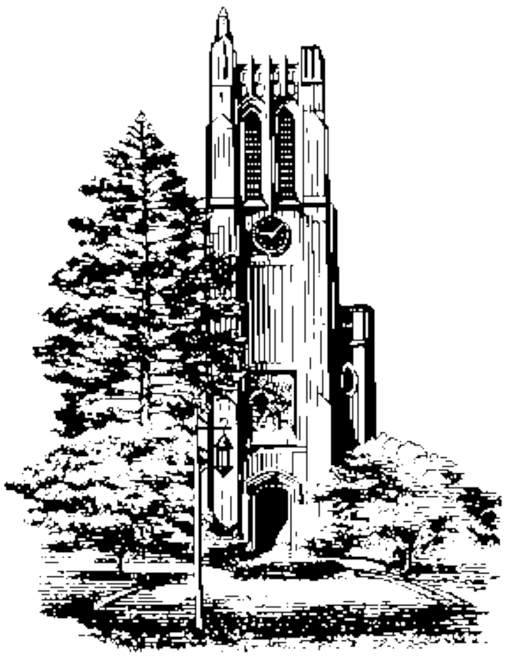
Lecture 04

Thursday January 21, 2016



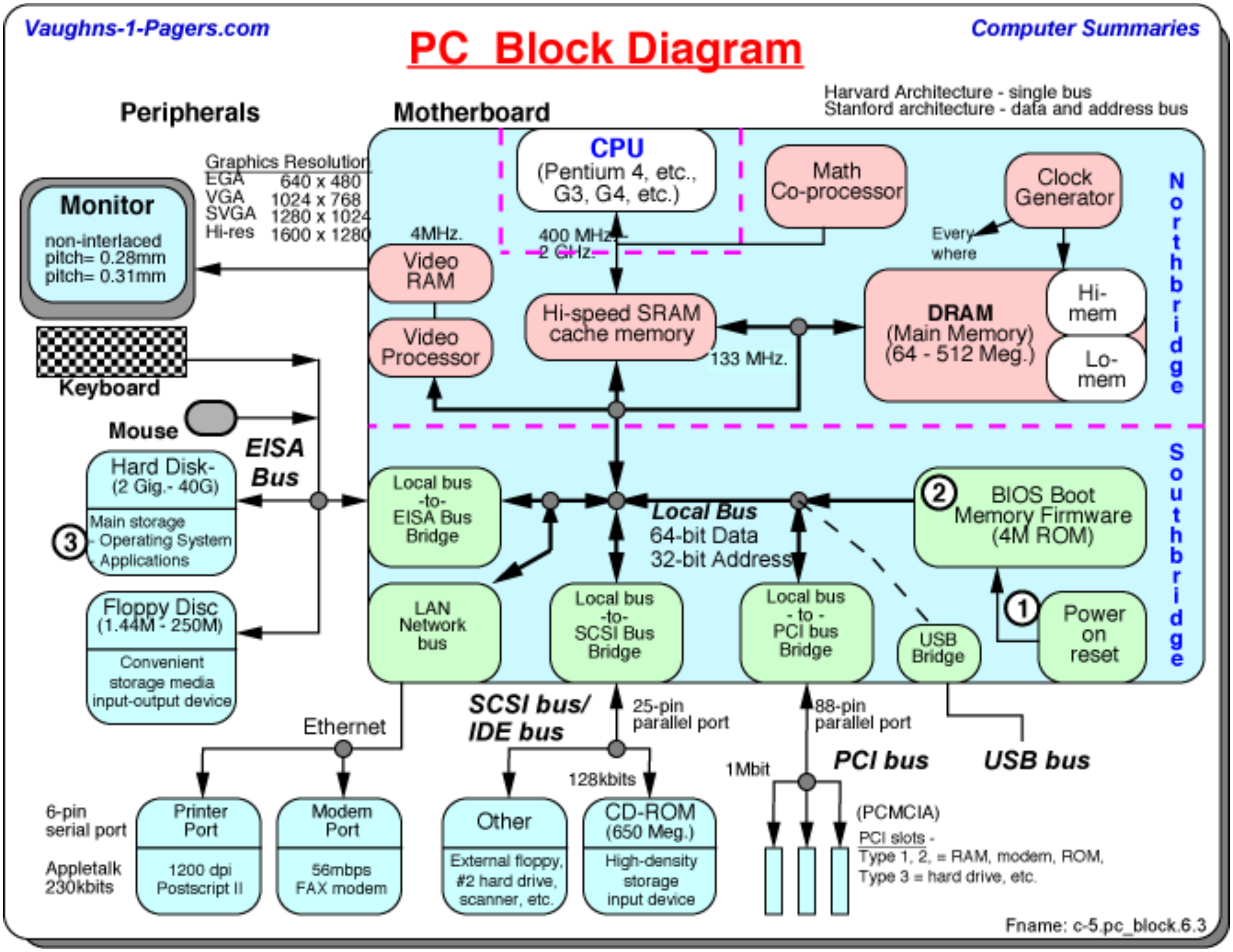
Notables

- Homework #2 will be posted
  - Due Thursday September 22nd , 2015
- Forthcoming topics:
  - System review

Main Components

- **Hardware**
  - Physical devices: Processor, memory, keyboard, monitor, mouse, etc.
- **Software**
  - Executable Programs: word processor, spread sheet, internet browser, etc.

PC Schematic (http://www.vaughns-1-pagers.com/computer/pc-block-diagram.htm)



Major Components of a Computer

- The Processor
- The Internal Memories
  - Random Access Memory (RAM)
  - Cache Memory (L1, L2)
    - L1 on the processor chip
    - L2 on the Motherboard
- The external Memories
  - Hard drives, etc
- The Chipset
  - The North Bridge chip(s)
    - handles communication between the graphics bus (if it exists), RAM, processor
  - The South Bridge chip(s)
    - handles all the Input and output of the computer, including the PCI, PCI-e, ISA ….Bus.

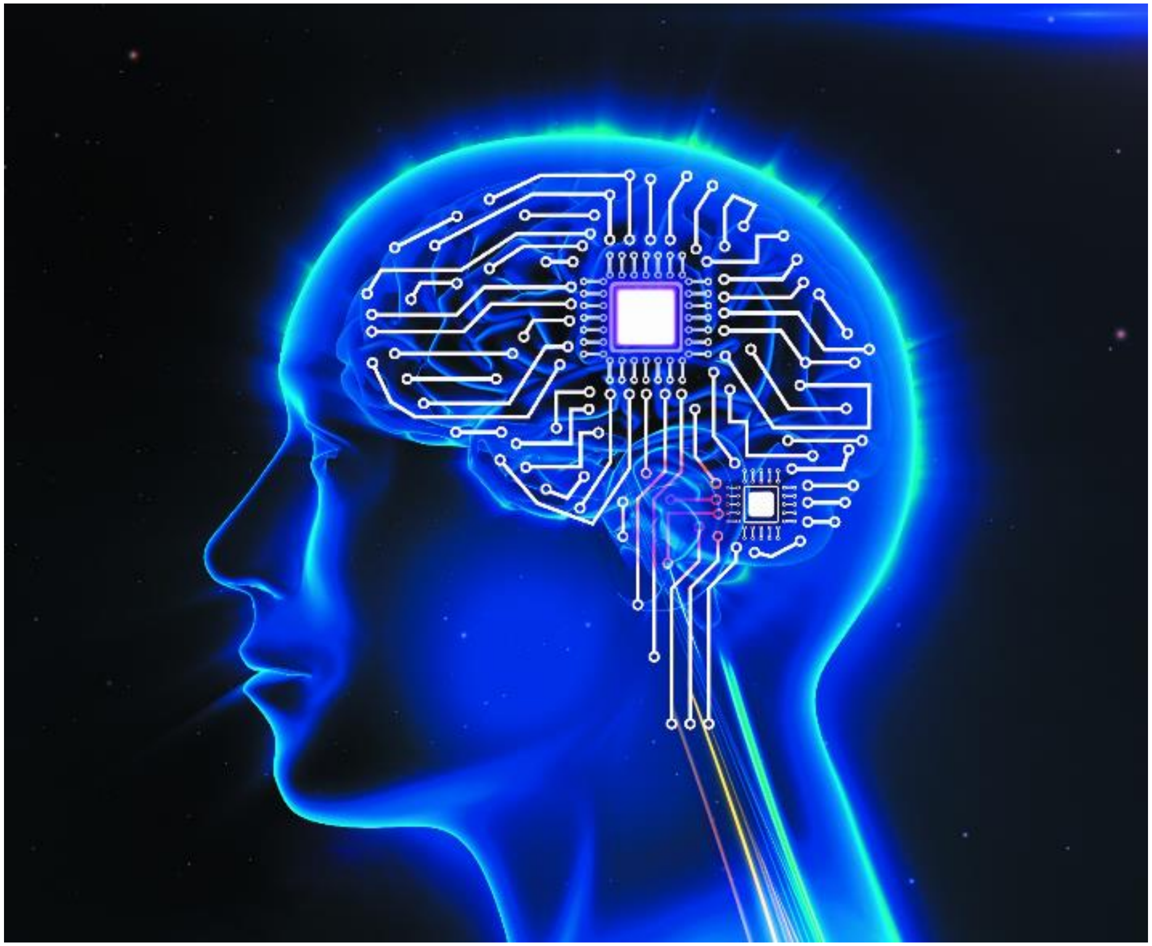
- *PCI stands* for "Peripheral Component Interconnect”
- ISA stands for Industrial standard Architecture

