Topic 1

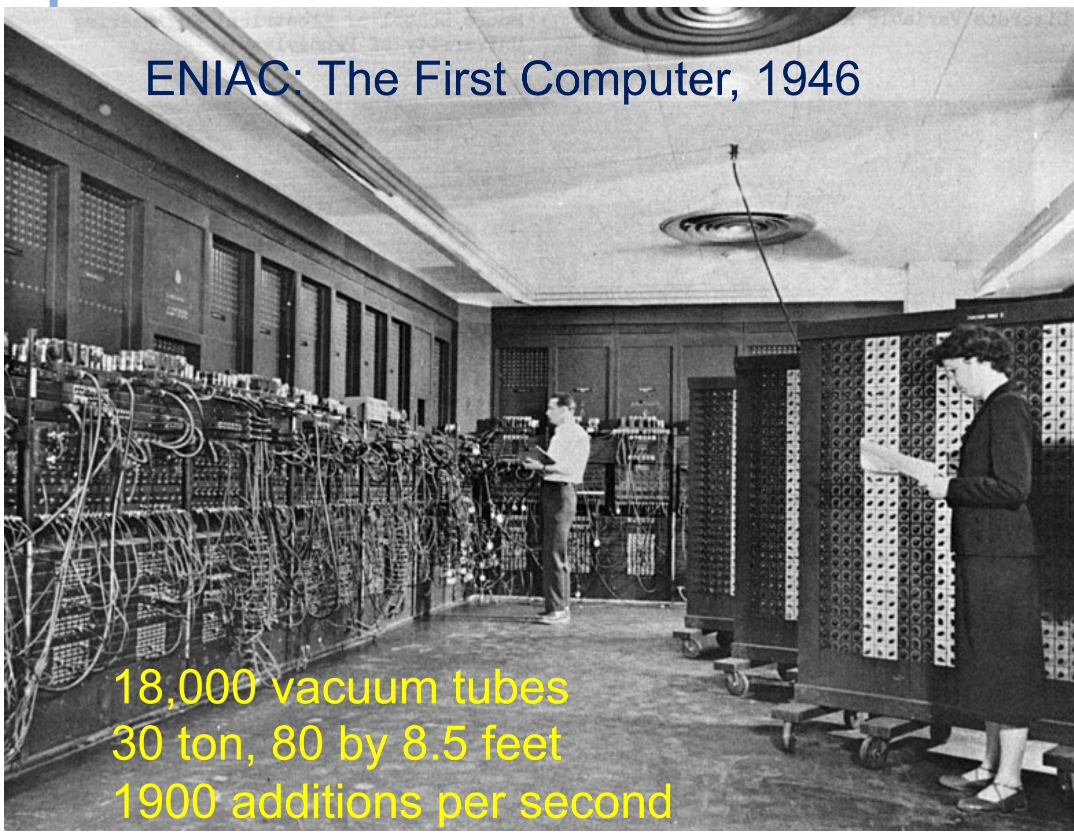
Introduction to Computer

What is a “Computer”?

