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Hierarchy,Components & Technology

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2023 Spring Semester

COMP1047 Systems & Architecture

Computer Architecture Scope and Definitions

What is Architecture?

Scan the code to provide your opinion, or go to https://www.menti.com/bvxzbc7t6q

Computer Architecture Scope and Definitions

The art or science of designing and creating <u>buildings</u>

Computer Architecture Scope and Definitions

Computer Architecture

The art or science of designing a <u>Computer</u>

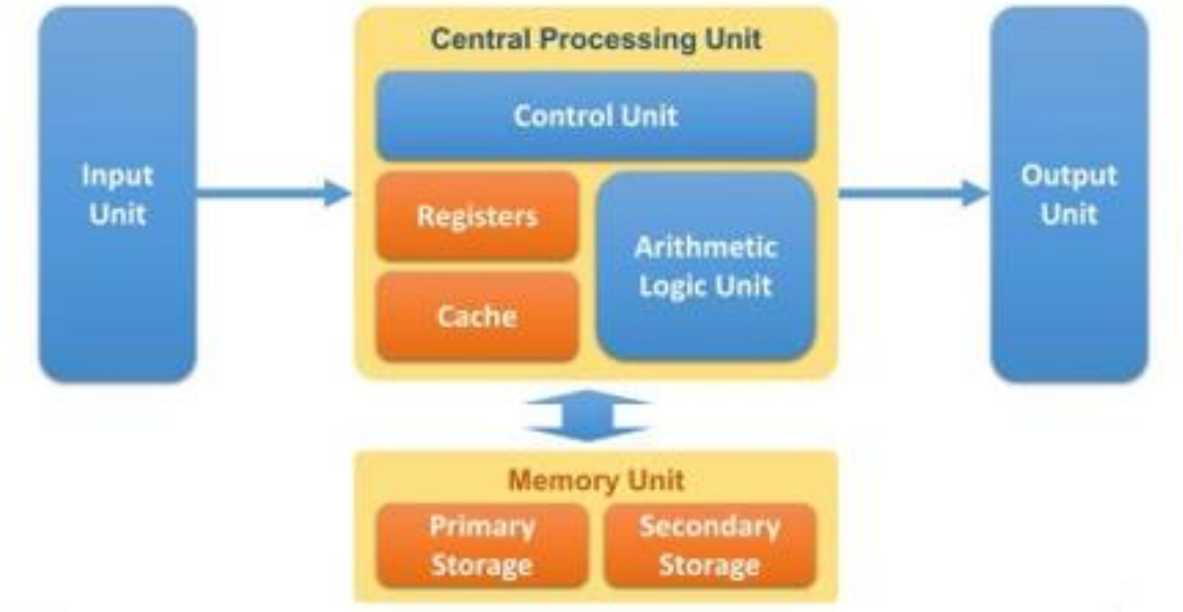


Image Link

Types of Computers

- **Personal Computers (PCs)**
  - General purpose use
  - Usually execute a variety of third-party software
  - Subject to cost/performance tradeoff

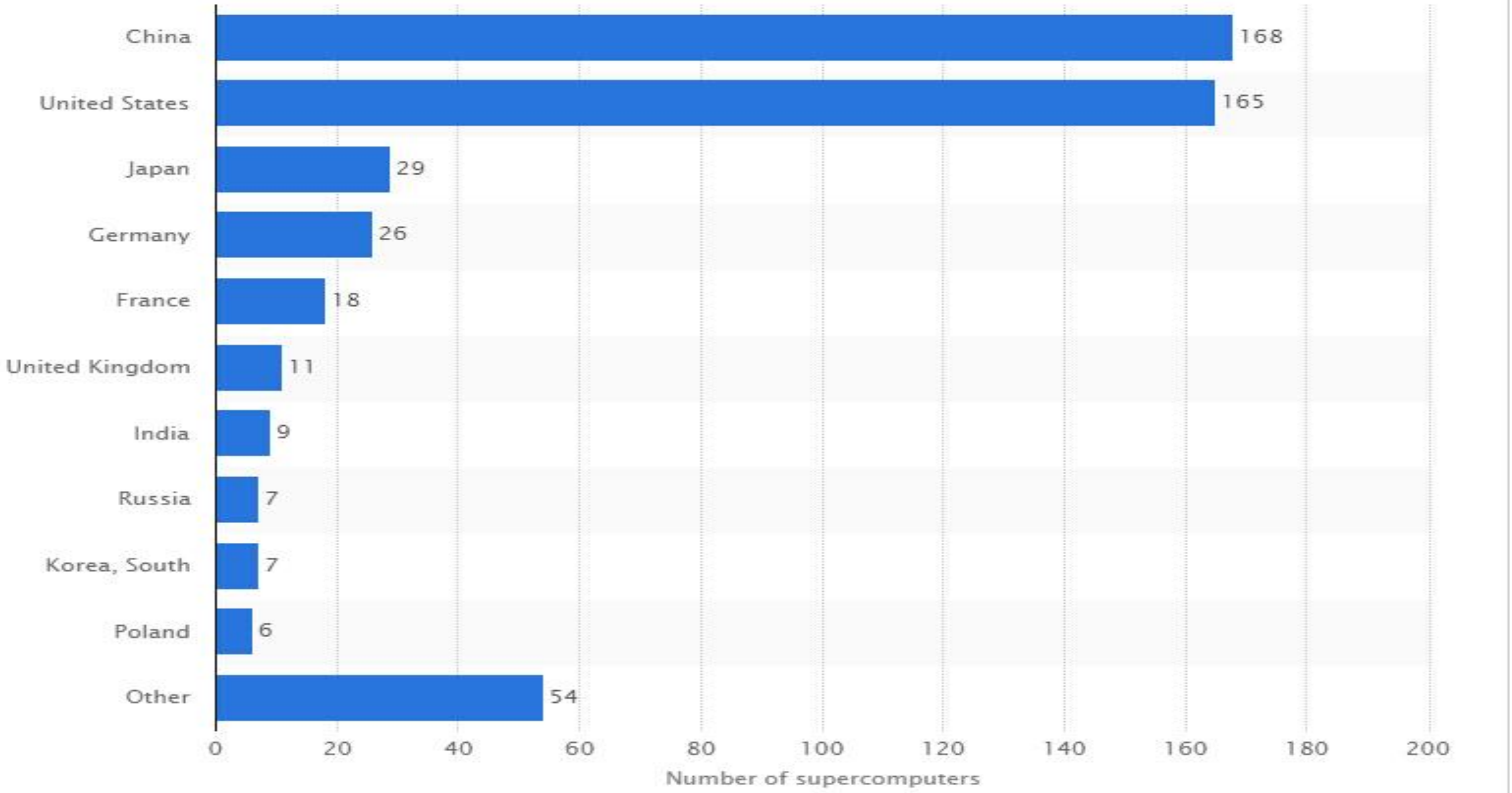
- **Servers**
  - Typically assessed via a network
  - Carry large workloads (single complex application/many small jobs)
  - Range from small servers to building sized

