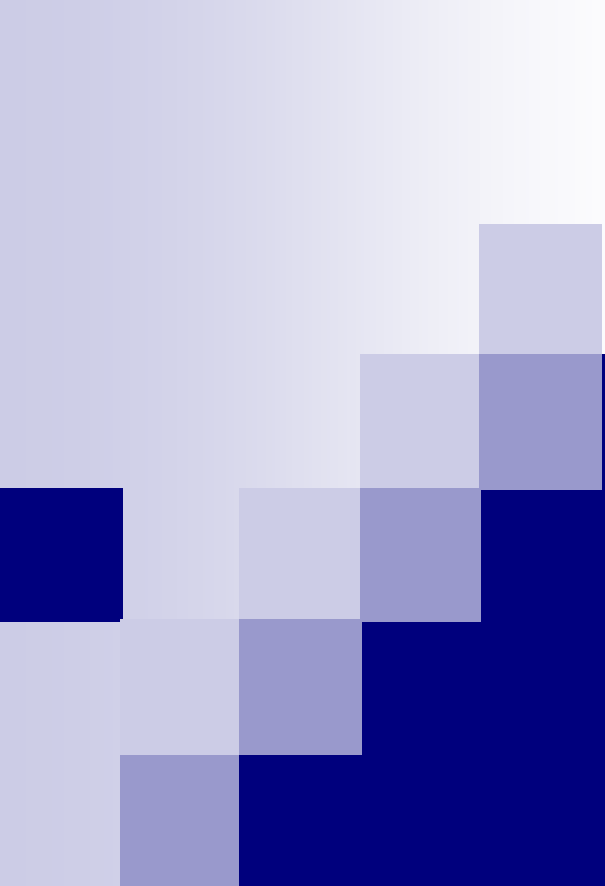




COMPUTER ARCHITECTURE

2 The evolution of the computing machines



The evolution of the 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

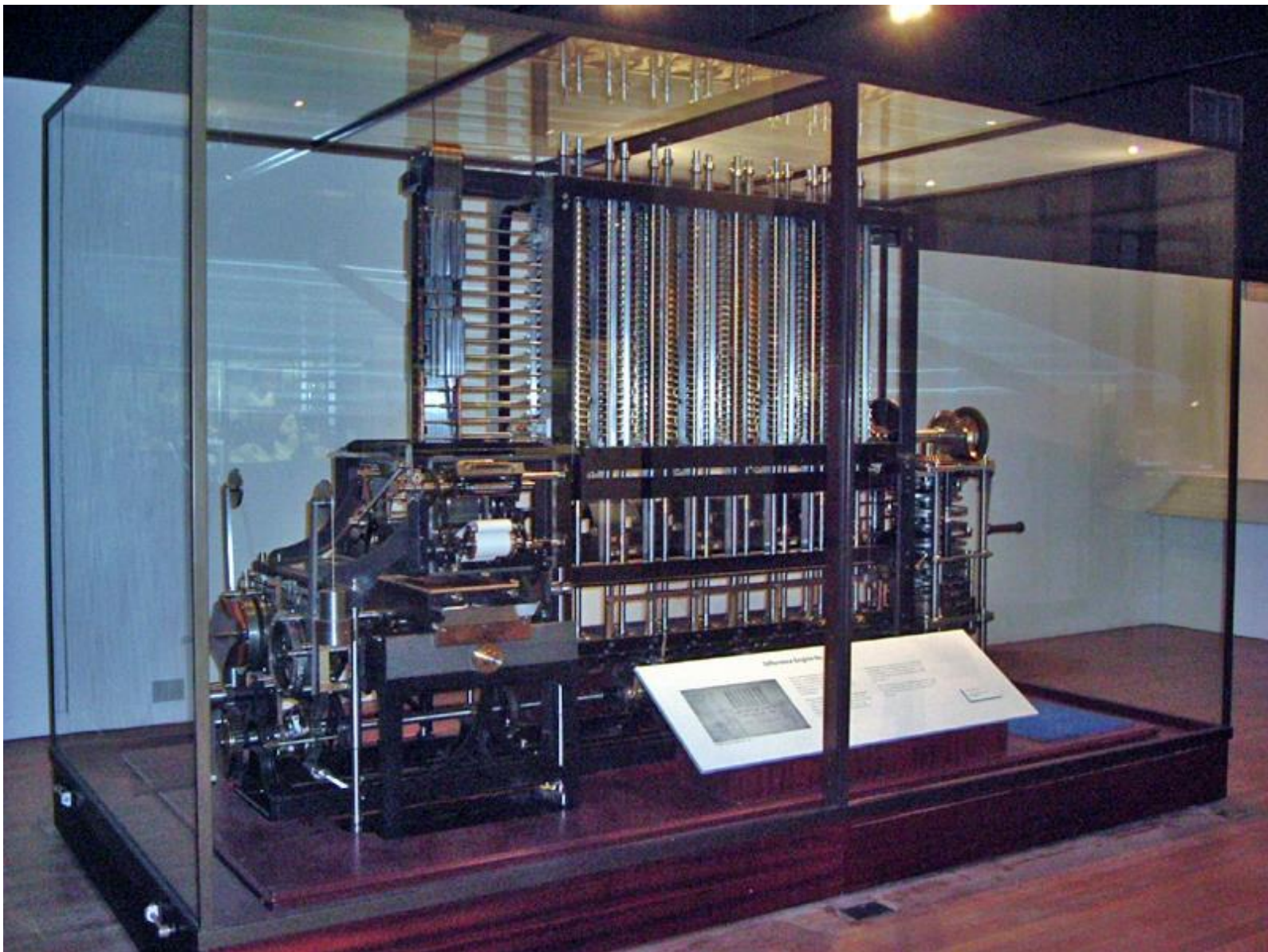
IV. Electronic stored program computers (1945 →)

