COMPUTER ARCHITECTURE

2 The evolution of computing machines

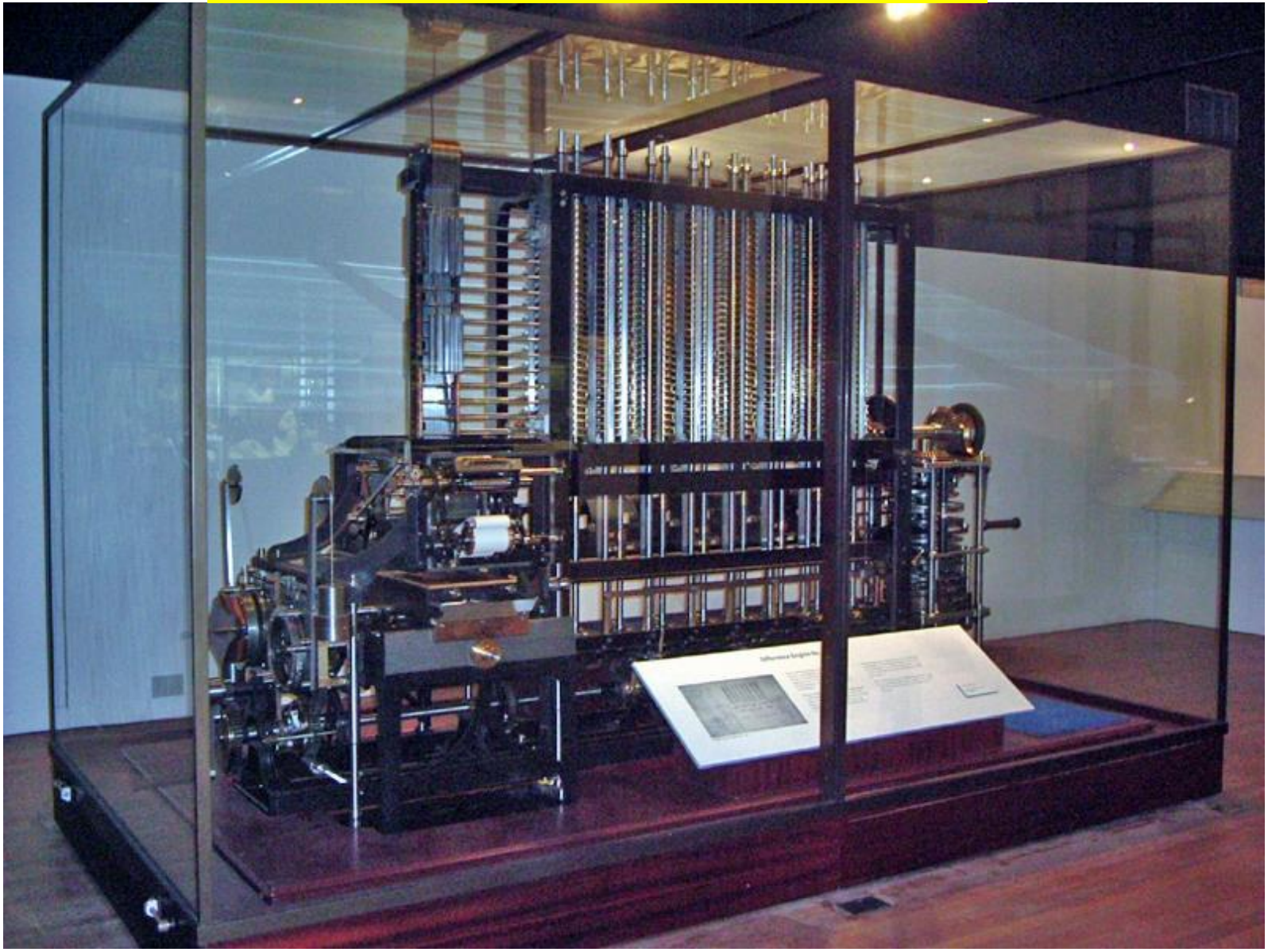
The evolution of computing machines and other devices for computation can be chronologically divided into five major groups:

