

# WELCOME TO COURSE COSC 2425 COMPUTER ORGANIZATION

JAVAD AMERI

# Computer Organization

# Overview

- Why study computer organization and 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.

# Computer organization vs Computer architecture

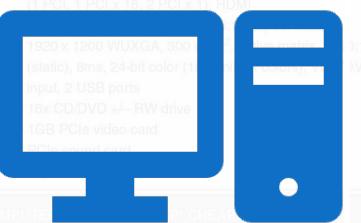
## Computer organization

- Encompasses all physical aspects of computer systems (e.g., circuit design, control signals, memory types)
- How does a computer work?

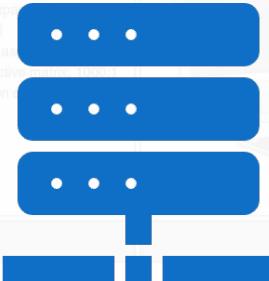
## Computer architecture

- Logical aspects of system implementation as seen by the programmer (e.g., instruction sets, instruction formats, data types, addressing modes)
- How do I design a computer?

# Computer System



# Hardware Software



- Compact computer
- Intel i9 16 Core, 4.20 GHz
- 3733MHz 32GB DDR4 SDRAM
- 128KB L1 cache, 2MB L2 cache
- Dual storage (7200RPM SATA 1TB HDD, 128GB SSD)
- Wireless 802.11 + Bluetooth 4.0
- 7-in-1 card reader
- 10 USB ports, 1 serial port, 4 PCI expansion slots (1 PCI, 1 PCI x 16, 2 PCI x 1), HDMI
- 24" widescreen LCD monitor, 16:10 aspect ratio, 1920 x 1200 WUXGA, 300 cd/m<sup>2</sup>, active matrix, 1000:1 (static), 8ms, 24-bit color (16.7 million colors), VGA/DVI input, 2 USB ports
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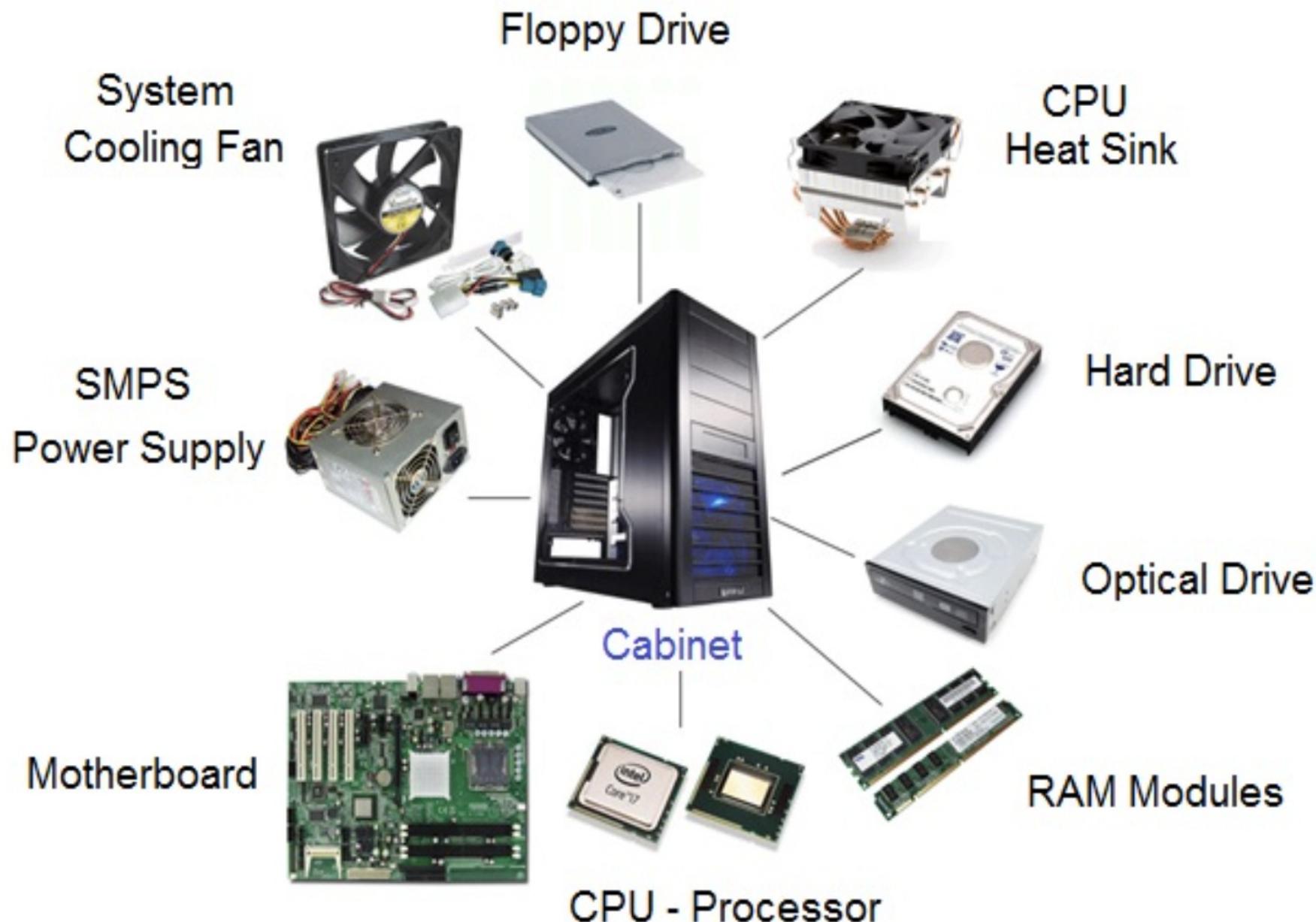
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# Computer System

At the most basic level, a computer is a device consisting of three pieces:

- A CPU( processor) to interpret and execute programs
- A memory to store both data and programs
- A mechanism for transferring data to and from the outside world

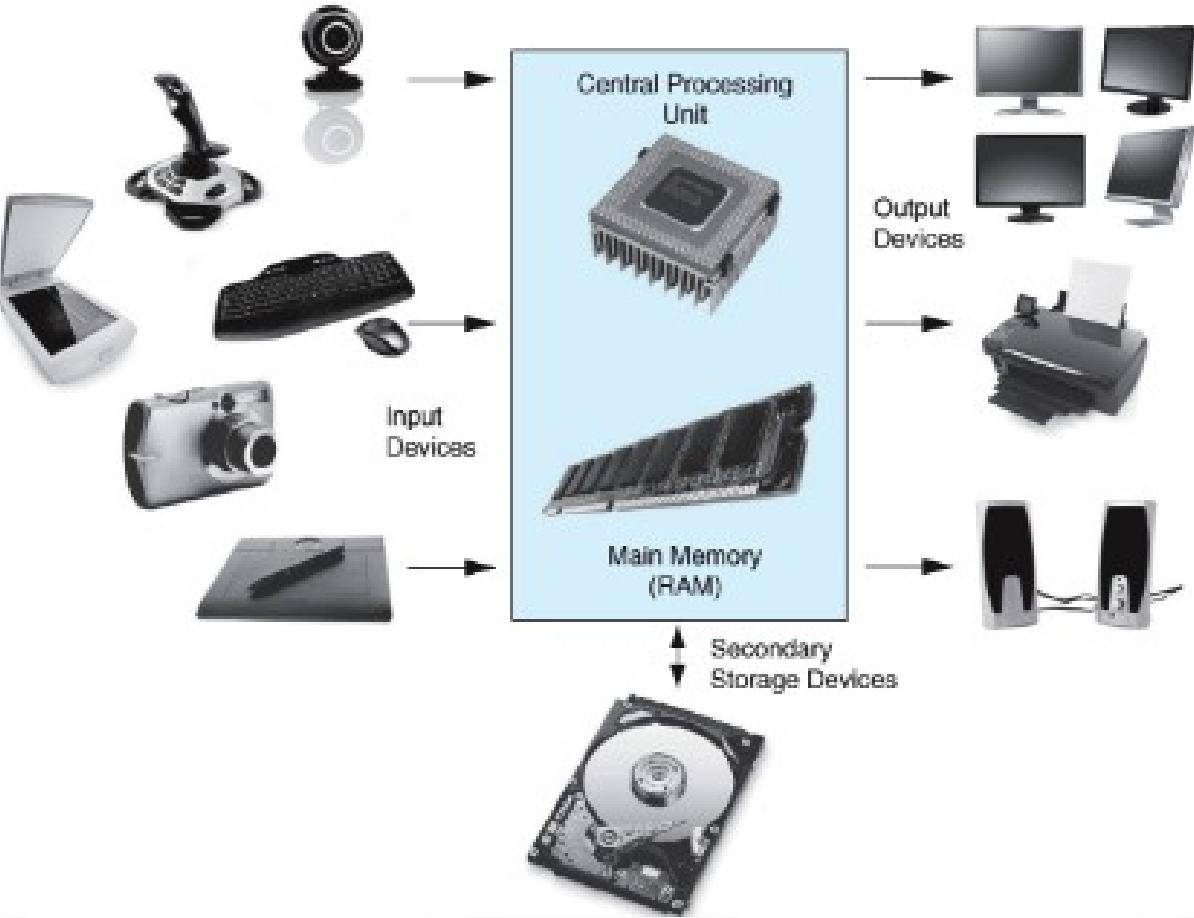
# Computer System - Internal Hardware Components



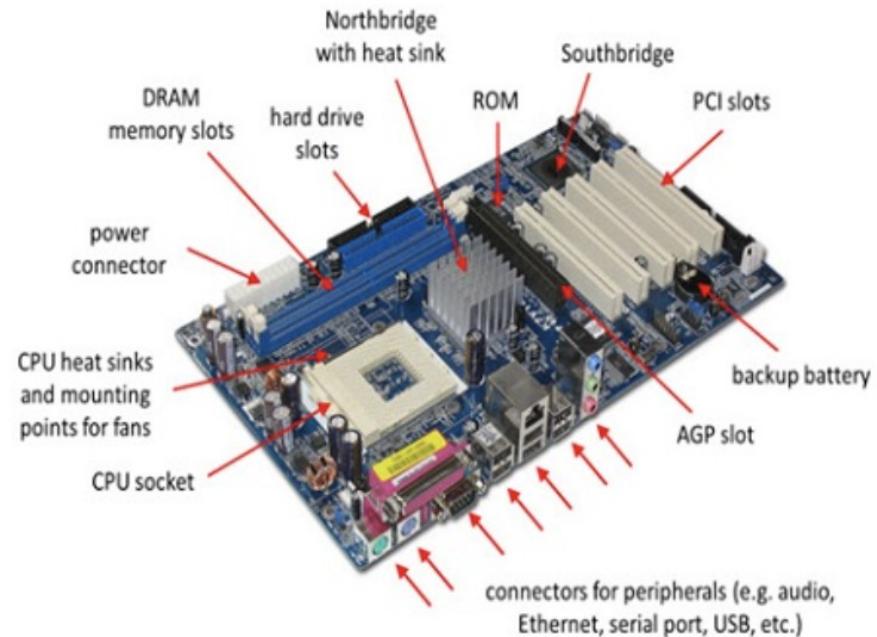
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# System configuration

