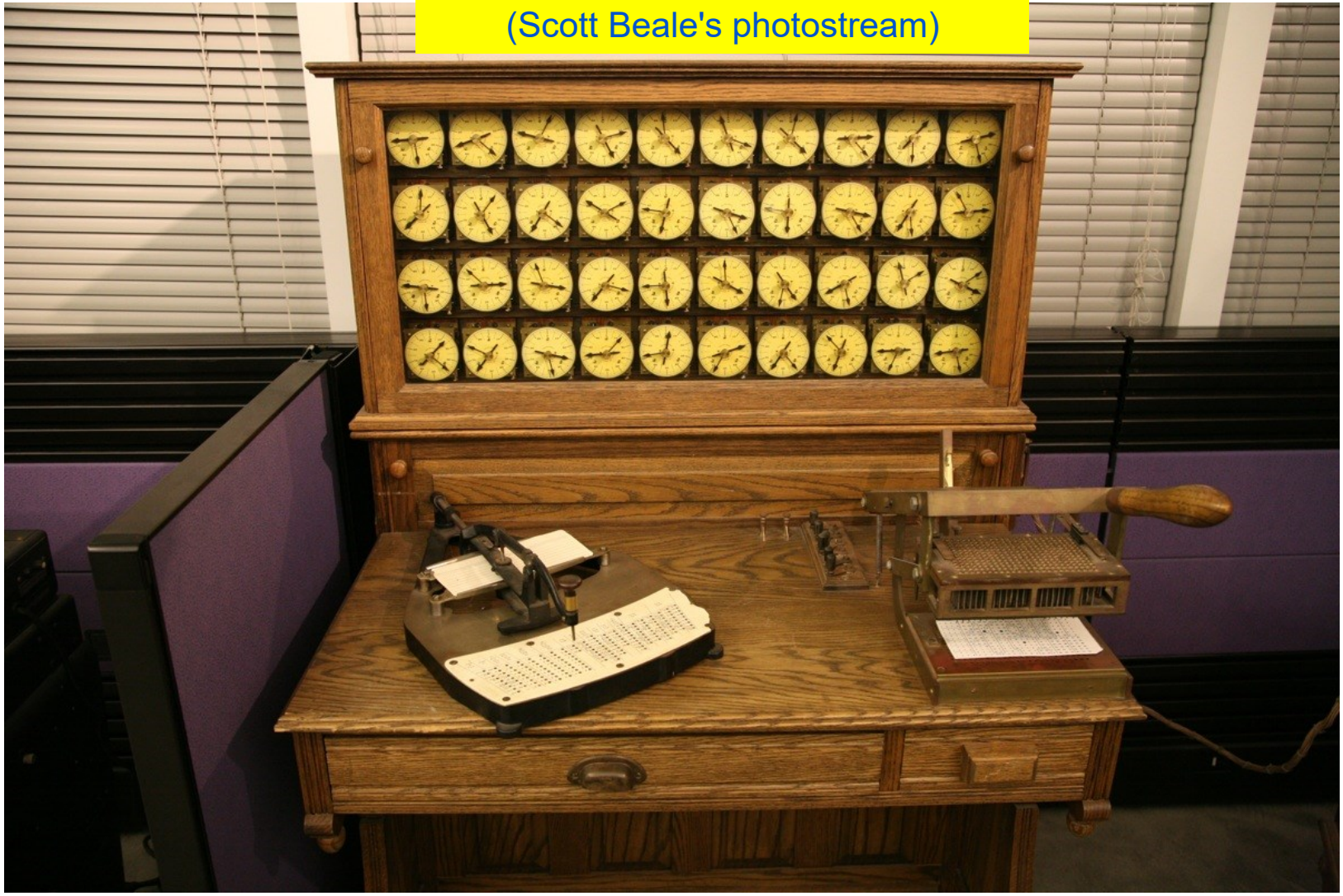
https://www.youtube.com/watch?v=XSkGY6LchJs

II. Electro-mechanical computers

- The development of electrical engineering has opened up new possibilities for the realization of computing machines
  - The drive the gears, electric motors are used (previously manually driven or by a steam engine)
  - In systems based on punched cards the presence or absence of holes is determined electrically and no longer mechanically
- Herman Hollerith: 1887 for the first time successfully used the device based on punched cards

Hollerith machine

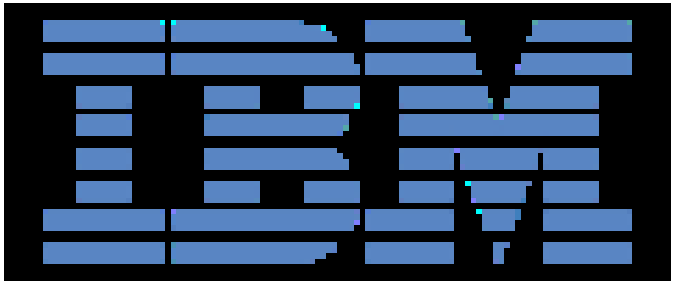
Hollerith machine used in the census
(Scott Beale's photostream)



Hollerith and IBM

- Hollerith has founded in 1896 Tabulating Machine Company. That was later joined with two more in 1924 and renamed to International Business Machines Corporation - IBM