- **Embedded Computers**
  - Hidden as components of systems
  - Designed to run one predetermined application or collection of software
  - Low cost
  - Low tolerance for failure (technologies of redundancy employed)



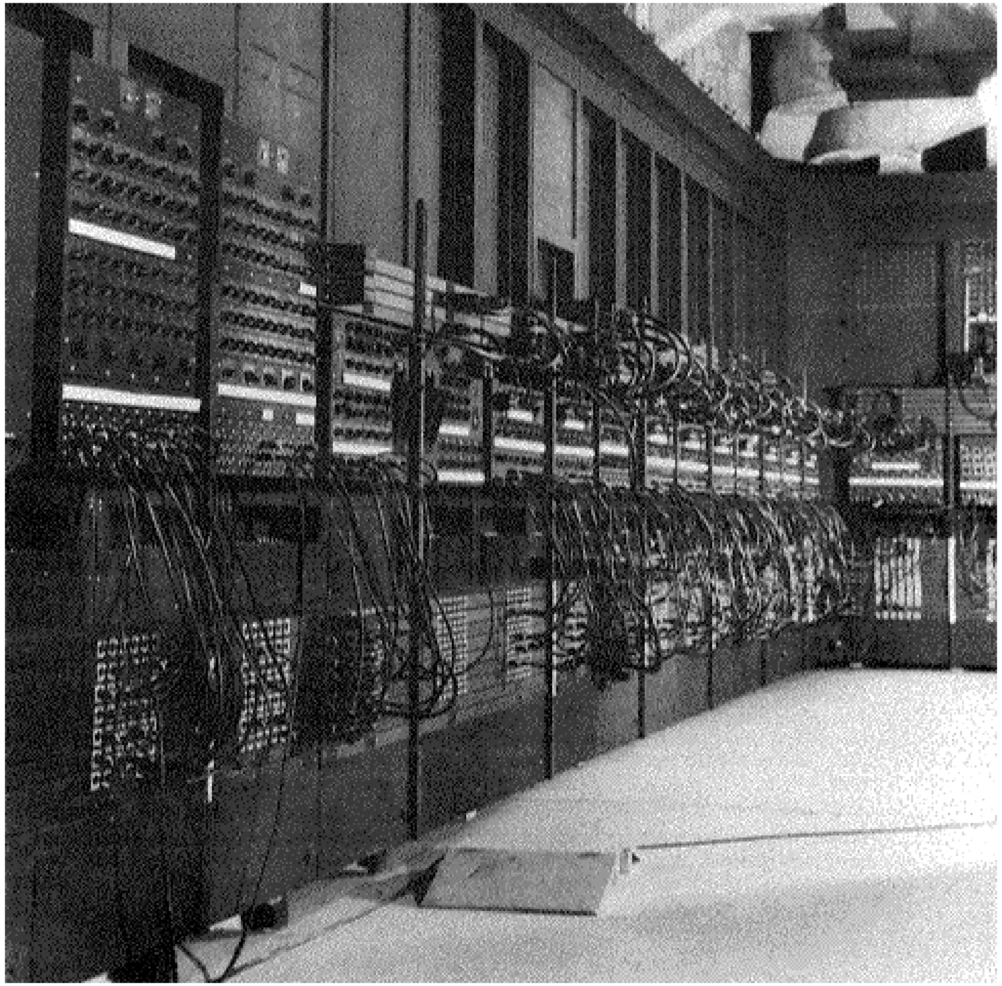

Types of Computers

- **Supercomputers**
  - A class of servers with the highest performance
  - Perform high-end scientific and engineering calculations
  - Expensive to build (typically 10s to 100s of millions of dollars)



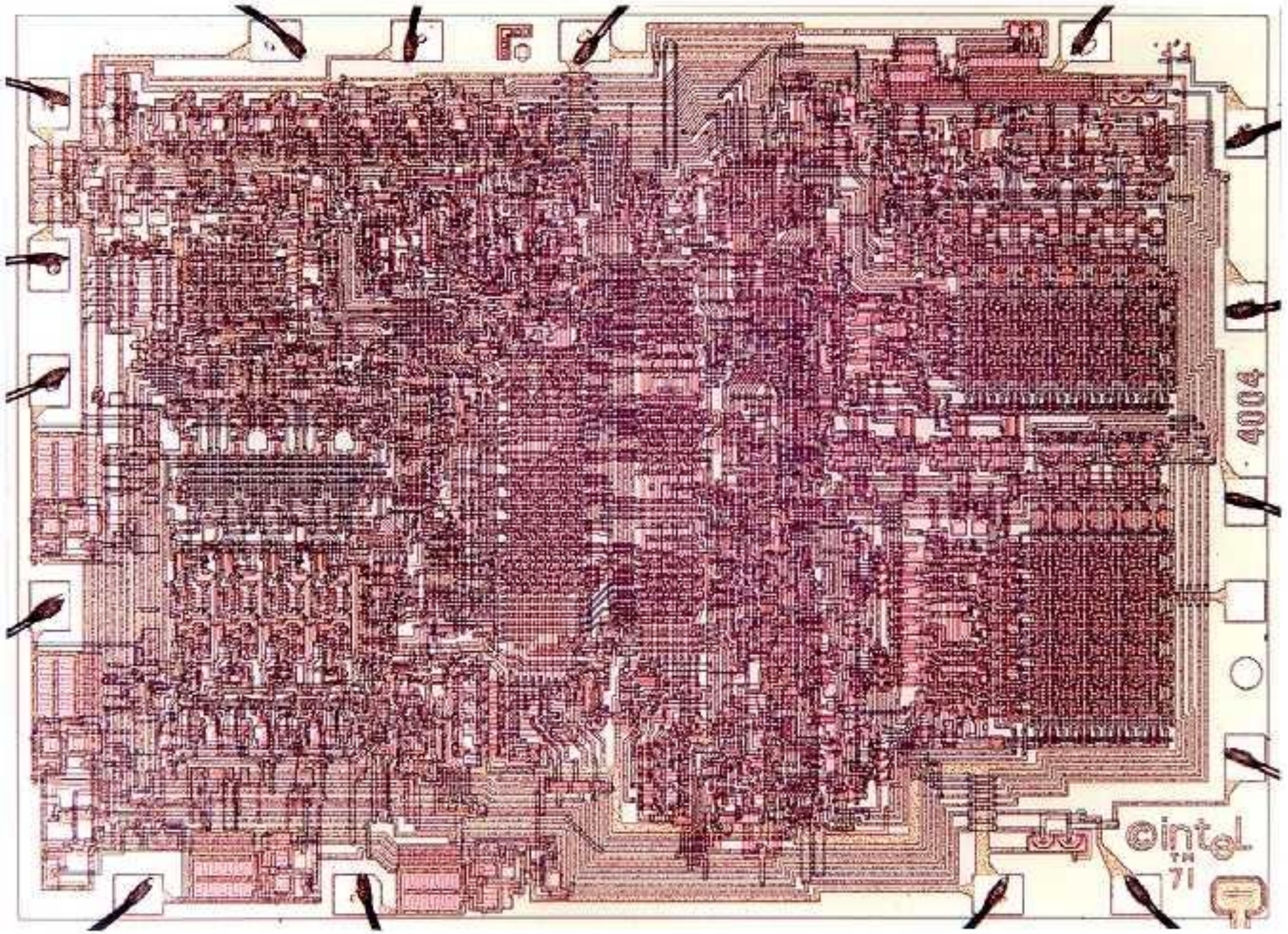
Top 500 Supercomputers (June 2016)