- EDVAC, the IAS

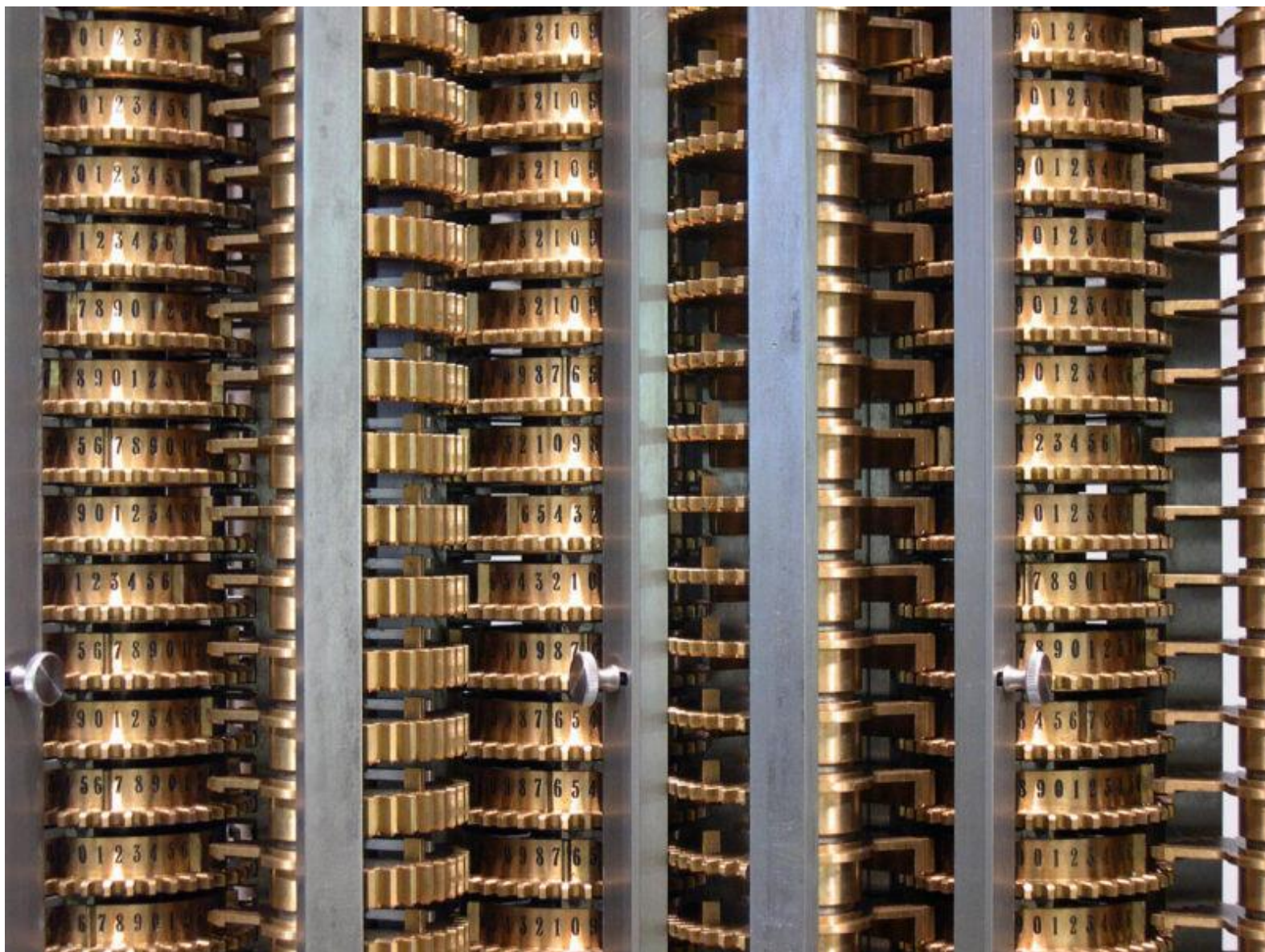
V. Rapid development of computers after 1950

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.



