Topic 1

Introduction to Computer

What is a “Computer”?

- **Wiki**: A machine that can be programmed to carry out sequences of arithmetic or logical operations automatically.
- My definition – A computing machine.

The Computer Revolution

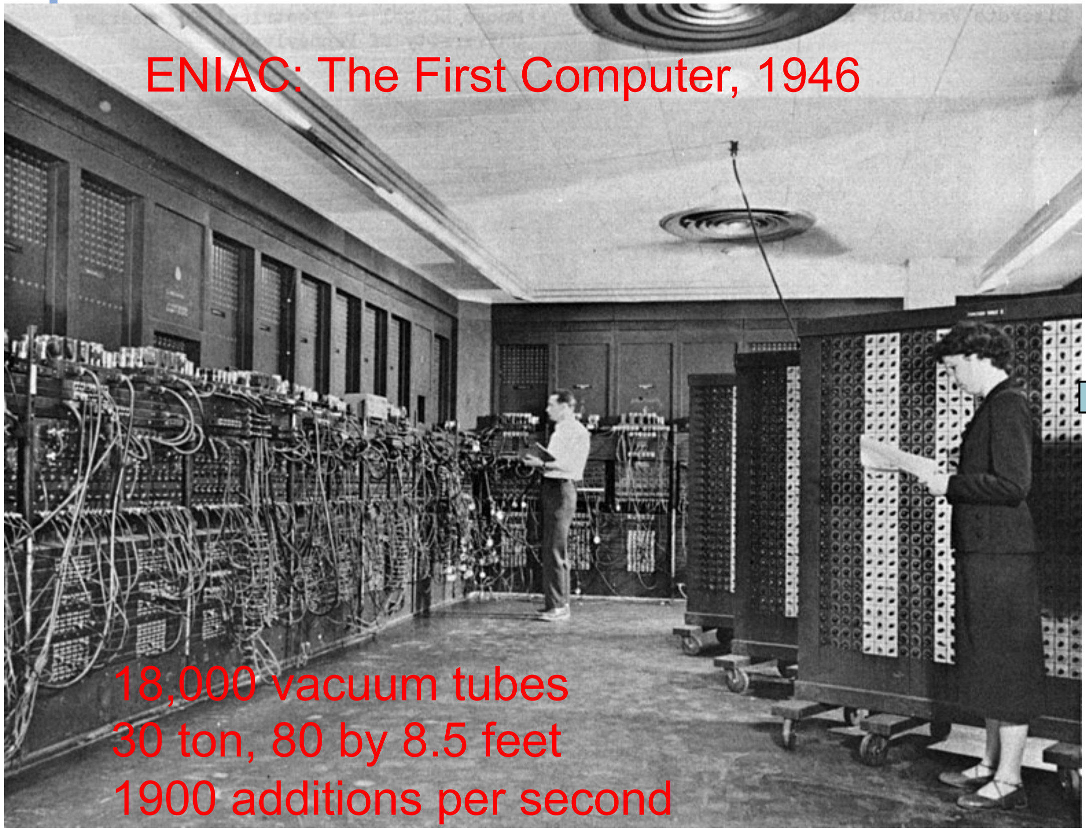


Image: https://commons.wikimedia.org/

IBM 2nm Chip, 2021

Image: IBM

50 billion transistors

The Computer Revolution

- Makes novel applications feasible
  - Auto pilot vehicle
  - Cell phones
  - Robotic arms
  - Internet+
  - ……
- Computers are pervasive

Classes of Computers

- Personal computers
  - General purpose, variety of software
  - Subject to cost/performance tradeoff

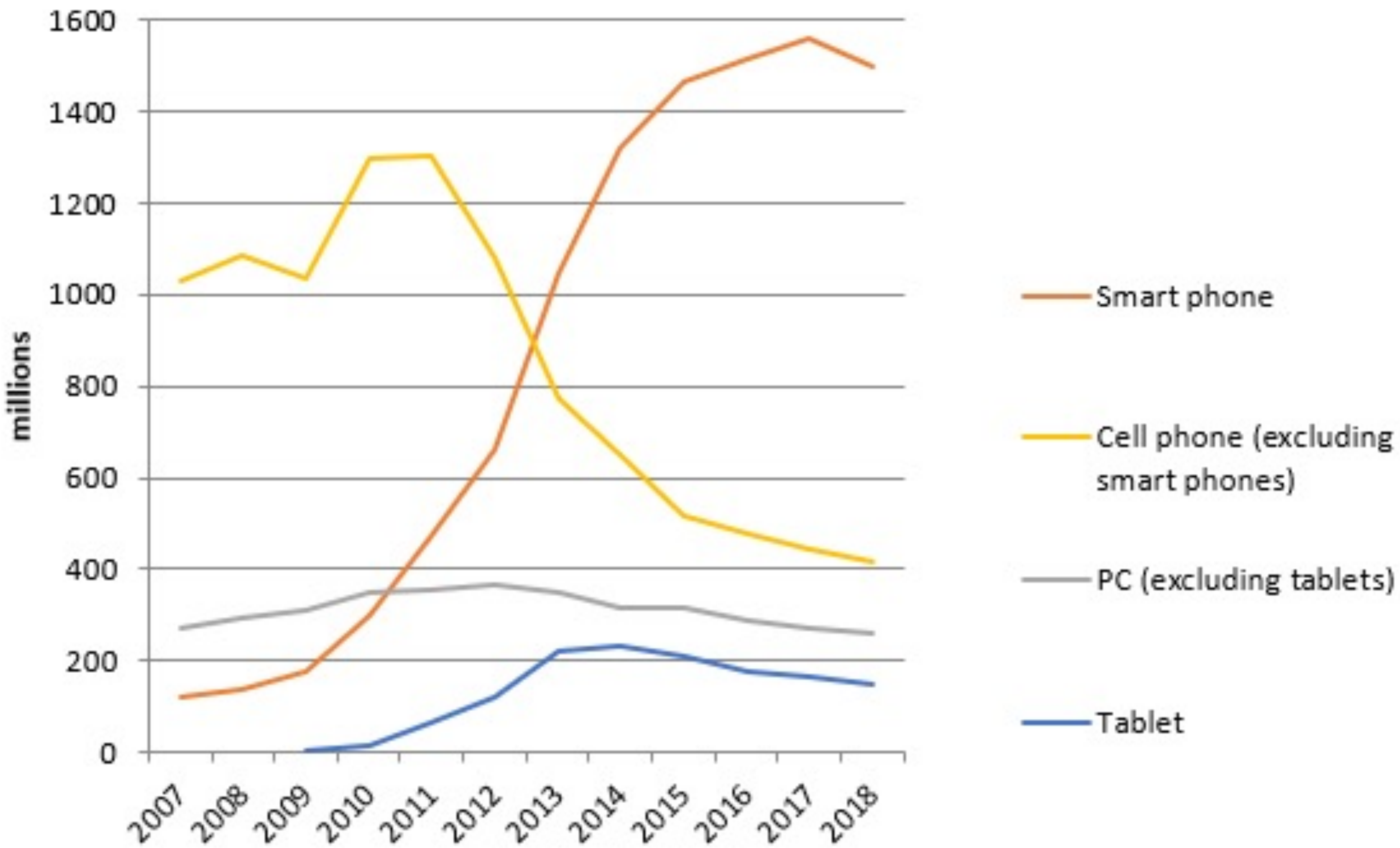
- Server computers
  - Network based
  - High capacity, performance, reliability
  - Range from small servers to building sized

