Computers

Hardware

Acknowledgments

Thanks to the following web site and people for the materials and images used in this presentation:

-Wikipedia
-Prof. Patrice Koehl
-Sean Davis
-Nick Puketza
-http://microsoft.toddverbeek.com
-http://www.webopedia.com
-http://www.engin.umd.umich.edu/
-http://www.dell.com
-http://www.intel.com
-http://www.apple.com
-http://www.ibm.com
-http://homepages.feis.herts.ac.uk/~msc_ice/unit2/
-http://www.howstuffworks.com

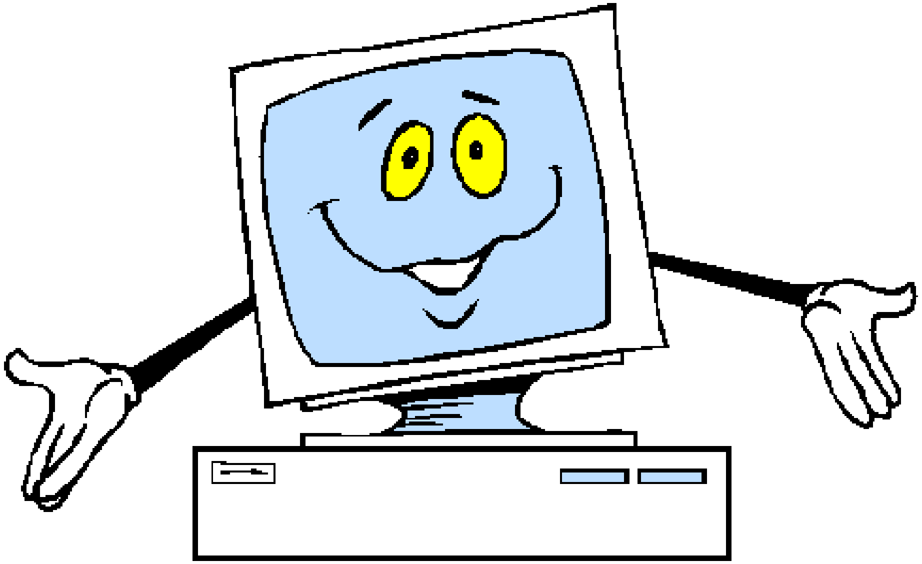
Computer Layers

Hardware

BIOS

Operating System

Applications



Computer Layers

<u>Hardware</u>

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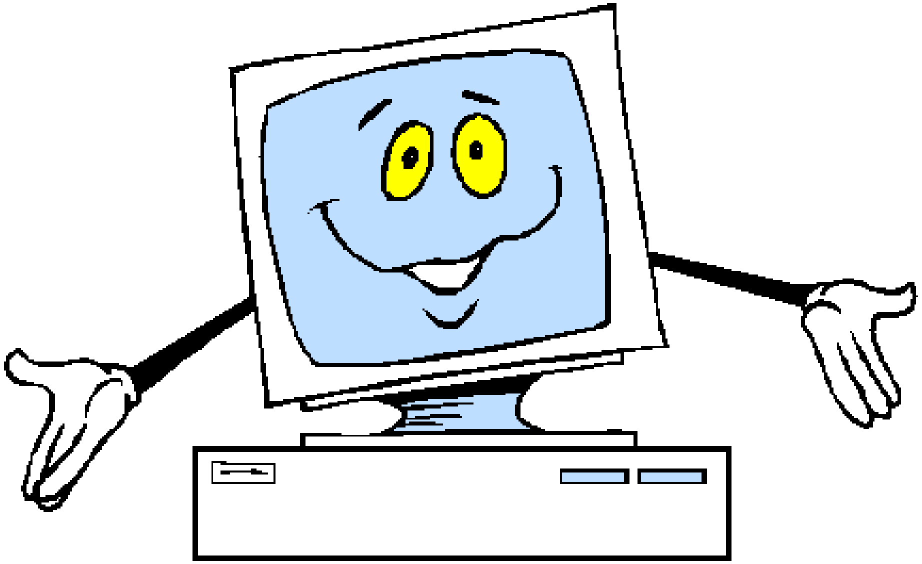


