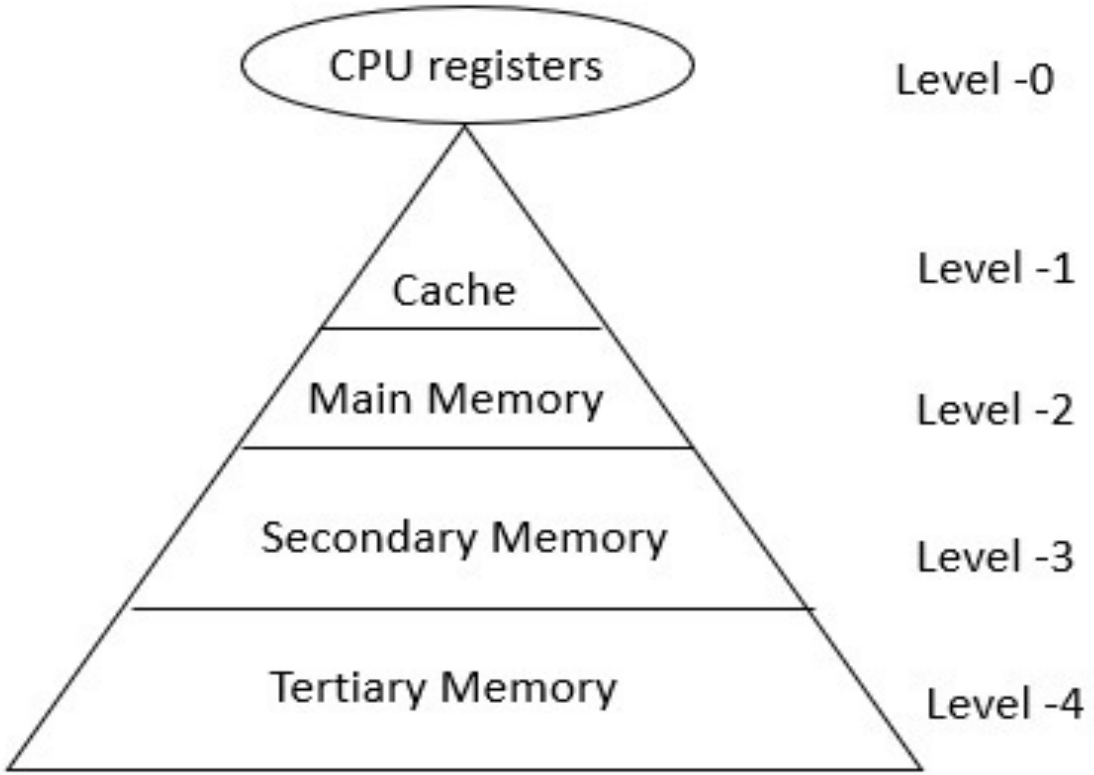
What is memory hierarchy?

Hierarchy of Memory

The Computer memory hierarchy looks like a pyramid structure which is used to describe the differences among memory types. It separates the computer storage based on hierarchy.

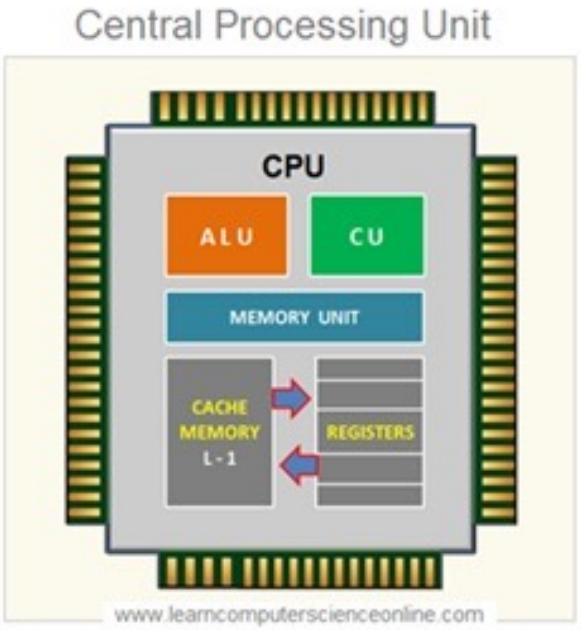
- Level 0: CPU registers
- Level 1: Cache memory
- Level 2: Main memory or primary memory
- Level 3: Magnetic disks or secondary memory
- Level 4: Optical disks or magnetic types or tertiary Memory