- 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 →

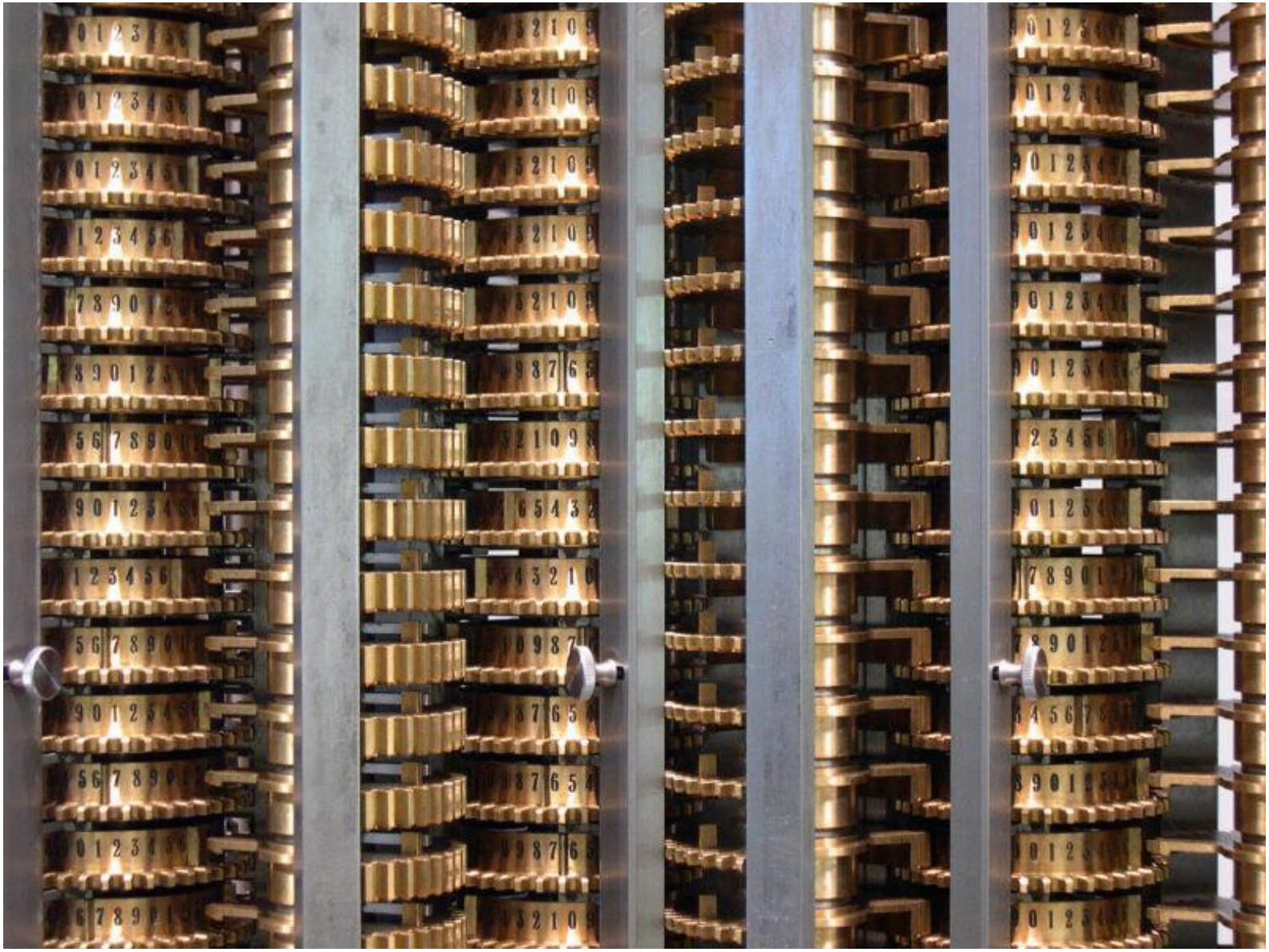
I. period of mechanics

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

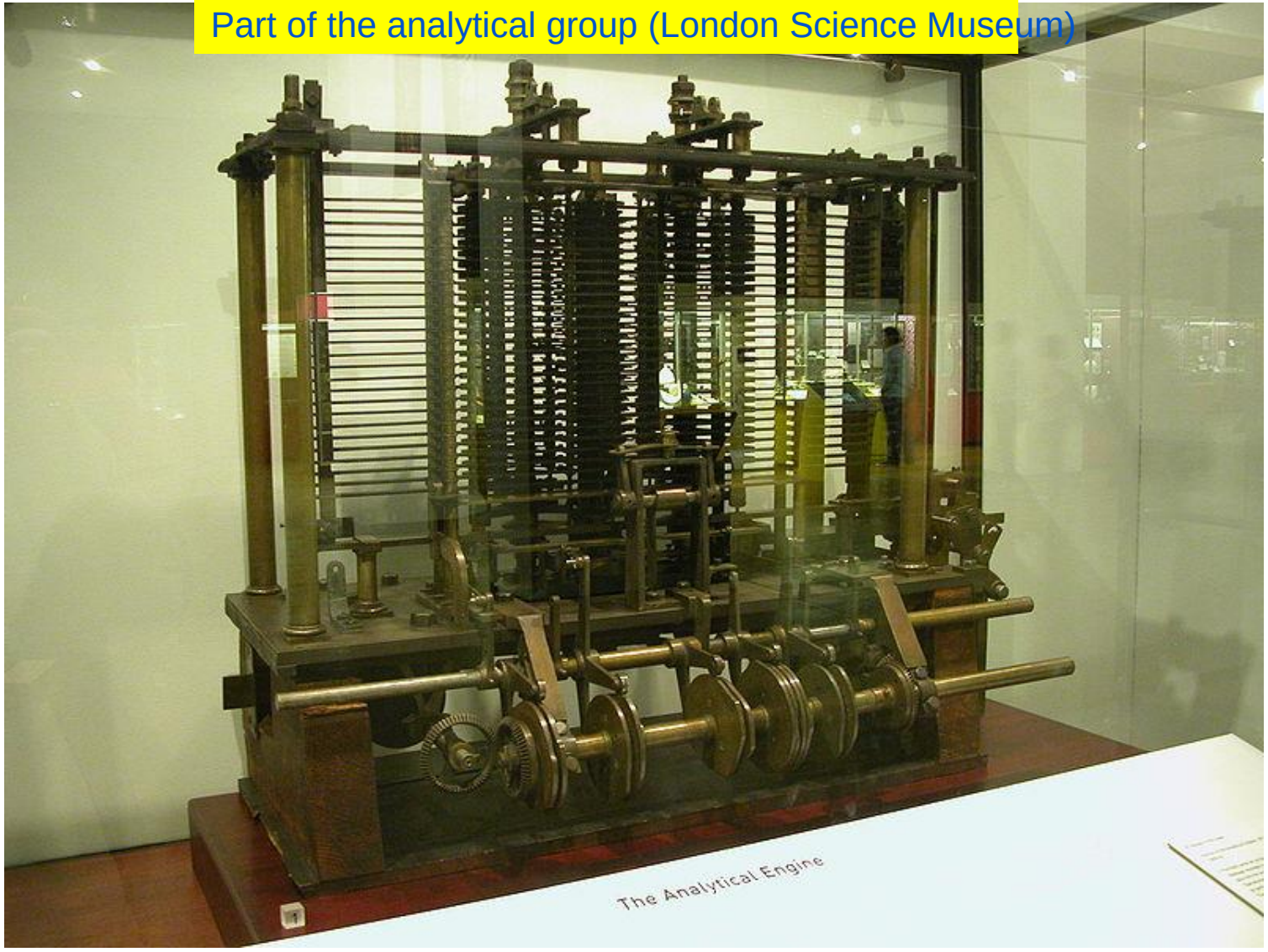
Differential machine 2 (London Science Museum)



