What is the study of Computer Architecture?

It's the study of the ___________ of computers

- **Structure**: static arrangement of the parts
- **Organization**: dynamic interaction of the parts and their control
- **Implementation**: design of specific building blocks
- **Performance**: behavioral study of the system or of some of its components
What is a Computer Architecture

- Two definitions:
  - (1) Architecture is an **interface** between layers
  - ISA is the interface between hardware and software
  - ISA is what is visible to the programmer (and ISA might be different for O.S. and applications)
- ISA consists of:
  - instructions (operations and how they are encoded)
  - information units (size, how they are addressed etc.)
  - registers (or more generally processor state)
  - input-output control
  - Execution model
(2) The microarchitecture (organization)
- the basic blocks of a computer system, more specifically
  - basic blocks of the CPU
  - basic blocks of the memory hierarchy
- how are the basic blocks designed, controlled, connected?
- Organization used to be transparent to the ISA.
- Today more and more of the ISA is “exposed” to the user/compiler.
The Babbage Machine

The Babbage Difference Engine (1832)

25,000 parts

cost: £17,470
ENIAC
The First Transistor
The integrated circuit

1966, ECL Logic
Intel 4004

~ 1000 xtrs
1971
Pentium IV

~ 44M xtrs
2000
Memory

- Human memory
- Human DNA
- Book
- Encyclopedia
- 2 hrs CD Audio
- 30 sec HDTV

Number of bits per chip

Year


10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^10

0.08µm 0.15-0.2µm 0.15-0.2µm 0.25-0.3µm 0.35-0.4µm 0.5-0.6µm 0.7-0.8µm 1.0-1.2µm 1.6-2.4µm

16 Mbits 64 Mbits 256 Mbits 4 Gbits 1 Gbits 4 Gbits 64 Gbits
Illustration of Moore’s Law
Power Dissipation

![Graph showing power dissipation over time and processor generations.](image)
Evolution of Intel Microprocessor Speeds
Why have an ISA?

- Computers that have the same (or very similar) ISA
  - Compatibility of software between various implementations
- IBM
  - 704, 709, 70xx etc. From 1955 till 1965
  - 360, 370, 43xx, 33xx From 1965 to the present
  - Power PC
- DEC
  - PDP-11, VAX From 1970 till 1985
  - Alpha (now Compaq, now HP) in 1990’s
More computer families

- **Intel**
  - Early micros 40xx in early 70’s
  - x86 (086,…,486, Pentium, Pentium Pro, Pentium 3, Pentium 4) from 1980 on
  - IA-64 (Itanium) in 2001
- **SUN (Berkeley RISC)**
  - Sparc, Ultra Sparc 1985 on
- **MIPS-SGI (Stanford RISC)**
  - Mips 2000, 3000, 4400, 10000 from 1985 on
MIPS is a RISC

- RISC = Reduced Instruction Set Computer
- R could also stand for “regular”
- All arithmetic-logical instructions are of the form
- MIPS (as all RISC’s) is a Load-Store architecture
  - ALU operates only on operands that are in registers
  - The only instructions accessing memory are load and store

\[ R_a \leftarrow R_b \text{ op } R_c \]
Registers

- Registers are the “bricks” of the CPU
- Registers are an essential part of the ISA
  - Visible to the hardware and to the programmer
- Registers are
  - Used for high speed storage for operands. For example, if variables \( a, b, c \) are in registers 8, 9, 10 respectively
    
    ```
    add $8,$9,$10  # \( a = b + c \)
    ```
  - Easy to name (most computers have 32 registers visible to the programmer and their names are 0, 1, 2, ..., 31)
  - Used for addressing memory