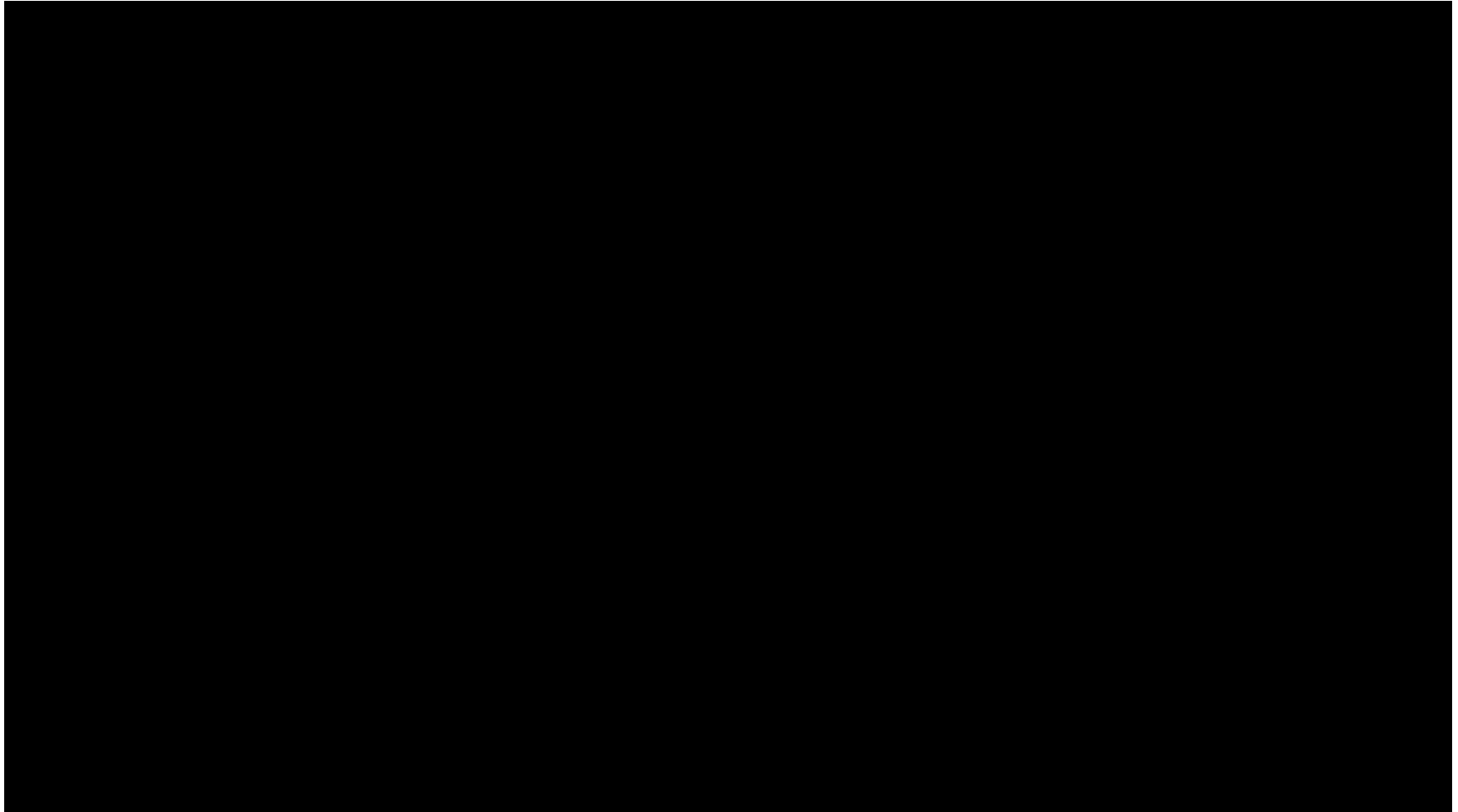
Differential machine 2 (London Science Museum)