Computers

- Laptop, desktop
- PC
- Mainframe
- Supercomputer
- Server farm and data center

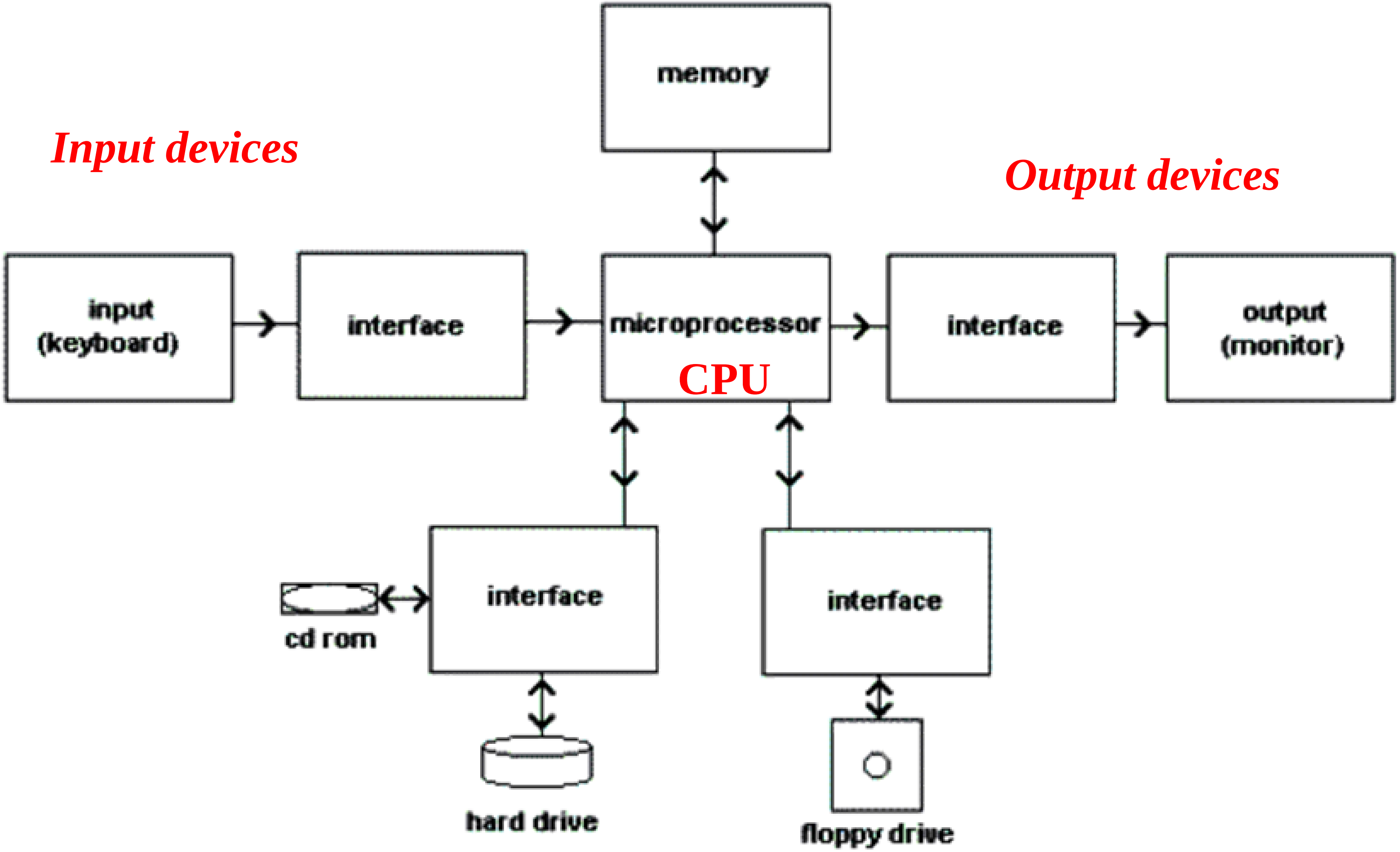
Looking inside a computer…

Computers come in different shapes and sizes, from small laptops (notebooks), desktops to mainframe computers. They all share however the same internal architecture!