Differential machine 2 close-up picture

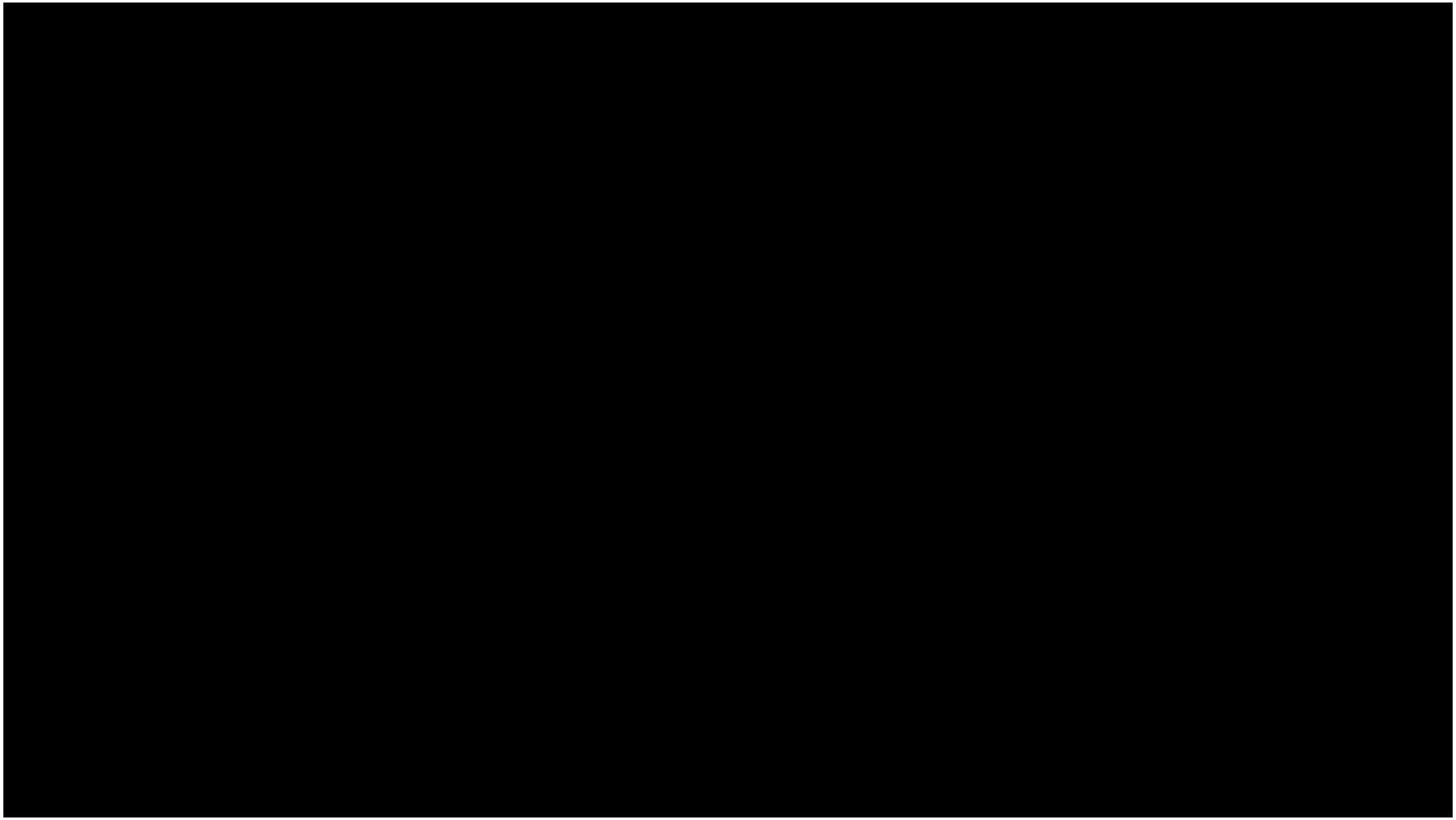


Part of the analytical group (London Science Museum)



Babbage: Analytical Machine

YT Video: False Dawn: The Babbage Engine



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

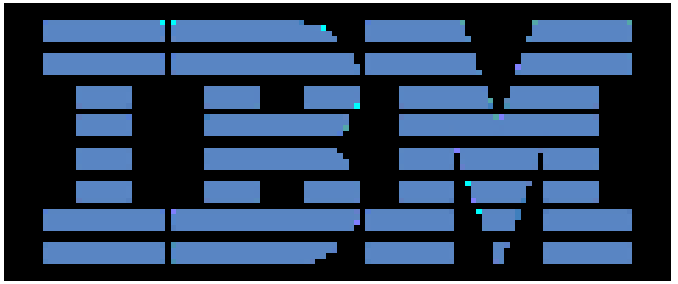
II. Electro-mechanical computers

- 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 used in the census (Scott Beale's photostream)

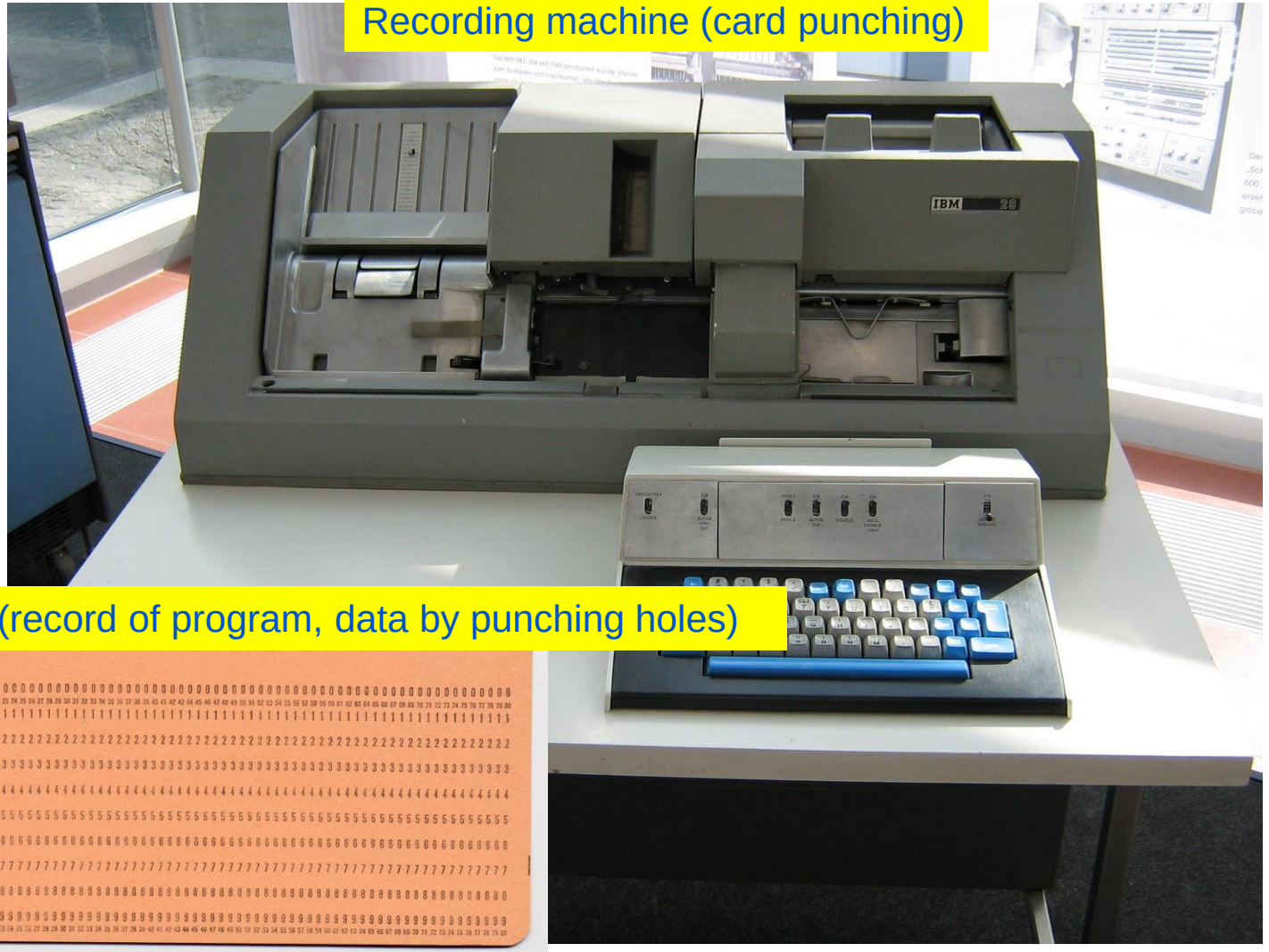
- Hollerith has founded in 1896 Tabulating Machine Company. That was later joined with two more in 1924 and renamed to International Business Machines Corporation - IBM