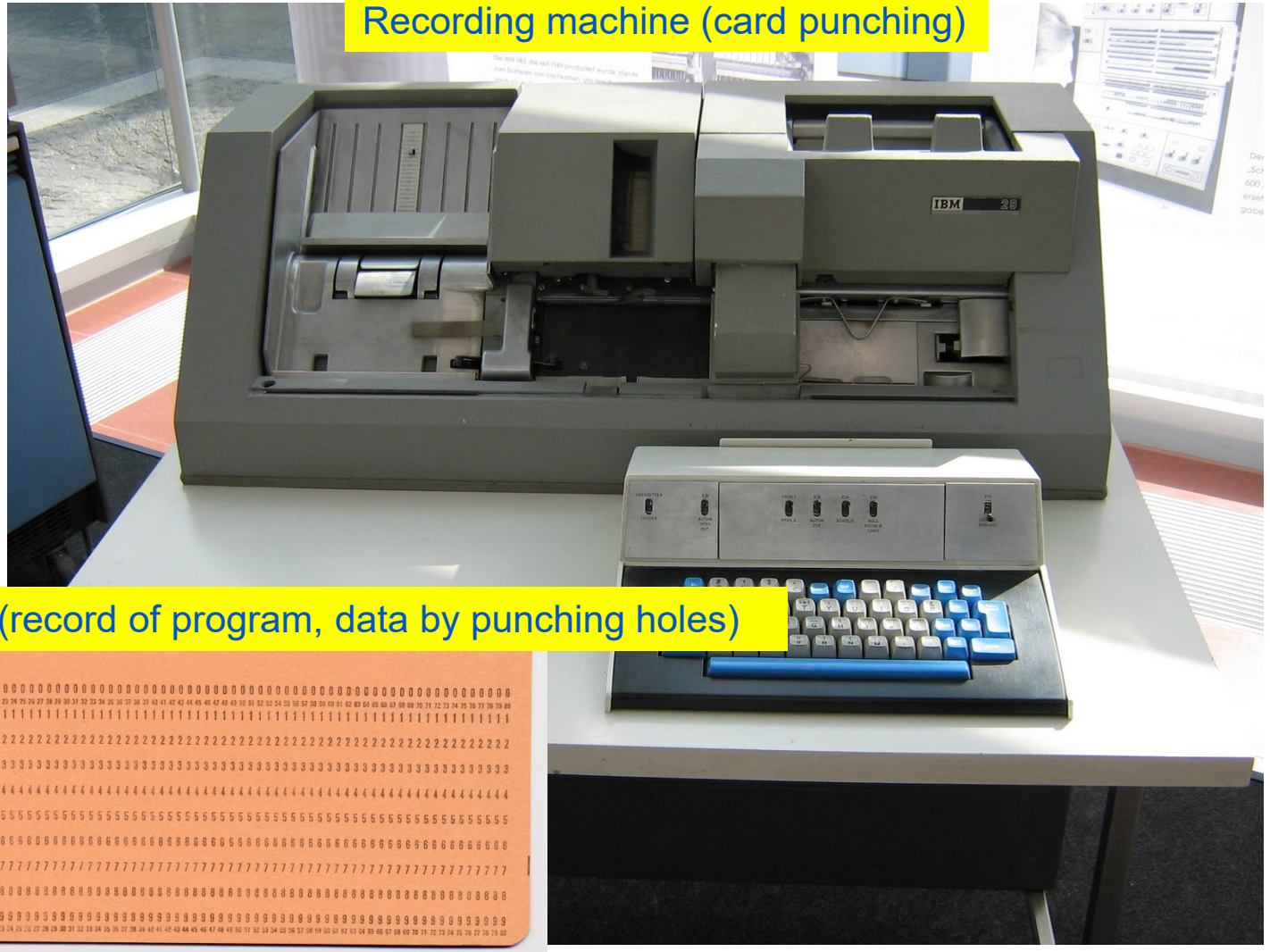
The first logo of IBM company



The logo used since 1972

IBM

Recording machine (card punching)



A machine for punching cards and card

Punched card (record of program, data by punching holes)