WHAT IS A PROCESSOR?

Processor

- The processor is the “brain” of a computer.
- The processor controls the other devices as well as performing calculations

Explain the Functions of a CPU or the Processor

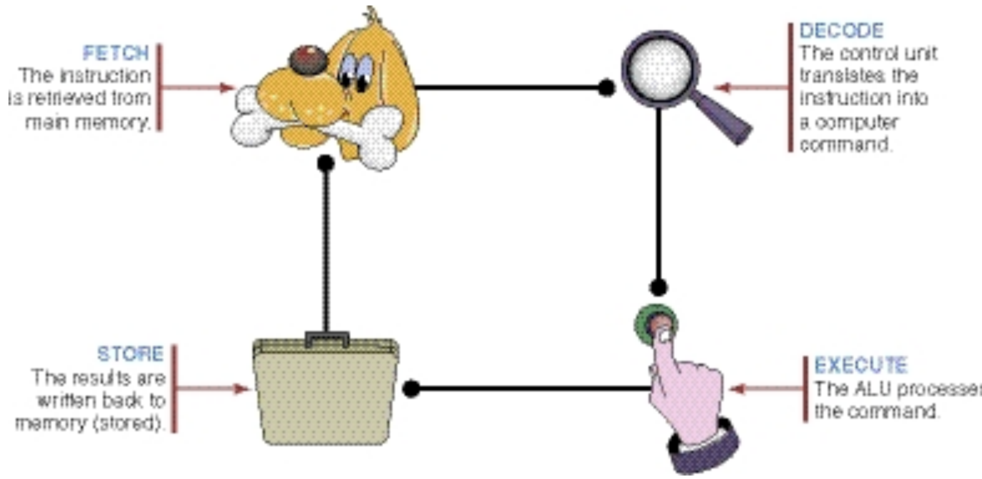


Functions of the CPU

- Central Processing Unit (CPU or processor)
  - Brain of the computer housed on the motherboard
  - Arithmetic Logic Unit (ALU)
    - Perform calculations (ALU)
  - Control Unit: Manages data movement through the CPU
    - Execute instructions (Control Unit)
    - Make decisions (control unit)

Definition of the : "Instruction Cycle"

- There are four steps in the instruction cycle:
  - ✓Fetch
    - Instruction is retrieved from main memory
  - ✓Decode
    - Translates instruction into computer command
  - ✓Execute
    - ALU processes the command
  - ✓Store
    - Results are written back to memory



Visualizing Technology, 5th edition, Chapter 4, Debra Geoghan, Pearson

CPU Performance

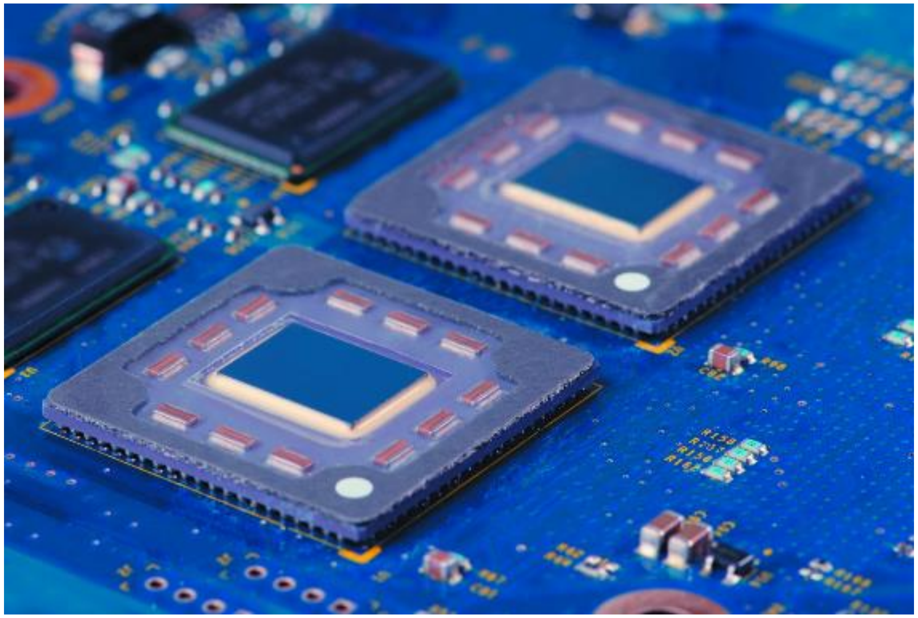
- CPU performance is measured in:
  - Clock speed:
    - Speed at which the processor executes the machine cycles
    - Overclock
  - Gigahertz (GHz):
    - Billions of cycles per second

CPU Performance

- The CPU works so fast it is difficult for us to comprehend.
- The speed at which the processor executes the machine cycle is called clock speed. The clock speed is measured in gigahertz. If a CPU runs at 3 GHz, it means that the processor executes 3 billion data cycles per second.

CPU Performance

- Multi-core processor:
  - Two or more processors integrated on a single chip
    - Increases processing speed
    - Reduces energy consumption
  - GPU (graphics processing unit)
    - A video card that has its own processor



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CPU Performance

- Parallel processing:
  - Uses multiple processors, or multicore processors, to divide up processing tasks
  - Each processor can use pipelining to further boost processing efficiency

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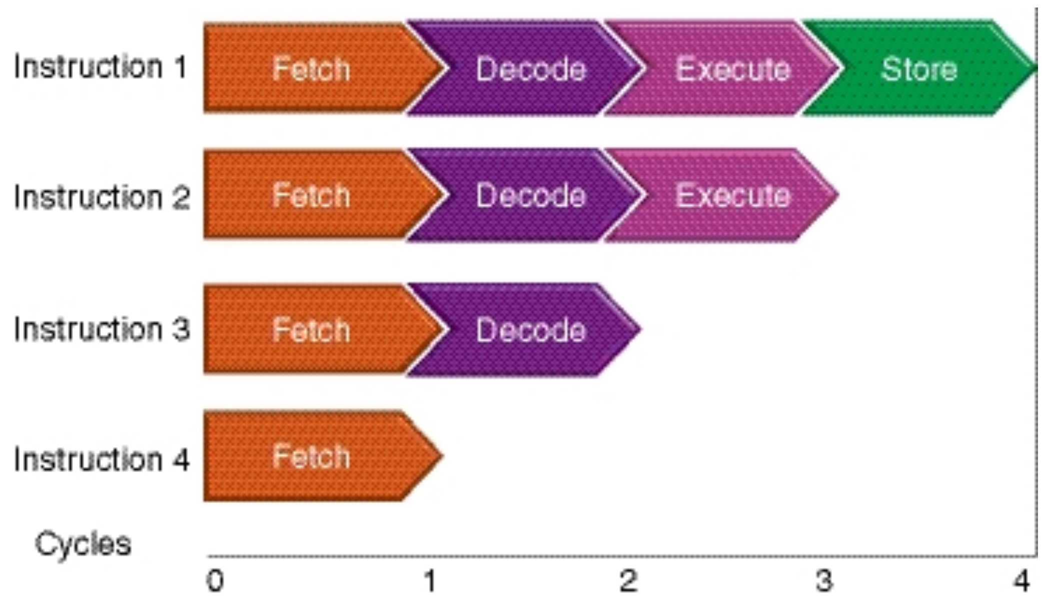
CPU Performance