The first logo of IBM company



The logo used since 1972

Recording machine (card punching)



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

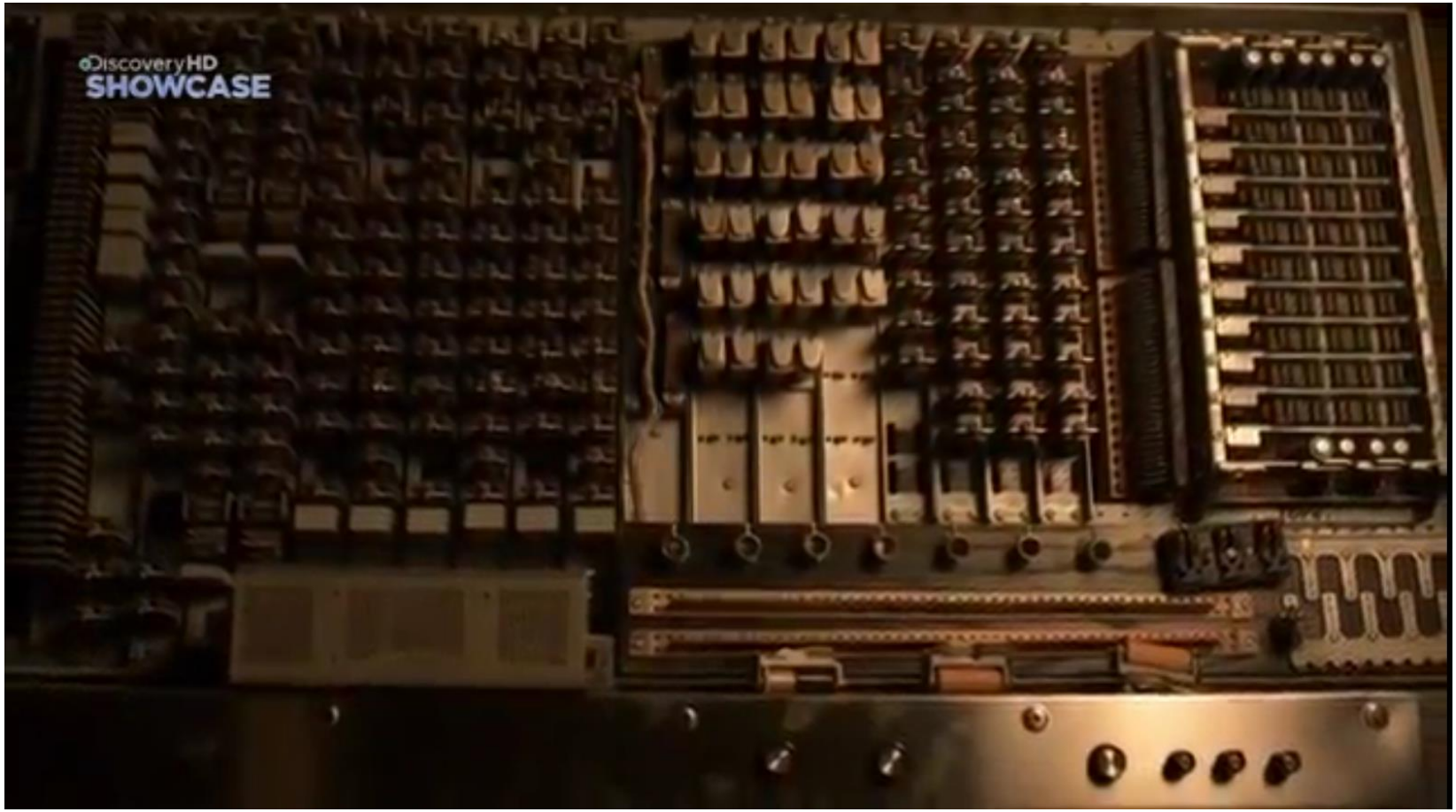
A machine for punching cards and card

- Konrad Zuse (1910 - 1996):
  - Electro-mechanical switch
    - 1939: Relay,

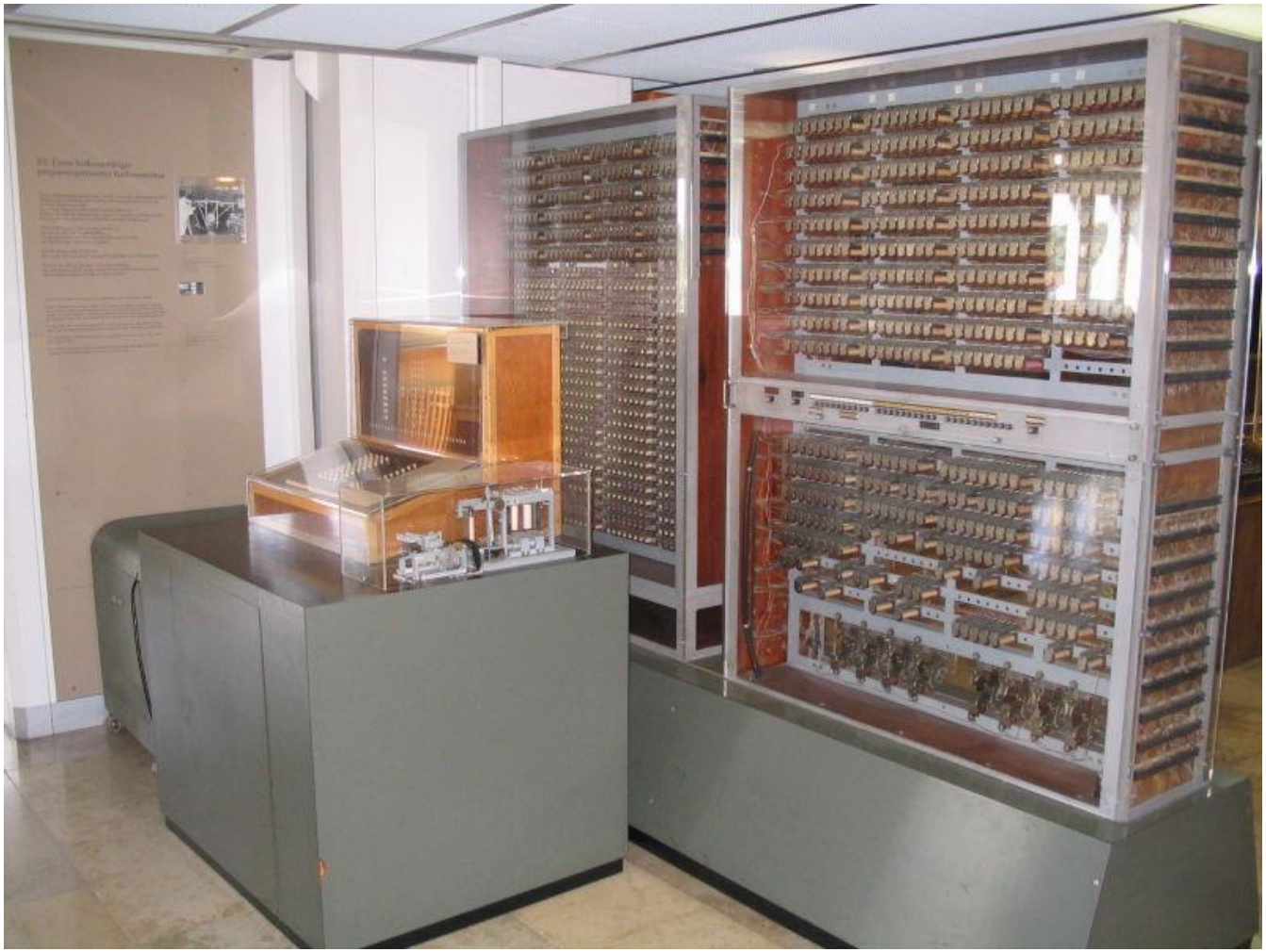
  - **Z1** (1938)
    - first working machine of Babbage‘s kind, although he did not know for Babbage‘s work - completely mechanical
  - **Z2**
    - arithmetical unit built with telephone relays, mechanical memory of the Z1 - unfinished