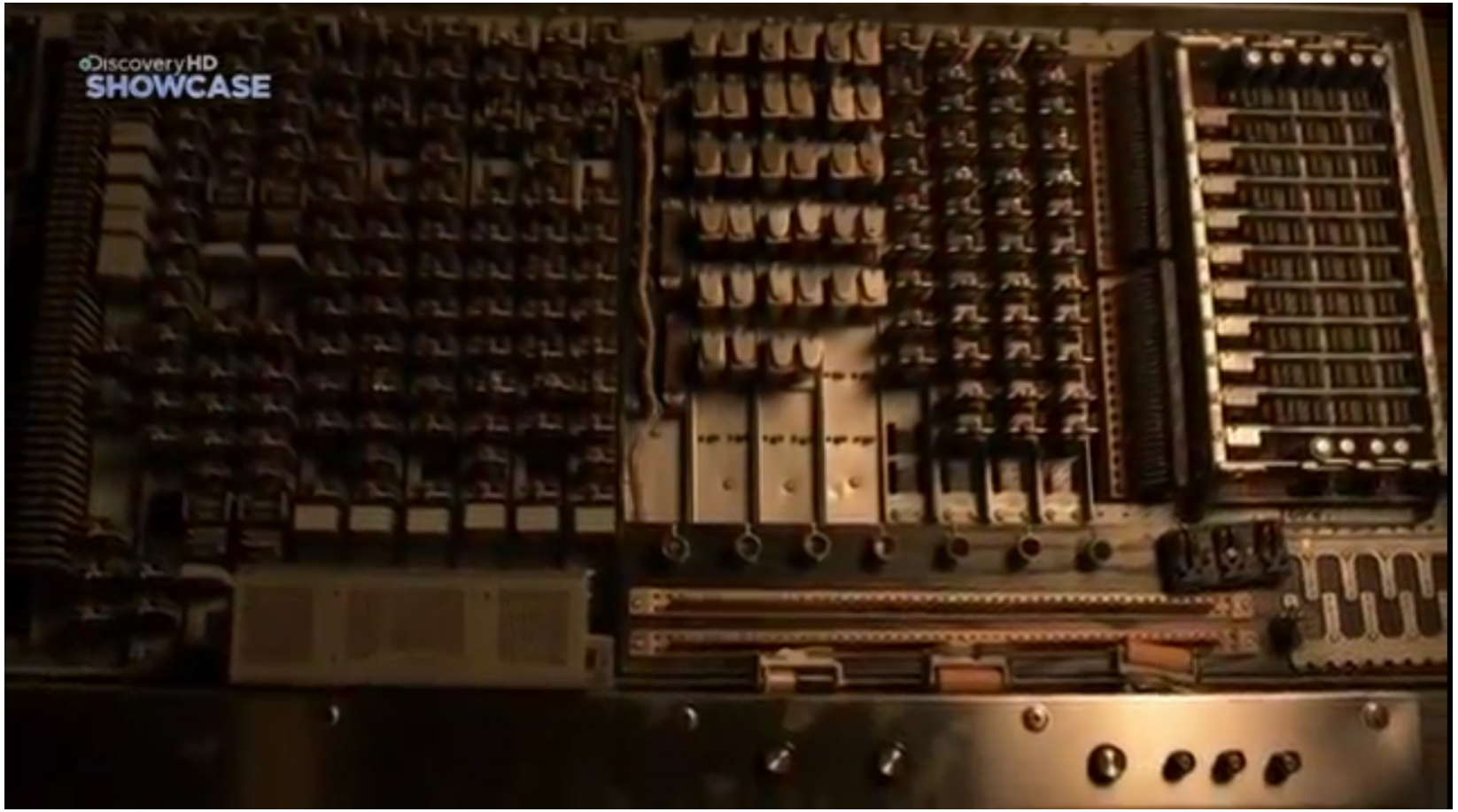
Konrad Zuse (1910 - 1996):

- Electro-mechanical switch
  - 1939: Relay,

- **Z1** (1938)
  - first working machine of Babbage‘s kind, although he did not know for Babbage‘s work - completely mechanical
- **Z2**
  - arithmetical unit built with telephone relays, mechanical memory of the Z1 - unfinished
- **Z3** (1941)
  - first working program guided electro-mechanical general-purpose computer
  - used binary-based (not decimal-based) arithmetic
    - 2600 telephone relays
    - relay memory consisting of 64 22-bit words
    - 8-bit instructions stored on a perforated tape

Z3 in the Technical Museum Munich

Computer History - Z3



Z3 in the Technical Museum Munich

Harvard **MARK I**, II, II, IV

- Harvard **MARK I** completed in 1943 in the US, the machine equivalent to Babbage‘s analytical machine
  - Howard Aiken – a physicist at Harvard University - unlike Zuse, he knew Babbage‘s work
- Followed by **MARK II**, **III,** and **IV**
- Harvard Mark I and Zuse Z3 are similar machines:
  - Z3 - binary arithmetics
  - Harvard Mark I - decimal arithmetics
  - In both: storage of instructions on a punched tape

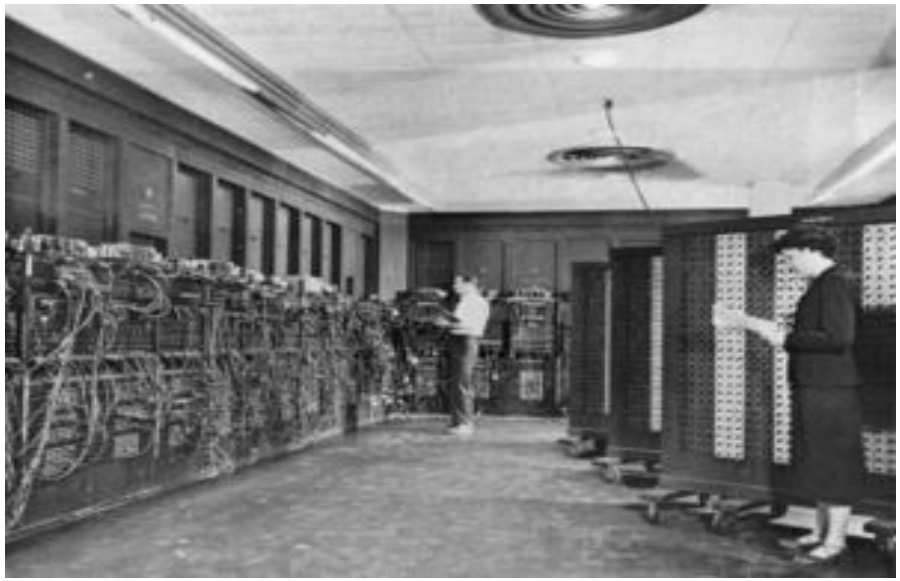
III. First electronic computers

- Electrical switch
  - 1945-1955: Vacuum tube,

- Relays replaced by electronic Tubes - switching time 5 ~ μs
- The first attempt using tubes instead of relays was an analog computer (John Atanasoff, Iowa State University)
- Machines for the decryption of messages developed during World War 2 in Britain
- ENIAC (J. Mauchly and Eckert J., University of Pennsylvania - Moore School of Electrical Engineering)

ENIAC

- ENIAC (Electronic Numerical integrator and Calculator)
  - completed in 1945
  - ~ 500 to 1000 times faster than Mark I
  - The physical dimensions of 30m x 3m x 1m
  - 18,000 tubes, 150 relays, 140kW
  - Programming using switches (> 6000 switches) and connecting cables



