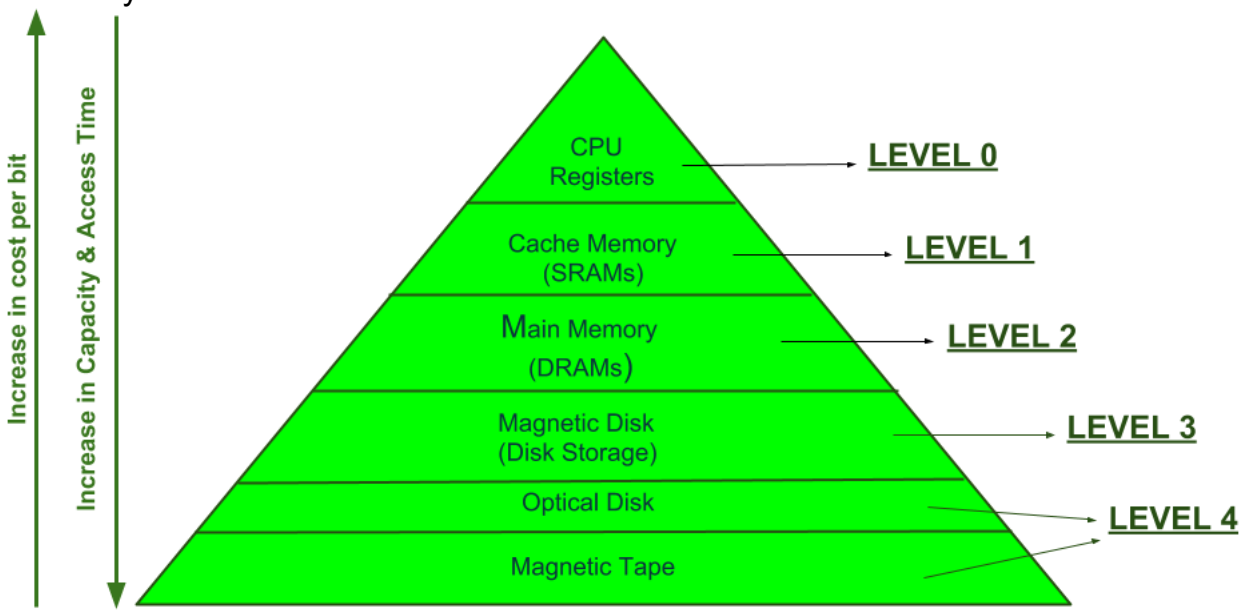
Memory Hierarchy Design and its Characteristics

In the Computer System Design, Memory Hierarchy is an enhancement to organize the memory such that it can minimize the access time. The Memory Hierarchy was developed based on a program behavior known as locality of references.The figure below clearly demonstrates the different levels of memory hierarchy :



MEMORY HIERARCHY DESIGN

This Memory Hierarchy Design is divided into 2 main types:

1. **External Memory or Secondary Memory –** Comprising of Magnetic Disk, Optical Disk, Magnetic Tape i.e. peripheral storage devices which are accessible by the processor via I/O Module.
2. **Internal Memory or Primary Memory –** Comprising of Main Memory, Cache Memory & CPU registers. This is directly accessible by the processor.

There are typically four levels of memory in a memory hierarchy:

Registers: Registers are small, high-speed memory units located in the CPU. They are used to store the most frequently used data and instructions. Registers have the fastest access time and the smallest storage capacity, typically ranging from 16 to 64 bits.

Cache Memory: Cache memory is a small, fast memory unit located close to the CPU. It stores frequently used data and instructions that have been recently accessed from the main memory. Cache memory is designed to minimize the

time it takes to access data by providing the CPU with quick access to frequently used data.

Main Memory: Main memory, also known as RAM (Random Access Memory), is the primary memory of a computer system. It has a larger storage capacity than cache memory, but it is slower. Main memory is used to store data and instructions that are currently in use by the CPU.

Secondary Storage: Secondary storage, such as hard disk drives (HDD) and solid-state drives (SSD), is a non-volatile memory unit that has a larger storage capacity than main memory. It is used to store data and instructions that are not currently in use by the CPU. Secondary storage has the slowest access time and is typically the least expensive type of memory in the memory hierarchy.

We can infer the following characteristics of Memory Hierarchy Design from above figure:

1. **Capacity:** It is the global volume of information the memory can store. As we move from top to bottom in the Hierarchy, the capacity increases.
2. **Access Time:** It is the time interval between the read/write request and the availability of the data. As we move from top to bottom in the Hierarchy, the access time increases.
3. **Performance:** Earlier when the computer system was designed without Memory Hierarchy design, the speed gap increases between the CPU registers and Main Memory due to large difference in access time. This results in lower performance of the system and thus, enhancement was required. This enhancement was made in the form of Memory Hierarchy Design because of which the performance of the system increases. One of the most significant ways to increase system performance is minimizing how far down the memory hierarchy one has to go to manipulate data.
4. **Cost per bit:** As we move from bottom to top in the Hierarchy, the cost per bit increases i.e. Internal Memory is costlier than External Memory.

According to the memory Hierarchy, the system supported memory standards are defined below:

Level	**1**	**2**	**3**	**4**
Name	Register	Cache	Main Memory	Secondary Memory
Size	<1 KB	less than 16 MB	<16GB	>100 GB
Implementation	Multi-ports	On-	DRAM	Magnetic

		chip/SRAM	(capacitor memory)	
Access Time	0.25ns to 0.5ns	0.5 to 25ns	80ns to 250ns	50 lakh ns
Bandwidth	20000 to 1 lakh MBytes	5000 to 15000	1000 to 5000	20 to 150
Managed by	Compiler	Hardware	Operating System	Operating System
Backing Mechanism	From cache	from Main Memory	from Secondary Memory	from ie

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