CPU  
RAM  
ROM  
CMOS

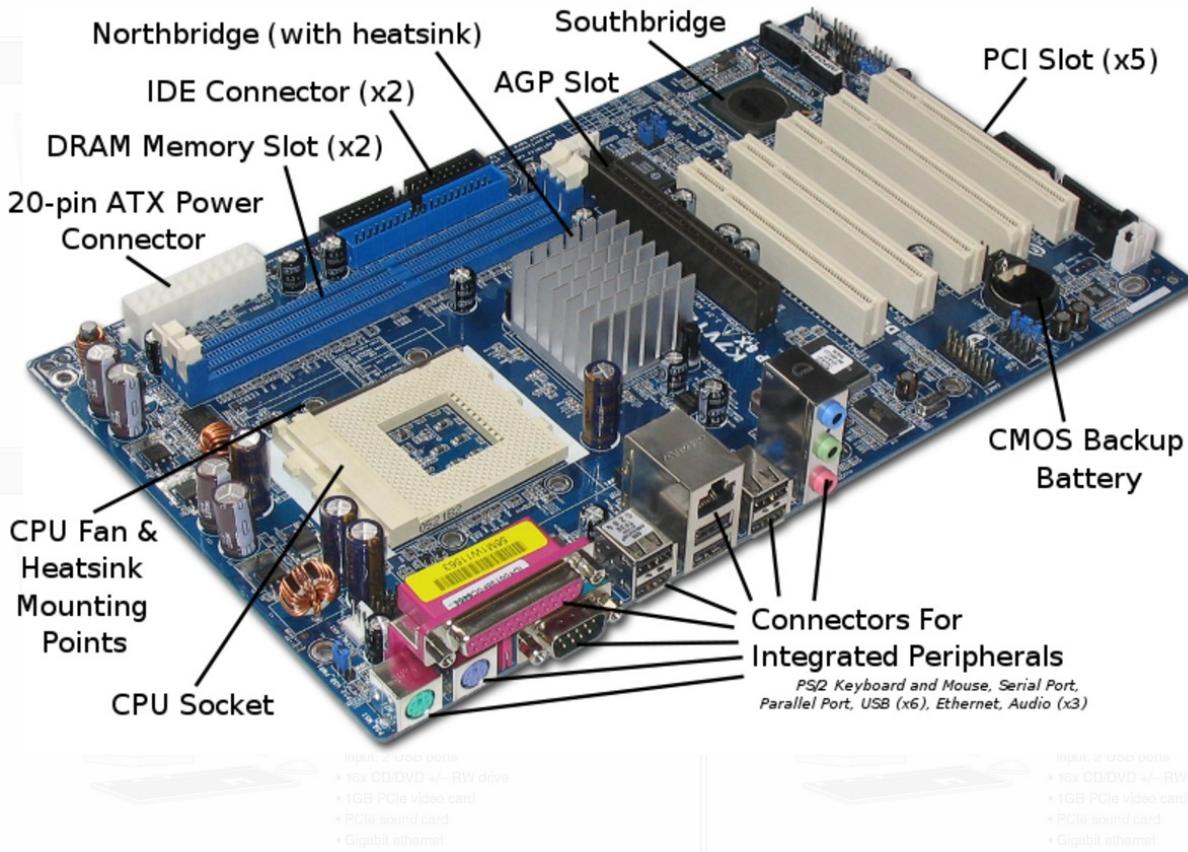
CACHE MEMORY  
SOUND CARD  
GRAPHIC CARD  
POWER SUPPLY  
HD(MAGNETIC/  
SSD)

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# Computer Hardware

A typical computer system consists of the following major components:

The central processing unit (CPU)

Main memory

Secondary storage devices

Input devices

Output devices

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# COMPUTER SYSTEM

CPU

Main  
memory

Secondar  
y storage  
devices

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# Computer internal memory

Read & Write - volatile

**RAM**  
(Rando m Access memory )

**ROM**  
(Read only memory )

Read & Write - volatile

**Cache memory**

**CMOS memory**

Data / Instruction flow:

- 1 - Read only
- 2 - Read & Write

Read Only - Non-volatile

Read & Write - volatile

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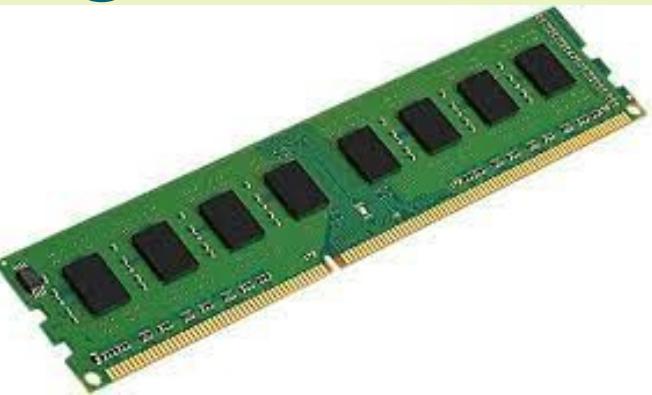
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# Internal Storage Devices

Name
1 - RAM-Random Access Memory
2 - ROM-Read Only Memory
3 - Cache Memory(L1,L2, L3)
4 - CMOS



- \* Wireless 802.11 + Bluetooth 4.0
- \* 7-in-1 card reader
- \* 10 USB ports, 1 serial port, 4 PCI expansion slots

(1)  
\* 24'  
18'  
(8)  
inp  
\* 16'  
\* 1G  
\* PC  
\* Gig

- \* Co
  - \* Int
  - \* 3D
  - \* 128
  - \* Du
  - \* Wi
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- 1920 x 1200 WUXGA, 300 cd/m<sup>2</sup>, active matrix, 1000:1 (static), 8ms, 24-bit color (16.7 million colors), VGA/DVI input, 2 USB ports  
\* 16x CD/DVD +/- RW drive  
\* 1GB PCIe video card  
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# What is the storage unit in computer storage devices?

- In most computer systems, a **byte** is a unit of data
- A **byte** is the unit most computers use to represent a character such as a letter, number or typographic symbol
- **byte**, the basic unit of information in computer storage and processing
- A byte consists of 8 adjacent binary digits (**bits**), each of which consists of a 0 or 1

# RAM

**RAM(Random Access Memory)** is a part of computer's Main Memory which is directly accessible by CPU. RAM is used to Read and Write data into it which is accessed by CPU randomly. RAM is volatile in nature, it means if the power goes off, the stored information is lost

RAM (Random Access Memory) is a device that holds data and instructions

RAM holds the sequence of instructions in the programs that are running and the data those programs are using

# Computer internal memory- RAM

\* 3.7GHz 32GB DDR4 SDRAM

\* 128KB L1 cache, 2MB L2 cache

\* Dual storage (7200RPM SATA 1TB HDD, 128GB SSD)

\* Wireless 802.11 + Bluetooth 4.0

\* 7-in-1 card reader

\* 10 USB ports, 1 serial port, 4 PCI expansion slots

(1 PCI, 1 PCI x 16, 2 PCI x 1), HDMI

\* 24" widescreen LCD monitor, 16:10 aspect ratio,

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(static), 8ms, 24-bit color (16.7 million colors), VGA/DVI

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## Ram(Random Access Memory) ☰ Main Memory

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(1 PCI, 1 PCI x 16, 2 PCI x 1), HDMI

RAM's purpose is to **store the short-term data & Instructions that a computer requires to properly operate**

\* Compact computer

\* Compact computer

\* Compact computer

RAM (random access memory) is a computer's short-term memory, where the data & Instructions that the CPU(processor) is currently using is stored

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**RAM is volatile memory that temporarily stores the files you are working on**

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# RAM



Main memory is an ordered sequence of cells, called **memory cells(bytes)**



Each cell has a unique location in main memory, called the **address** of the cell



When the computer is turned off, RAM loses its data

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	149	17	18
20	21	22	23	72	24	25	26	27	28

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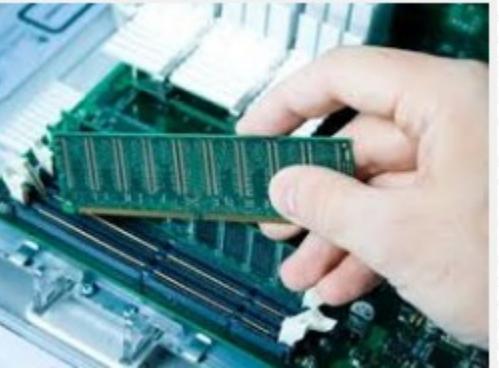
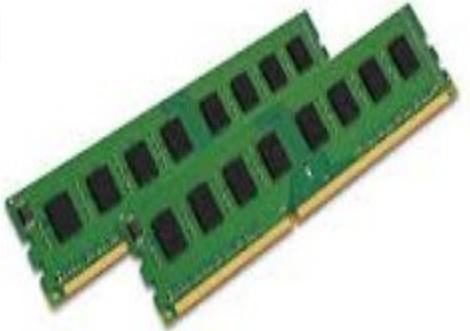
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## Hotworld Desktop RAM



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# An Example System

FOR SALE: OBSOLETE COMPUTER – CHEAP! CHEAP! CHEAP!



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# Measures of capacity

- Kilo - (K) = 1 thousand =  $10^3$  and  $2^{10}$
- Mega - (M) = 1 million =  $10^6$  and  $2^{20}$
- Giga - (G) = 1 billion =  $10^9$  and  $2^{30}$
- Tera - (T) = 1 trillion =  $10^{12}$  and  $2^{40}$
- Peta - (P) = 1 quadrillion =  $10^{15}$  and  $2^{50}$
- Exa - (E) = 1 quintillion =  $10^{18}$  and  $2^{60}$
- Zetta - (Z) = 1 sextillion =  $10^{21}$  and  $2^{70}$
- Yotta - (Y) = 1 septillion =  $10^{24}$  and  $2^{80}$
- Whether a metric refers to a power of ten or a power of two typically depends upon what is being measured.

# Measures of capacity and speed:

- Kilo- (K) = 1 thousand = and
- Mega- (M) = 1 million = and
- Giga- (G) = 1 billion = and
- Tera- (T) = 1 trillion = and
- Peta- (P) = 1 quadrillion = 10<sup>15</sup> and 250
- Exa- (E) = 1 quintillion = 10<sup>18</sup> and 260
- Zetta- (Z) = 1 sextillion = 10<sup>21</sup> and 270
- Yotta- (Y) = 1 septillion = 10<sup>24</sup> and 280
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# Memory capacity

Prefix	Symbol	Exponent ial	Numeric	Binary	Decimal value
Kilo	K	$10^3$	1,000	$2^{10}$	1024
Mega	M	$10^6$	1,000,000	$2^{20}$	1,048,576
Giga	G	$10^9$	1,000,000,000	$2^{30}$	1,073,741,824
Tera	T	$10^{12}$	1,000,000,000,000	$2^{40}$	1,099,511,627,776
Peta	P	$10^{15}$	1,000,000,000,000,000	$2^{50}$	
Exa	E	$10^{18}$	$4 \text{ TB RAM} - 4 * 1,000,000,000,000 = 4,000,000,000,000$		
Zetta	Z	$10^{21}$	00	0	

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# • Hertz = clock cycles per second (frequency)

- $1\text{MHz} = 1,000,000\text{Hz}$
- Processor speeds are measured in MHz or GHz.

