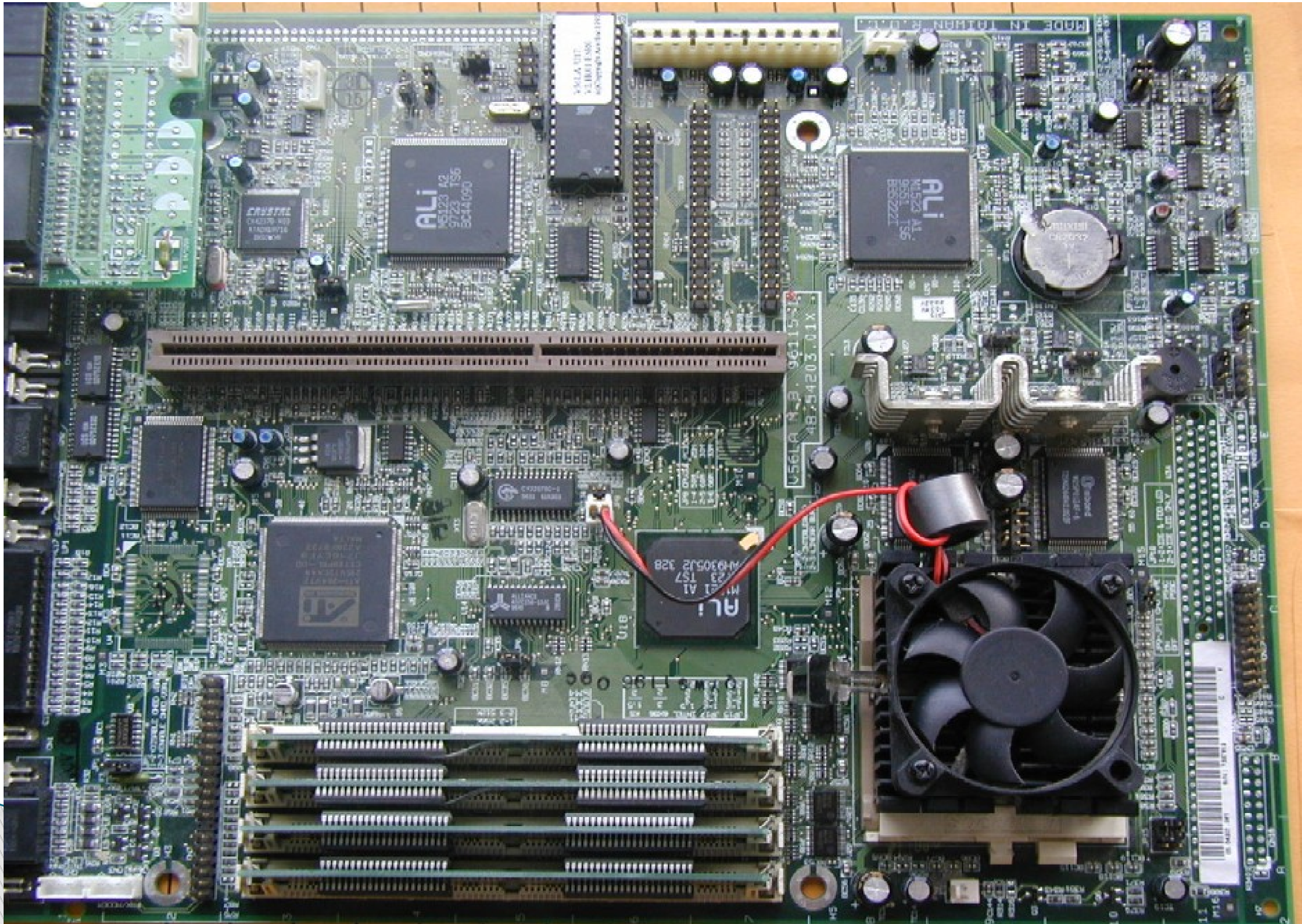
Computer architecture

Introduction

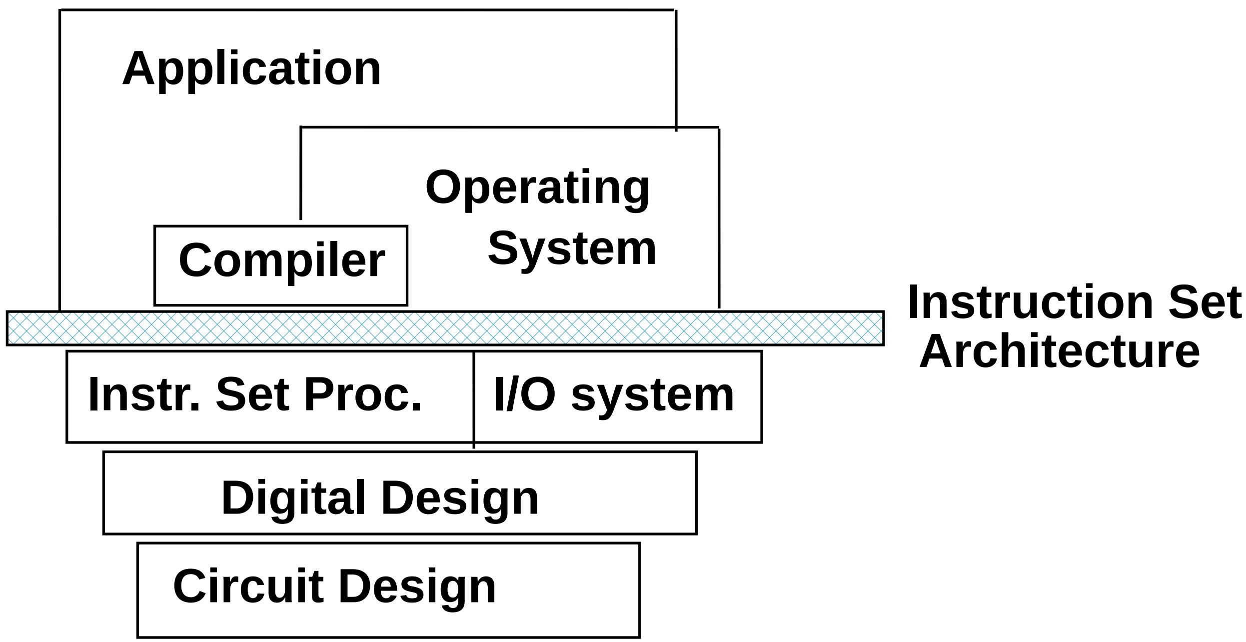
Computer Architecture



What is "Computer Architecture”?

A system concept integrating software, hardware, and firmware to specify the design of computing systems

° Co-ordination of *levels of abstraction*



° Under a set of rapidly changing *Forces*

Introduction