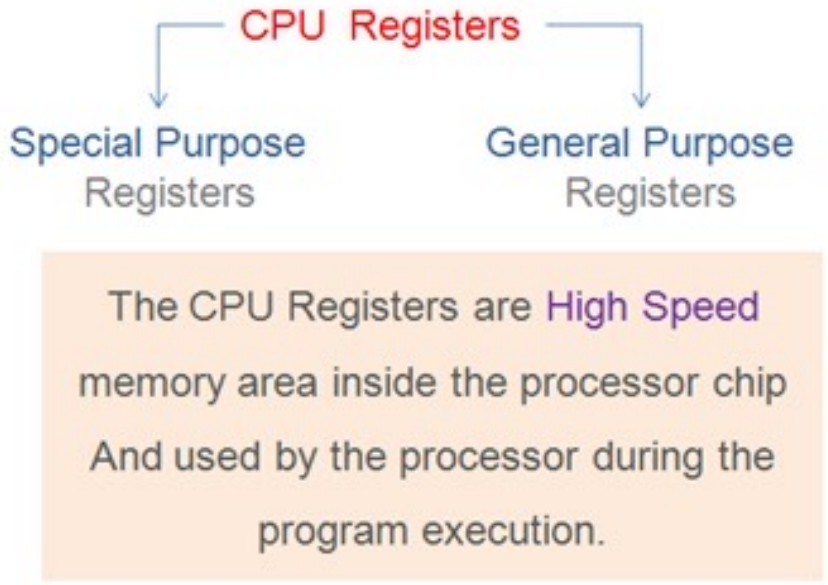


In Memory Hierarchy the cost of memory, capacity is inversely proportional to speed.
Here the devices are arranged in a manner Fast to slow, that is form register to Tertiary memory.

Level-0 – Registers

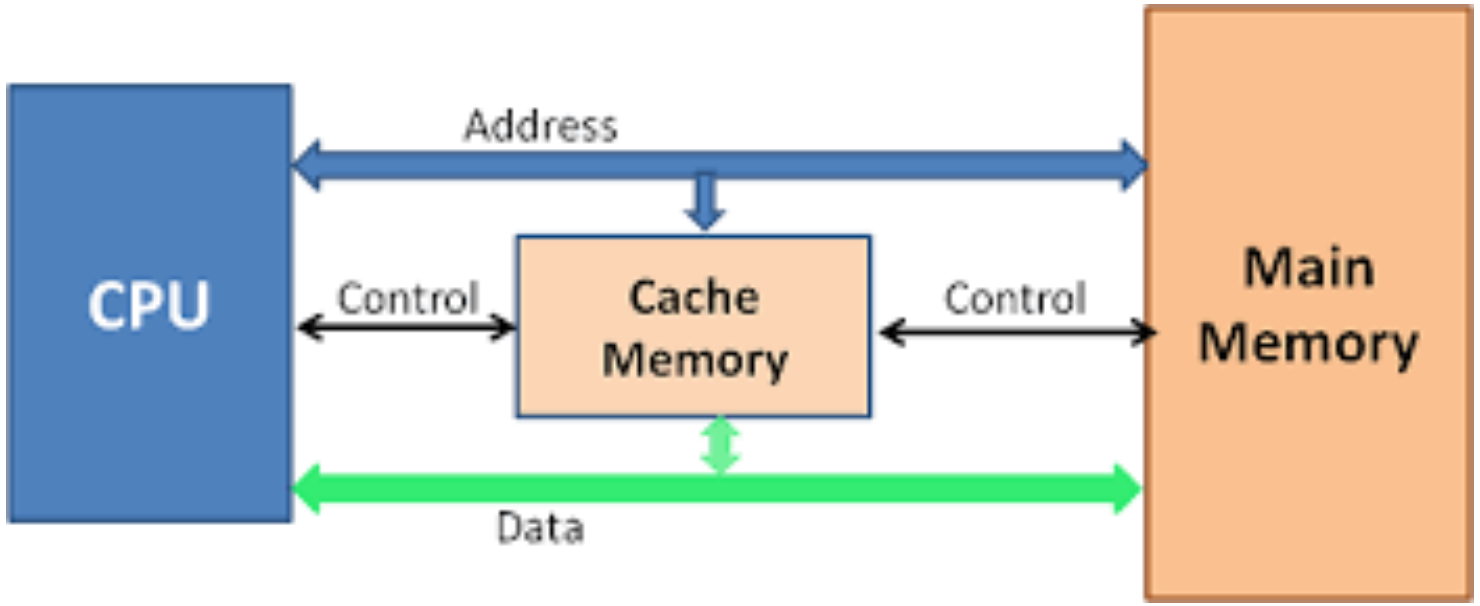
The registers are present inside the CPU. As they are present inside the CPU, they have least access time. Registers are most expensive and smallest in size generally in kilobytes. They are implemented by using Flip-Flops.