- Pipelining:
  - Used by a single processor
  - When the first instruction moves from stage 1 to stage 2 of the machine cycle, the next instruction moves into stage 1 — like an assembly line



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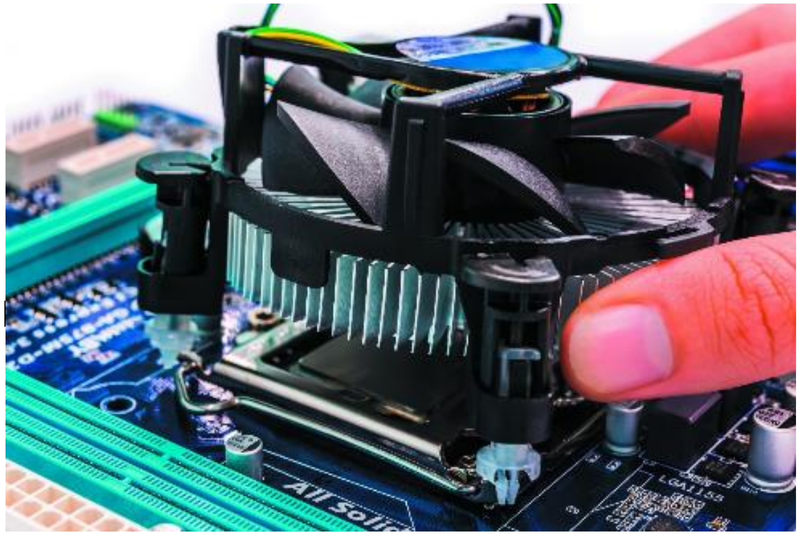
CPU Performance and Cooling

- Processing generates heat
  - To prevent overheating, the CPU uses:
    - Heat sink –draws heat away from the processor
    - Cooling fan – positioned above the processor
  - System units have at least one system fan



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Activity Question

Today's processor speeds are measured in __________.

- A) KHz
- B) MHz
- C) GHz
- D) THz

Activity Question

- __________ uses multiple processors, or multi-core processors, to share processing tasks.
- A) Distributed processing
- B) Parallel processing
- C) Pipelining
- D) Serial processing

PROCESSOR COMPONENTS

Processor Components

- Control Unit
  - fetches an instruction from primary storage
  - decodes it to decide which instruction it is
  - instructs the ALU to perform a calculation
- Arithmetic-Logic Unit (ALU)
  - performs arithmetic calculations
  - and logical calculations such as comparison

Processors: smaller, faster, ...

- One of the things that have made processors (and thus computers) so amazing over the last fifty years is:
  - How much faster they are
  - How much smaller they are
  - How much cheaper they are...

Little Processors

- Processors like the Intel P4 have 55 million transistors in them

Identify the Parts of a System Unit and Motherboard

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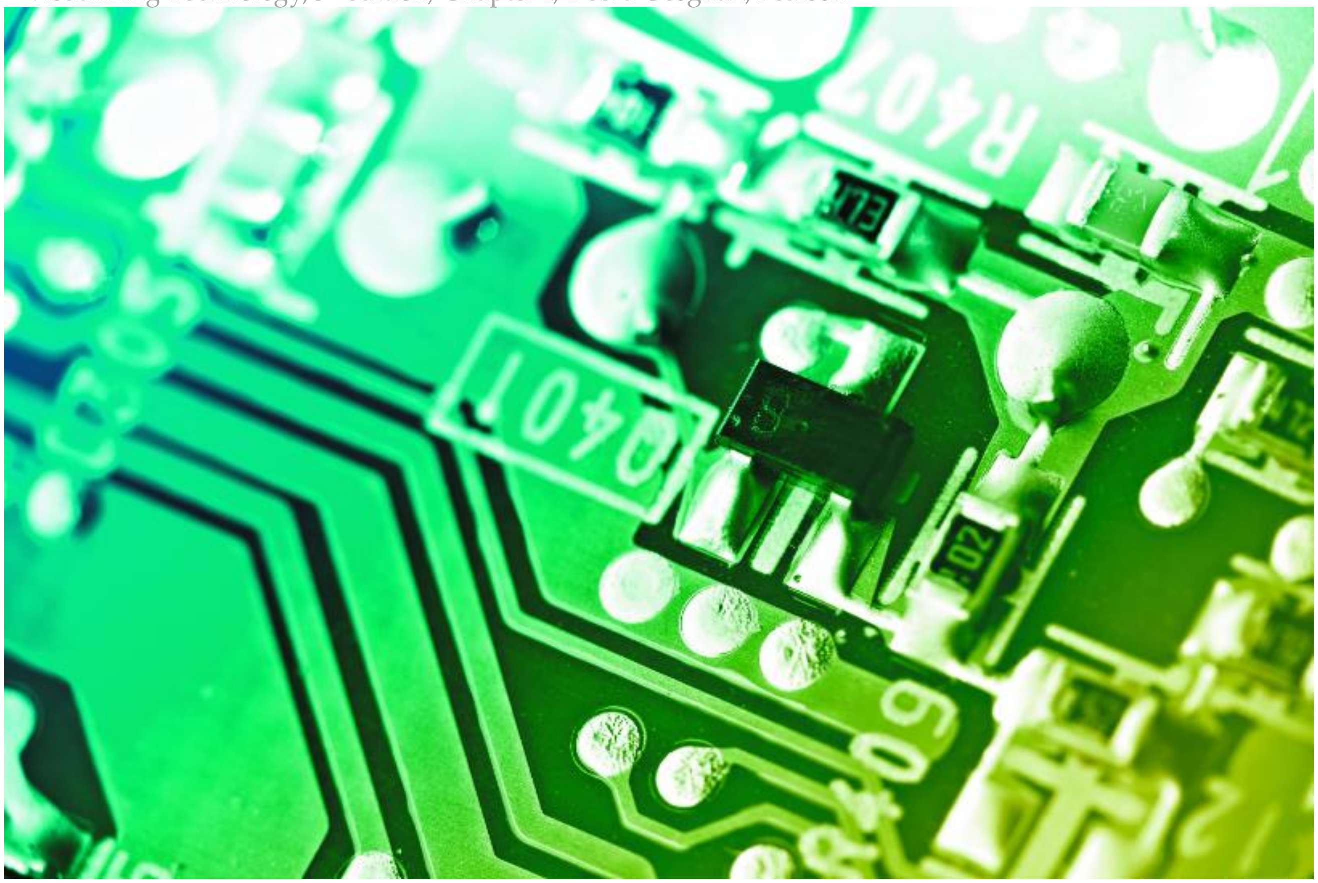

the parts of a system unit and motherboard.
It explains how information flows over data buses and identifies system components such as drive controllers, ports, connectors, and the various types of memory

The Motherboard

The Main Circuit Board of the Computer

- This system unit contains:
  - ✓The CPU or processor (under the cooling fan)
  - ✓The power supply
  - ✓Motherboard (mostly obscured by other components)
  - ✓Memory

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The Motherboard

The Main Circuit Board of the Computer

The system unit is the physical case that protects the power supply, motherboard, CPU, and memory.

The motherboard houses the CPU, drive controllers and interfaces, expansion slots, data buses, ports and connectors, BIOS, and memory.

An expansion board plugs into an expansion slot and lets you connect devices such as video and sound cards.

Drive controllers and interfaces connect disk drives to the processor.

Data buses provide connections for information to flow over wires.