Computer: basic scheme

Input devices

Output devices



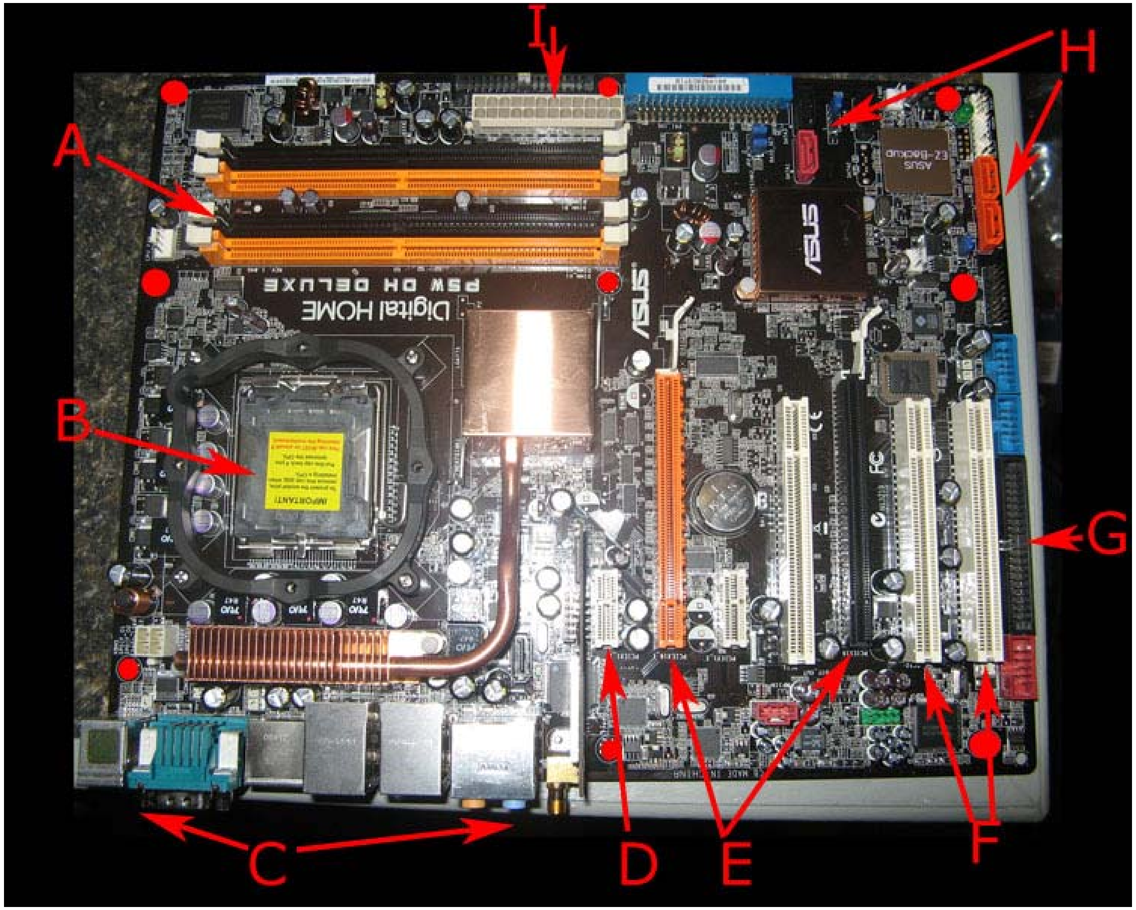
Storage

The motherboard: backbone of the computer

Power supply connector

Slot for memory: RAM

Slot for CPU

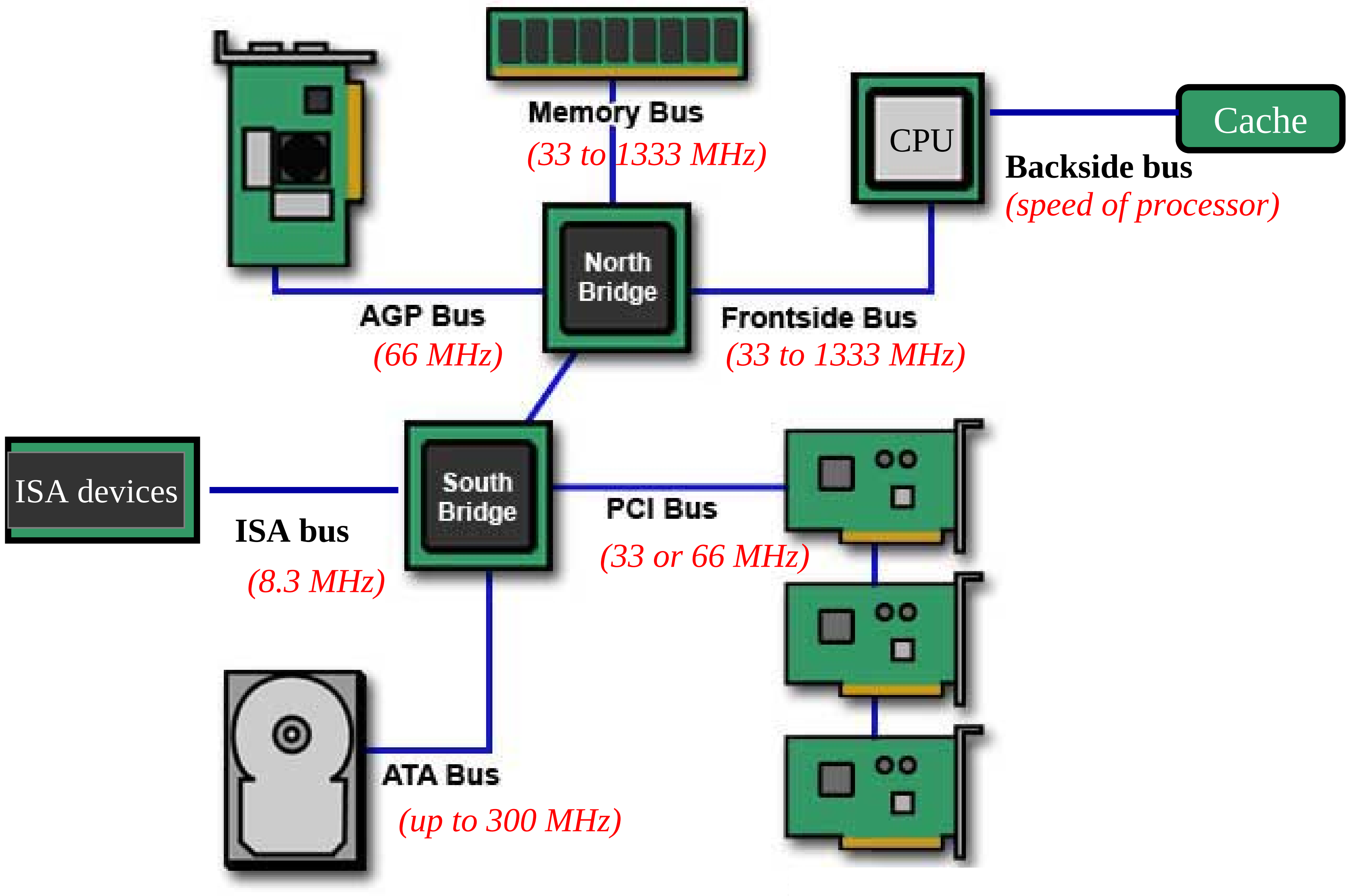


Hard drive connectors

Input/Output: Keyboard, Mouse,…

Extension cards: Video, sound, internet…

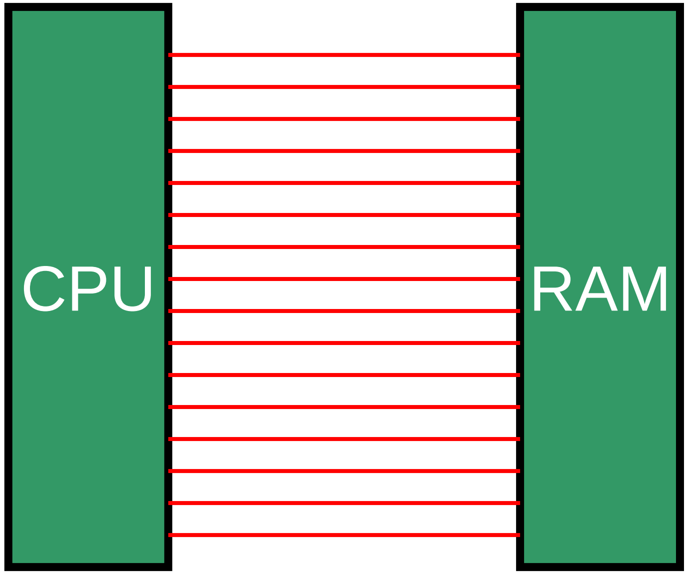
Hardware communication: buses



Hardware communication: buses

The memory bus:

a 16 bit bus



Communication between the CPU and the RAM is defined by:

-the CPU speed
-The RAM speed
-The number of bits transferred per cycle

Other buses:

USB, Firewire, PCI Express,…

CPU

The Central Process Unit (CPU): The "brain" of the computer

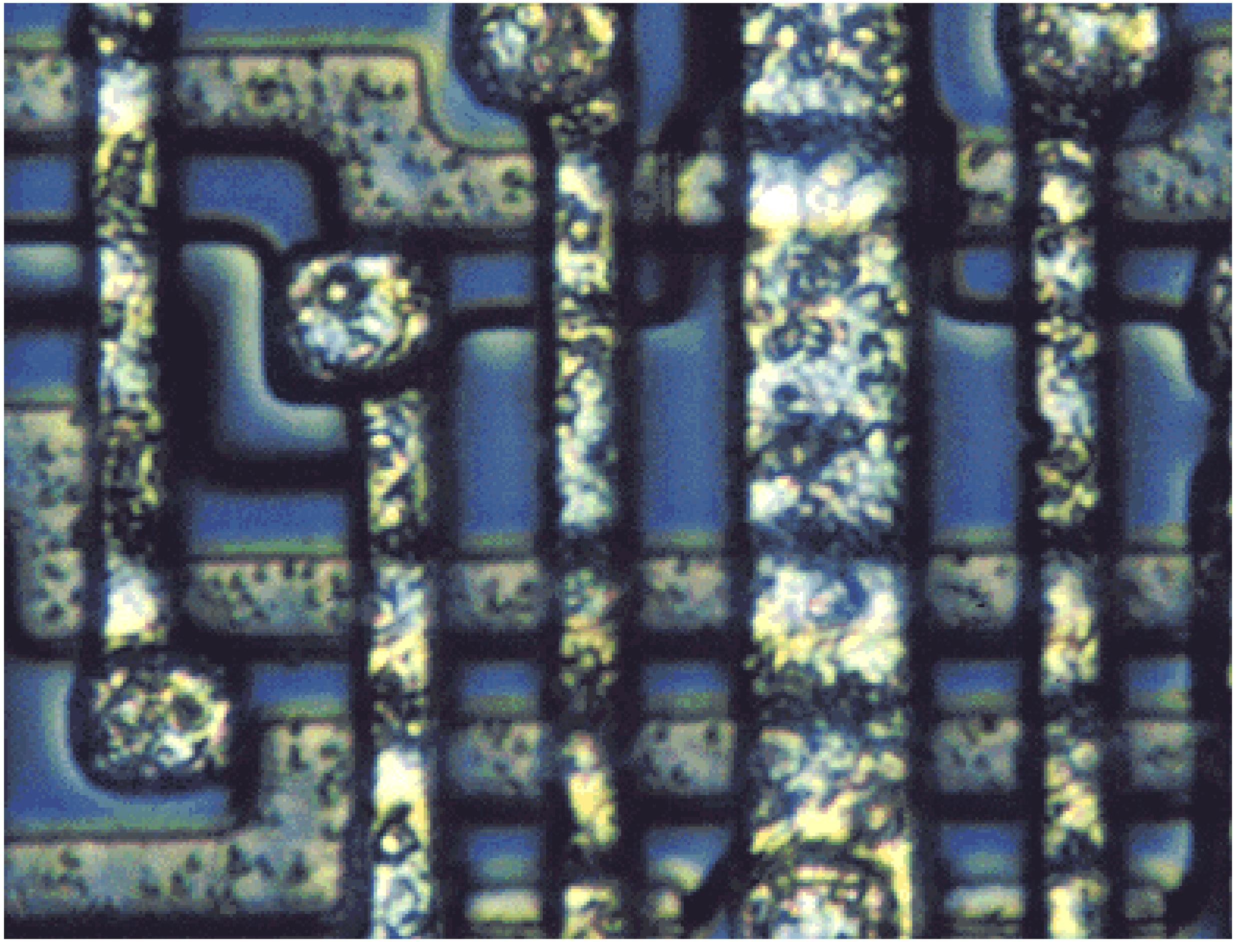
CPUs are getting smaller, and can include more than one "core" (or processors).

CPUs get hot, as their internal components dissipate heat:it is important to add a heat sink and fans to keep them cool.

CPU

- Transistors
- The integrated circuit (**IC**) allowed a large number of transistors to be manufactured on a single semiconductor-based die, or "chip."
- VLSI (very large scale IC)
- Also known as microprocessor, microcontroller, etc.
- It starts from the beach....

From Computer Desktop Encyclopedia



800x magnification of an early chip

Moore’s Law

- The empirical observation that the transistor density of integrated circuits, with respect to minimum component cost, doubles every 24 months.
  - attributed to Gordon E. Moore, a co-founder of Intel.
- Doubling is very powerful.

A few numbers

Name	Date	Transistors	Microns	Clock speed	Data width	MIPS
8080	1974	6,000	6	2 MHz	8 bits	0.64
8088	1979	29,000	3	5 MHz	16 bits 8-bit bus	0.33
80286	1982	134,000	1.5	6 MHz	16 bits	1
80386	1985	275,000	1.5	16 MHz	32 bits	5
80486	1989	1,200,000	1	25 MHz	32 bits	20
Pentium	1993	3,100,000	0.8	60 MHz	32 bits 64-bit bus	100
Pentium II	1997	7,500,000	0.35	233 MHz	32 bits 64-bit bus	~300
Pentium III	1999	9,500,000	0.25	450 MHz	32 bits 64-bit bus	~510
Pentium 4	2000	42,000,000	0.18	1.5 GHz	32 bits 64-bit bus	~1,700
Pentium 4 "Prescott"	2004	125,000,000	0.09	3.6 GHz	32 bits 64-bit bus	~7,000

CPU speed

- **1 hertz = 1 "cycle" per second**
- **A typical watch operates at 1 Hertz**
- **(one "clock tick" per second)**
- **Intel Pentium D: 3.20 GigaHertz (GHZ)**
- **3.2 billion cycles per second**

CPU

- ALU (Arithmetic logic unit)
- Control Unit
- Register
- Cache

- Connected to memory through North Bridge.
- Instructions are stored in machine language as binary number.