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

The Computer Revolution

ENIAC: The First Computer, 1946



18,000 vacuum tubes
30 ton, 80 by 8.5 feet
1900 additions per second

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

IBM 2nm Chip, 2021

Image: IBM

50 billion transistors
On a chip the size of a fingernail

The Computer Revolution

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

Classes of Computers

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

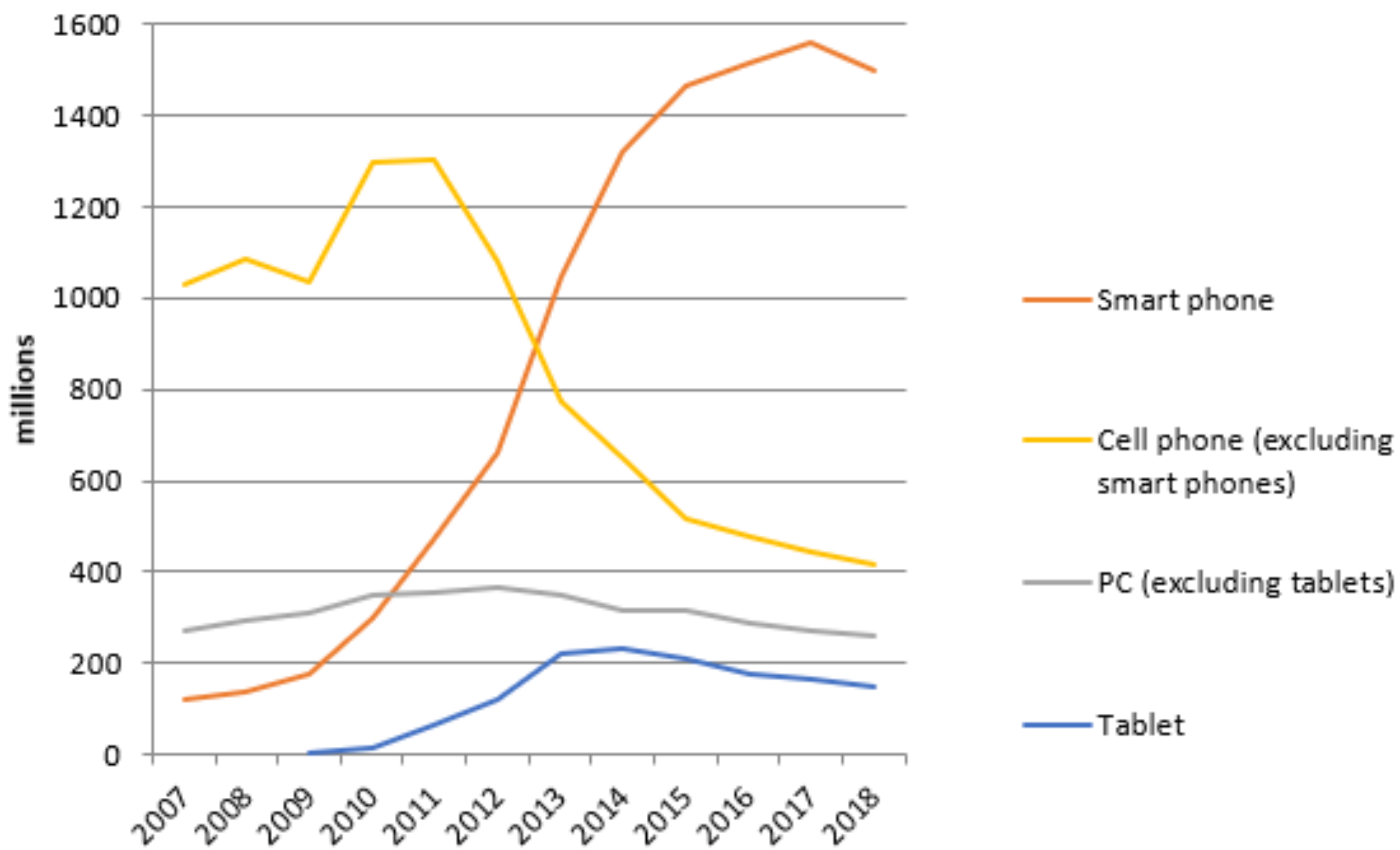
- Server computers
  - Network based
  - High capacity, performance, reliability
  - Range from small servers to building sized

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.

Product: Nintendo Wii Controller
Microprocessor: IBM 32-bit Power RISC

Product: Apple iWatch

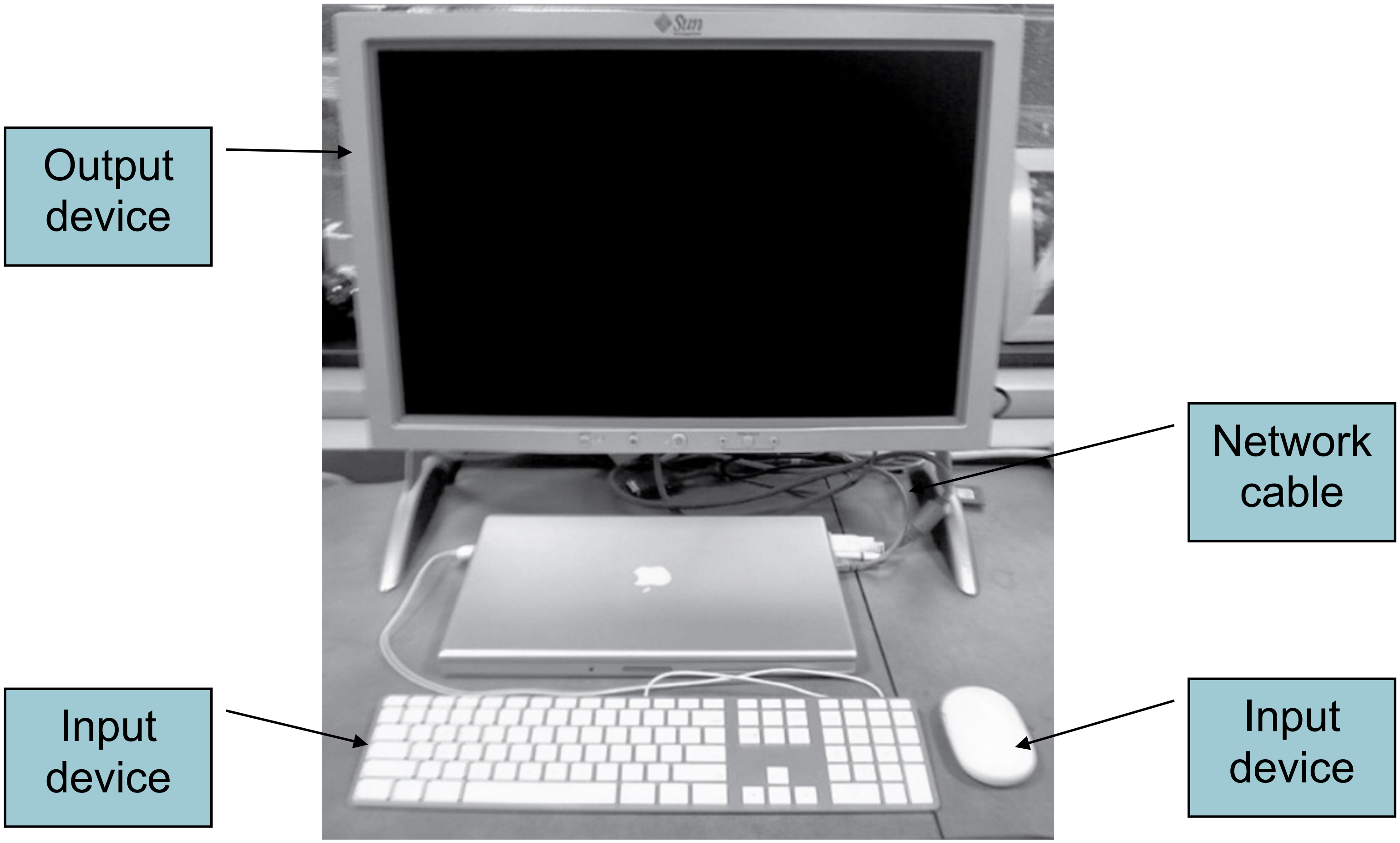
Microprocessor: 32-bit Apple A6 and M7 Coprocessor