IV. Electronic Stored program Computers

- The author of the idea of stored program computer is probably an American mathematician of Hungarian origin - John von Neumann (1903 - 1957)

- the idea von Neumann first published in 1945 in the proposal for a new electronic computer EDVAC (Electronic Discrete Variable Computer)

First Draft of a Report
on the EDVAC

by

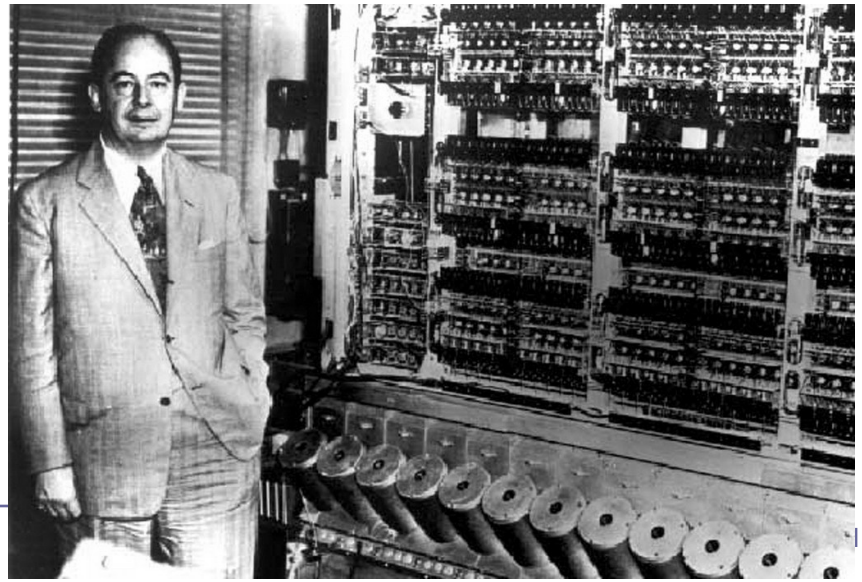
John von Neumann

Moore School of Electrical Engineering
University of Pennsylvania

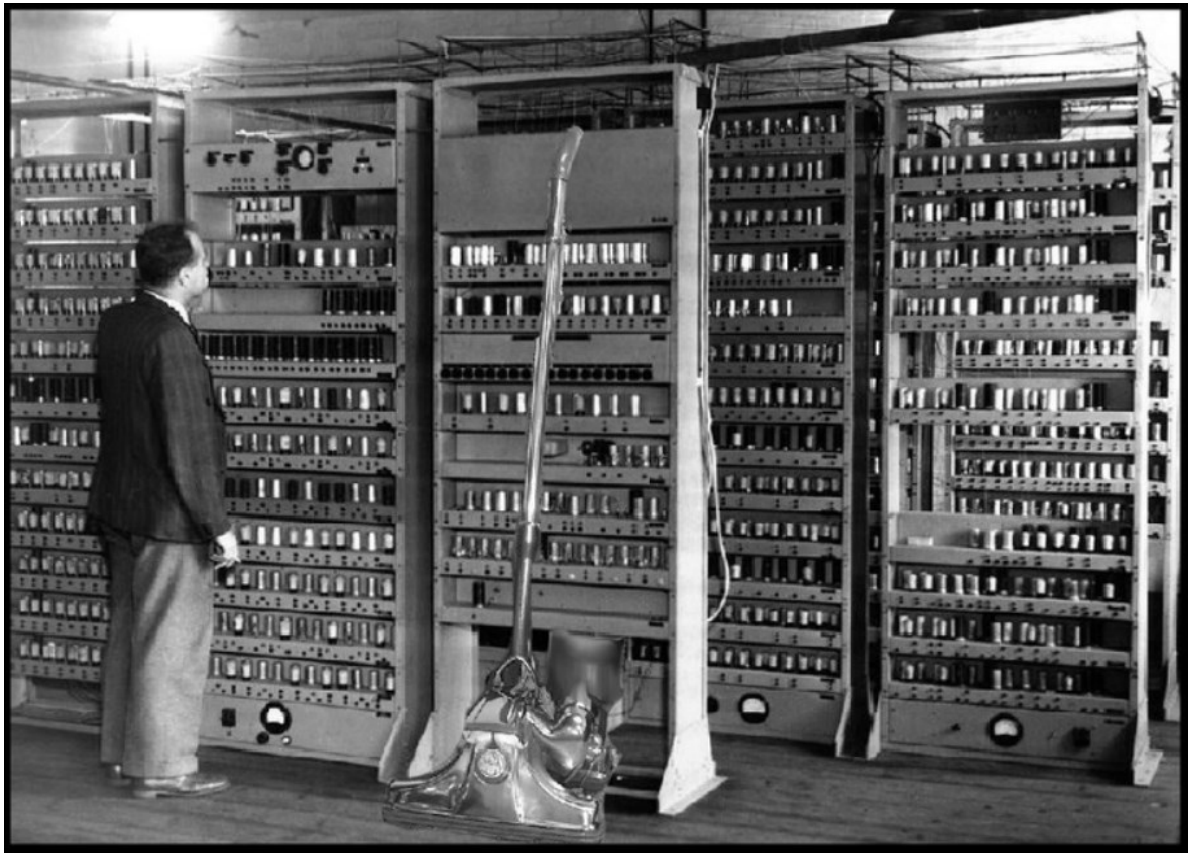
June 30, 1945

- EDSAC, EDVAC, IAS

IAS and John von Neumann (Institute for Advanced Studies)