A Bit of History



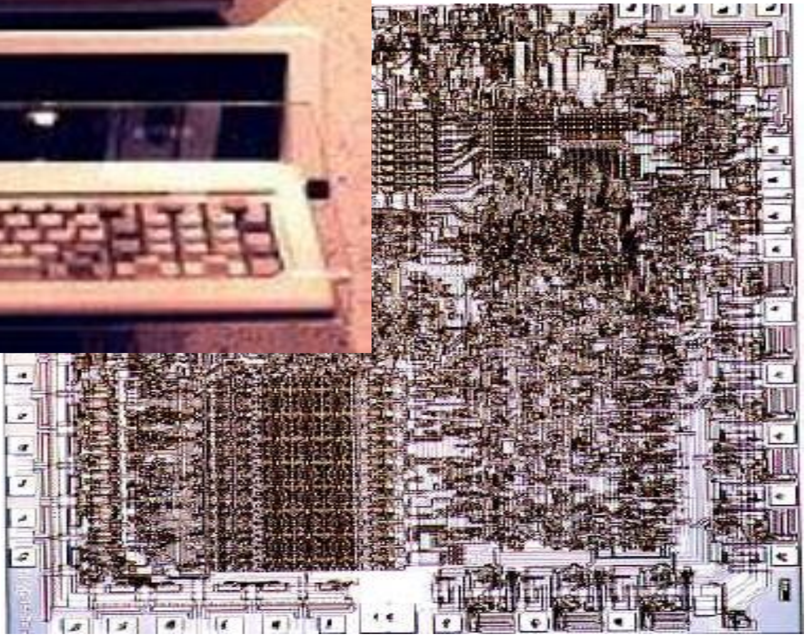
- Electronic Numerical Integrator And Computer (ENIAC)
- The first electronic general-purpose computer dedicated at the University of Pennsylvania on February 15, 1946
  - Weighted more than 27 tons, was roughly 2.4m × 0.9m × 30m, occupied 167m^2 and consumed 150 kW of electricity
  - Performance: roughly a few kilo-floating-point operations per second (kflops) (10^3)
- TaihuLight (2016) - 93 petaflops (10^{15})

A Bit of History



- Microprocessor
  - Computer CPU on a single chip (IC)
  - Contain a number of transistors connected by wires
- First commercial microprocessor: Intel 4004
  - Introduced in 1971
  - 2300 transistors
  - Technology: 10 µm (transistors are 10 µm across)
  - Has roughly the same processing power as ENIAC

A Bit of History

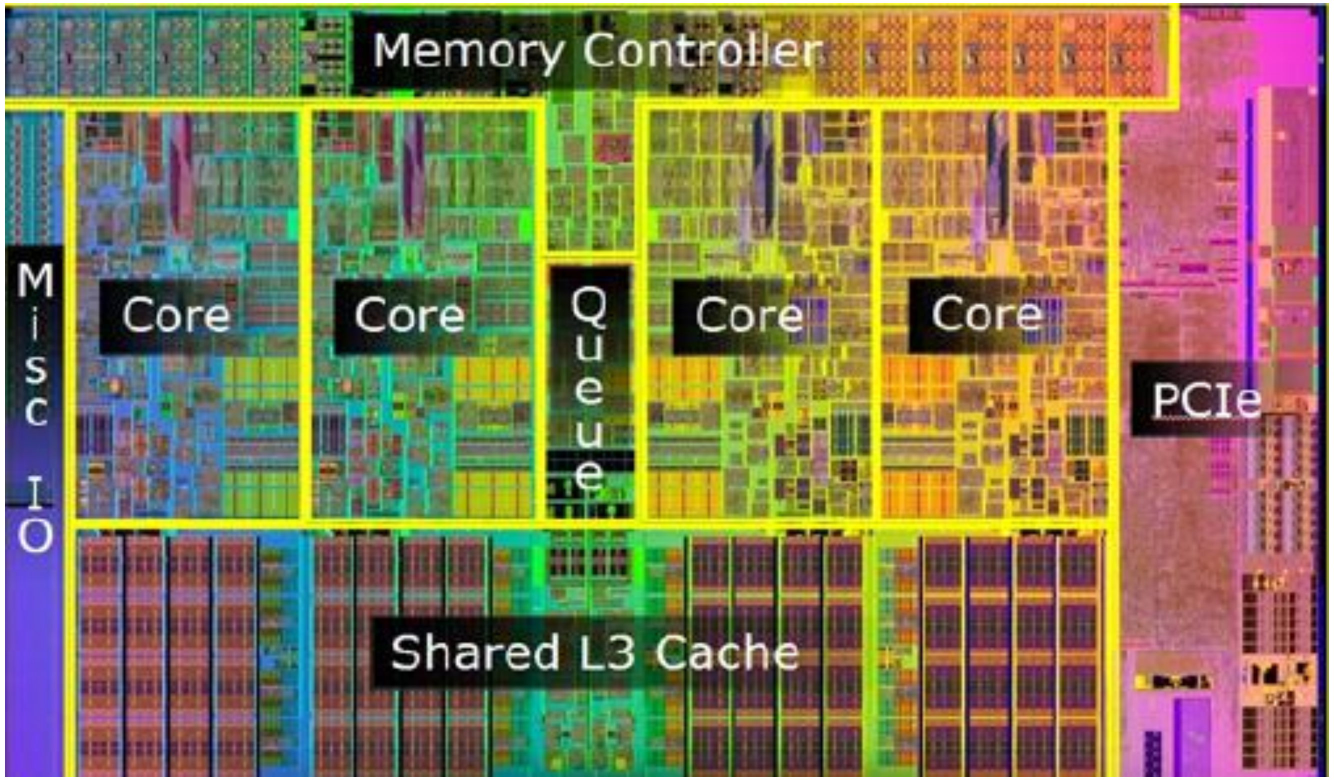


- Intel 8088
  - Use by IBM in its Original PC in 1981
  - 29000 transistors
  - Technology: 3 µm (transistors are 3 µm across)
  - Use operating system (MS-DOS) designed by Microsoft

A Bit of History

- Intel Pentium4
  - Introduced in 2003
  - 55M transistors
  - Technology: 90 nm (transistors are 90 nm across)
  - Application: desktop/server

A Bit of History



- Multicore processor
  - A single chip contains more than one microprocessor core
- Intel Core i7
  - Introduced in 2009
  - 774M transistors
  - Technology: 32 nm (transistors are 32 nm across)
  - Four-core multicore
  - Application: desktop/server

[Video: How Microchips are made?]