  - **Z3** (1941)
    - first working program guided electro-mechanical 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



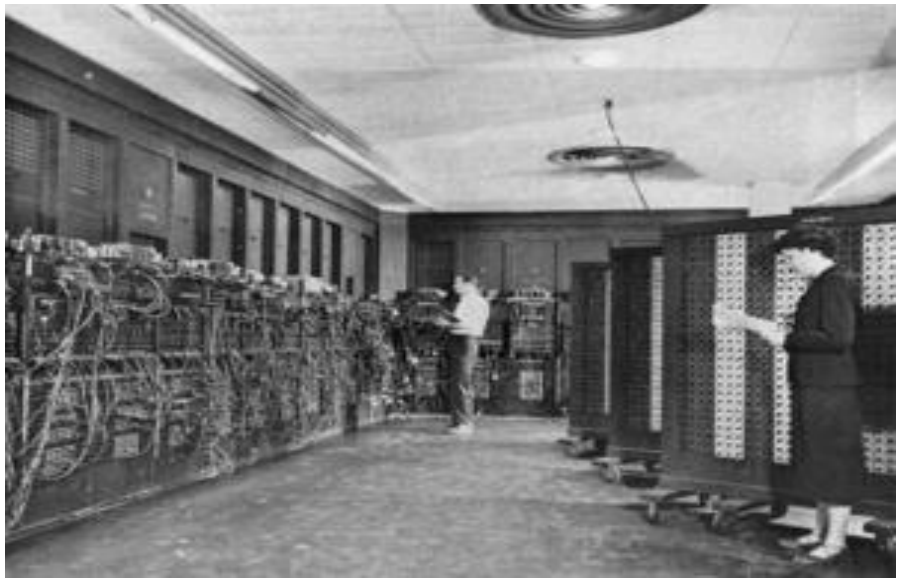
- Harvard **MARK I** completed in 1943 in the US, the machine equivalent to Babbage's analytical machine
  - Howard Aiken – a physicist at Harvard University - unlike Zuse, he knew Babbage's work
- Followed by **MARK II**, **III,** and **IV**
- Harvard Mark I and Zuse Z3 are similar machines:
  - Z3 - 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 (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