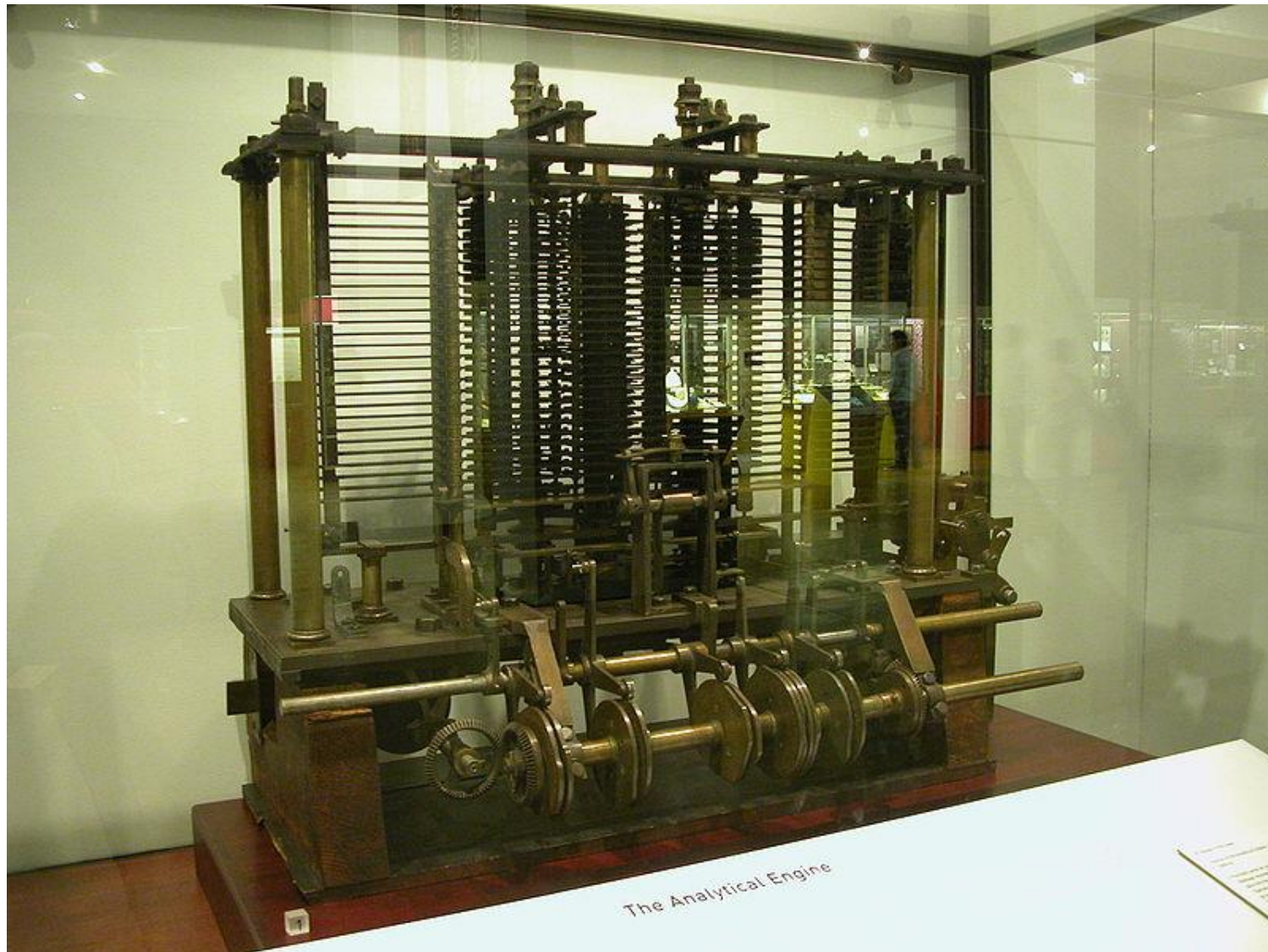
Differential machine 2 close-up picture

Babbage: Analytical Machine

YT Video: [False Dawn: The Babbage Engine](https://www.youtube.com/watch?v=XSkGY6LchJs)



The development of computing machines - Period of mechanics



Part of the analytical group (London Science Museum)

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 **punch cards** the presence or absence of holes is determined **electrically** and no longer mechanically

The development of computing machines - Electromechanical machines



A machine for punching cards and card

■ Konrad Zuse (1910 - 1996):

□ **Z1** (1938)

- first working machine of Babbage kind, although he did not know for Babbage's work - completely mechanical

□ **Z2**

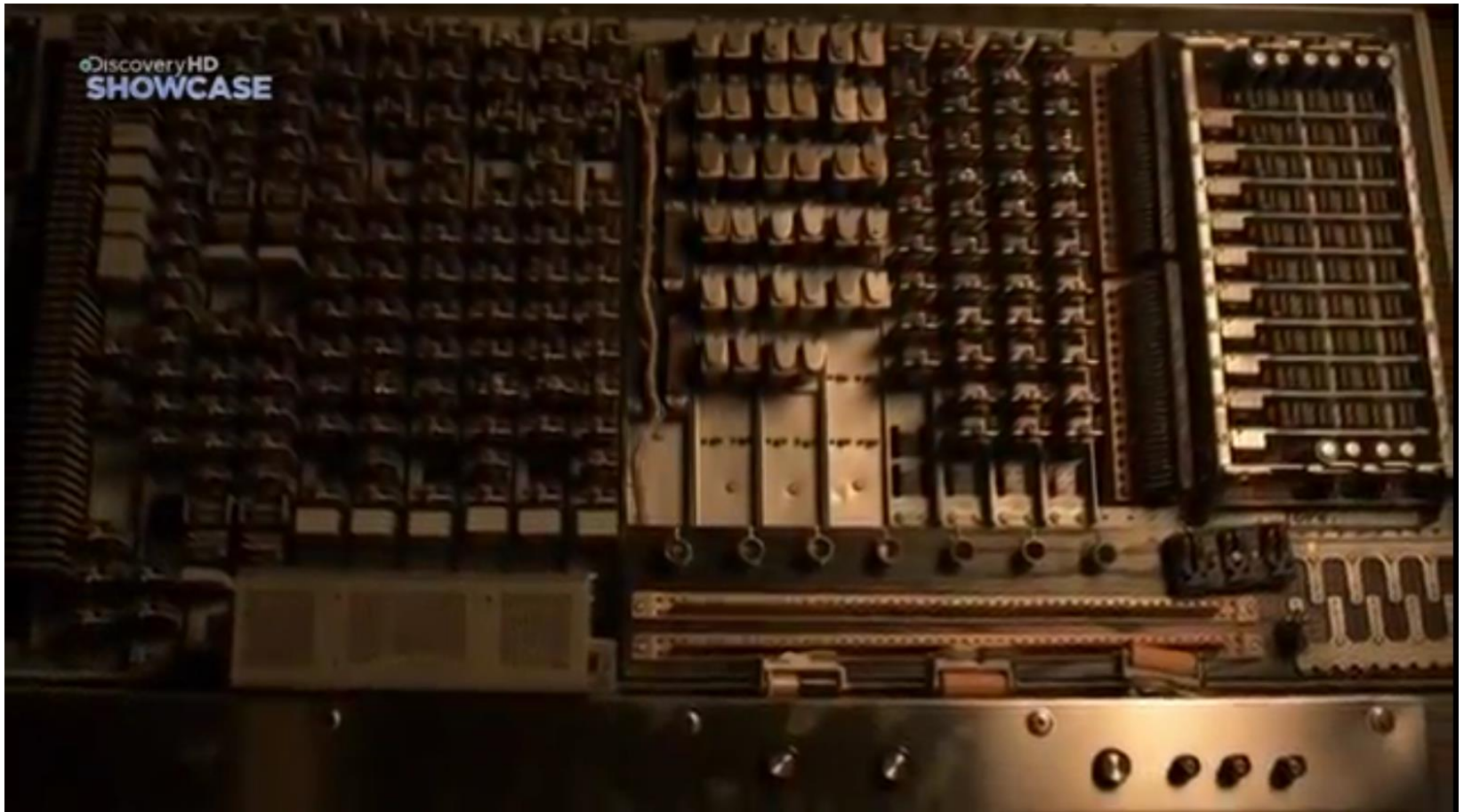
- arithmetical unit built with telephone relays, mechanical memory of the Z1 - unfinished