Product: HUAWEI P20 Pro

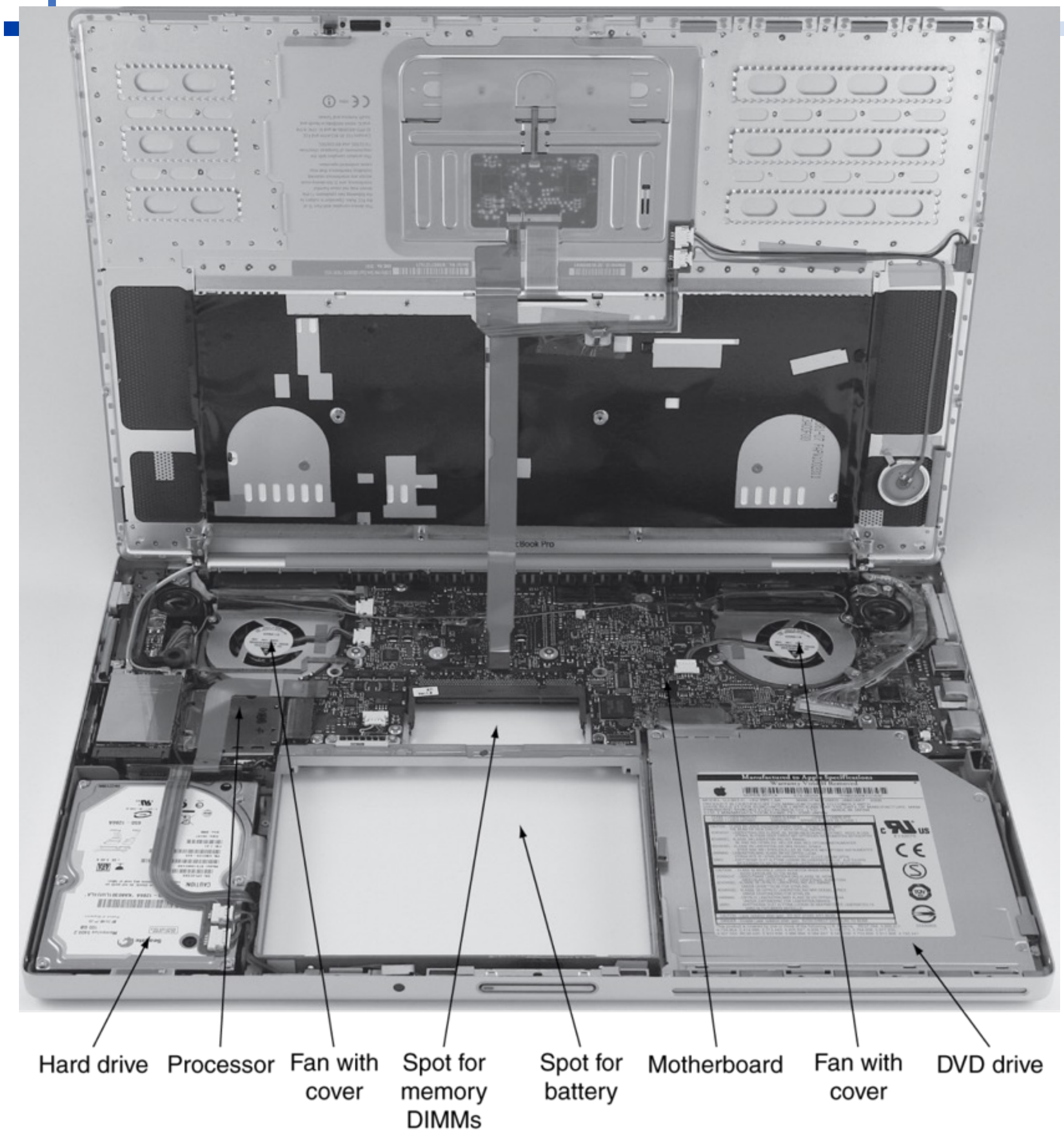
Microprocessor:
8 64-bit ARMv8-A, the same architecture as iPhone X

