Computer Architecture and Operating System

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Evolution of Computer Systems

Introduction

- Computers have become part and parcel of our daily lives.
  - They are everywhere (embedded systems?)
  - Laptops, tablets, mobile phones, intelligent appliances.
- It is required to understand how a computer works.
  - What are there inside a computer?
  - How does it work?
- We distinguish between two terms: *Computer Architecture* and *Computer Organization.*

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- **Computer Organization:**
  - Design of the components and functional blocks using which computer systems are built.
  - **Analogy**: civil engineer's task during building construction (cement, bricks, iron rods, and other building materials).
- **Computer Architecture:**
  - How to integrate the components to build a computer system to achieve a desired level of performance.
  - **Analogy**: architect's task during the planning of a building (overall layout, floorplan, etc.).

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Historical Perspective

- Constant quest of building automatic computing machines have driven the development of computers.
  - Initial efforts: mechanical devices like pulleys, levers and gears.
  - During World War II: mechanical relays to carry out computations.
  - Vacuum tubes developed: first electronic computer called ENIAC.
  - Semiconductor transistors developed and journey of miniaturization began.
    - SSI → MSI → LSI → VLSI → ULSI → …. Billions of transistors per chip

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Generation	Main Technology	Representative Systems
First (1945-54)	Vacuum tubes, relays	Machine & assembly language ENIAC, IBM-701
Second (1955-64)	Transistors, memories, I/O processors	Batch processing systems, HLL IBM-7090
Third (1965-74)	SSI and MSI integrated circuits Microprogramming	Multiprogramming / Time sharing IBM 360, Intel 8008
Fourth (1975-84)	LSI and VLSI integrated circuits	Multiprocessors Intel 8086, 8088
Fifth (1984-90)	VLSI, multiprocessor on-chip	Parallel computing, Intel 486
Sixth (1990 onwards)	ULSI, scalable architecture, post-CMOS technologies	Massively parallel processors Pentium, SUN Ultra workstations

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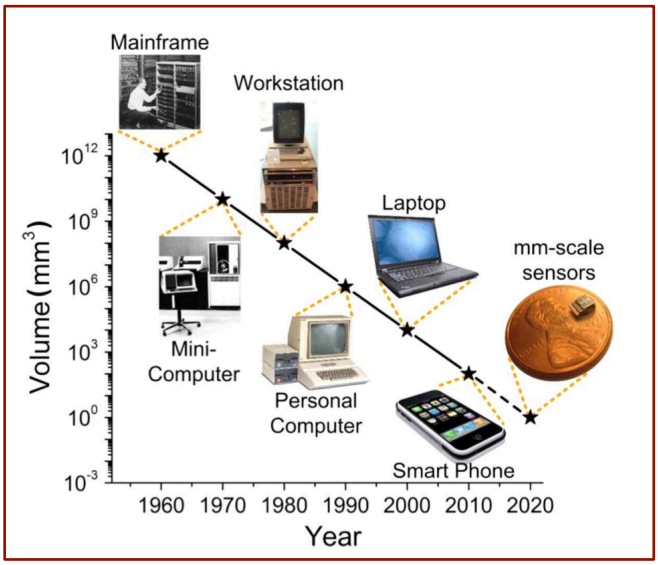
Evolution of the Types of Computer Systems

The future?

- Large-scale IoT based systems.
- Wearable computing.
- Intelligent objects.



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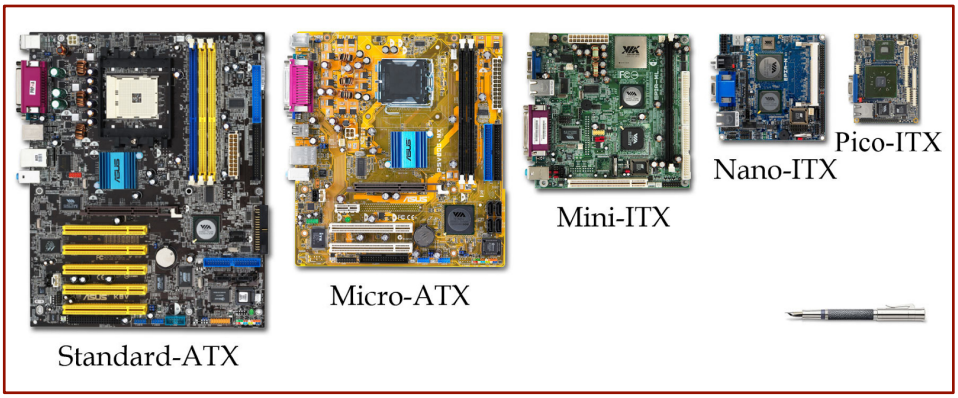
Evolution of PC form factors over the years