A Bit of History

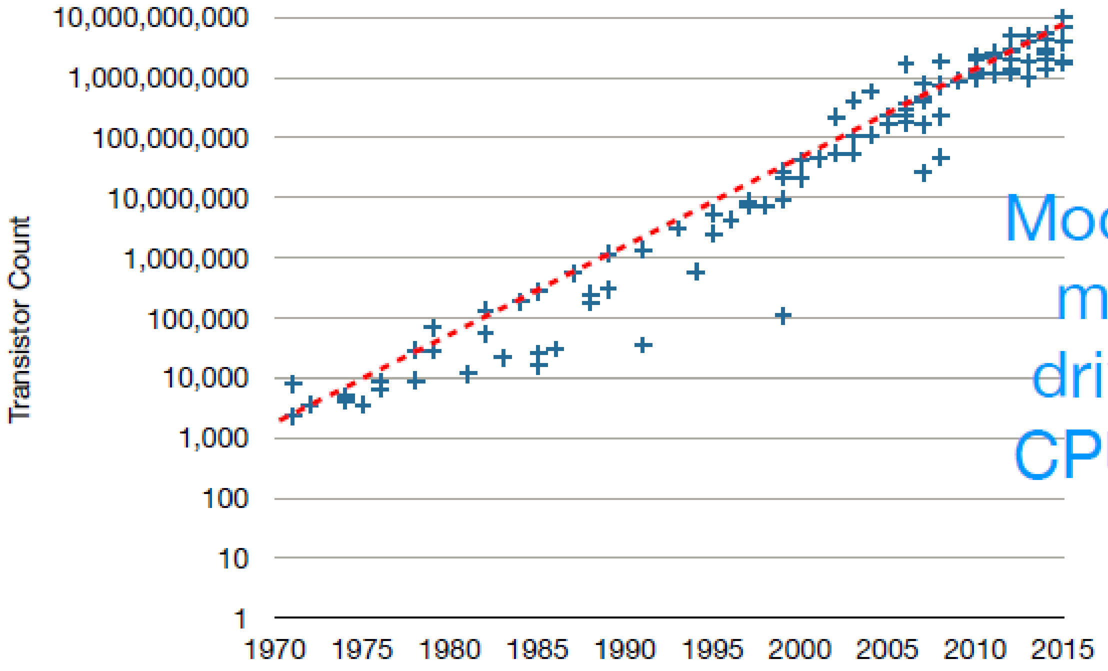
- Human hair is about 100 µm across
- Intel 4004 transistors are 10 µm across
- Intel 8088 transistors are 3 µm across
- Intel Pentium 4 transistors are 90 nm across
- Intel Core i7 transistors are 32 nm across
- Smaller transistors allow
  - More transistors per chip
  - More processing power
  - Smaller/cheaper chips

Moore's Law

The number of transistors we can build in a fixed area of silicon doubles every 12 ~ 24 months.

The chip performance would double every two years

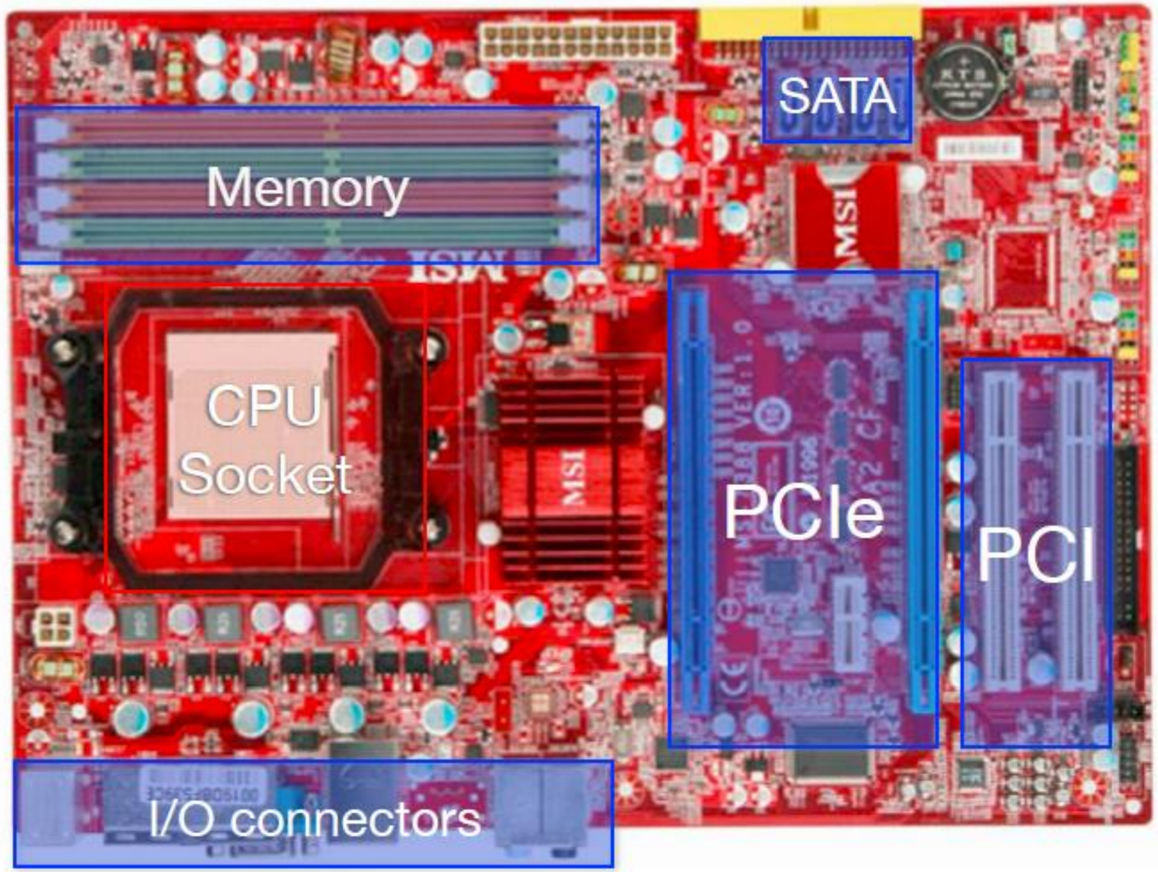
In celebration of ENIAC's 50th Anniversary, the machine was re-implemented using modern integrated circuit technology. The room-sized computer could now fit in the palm of a hand.



