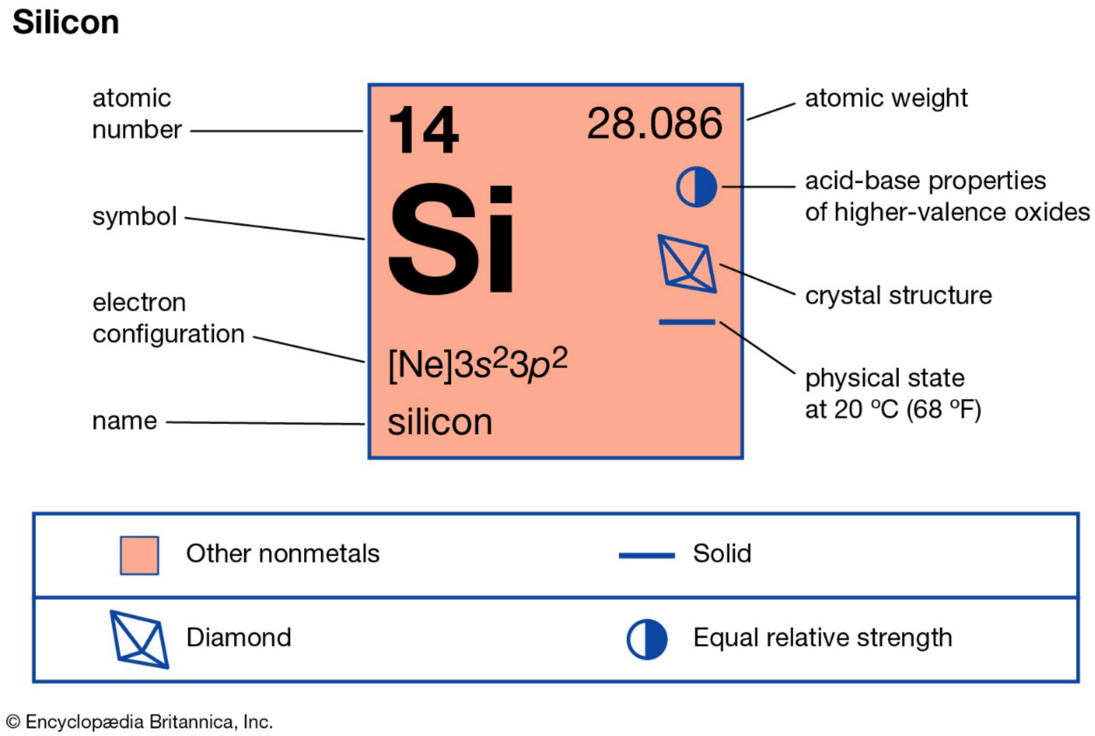
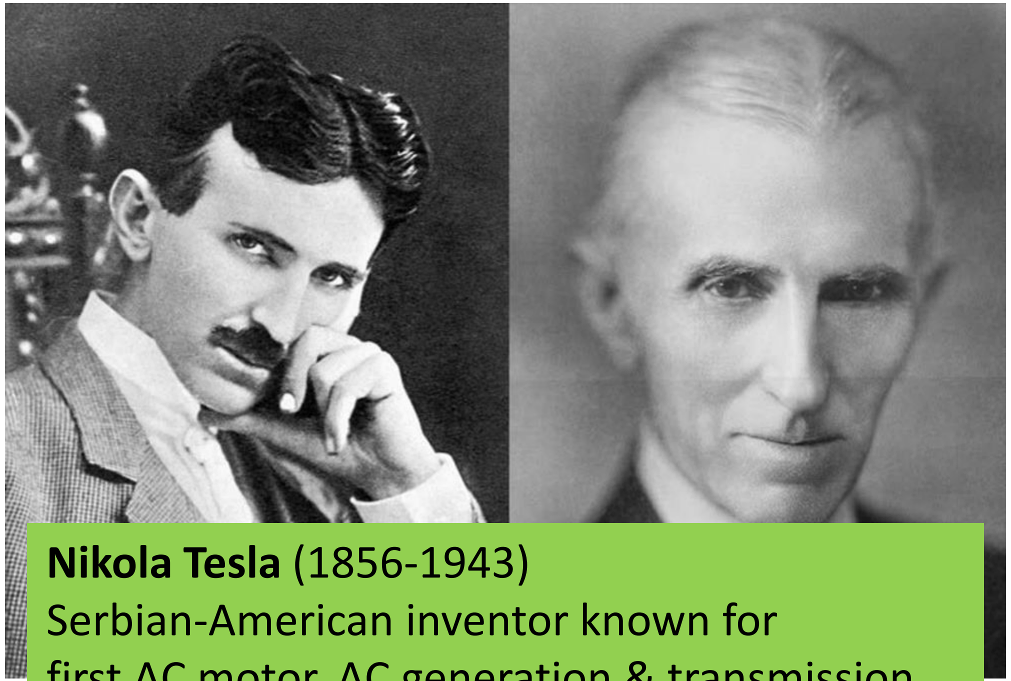
Unit 01 - Introduction to Microprocessors

COMPUTER ENGINEERING
UNIVERSITY of SAN CARLOS

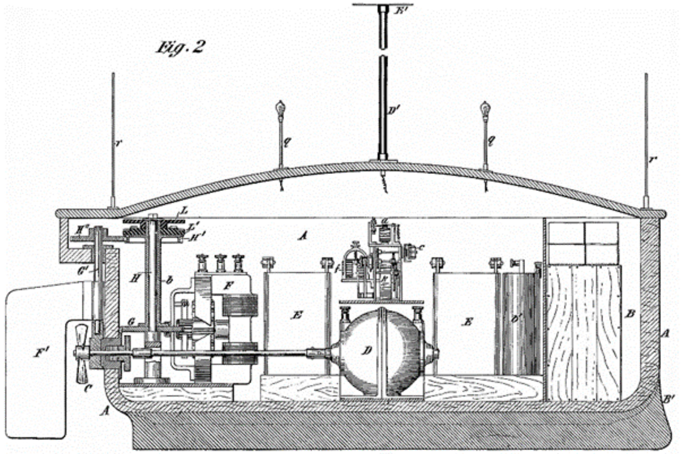
Historical Background of Microprocessors

Jons Jacob Berzelius (1779-1848)
Swedish chemist known for atomic weights, chemical notation, catalysis, silicon, selenium, thorium, cerium

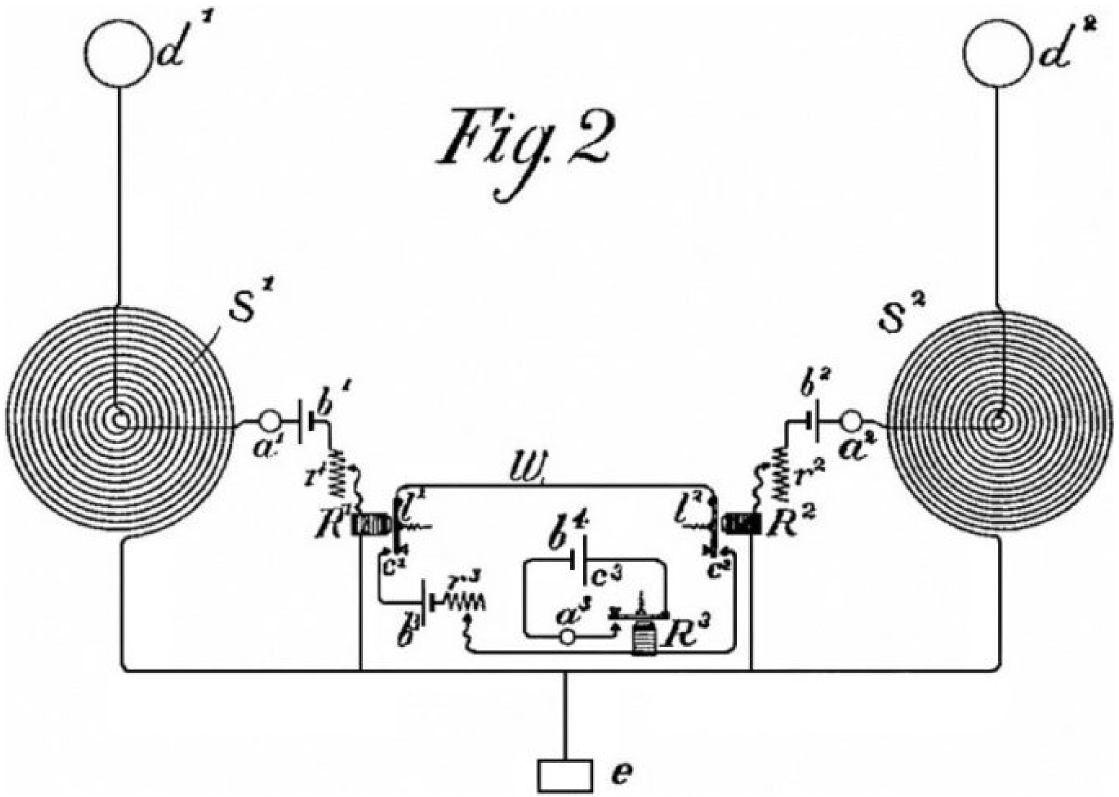


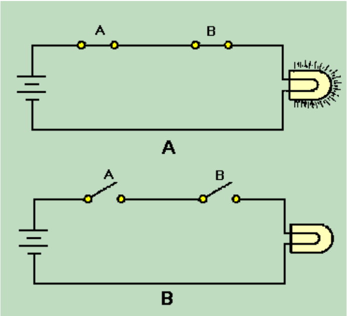


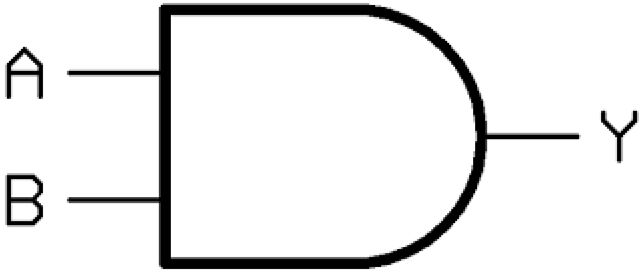
Nikola Tesla (1856-1943)
Serbian-American inventor known for
first AC motor, AC generation & transmission, radar, x-ray, remote control, rotating magnetic field, Tesla coil – wireless technologies

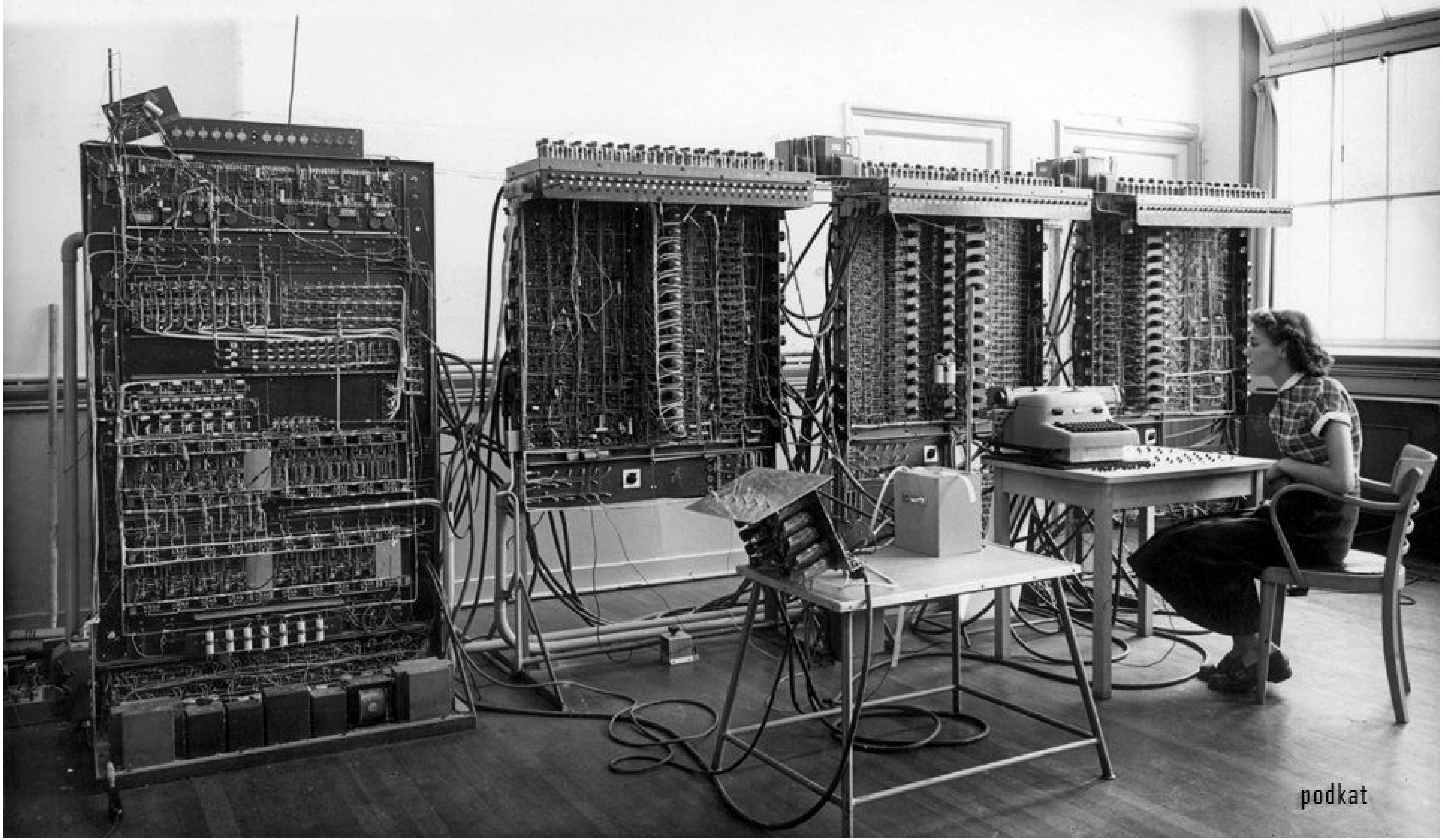


“the art of individualization”