# • Byte = a unit of storage

- $1\text{KB} = 2^{10} = 1024 \text{ Bytes}$
- $1\text{MB} = 2^{20} = 1,048,576 \text{ Bytes}$
- $1\text{GB} = 2^{30} = 1,099,511,627,776 \text{ Bytes}$
- Main memory (RAM) is measured in GB.
- Disk storage is measured in GB for small systems, TB (240) for large systems.

# Measures of time and space:

- Milli- (m) = 1 thousandth =  $10^{-3}$
- Micro- ( $\mu$ ) = 1 millionth =  $10^{-6}$
- Nano- (n) = 1 billionth =  $10^{-9}$
- Pico- (p) = 1 trillionth =  $10^{-12}$
- Femto- (f) = 1 quadrillionth =  $10^{-15}$
- Atto- (a) = 1 quintillionth =  $10^{-18}$
- Zepto- (z) = 1 sextillionth =  $10^{-21}$
- Yocto- (y) = 1 septillionth =  $10^{-24}$

- Millisecond = 1 thousandth of a second
  - Hard disk drive access times are often 10 to 20 milliseconds.
- Nanosecond = 1 billionth of a second
  - Main memory access times are often 50 to 70 nanoseconds.
- Micron (micrometer) = 1 millionth of a meter
  - Circuits on computer chips are measured in microns.

# Cycle time is the reciprocal of clock frequency

A bus operating at 133MHz has a cycle time of 7.52 nanoseconds:

$$133,000,000 \text{ cycles/second} = 7.52 \text{ ns/cycle}$$

# DDR2 VS DDR3 VS DDR4 RAM

Feature	DDR2	DDR3	DDR4	DDR5
TRANSFER RATE (MB/S) (MEGA BITS PER SECOND)	400 MB/S – 1066 MB/S	800MB/S- 2133MB/S	1600MB/S- 3200MB/S	
MEMORY DENSITY		512MB – 8GB	2GB – 16GB	
VOLTAGE	1.8 VOLTS	1.5 VOLTS		

# Computer internal memory- ROM

- \* Intel i9-10900K, 4.20 GHz
- \* 3739MHz 32GB DDR4 SDRAM
- \* 128KB L1 cache, 2MB L2 cache
- \* Dual storage (7200RPM SATA 1TB HDD, 128GB SSD)
- \* Wireless 802.11 + Bluetooth 4.0
- \* 7-in-1 card reader
- \* 10 USB ports, 1 serial port, 4 PCI expansion slots (1 PCI, 1 PCI x 16, 2 PCI x 1), HDMI
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ROM **stands for non-volatile memory in computers**, which means the information is permanently stored on the ROM chip

ROM is non-volatile; even after you turn off your computer, the contents of ROM will remain

Almost every computer comes with a small amount of ROM containing the boot firmware. This consists of a few kilobytes of code that tell the computer what to do when it starts up, e.g., running hardware diagnostics and loading the operating system into RAM. On a PC, the boot firmware is called the BIOS

# The organization of the CPU

Arithmetic & Logic unit  
(ALU)

Control  
unit

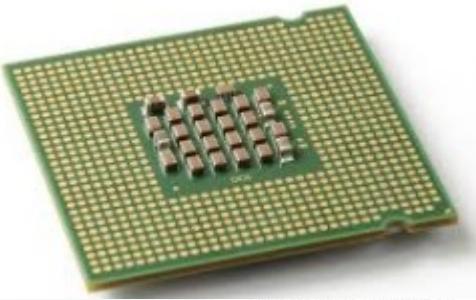
Internal Registers

Cache Memory  
(L1)

ALU is designed  
to perform  
mathematical  
operations

COORDINATES  
ALL OF THE  
COMPUTER'S  
OPERATIONS

# CPU images



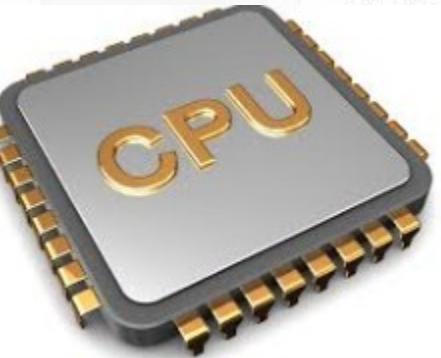
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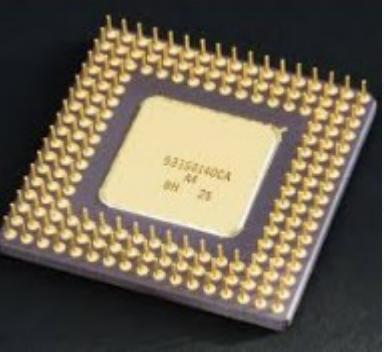
[www.cpu-world.com](http://www.cpu-world.com) PCI expansion slots



PCI slots



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HDD, 128GB SSD)



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# CPU speed unit

Every computer has an internal clock, which emits electronic pulse at a constant rate.

These pulses are used to control and synchronize the pace of operations

The unit of measurement of clock speed is the hertz (HZ), with 1 hertz equaling 1 pulse per second

## CPU SAMPLE

2 MHZ

2 \* 1,000,000 HZ

**2 GHZ**

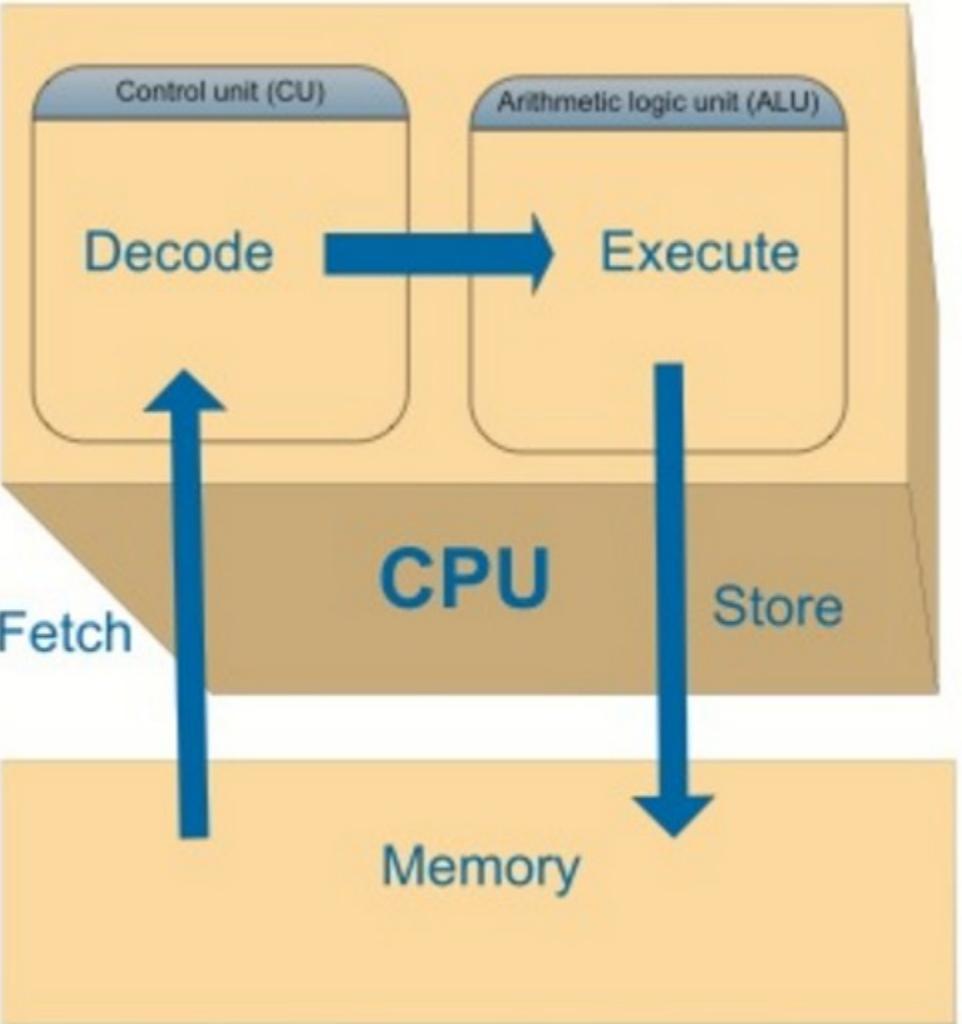
**2 \* 1,000,000,000 HZ**

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Portable desktop computer (Intel i9-10900K)

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# THE CPU'S JOB

## Fetch:

- The CPU's control unit fetches, from main memory, the next instruction in the sequence of program instructions

CPU

RAM

# THE CPU'S JOB

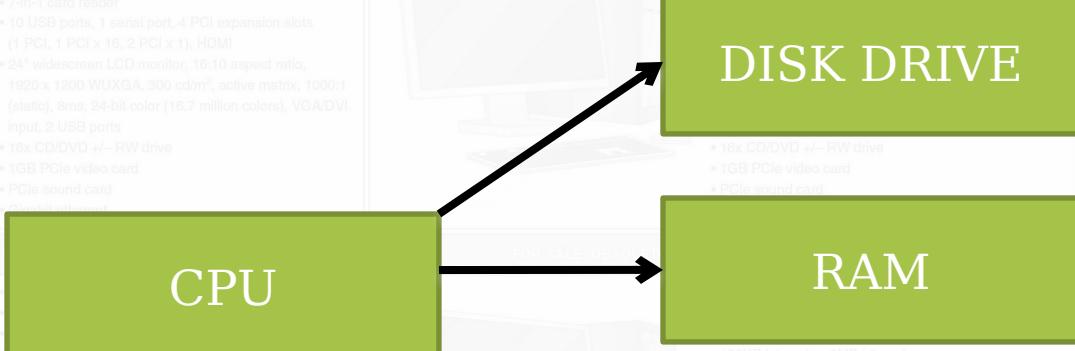
## Decode:

- The instruction is encoded in the form of a number. The control unit decodes the instruction and generates an electronic signal

# The job CPU

## Execute:

- The signal is routed to the appropriate component of the computer (such as the ALU, a disk drive, or some other device). The signal causes the component to perform an operation



# CPU & MAIN MEMORY COMMUNICATION

A CPU core communicates with main memory (RAM) over a bus

The CPU also communicates with peripherals via buses

A bus is a communication system that transfers data between components inside a computer

The computer buses are electrical wires which connect the various hardware components in a computer system