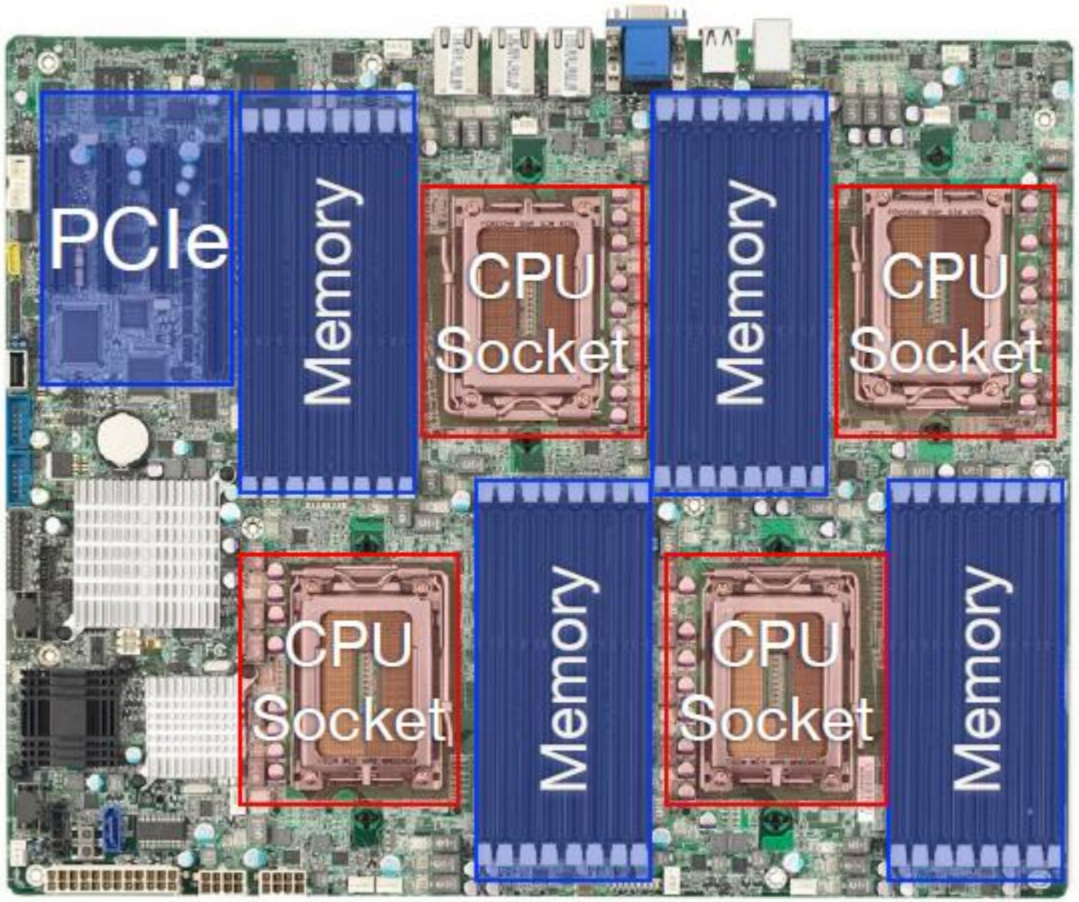
Moore's Law is the most important driver for historic CPU performance gains