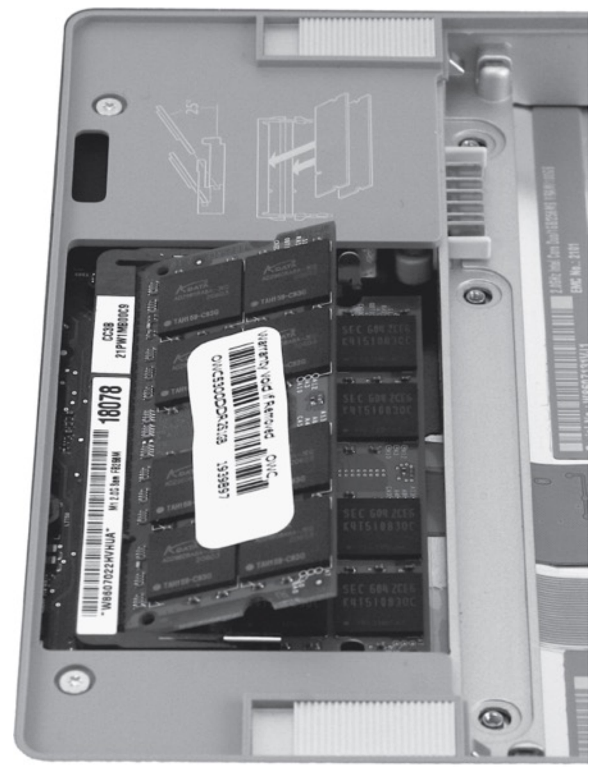
by Daniel W. Lewis

Anatomy of a Computer Hardware



Opening the Box



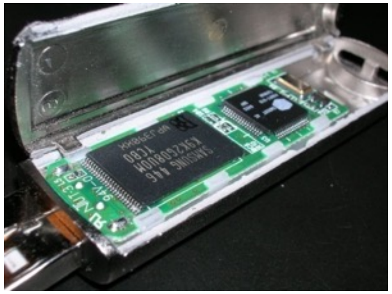


Inside the Processor (CPU)