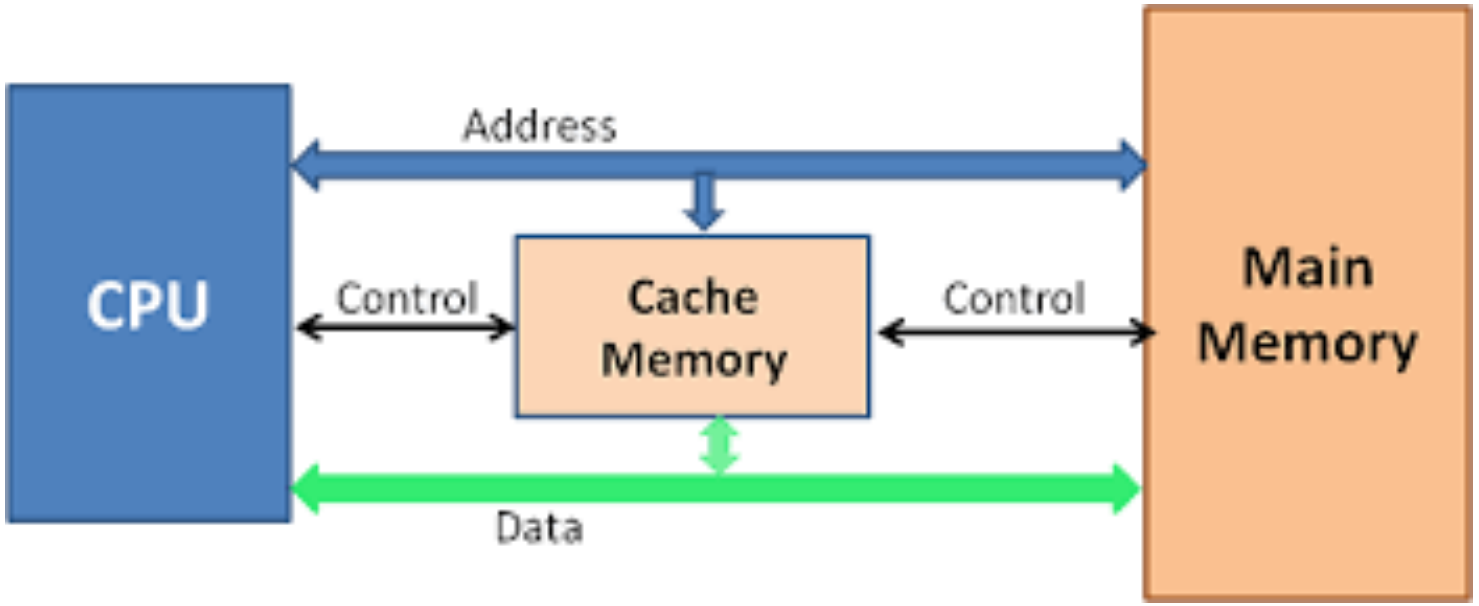
Level-1 – Cache

Cache memory is used to store the segments of a program that are frequently accessed by the processor. It is expensive and smaller in size generally in Megabytes and is implemented by using static RAM.