The Fetch/Execute Cycle

A machine cycles through a series of operations, performing an instruction on each round

- Fetch/execute cycle is a five-step cycle:

1. Instruction Fetch (IF)
2. Instruction Decode (ID)
3. Data Fetch (DF)
4. Instruction Execution (EX)
5. Result Return (RR)

Acknowledgement: Lawrence Snyder, “fluency with information technology”, for following slides

Control Unit

- Hardware implementation of the Fetch/Execute Cycle
- Its circuitry fetches an instruction from memory and performs other operations of the cycle on it
  - A typical instruction might have the form ADD 2000, 2080, 4000
  - This instruction asks that the numbers stored in locations 2000 and 2080 be added together, and the result stored in location 4000
  - Data Fetch step must get these two values and after they are added, Result Return step will store the answer in location 4000

Instruction Interpretation

- Process of executing a program
  - Computer is interpreting our commands, but in its own language
- Before the F/E Cycle begins, some of the memory locations and the PC are visible in the control unit

Instruction Interpretation (cont'd)

- Execution begins by moving instruction at the address given by the PC from memory to control unit

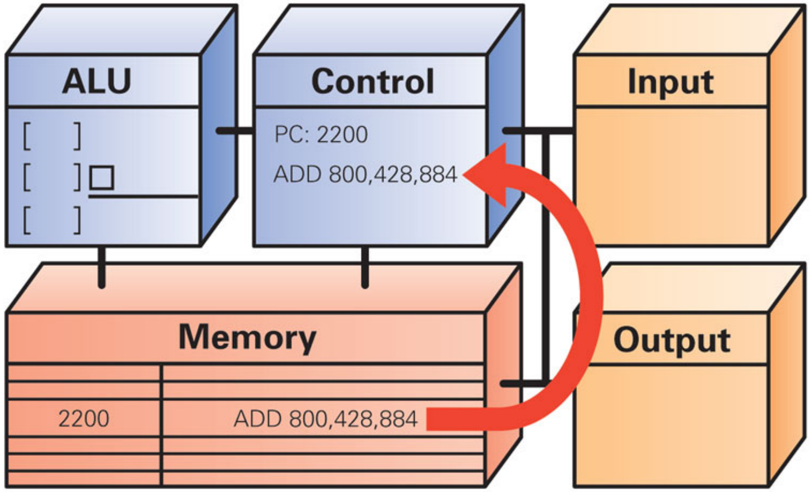


Figure 9.6. *Instruction Fetch: Move instruction from memory to the control unit.*

Instruction Interpretation (cont'd)

- Bits of instruction are placed into the decoder circuit of the CU
- Once instruction is fetched, the PC can be readied for fetching the next instruction

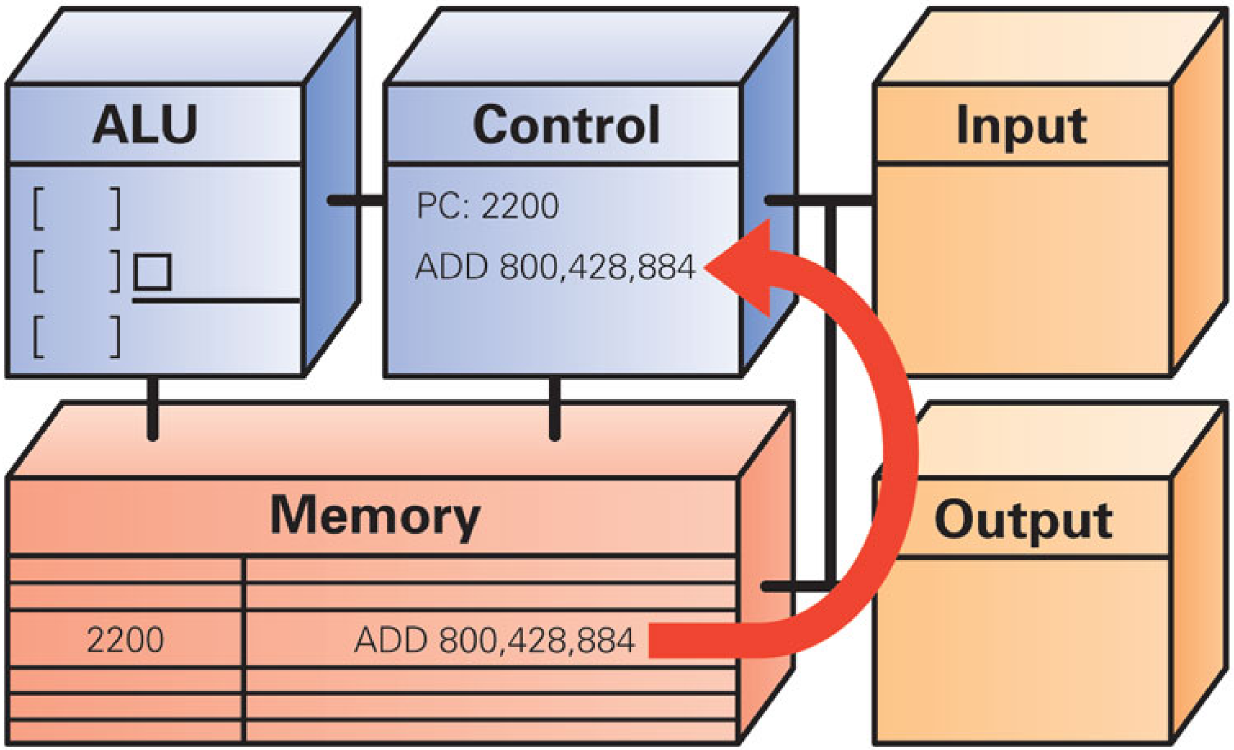


Figure 9.6. *Instruction Fetch: Move instruction from memory to the control unit.*

Instruction Interpretation (cont'd)

- In Instruction Decode step, ALU is set up for the operation
- Decoder will find the memory address of the instruction's data (source operands)
  - Most instructions operate on two data values stored in memory (like ADD), so most instructions have addresses for two source operands
  - These addresses are passed to the circuit that fetches them from memory during the next step, Data Fetch
- Decoder finds destination address for the Result Return step, and places it in RR circuit
- Decoder determines what operation the ALU will perform, and sets it up appropriately

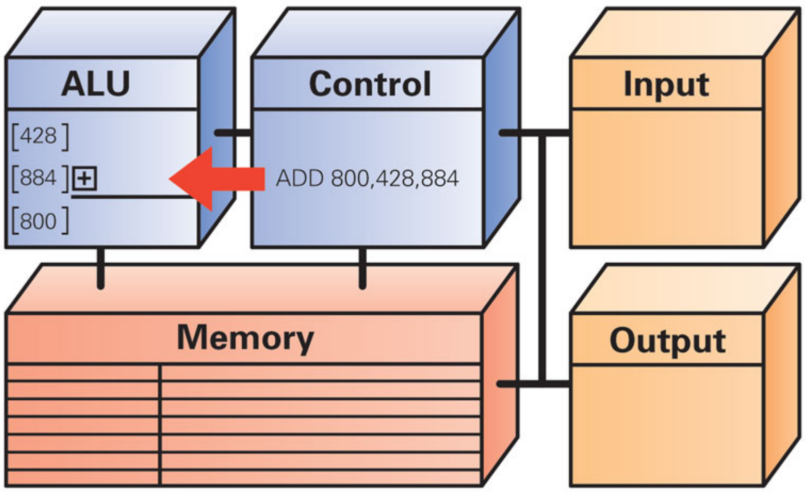


Figure 9.7. Instruction Decode: Pull apart the instruction, set up the operation in the ALU, and compute the source and destination operand addresses.

