Microprocessors

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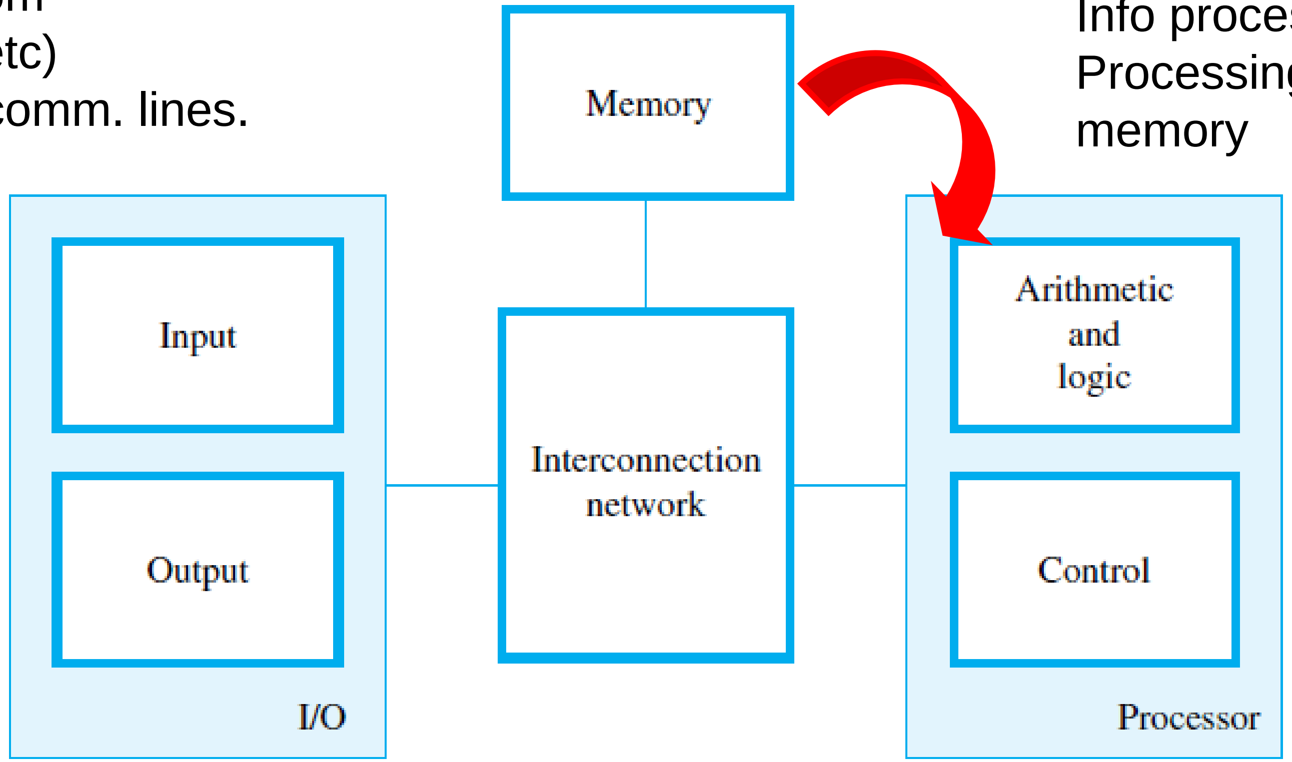
Functional Units

Computer Organization and Embedded Systems, Hamacher et. al

Functional units

accepts coded information from
human operators (keyboard etc)
other computers over digital comm. lines.

Info processed immidiately or later.
Processing steps are also stored in memory



the results are sent back to the outside world through the output unit

Actions are coordinated by the control unit

provides the means for
the functional units to exchange information and
coordinate their actions.

Some definitions/notations

- *Processor:* arithmetic and logic circuits, in conjunction with the main control circuits.
- *Input-output* (I/O) unit: Input and output equipment.
- The information handled by a computer: *instructions* or *data*.
- *Instructions*, or *machine instructions*, are explicit commands that
  - Govern the transfer of information within a computer as well as between the computer and its I/O devices
  - Specify the arithmetic and logic operations to be performed.
- *Data* are numbers and characters that are used as operands by the instructions. Stored in the memory.