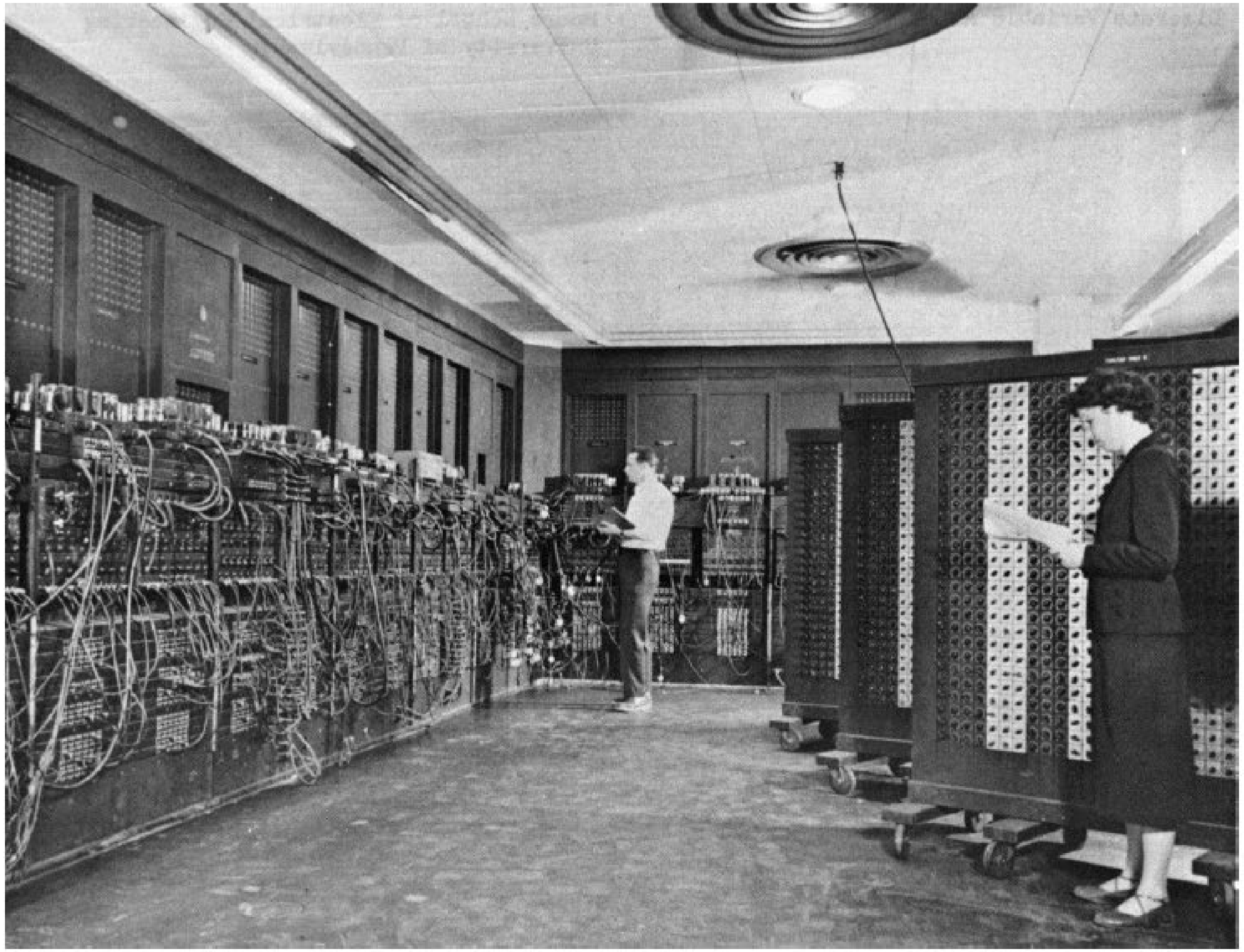





podkat

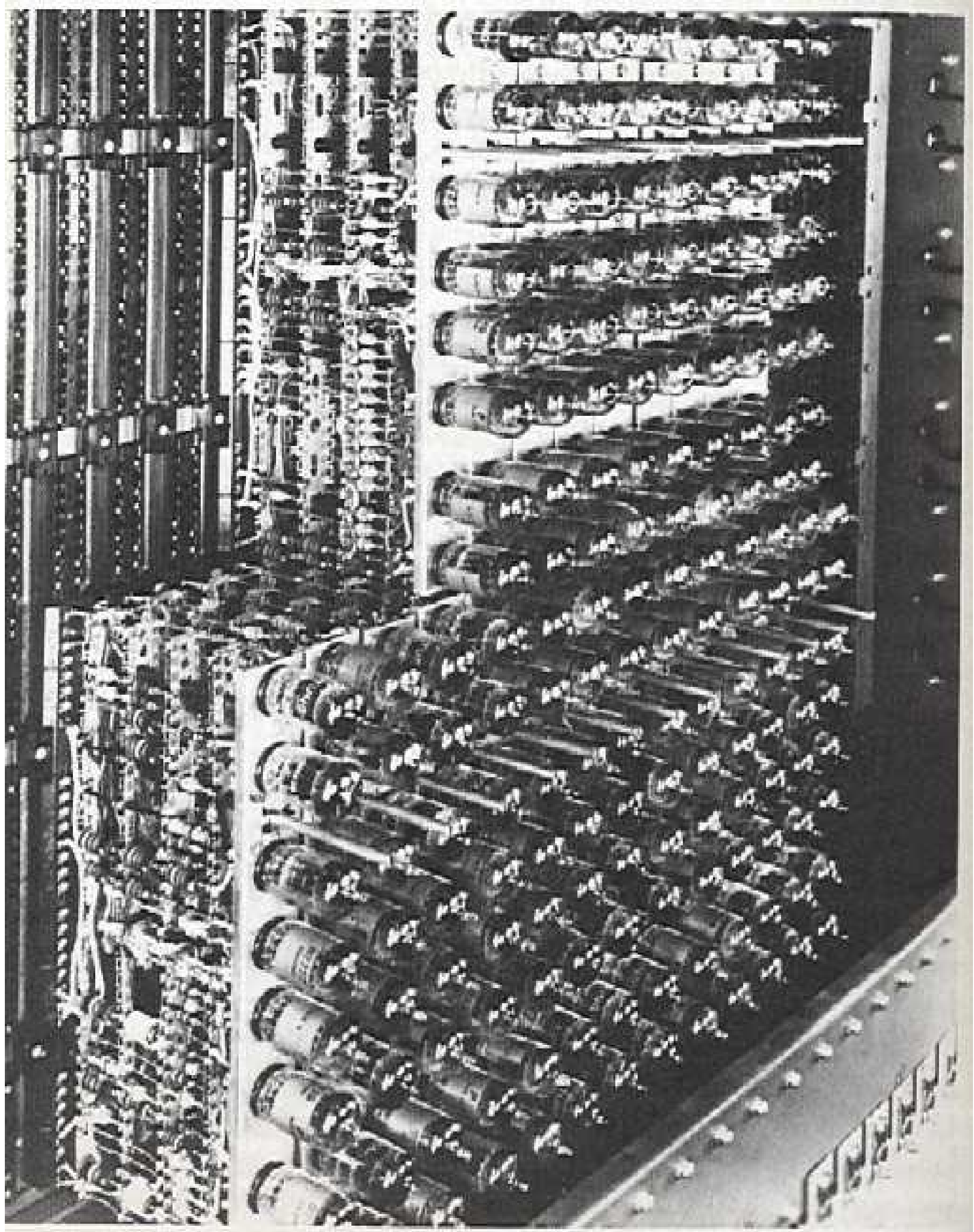
ENIAC

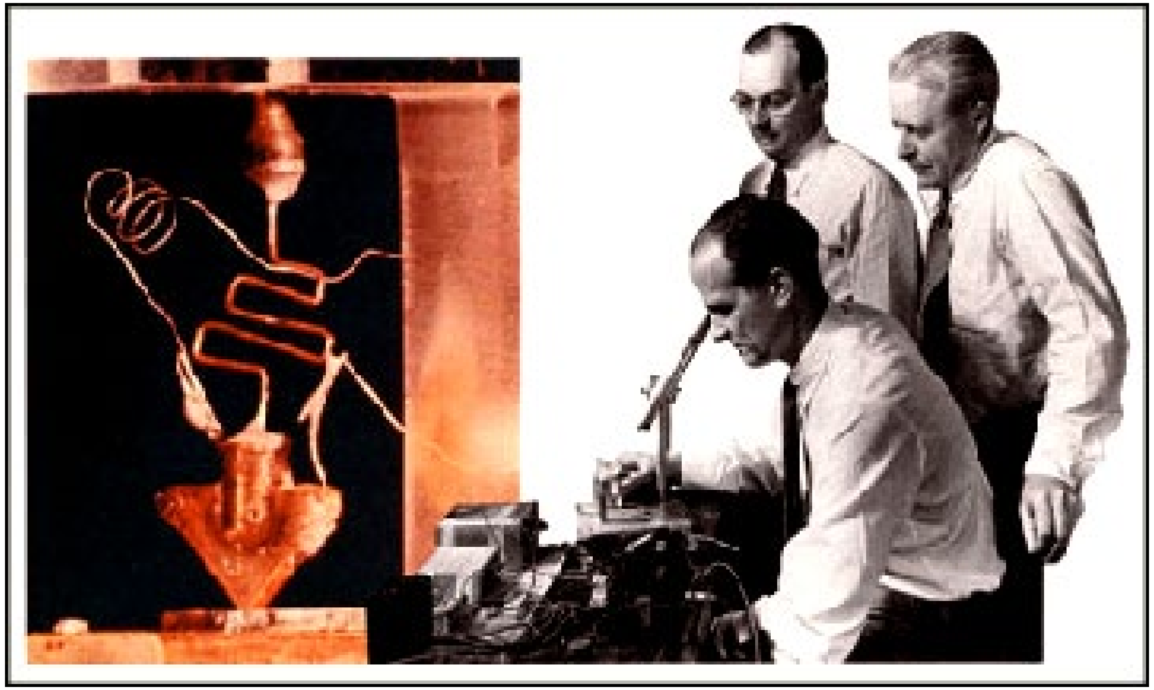
Electrical Numerical Integrator and Calculator



Glen Beck and Betty Snyder program the ENIAC in BRL building 328. (Picture: U.S. Army)

- Designed for US Army Ballistic Research Lab
- 17,468 vacuum tubes
- 7,200 crystal diodes
- 1,500 relays
- 70,000 resistors
- 10,000 capacitors
- Consumes 150kW of power
- Occupied 72 sq. m.
- Weighs 27 tons
- Suffer failures every 6 hours average



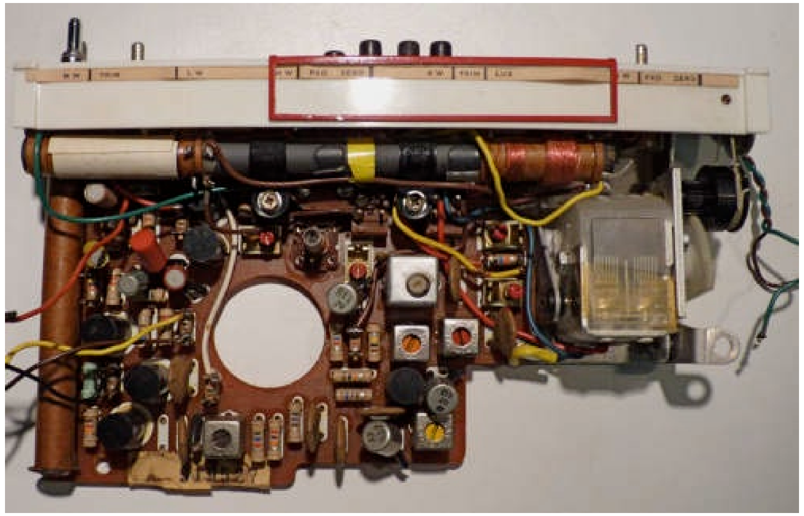


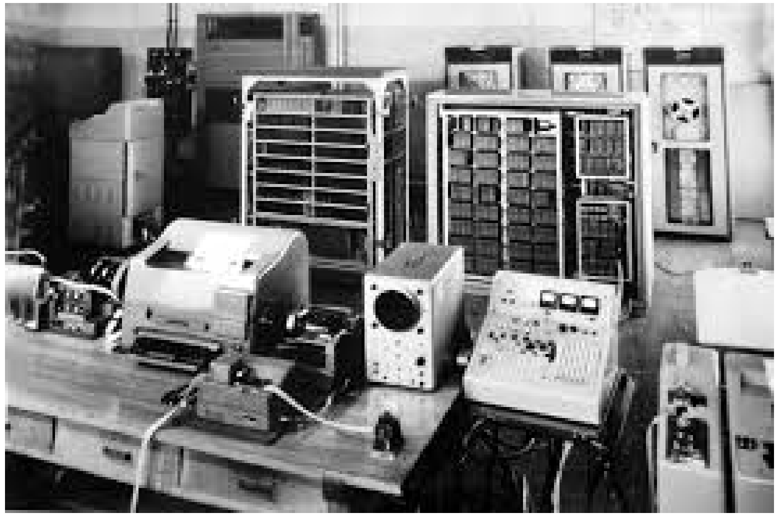
The Nobel Prize in Physics 1956

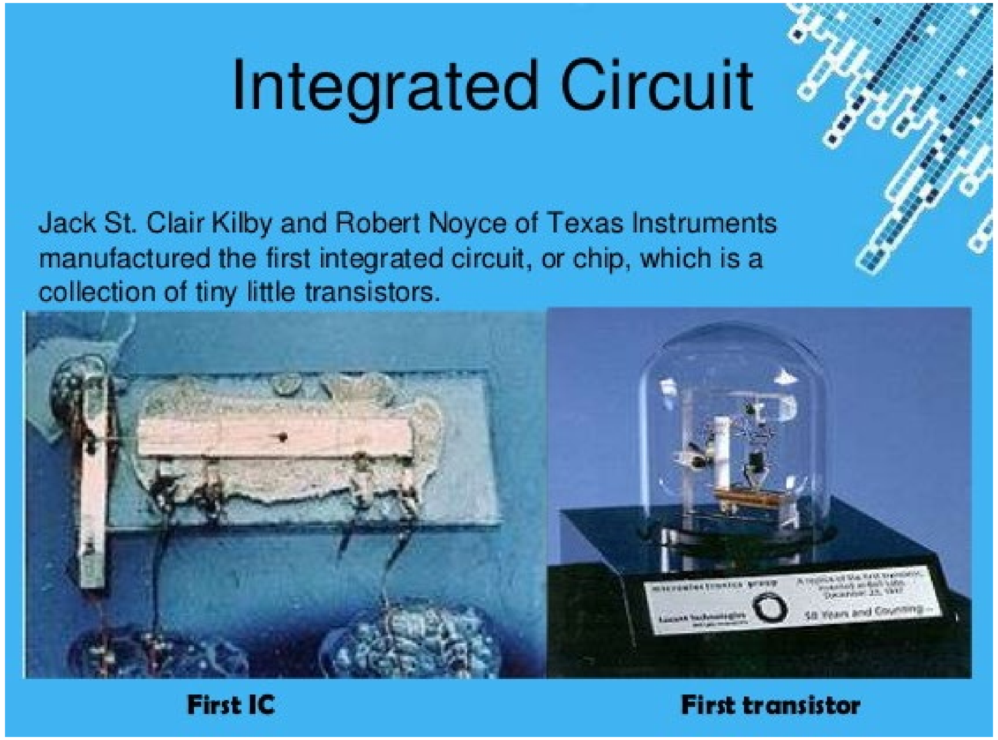
William Bradford Shockley
Prize share: 1/3

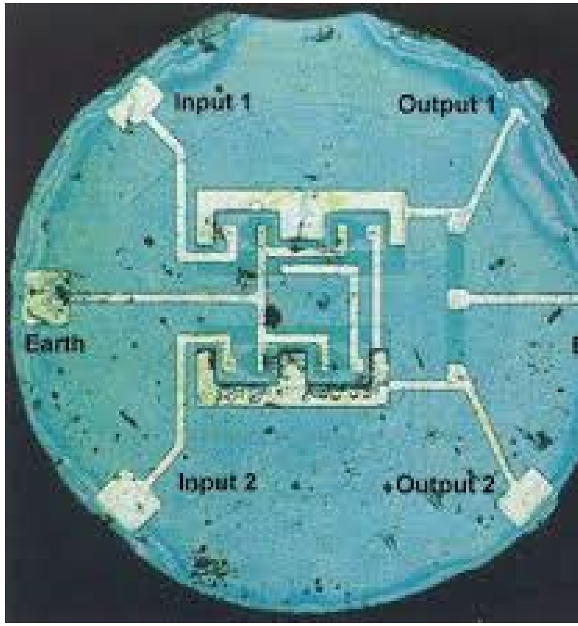
John Bardeen
Prize share: 1/3

Walter Houser Brattain
Prize share: 1/3

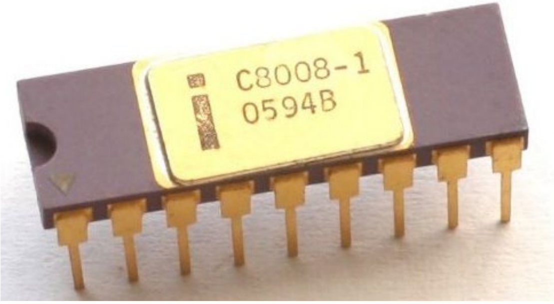


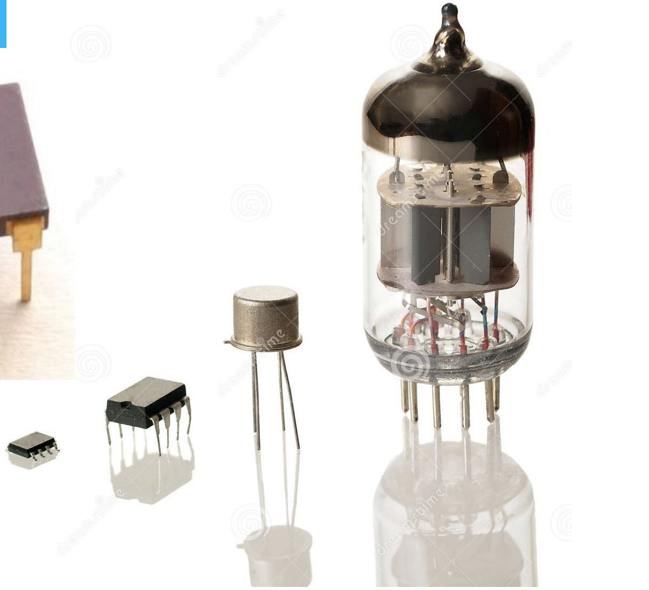




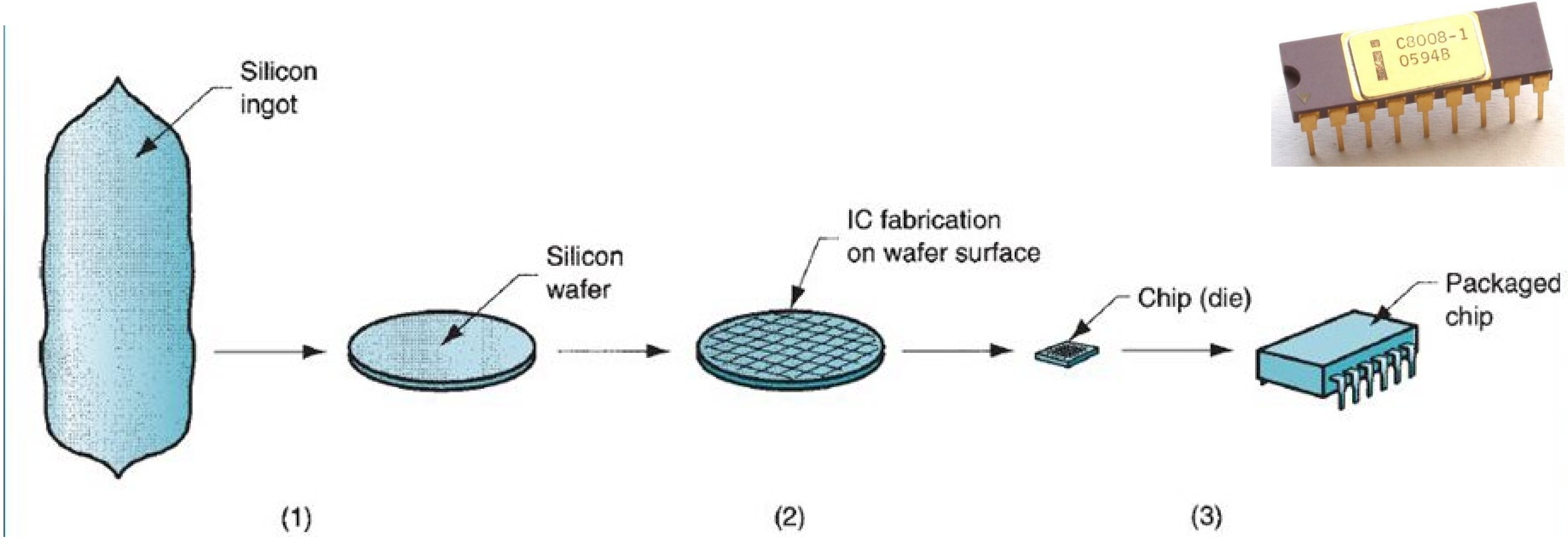


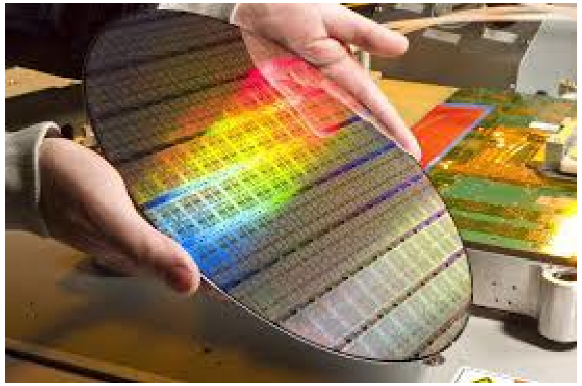
Robert Noyce (1927-1990)
American physicist, co-inventor of Integrated Circuit (IC), co-founder of Fairchild Semiconductor & Intel Corp., known as "Mayor of Silicon Valley"