- *Consider three terms* – Computer organization, computer architecture and computer design
- *Computer Organization* refers to the level of concept between digital logic level and OS.
- The major components are functional units or subsystems that correspond to specific pieces of hardware built from the lower level building blocks.

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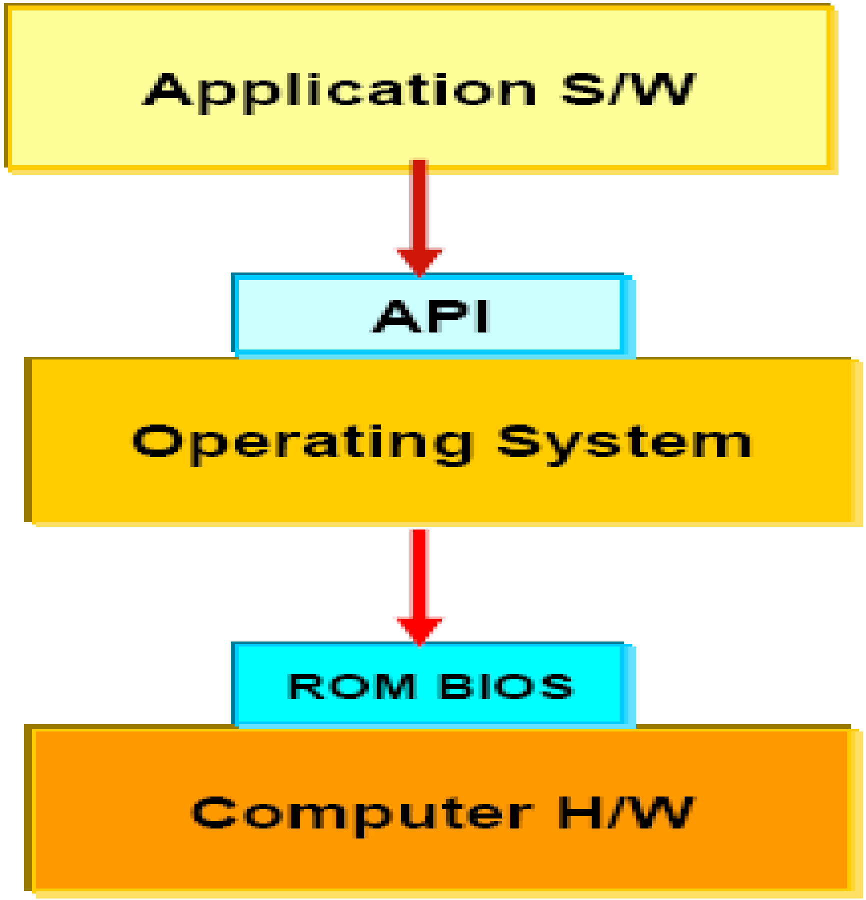