Uncover a Computer

A Desktop PC

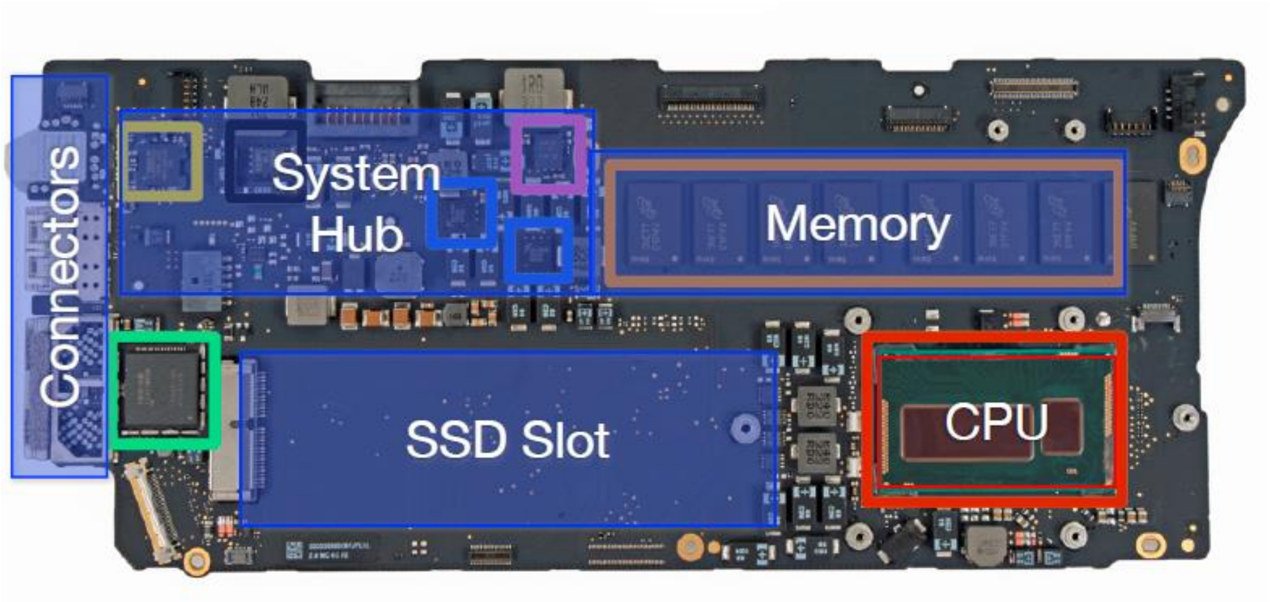


A Server

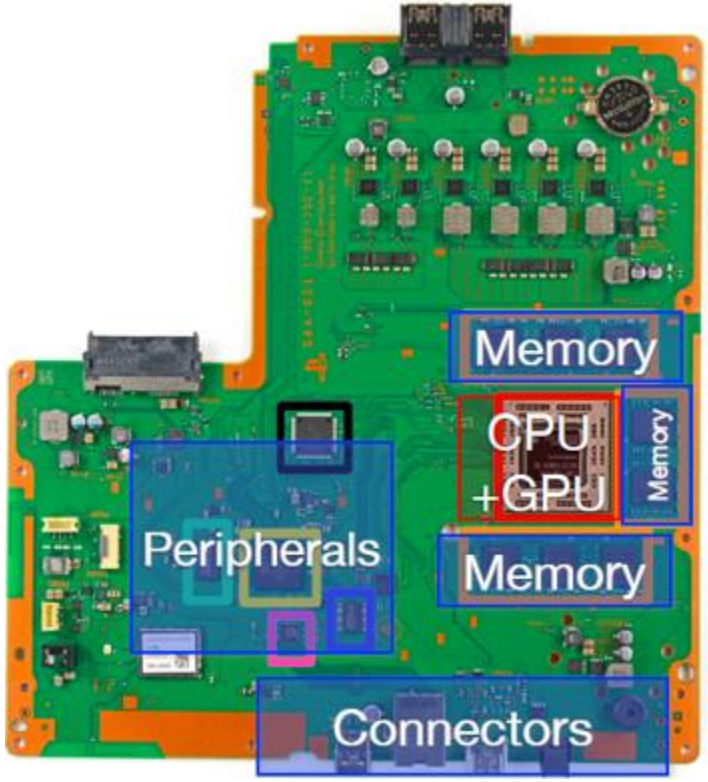


Uncover a Computer

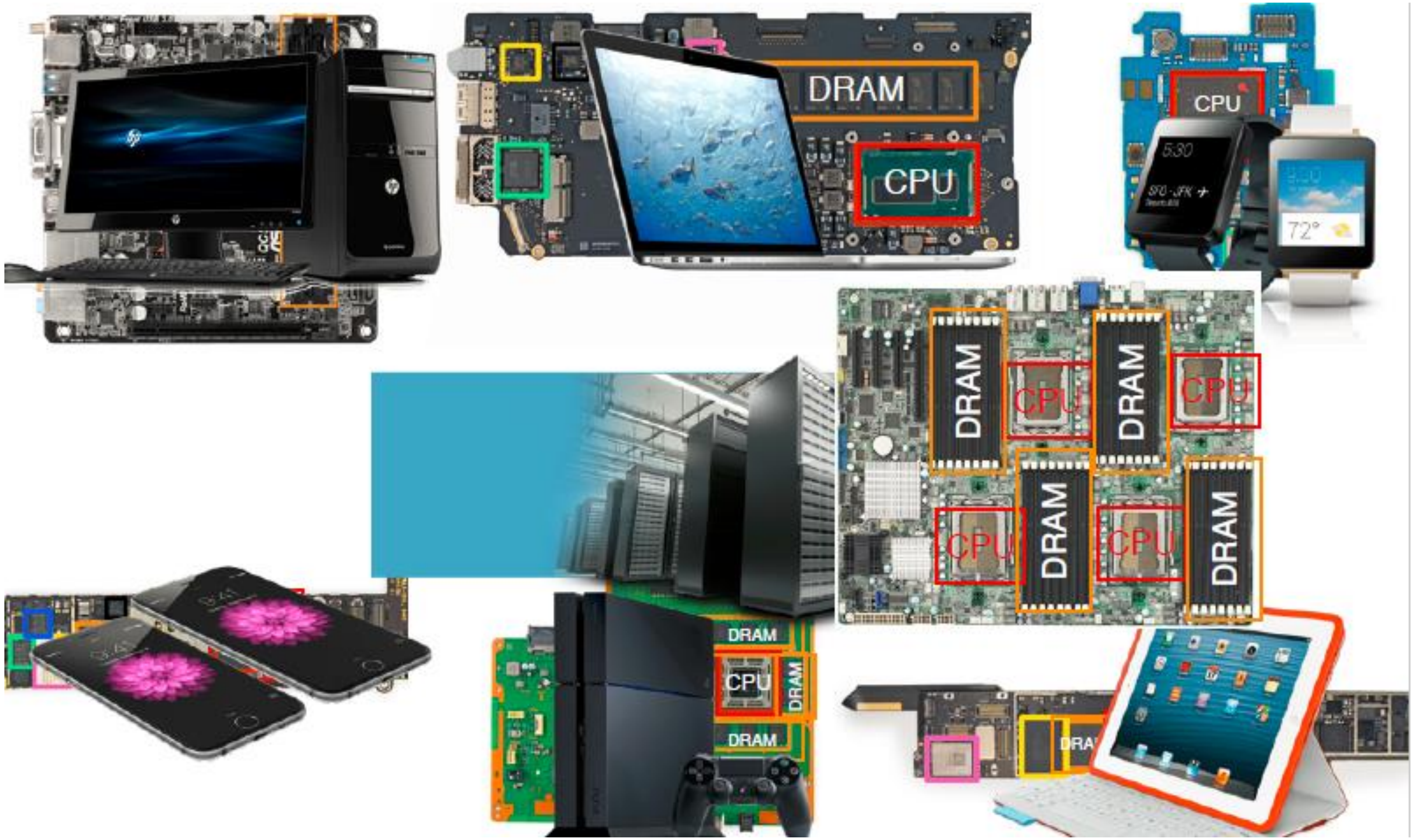
A MacBook Pro



A PlayStation 4



Uncover a Computer



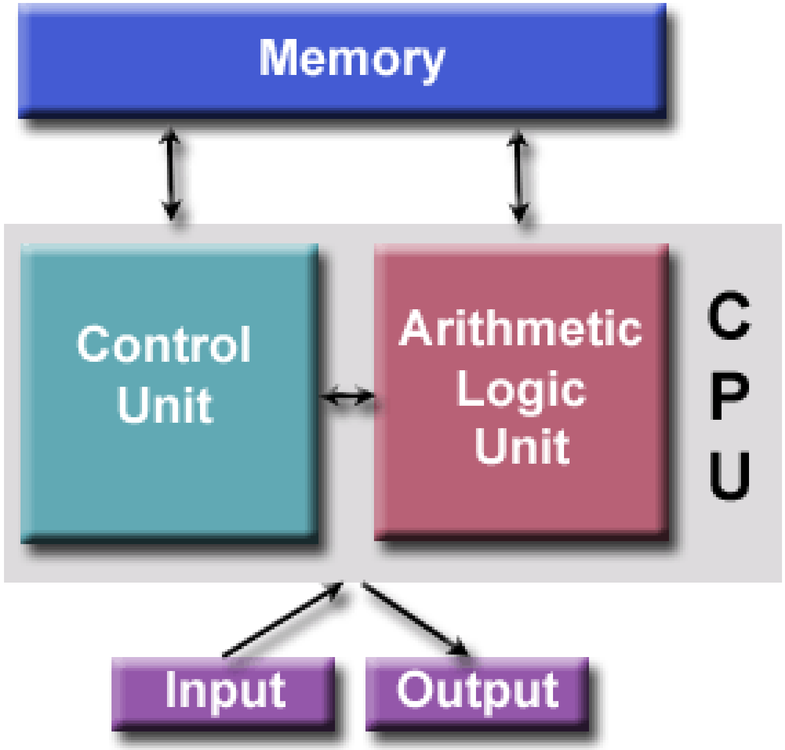
Difference faces, same spirit

Uncover a Computer

Von Neumann architecture (also called Princeton architecture) is still the state-of-the-art computing architecture adopted.