Ports and Connectors

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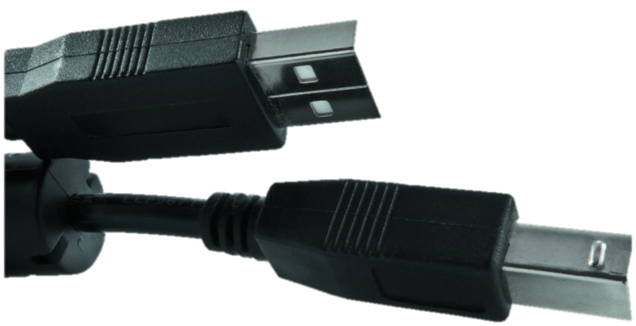
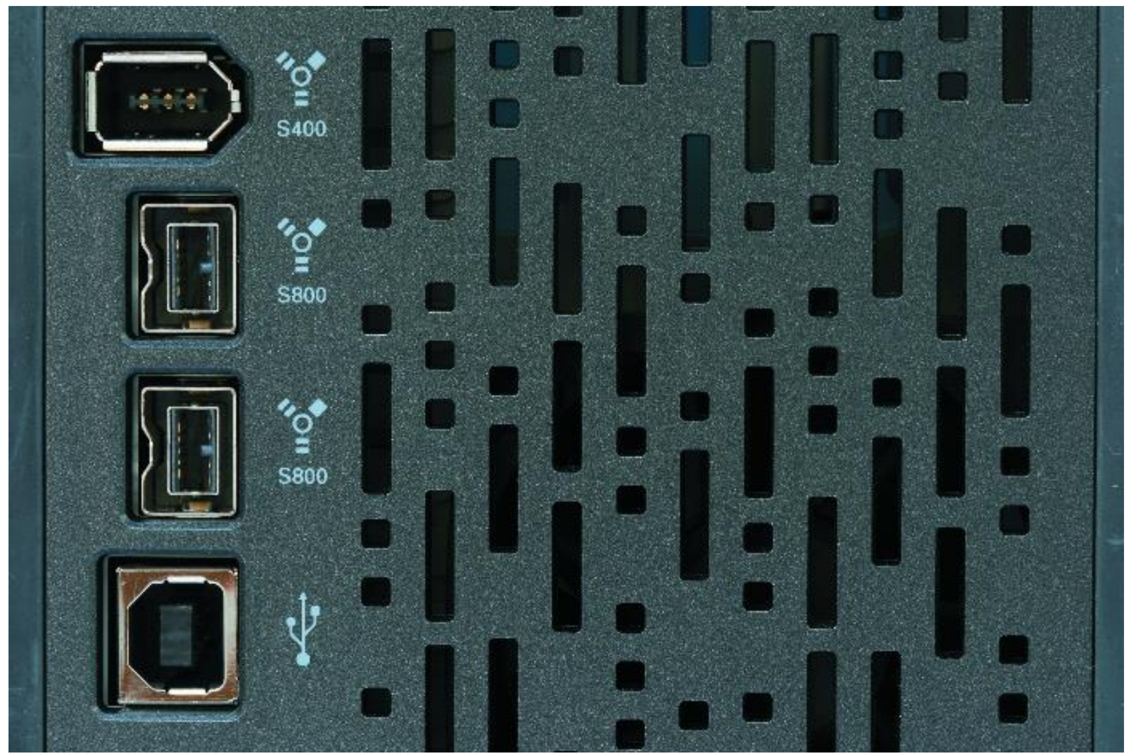
Ports & Connectors

Connect Peripherals to the Motherboard

- Most common ports:
  - ✓USB
  - ✓Firewire (IEEE 1394)





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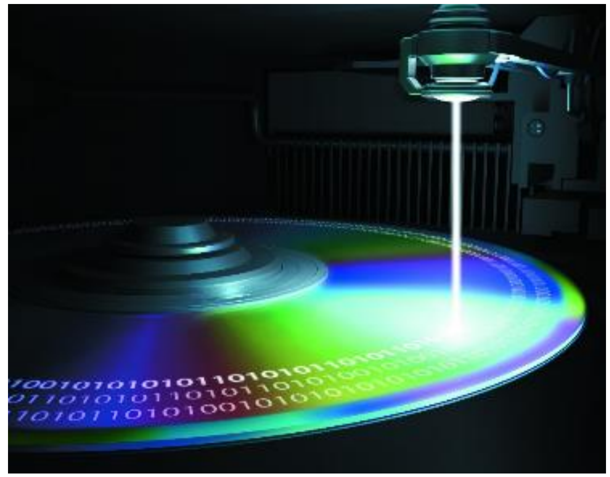
Memory (Primary Storage)
Temporary Storage Holds Instructions & Data

- Types of memory used by computers:
  - Random Access Memory (RAM):
    - Volatile memory that holds the OS, programs, and data the computer is currently using
  - Cache memory: Very fast memory used to store frequently accessed information; located close to the processor
    - Level 1 (L1) – built into the processor
    - Level 2 (L2) – built into the processor on new systems or on the motherboard near the processor on older ones
    - Level 3 (L3) – a separate chip on the motherboard near the processor

Compare Storage Devices

Storage Devices

- Optical discs
  - ✓ CDs
  - ✓ DVDs
  - ✓ Blu-ray
- Solid-state storage
  - ❑ Flash drives
  - ❑ Memory cards
  - ❑ Mobile devices
- Magnetic storage
  - ❑ Hard drive

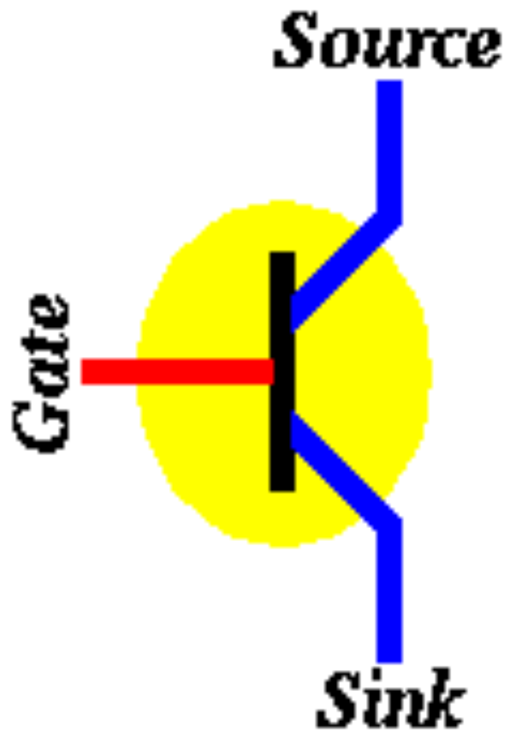


WHAT ARE TRANSISTORS?