Classes of Computers

- Supercomputers
  - Type of server
  - High-end scientific and engineering calculations
  - Highest capability but represent a small fraction of the overall computer market

- Embedded computers
  - Hidden as components of systems
  - Power/performance/cost constraints

The PostPC Era



Where can we find Computers

- Desktop, Laptop, hand held PC, …
- Automotive
  - Automatic Ignition Systems, Cruise, ABS, traction control, airbag release system…
- Consumer Electronics
  - TV, PDA, appliances, toys, cell phones, camera …
- Industrial Control
  - robotics, control systems …
- Medical
  - Infusion Pumps, Dialysis Machines, Prosthetic Devices, Cardiac Monitors, …
- Networking
  - wired and wireless routers, hubs, …
- Office Automation
  - fax, photocopiers, printers, scanners, …
- Aerospace applications
  - Flight-control systems, engine controllers, auto-pilots and passenger in-flight entertainment systems…
- Defense systems
  - Radar systems, fighter aircraft flight-control systems, radio systems, missile guidance systems…

Product: Hunter Programmable Digital Thermostat.

Microprocessor: 4-bit

by Daniel W. Lewis

Product:Vendo V-MAX 720 vending machine.

Microprocessor: 8-bit Motorola 68HC11.

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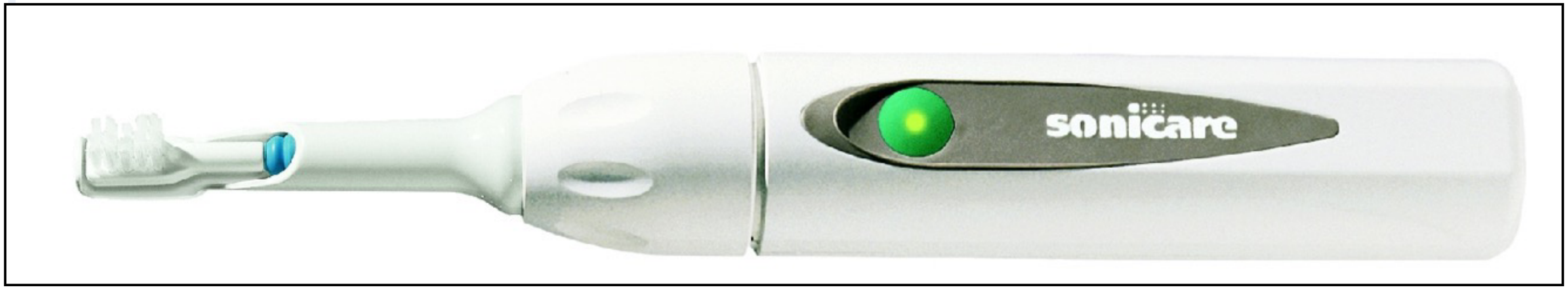
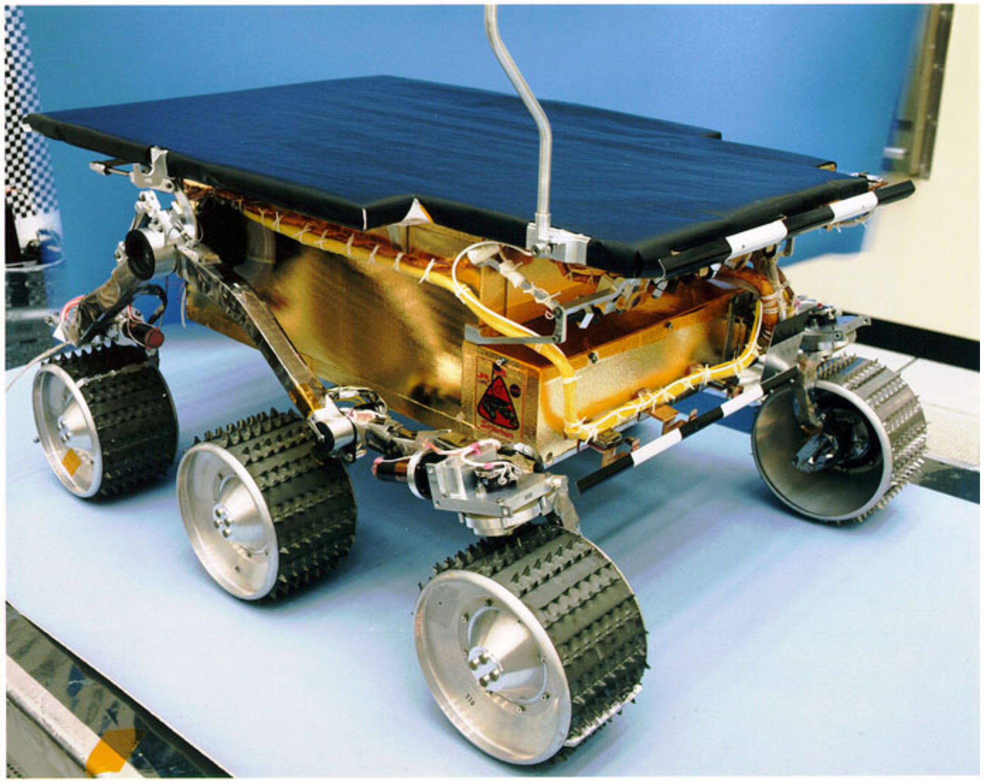
Product: Sonicare Plus toothbrush.
Microprocessor: 8-bit Zilog Z8.



by Daniel W. Lewis

Product: Miele dishwashers.