Introduction

- *Computer organization* is concerned with the way the hardware components
- Operation and connection together to form the computer system.
- It is concerned with all physical aspects of computer systems e.g. circuit design, control signals, memory types.
- The various components are assumed to be placed for proper functioning

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- *Computer design* is concerned with the hardware design of the computer.
- Once the computer specifications are formulated, designer develops the hardware.
- Determine what hardware should be used and how the parts should be connected.
- Sometimes referred to as computer implementation.

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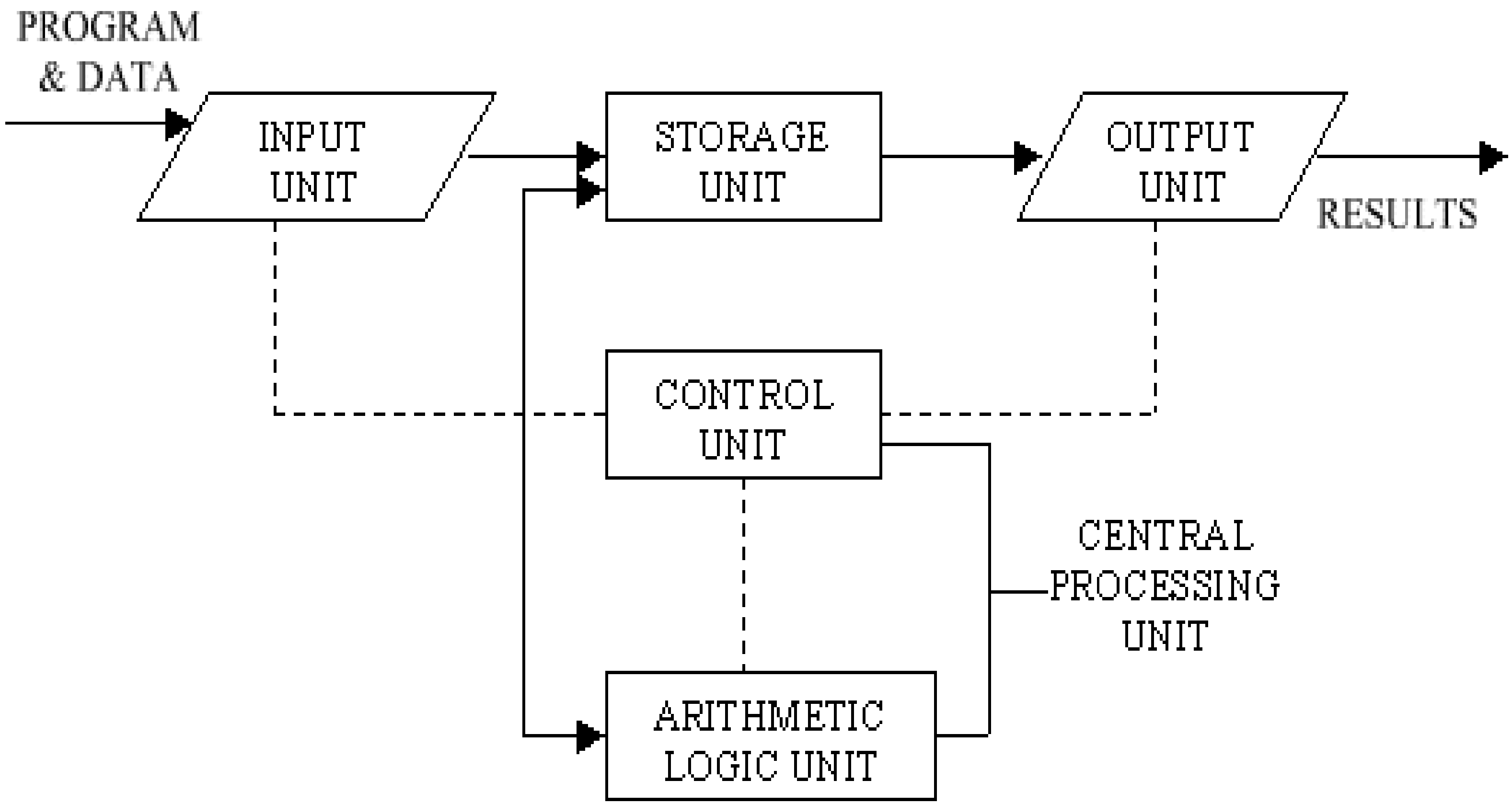
- *Computer architecture* is concerned with the structure and behavior of the computer as seen by the users.
- It includes the information formats, the instruction set, and techniques for addressing memory.
- It concerns with the specification of processors and memories, and structuring them to gather into a computer system.
- It deals with all logical aspects e.g. instruction sets, instruction formats, data types, addressing modes.