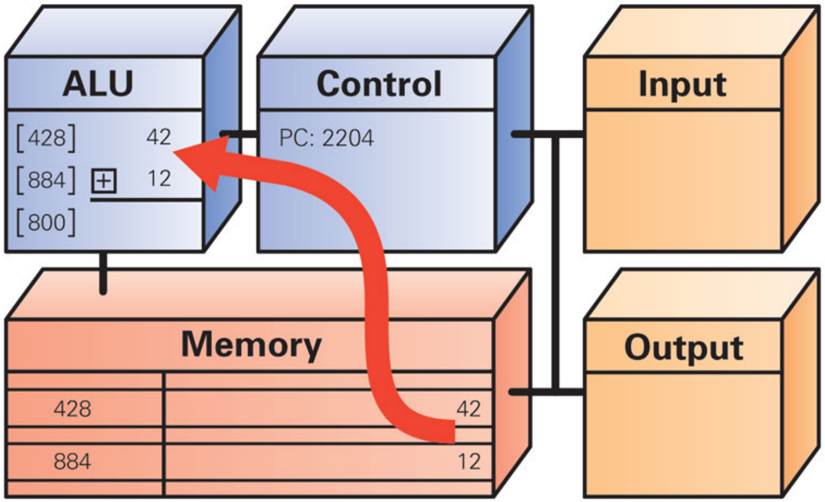


Figure 9.8. Data Fetch: Move the operands from memory to the ALU.

Instruction Execution

- Instruction Execution: The actual computation is performed. For ADD instruction, the addition circuit adds the two source operands together to produce their sum

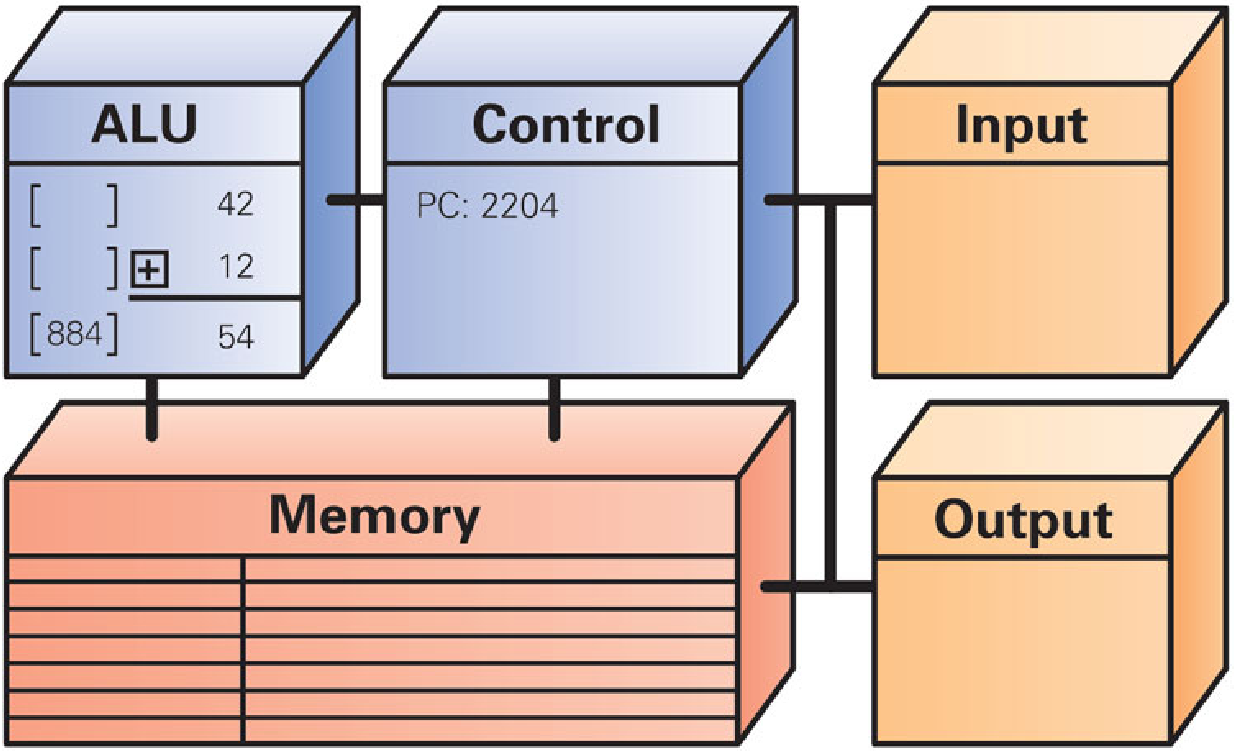


Figure 9.9. *Instruction Execute: Compute the result of the operation in the ALU.*

Instruction

- Result Return: result of execution is returned to the memory location specified by the destination address.
- Once the result is returned, the cycle begins again.