Microprocessor: 8-bit Motorola 68HC05.



Product: NASA's Mars Sojourner Rover.

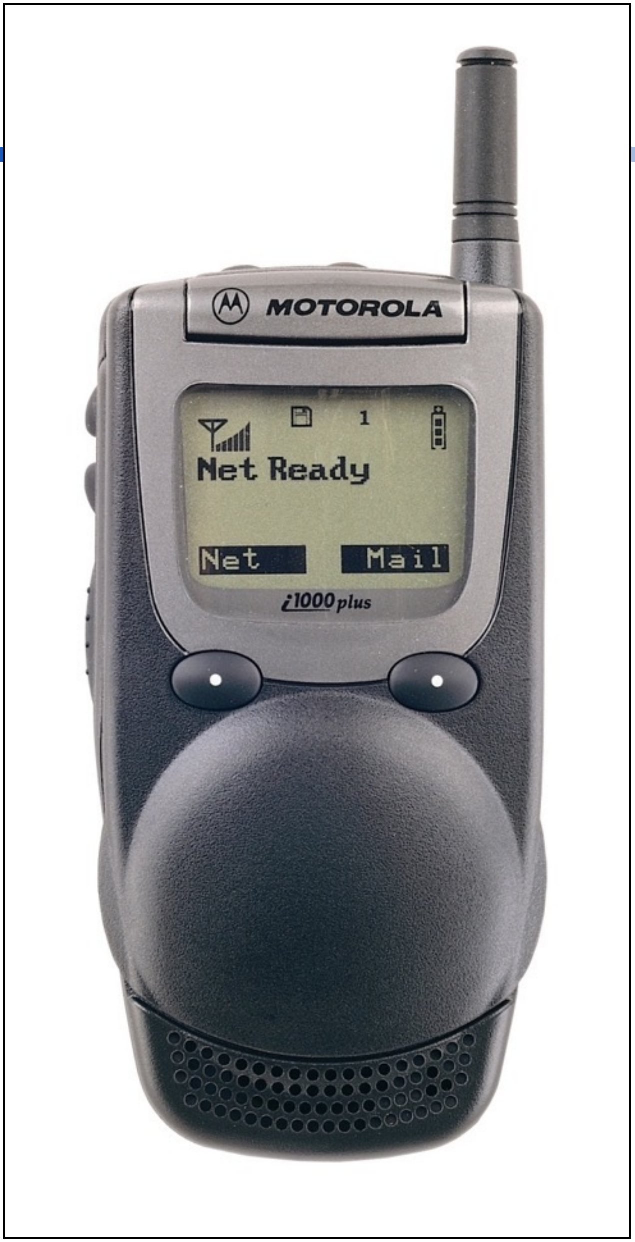
Microprocessor: 8-bit Intel 80C85.

Product: CoinCo USQ-712 coin changer.

Microprocessor: 8-bit Motorola 68HC912.

Product: Garmin Nüvi GPS Receiver

Microprocessor: 32-bit.



Product: Motorola i1000plus iDEN Multi-Service Digital Phone.

Microprocessor: Motorola 32-bit MCORE.

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Product: Nintendo Wii Controller

Microprocessor: IBM 32-bit Power RISC

Product: Apple iPad

Microprocessor:
Apple A4,
a 32-bit ARM RISC.

Product: Apple iWatch

Microprocessor:
32-bit Apple A6 and M7 Coprocessor

Product: HUAWEI P20 Pro

Microprocessor:
8 64-bit ARMv8-A, the same architecture as iPhone X

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Product: Sony Aibo ERS-110 Robotic Dog.

Microprocessor: 64-bit MIPS RISC.