□ **Z3** (1941)

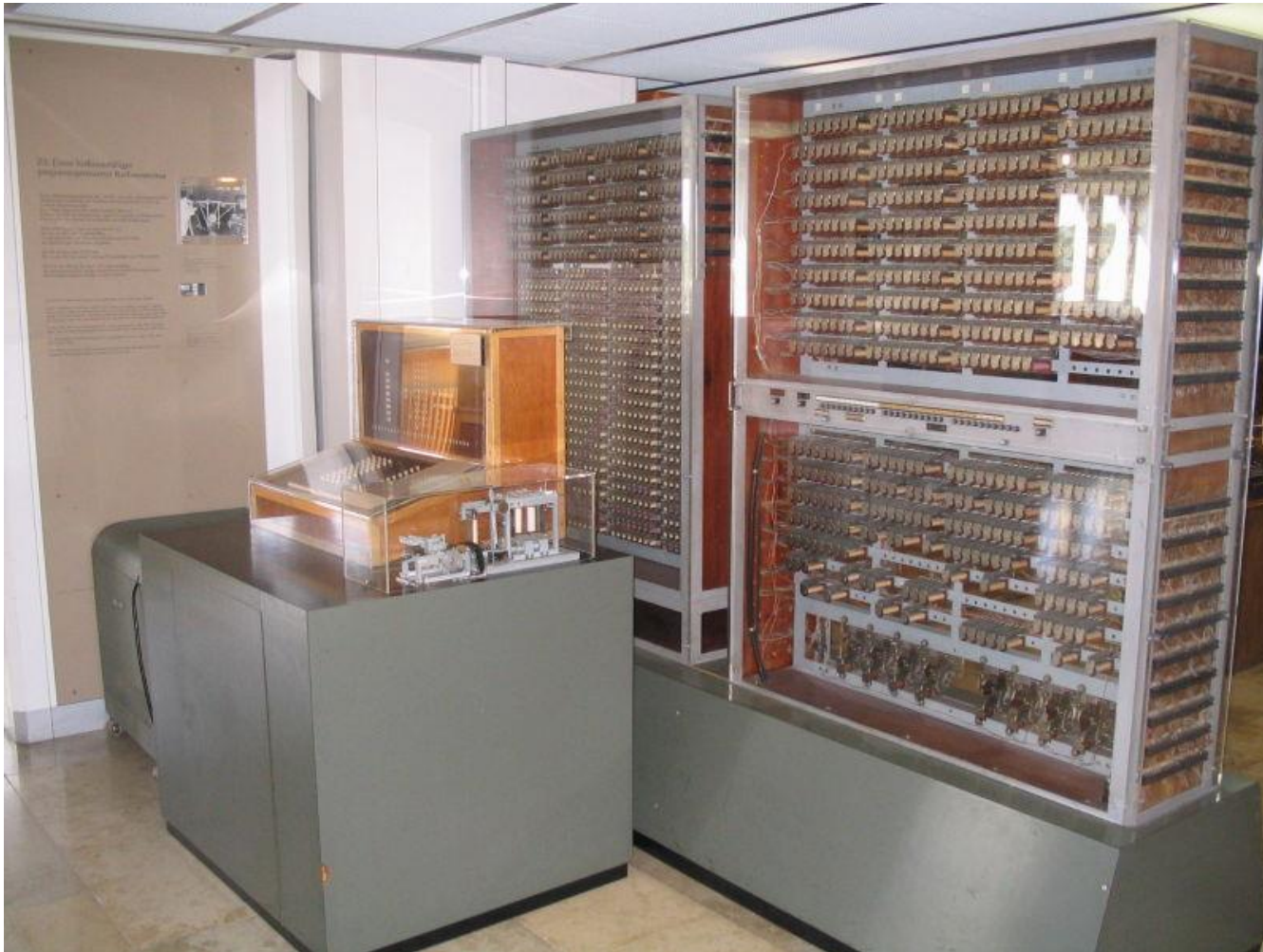
- first working program guided electromechanical general purpose computer
- used binary-based (not decimal-based) arithmetic
 - 2600 telephone relays
 - relay memory consisting of 64 22-bit words
 - 8-bit instructions stored on a perforated tape