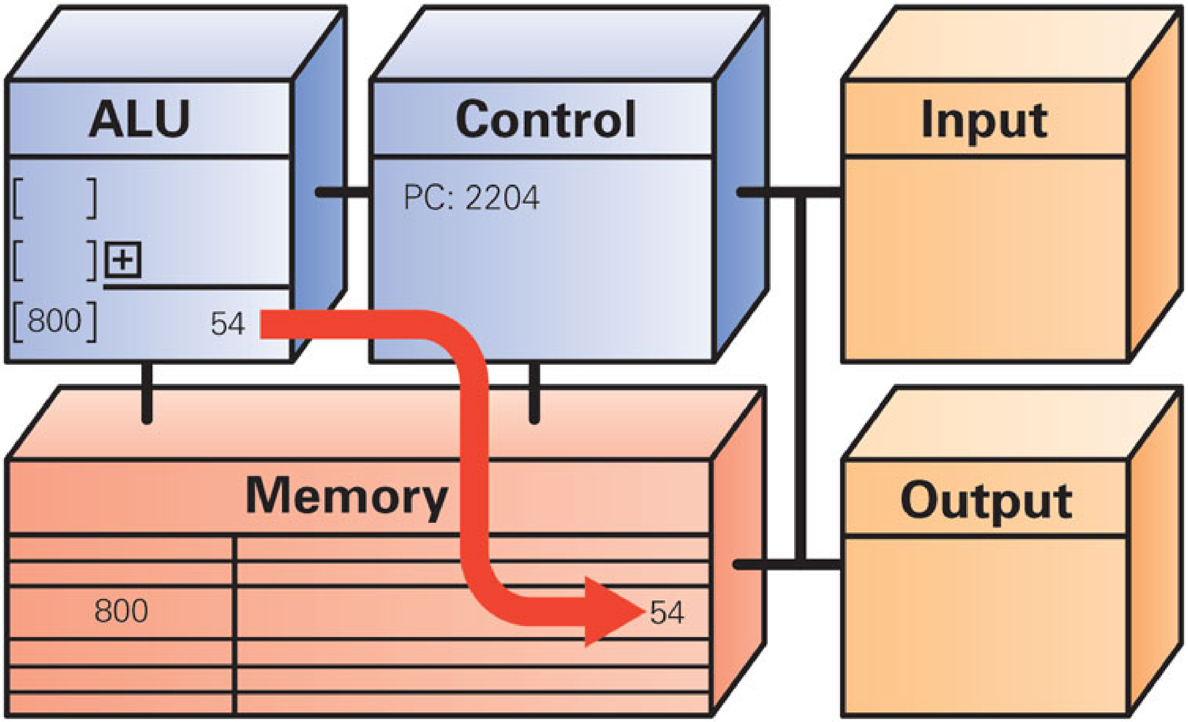


Figure 9.10. Result Return: Store the result from the ALU into the memory at the destination address.

Many, Many Simple Operations

- Computers can only perform about 100 different instructions
  - About 20 different kinds of operations (different instructions are needed for adding bytes, words, decimal numbers, etc.)
- Everything computers do must be reduced to some combination of these primitive, hardwired instructions

Examples of Other Instructions

- Besides ADD, MULT (multiply) and DIV (divide), other instructions include:
  - Shift the bits of a word to the left or right, filling the emptied places with zeros and throwing away bits that fall off the end
  - Compute logical AND (test if pairs of bits are both true, and logical OR, which tests if at least one of two bits is true
  - Test if a bit is zero or non-zero, and jump to new set of instructions based on outcome
  - Move information around in memory
  - Sense signals from input/output devices
- CISC vs. RISC

Cycling the F/E Cycle

- Computers get their impressive capabilities by executing many of these simple instructions per second
- The Computer Clock: Determines rate of F/E Cycle
  - Measured in megahertz, or millions of cycles per second

CPU: Instruction Execution Engines

- What computers can do
  - Deterministically perform or execute instructions to process information
  - The computer must have instructions to follow
- What computers can't do
  - Have no imagination or creativity
  - Have no intuition
  - Have no sense of irony, subtlety, proportion, decorum, or humor
  - Are not vindictive or cruel
  - Are not purposeful
  - Have no free will
  - Do not get mad even if one asks the same thing over and over,

Acknowledgement: Lawrence Snyder, "fluency with information technology"

How Important is Clock Speed?

- Modern computers try to start an instruction on each clock tick
- Pass off finishing instruction to other circuitry
  - Five instructions can be in process at the same time
- Does a 1 GHz clock really execute a billion instructions per second?
  - Not a precise measurement. Computer may not be able to start an instruction on each tick, but may sometimes be able to start more than one instruction at a time

Multiprocessing and Multi-core

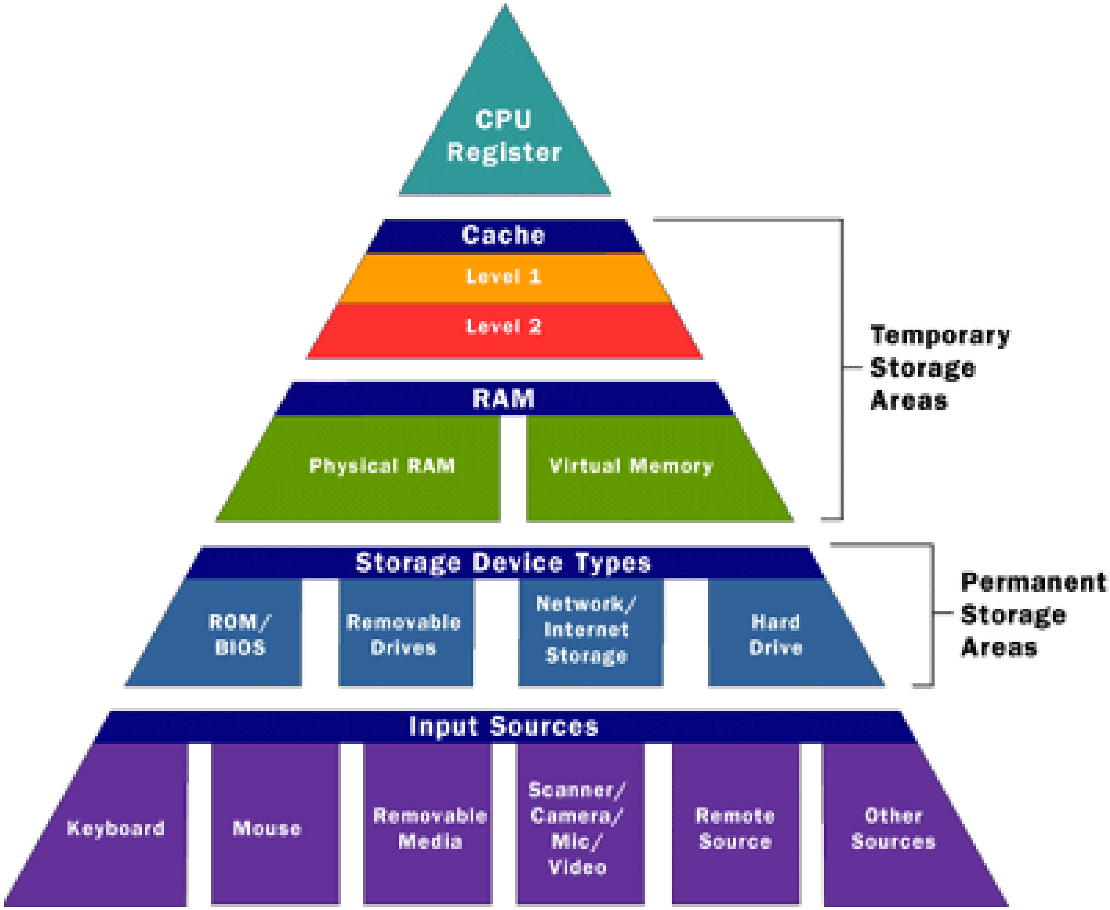
- The use of multiple CPUs in the same computer
  - Dual-core, Quad-core, multi-core