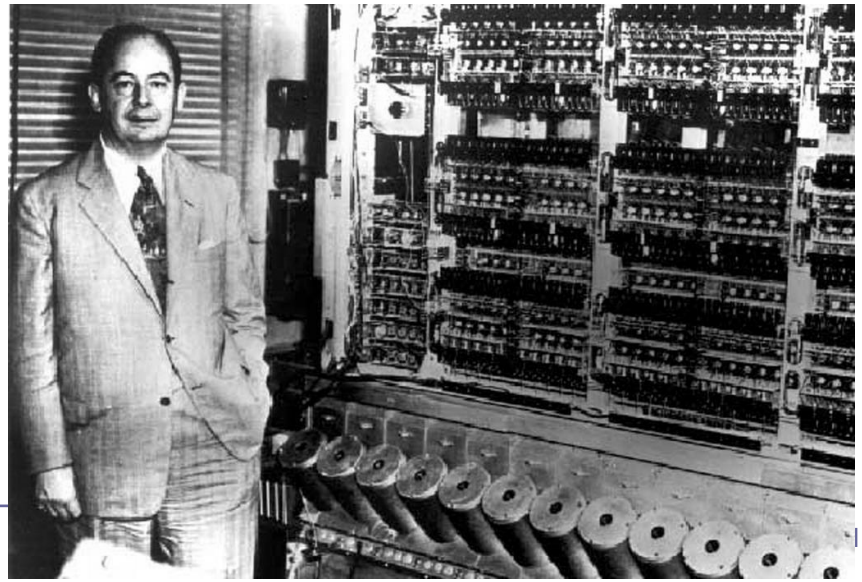
John von Neumann

Moore School of Electrical Engineering
University of Pennsylvania

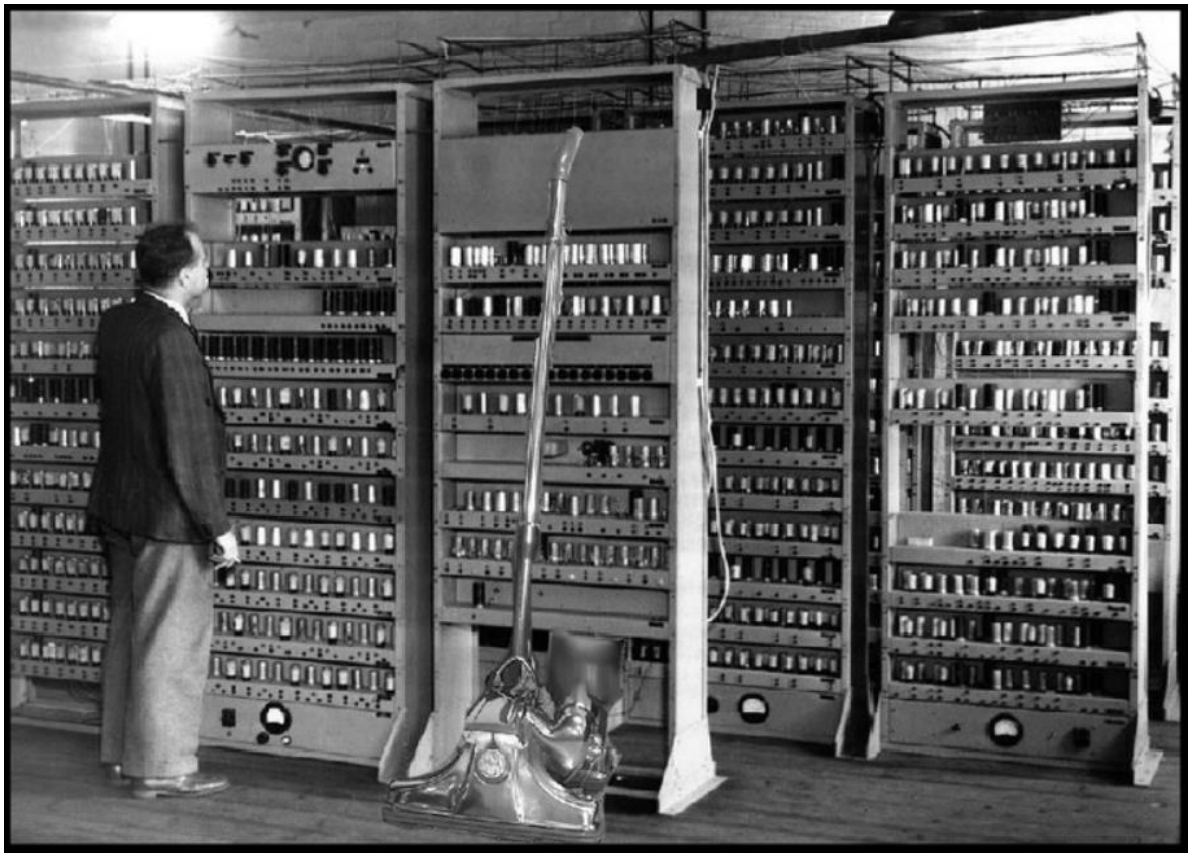
June 30, 1945

- 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



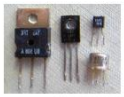
- EDSAC (Electronic Delay Storage Automatic Calculator)
  - Completed in 1949 in Cambridge, England - the first operational stored-program computer – just before EDVAC
  - Introduction of the rule that is still followed nowadays :

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

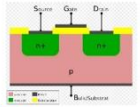
- IAS (acronym for Institute for Advanced Study)
  - Parallel machine, approx. 10 times faster than ENIAC (EDVAC and EDSAC operated in serial order - a bit-by-bit)
  - Random access memory
  - Program Counter - register that contains the address of the next instruction

V. The rapid development of computers after 1950

- 1955: Transistors → ,



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



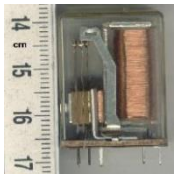
- Development was more in a technological than architectural sense
- Since 1955, the tubes began to fade and were replaced by transistors
  - that are smaller, faster, more reliable
- Milestones:
  - Appearance of Microprocessors 1971 (Intel 4004)
  - Personal computer IBM PC in 1980
  - First ARM processor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

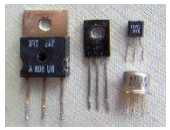
- Electro-mechanical switch



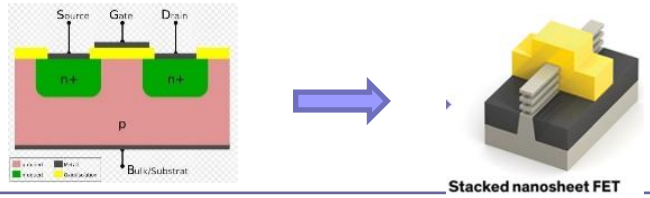
  - 1939: Relay, switching time 1-10ms

- Electrical switch

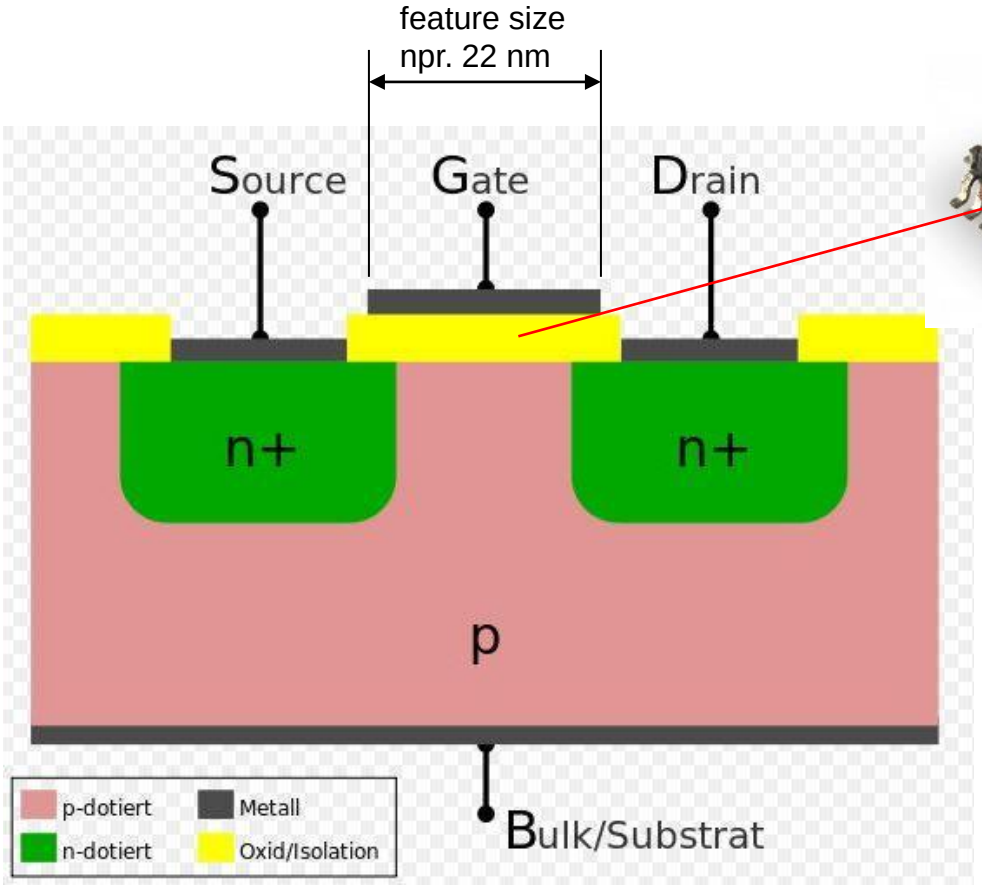
  - 1945-1955: Vacuum tube, switching time ~ 5μs