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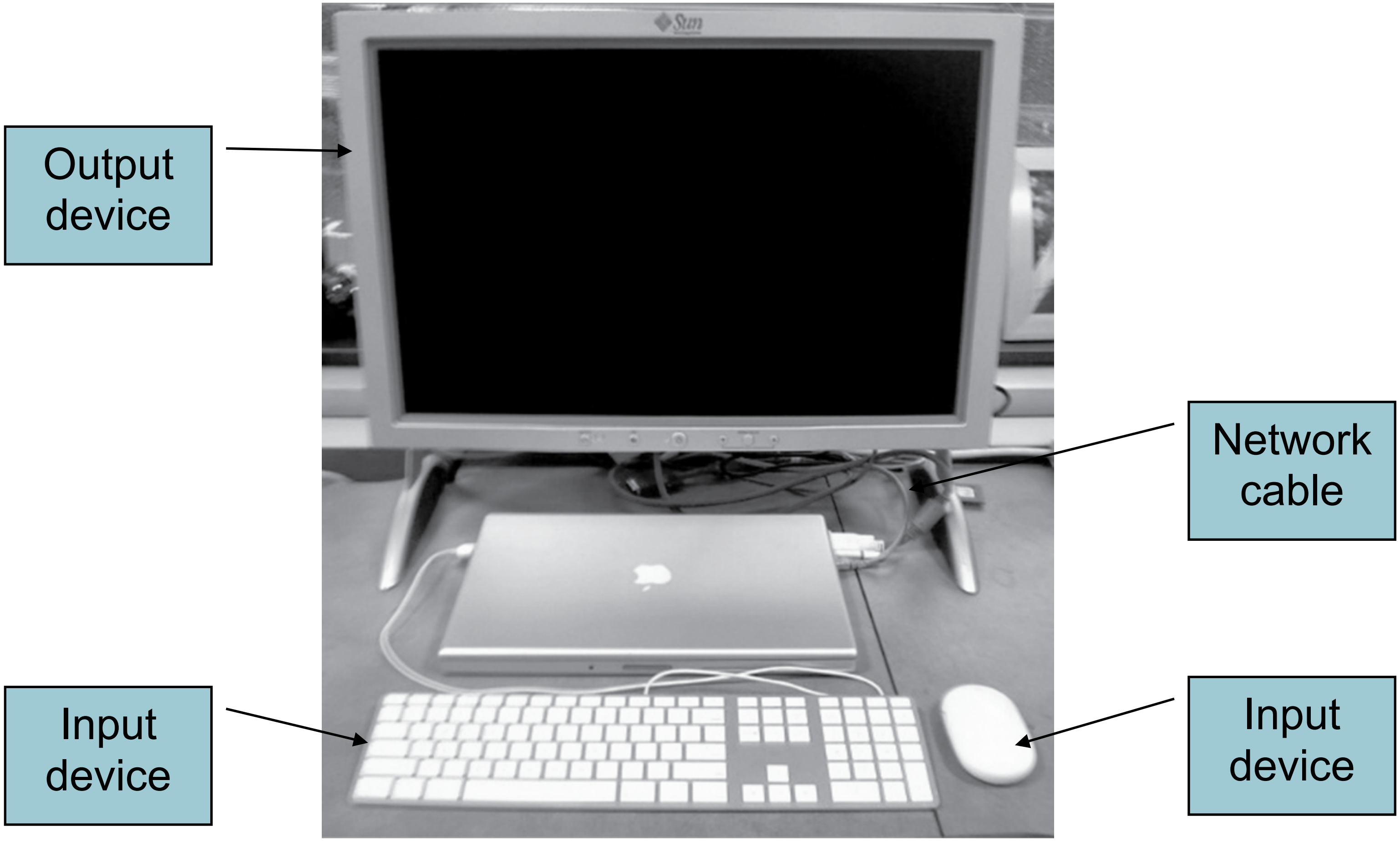
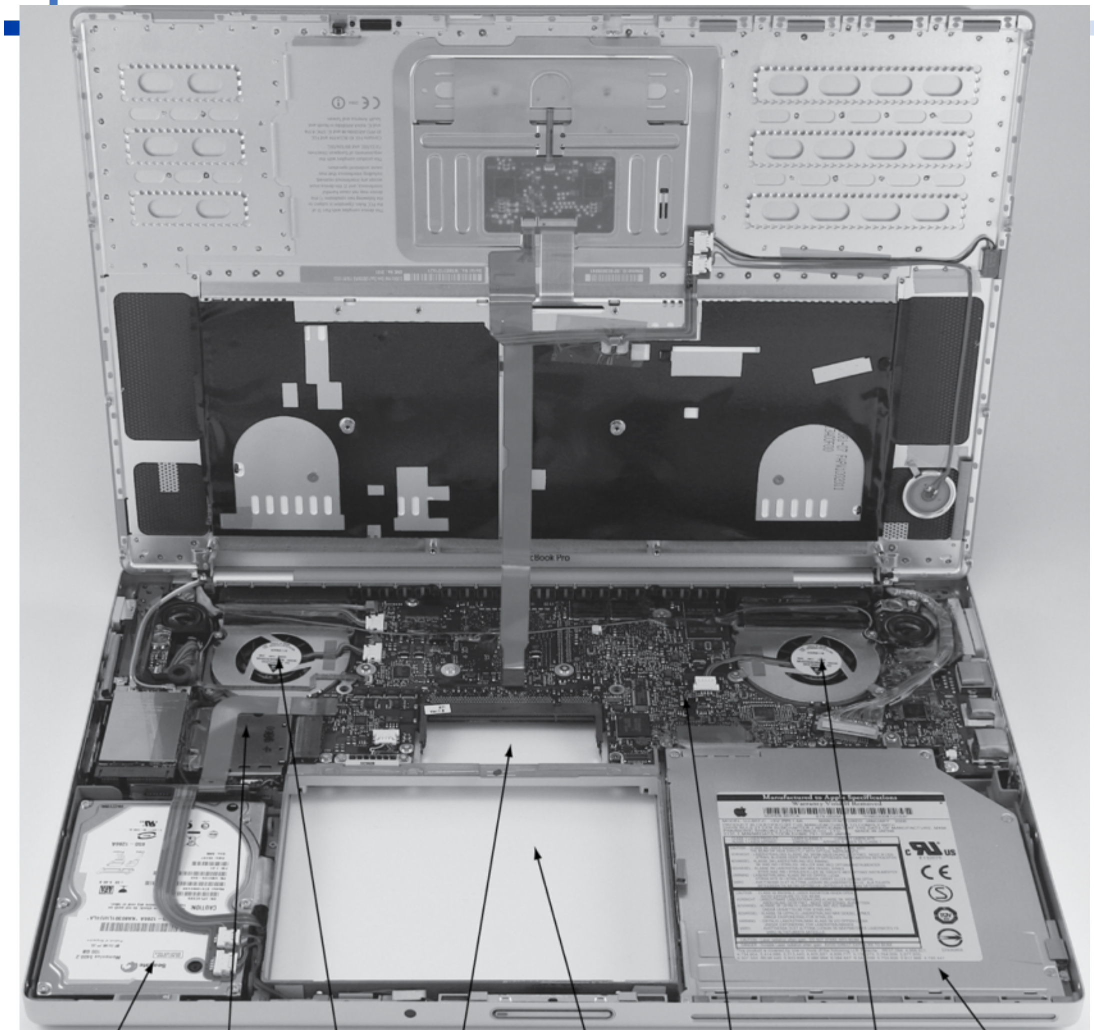
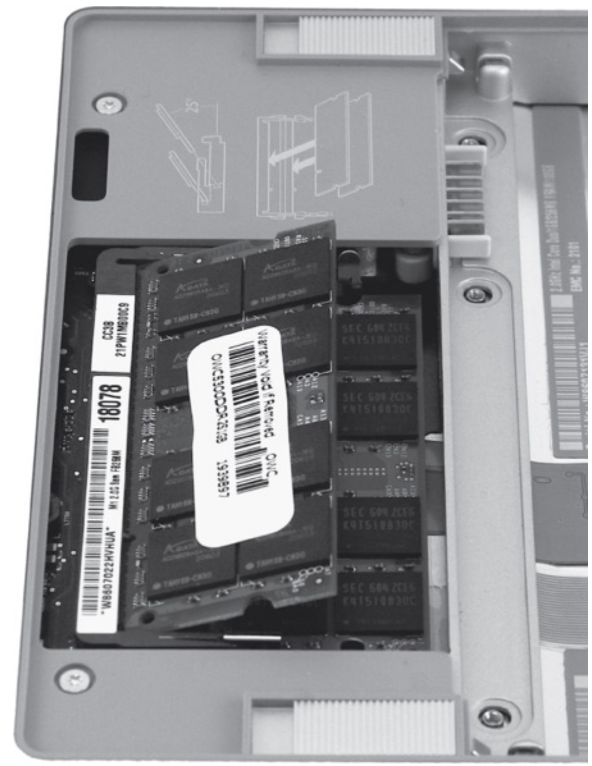
Anatomy of a Computer