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

Outside Peripheral – Memory

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



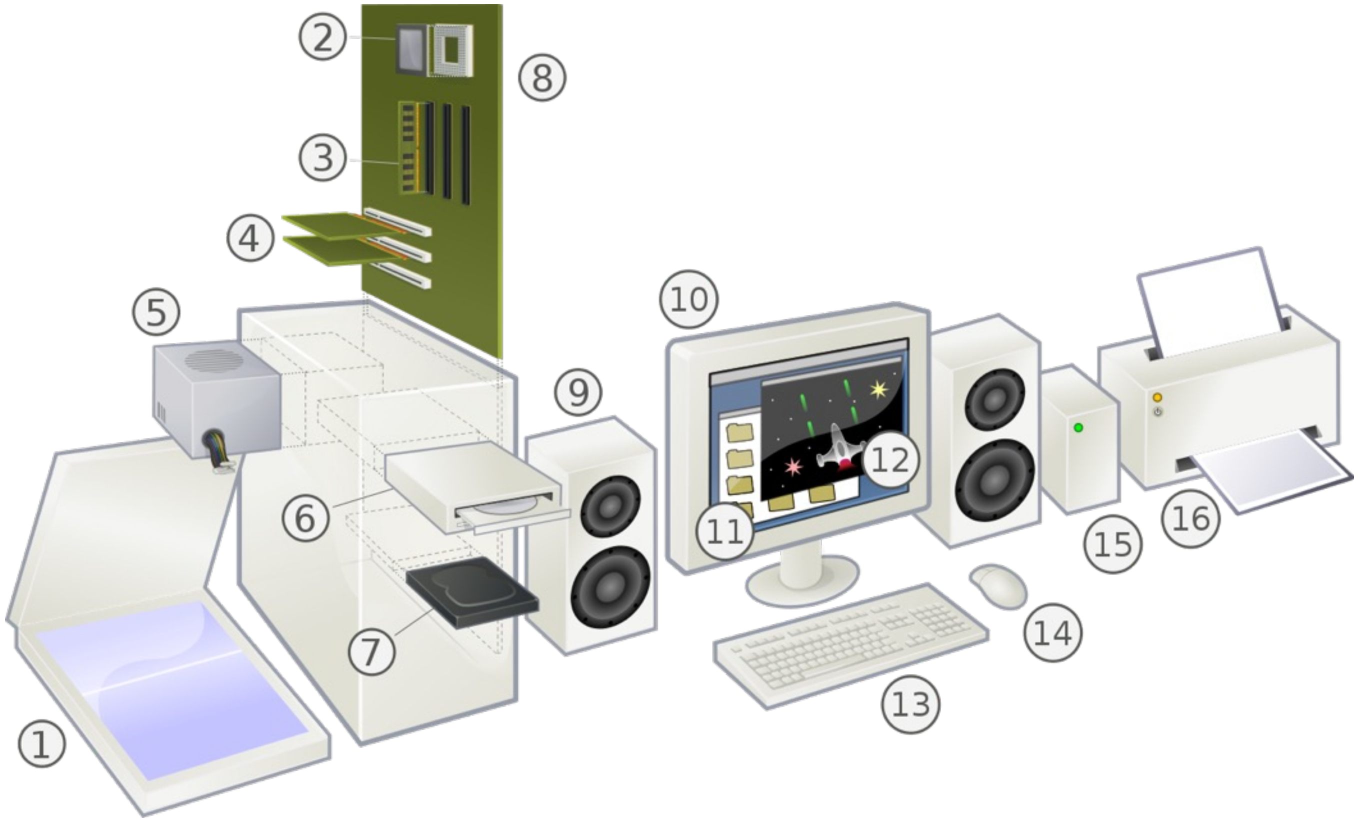
Outside Peripheral – Networks

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

Outside Peripheral – Graphics Card

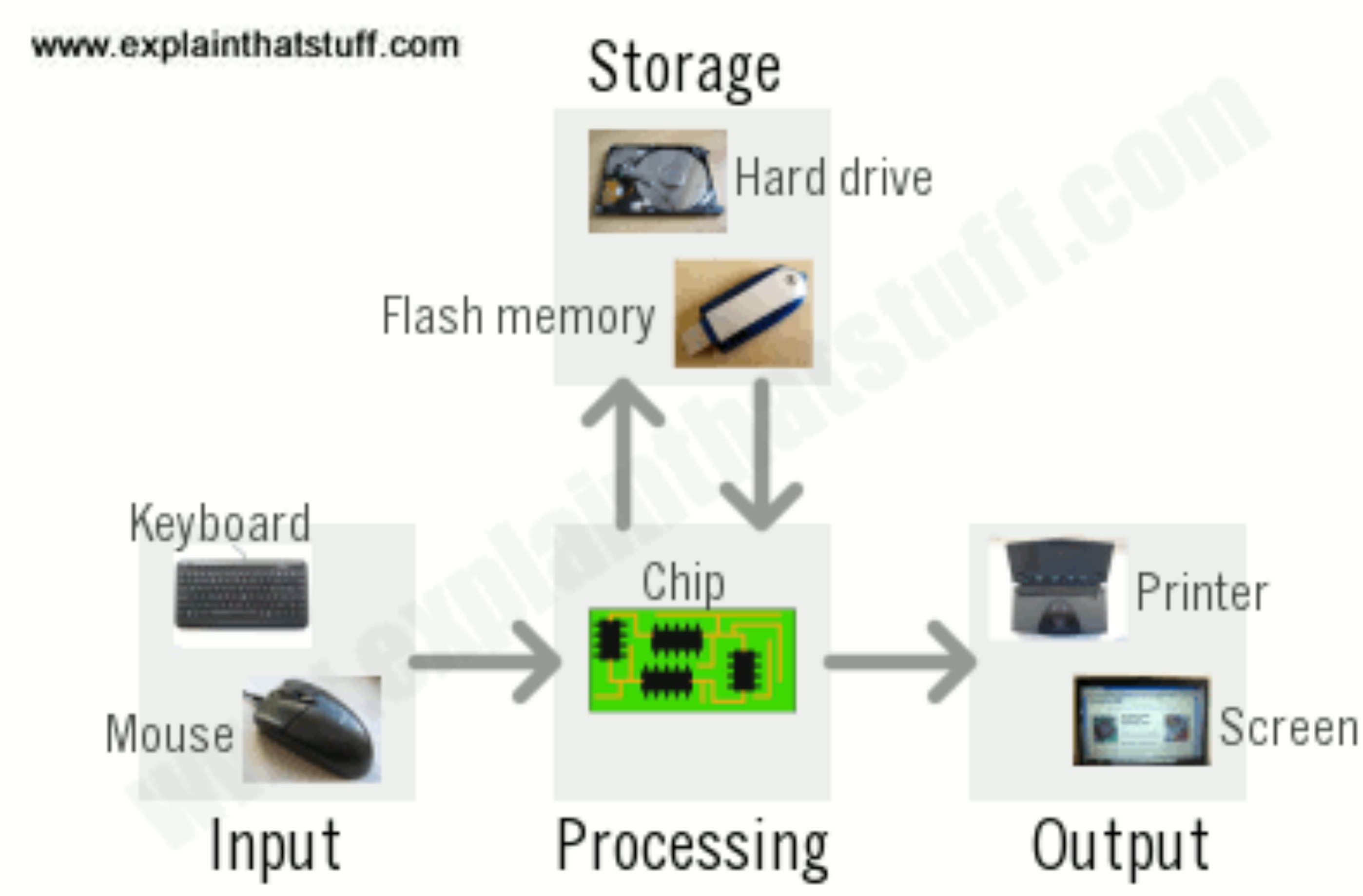
- Processes and generates images to feed to displaying devices
- Graphics processing unit takes some workload from CPU by performing some necessary computation