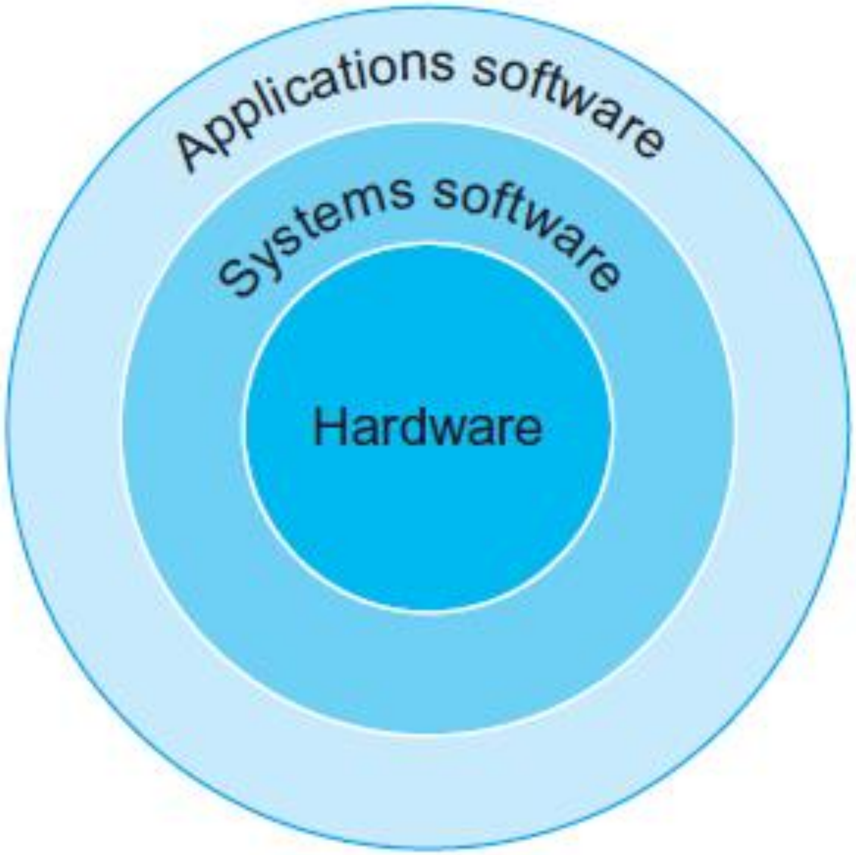
Even in Quantum Computing. Quantum computing differentiates by its bit representation (q-bit), but many of the quantum computers still follow the von Neumann architecture.

Other architectures exist
- Harvard architecture
- Dataflow architecture
- Neural computing
- etc.



Below Your Program

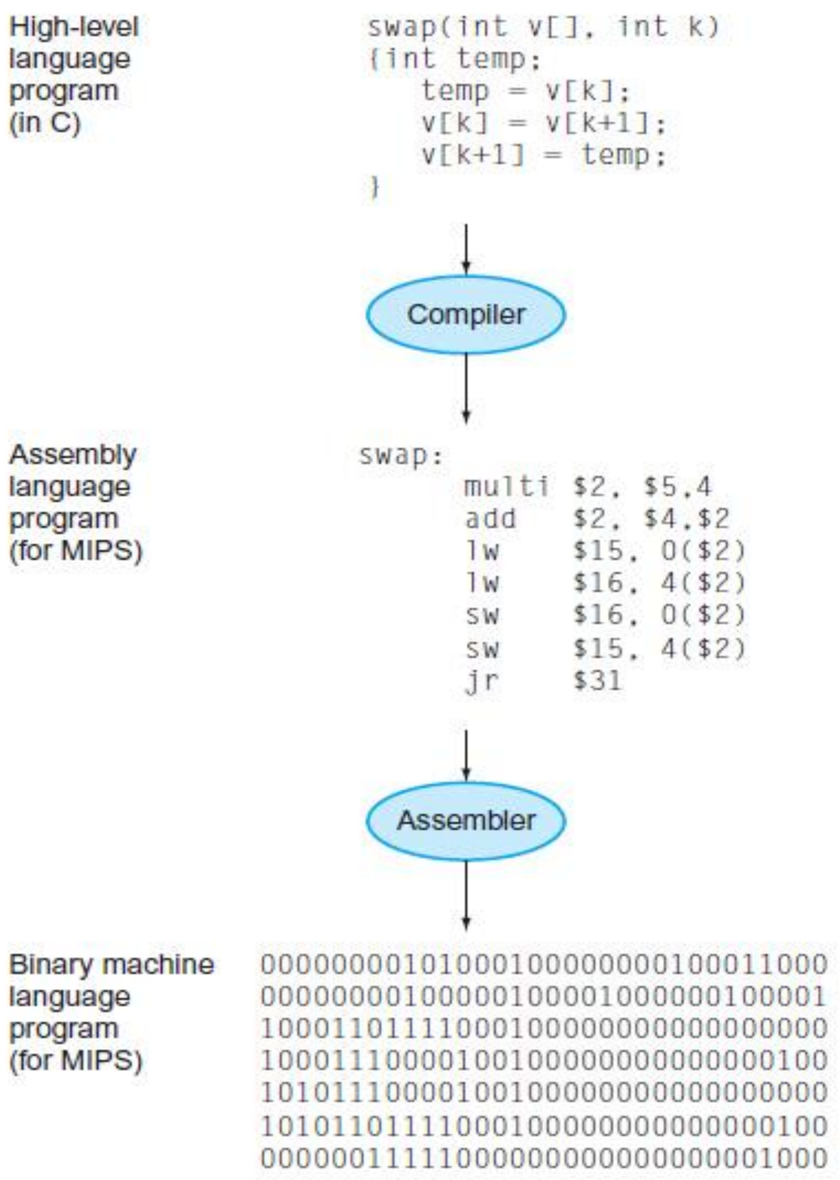
- Application software
  - Written in high-level language (HLL)
- System software
  - Compiler
    - Translate HLL code to machine code
  - Operating system
    - Handling basic input/output operations
    - Managing memory and storage
    - Scheduling tasks & sharing resources
- Hardware
  - Processor
  - Memory
  - I/O controllers



Programming the Machine

- To actually speak to electronic hardware, we need to send electrical signals
- The easiest signal for computers to understand – on/off
  - This corresponds to turning on and off transistors
- Therefore the hardware can only understand binary representations
- How can we program the machine?
  - Suppose you write a program in C, how can the machine understand it?
- Solution
  - Translate high-level language code into intermediate-level code (assembly code) which is more human-friendly
  - Then translate the assembly code into the machine's language (binary code).

Programming the Machine



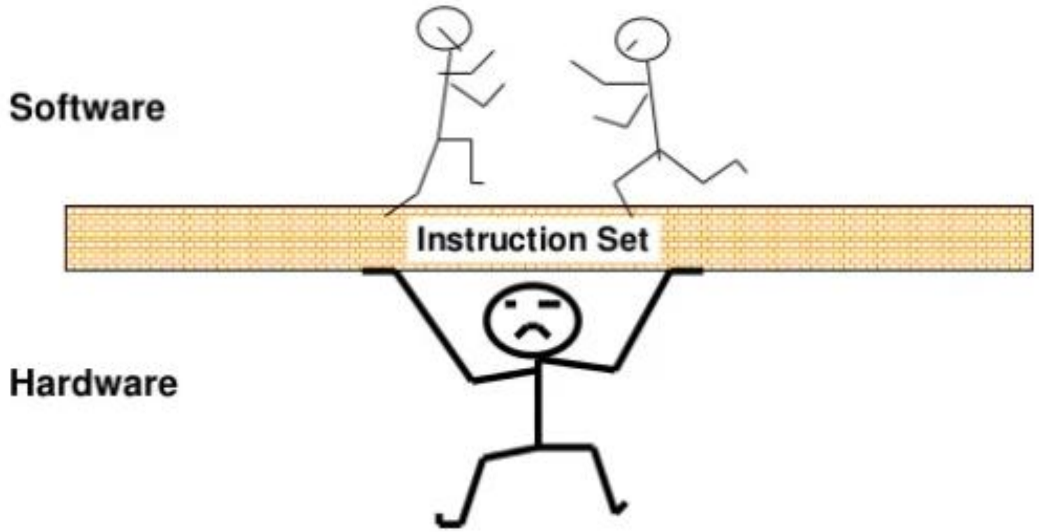
- Compiler – A program that translates high-level language statements into assembly language statements
- Instruction – A command that computer hardware understands and obeys
- Assembler – A program that translates a symbolic version of instructions into the binary versions
- Assembly language – A symbolic representation of machine instructions
- Machine language – A binary representation of machine instructions