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 - 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 perforated tape**

III. First electronic computers

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

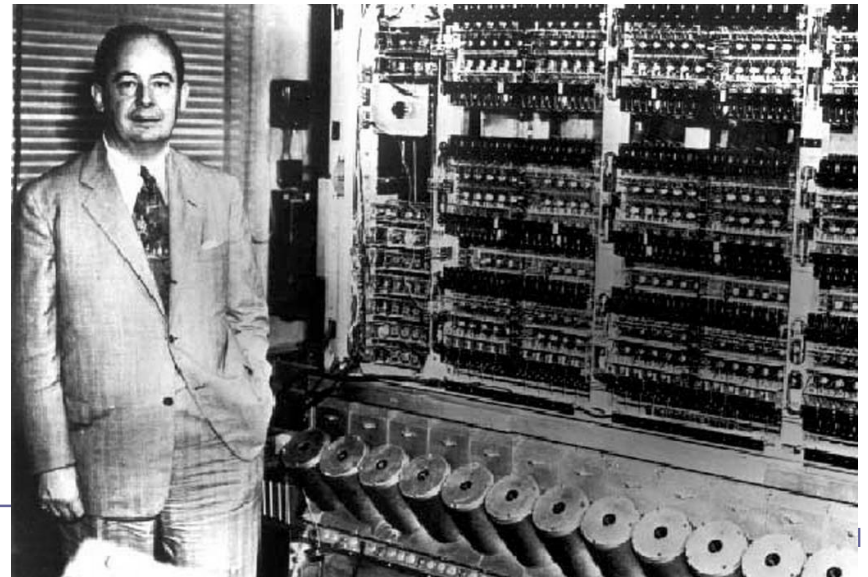
- **ENIAC** (Electronic Numerical integrator and Calculator)
 - completed in 1945
 - ~ 500 to 1000 times faster than Mark I
 - The physical dimensions of 30m x 3m x 1m
 - 18,000 tubes, 150 relays, 140kW
 - Programming using switches (> 6000 switches) and connecting cables



IV. Electronic Stored program Computers

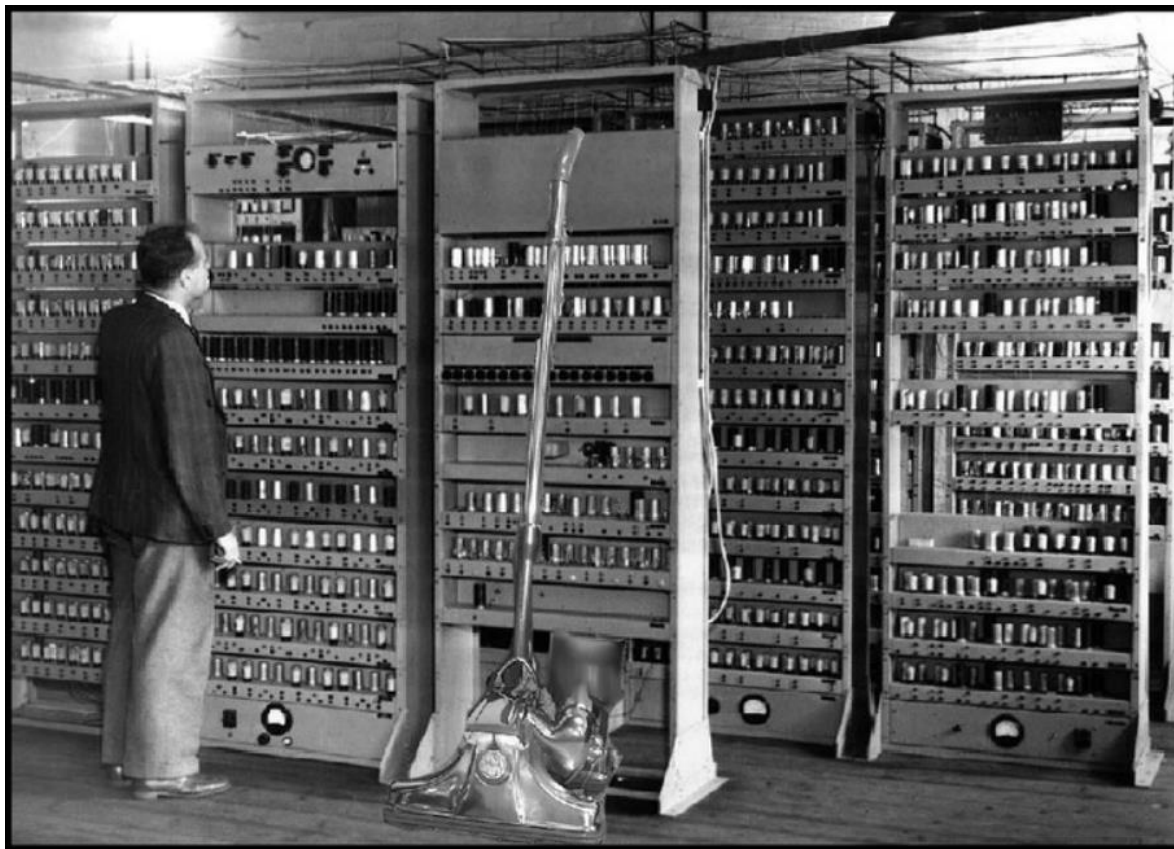
- Author of the idea of stored program computer is probably an American mathematician of Hungarian origin - John von Neumann (1903 - 1957)
- the idea **von Neumann** first published in 1945 in the proposal for a new electronic computer **EDVAC** (Electronic Discrete Variable Computer)
- EDSAC, EDVAC, 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 of 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. Rapid development of computers after 1950