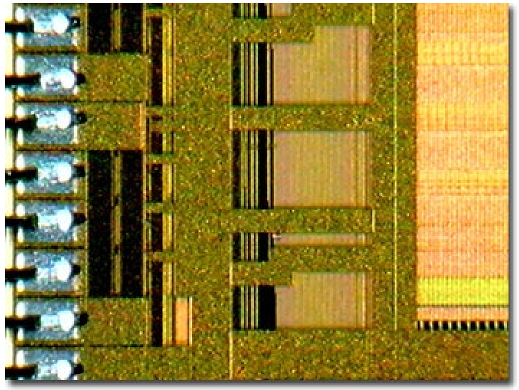




Microprocessors Fabrication







Transistor Generation

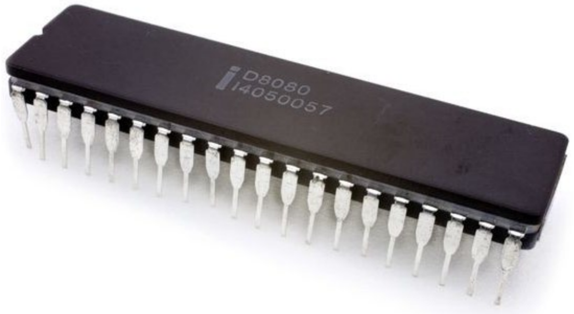
G1

Vacuum Tube

G2

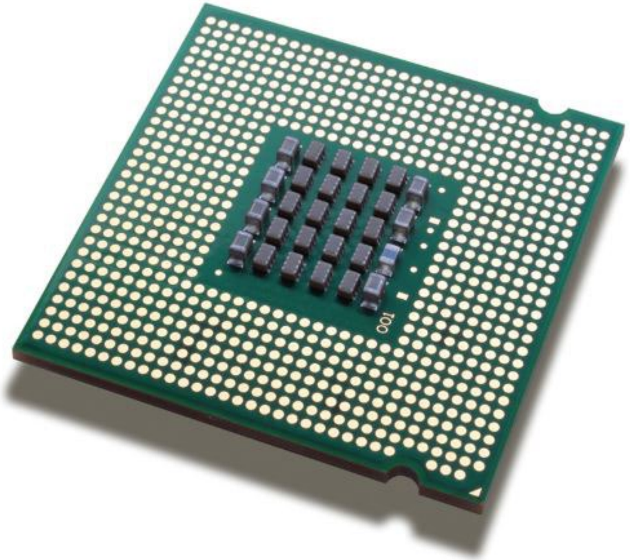
Transistor

G3

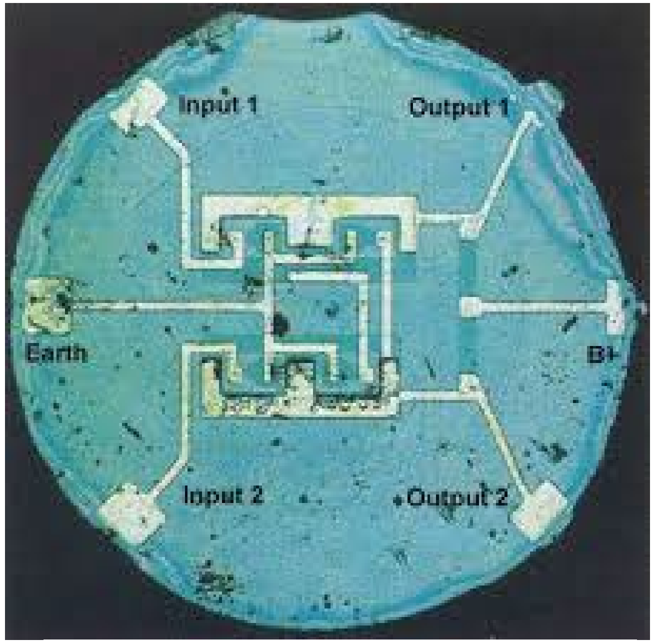


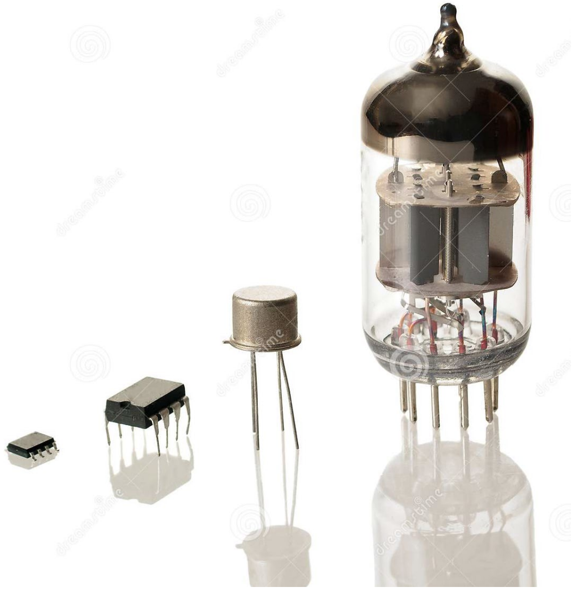
IC

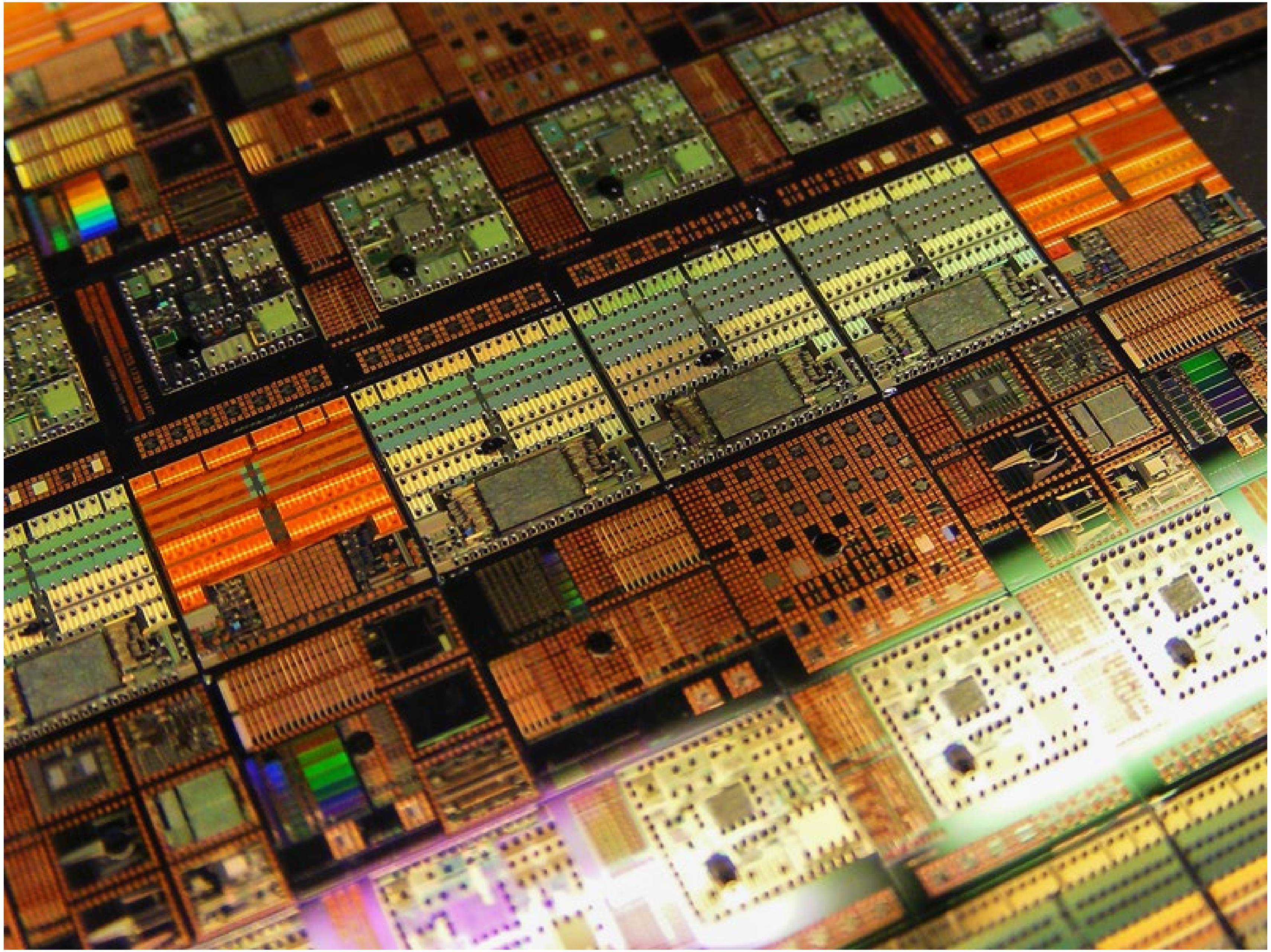
G4



Better IC technology







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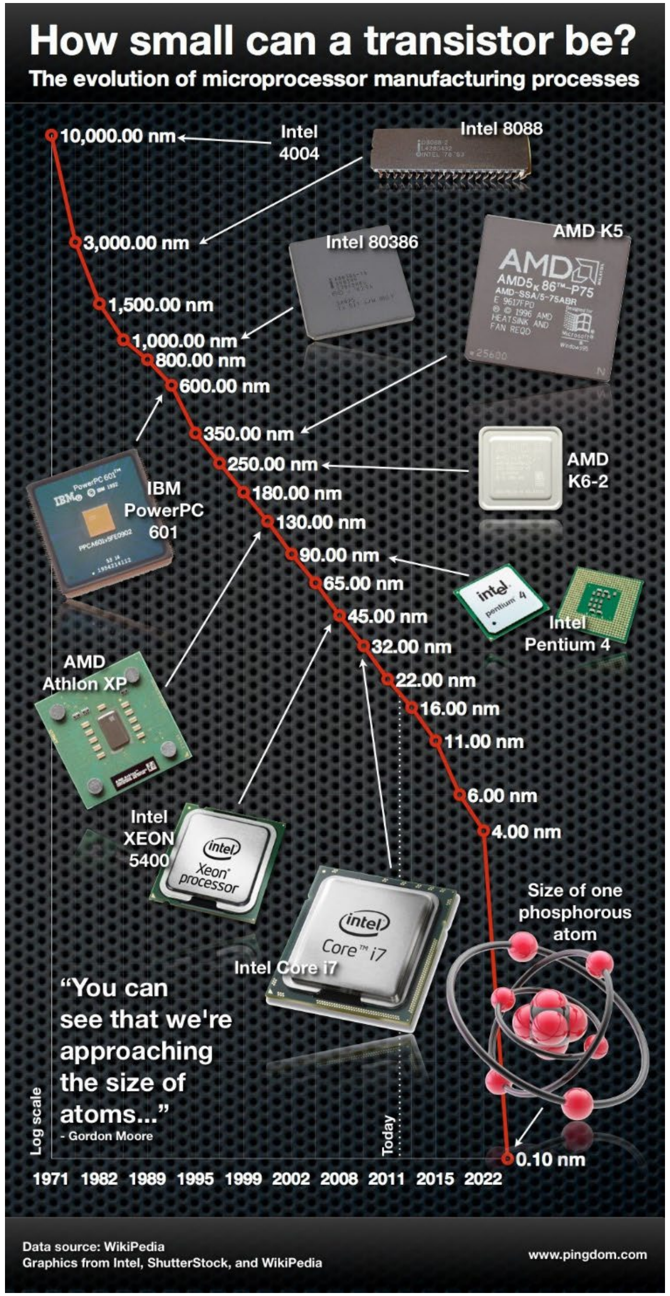
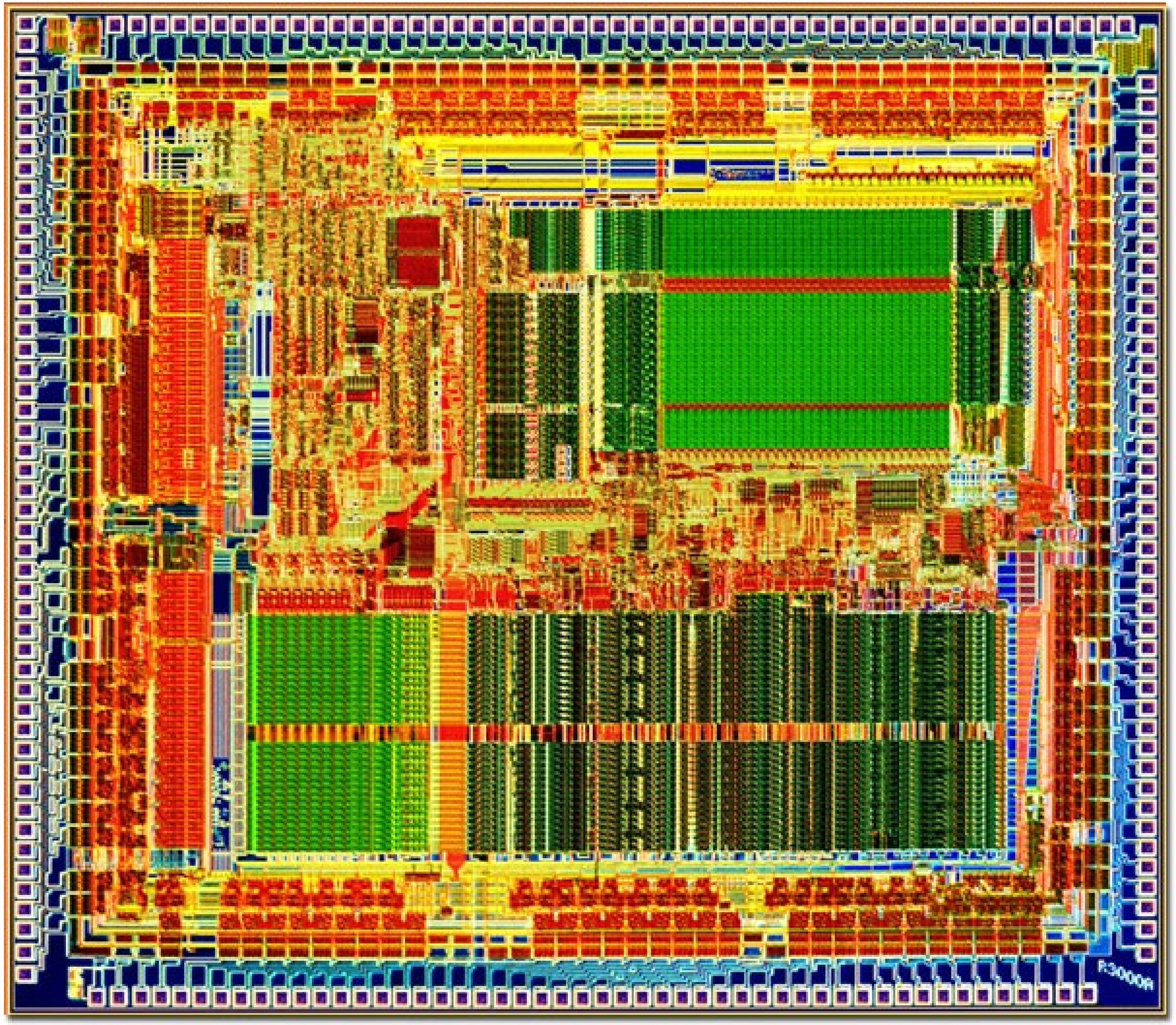