Instruction Set Architecture

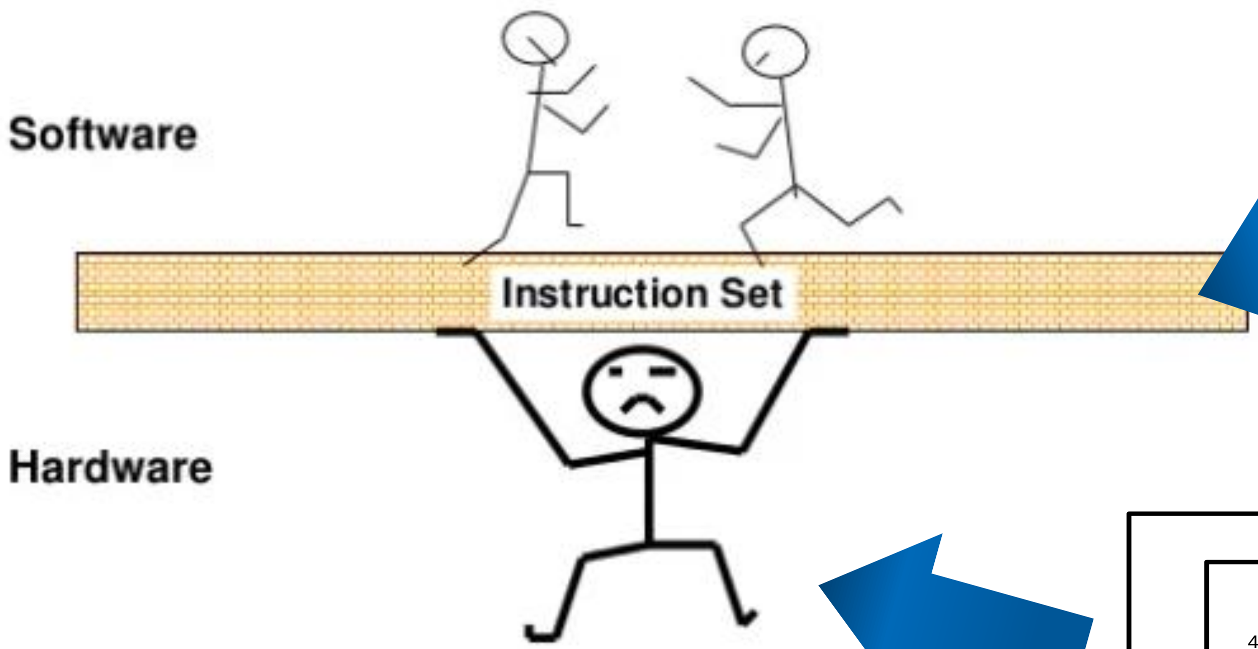
- Defines the set of instructions that a computer/processor can execute

- The contract between the hardware and software
  - "Contract": given an ISA, your sw and hw must be designed for the ISA! A glue for high and low levels of the system!

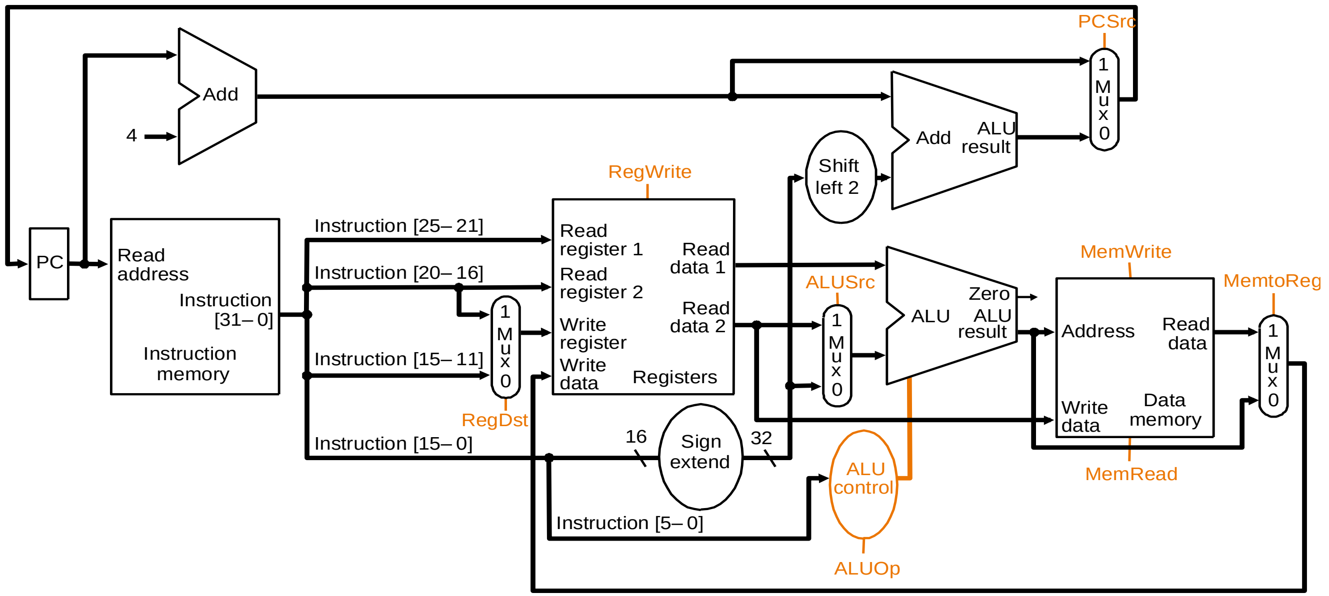
- Example ISAs:
  - x86: intel Xeon, intel Core i7/i5/i3, intel atom, AMD Athlon/Opteron, AMD FX, AMD A-series
  - ARM: Apple A-Series, Qualcomm Snapdragon, TIOMAP, NVidia Tegra
  - MIPS: Sony/Toshiba Emotion Engine, MIPS R-4000(PSP)
  - DEC Alpha, PowerPC, IA-64, SPARC and so on …



Instruction Set Architecture




```
hanoi:    addi $a0, $a0, -1
          bne  $a0, $zero, hanoi_1
          addi $v0, $zero, 1
          j    return
hanoi_1:  jal  hanoi
          sll  $v0, $v0, 1
          addi $v0, $v0, 1
return:   jr   $ra
```



What you will learn

- **The binary number fundamentals – an deeper view from CSF**
- **What determines the performance of your computer**
- **The assembly language**
  - How does software instruct the hardware to perform needed functions
- **How programs are translated into the machine language**
- **How does the hardware execute the machine language**
- **How computers communicate with each other**

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Stay Tuned.