There are three types of Buses:

- Address bus
- Control bus
- Data bus

# CPU & MAIN MEMORY COMMUNICATION

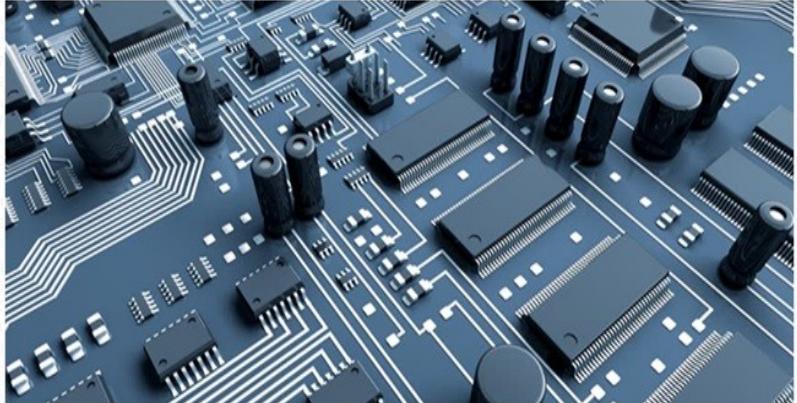
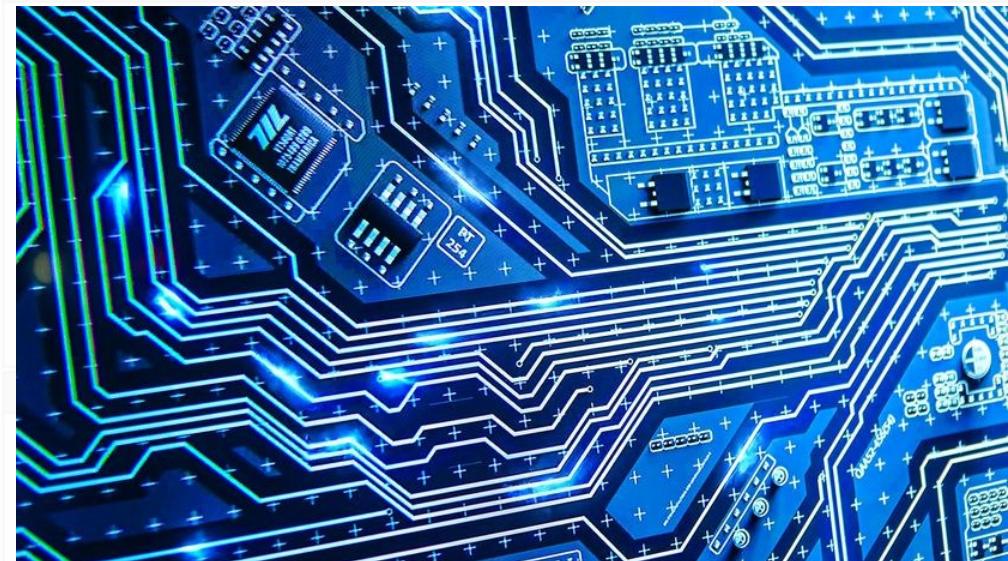
CPU

ADDRES  
S BUS

DATA  
BUS

CONTRO  
L BUS

MEMORY



Computer – Data , Address , Control Buses

# Data Bus

A data bus **can transfer data to and from the memory of a computer**, or into or out of the central processing unit (CPU) that acts as the device's "engine." A data bus can also transfer information between two computers.

- \* PCIe sound card
- \* Gigabit ethernet

- \* PCIe sound card
- \* Gigabit ethernet

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# Control Bus

The control bus is used to transfer the **control signals** from one component to another computer

A control bus is used by the CPU to communicate with the devices that are connected to the computer system

These devices are connected with the help of cables and printed circuits boards such as motherboard

The Central Processing Unit (CPU) transmits different types of control signals to the system components. The devices also communicate with CPU by transmitting the control signals using the control bus

# Address Bus!?

- 16x CD/DVD +/- RW drive
- 1GB PCIe video card
- PCIe sound card

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- 1GB PCIe video card
- PCIe sound card

The **computer program** consist of number of program instructions. These instructions direct the CPU to perform desired operation.

The **operating system** loads the program instructions and the data into the main memory . The CPU executes the program instructions one-by-one by fetching the program instructions from the main memory **RAM** ( Random Access Memory ) .

In order to perform the memory read or write operation from the main memory RAM , the CPU sends either read or write control signal on the control bus and address of the memory location along the “Address Bus” from where the operation is to be performed .

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# The organization of the CPU

Arithmetic & Logic unit  
(ALU)

Control  
unit

Internal Registers

Cache Memory  
(L1)

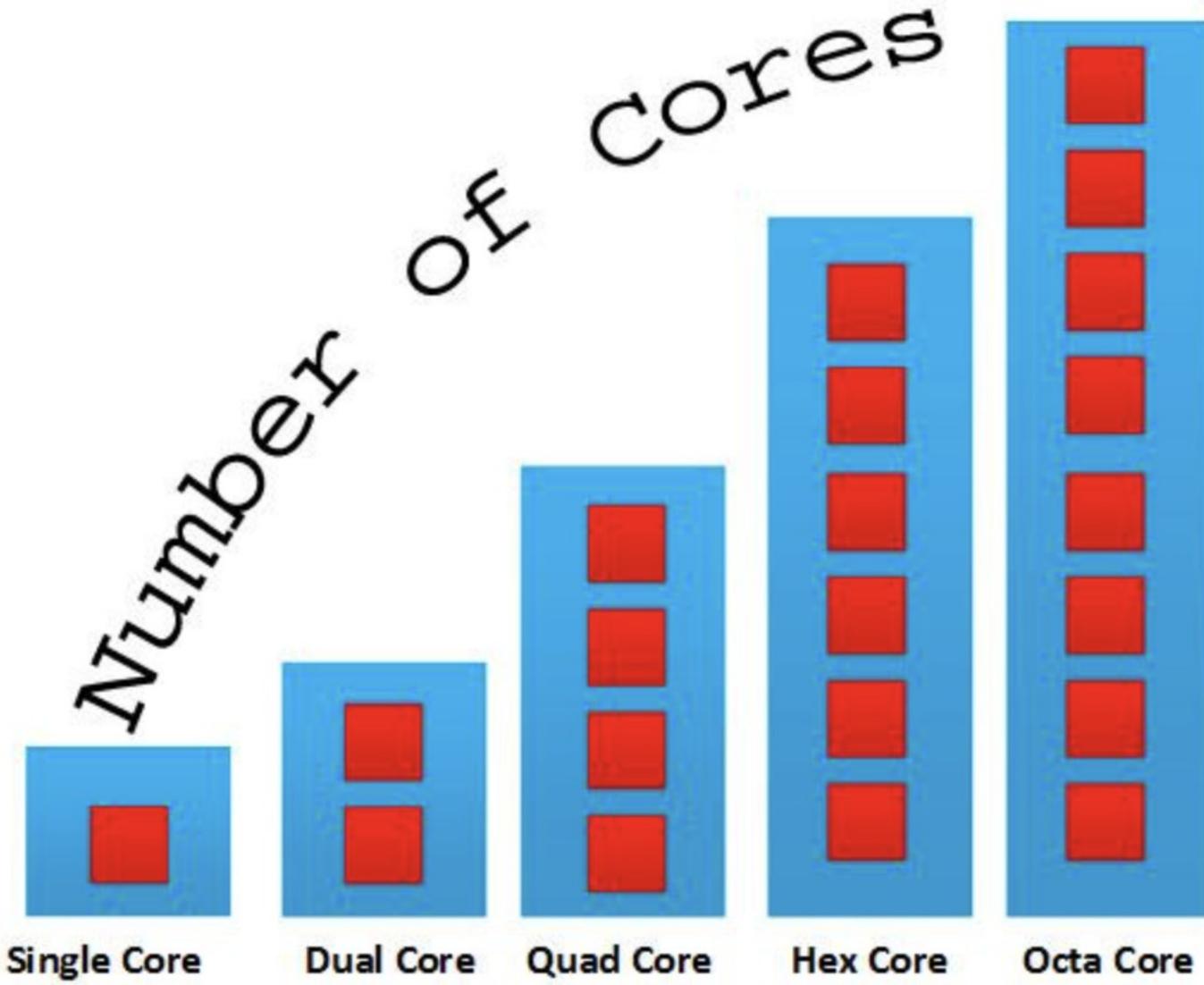
ALU is designed  
to perform  
mathematical  
operations

COORDINATES  
ALL OF THE  
COMPUTER'S  
OPERATIONS

# Multicore CPU ???

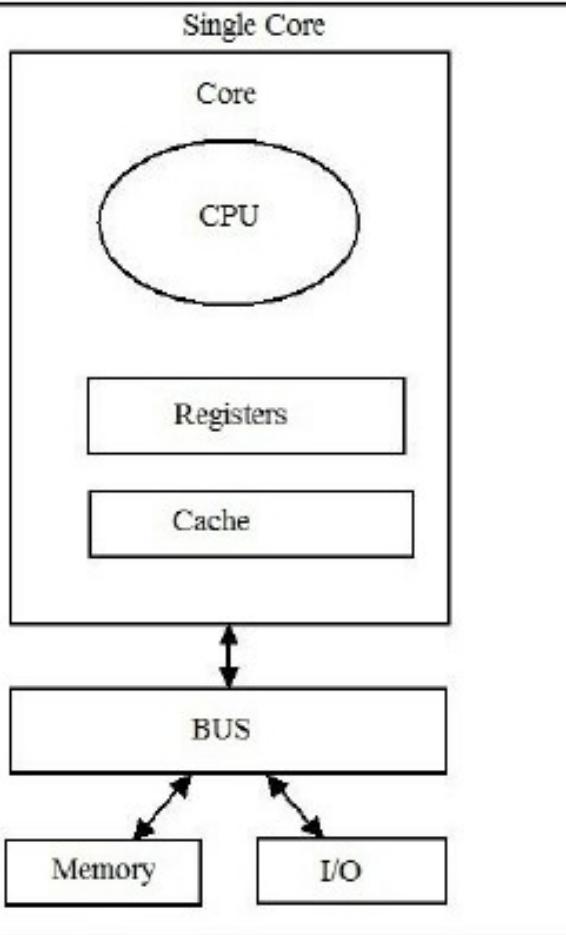
- With all of the difficulties designers have turned to a fundamentally new approach to improving performance
- Placing multiple processors on the same chip, with a large shared cache
- The use of multiple processors on the same chip, also referred to as multiple cores, or multicore, provides the potential to increase performance without increasing the clock rate