How small can a transistor be?
The evolution of microprocessor manufacturing processes
10,000.00 nm
Intel 4004
Intel 8088
3,000.00 nm
Intel 80386
AMD K5
1,500.00 nm
1,000.00 nm
800.00 nm
600.00 nm
350.00 nm
250.00 nm
AMD K6-2
IBM PowerPC 601
180.00 nm
130.00 nm
90.00 nm
65.00 nm
45.00 nm
Intel Pentium 4
32.00 nm
AMD Athlon XP
22.00 nm
16.00 nm
11.00 nm
6.00 nm
4.00 nm
Intel XEON 5400
Size of one phosphorous atom
Intel Core i7
"You can see that we're approaching the size of atoms..."
- Gordon Moore
Log scale
Today
0.10 nm
1971 1982 1989 1995 1999 2002 2008 2011 2015 2022
Data source: WikiPedia
Graphics from Intel, ShutterStock, and WikiPedia
www.pingdom.com



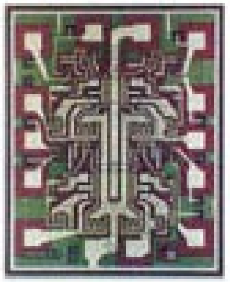
1950s

Silicon Transistor

1 Transistor

1960s

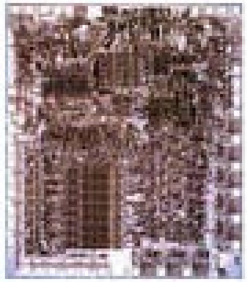
TTL Quad Gate



16 Transistors

1970s

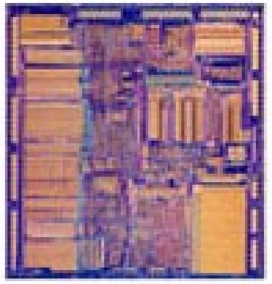
8-bit Microprocessor



4500 Transistors

1980s

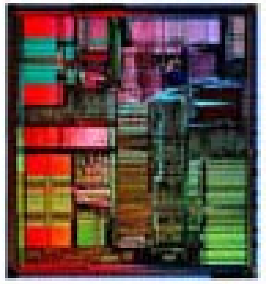
32-bit Microprocessor



275,000 Transistors

1990s

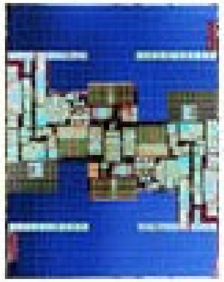
32-bit Microprocessor



3,100,000 Transistors

2000s

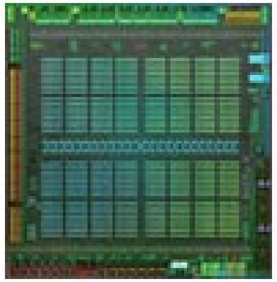
64-bit Microprocessor



592,000,000 Transistors

2010s

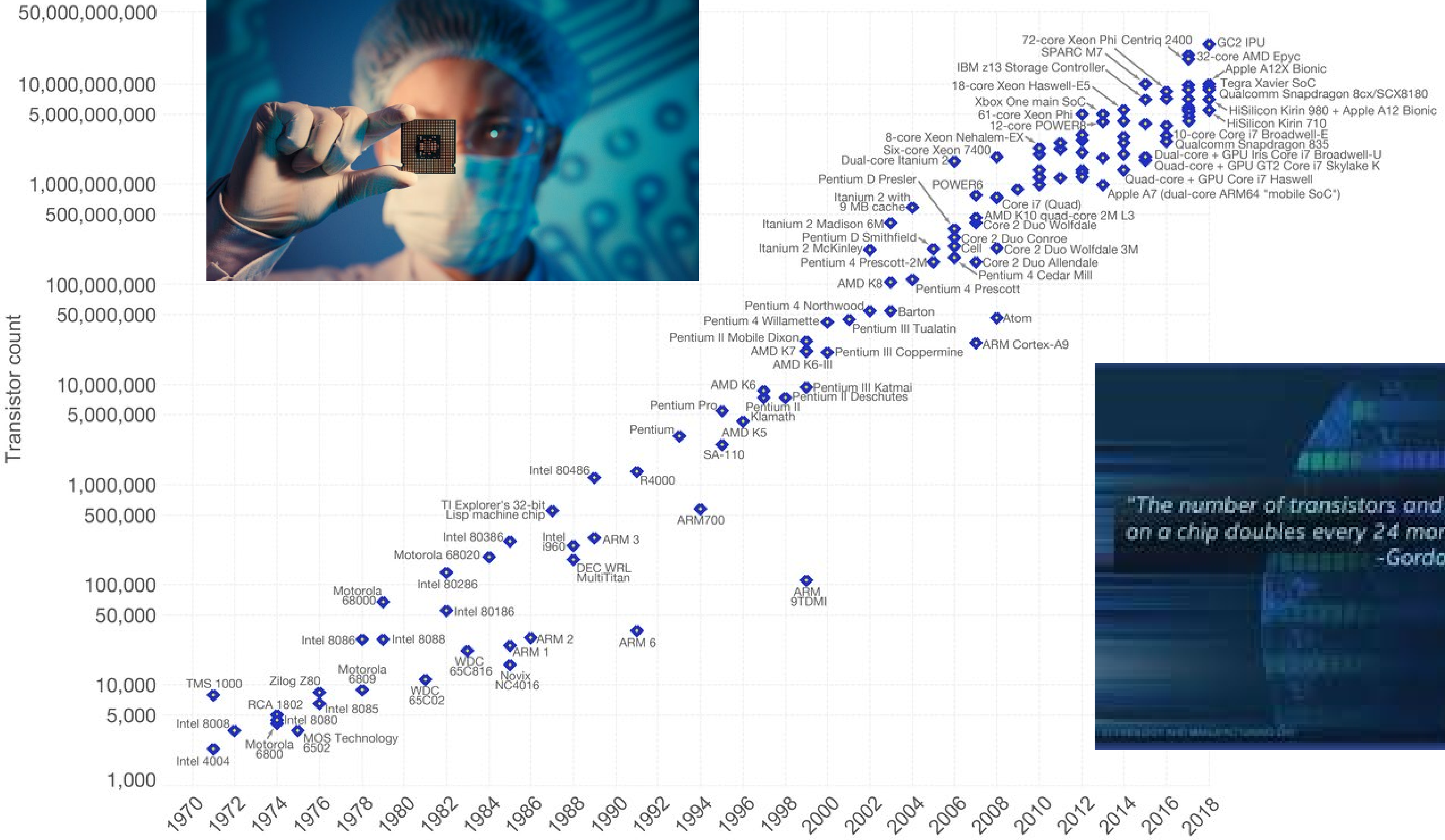
3072-Core GPU

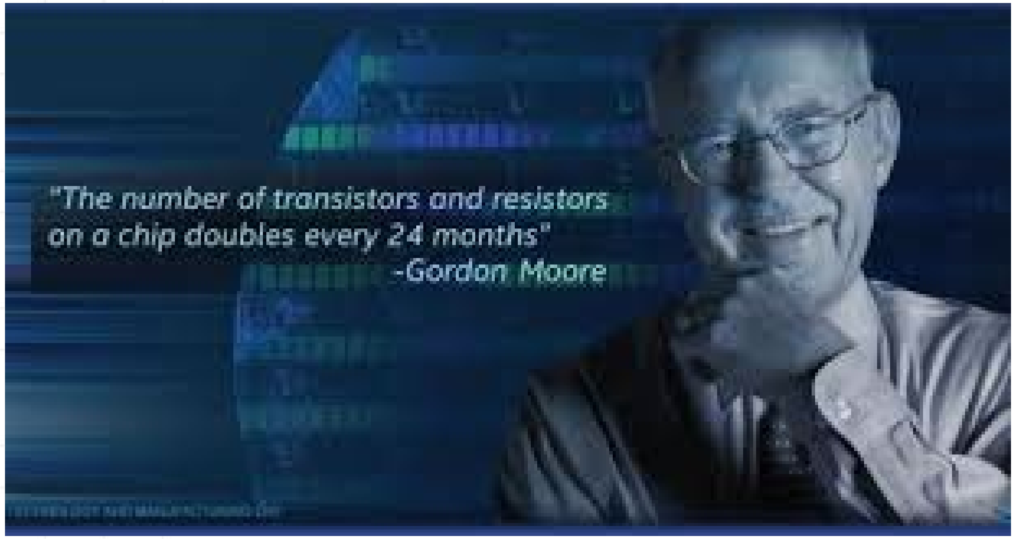


8,000,000,000 Transistors

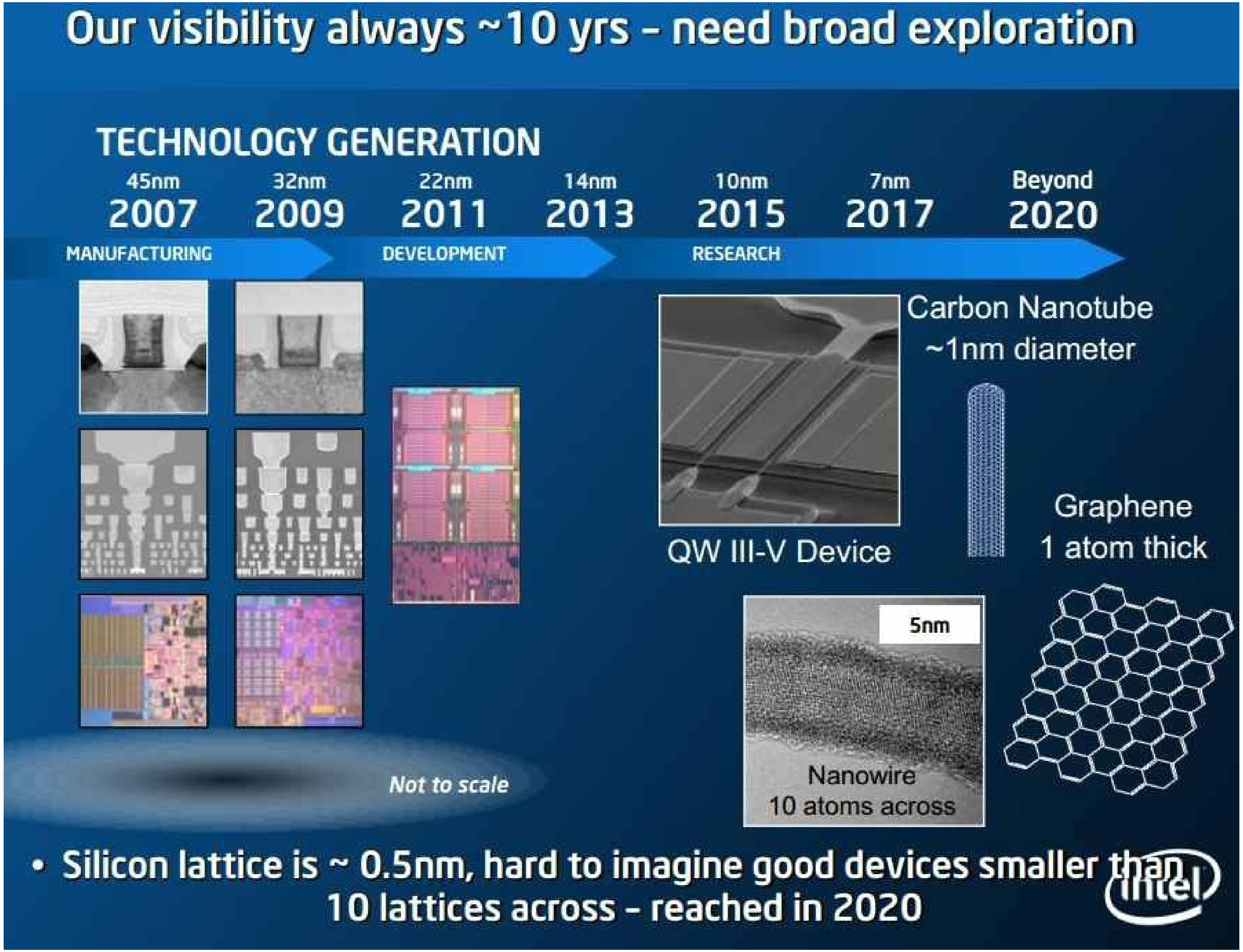
Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

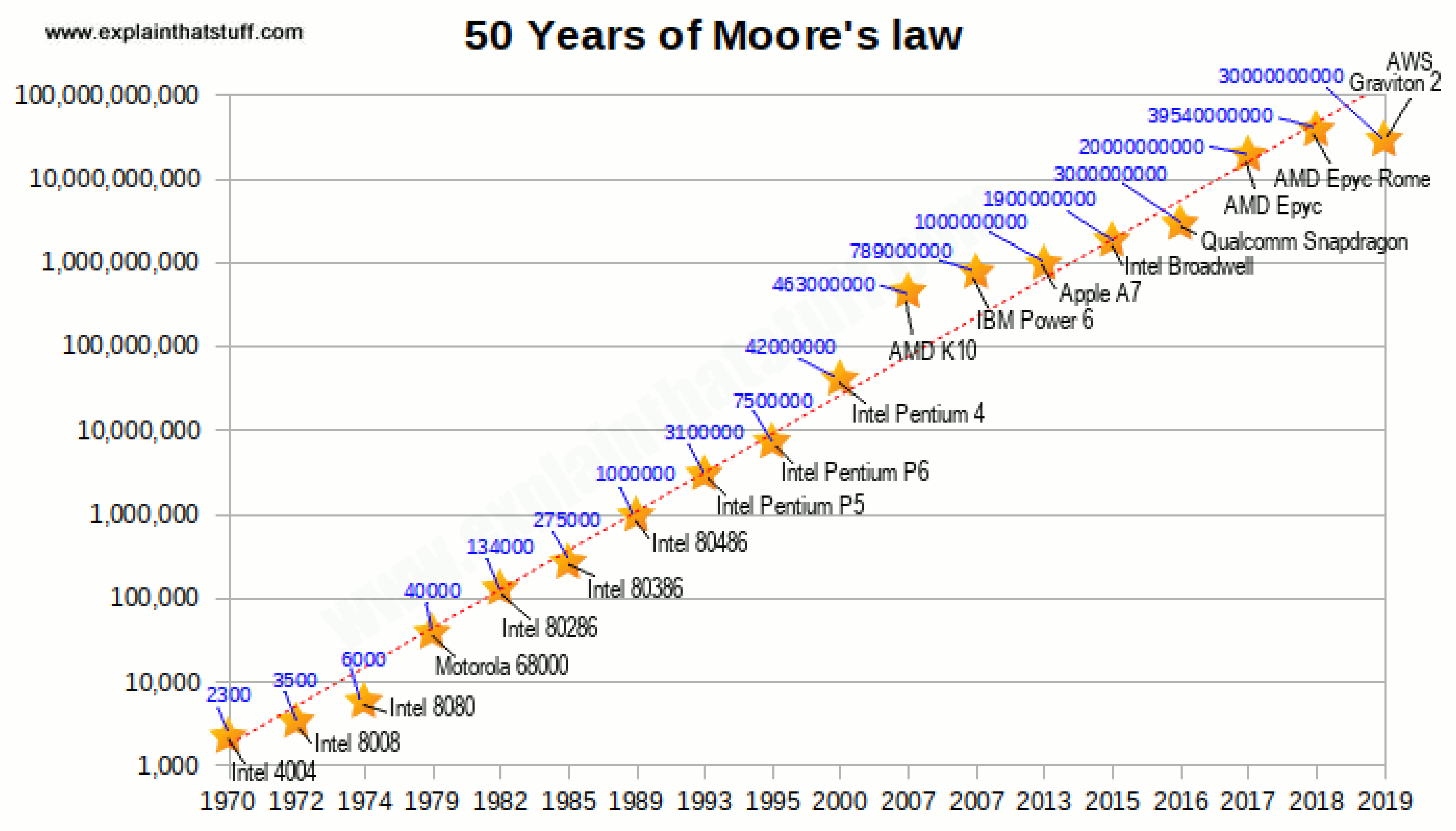
Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.