- Benefits:

- Challenges:

Memory & Storage

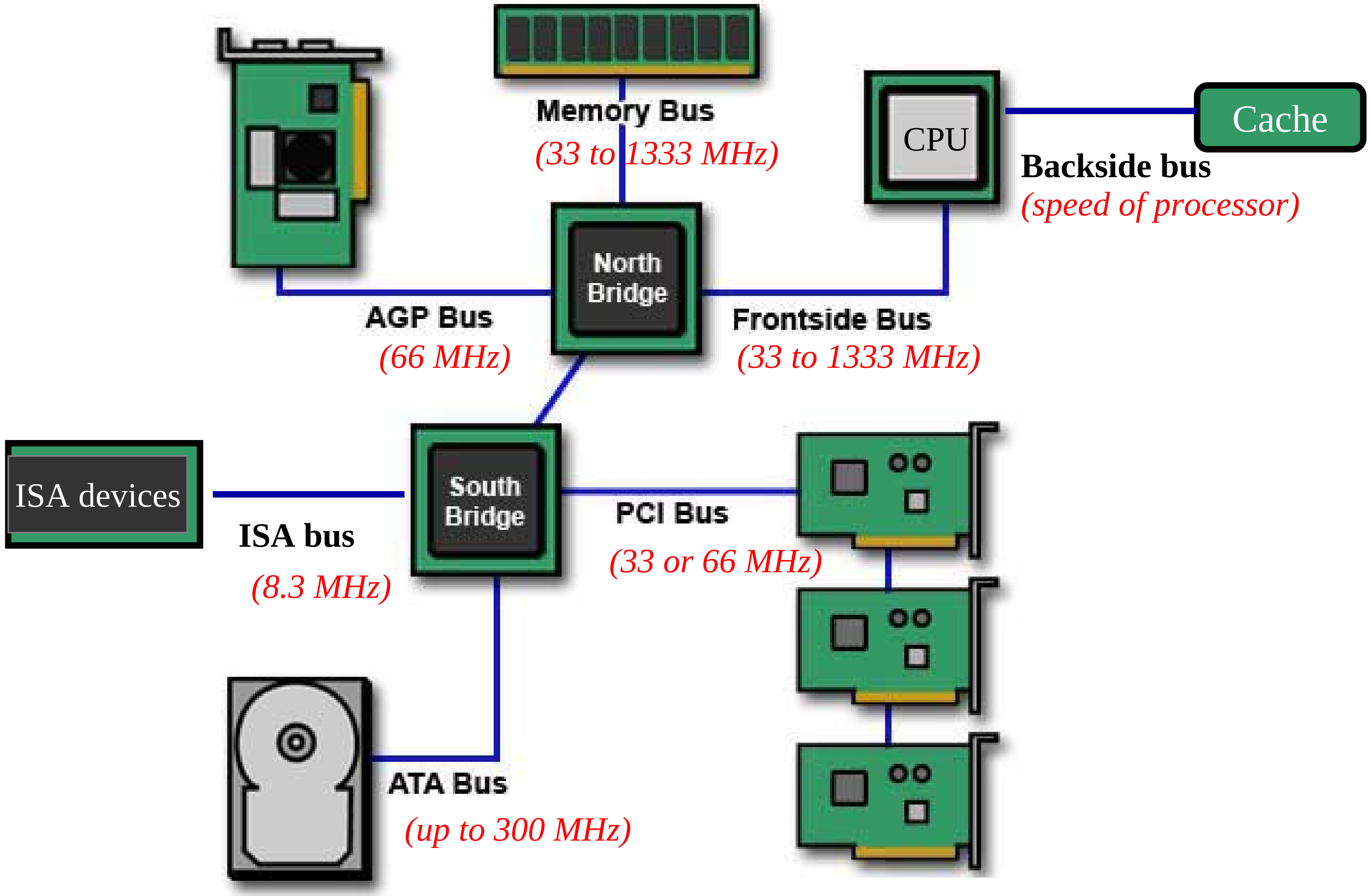
Memory and Storage



Memory

- Hierarchical structure
- CPU <-> Cache <--> Ram <--> virtual memory/hard-disk

Hardware communication: buses



RAM

- RAM: Random access memory (RAM) is the best known form of computer memory. RAM is considered "random access" because you can access any memory cell directly if you know the row and column that intersect at that cell
- Capacitors
- Word: cells of memory (one byte or multiple bytes)
- Address (grid structure)

Types

- SRAM: Static random access memory
- DRAM: Dynamic random access memory