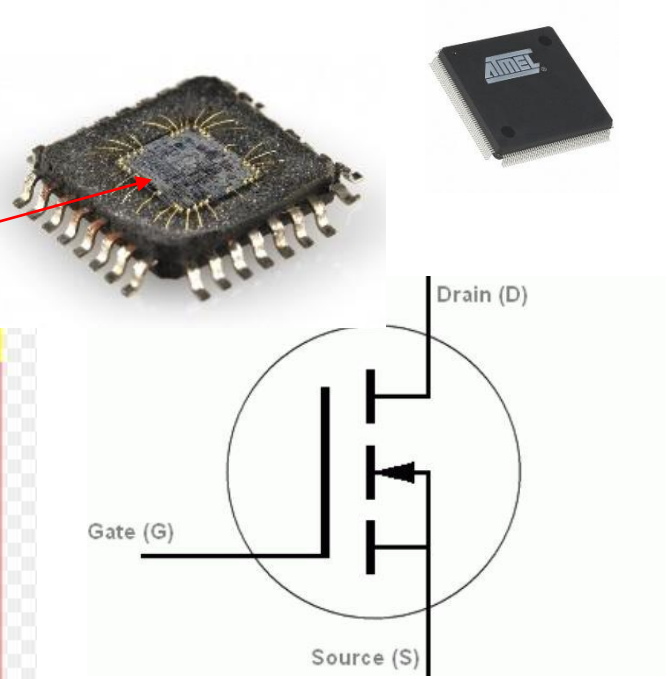


  - 1955: Transistors → , switching time ~10ns
    - 1958: Integrated circuit - chip, switching time 2-10ns
    - 1980: VLSI integrated circuit switching time < 0.1ns
      - Very Large Scale Integration



Transistors as a part of the integrated circuit VLSI





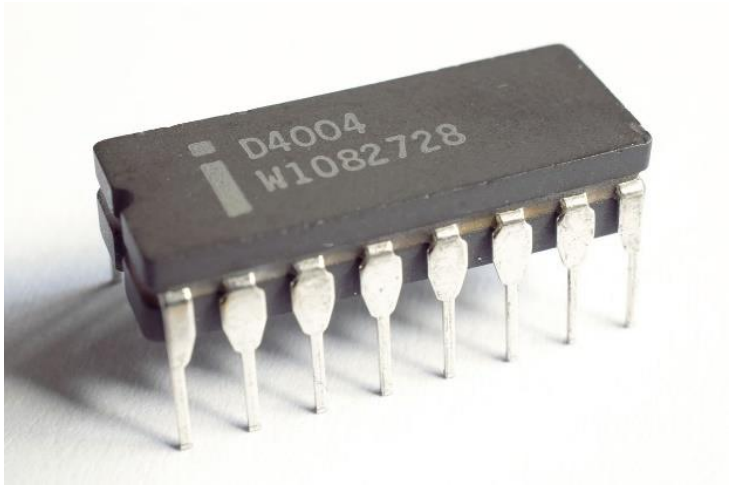
V. The rapid development of computers after 1950

Milestones:

- I. Appearance of microprocessors 1971 (Intel 4004)
- II. Personal computer IBM PC in 1980
- III. First ARM processor 1985
- IV. First publication on RISC-V ISA 2011

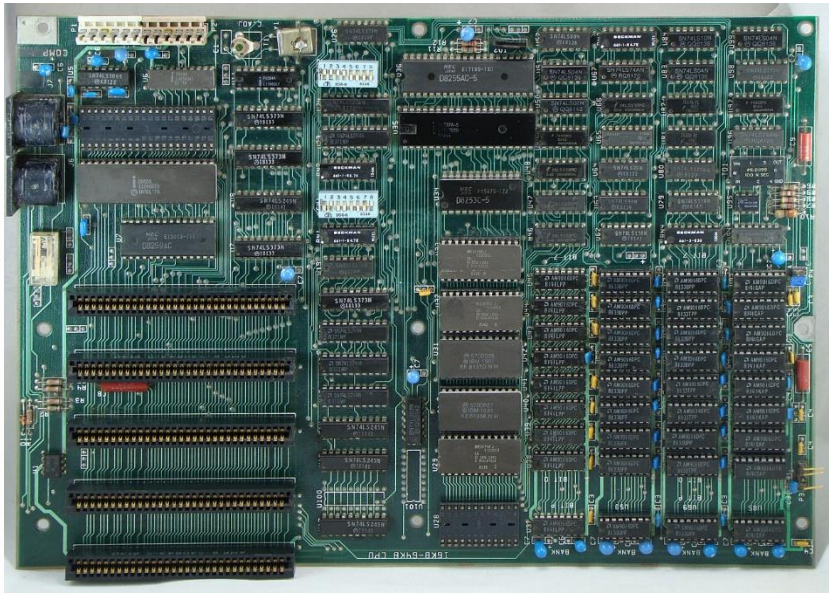
Milestone I: Microprocessors‘ appearance in 1971

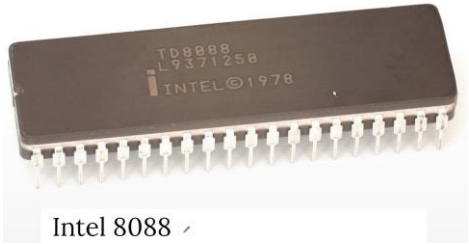
- First microprocessor on one chip - Intel 4004 (1971)
  - 2.250 transistors on board 3,2 x 4,2 mm
  - feature size 10 μm = 10×10^{-6} m = 0,00001 m,
    - Human hair diameter approx. 100 μm)
  - 16 pins
  - Instruction execution in 10,8 μs (= 0,0000108 s) or 21,6 μs
  - Power 1,0 W
  - Price (projected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