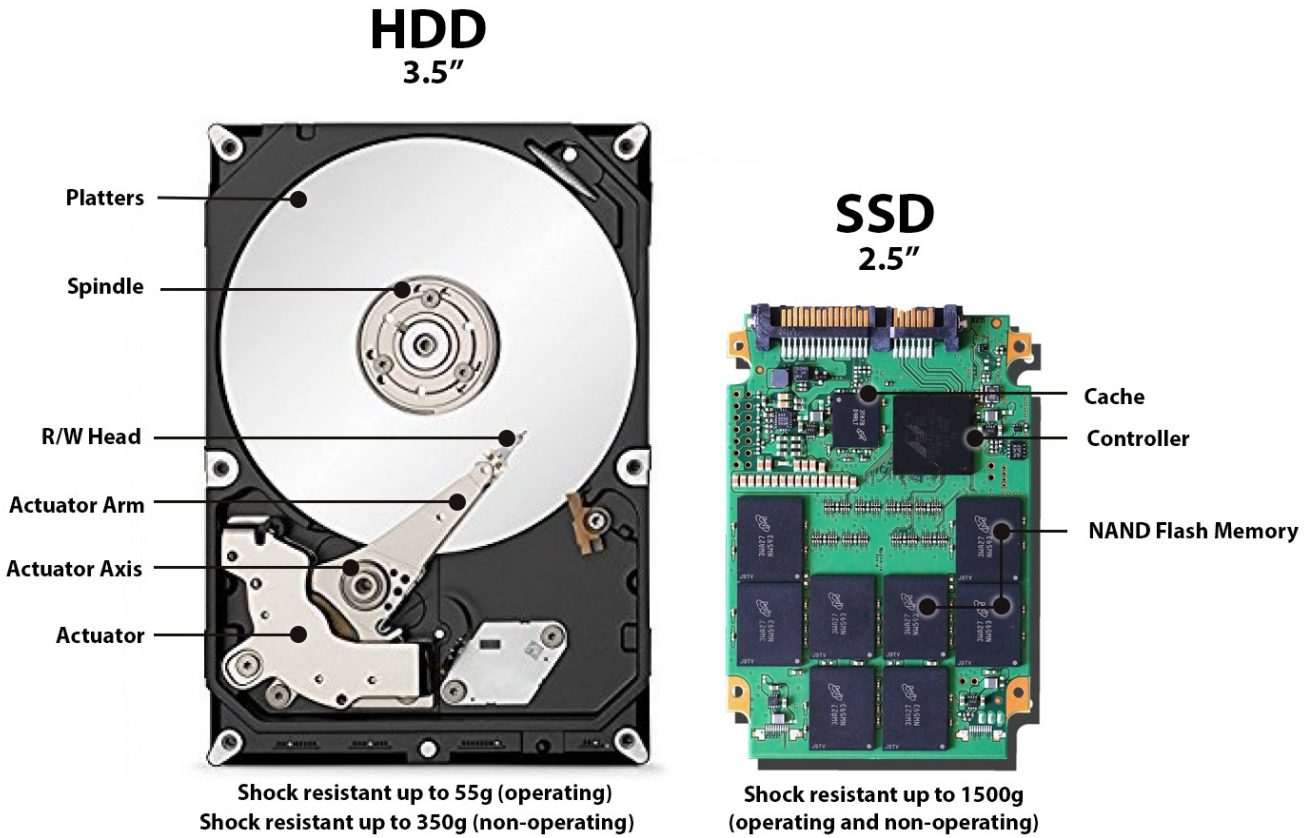
Level-2 – Primary or Main Memory

It directly communicates with the CPU and with auxiliary memory devices through an I/O processor. Main memory is less expensive than cache memory and larger in size generally in Gigabytes. This memory is implemented by using dynamic RAM.