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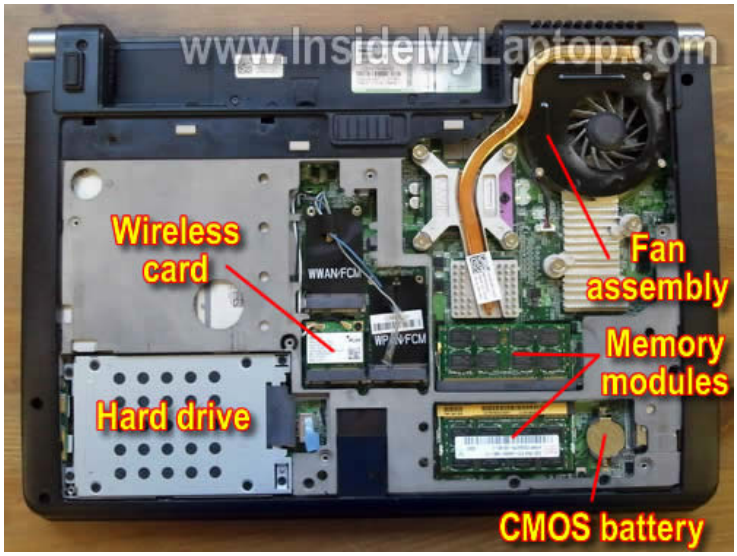
Inside a laptop

- Miniaturization in feature sizes of all parts.
- Hard drive getting replaced by flash-based memory devices.
- Cooling is a major issue.



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Moore's Law

- Refers to an observation made by Intel co-founder Gordon Moore in 1965.
  - The number of transistors per square inch on integrated circuits shall double every year.
  - Moore's law predicts that this trend will continue into the foreseeable future.
- Although the pace has slowed, the number of transistors per square inch has since doubled approximately every 18 months.
  - This is used as the current definition of Moore's law.

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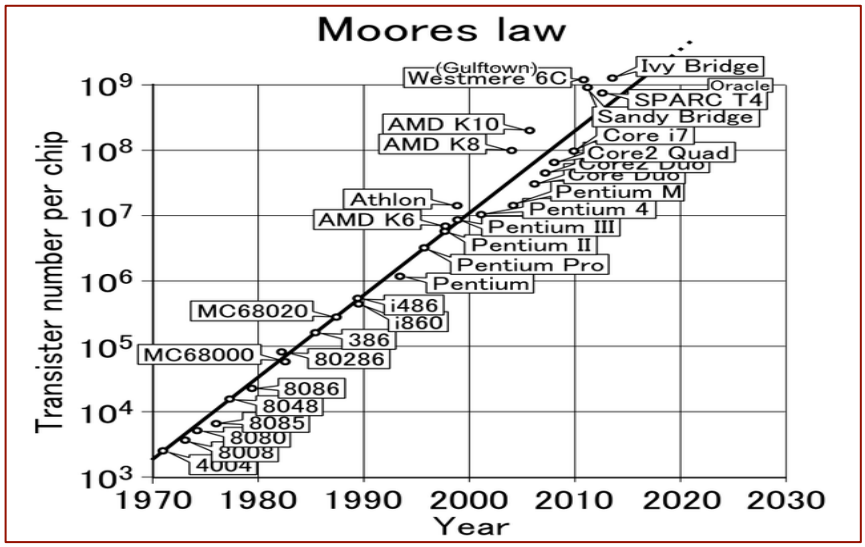
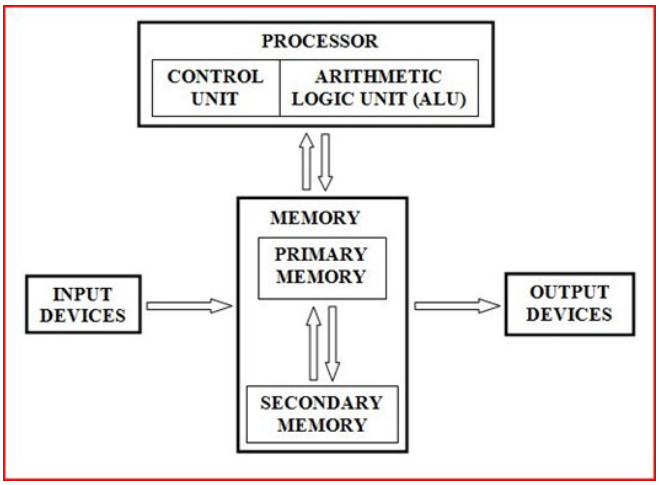
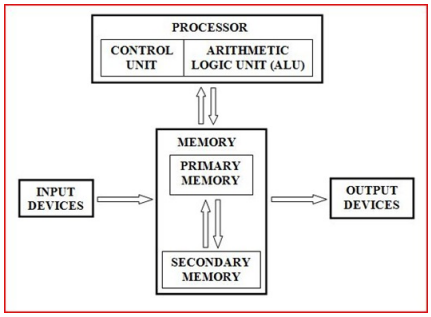


Simplified Block Diagram of a Computer System

- All instructions and data are stored in memory.
- An instruction and the required data are brought into the processor for execution.
- Input and Output devices interface with the outside world.