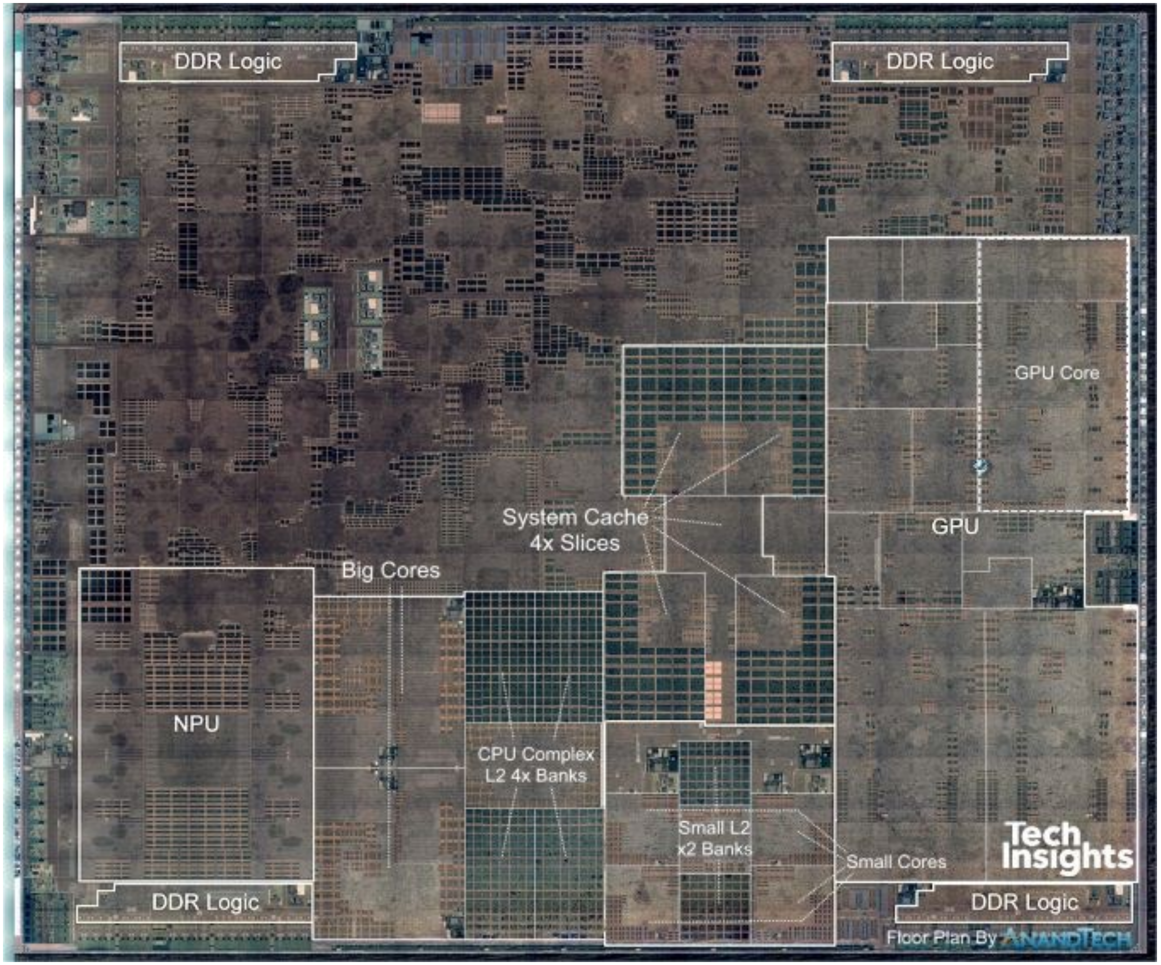
Opening the Box





Inside the Processor

- A12 processor

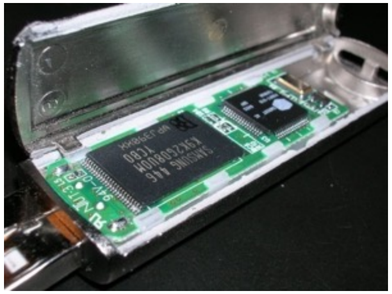


Inside the Processor (CPU)

- Datapath: performs operations on data
- Control: controls how data flows
- Cache memory
  - Small fast SRAM memory for immediate access to data