# Single Core - Octa Core CPU

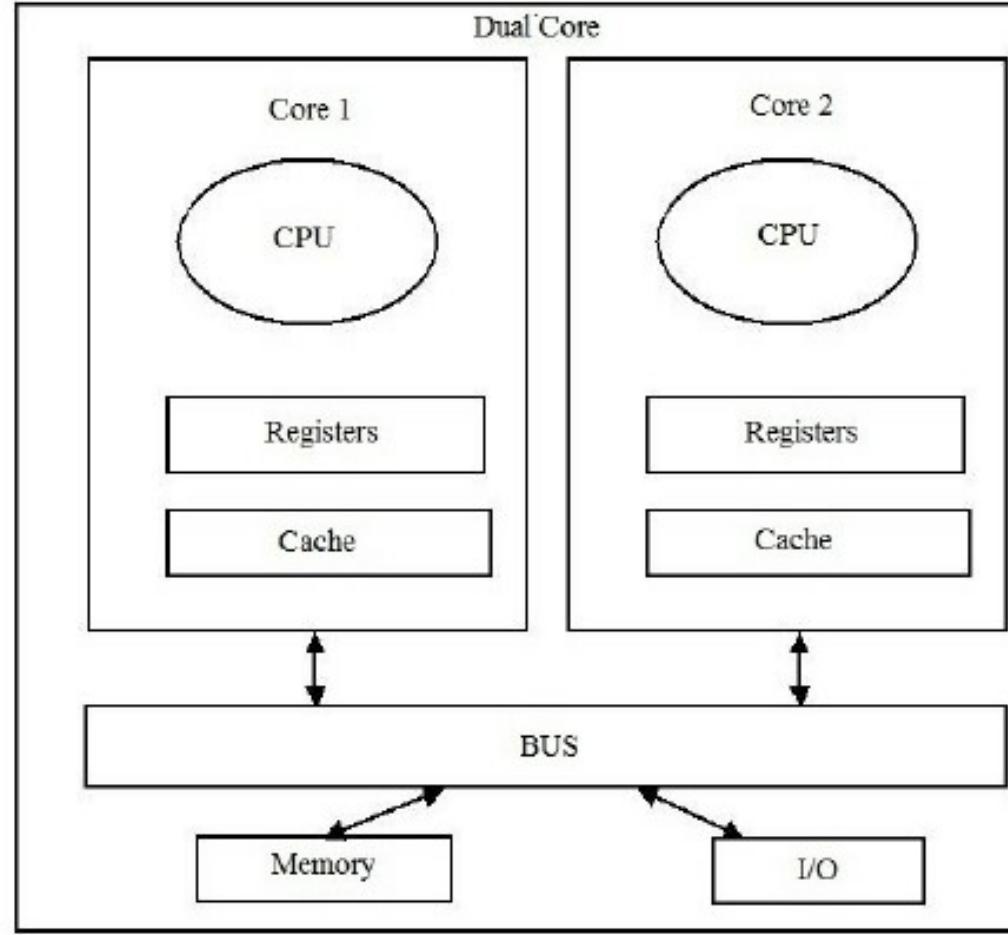


# Single Core VS Dual Core CPU

(static), 8ms, 24-bit color (16.7 million colors), VGA/DVI  
input, 2 USB ports



(static), 8ms, 24-bit color (16.7 million colors), VGA/DVI  
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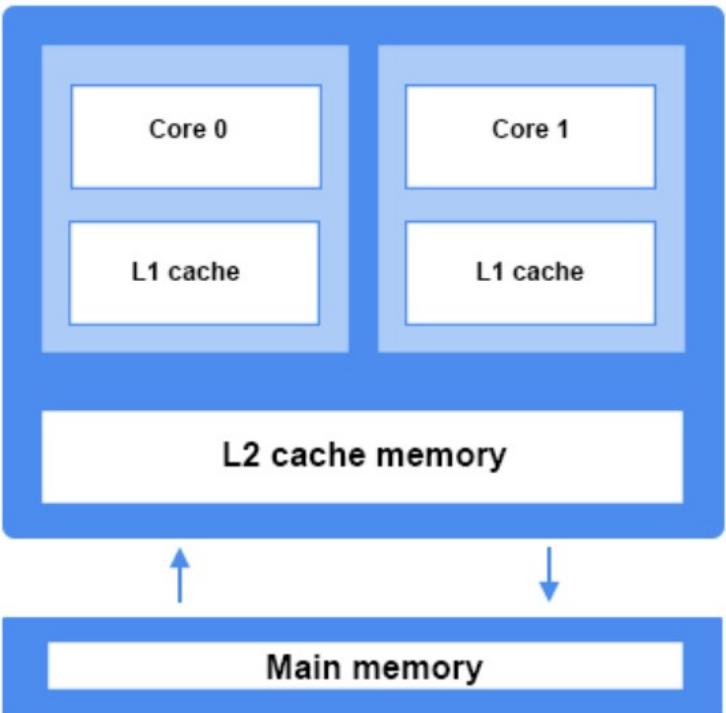
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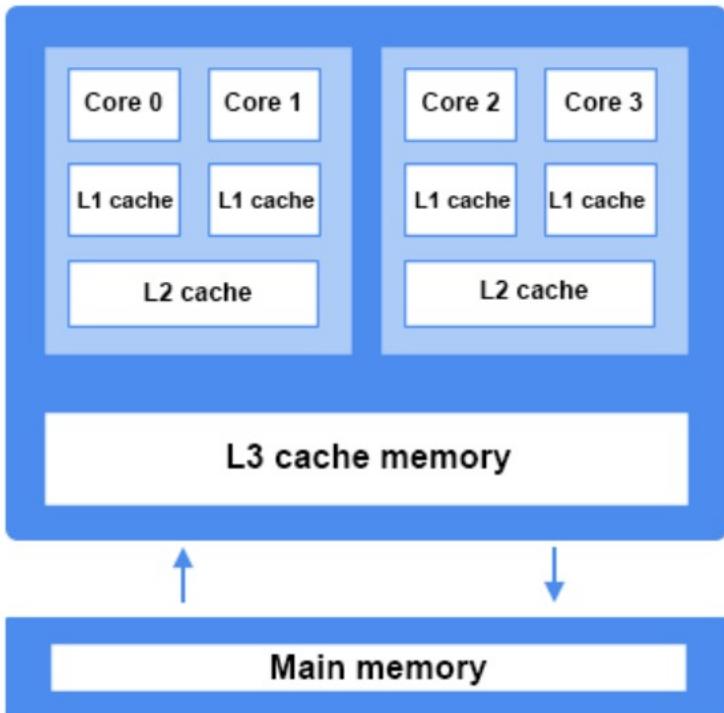
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# Dual-Core VS Quad-Core CPU

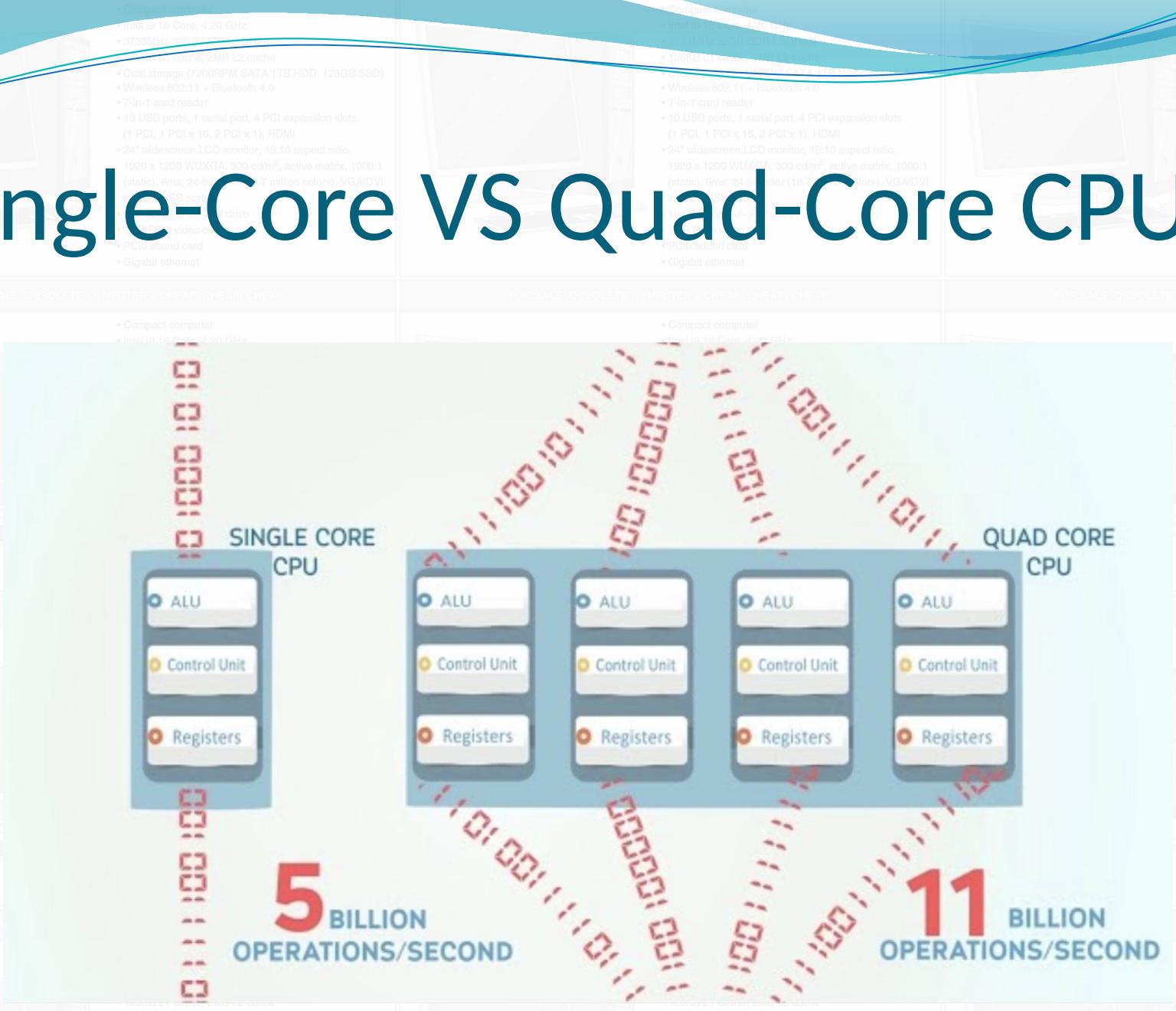
**Dual-core CPU:**



**Quad-core CPU:**



# Single-Core VS Quad-Core CPU



# BUS ARCHITECTURE

- \* PCIe sound card
- \* Gigabit ethernet

- \* PCIe sound card
- \* Gigabit ethernet

• Pentium desktop computer (Intel Pentium 4)

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**Storage Devices**

e.g., Disk, CD, and Tape

**Memory**

- \* Compact computer
- \* Intel i9 16 Core, 4.20 GHz
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**CPU**