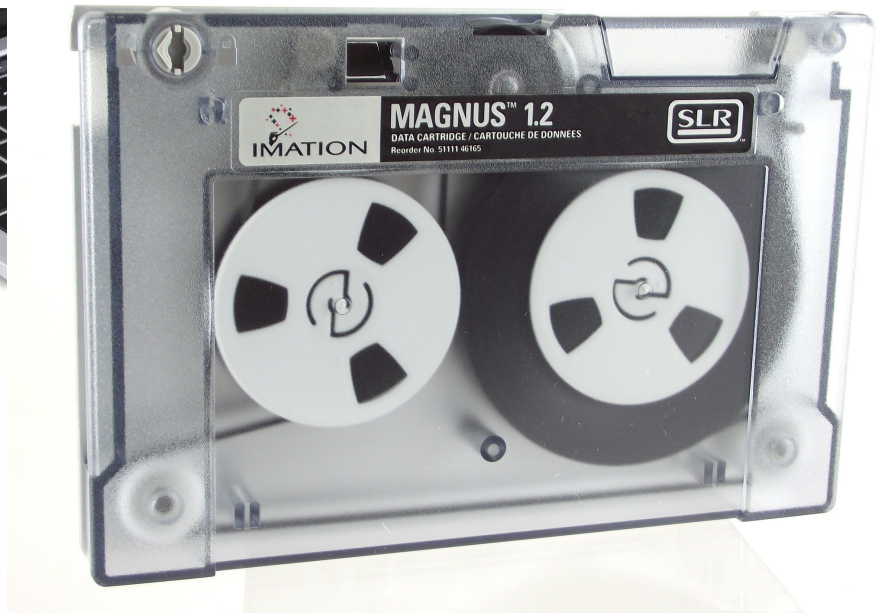
Level-3 – Secondary storage

Secondary storage devices like Magnetic Disk are present at level 3. They are used as backup storage. They are cheaper than main memory and larger in size generally in a few TB.



Level-4 – Tertiary storage

Tertiary storage devices like magnetic tape are present at level 4. They are used to store removable files and are the cheapest and largest in size (1-20 TB).



Why memory Hierarchy is used in systems?

- Memory hierarchy is arranging different kinds of storage present on a computing device based on speed of access. At the very top, the highest performing storage is CPU registers which are the fastest to read and write to. Next is cache memory followed by conventional DRAM memory, followed by disk storage with different levels of performance including SSD, optical and magnetic disk drives.
- To bridge the processor memory performance gap, hardware designers are increasingly relying on memory at the top of the memory hierarchy to close / reduce the performance gap. This is done through increasingly larger cache hierarchies (which can be accessed by processors much faster), reducing the dependency on main memory which is slower.

Primary Memory

- RAM (RANDOM ACCESS MEMORY)
- ROM (READ ONLY MEMORY)

RAM – Random Access Memory

- What is RAM?

It is one of the parts of the Main memory, also famously known as Read Write Memory. Random Access memory is present on the motherboard and the computer's data is temporarily stored in RAM.

- How Does RAM Work?

RAM is constructed of small transistors and capacitors, which can stored an electric charge that corresponds to data bits. electrical charge is necessary to regular charge of it. If not, the data removed from RAM and the capacitors lose their charge.

RAM – Random Access Memory

Features of RAM

- RAM is volatile in nature, which means, the data is lost when the device is switched off.
- RAM is known as the Primary memory of the computer.
- RAM is known to be expensive since the memory can be accessed directly.
- RAM is the fastest memory, therefore, it is an internal memory for the computer.
- The speed of computer depends on RAM, say if the computer has less RAM, it will take more time to load and the computer slows down.

RAM – Random Access Memory

Types of RAM

- RAM is further divided into two types,
  - SRAM – Static Random Access Memory and
  - DRAM- Dynamic Random Access Memory.
- SRAM
  - SRAM is used for Cache memory.
  - Although SRAM is faster, it requires more power and is more expensive in nature.
- DRAM
  - DRAM is used for the Main memory
  - Although DRAM is slower, it can store more bits per chip
  - DRAM requires less power and hence, less heat is produced.

ROM-Read Only Memory

- **What is Read-Only Memory (ROM)?**

  ROM stands for Read-Only Memory. It is a non-volatile memory that is used to store important information which is used to operate the system. As its name refers to read-only memory, we can only read the programs and data stored on it.

- **Features of ROM (Read-Only Memory)**
  - ROM is a non-volatile memory.
  - Information stored in ROM is permanent.
  - Information and programs stored on it, we can only read and cannot modified.
  - Information and programs are stored on ROM in binary format.
  - It is used in the start-up process of the computer.

ROM-Read Only Memory

- **Types of Read-Only Memory (ROM)**
  - MROM (Masked read-only memory)
  - PROM (Programmable read-only memory)
  - EPROM (Erasable programmable read-only memory)
  - EEPROM (Electrically erasable programmable read-only memory)

Secondary Storage Devices

- HDD – HARD DISK DRIVE
  - A hard disk is also known as a hard drive or fixed disk. It is said to be rigid magnetic disc that stores data. It is located within a drive unit. Hard disk is a non-volatile storage device that contains platters and magnetic disks rotating at high speeds. Non-volatile means the data retains when the computer shuts down.