Peripheral – Memory

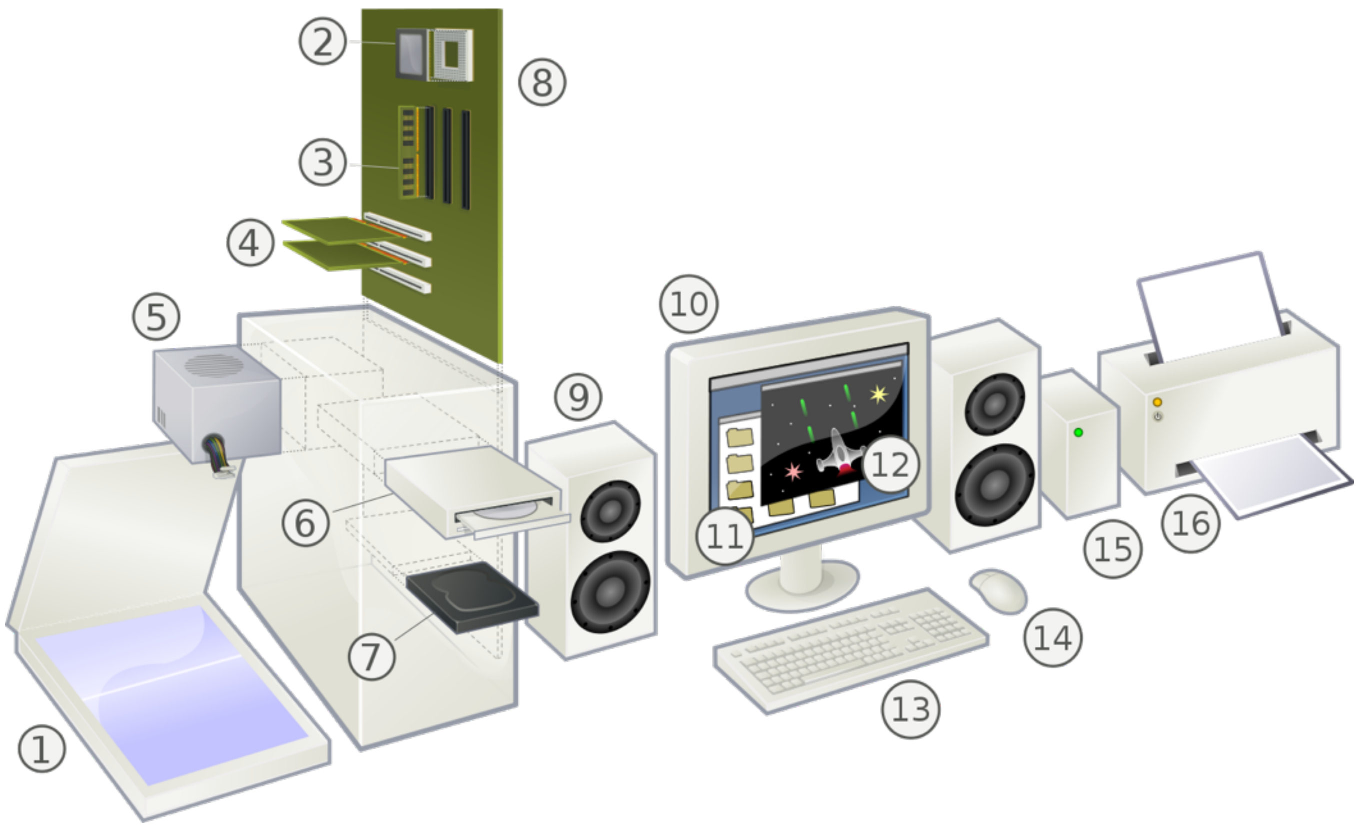
- Volatile main memory
  - Loses instructions and data when power off
- Non-volatile secondary memory
  - Magnetic disk
  - Flash memory
  - Optical disk (CDROM, DVD)



Peripheral – Networks

- Communication and resource sharing
- Local area network (LAN): Ethernet
  - Within a building
- Wide area network (WAN): the Internet
- Wireless network: WiFi, Bluetooth

Peripheral – many others



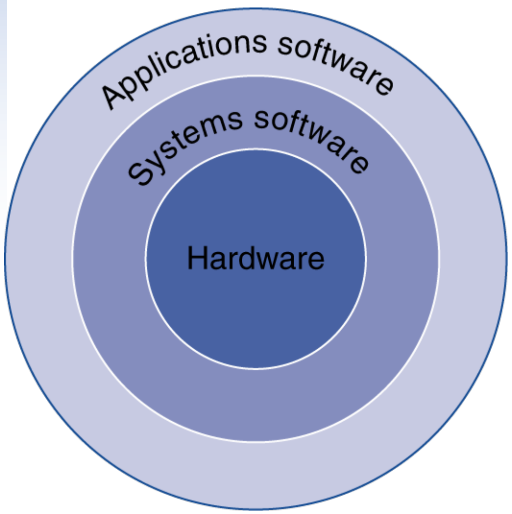
(*Source: Wikipedia.org*)

Hardware vs. Software

- **Hardware** is any part of your computer that has a **physical structure**, such as the keyboard or mouse. It also includes all of the computer's internal parts, which you can see in the image below.
- **Software** is any **set of instructions** that tells the hardware **what to do** and **how to do it**. Examples of software include web browsers, games, and word processors.