Transistors

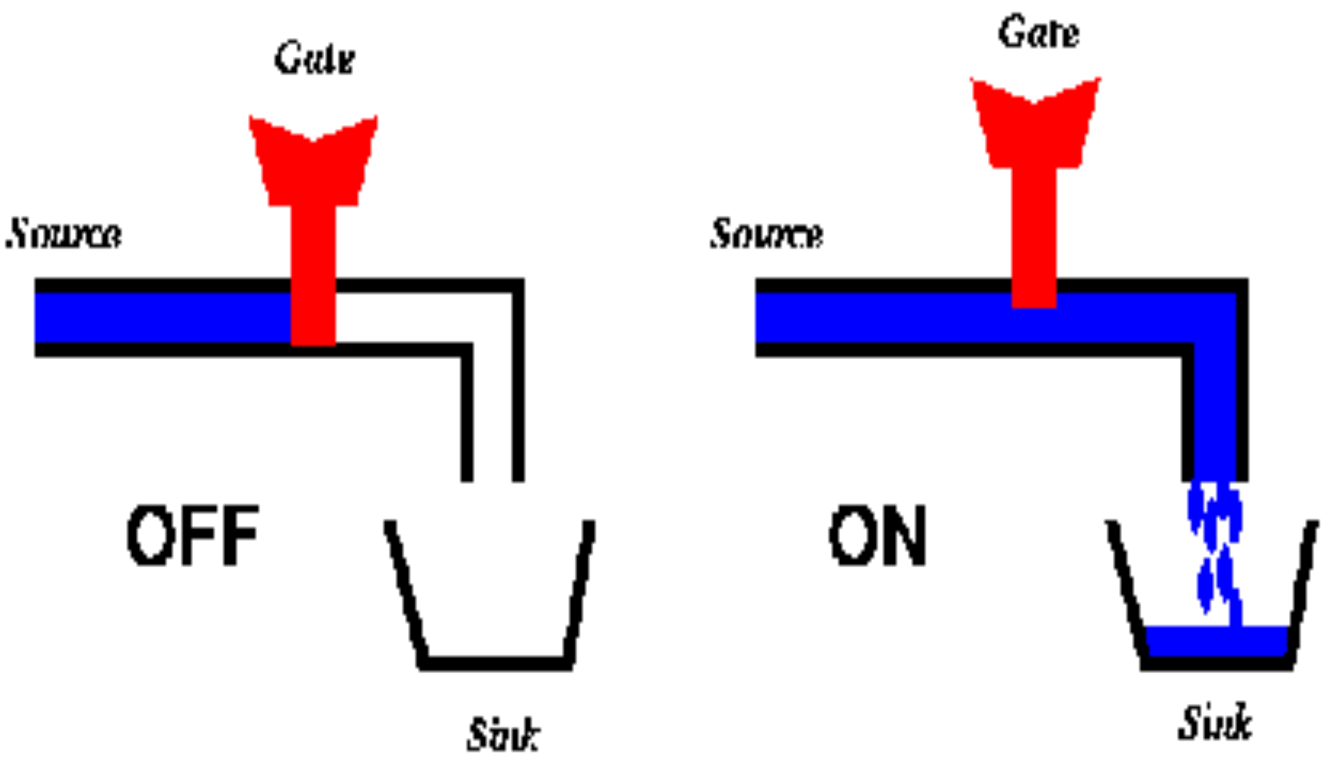
- Transistors work as **amplifiers** or **switches**.
- For computers it works as a switch.
  - A tiny electric current flowing through one part of a transistor can make a much bigger current flow through another part of it.
  - In other words, the small current switches on the larger one. This is essentially how all computer chips work.
  - For example, a memory chip contains hundreds of millions or even billions of transistors, each of which can be switched on or off individually. Since each transistor can be in two distinct states, it can store two different numbers, zero and one. With billions of transistors, a chip can store billions of zeros and ones, and almost as many ordinary numbers and letters (or characters, as we call them).

Transistors

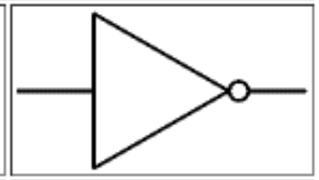
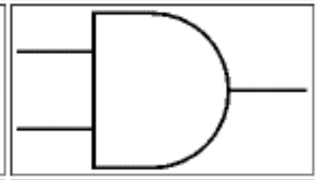
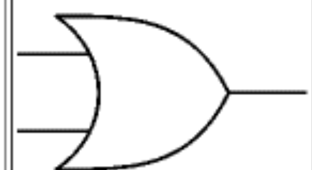
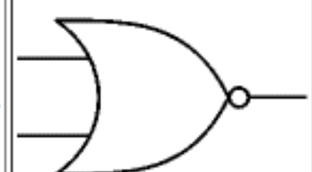


What are the transistors

- Little electronic switches (only discovered in the 50's).



Logical Gates

Gate	
NOT	
AND	
OR	
NOR	

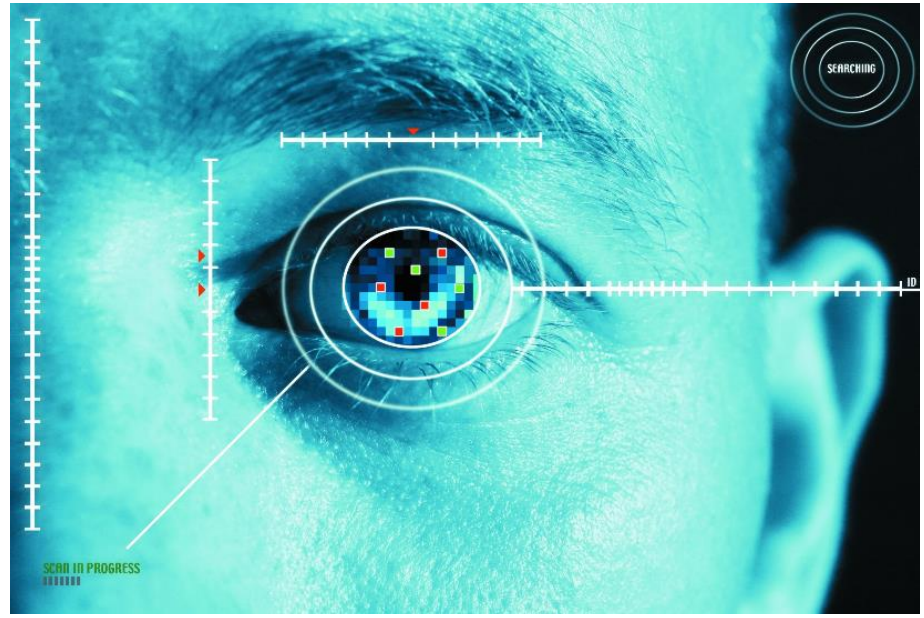
Transistor count (http://en.wikipedia.org/wiki/Transistor_count)

AMD K10	463,000,000[1]	2007	AMD	65 nm	
AMD K10	758,000,000[1]	2008	AMD	45 nm	
Itanium 2 with 9MB cache	592,000,000	2004	Intel	130 nm	
Core i7 (Quad)	731,000,000	2008	Intel	45 nm	263 mm²
Six-Core Xeon 7400	1,900,000,000	2008	Intel	45 nm	
POWER6	789,000,000	2007	IBM	65 nm	341 mm²
Six-Core Opteron 2400	904,000,000	2009	AMD	45 nm	346 mm²
16-Core SPARC T3	1,000,000,000[2]	2010	Sun/Oracle	40 nm	377 mm²
Six-Core Core i7	1,170,000,000	2010	Intel	32 nm	240 mm²
8-core POWER7	1,200,000,000	2010	IBM	45 nm	567 mm²
Quad-core z196[3]	1,400,000,000	2010	IBM	45 nm	512 mm²
Dual-Core Itanium 2	1,700,000,000[4]	2006	Intel	90 nm	596 mm²
Quad-Core Itanium Tukwila	2,000,000,000[5]	2010	Intel	65 nm	699 mm²
8-Core Xeon Nehalem-EX	2,300,000,000[6]	2010	Intel	45 nm	684 mm²
10-Core Xeon Westmere-EX	2,600,000,000	2011	Intel	32 nm	512 mm²

INPUT DEVICES

List and Describe Common Input Devices

- An input device is a device used to enter data into a computer system.
- The type of input device you use depends on the data to input, the type of computer the input device is connected to, and the application being used.
- The keyboard and mouse are the most common input devices, but others include the keypad, touchpad, and stylus.



Input Devices

Devices Used to Get Data into the Computer

- Keyboard
- Keypad
- Mouse
- Touchpad
- Stylus

Input Devices

Devices Used to Get Data into the Computer

- Digital cameras and webcams
- Optical scanners
- QR code readers
- Near field communication (NFC) devices
- Magnetic strip reader
- Biometric scanners
- Joysticks

OUTPUT DEVICES

Video Output Devices

Monitors

- Work by lighting pixels (picture elements) on the screen
  - CRT
    - Cathode ray tube; considered legacy technology
  - LCD
    - Liquid crystal display; popular in desktops and notebooks
  - Plasma
    - Larger in size; mostly used with media center systems or in conference rooms

Video Output Devices
Monitors (cont.)