Secondary Storage Devices

- Advantages of the hard disk
  - The advantages of a Hard Disk Drive are given as follows:
  - One of the significant advantages of a Hard Disk drive is that its cost is low.
  - Another advantage of a Hard Disk is that it is readily available in the market.
  - Hard Disk is faster than optical disks.
  - The capacity for storing the data in HDDs is large.
- Disadvantages of the hard disk
  - The disadvantages or limitations of Hard Disk Drive are given as follows:
  - The speed of reading and writing in HDD is slower than the RAM.
  - HDDs are noisy.
  - Another disadvantage of HDD is energy inefficiency.
  - HDDs consume more power.
  - The form factor of HDDs is heavier than the SSDs.

Secondary Storage Devices

- SSD – SOLID STATE DRIVE
  - SSD is a non-volatile storage device, which stands for Solid State Drive.
  - Unlike the HDDs (Hard Disk Drives), SSDs do not have any moving parts.
  - Compared to electromechanical drives, SSDs have lower latency and access quickly
  - SSDs offer advantages such as reduced boot times, quicker file transfers, and advanced system overall performance.

CLOUD STORAGE MODELS (S3 Storage)

- S3 (Simple Storage Service – Amazon Cloud)
- S3 is an object storage service.
- Offers industry-leading scalability, data availability, security and performance.
- S3 can be used to store any amount of data for data lakes, websites, mobile applications, backup and restore, archive, enterprise applications, IoT devices, and big data analysis.
- It is part of AWS (Amazon Web Services)

CLOUD STORAGE MODELS (Azure Blob Storage)

- Azure blob storage is Microsoft’s object storage solution for the cloud.
- Blog storage is optimized for storing massive amounts of unstructured data.
- Unstructured data is data that doesn’t adhere to a particular data model or definition.(e.g. text or binary)
- Helps to create data lakes for data analysis.
- Provide storage to build powerful cloud-native and mobile apps.
- Azure is Microsoft’s Cloud solution and BLOB is Binary Large object that includes image or other multimedia files.

Flash based storage- SSD

- SSD stands for Solid State Drive
- Non volatile type of storage used in computers
- It replaces traditional hard drive.
- SSD has no moving parts, instead it has
  - Flash controller
  - NAND flash memory chips.