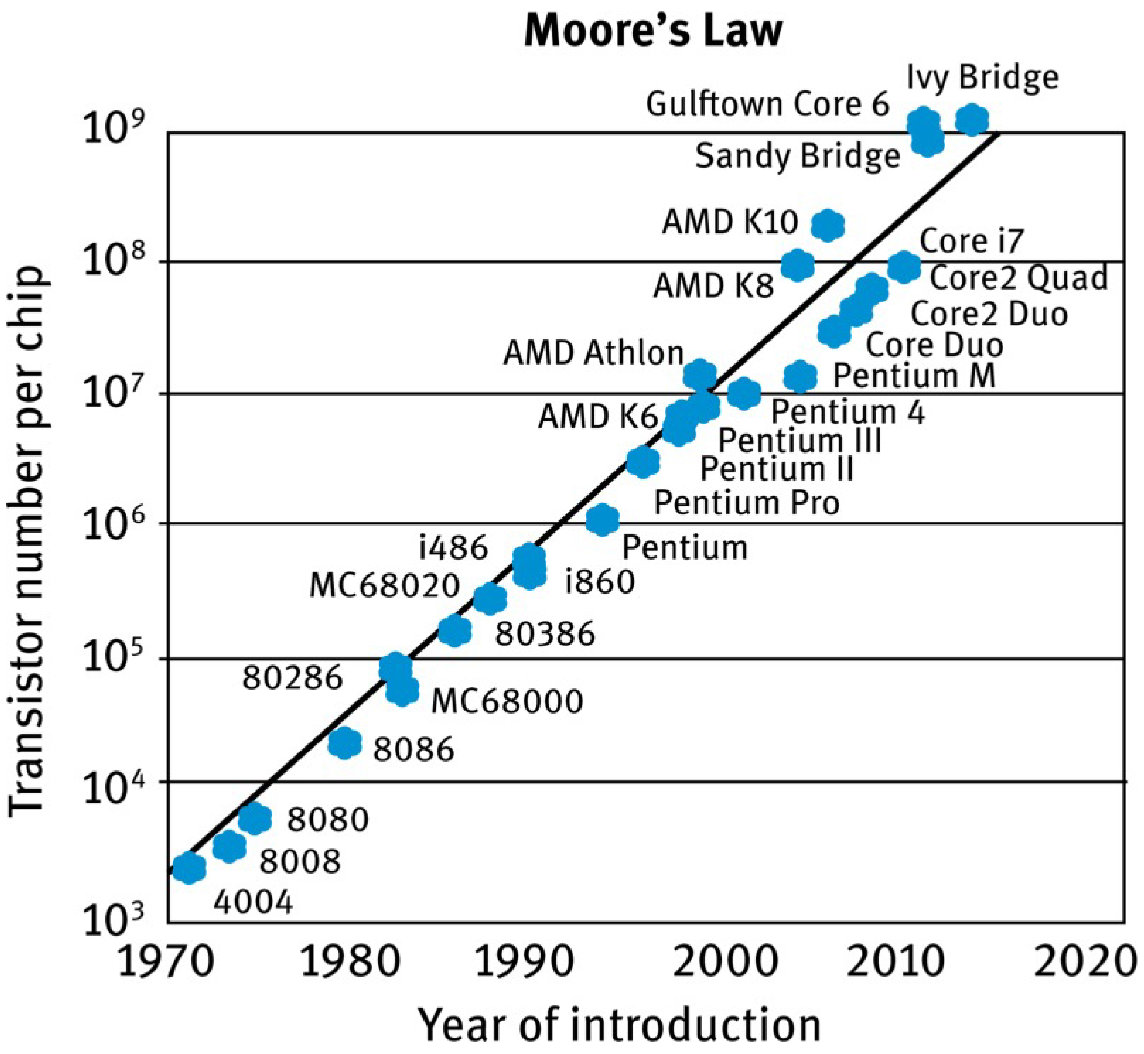


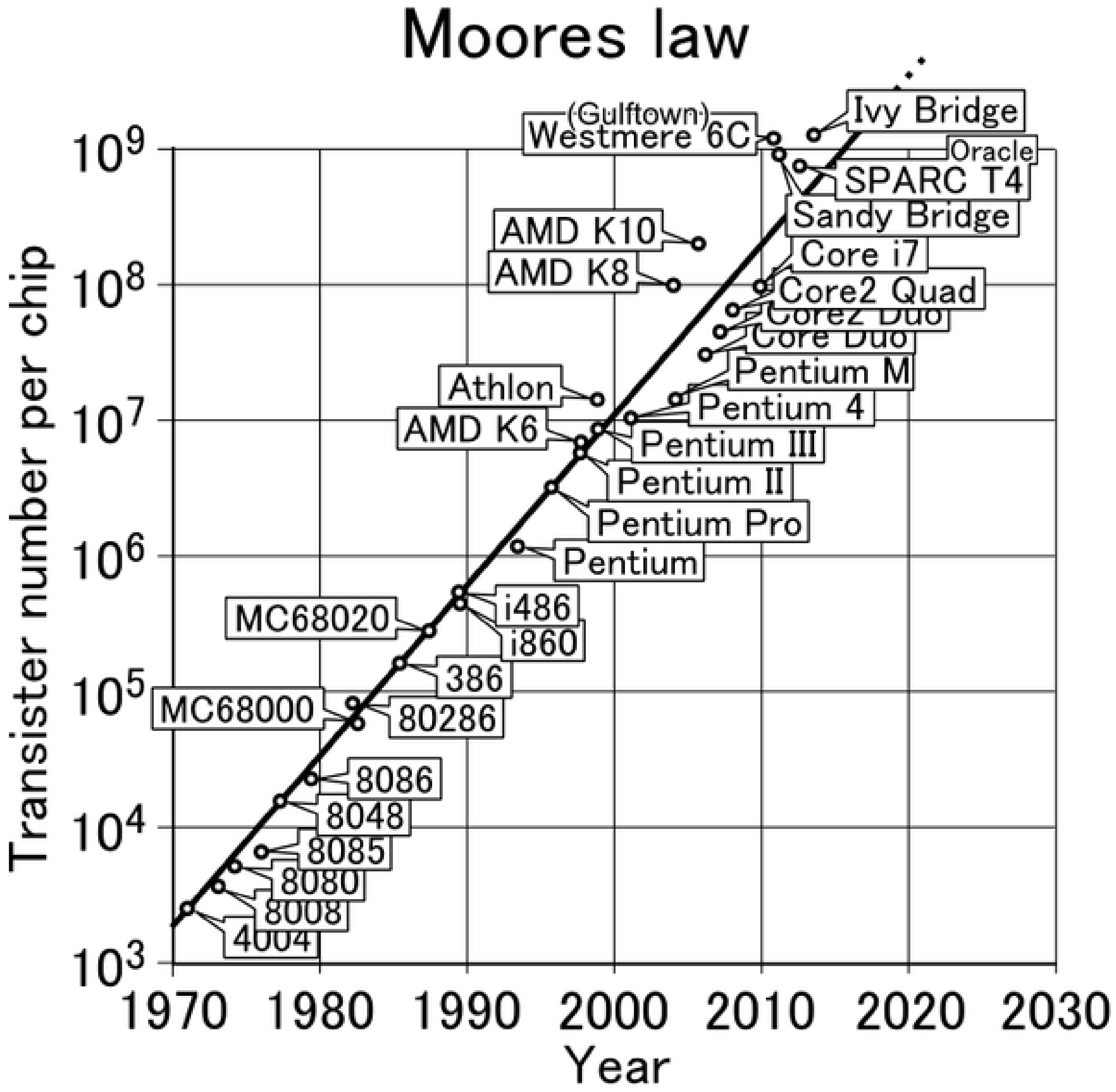


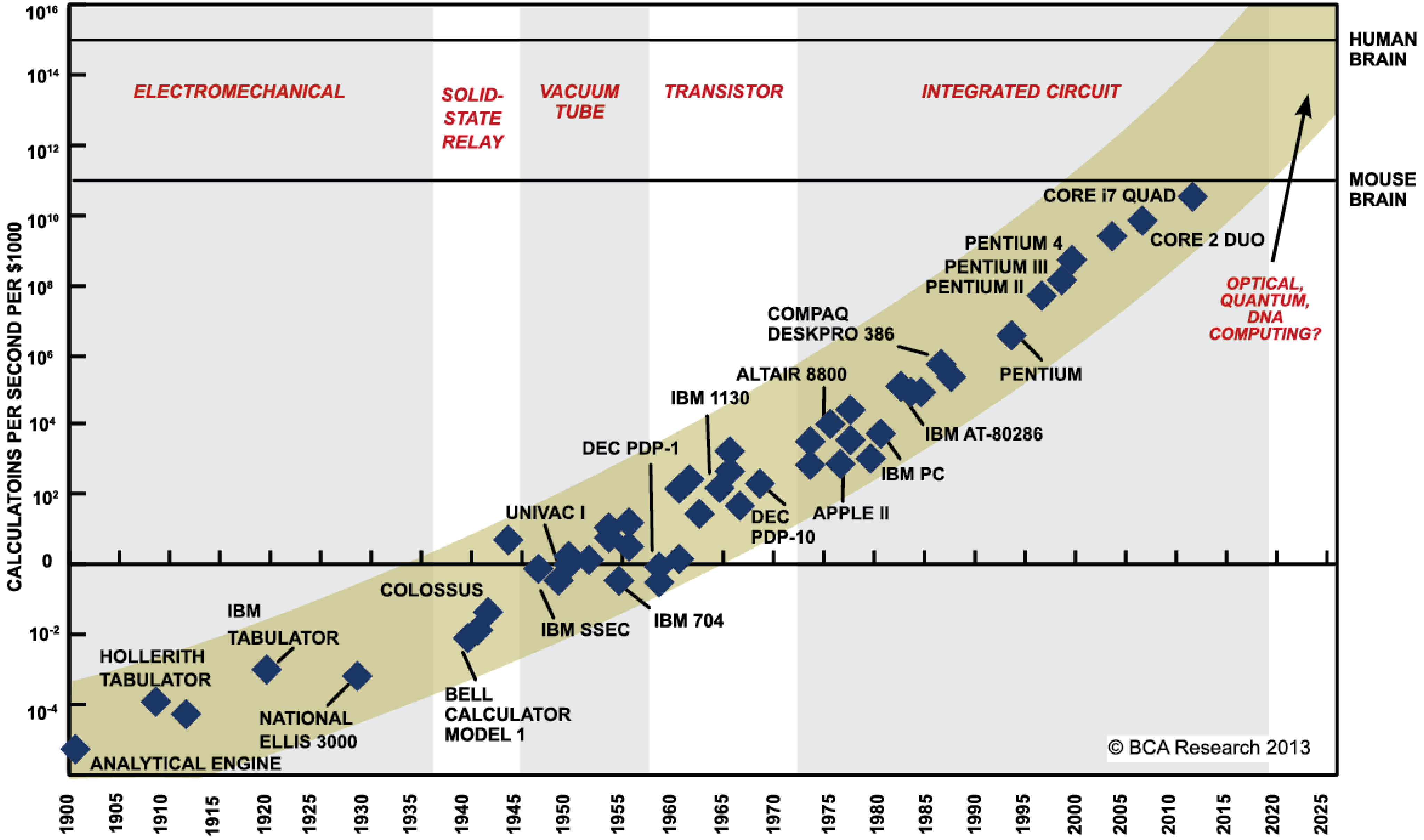
Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)
The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.


Our visibility always ~10 yrs – need broad exploration
TECHNOLOGY GENERATION
45nm
2007
32nm
2009
22nm
2011
14nm
2013
10nm
2015
7nm
2017
Beyond
2020
MANUFACTURING
DEVELOPMENT
RESEARCH
Carbon Nanotube
~1nm diameter
QW III-V Device
Graphene
1 atom thick
5nm
Nanowire
10 atoms across
Not to scale
• Silicon lattice is ~ 0.5nm, hard to imagine good devices smaller than 10 lattices across – reached in 2020
intel


www.explainthatstuff.com
50 Years of Moore's law
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
1970
1972
1974
1979
1982
1985
1989
1993
1995
2000
2007
2007
2013
2015
2016
2017
2018
2019
2300
Intel 4004
3500
Intel 8008
6000
Intel 8080
40000
Motorola 68000
134000
Intel 80286
275000
Intel 80386
1000000
Intel 80486
3100000
Intel Pentium P5
7500000
Intel Pentium P6
42000000
Intel Pentium 4
463000000
AMD K10
789000000
IBM Power 6
1000000000
Apple A7
1900000000
Intel Broadwell
3000000000
Qualcomm Snapdragon
20000000000
AMD Epyc
39540000000
AMD Epyc Rome
30000000000
AWS Graviton 2

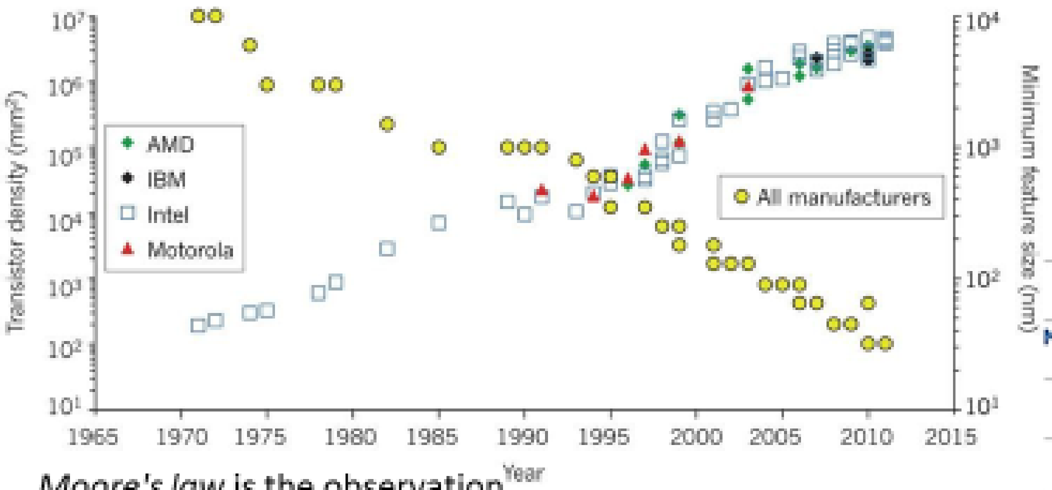

Moore's Law
Transistor number per chip
Year of introduction
Ivy Bridge
Gulftown Core 6
Sandy Bridge
AMD K10
AMD K8
Core i7
Core2 Quad
Core2 Duo
Core Duo
AMD Athlon
Pentium M
AMD K6
Pentium 4
Pentium III
Pentium II
Pentium Pro
Pentium
i486
MC68020
i860
80386
80286
MC68000
8086
8080
8008
4004


Moores law
Transister number per chip
Year
(Gulftown)
Westmere 6C
Ivy Bridge
Oracle
SPARC T4
Sandy Bridge
AMD K10
AMD K8
Core i7
Core2 Quad
Core2 Duo
Core Duo
Pentium M
Athlon
Pentium 4
AMD K6
Pentium III
Pentium II
Pentium Pro
Pentium
MC68020
i486
i860
386
MC68000
80286
8086
8048
8085
8080
8008
4004



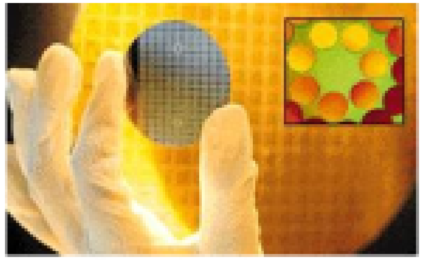
SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

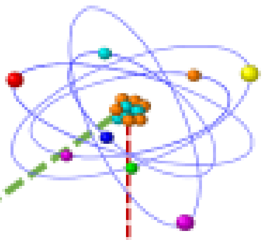
Moore's law & Future of Computers

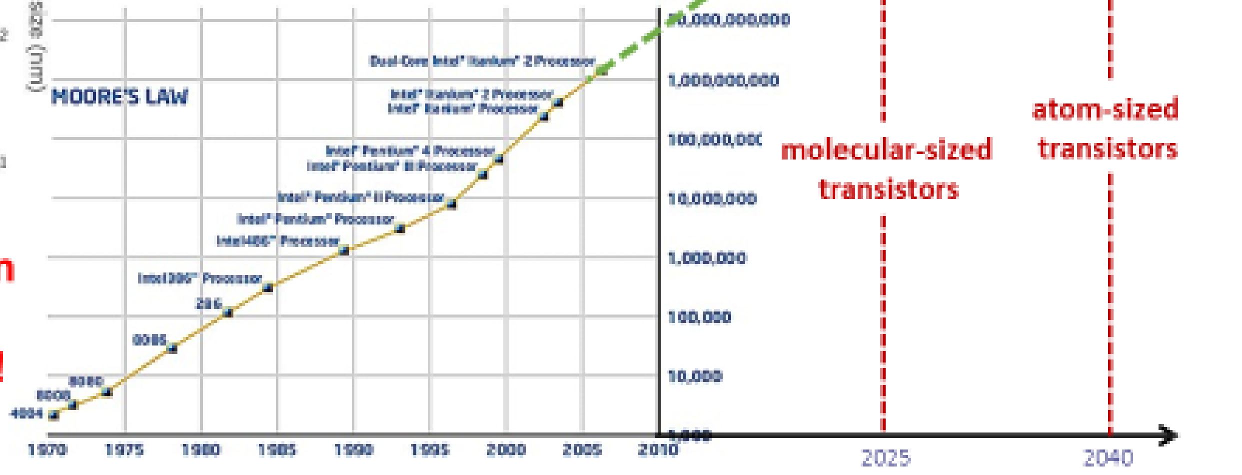


Moore's law is the observation that the number of transistors in a dense integrated circuit doubles about every two years.

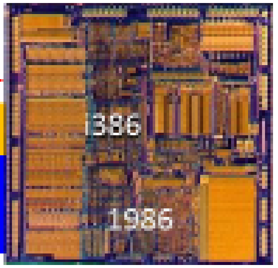
Moore's law will soon run into major physical constraints!







Moore, G. E. *Electronics* **8**, 114–117 (1965).
Image from: Ferain, I. *et al.*, *Nature* **479**, 310–316 (2011).