- Work by lighting pixels (pixel elements) on the screen
  - OLED
    - Organic light-emitting diode; considered next technology of monitors
  - AMOLED
    - Active matrix OLED screens; found in some mobile devices
    - Sharper and have a wider viewing angle

Objective 5

Video Output Devices
Projectors

- Produce larger output
- More practical for presentations
- Examples:
  - ✓ DLP (digital light processing) projectors
    - Hundreds of thousands of tiny swiveling mirrors that create an image
    - Higher contrast and deeper blacks
  - ✓ LCD projector
    - Pass light through a prism
    - Poorer contrast and washed-out blacks

Video Cards and Audio Output Devices

Video Cards

- Expansion cards that provide the data signal and connector for a monitor or projector
- The card can be integrated on the mother board or connected via:
  - ✓ Expansion card
  - ✓ External USB
  - ✓ FireWire

Video Cards and Audio Output Devices

Audio Output

- Converts digital signals into sound
- Provided by:
  - Speakers
  - Headphones
- Provides audio connections for both:
  - Input devices
  - Output devices

Objective 5

Moore's Law

- Gordon Moore is one of the founders of the chip maker Intel
- In 1965, he has observed (over that last 15 years or so) the growth rate of the number of transistors in a circuit
- Made a famous prediction

The "law"

"The complexity for minimum component costs has increased at a rate of roughly a factor of two per year ... Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65,000. I believe that such a large circuit can be built on a single wafer"

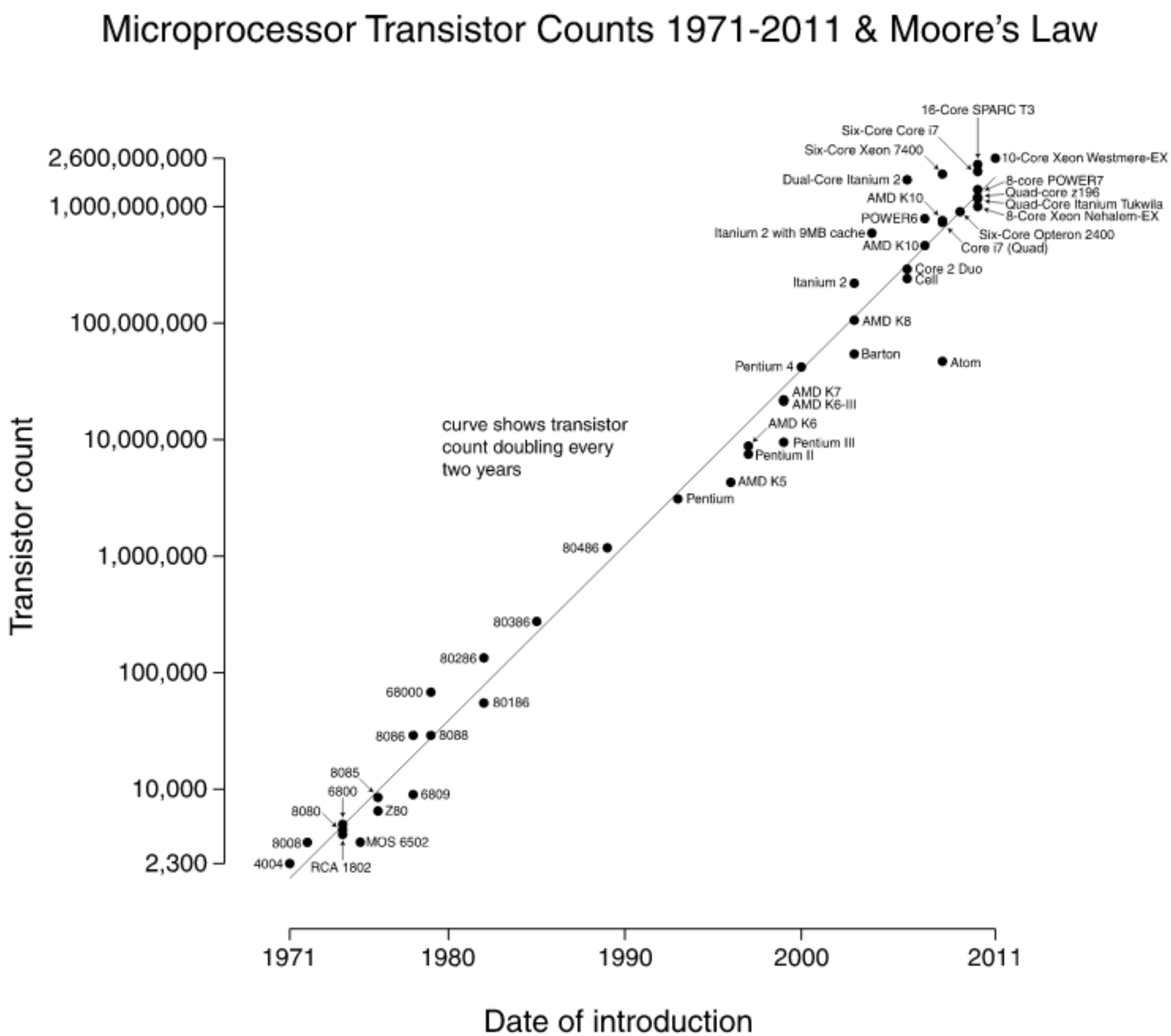
Electronics Magazine 19 April 1965

https://en.wikipedia.org/wiki/Moore%27s_law

Moore’s Law

- Gordon Moore is one of the founders of the chip maker Intel
- In 1965, he has observed (over that last 15 years or so) the growth rate of the number of transistors in a circuit
- Made a famous prediction

Transistor count
Source: http://upload.wikimedia.org/wikipedia/commons/0/00/Transistor_Count_and_Moore%27s_Law_-_2011.svg



What it means

- Roughly, since 1965, the number of transistors on a chip had doubled every 18 months for approximately the same cost
- Often quoted as the speed of a cpu doubling every 18 months for the same cost
- Speed and density are related

How Fast?

- Typical processor “clock” runs at GHz frequency, that is, one billion changes per second.
- This translates to processor doing one billion “operations” a second; or one operation every one nanosecond (one *billionth* of a second)
- How far can a runner go in one nanosecond?

Nanosecond

- How fast electricity can travel in one billionth of a second.

Nanoseconds

- Speed of light =186,000 miles/sec, 3×10^8 meters/sec (actually 299,792,458)
- nanosecond = 10^{-9} seconds
- So light travels 30 centimeters or 11.8 inches in one nanosecond

Speed pushing up against physics

- The processor "clock" is like a drummer in the band. The faster it beats, the faster the operations.
- In 1 clock tick, electricity can travel
  - About 1 foot if the clock ticks at 1GHz
  - About 6 inches if the clock ticks at 2GHz
  - About 3 inches if the clock ticks at 4GHz
  - …
- Ultimately it becomes very difficult to get electricity across the board fast enough!

How to get around physics

- So if physics is getting in the way (and it is), you find a way to get around it.
- If you can’t make processors faster, what do you do?
  - Use more cores