Source: https://edu.gcfglobal.org/en/computerbasics/what-is-a-computer/1/

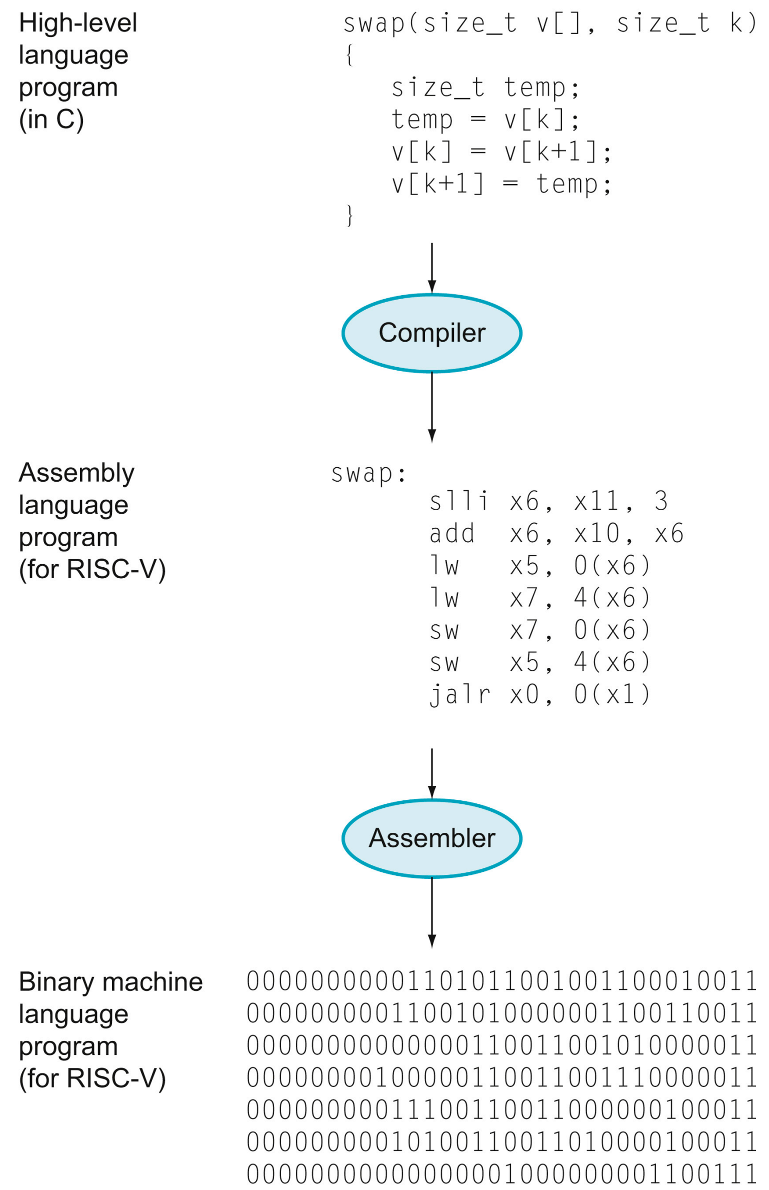
Together with Software



- Application software
  - Written in high-level language (HLL)
- System software
  - Operating System: service code
    - Handling input/output
    - Managing memory and storage
    - Scheduling tasks & sharing resources
  - Written in C and assembly
- Hardware
  - Processor, memory, I/O controllers

Levels of Program Code

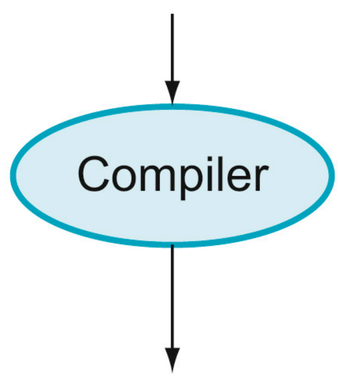
- **High-level language**
  - What we use
- **Assembly language**
  - What both we and computers can use
- **Machine instruction**
  - What computers use



Levels of Program Code

- **High-level language**
  - Syntax is similar to English
  - A translator is required to translate the program – compile
  - Allows the user to work on the program logic at higher level

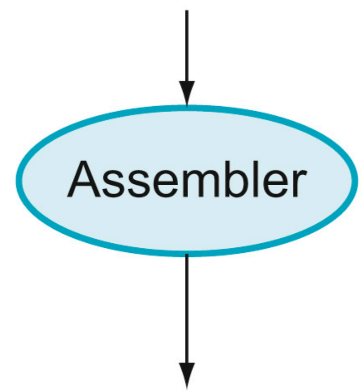
```
swap(size_t v[], size_t k)
{
    size_t temp;
    temp = v[k];
    v[k] = v[k+1];
    v[k+1] = temp;
}
```



Levels of Program Code

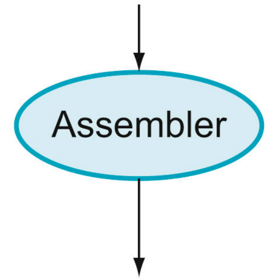
- **Assembly language**
  - Composed of assembly ***instructions***
  - An assembly instruction is a mnemonic representation of a machine instruction
  - Assembly instruction must be translated before it can be executed – assembler
  - Programmers need to work on the program logic at a very low level, hard to achieve high productivity.

```
swap:
        slli x6, x11, 3
        add  x6, x10, x6
        lw   x5, 0(x6)
        lw   x7, 4(x6)
        sw   x7, 0(x6)
        sw   x5, 4(x6)
        jalr x0, 0(x1)
```



Levels of Program Code

- **Machine instruction**
  - A sequence of binary digits which can be executed by the processor
  - Hard to understand, program, and debug for human being




```
00000000001101011001001100010011
00000000011001010000001100110011
00000000000000110011001010000011
00000000100000110011001110000011
00000000011100110011000000100011
00000000010100110011010000100011
00000000000000001000000001100111
```