• Inside the Processor

- Also called *Central Processing Unit* (CPU).
- Consists of a *Control Unit* (CU) and an *Arithmetic Logic Unit* (ALU).
  - All calculations happen inside the ALU.
  - CU generates sequence of control signals to carry out all operations.
- The processor *fetches* an instruction from memory for execution.
  - An instruction specifies the exact operation to be carried out.
  - It also specifies the data that are to be operated on.
  - A *program* refers to a set of instructions that are required to carry out some specific task (e.g. sorting a set of numbers).

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• What is the role of ALU?

- It contains several *registers*, some general-purpose and some special-purpose, for temporary storage of data.
- It contains circuitry to carry out *logic operations*, like AND, OR, NOT, shift, compare, etc.
- It contains circuitry to carry out *arithmetic operations* like addition, subtraction, multiplication, division, etc.
- During instruction execution, the data (operands) are brought in and stored in some registers, the desired operation carried out, and the result stored back in some register or memory.
  - *Fetch-Decode-Execute cycle.*

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- **What is the role of control unit?**
  - Acts as the nerve center that senses the states of various functional units and sends control signals to control their states.
  - To carry out a specific operation (say, R1 ← R2 + R3), the control unit must generate control signals in a specific sequence.
    - Enable the outputs of registers R2 and R3.
    - Select the addition operation.
    - Store the output of the adder circuit into register R1.
  - When an instruction is fetched from memory, the operation (called *opcode*) is decoded by the control unit, and the control signals issued.

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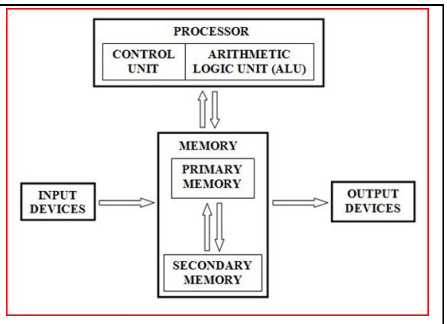

- **Inside the Memory Unit**
  - Two main types of memory subsystems.
    - *Primary or Main memory*, which stores the active instructions and data for the program being executed on the processor.
    - *Secondary memory*, which is used as a backup and stores all active and inactive programs and data, typically as files.
  - The processor only has direct access to the primary memory.
  - In reality, the memory system is implemented as a hierarchy of several levels.
    - L1 cache, L2 cache, L3 cache, primary memory, secondary memory.
    - Objective is to provide faster memory access at affordable cost.

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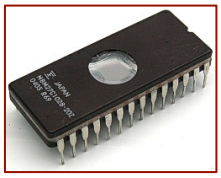

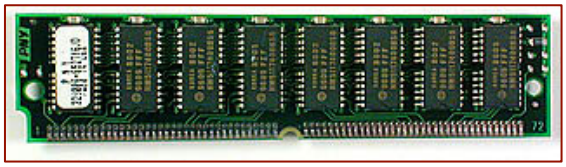

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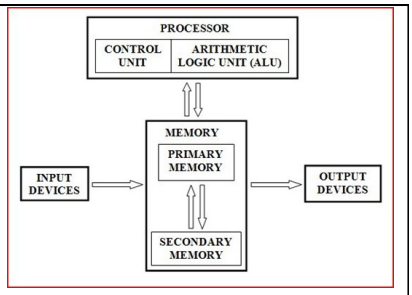
Input Devices



- Used to feed data to the computer system from the external environment.
  - Data are transferred to the processor/memory after appropriate encoding.
- Common input devices:
  - Keyboard
  - Mouse
  - Joystick
  - Camera

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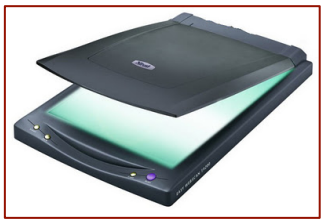



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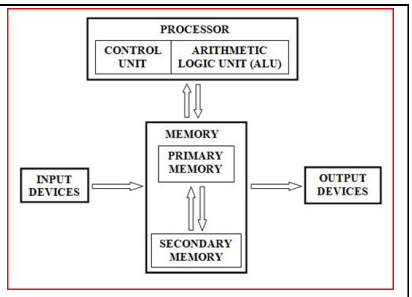
Output Devices



- Used to send the result of some computation to the outside world.
- Common output devices:
  - LCD/LED screen
  - Printer and Plotter
  - Speaker / Buzzer
  - Projection system

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