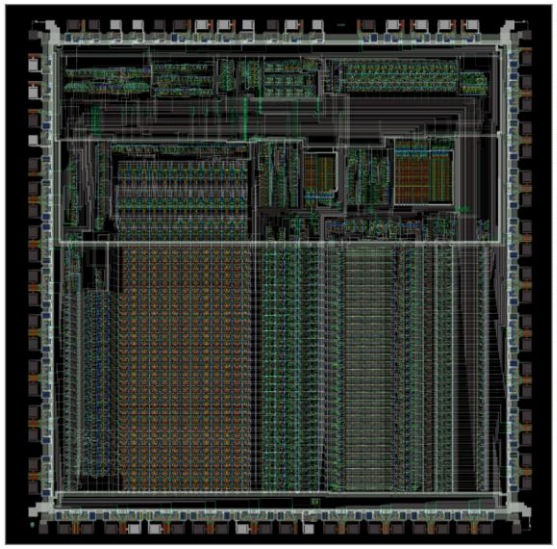


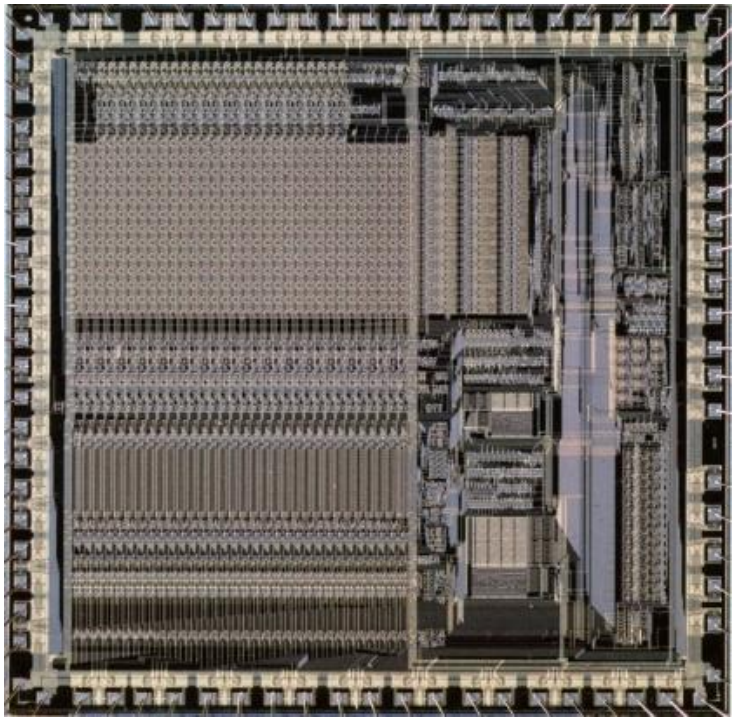


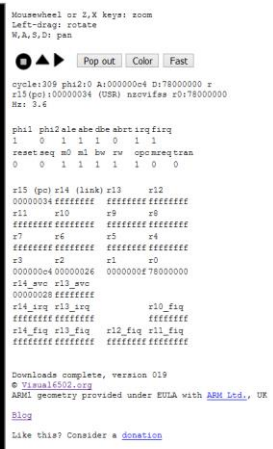
Intel 8088

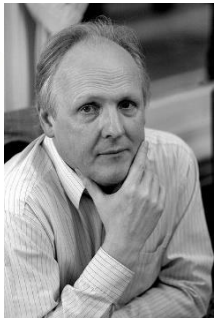
Milestone III : First ARM processor 1985

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







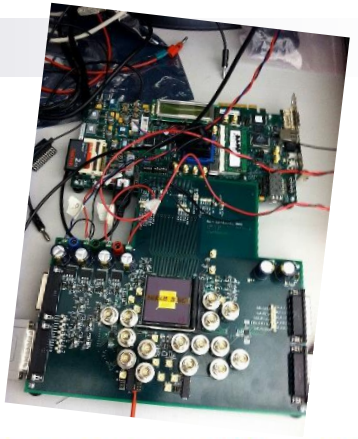


Steve Furber
principal designer of the BBC Micro and the ARM 32-bit RISC microprocessor.[15]

Online simulation:

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

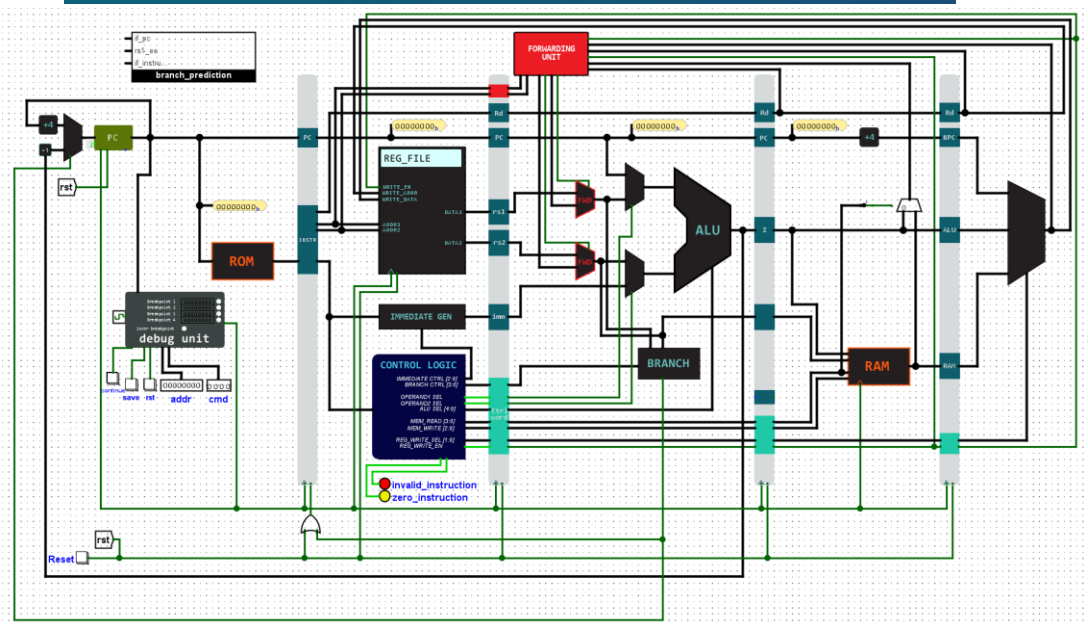
Milestone IV : First publication RISC-V ISA (2011)



- 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

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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