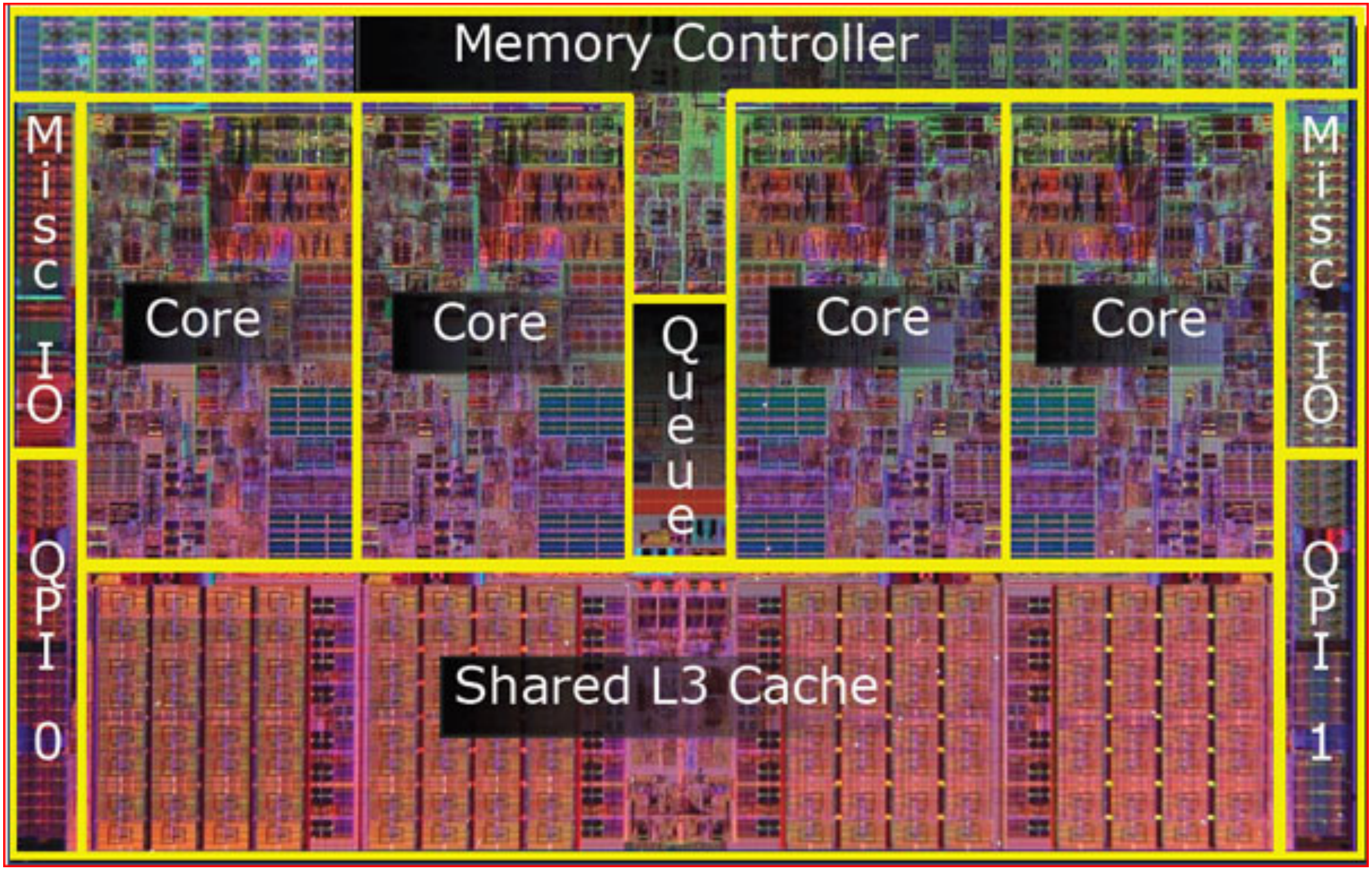
What is a core?

- A core is usually the basic computation unit of the CPU - it can run a single program context (or multiple ones if it supports hardware threads such as hyperthreading on Intel CPUs), maintaining the correct program state, registers, and correct execution order, and performing the operations through ALUs. For optimization purposes, a core can also hold on-core caches with copies of frequently used memory chunks.

What is a core?

- A CPU may have one or more cores to perform tasks at a given time. These tasks are usually software processes and threads that the OS schedules. Note that the OS may have many threads to run, but the CPU can only run X such tasks at a given time, where X = number cores * number of hardware threads per core. The rest would have to wait for the OS to schedule them whether by preempting currently running tasks or any other means.

Inside of Core i7



http://www.pcper.com/reviews/Processors/Intel-Core-i7-3770K-Ivy-Bridge-Processor-Review/Core-i7-3770K-and-CPU-Lineup

Brand	CORE i7	CORE i7	CORE i5	CORE i5	CORE i5
Processor Number	Core i7-3770K	Core i7-3770	Core i5-3570K	Core i5-3550	Core i5-3450
Price	$313	$278	$212	$194	$174
TDP	77	77	77	77	77
Cores/ Threads	4 / 8	4 / 8	4 / 4	4 / 4	4 / 4
CPU Base Freq (GHz)	3.50	3.40	3.40	3.30	3.10
Max Turbo Freq (GHz)	3.90	3.90	3.80	3.70	3.50
DDR3 (MHz)	1600	1600	1600	1600	1600
L3 Cache	8M	8M	6M	6M	6M
Intel® HD Graphics 2500/4000	4000	4000	4000	2500	2500
Graphics Base Render Frequency	650MHz	650MHz	650MHz	650MHz	650MHz
Graphics Max Dynamic Frequency	1150MHz	1150MHz	1150MHz	1150MHz	1100MHz
PCIe Gen3.0	yes	yes	yes	yes	yes
Intel® Secure Key	yes	yes	yes	yes	yes
Intel® OS Guard	yes	yes	yes	yes	yes
Intel® SIPP		yes		yes	
Intel® vPro™ Technology		yes		yes	
Intel® VT-d		yes		yes	
Intel® TXT		yes		yes	

Summary of Cores

- A core is a physical CPU
- CPU has to constantly move data in and out of memory as it processes the code.
- A CPS may have few caches
  - LI, 32kb, within CPU
  - L2, 256/512kb, next to it on the chip
  - L3, several megabytes, shared by all cores,

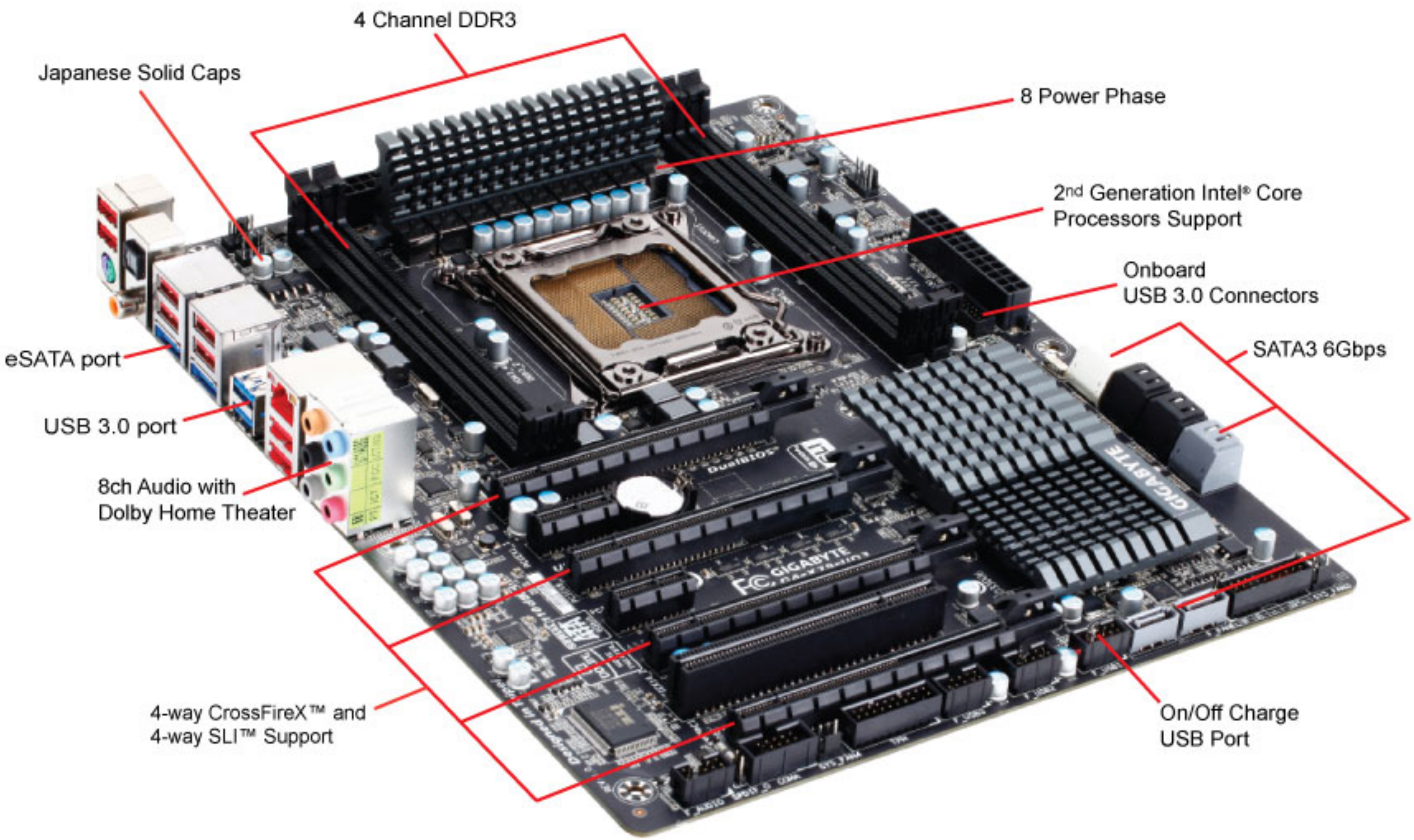
The boot process

- When you turn your computer on, the following activities happen:
  - Power is sent to the internal fans and the motherboard
  - The boot program stored inside of ROM activates the Power-On Self-Test (POST) which runs and tests required system components
  - The operating system/environment is loaded
  - Configuration and customization routines are executed which set your computer environment