Richard Feynman

***"There's Plenty of Room at the Bottom"* (1959)**

"When we get to the very, very small world – say circuits of seven atoms – we have a lot of new things that would happen that represent **completely new opportunities for design.** *Atoms on a small scale behave like nothing on a large scale, for they satisfy the laws of quantum mechanics..."*

6

What is a quantum computer?

- **Quantum Computer**
  - A computer that uses laws of quantum mechanics to perform massively parallel computing through superposition, entanglement, and decoherence.

- **Classical Computer**
  - A computer that uses voltages flowing through circuits and gates, which can be controlled and manipulated entirely by classical mechanics.

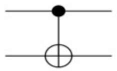
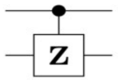
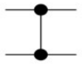
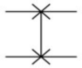
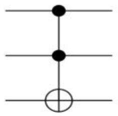
What does a quantum computer look like?

Chinese 76-qubit photon-based quantum computer

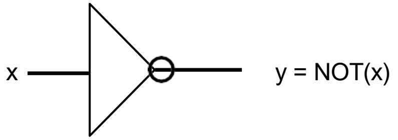
IonQ, ion-trap-based 32-qubit quantum computer

IBM 53-qubit superconductor-based quantum computer

Quantum vs. Classic Gates

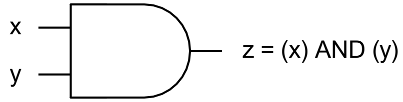
Operator	Gate(s)		Matrix
Pauli-X (X)	$\boxed{X}$	$\oplus$	$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$
Pauli-Y (Y)	$\boxed{Y}$		$\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$
Pauli-Z (Z)	$\boxed{Z}$		$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$
Hadamard (H)	$\boxed{H}$		$\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
Phase (S, P)	$\boxed{S}$		$\begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$
$\pi/8$ (T)	$\boxed{T}$		$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi/4} \end{bmatrix}$
Controlled Not (CNOT, CX)			$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$
Controlled Z (CZ)			$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$
SWAP			$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
Toffoli (CCNOT, CCX, TOFF)			$\begin{bmatrix} 1&0&0&0&0&0&0&0 \\ 0&1&0&0&0&0&0&0 \\ 0&0&1&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0 \\ 0&0&0&0&1&0&0&0 \\ 0&0&0&0&0&1&0&0 \\ 0&0&0&0&0&0&0&1 \\ 0&0&0&0&0&0&1&0 \end{bmatrix}$

NOT gate



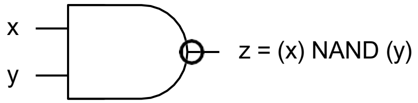
x	y
0	1
1	0

AND gate



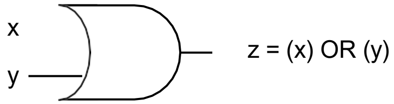
x	y	z
0	0	0
0	1	0
1	0	0
1	1	1

NAND gate



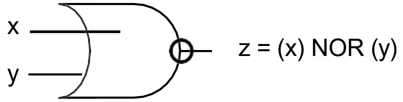
x	y	z
0	0	1
1	1	0
0	1	1
1	0	1

OR gate



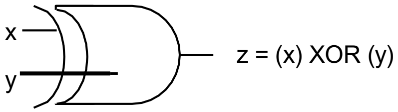
x	y	z
0	0	0
0	1	1
1	0	1
1	1	1

NOR gate



x	y	z
0	0	1
0	1	0
1	0	0
1	1	0

XOR gate



x	y	z
0	0	0
0	1	1
1	0	1

Classification of Computers

Classification of Computers

Minicomputers

- A minicomputer is powerful enough to be used by multiple users (between 10 to 100) but is smaller in size and memory capacity and cheaper than mainframes.
- Two classic examples were the:
  - Digital Equipment Corporation VAX and
  - IBM AS/400.

Microcomputers

- The microcomputer has been intended to meet the personal computing needs of an individual.
- It typically consists of a microprocessor chip, a memory system, interface units and various I/O ports, typically resided in a motherboard.
- There are many types of microcomputers available.
  - Desktop computer A micro computer sufficient to fit on a desk.
  - Laptop computer A portable microcomputer with an integrated screen and keyboard.
  - Palmtop computer/Digital diary/Notebook/PDAs -a hand sized microcomputer having no keyboard. The screen serves both as an input and output device.

Microcomputer, Microprocessor, Microcontroller

Microcomputer

- A computer with a microprocessor as its CPU which includes memory and I/O devices

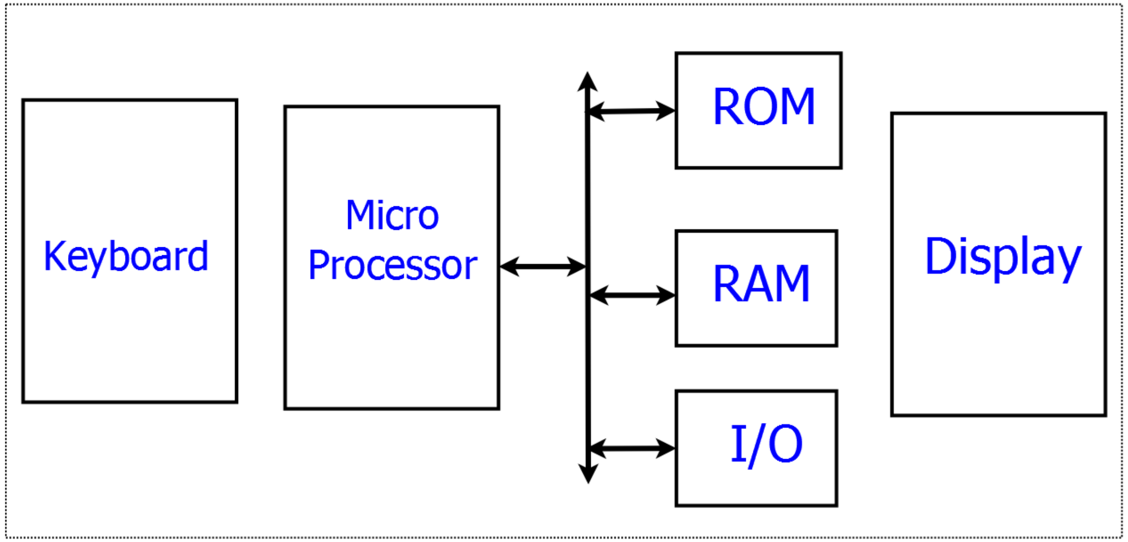
Microprocessor

- A silicon chip which includes an ALU, register circuits and control circuits

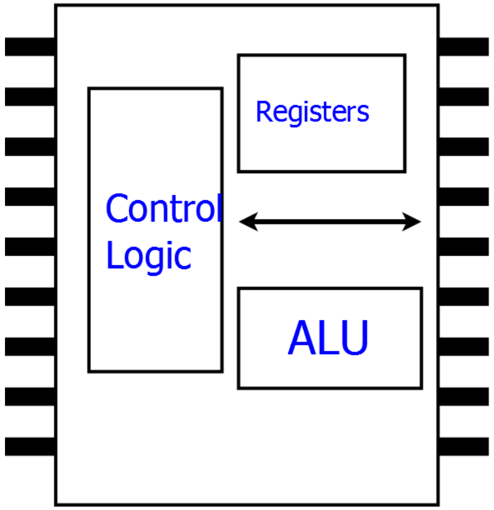
Microcontroller

* A silicon chip which includes a microprocessor, memory, I/O in a single package

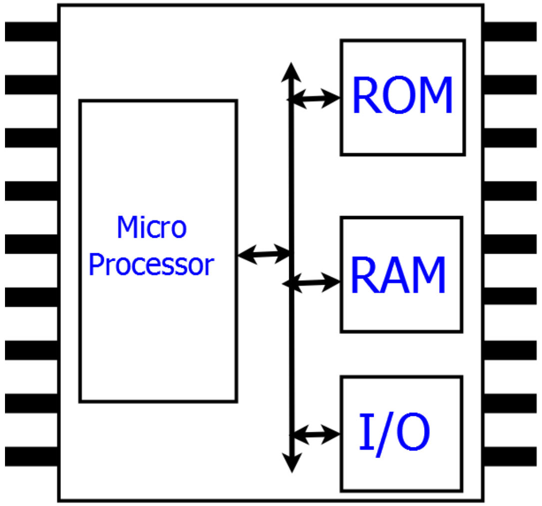
Microcomputer



Microprocessor



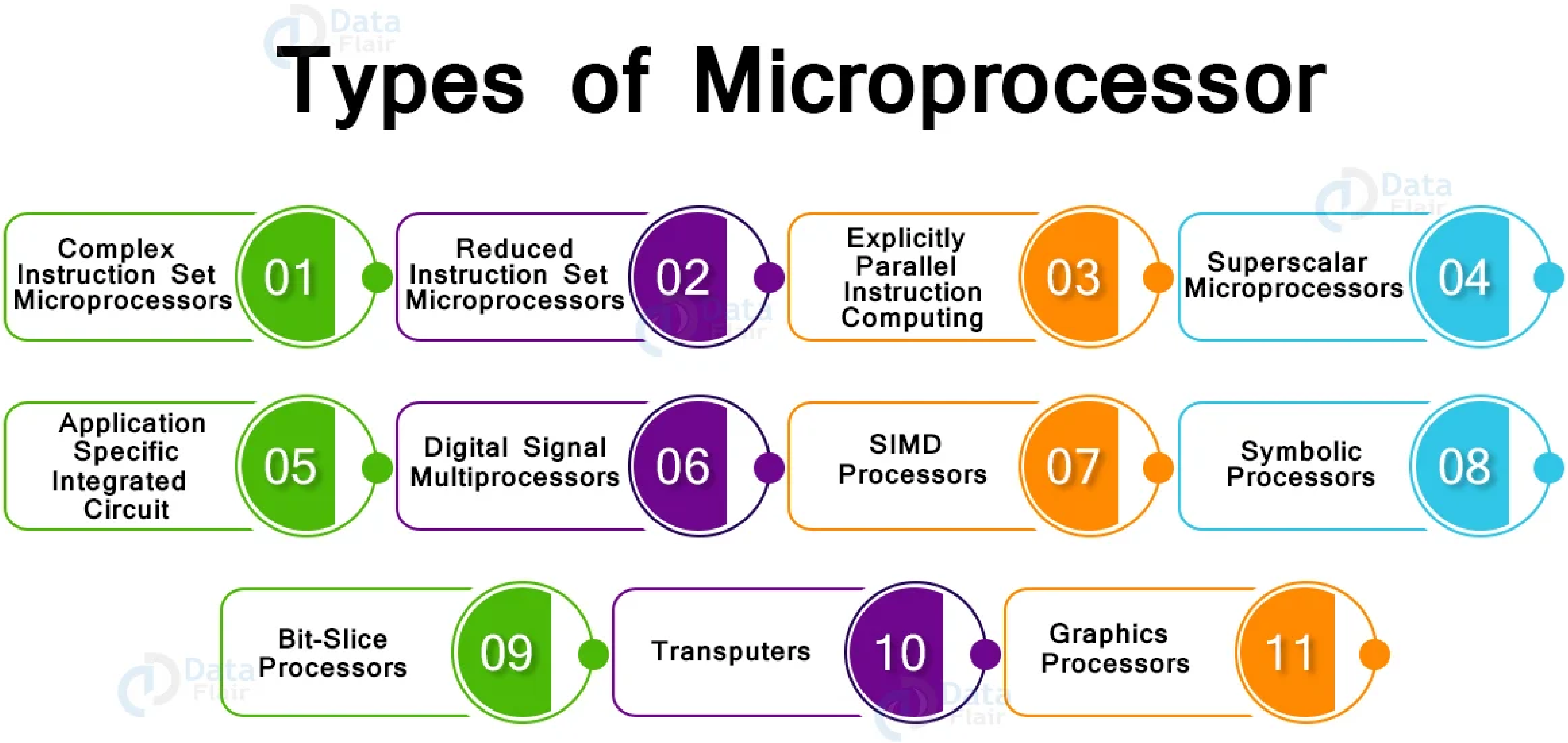
Microcontroller



Difference between μP vs μC

Microprocessor	Microcontroller
Center of a computer system.	Center of embedded system.
Memory and I/O components are external to it.	Memory and I/O components are internal to it.
Large Circuit	Smaller Circuit
Not compatible with compact systems	Compatible with compact systems.
Higher cost	Lower Cost
High Power Consumption	Low Power Consumption
Mostly don't have power features	Mostly have power features.
Mainly present in personal computers.	Mainly present in washing machines, music players, and embedded systems.
Less number of registers.	More number of registers.
Follows Von Neumann model	Follows Harvard architecture
Made on a silicon-based integrated chip.	Byproduct microprocessors and peripherals.
RAM, ROM, and other peripherals are absent.	RAM, ROM, and other peripherals are present.
Has an external bus to interface with devices.	Uses an internal controlling bus for communication.
Has a high speed.	Speed depends on the architecture.
Ideal for general purpose to handle more data.	Ideal for the specific applications.
Complex and Expensive	Simple and affordable
Requires more instructions	Requires less instructions

Types of Microprocessors


Types of Microprocessor
Complex Instruction Set Microprocessors
01
Reduced Instruction Set Microprocessors
02
Explicitly Parallel Instruction Computing
03
Superscalar Microprocessors
04
Application Specific Integrated Circuit
05
Digital Signal Multiprocessors
06
SIMD Processors
07
Symbolic Processors
08
Bit-Slice Processors
09
Transputers
10
Graphics Processors
11

Microprocessors

- Program controlled semiconductor device made up of integrated circuits (IC) which fetches, decodes and executes instructions from memory.

- Used as Central Processing Unit (CPU) in computers.

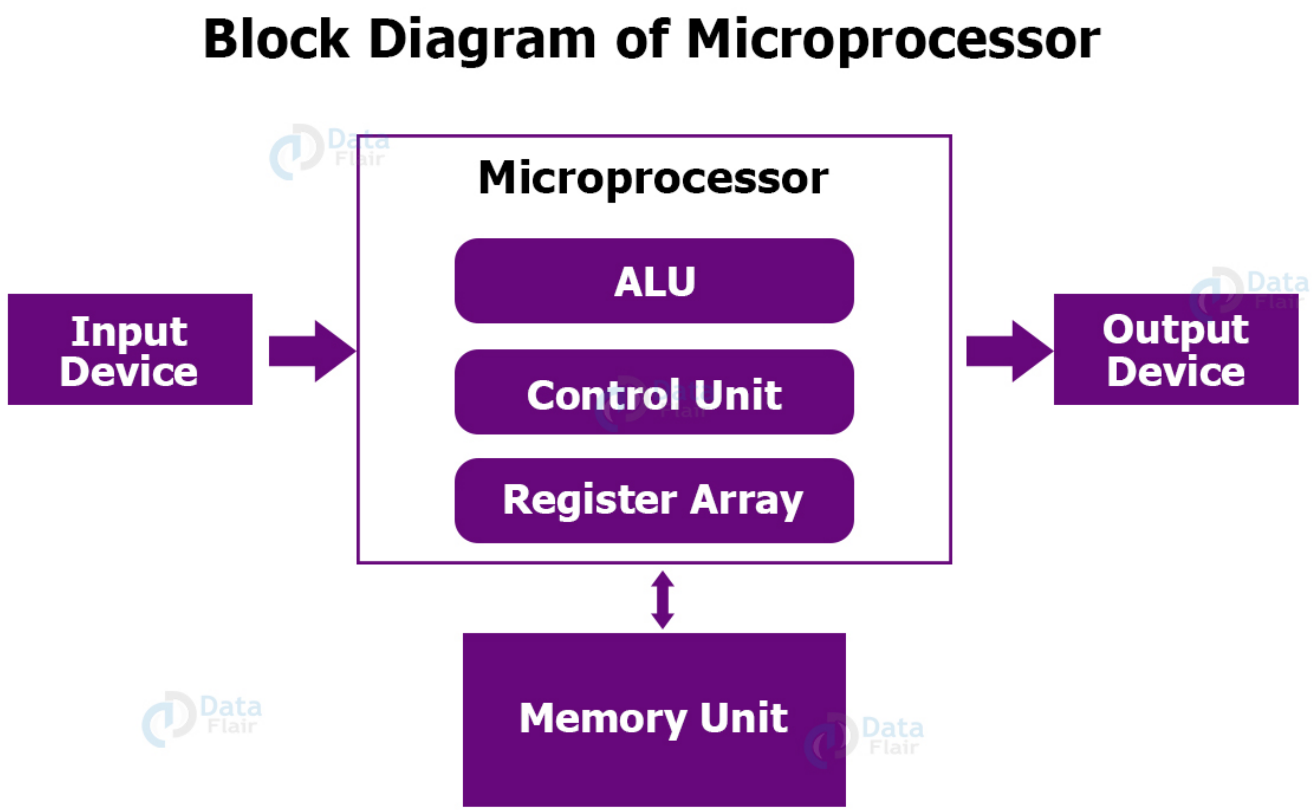
- A digital computer with one microprocessor which acts as a CPU is called microcomputer.

- It is a programmable, multipurpose, clock -driven, register-based electronic device that reads binary instructions from a storage device called memory, accepts binary data as input and processes data according to those instructions and provides results as output.