- EDVAC (Electronic Discrete variable Computer)
  - Completed in 1951 - the basis is the idea of a program stored in the memory



EDSAC, IAS

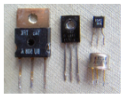
- EDSAC (Electronic Delay Storage Automatic Calculator)
  - Completed in 1949 in Cambridge, England - the first operational stored-program computer – just before EDVAC
  - Introduction of the rule that is still followed nowadays :

If the instruction doesn‘t require otherwise (JUMP, GOTO instruction), instructions are read and executed in ascending address order

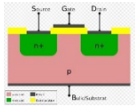
- IAS (acronym for Institute for Advanced Study)
  - Parallel machine, approx. 10 times faster than ENIAC (EDVAC and EDSAC operated in serial order - a bit-by-bit)
  - Random access memory
  - Program Counter - register that contains the address of the next instruction

V. The rapid development of computers after 1950

- 1955: Transistors → ,



  - 1958: Integrated circuit - chip,
  - 1980: VLSI integrated circuit
    - Very Large Scale Integration

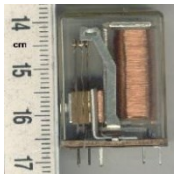
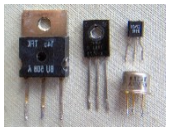


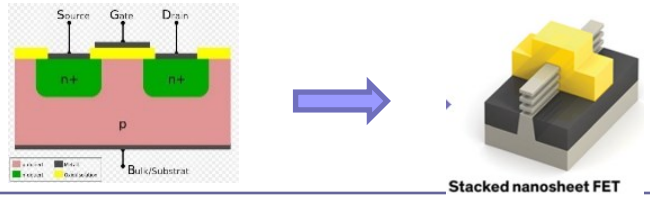
- Development was more in a technological than architectural sense
- Since 1955, the tubes began to fade and were replaced by transistors
  - that are smaller, faster, more reliable
- Milestones:
  - 1971: Appearance of Microprocessors (Intel 4004)
  - 1980: Personal computer IBM PC
  - 1985: First ARM processor (RISC idea)
  - 1999: AMD Athlon, (Opteron 2003)
  - 2011: First publication on RISC-V ISA 2011

Prefixes for units of measurement

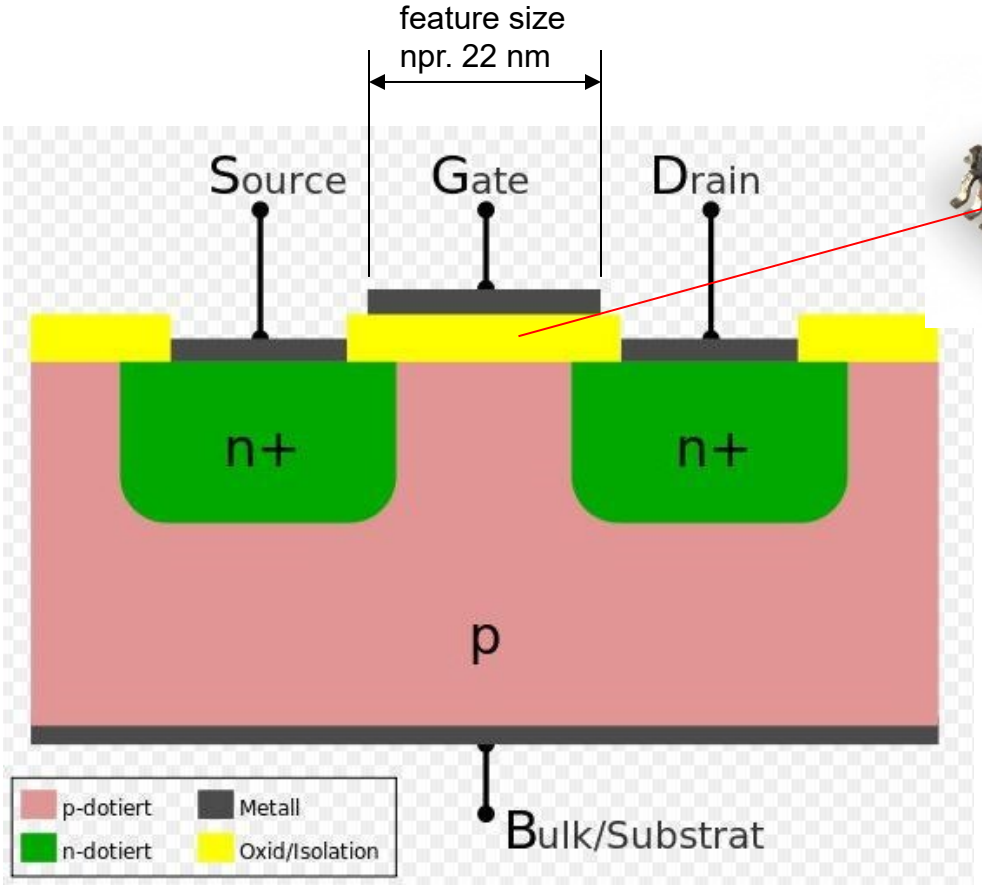
Abbreviation	Name	Value	Exponent (scientific notation)
p	pico	0,000 000 000 001	10^{-12}
n	nano	0,000 000 001	10^{-9}
μ	micro	0,000 001	10^{-6}
m	milli	0,001	10^{-3}
K	kilo	1 000	10^{3}
M	mega	1 000 000	10^{6}
G	giga	1 000 000 000	10^{9}
T	tera	1 000 000 000 000	10^{12}