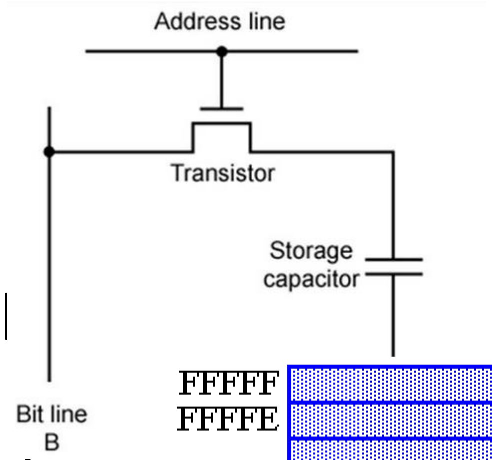
Some definitions/notations

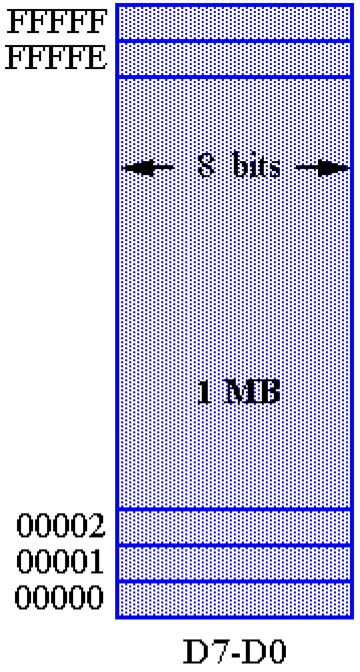
- A *program* is a list of instructions which performs a task.
  - stored in the memory.
  - The processor *fetches* the program instructions from the memory to perform
  - External *interruption* by an operator or by I/O devices connected to it is possible.
- The instructions and data handled by a computer must be *encoded* in a suitable *format*.
- Instruction, number, or character is encoded as a string of binary digits called *bits*.
- 8-bits → bytes

Memory unit

- Stores programs and data.
- Consists of a large number of semiconductor storage cells.
- Cells are handled in groups of fixed size called *words.*
- The number of bits in each word is the *word length*, typicall 32, or 64 bits.
- To provide easy access to any word in the memory, a distinct *address* is associated with each word location.

1. Primary memory (main memory)
2. Cache Memory
3. Secondary Storage





Primary memory (main memory)

- A fast memory. Programs must be stored in this memory while they are being executed.
- *Random-access memory* (RAM).
- The time required to access one word is called the *memory access time*. This time is independent of the location of the word being accessed. It typically ranges from a few nanoseconds (ns) to about 100 ns for current RAM units.

Cache Memory

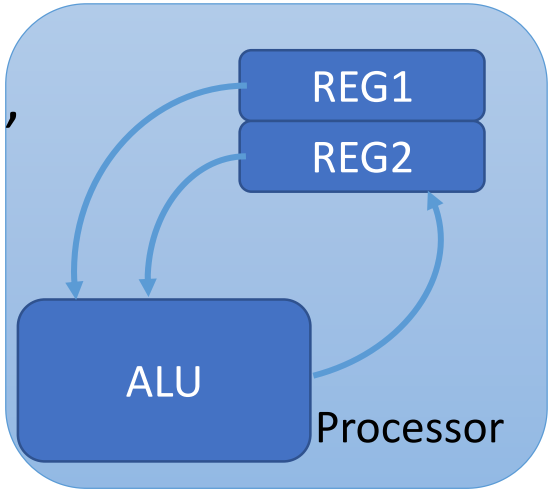
- Smaller and faster than primary memory.
- Purpose: to facilitate high instruction execution rates.
  - Be close to the processor: cache is tightly coupled with the processor and is usually contained on the same integrated-circuit chip.
  - Hold sections of a program that are currently being executed, along with any associated data.
- Operation:
  - At the start of program execution, the cache is empty.
  - As execution proceeds, instructions are fetched into the processor chip, and a copy of each is placed in the cache. The fetched data are also copied to cache.

Secondary Storage

- Primary memory does not retain information when power is turned off.
- Additional, less expensive, permanent
- Access times for secondary storage are longer than for primary memory.
- Ex. *magnetic disks*, *optical disks* (DVD and CD), and *flash memory devices*.

Arithmetic and Logic Unit

- Most computer operations are executed in the ALU:
  - Any arithmetic or logic operation, such as addition, subtraction, multiplication, division, or comparison of numbers..