- The microprocessor contains millions of tiny components like transistors, registers, and diodes that work together

Microprocessor

- Program controlled semiconductor device (IC) which fetches (from memory), decodes and executes instructions.
- It is used as CPU (Central Processing Unit) in computers
- A microprocessor consists of an ALU, control unit and register array.
- ALU performs arithmetic and logical operations on the data received from an input device or memory.
- Control unit controls the instructions and flow of data within the computer.



Types of Microprocessors

Vector Processors

- A vector processor is designed for vector computations.
- A vector is an array of operands of the same type.

Array Processors or SIMD Processors

- Array processors are also designed for vector computations.
- Difference between an array processor and a vector processor is that a vector processor uses multiple vector pipelines whereas an array processor employs a number of processing elements to operate in parallel.
- An array processor contains multiple numbers of ALUs.
- Each ALU is provided with the local memory.
- The ALU together with the local memory is called a **Processing Element** (**PE**).
- An array processor is a SIMD (**Single Instruction Multiple Data**) processor.
- Thus using a single instruction, the same operation can be performed on an array of data which makes it suitable for vector computations.

Types of Microprocessors

- **Scalar Processors**
  - A processor that executes scalar data is called scalar processor.
  - Simplest scalar processor makes processing of only integer instruction using fixed-points operands.
  - A powerful scalar processor makes processing of both integer as well floating- point numbers.
  - It contains an integer ALU and a Floating Point Unit (FPU) on the same CPU chip.
  - A scalar processor may be RISC processor or CISC processor.

  Examples of CISC processors are:
    - Intel 386, 486; Motorola's 68030, 68040; etc.

  Examples of RISC scalar processors are:
    - Intel i860, Motorola MC8810, SUN's SPARC CY7C601, etc.

- **Superscalar Processors**
  - A superscalar processor has multiple pipelines and executes more than one instruction per clock cycle.

  Examples of superscalar processors are:
    - Pentium, Pentium Pro, Pentium II, Pentium III, etc.

Types of Microprocessors

Digital Signal Processors (DSP)

- DSP is specially designed to process the analog signals into a digital form.
- This is done by sampling the voltage level at regular time intervals and converting the voltage at that instant into a digital form.
- This process is performed by a circuit called an analogue to digital converter, A to D converter or ADC.
- They receive some digitized signal information, perform some mathematical operations on the information and give the result to an output device.
- They implement integration, differentiation, complex fast Fourier transform, etc. using hardware.

Types of Microprocessors

A DSP contains the following components:

- **Program Memory**: It stores the programs that DSP will use to process data.
- **Data Memory**: It stores the information to be processed.
- **Compute Engine**: It performs the mathematical processing, accessing the program from the program memory and the data from the data memory.
- **Input/Output**: It connects to the outside world.

Its applications are:

- Sound and music synthesis
- Audio and video compression
- Video signal processing
- 2D and 3d graphics acceleration.

Examples of digital signal processors are:

- Texas instruments' TMS 320 series, e.g., TMS 320C40, TMS320C50, TMS 320C25,
- Motorola 56000,
- National LM 32900,
- Fujitsu MBB 8764, etc.

Types of Microprocessors

Symbolic Processors

- Symbolic processors are designed for expert system, machine intelligence, knowledge based system, pattern-recognition, text retrieval, etc.
- The basic operations which are performed for artificial intelligence are:

  Logic interference, compare, search, pattern matching, filtering, unification, retrieval, reasoning, etc.
- This type of processing does not require floating point operations. Symbolic processors are also called LISP processors or PROLOG processors.

Types of Microprocessors

Bit-Slice Processors

- The processor of desired word length is developed using the building blocks.
- The basic building block is called Bit-Slice where the building blocks include 4-bit ALUs, micro programs sequencers, carry look-ahead generators, etc.
- The word 'slice' was used because the desired number of ALUs and other components were used to build an 8-bit, 16-bit or 32-bit CPU.

Examples of Bit-Slice Processors were:

- AMD-2900, AMD 2909, AMD 2910, AMD 29300 series,
- Texas instrument's SN-74AS88XX series, etc.

Types of Microprocessors

Transputers (Transistor Computer)

- In a multiprocessor system, a transputer is a specially designed microprocessor to operate as a component processor.
- A transputer is a specially designed microprocessor with its own local memory and having communication links to connect one transputer to another transputer for inter-processor communications.
- The communication link was to provide point-to-point connection between transputers.
- It was first designed in 1980 by Inmos and is targeted to the utilization of VLSI technology.
- A transputer can be used as a single processor system or can be connected to external links, which reduces the construction cost and increases the performance.
- A transputer contains FPU, on-chip RAM, high-speed serial link, etc.

  Examples of transputers are:
  - INMOS T414, Where, T414 was a 32-bit processor with 2 KB memory.
  - INMOS T800, Where, T800 was FPU version of 32-bit transputer with 4 KB memory.
  - 16-bit T212
  - 32-bit T425
  - the floating point (T800, T805 & T9000) processors
  - etc.

Types of Microprocessors

Graphic Processors

- Graphics Processors are specially designed processors for graphics.
- Intel has developed Intel 740-3D graphics chip.
- It is optimized for Pentium II PCs, using a hyper pipelined 3D architecture with additional 2D acceleration.
- Like most 3D graphics chips, the I-740 will be marketed in performance, not the main stream category.
- It is designed mostly for such heavy multimedia uses as games and movies.

  Examples of Graphic Processors are:
  - Intel 82786 graphics coprocessor
  - IBM's 8514/A,
  - Texas Instruments' TMS34010 and TMS34020,
  - Intel i860 and Intel i750, etc.

Types of Microprocessors

Special Processors

- These are the processors which are designed for some special purposes.
- Few of the special processors are briefly discussed:

Coprocessor

- A coprocessor is a specially designed microprocessor, which can handle its particular function many times faster than the ordinary microprocessor.

  For example: Math Coprocessor.
- Some Intel math-coprocessors are:
  - 8087-used with 8086
  - 80287-used with 80286
  - 80387-used with 80386

Input/Output Processor

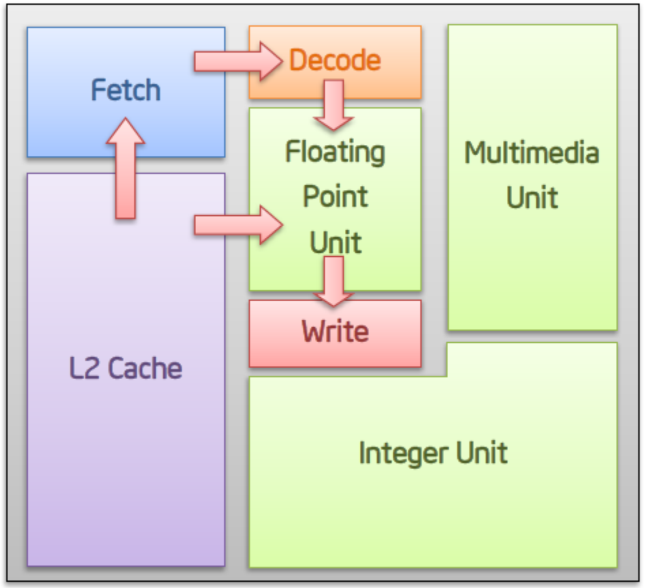
- It is a specially designed microprocessor having a local memory of its own, which is used to control I/O devices with minimum CPU involvement.

  For example:
  - DMA (direct Memory Access) controller
  - Keyboard/mouse controller
  - Graphic display controller
  - SCSI port controller

Fetch-Decode-Execute Cycle

Types of Microprocessors

Simplified Microprocessor



Fetch Unit gets the next instruction from the cache.

Decode Unit determines type of instruction.

Instruction and data sent to Execution Unit.

Write Unit stores result.

Instruction → | Fetch | Decode | Execute | Write |

Sequential Processing (386)

Cycle	1	2	3	4	5	6	7	8	9
$Instr_1$	Fetch	Decode	Execute	Write					
$Instr_2$					Fetch	Decode	Execute	Write	
$Instr_3$									Fetch

- Sequential processing works on one instruction at a time

Pipelined Processing (486)

Cycle	1	2	3	4	5	6	7	8	9
$Instr_1$	Fetch	Decode	Execute	Write					
$Instr_2$		Fetch	Decode	Execute	Write				
$Instr_3$			Fetch	Decode	Execute	Write			
$Instr_4$				Fetch	Decode	Execute	Write		
$Instr_5$					Fetch	Decode	Execute	Write	
$Instr_6$						Fetch	Decode	Execute	Write

In-Order Pipeline (486)

Cycle	1	2	3	4	5	6	7	8	9
$Instr_1$	Fetch	Decode	Execute			Write			
$Instr_2$		Fetch	Decode	Wait		Execute	Write		
$Instr_3$			Fetch	Decode	Wait		Execute	Write	
$Instr_4$				Fetch	Decode	Wait		Execute	Write
$Instr_5$					Fetch	Decode	Wait		Execute
$Instr_6$						Fetch	Decode	Wait	

Out-of-Order Execution (Pentium II)

Cycle	1	2	3	4	5	6	7	8	9
$Instr_1$	Fetch	Decode	Execute			Write			
$Instr_2$		Fetch	Decode	Wait		Execute	Write		
$Instr_3$			Fetch	Decode	Execute	Write			
$Instr_4$				Fetch	Decode	Wait	Execute	Write	
$Instr_5$					Fetch	Decode	Execute	Write	
$Instr_6$						Fetch	Decode	Execute	Write

Superscalar Issue (Pentium)

Cycle	1	2	3	4	5	6	7	8	9
$Instr_1$	Fetch	Decode	Execute			Write			
$Instr_2$	Fetch	Decode	Wait			Execute	Write		
$Instr_3$		Fetch	Decode	Execute	Write				
$Instr_4$		Fetch	Decode	Wait			Execute	Write	
$Instr_5$			Fetch	Decode	Execute	Write			
$Instr_6$			Fetch	Decode	Execute	Write			
$Instr_7$				Fetch	Decode	Execute	Write		
$Instr_8$				Fetch	Decode	Execute	Write		

Computer Architectures

Computer Architectures

- Memory Architecture
- Software/Instruction Set Architecture (ISA)
- Hardware Architecture
- Bus System Architecture

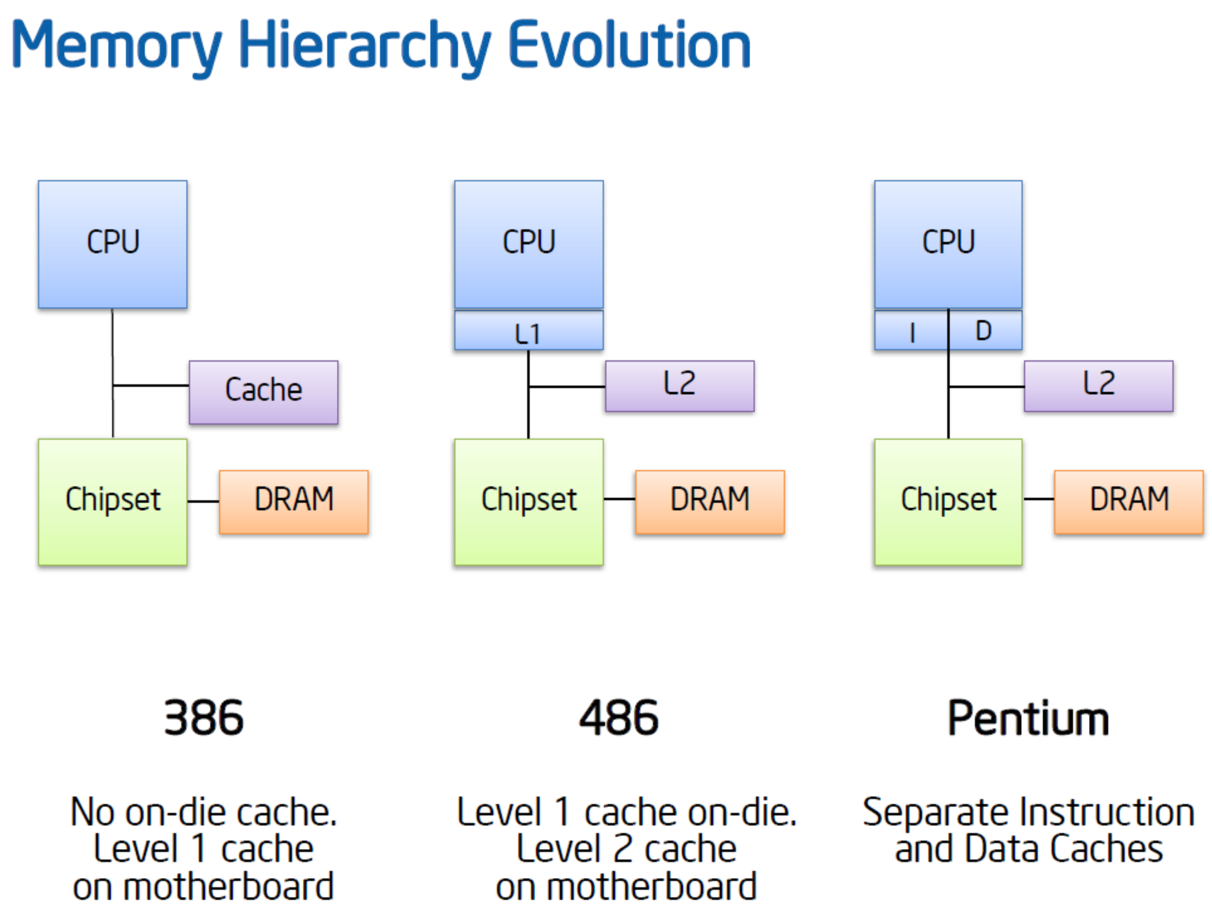
Memory Architecture

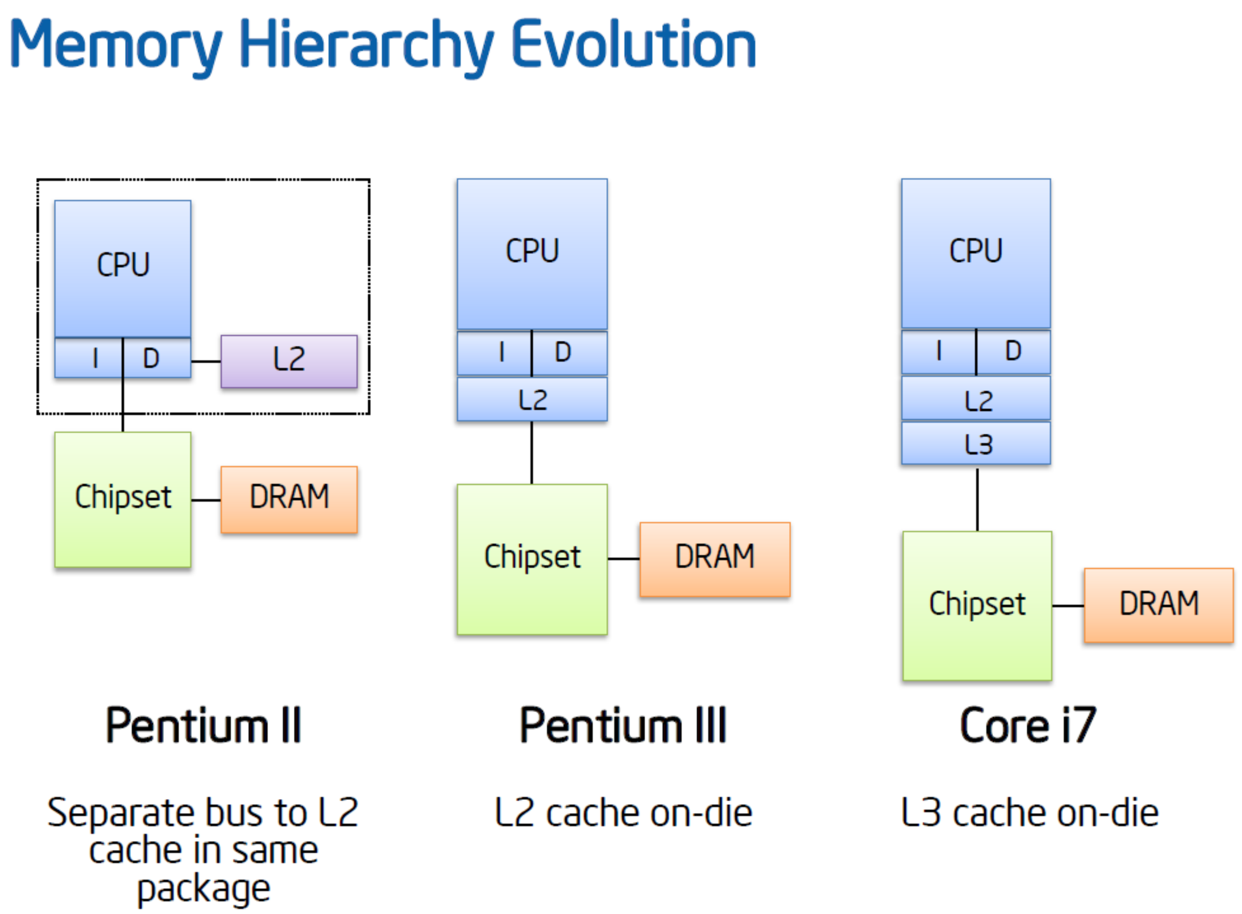
9/2/2024

Memory Hierarchy

Capacity		Access Time
~1kB	Register File	~1ns
~100kB	Level 1 Cache	~5ns
~1MB	Level 2 Cache	~10ns
~10MB	Level 3 Cache	~20ns
~10GB	Main Memory	~100ns
~1TB	Hard Drive	~10ms

Registers/Cache Hierarchy





Microprocessor Instruction Set Architectures (ISA)

Instruction Set Architectures

RISC and CISC Processors

- **RISC** stands for **Reduced Instruction Set Computer** and
- **CISC** stands for **Complex Instruction Set Computer**.