Processors Information

- **Comparison of Intel processors**
  - http://en.wikipedia.org/wiki/Comparison_of_Intel_processors
- **Comparison of AMD Processors**
  - http://en.wikipedia.org/wiki/Comparison_of_AMD_Processors
- The are other processors, like Atom, Arm…

Motherboard…(Gigabyte **GA-X79-UD3**)



Primary Storage

- Stores instructions and data for current program(s)
- Other names: primary or main memory, RAM (Random Access Memory)
- Memory is “dynamic” so it requires power to retain information
- Often few of Gigabytes (billion-bytes)

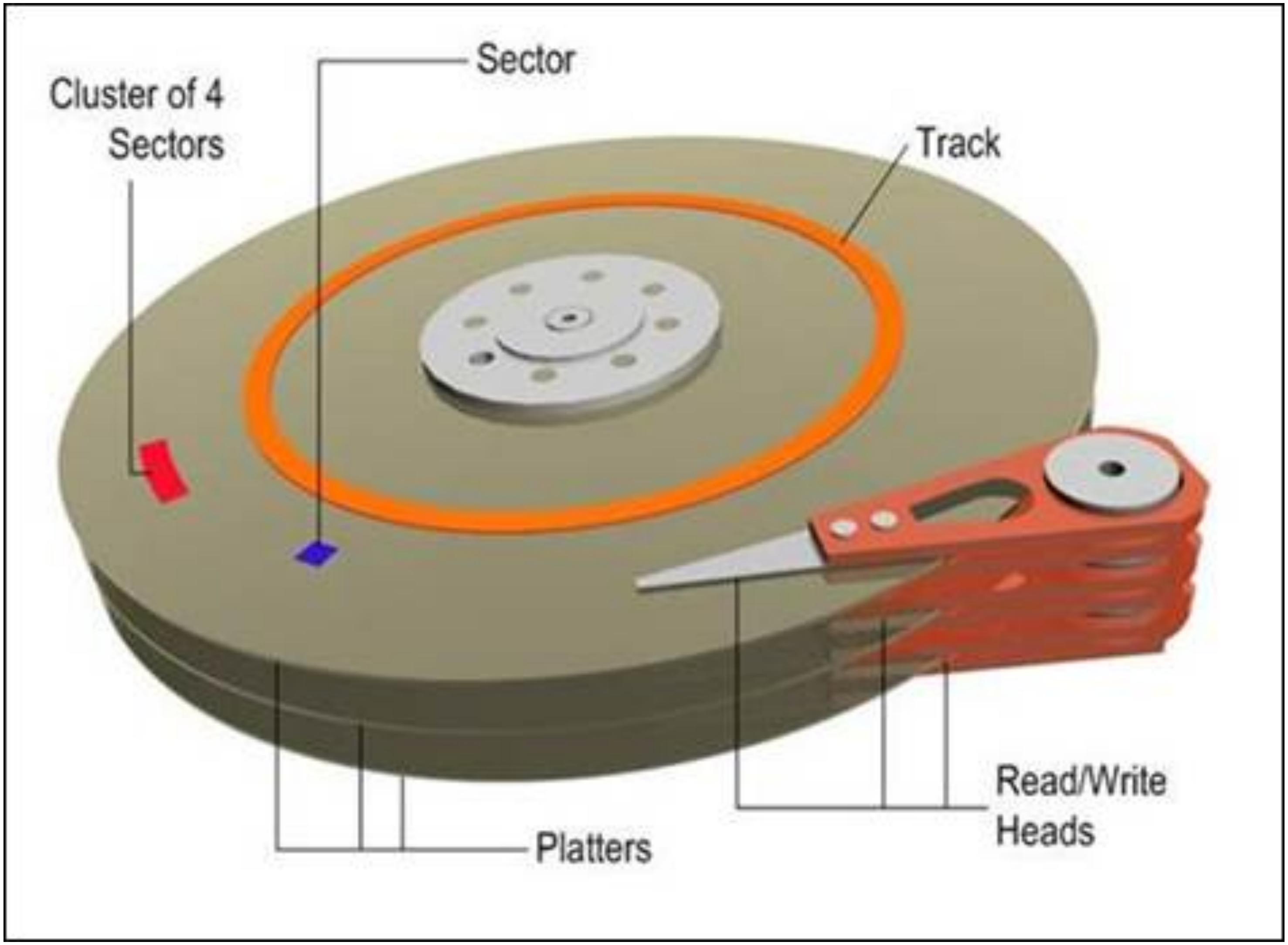
Peripheral Devices

- Secondary storage devices
  - disk (hard & floppy), tape, usb drives, flash drives, etc.
- Input devices
  - keyboard, mouse, camera, mice, etc.
- Output devices
  - monitor, printer, speaker, etc.
- Network
  - wireless, bluetooth, Ethernet, etc.

Secondary Storage

- nonvolatile -- information is recorded magnetically so power is not needed
- disks hold Gigabytes (billions of bytes)
- cheap, but slow
  - RAM access is a hundred CPU clock ticks
  - disk access is a million CPU clock ticks
- not directly accessed by CPU

Disk schematic (http://www.recovermyfiles.com/data-recovery-help/fundamentals.php)



PC Architecture
- a book by Michael Karbo.

- http://www.karbosguide.com/books/pcarchitecture/start.htm

Software

- The programs available for execution
- Simple classification
  - System software
  - Application software

System Software

- Operating systems
  - manages system resources,
    - Windows, UNIX, Mac OS
- User interface
  - interfaces with operating system,
    - X, Windows
- Combined
  - OS & interface
    - Windows 8.1, Mountain Lion

Operating system

- **Processor management**
  - Scheduling
- **Memory management**
- **Device management**
- **Storage management**
- **Application interface**
- **User interface**

Threads

- A thread is a piece of code to be executed
- Each CPU has a pipeline for executing codes
- Without hyperthreading, the pipeline may look like this:
  - *thread1— thread1— (delay)— thread1—- thread2— (delay)— thread2— thread3— thread3— thread3—*
- With hyperthreading, the pipeline may look like this:
  - *thread1— thread1— thread2— thread2— thread1— thread2— thread1— thread2— thread2—*

Human time vs CPU time

- Typical CPU works at nanosecond speed, that is, 10^{-9} of a second
- Humans, as consumers of sound, pictures…, operate at 1/60th of a second, say, roughly 10^{-2} of a second.
  - Thus a CPU can do $10^7 = 10$ million other things before attending to a human

Application Software

- Programs which perform specific tasks for the user (and use the operating system to interact with the hardware)
  - Examples: word processor, spreadsheet, internet browser, etc.

Program

- A program is a sequence of instructions.
- Programs and data are both in main memory when they are active.
- To *run* a program is to:
  - Create the sequence of instructions according to your design and the language rules
  - Turn that program into the binary commands (known as machine instruction) the processor understands
  - Give the binary code to the OS, so it can give it to the processor
  - OS tells the processor to run the program
  - When finished (or it dies :-)), OS cleans up.

Programming Languages

- High level
- Low level
  - Machine instructions
  - Good example
    - https://chortle.ccsu.edu/java5/Notes/chap04/ch04_4.html
- General or dedicated
- What's the best programming language?

Reference:

- Visualizing Technology, 5th edition, Chapter 4, Debra Geoghan, Pearson Publishing.
- Wikipedia