- Development was more in technological than architecture sense
- Since 1955, the tubes began to fade and being replaced by transistors
 - that are smaller, faster, more reliable
- Appearance of microprocessors 1971
- Personal computer IBM PC in 1980
- First ARM processor 1985

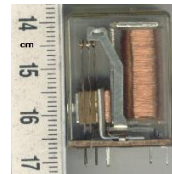
Prefixes for units of measurement

Abbrevi ation	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:

□ Electromechanical switch

- 1939: Relay,



switching time

1-10ms

□ Electrical switch

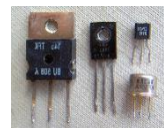
- 1945-1955: Vacuum tube,



switching time

~ 5 μ s

- 1955: Transistors → ,



switching time

~10ns

- 1958: Integrated circuit - chip,

switching time

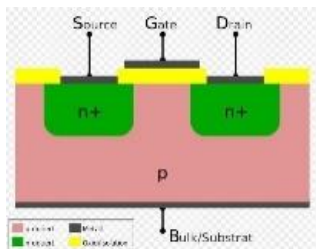
2-10ns

- 1980: VLSI integrated circuit

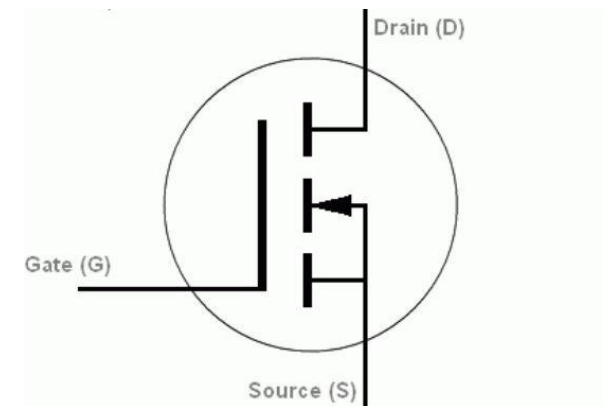
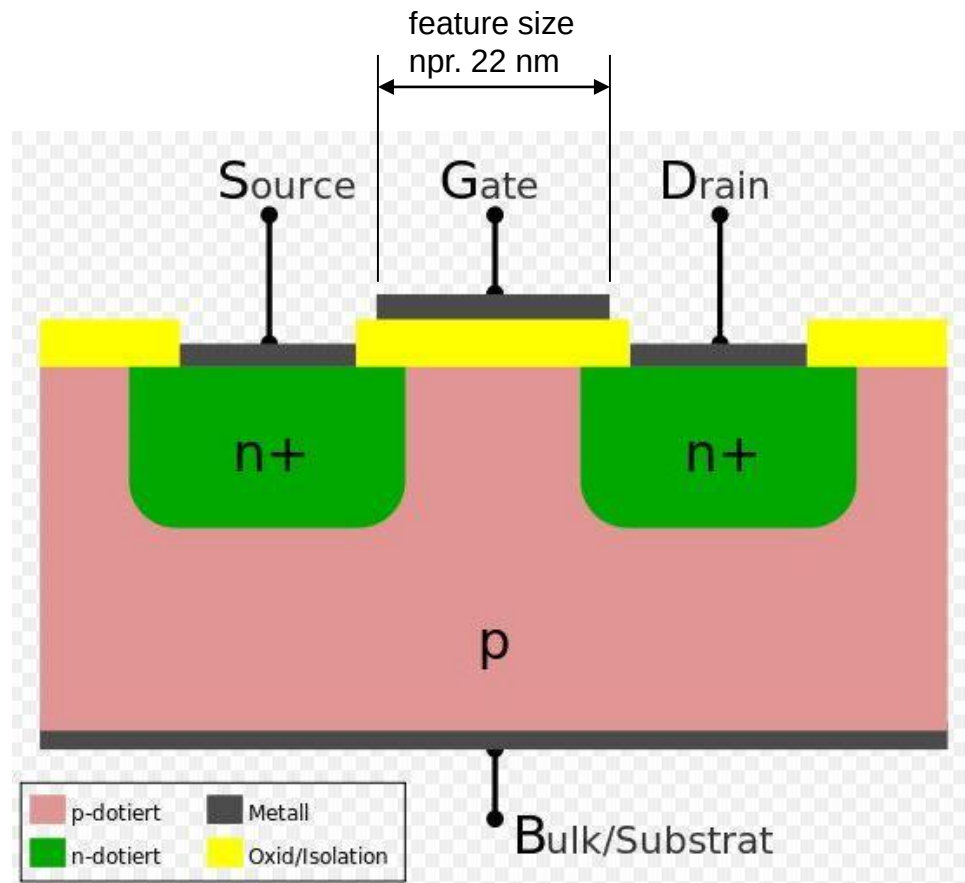
switching time