There are two approaches of the design of the control unit of a microprocessor i.e.

- Hardware approach and
- Software approach.

Instruction Set Architectures

RISC Processors

- To execute an instruction, a number of steps are required.
- By the control unit of the processor, a number of control signals are generated for each step.
- To execute each instruction, if there is a separate electronic circuitry in the control unit, which produces all the necessary signals, this approach of the design of the control section of the processor is called RISC design.
- It is hardware approach.
- It is also called hard-wired approach.

Instruction Set Architectures

RISC ISA

- It is designed to reduce the execution time by simplifying the instruction set of the computer.
- Using RISC processors, each instruction requires only one clock cycle to execute results in uniform execution time.
- This reduces the efficiency as there are more lines of code, hence more RAM is needed to store the instructions.
- The compiler also has to work more to convert high-level language instructions into machine code.

Some of the RISC processors are:

- Power PC: 601, 604, 615, 620
- DEC Alpha: 210642, 211066, 21068, 21164
- MIPS: TS (R10000) RISC Processor
- PA-RISC: HP 7100LC
- SUN's: SPARC and ULTRA SPARC;
- PowerPC processors
- etc.

Instruction Set Architectures

CISC Processors

- If the control unit contains a number of micro electronic circuitry to generate a set of control signals and each micro circuitry is activated by a microcode, this design approach is called CISC design.
- This is a software approach of designing a control unit of the processor.

Instruction Set Architectures

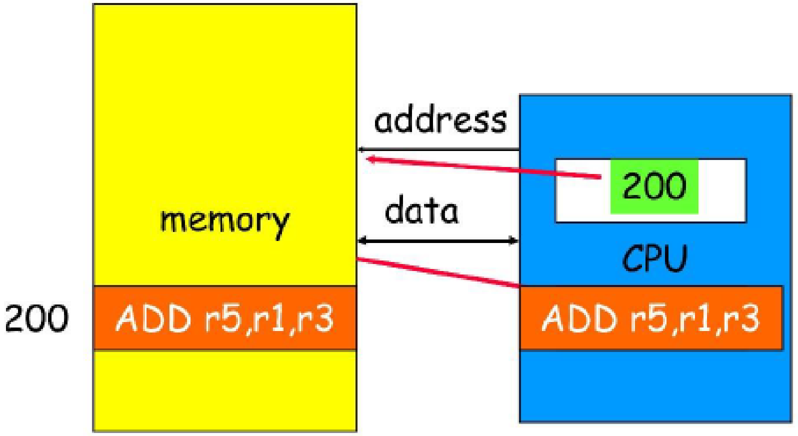
CISC ISA

- It is designed to minimize the number of instructions per program, ignoring the number of cycles per instruction.
- The emphasis is on building complex instructions directly into the hardware.
- The compiler has to do very little work to translate a high-level language into assembly level language/machine code because the length of the code is relatively short, so very little RAM is required to store the instructions.

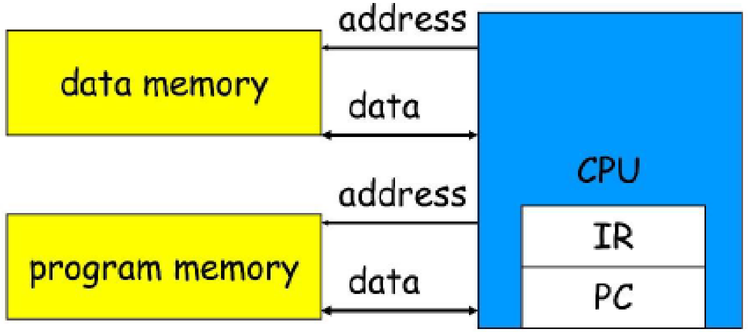
- Some of the CISC Processors are:
- IBM 370/168
- VAX 11/780
- Intel 4004, 8086, 8088, 80186, 80286, 80386, 80486;
- Pentium Pro, Pentium, Pentium II, Pentium III, Pentium 4;
- Motorola's 68000, 68020, 68030, 68040, etc.

Microprocessor HardwareArchitectures: RISC vs CISC

von Neumann



Harvard Architecture



von Neumann vs. Harvard

- von Neumann
  - Same memory holds data, instructions.
  - A single set of address/data buses between CPU and memory
- Harvard
  - Separate memories for data and instructions.
  - Two sets of address/data buses between CPU and memory

von Neumann vs. Harvard

- Harvard allows two simultaneous memory fetches.
- Most DSPs use Harvard architecture for streaming data:
  - greater memory bandwidth;
  - more predictable bandwidth.

Microprocessor Hardware Architectures

RISC vs. CISC

- Reduced Instruction Set Computer (RISC)
  - Compact, uniform instructions → facilitate pipelining
  - More lines of code → large memory footprint
  - Allow effective compiler optimization
- Complex Instruction Set Computer (CISC)
  - Many addressing modes and long instructions
  - High code density
  - Often require manual optimization of assembly code for embedded systems

Microprocessors

	von Neumann	Harvard
RISC	ARM7	ARM9
CISC	Pentium	SHARC (DSP)

Difference between RISC and CISC

No.	RISC	CISC
1.	Simple instruction set	Complex instruction set
2.	Consists of Large number of registers.	Less number of registers
3.	Larger Program	Smaller program
4.	Simple processor circuitry (small number of transistors)	Complex processor circuitry (more number of transistors)
5.	More RAM usage	Little Ram usage
6.	Simple addressing modes	Variety of addressing modes
7.	Fixed length instructions	Variable length instructions
8.	Fixed number of clock cycles for executing one instruction	Variable number of clock cycles for each instructions

Microprocessor Hardware Architectures

CISC

Advantages of complex instruction set machines (CISC)

- Less expensive due to the use of microcode;
- no need to hardwire a control unit
- Upwardly compatible because a new computer would contain a superset of the instructions of the earlier computers
- Fewer instructions could be used to implement a given task, allowing for more efficient use of memory
- Simplified compiler, because the microprograming instruction sets could be written to match the constructs of high-level languages
- More instructions can fit into the cache, since the instructionsare not a fixed size

Disadvantages of CISC

- Although the CISC philosophy did much to improve computer performance, it still had its drawbacks
- Instruction sets and chip hardware became more complex with each generation of computers, since earlier generations of a processor family were contained as a subset in every new version
- Different instructions take different amount of time to execute due to their variable-length
- Many instructions are not used frequently; Approximately 20% of the available instructions are used in a typical program

RISC

Advantages of a reduced instruction set machine (RISC)

- Faster
- Simple hardware
- Shorter design cycle due to simpler hardware

Disadvantages of RISC

- Programmer must pay close attention to instruction scheduling so that the processor does not spend a large amount of time waiting for an instruction to execute
- Debugging can be difficult due to the instruction scheduling Require very fast memory systems to feed them instructions
- Nearly all modern microprocessors, including the Pentium (hybrid RISC/CISC) PowerPC, Alpha and SPARC microprocessors are superscalar

Architecture of RISC processors

Architecture of RISC

- uses highly-optimized set of instructions.
- It is used in portable devices like Apple iPod due to its power efficiency.

Characteristics of RISC:

- It consists of simple instructions.
- It supports various data-type formats.
- It utilizes simple addressing modes and fixed length instructions for pipelining.
- It supports register to use in any context.
- One cycle execution time.
- "LOAD" and "STORE" instructions are used to access the memory location.
- It consists of larger number of registers.
- It consists of less number of transistors.

Microprocessor Architectures

Architecture of CISC

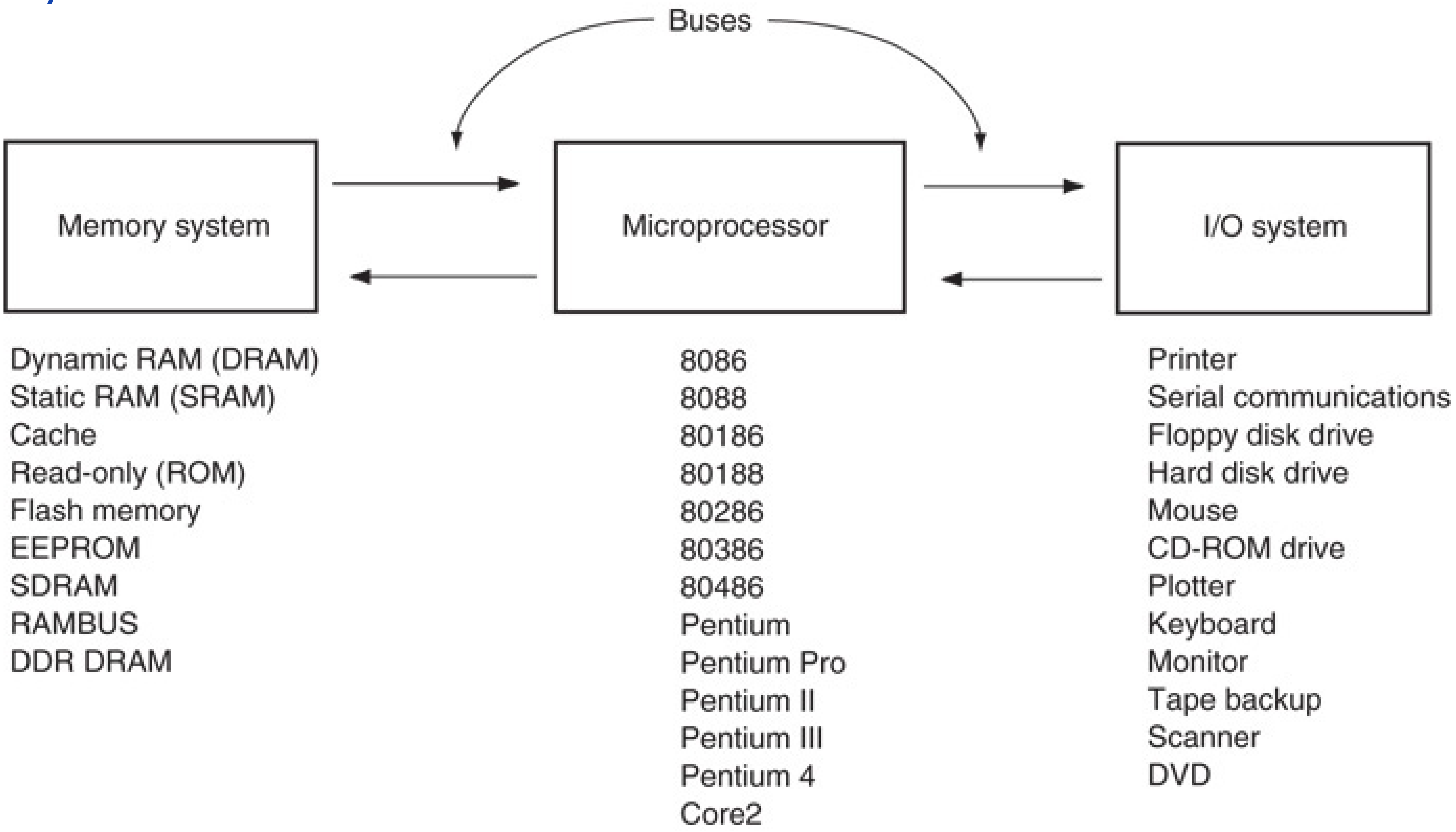
- Its architecture is designed to decrease the memory cost because more storage is needed in larger programs resulting in higher memory cost.
- To resolve this, the number of instructions per program can be reduced by embedding the number of operations in a single instruction.

Characteristics of CISC:

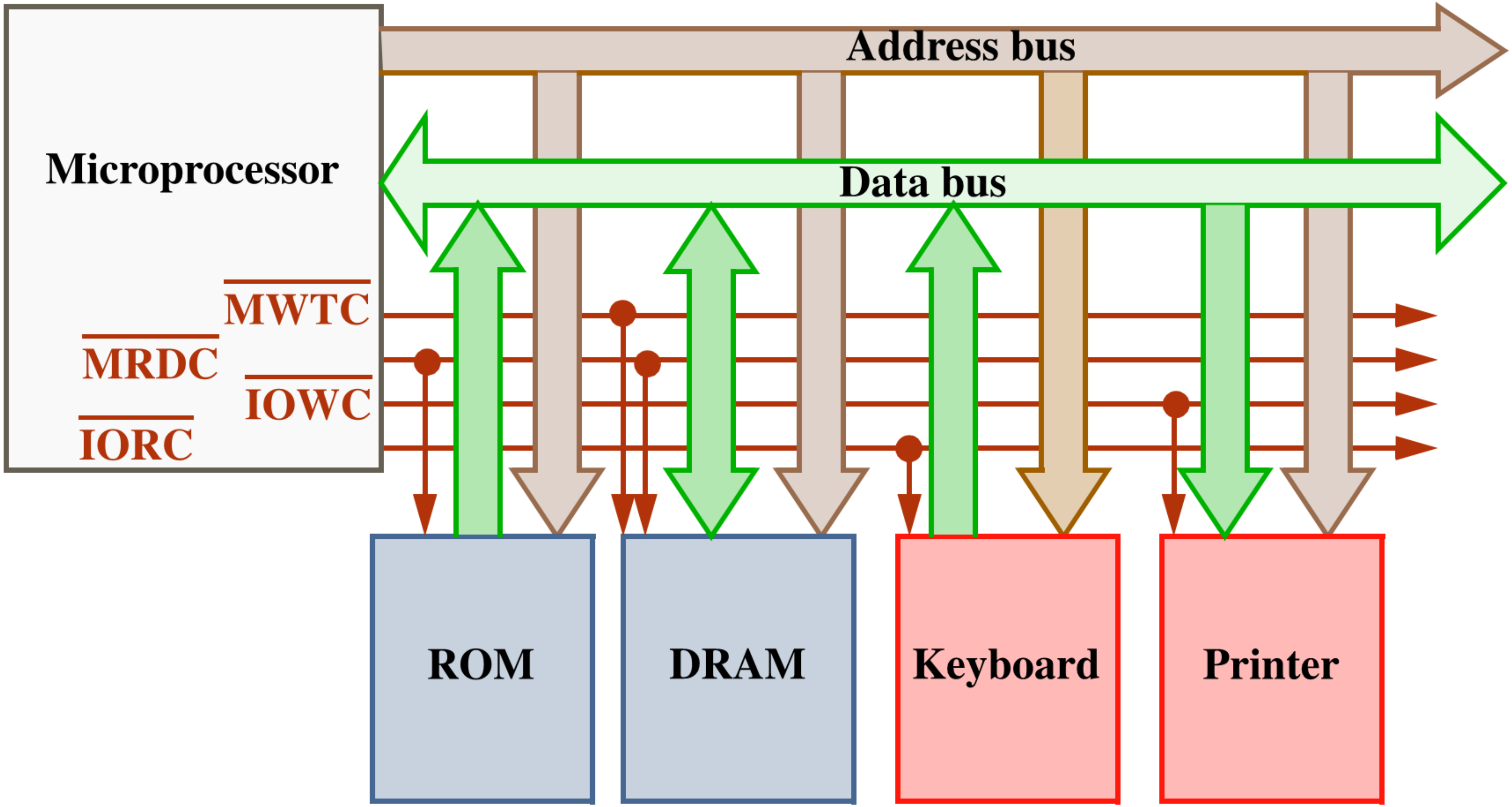
- Variety of addressing modes.
- Larger number of instructions.
- Variable length of instruction formats.
- Several cycles may be required to execute one instruction.
- Instruction-decoding logic is complex.
- One instruction is required to support multiple addressing modes.

Microprocessor Bus System Architectures

Basic Bus System Architecture



3-Bus System Architecture



3-Bus System Architecture

A collection of electronic signals all dedicated to particular task is called a **bus.**

Three types of buses:

- data bus
- address bus
- control bus

Data Bus

- width of the data bus determines how much data the processor can read or write in one memory or I/O cycle (Machine Cycle)
- 8-bit microprocessor has an 8-bit data bus
- 80386SX 32-bit internal data bus, 16-bit external data bus
- 80386 32-bit internal and external data busses
- Data Buses are bidirectional.
- More data means more expensive computer however faster processing speed

3-Bus System Architecture

Address Bus

- Address Buses are uni-directional
- The address bus is used to identify the memory location or I/O device (also called port) the processor intends to communicate with
- 20 bits for the 8086 and 8088
- 32 bits for the 80386/80486 and the Pentium
- 36 bits for the Pentium Pro
- 8086 has a 20-bit address bus and therefore addresses all combinations of addresses from all 0s to all 1s.
- This corresponds to 2^{20} addresses or 1M (1 Meg) addresses or memory locations.
- Pentium: 4Gbyte main memory

Control Bus

- Control bus is uni-directional
- How can we tell the address is a memory address or an I/O port address
  - Memory Read
  - Memory Write
  - I/O Read
  - I/O Write
- When Memory Read or I/O Read are active, data is input to the processor.
- When Memory Write or I/O Write are active, data is output from the processor.