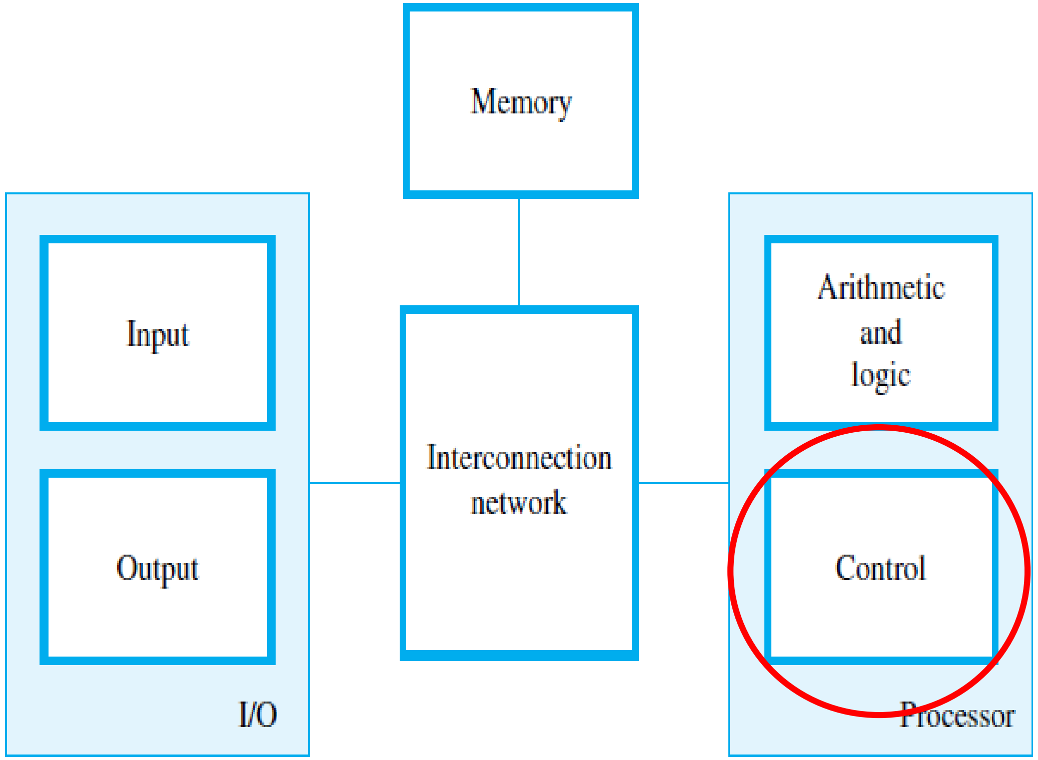
- Ex: add two numbers located in the memory
  1. They are brought into the processor.
  2. The addition is carried out by the ALU.
  3. The sum may then be stored in the memory or retained in the processor for immediate use.
- When *operands* are brought into the processor, they are stored in high-speed storage elements: *registers*. Each register can store one word of data. Access times to registers is very short.

I/O Units

- **Input Unit:** human-computer interaction tools, keyboard, touchpad, mouse, trackball, microphones, camera; digital communication facilities, other computers.
- **Output Unit:** human-computer interaction tools, printer, graphic displays, other computers.

Control Unit

- Coordination of the memory, arithmetic and logic, and I/O units.
- I/O transfers, are controlled by program instructions that identify the devices involved and the information to be transferred.
- *Timing signals* are generated by control circuits. Timing signals
    - govern the transfers and determine when a given action is to take place.
    - Manage data transfers between the processor and the memory



- Much of the control circuitry is physically distributed throughout the computer.
- A large set of control lines (wires) carries the signals used for timing and synchronization of events in all units.

Problem

- Quantify the effect on performance that results from the use of a cache in the case of a program that has a total of 500 instructions, including a 100-instruction loop that is executed 25 times. Determine the ratio of execution time without the cache to execution time with the cache. This ratio is called the *speedup*.
- Assume that main memory accesses require 10 units of time and cache accesses require 1 unit of time. We also make the following further assumptions so that we can simplify calculations in order to easily illustrate the advantage of using a cache:
- Program execution time is proportional to the total amount of time needed to fetch instructions from either the main memory or the cache, with operand data accesses being ignored.
- Initially, all instructions are stored in the main memory, and the cache is empty.
- The cache is large enough to contain all of the loop instructions.

Solution

- Execution time without the cache is

$T = 400 \times 10 + 100 \times 10 \times 25 = 29{,}000$

- Execution time with the cache is

$T_{cache} = 500 \times 10 + 100 \times 1 \times 24 = 7{,}400$

- Therefore, the speedup is $T/T_{cache} = 3.92$