**Bus**

**Communication Devices**

e.g., Modem, and NIC

**Input Devices**

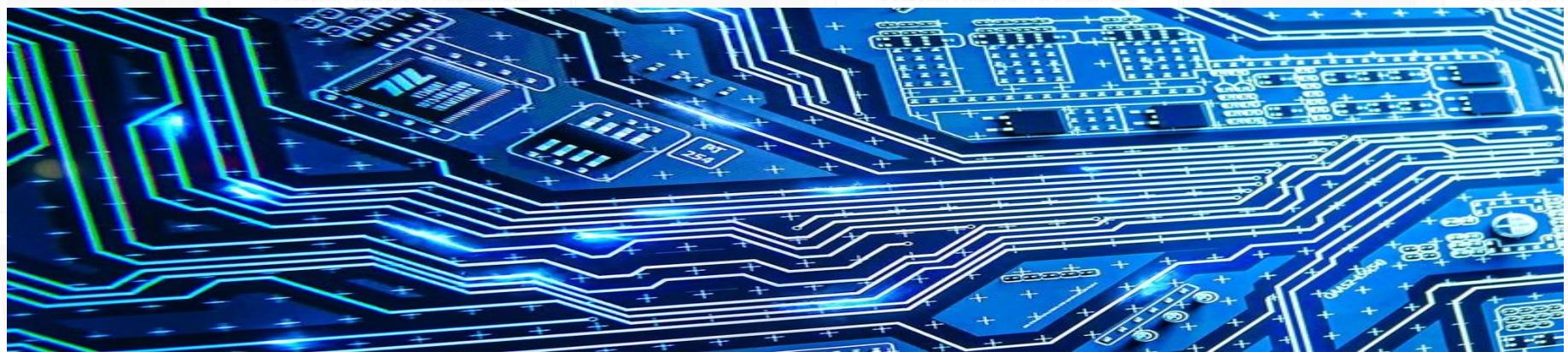
e.g., Keyboard, Mouse

**Output Devices**

e.g., Monitor, Printer

128GB DDR4 SDRAM  
2 cache  
1 SATA 1  
cache 4.0

\* 10 USB ports, 1 serial port, 4 PCI expansion slots



- \* 128KB L1 cache, 2MB L2 cache
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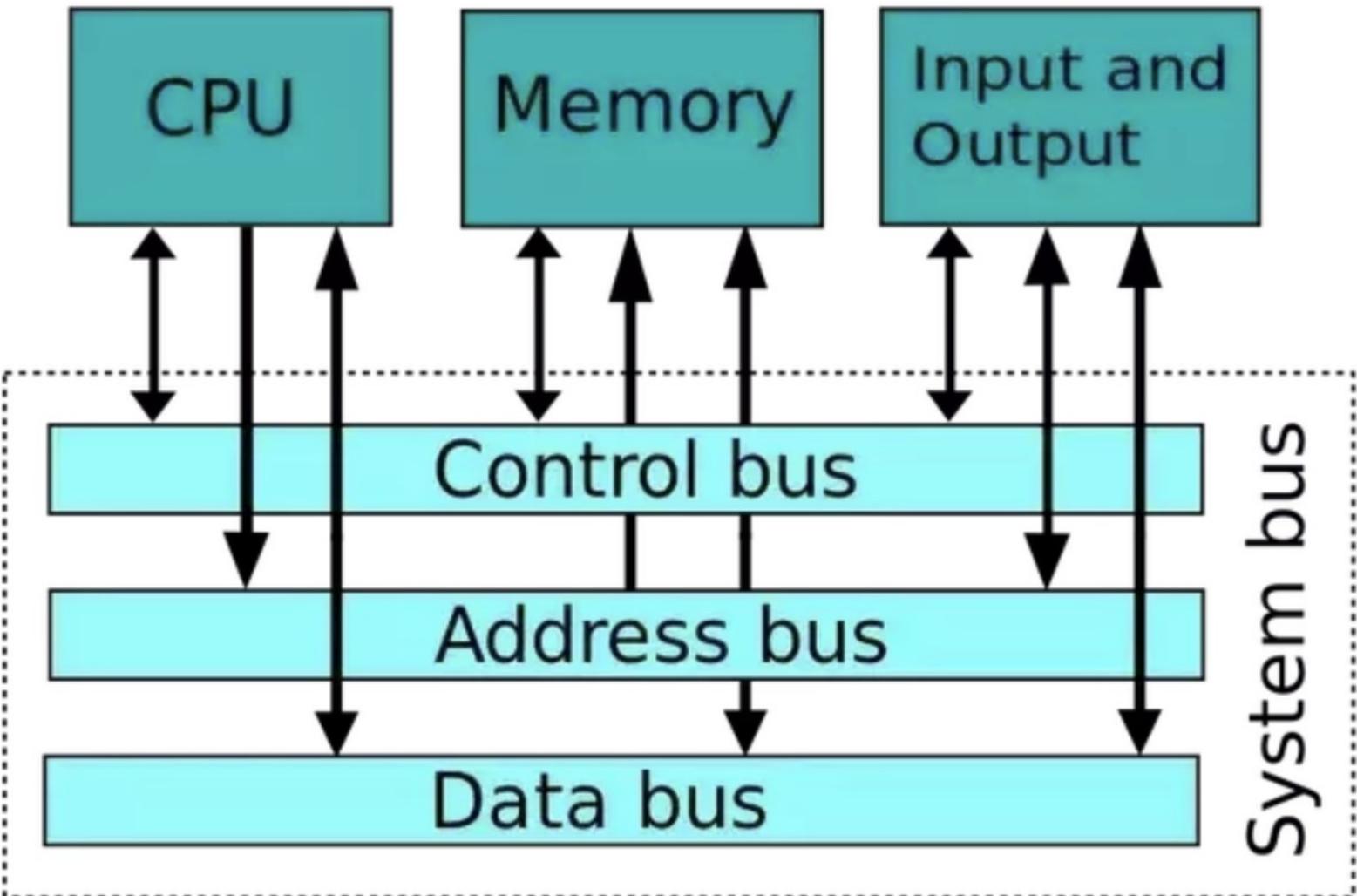
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- \* DVD +/- RW d

- \* 1GB PCIe video card

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# BUS ARCHITECTURE



# Binary Number System

## Byte

7	6	5	4	3	2	1	0
$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
128	64	32	16	8	4	2	1

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# Bit VS Byte

Bits are used to measure data transfer speed rate as Internet connection  
(Example: 25Mbps)

Bytes are used to measure file size and storage capacity (Example: 2GB)

# Secondary Storage Devices

## Hard disk

- Magnetic Hard Disk
- Solid State Drive(SSD)
- Magnetic tape

## Flash Memory

- Secure Digital card (SD) memory
- Compact memory card
- Flash Memory

## Compact Disk

- CD disk
- DVD disk
- Blue Ray disk



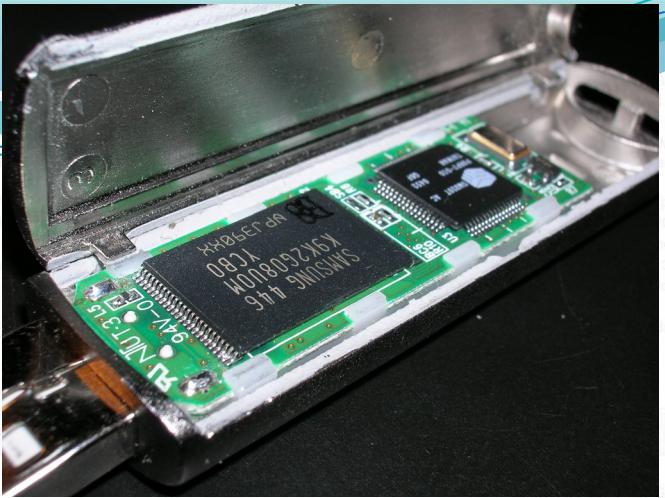
SD



SDHC



SDXC



- \* 3733MHz 32GB DDR4 SDRAM
- \* 128KB L1 cache, 2MB L2 cache

- \* 3733MHz 32GB DDR4 SDRAM
- \* 128KB L1 cache, 2MB L2 cache



CompactFlash

Card



4  
GB / Go

V Verbatim

- \* 3733MHz 32GB DDR4 SDRAM
- \* 128KB L1 cache, 2MB L2 cache
- \* Dual storage (7200RPM SATA 1TB HDD, 128GB SSD)
- \* Wireless 802.11 + Bluetooth 4.0
- \* 7-in-1 card reader
- \* 10 USB ports, 1 serial port, 4 PCI expansion slots