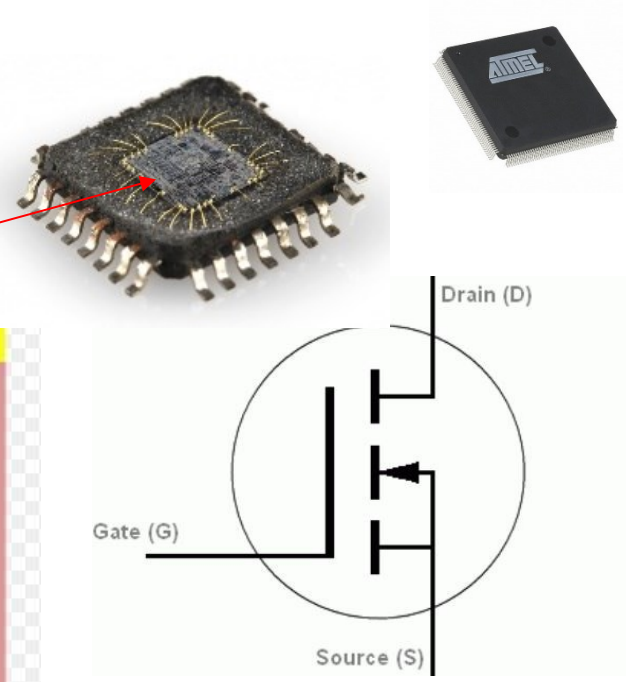
Realization of switches as the basic building block - summary

- Electro-mechanical switch
  - 1939: Relay,  switching time 1-10ms
- Electrical switch
  - 1945-1955: Vacuum tube,  switching time ~ 5μs
  - 1955: Transistors → ,  switching time ~10ns
    - 1958: Integrated circuit - chip, switching time 2-10ns
    - 1980: VLSI integrated circuit switching time < 0.1ns
      - Very Large Scale Integration



Transistors as a part of the integrated circuit VLSI





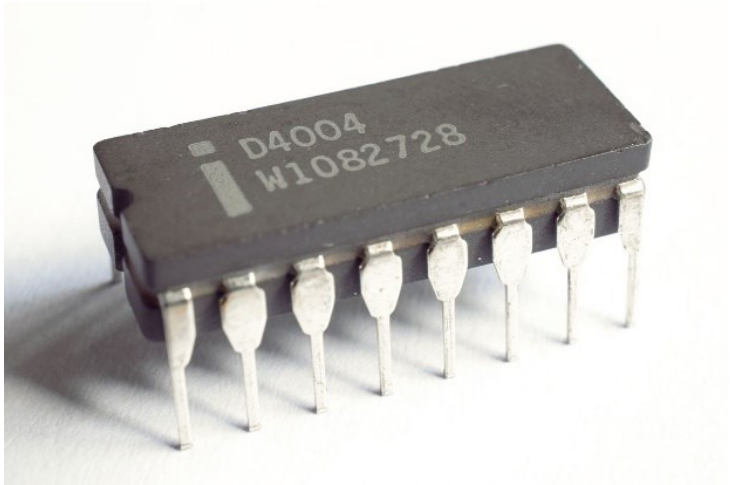
V. The rapid development of computers after 1950

Milestones:

- I. 1971: Appearance of microprocessors (Intel 4004)
- II. 1981: Personal computer IBM PC
- III. 1985: First ARM processor
- IV. 1999: AMD Athlon (Opteron 2003)
- IV. 2011: First publication on RISC-V ISA

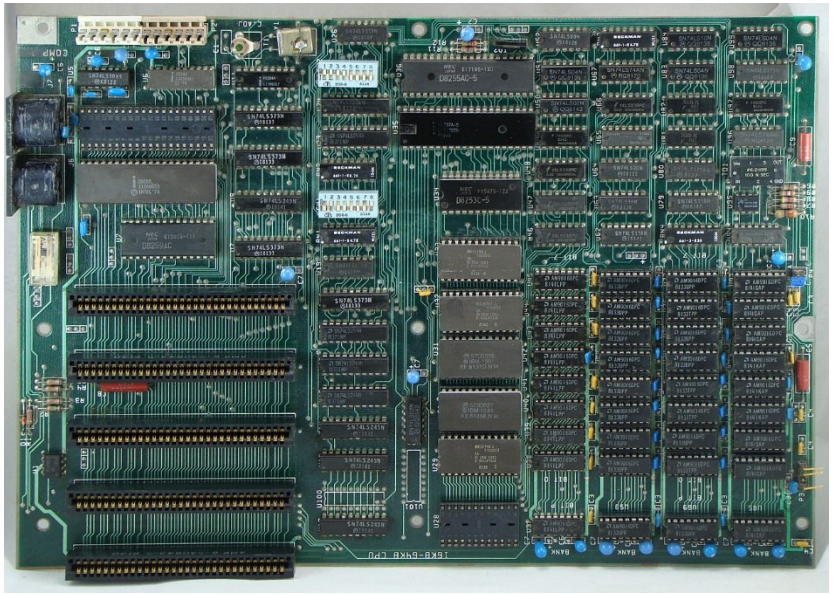
Milestone I: Microprocessors‘ appearance in 1971

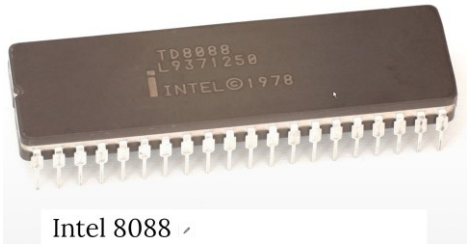
- First microprocessor on one chip - Intel 4004 (1971)
  - 2.250 transistors on board 3,2 x 4,2 mm
  - feature size 10 μm = 10×10^{-6} m = 0,00001 m,
    - Human hair diameter approx. 100 μm)
  - 16 pins
  - Instruction execution in 10,8 μs (= 0,0000108 s) or 21,6 μs
  - Power 1,0 W
  - Price (projected in current time) $26