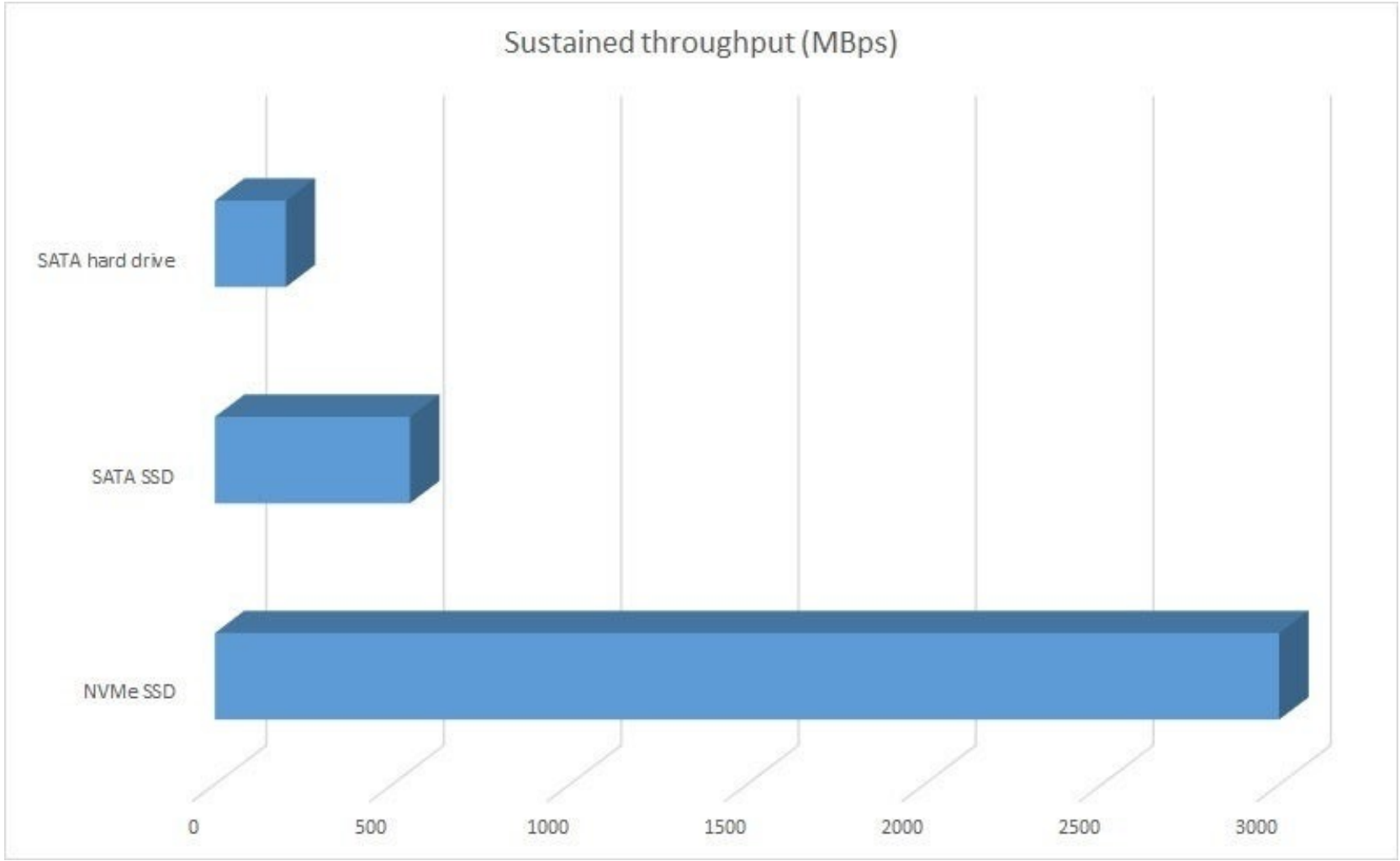
Flash based storage- SSD

- Advantages of SSD:
  - Faster Read/ Write Speed : Can access large file quickly
  - Quicker boot time and better performance:
    SSD has no moving parts, so they are more responsive and provides better load performance.
  - Better Durability:
    SSDs are more shock resistance.
    Can handle heat better than HDDs.
  - Low Power Consumption:
    Consumes less power then HDDs as they do not have any moving parts.
  - Quieter:
    No moving noise at all.
  - Variety of Sizes:
    Comes in variety of size factors unlike HDDs limited sizes.

Flash based storage- NVMe

- NVMe => Non-Volatile Memory Express
- NVMe is a communications standard developed specially for SSDs by a consortium of vendors including Intel, Samsung, Sandisk, Dell, and Seagate.
- Bottom line: NVMe is fast. Really fast.
- The reason the latest top-end PCs seem so much faster is because of the quantum leap in storage performance provided by SSDs, first SATA, and now NVMe.