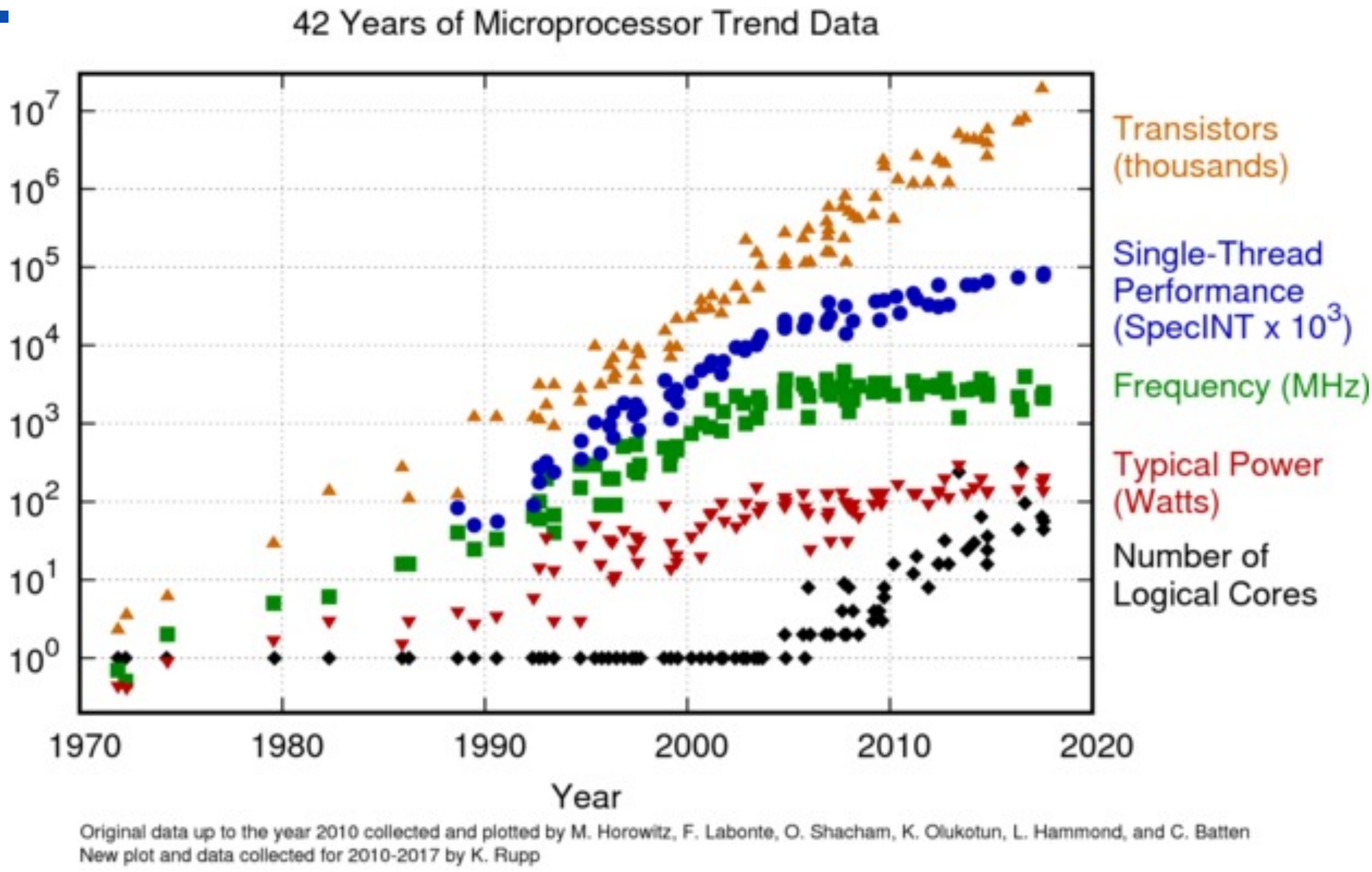
From Wikipedia

Technology Trends

- Electronics technology continues to evolve
  - Reduced cost
  - Parallelism
  - Low power
  - Increased capacity and performance

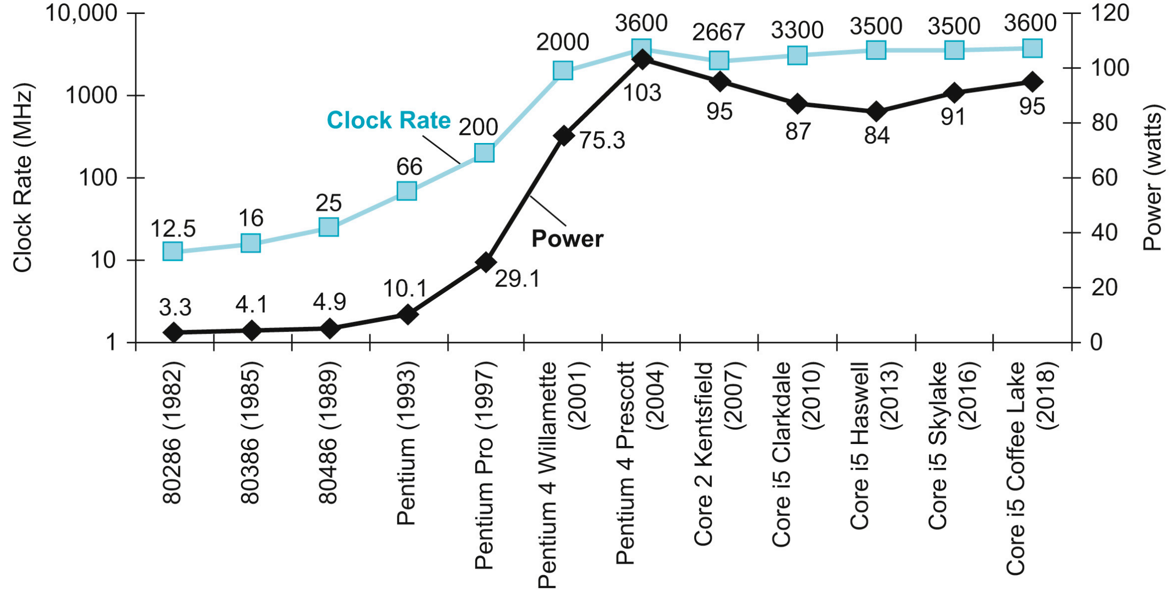
(From Wikipedia)

Technology Trends



https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/

Power Trends



- In CMOS IC technology

$$\text{Power} = \text{Capacitive load} \times \text{Voltage}^2 \times \text{Frequency}$$

×30

5V → 1V

×1000

Reducing Power

- Suppose a new CPU has
  - 85% of capacitive load of old CPU
  - 15% voltage and 15% frequency reduction

$$\frac{P_{new}}{P_{old}} = \frac{C_{old} \times 0.85 \times (V_{old} \times 0.85)^2 \times F_{old} \times 0.85}{C_{old} \times V_{old}{}^2 \times F_{old}} = 0.85^4 = 0.52$$

- The power wall
  - We can't reduce voltage further
  - We can't remove more heat
- How else can we improve performance?

Multiprocessors

- Multicore microprocessors
  - More than one processor per chip
- Requires explicitly parallel programming
  - Compare with instruction level parallelism
    - Hardware executes multiple instructions at once
    - Hidden from the programmer
  - Hard to do
    - Programming for performance
    - Load balancing
    - Optimizing communication and synchronization

Concluding Remarks

- Cost/performance is improving
  - Due to underlying technology development
- Hierarchical layers of abstraction
  - In both hardware and software
- Instruction set architecture
  - The hardware/software interface
- Power is a limiting factor
  - Use parallelism to improve performance