Introduction

- Why study computer architecture?
  - Design better programs, including system software such as compilers, operating systems, and device drivers.
  - Optimize program behavior.
  - Evaluate (benchmark) computer system performance.
  - Understand time, space, and price tradeoffs.

Introduction

Basic computer operation



Introduction

- A computer performs basically five major operations or functions irrespective of their size and make. These are:
  - 1) it accepts data or instructions by way of input,
  - 2) it stores data,
  - 3) it can process data as required by the user,
  - 4) it gives results in the form of output, and
  - 5) it controls all operations inside a computer.

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- **Basic Operational Concepts of a Computer**
- Most computer operations are executed in the ALU (arithmetic and logic unit) of a processor.
- Example: to add two numbers that are both located in memory.
  - Each number is brought into the processor, and the addition is carried out by the ALU.
  - The sum then may be stored in memory or retained in the processor for immediate use.

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- **Registers**
  - When operands are brought into the processor, they are stored in high-speed storage elements (registers).
  - A register can store one piece of data (8-bit registers, 16-bit registers, 32-bit registers, 64-bit registers, etc…)
  - Access time to registers are faster than access times to the fastest cache unit in the memory hierarchy.

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- **Instructions**
- Instructions for a processor are defined in the ISA (Instruction Set Architecture)
- Typical instructions include:
    - – Mov BX, LocA
  - Fetch the instruction
  - Fetch the contents of memory location LocA
  - Store the contents in general purpose register BX

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- **BUS STRUCTURES**:
  - A bus is basically a subsystem which transfers data between the components of computer
  - It connects peripheral devices at the same time.
- *Some properties*:
  - In single bus structure all units are connected in the same bus than connecting different buses as multiple bus structure.
  - Multiple bus structure's performance is better than single bus structure.
  - Single bus structure's cost is cheap than multiple bus structure.

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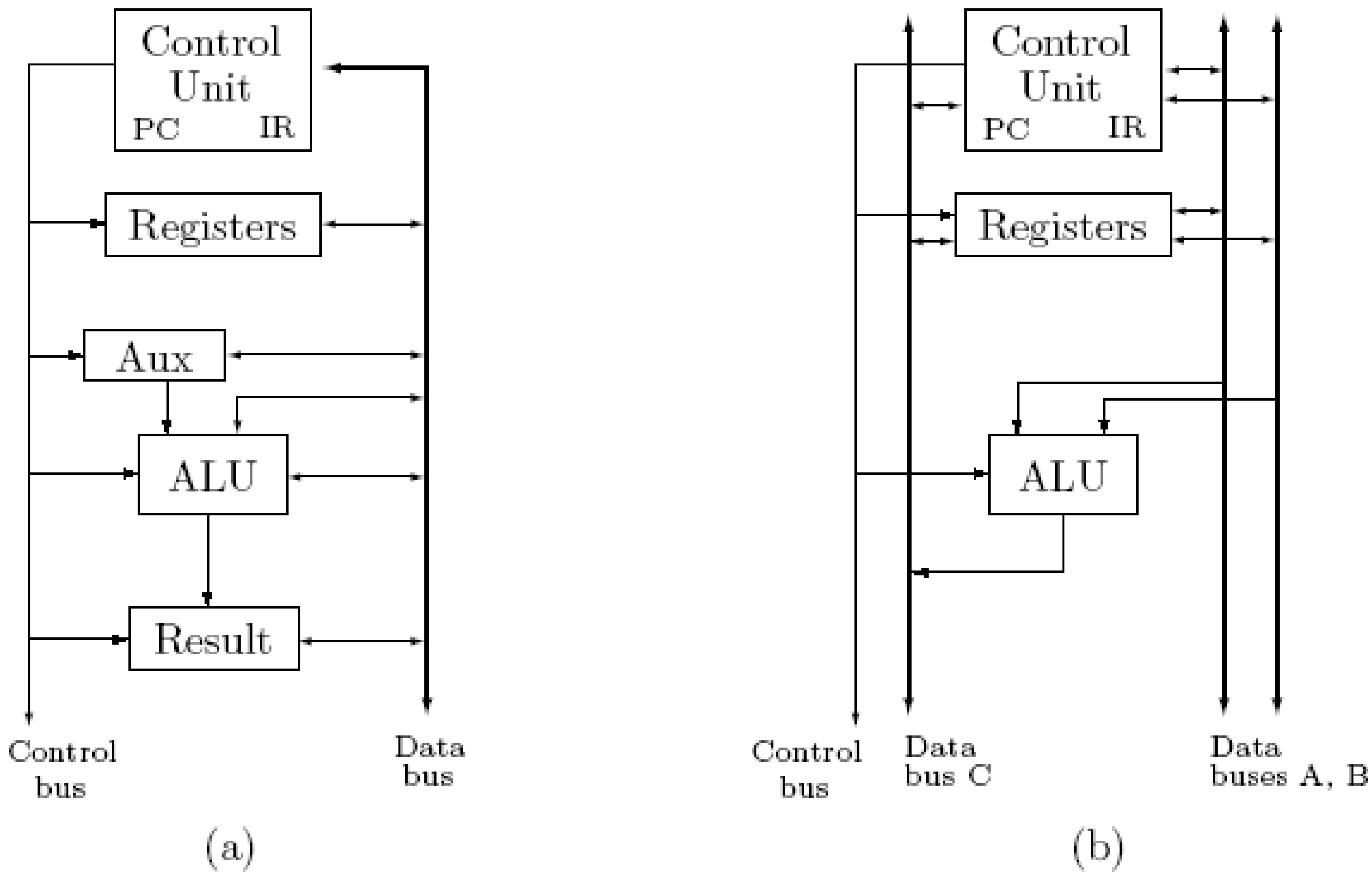
- **Single (a) and multiple (b) bus structures**