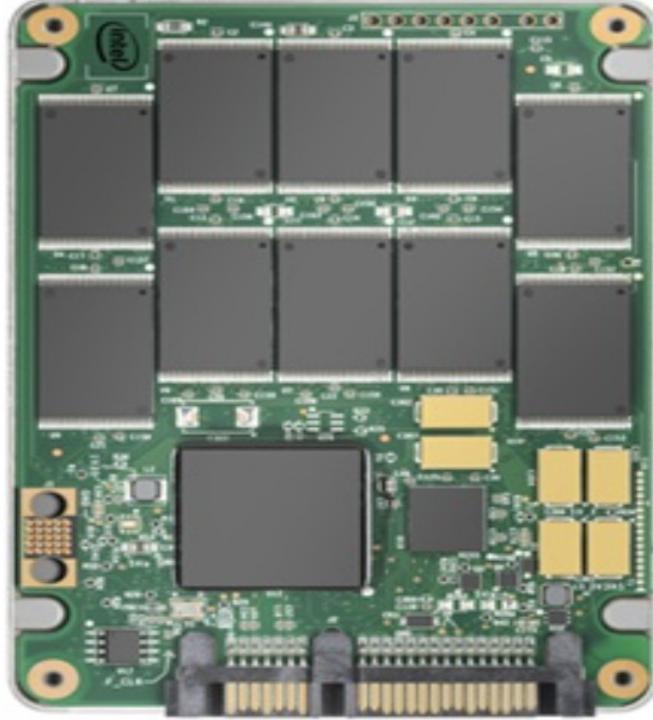
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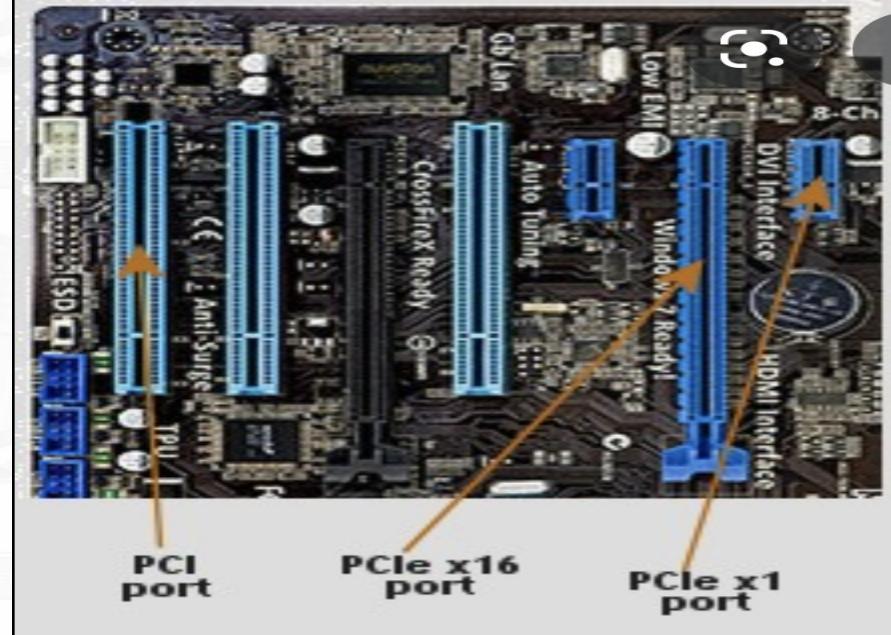
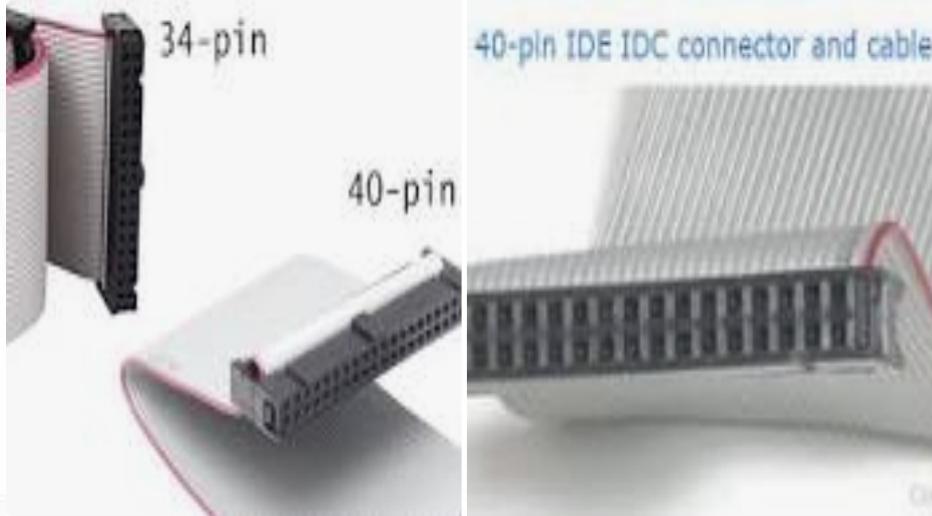
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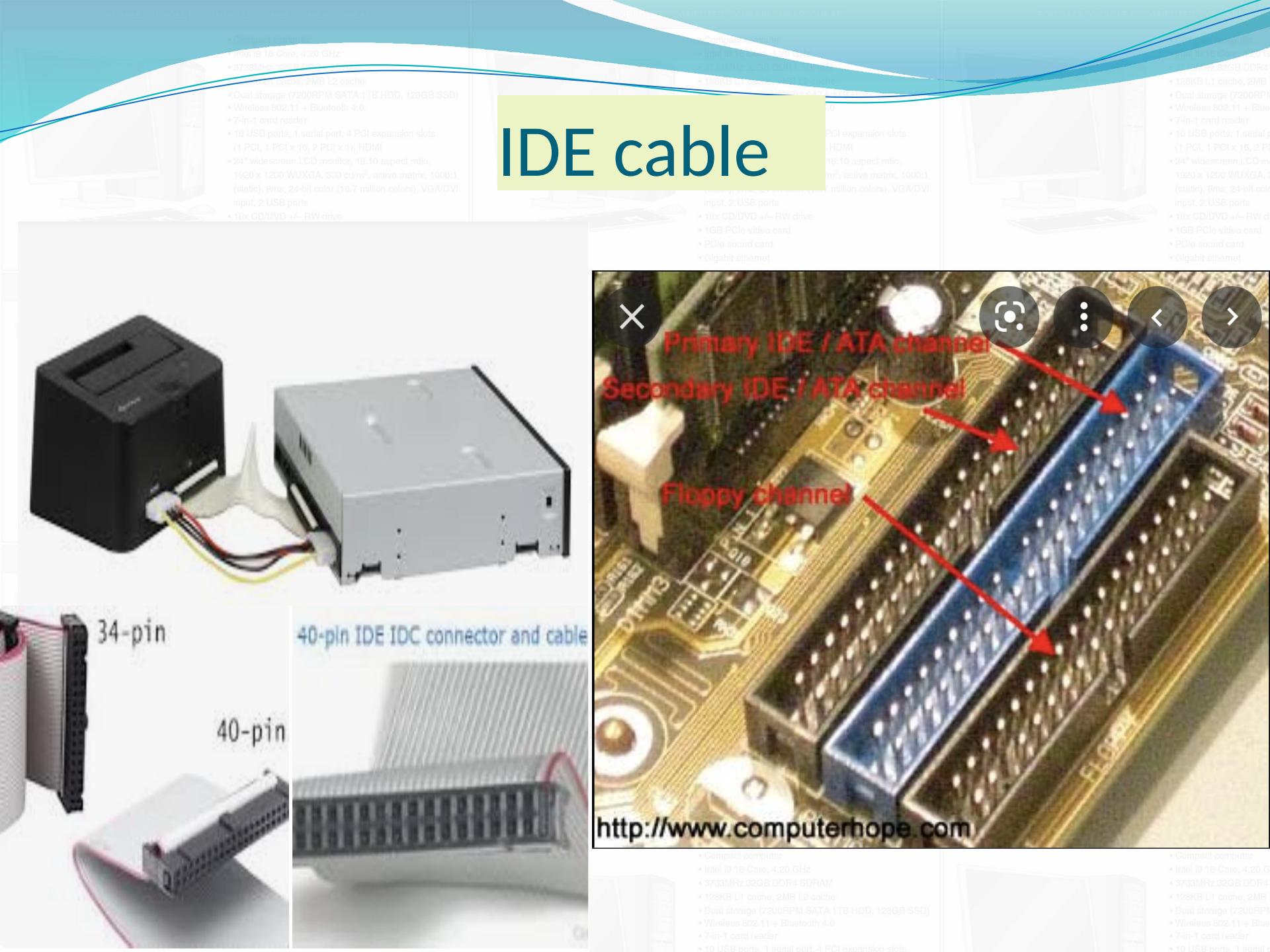
# HARD DISK DRIVE(HDD) VS SSD

Hard Disk Drive	Solid State Drive ( SSD )
<ul style="list-style-type: none"><li>• Compact computer</li><li>• Intel i9 16 Core, 4.20 GHz</li><li>• 3733MHz 32GB DDR4 SDRAM</li></ul>	<ul style="list-style-type: none"><li>• Compact computer</li><li>• Intel i9 16 Core, 4.20 GHz</li><li>• 3733MHz 32GB DDR4 SDRAM</li></ul>
	

# IDE cable

- IDE refers to the types of cables and ports used to connect some hard drives and optical drives to each other and to the motherboard





# IDE cable

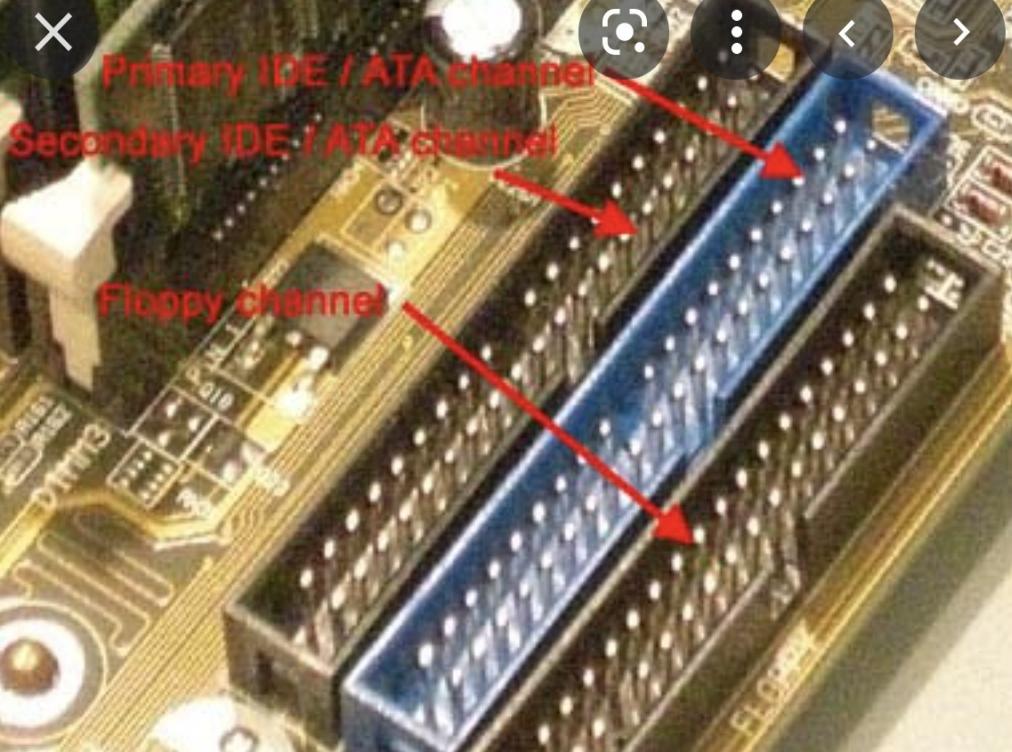
PCI expansion slots  
HDMI  
16:10 aspect ratio,  
1920 x 1200 WUXGA, 300 cd/m<sup>2</sup>, active matrix, 1000:1  
(static), 8ms, 24-bit color (16.7 million colors), VGA/DVI  
input, 2 USB ports

\* 16x CD/DVD +/- RW drive

\* 1GB PCIe video card

\* PCIe sound card

\* Gigabit ethernet



<http://www.computerhope.com>

\* Compact computer  
\* Intel i9 16 Core, 4.20 GHz  
\* 3739MHz 92GB DDR4 SDRAM  
\* 128KB L1 cache, 2MB L2 cache  
\* Dual storage (7200RPM SATA 1TB HDD, 128GB SSD)  
\* Wireless 802.11 + Bluetooth 4.0  
\* 7-in-1 card reader  
\* 10 USB ports, 1 serial port, 4 PCI expansion slots

# SATA CABLE

- Input: 2 USB ports
- 16x CD/DVD +/- RW drive
- 1GB PCIe video card
- PCIe sound card
- Gigabit ethernet