Milestone II: Personal Computer IBM PC / XT Year 1983

- The Intel CPU 8088, clock frequency of 4.77 MHz
  - x68 architecture (1st generation)
- Memory: from 128 KB to 640 KB
- One or two floppy disk units 5.25 "
- Hard disk with a capacity of 10 MB

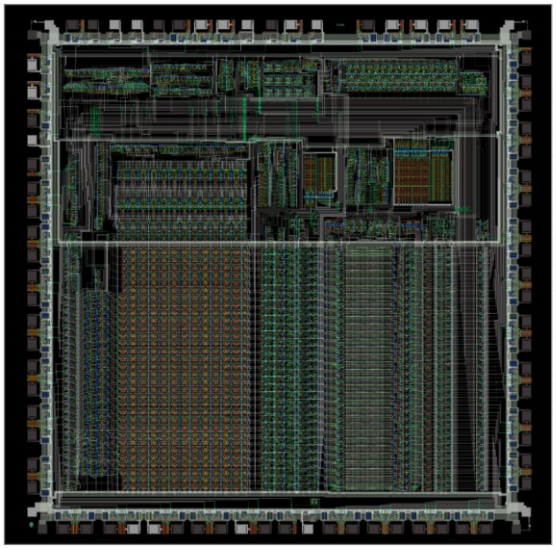


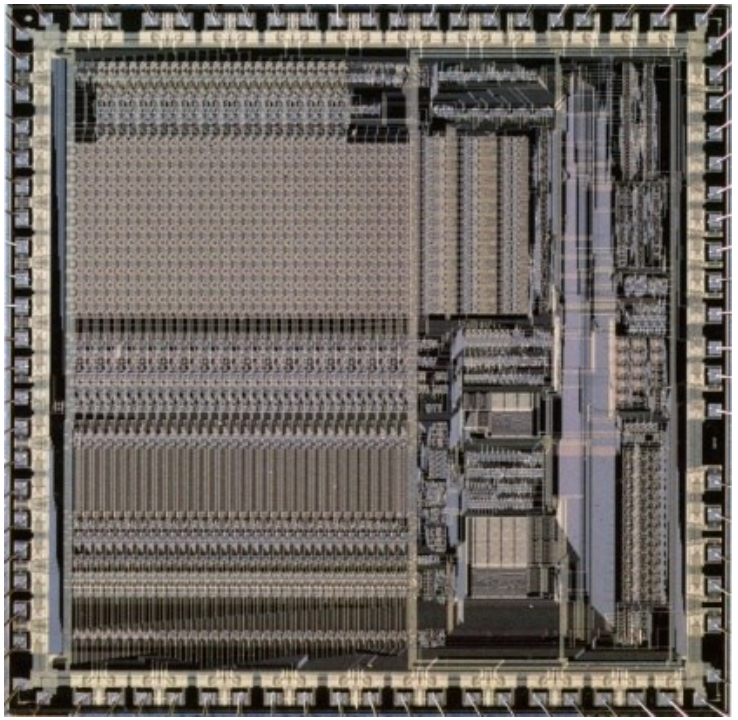


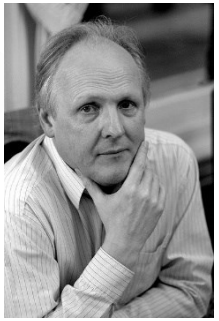
Intel 8088

Milestone III : First ARM processor 1985

- 25000 transistors
- Electrical consumption 1W
- Implementation of the RISC idea







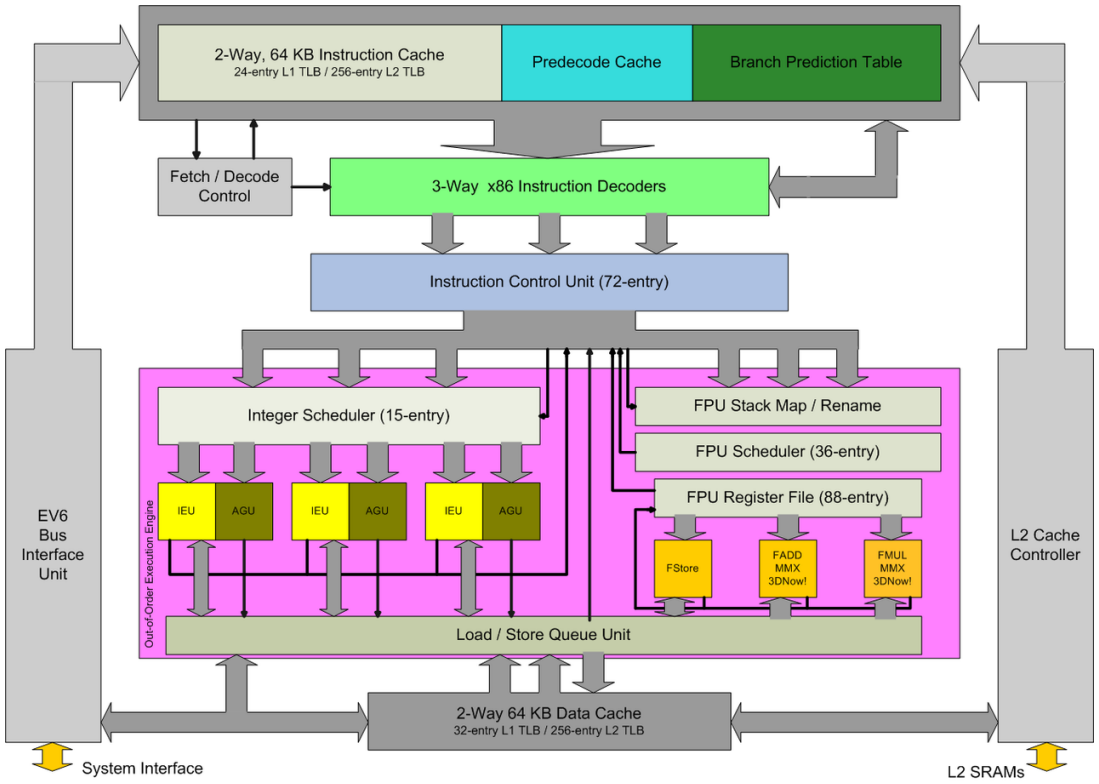
Steve Furber
principal designer of the BBC Micro and the ARM 32-bit RISC microprocessor.[15]