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- **Performance**
  - Computer performance is often described in terms of clock speed (usually in MHz or GHz).
  - This refers to the cycles per second of the main clock of the CPU.
  - It is somewhat misleading, as a machine with a higher clock rate may not necessarily have higher performance.
  - The manufacturers have moved away from clock speed as a measure of performance.

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- Modern CPUs can execute multiple instructions per clock cycle to speed up. Other factors influence speed:
  - The mix of functional units, bus speeds,
  - Available main and cache memory
  - The type and order of instructions in the programs being run
  - Performance is affected by a very wide range of design choices — for example, pipelining, parallel processing

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- There are two main types of speed - latency and throughput.
  - Latency is the time between the start of a process and its completion
  - Throughput is the amount of work done per unit time.
  - Interrupt latency is the guaranteed maximum response time of the system to an electronic event

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- **Why study performance?**
  - Make intelligent design choices
  - See through the marketing publicity
  - Key to understanding underlying computer organization
    - Why is some hardware faster than others for different programs?
    - What factors of system performance are hardware related? (e.g., Do we need a new machine, or a new operating system?)
    - How does a machine’s instruction set affect its performance?

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- **Design Tradeoff**
  - Maximum performance: measured by the numbers of instructions executed per sec
  - Minimum cost: measured by the size of the circuit.
  - Best performance/price: measured by the ratio of speed to size.

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- **Execution time**
  - Elapsed Time/Wall Clock Time: counts everything *(disk and memory accesses, I/O, etc.)* a useful number, but often not good for comparison purposes
  - CPU time: Doesn’t include I/O or time spent running other programs can be broken up into system time, and user time
  - Our focus on CPU time: Time spent executing actual instructions of “our” program

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- **Measure of performance:**
  - cycle time=time between ticks= seconds/cycle
  - clock rate (frequency)=cycles per second
    (1 Hz. = 1 cycle/sec)
  - A 200 MHz clock has a cycle time

    $$\frac{1}{200 \times 10^6} \times 10^9 = 5ns$$ (cycle time)

  - A 3 GHz clock has a cycle time

    $$\frac{1}{3 \times 10^9} \times 10^9 = 0.33ns$$ (cycle time)

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- The performance is measured in MIPS (million instructions per second) what is defined as:

$$MIPS = \frac{Clock / Second}{Average \quad Clocks \quad Per \quad Instruction} = \frac{Frequency \quad in \quad MHz}{CPI}$$

- Example:
  - Machine A has a clock cycle time of 10 ns. and a CPI of 2.0
  - Machine B has a clock cycle time of 20 ns. and a CPI of 1.2
  - What machine is faster for this program, and by how much?

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- Solution:

$$MIPS_A = \frac{10^{-6}/(10 \times 10^{-9})}{2} = 50$$

$$MIPS_B = \frac{10^{-6}/(20 \times 10^{-9})}{1.2} = 41.66$$

- Hence machine A is faster by a factor (50/41.66)=1.2