Peripheral – Others Hardware



(*Source: Wikipedia.org*)

How do computers work?

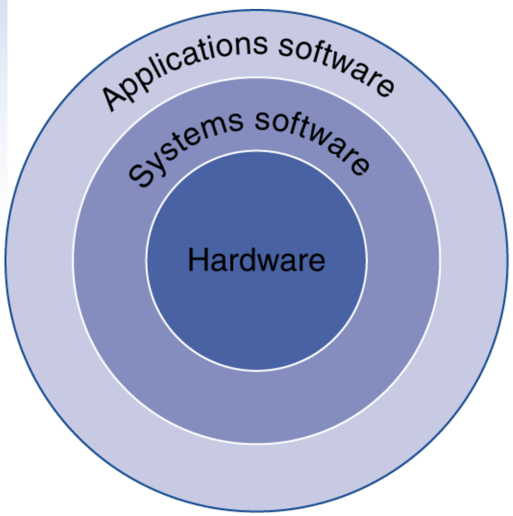


Hardware vs. Software

- **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/

Hardware & Software Together

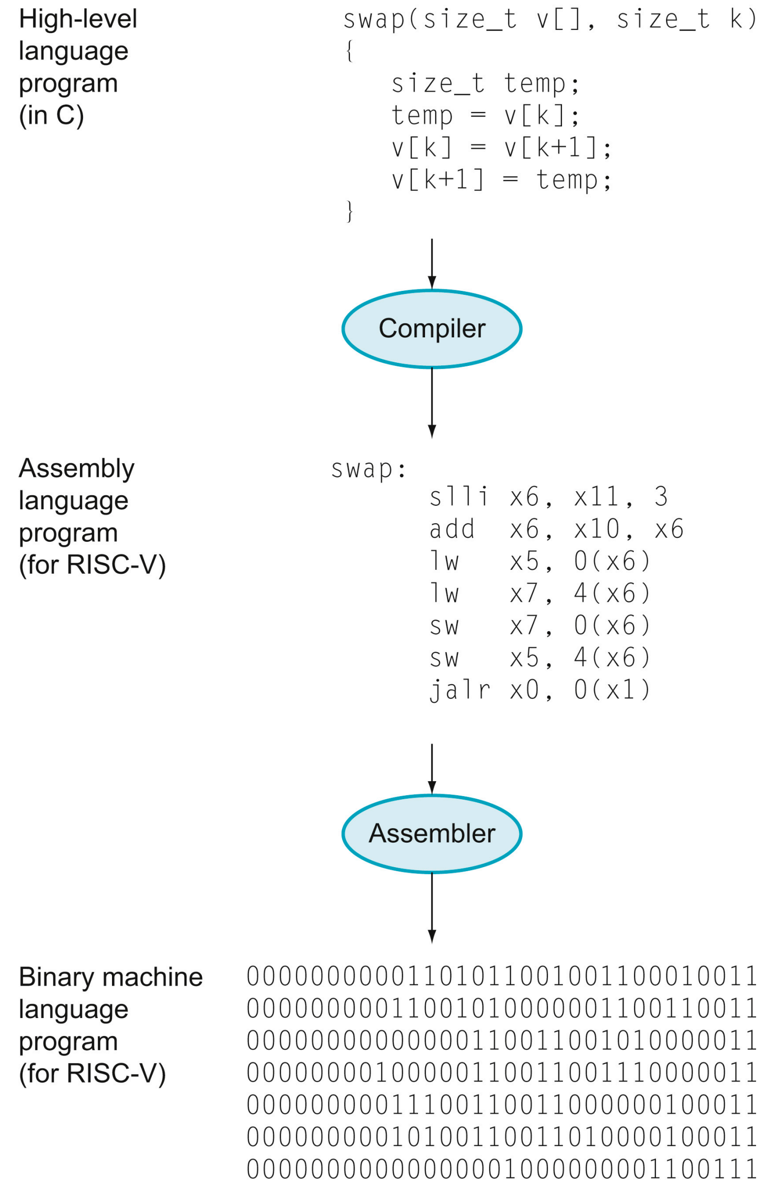


Computer Organization

- 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

Software

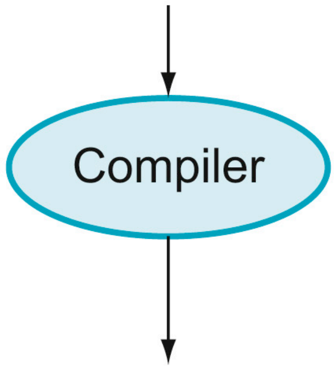
- **High-level language**
  - What we use
- **Assembly language**
  - What both we and computers can use
- **Machine instruction**
  - What computers use



Levels of Programing Language

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

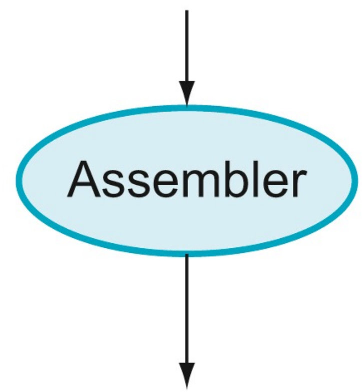
```
swap(size_t v[], size_t k)
{
    size_t temp;
    temp = v[k];
    v[k] = v[k+1];
    v[k+1] = temp;
}
```



Levels of Programing Language

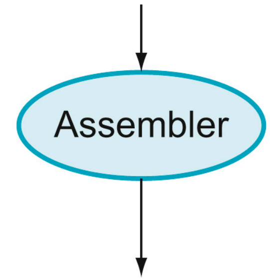
- **Assembly language**
  - Composed of assembly ***instructions***
  - An assembly instruction is a mnemonic representation of a machine instruction
  - Assembly instruction must be translated by **assembler** before it can be executed
  - Programmers need to work on the program logic at a very low 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 Programing Language