< 0.1ns

- Very Large Scale Integration



Transistors as a part of the integrated circuit VLSI



V. Rapid development of computers after 1950

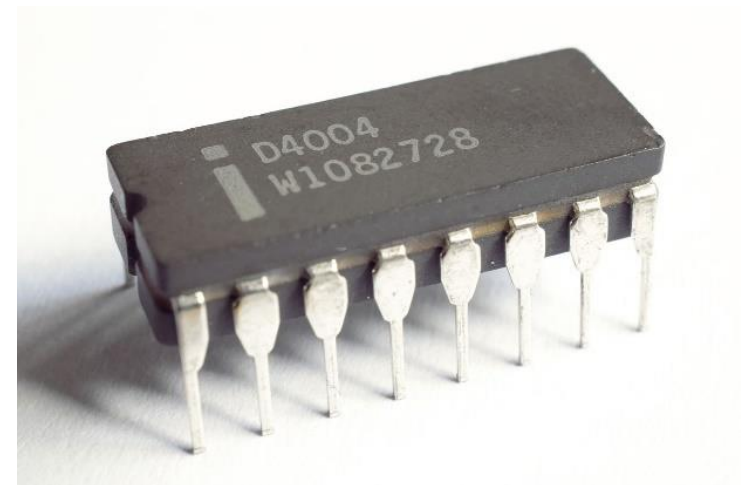
Milestones:

- Appearance of microprocessors 1971
- Personal computer IBM PC in 1980
- First ARM processor 1985

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 $10\text{ }\mu\text{m} = 10 \times 10^{-6}\text{ m} = 0,00001\text{ m}$,
 - Human hair diameter approx. $100\text{ }\mu\text{m}$)
- 16 pins
- Instruction execution in $10,8\text{ }\mu\text{s}$ ($= 0,0000108\text{ s}$) or $21,6\text{ }\mu\text{s}$
- 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 4.77 MHz
- ❑ Memory: from 128 KB to 640 KB
- ❑ One or two floppy disk units 5.25 "
- ❑ Hard disk with capacity of 10 MB



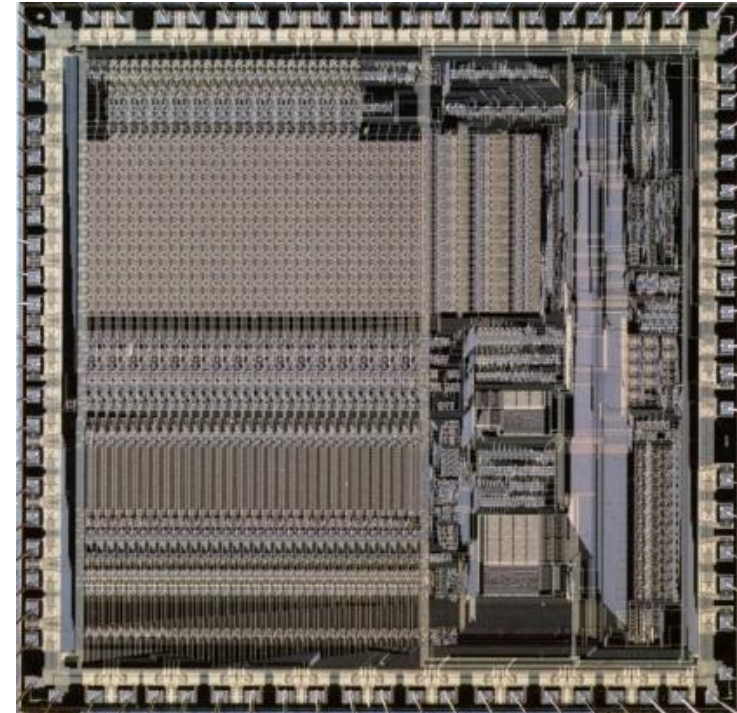
Milestone III : First ARM processor 1985

- ❑ 25000 transistors
- ❑ El. consumption 1W
- ❑ Implementation of RISC idea



[Online simulation:](http://visual6502.org/sim/varm/armgl.html)

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



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