Online simulation:

http: //visual6502.org/sim/varm/armgl.html

Milestone IV : First AMD procesor Athlon

- 22 milijon transistors
- Becomes serious competitor to Intel x86



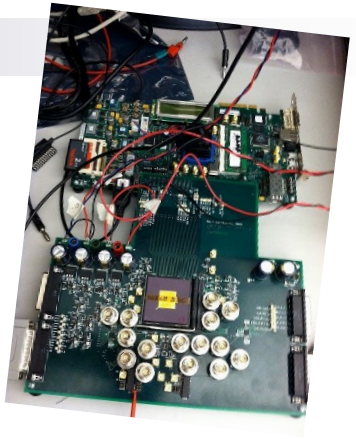
Athlon Classic

The logo of the Athlon "Classic"

General information	
Launched	June 23, 1999
Common manufacturer(s)	AMD
Performance	
Max. CPU clock rate	500 MHz to 1400 MHz
FSB speeds	200 MT/s to 266 MT/s
Architecture and classification	
Technology node	0.25 µm to 0.18 µm
Instruction set	x86

Milestone V : First publication RISC-V ISA (2011)

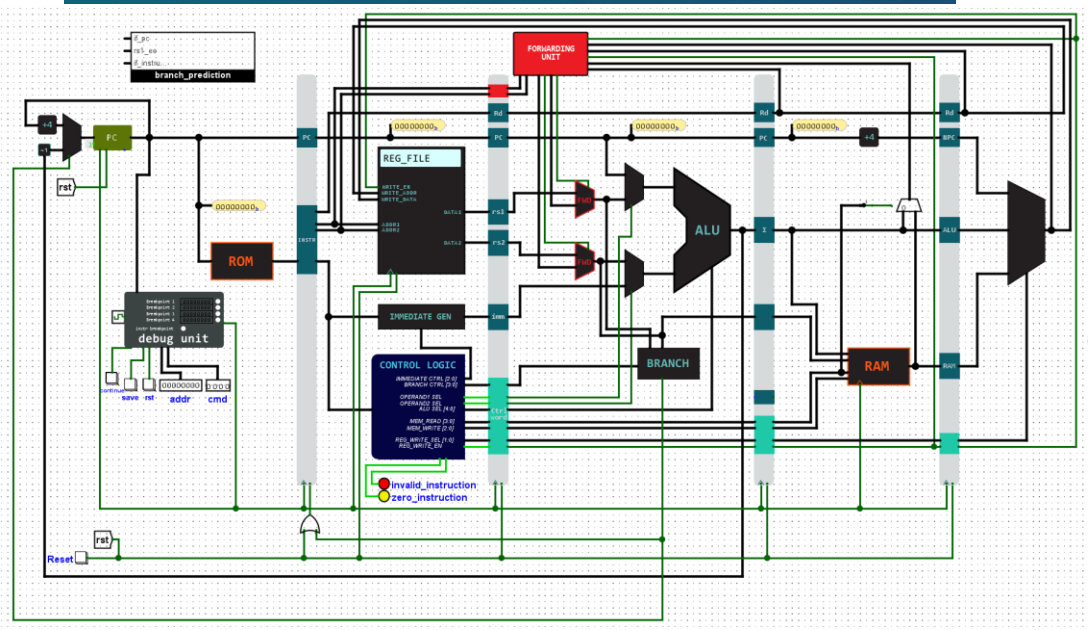
- Trully opened idea, realization (BSD)



RISC-V is an open standard Instruction Set Architecture (ISA) enabling a new era of processor innovation through open collaboration

RISC-V enables the community to share technical investment, contribute to the strategic future, create more rapidly, enjoy unprecedented design freedom, and substantially reduce the cost of innovation

The RISC-V Instruction Set Manual, Volume I: Base User-Level ISA



Andrew Waterman
Yunsup Lee
David A. Patterson
Krste Asanovic

https://riscv.org/about/history/

Electrical Engineering and Computer Sciences
University of California at Berkeley

Technical Report No. UCB/EECS-2011-62
http://www.eecs.berkeley.edu/Pubs/TechRpts/2011/EECS-2011-62.html

May 13, 2011

Zuse 23 first digital computer in Ljubljana in 1962/1963

Prvi računalniki v Sloveniji, 4. del – elektronski računalnik Zuse Z-23

Z naslova <https://www.racunalniski-muzej.si/prvi-racunalniki-v-sloveniji-4-del-elektronski-racunalnik-zuse-z-23/>

IBM computer 1130 - the first digital computer at the University of Ljubljana in 1971