- **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
```

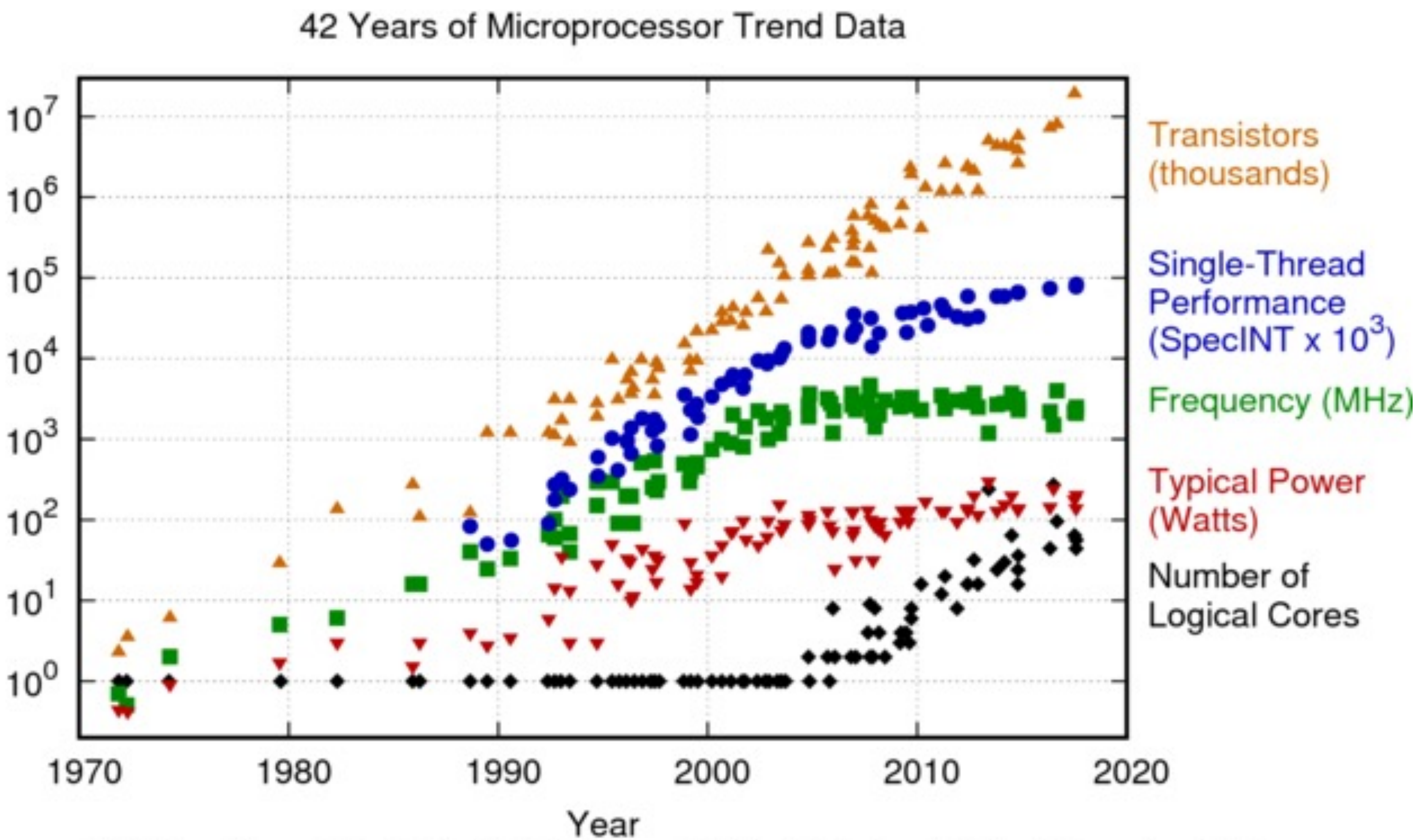
From Wikipedia

Technology Trends

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

(From Wikipedia)

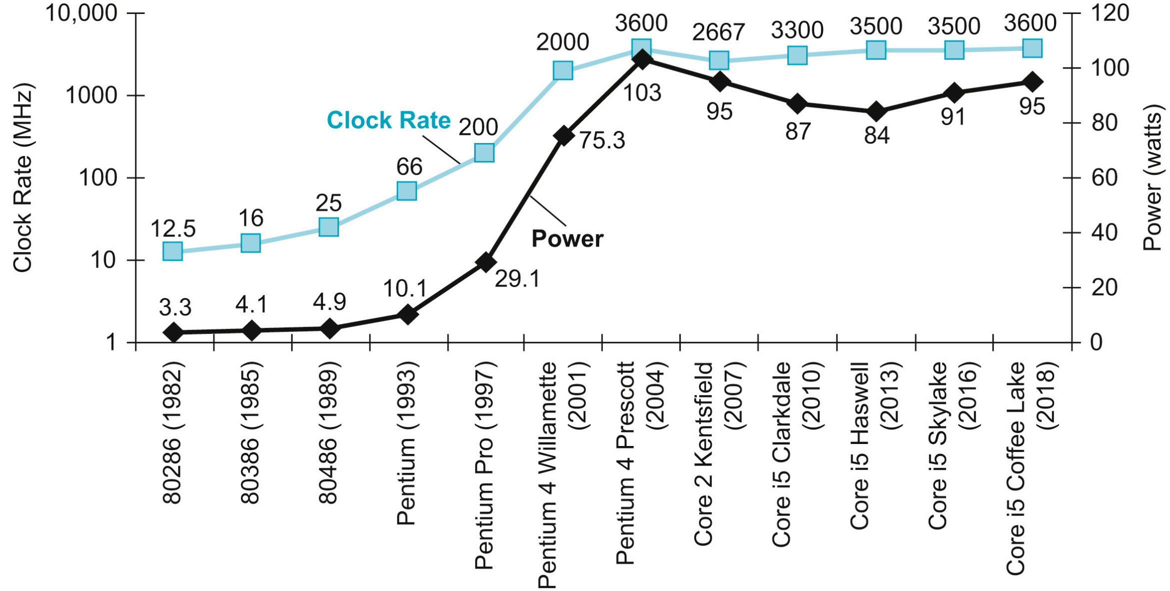
Technology Trends



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

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 dissipate 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

Rapid Evolution of Techs

- Techs that will transform our world
  - Ubiquitous computing
  - Connected and smart everything
  - Datafication of our world
  - AI
  - Extended reality (XR)
  - Digital trust
  - 3D printing
  - Gene-editing and synthetic biology
  - Nanotechnology and materials science
  - New energy solutions

(from Forbes.com)

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