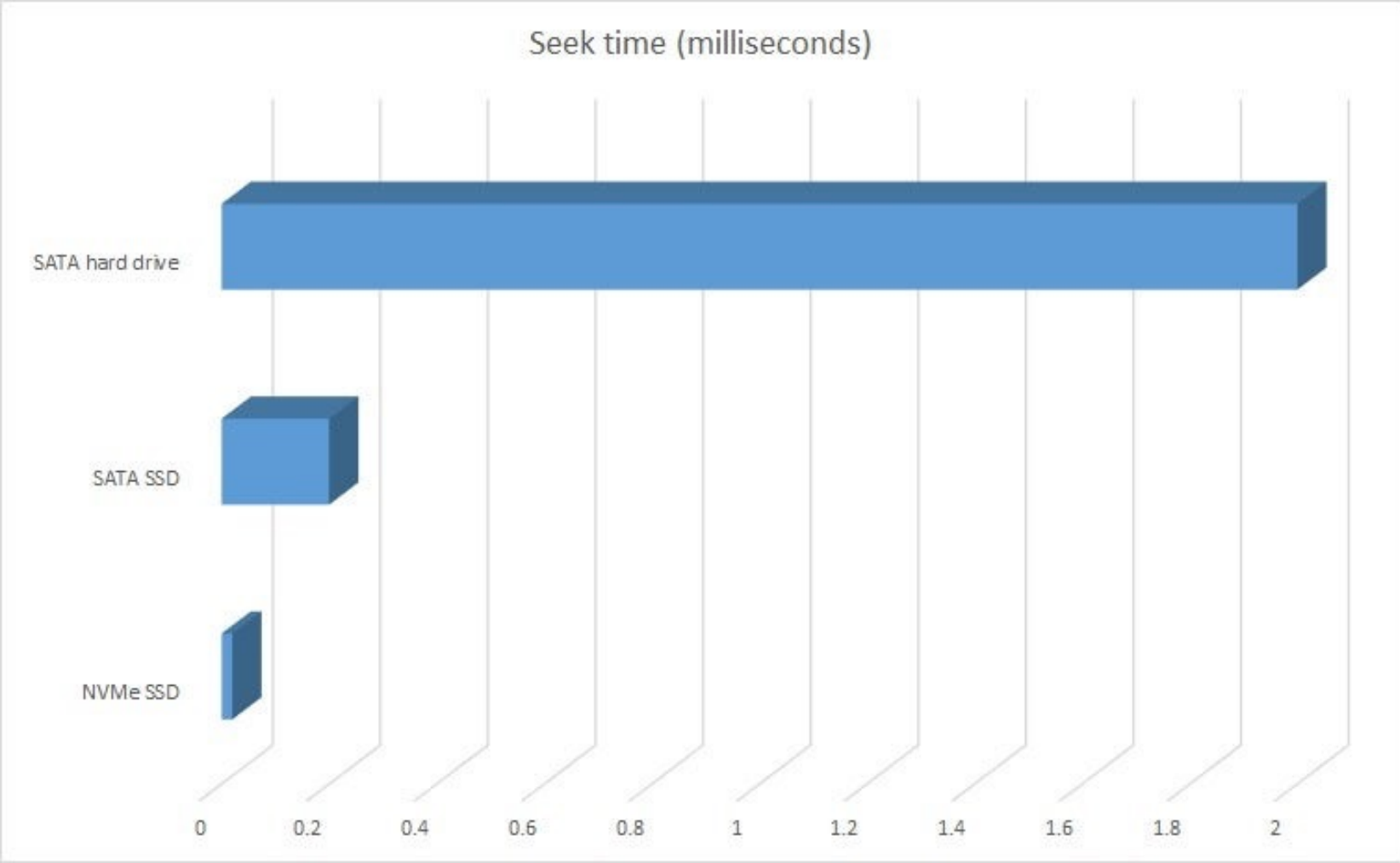
Flash based storage- NVMe



HDD = 200MBps,
SATA SSD = 550MBps,
NVMe SSD = 3GBps.

*Throughput is the SSD's data transfer speed, measured in bytes per second.

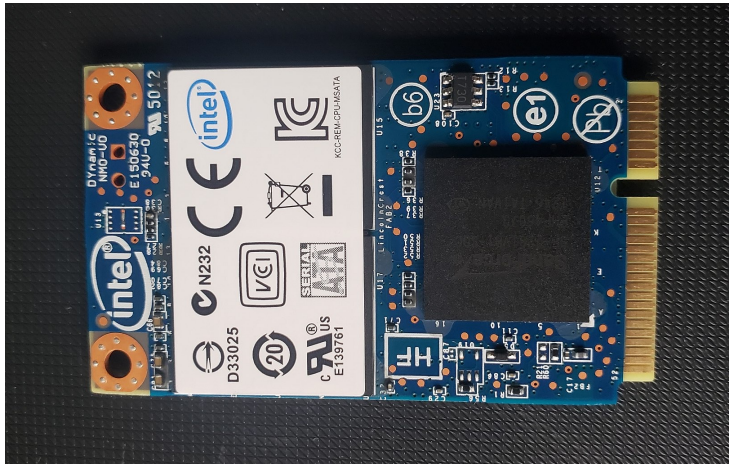
Flash based storage- NVMe



HD = 2-5 millisecond seek,
SATA SSD = 0.2 millisecond seek,
NVMe SSD = 0.02 millisecond seek

*Seek time is time taken for preparing a particular location on the memory in the storage device.

Flash based storage- NVMe



Inter mSATA SSD

SAMSUNG NVM Express M.2 SSD

Thank You