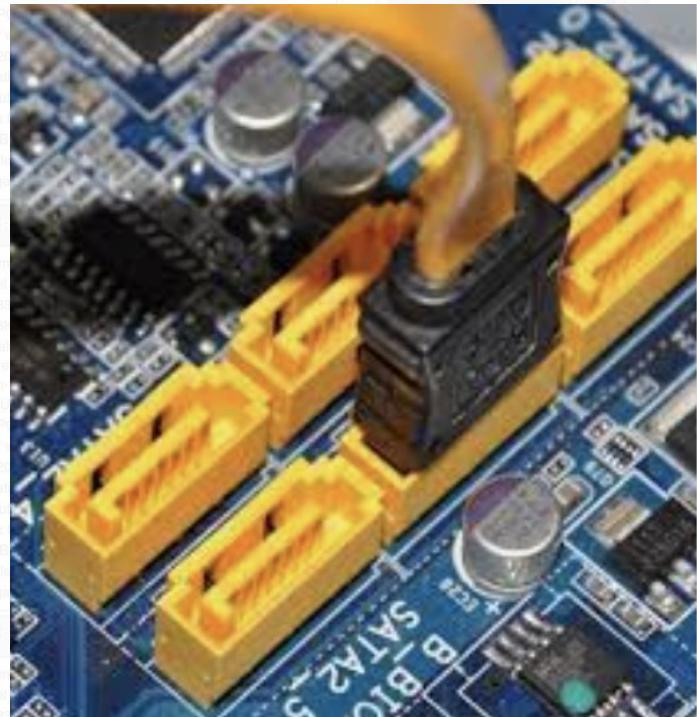
- Output: 2 USB ports
- 16x CD/DVD +/- RW drive
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- PCIe sound card
- Gigabit ethernet

- Serial ATA cables are **used to connect devices in computer cable assemblies**, such as storage devices



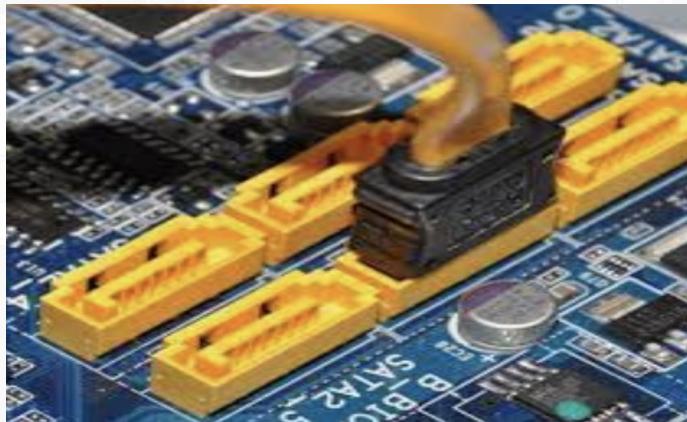
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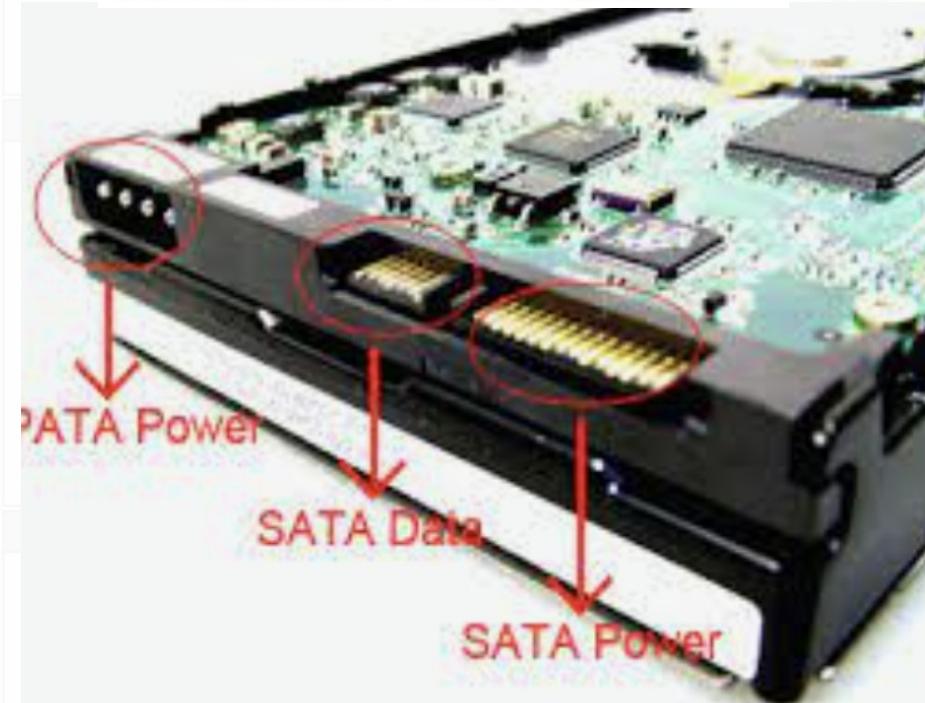


Motherboard SATA Ports

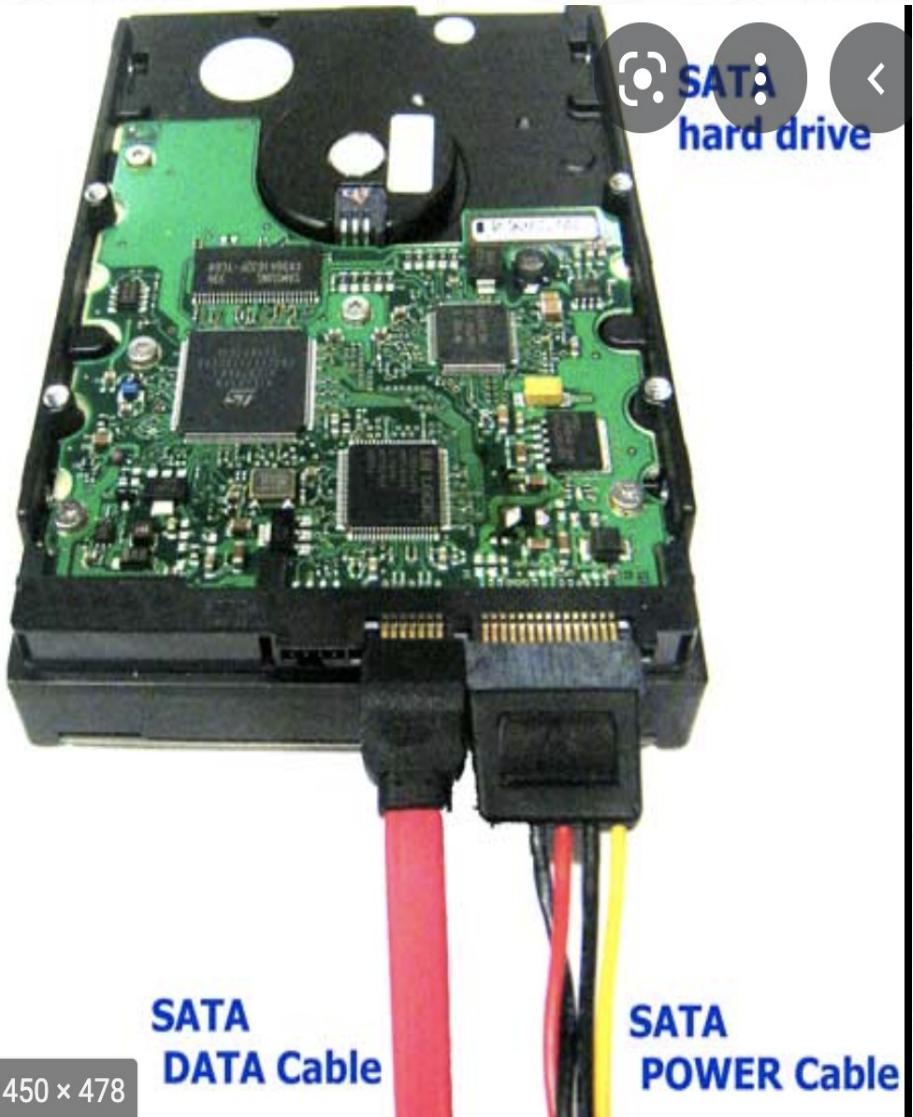
# SATA CABLE



Motherboard SATA Ports



450 x 478



# SATA CABLE TRANSFER SPEED RATE

## SATA I

**1.5 Gb/s**

## SATA II

**3 Gb/s**

## SATA III

**6 Gb/s**

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- \* 7-in-1 card reader
- \* 10 USB ports, 1 serial port, 4 PCI expansion slots (1 PCI, 1 PCI x 16, 2 PCI x 1), HDMI
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# USB PORTS

USB 1

USB 2

USB 3

USB-C



USB 1.X

USB 2.X

USB 3.X



# USB PORTS

Port	Speed	Numerical value	Speed Rate in bits
USB 1.0	12 Mbps	$12 * 2^{20}$	12,582,912 bit per sec
USB 2.0	480 Mbps	$480 * 2^{20}$	503,316,480 bit per sec
USB 3.0	4.8 Gbps	$4.8 * 2^{30}$	5,153,960,755 bit per sec
HDMI	10.2 Gbps	$10.2 * 2^{30}$	10,952,166,604 bit per sec

**USB-C**

**3GBPS - 10 GBPS**

# HDMI PORT

## HDMI TYPE

## SPEED

**HDMI**

**10.2 GBPS(GIGA BIT PER SECOND)**

**HDMI 2.0**

**14.4 GBPS(GIGA BIT PER SECOND)**

**HDMI 2.1**

**18 - 48 GBPS(GIGA BIT PER SECOND)**

# CELLULAR NETWORK

Type	Speed Rate
3G	<b>144 Kbps - 400 Kbps</b>
4G	<b>5 Mbps - 12 Mbps</b>
5G	<b>60 Mbps–30 Gbps</b>

**KBPS:** KILO BITS PER SECOND

**MBPS:** MEGA BITS PER SECOND

**GBPS:** GIGA BITS PER SECOND

# Software layers

User

Application

Operating system

Hardware

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# Computer Software

## • Operating System(OS) software

## • Application software

# Operating System software

- Windows
- OS operating system (MAC computers)
- Linux
- UNIX

# Operating System(OS)

- An operating system (OS) is **system software that manages computer hardware, software resources, and provides common services for computer programs**

# Types Of Application Software

01

## Word Processing Software

MS Word, Wordpad, Notepad

02

## Spreadsheet Software

Google Sheets, Microsoft Excel, Zoho Sheets

03

## Presentation Software

Powerpoint, Zoho Powerpoint, Google Presentation

04

## Multimedia Software

VLC Media Player, MX Player

05

## Web Browsers Software

Chrome, Firefox

# Application software

06

## Educational Softwares

MATLAB, Google Classroom

07

## Graphics Software

Adobe Photoshop, Unity 3d, PaintShop

08

## Freeware Software

MSN Messenger, Yahoo Messenger, Adobe PDF

09

## Shareware Software

Adobe Dreamweaver, Winzip, Getright

10

## Simulation Software

PCB Softwares, VLSI Simulation

11

## Open Source Software

OpenOffice, Gimp, MySQL,

12

## Closed Source Software

Skype, Google Earth, Adobe Flash, Adobe Reader

# Application software

Microsoft products such as Office, PowerPoint, Word, Excel, Outlook,

Music Application Software like Pandora and Spotify.

Real-time online communication like Skype, Google Meet, and Zoom.

Internet browsers like Chrome, Safari, and Firefox

# Application software

Application Software is a type of computer program that performs specific functions.

These functions, performed by application software, can be personal, business as well as educational

Application Software is also known as end-user software or productivity software

Application Software Programs are developed to execute a large variety of roles