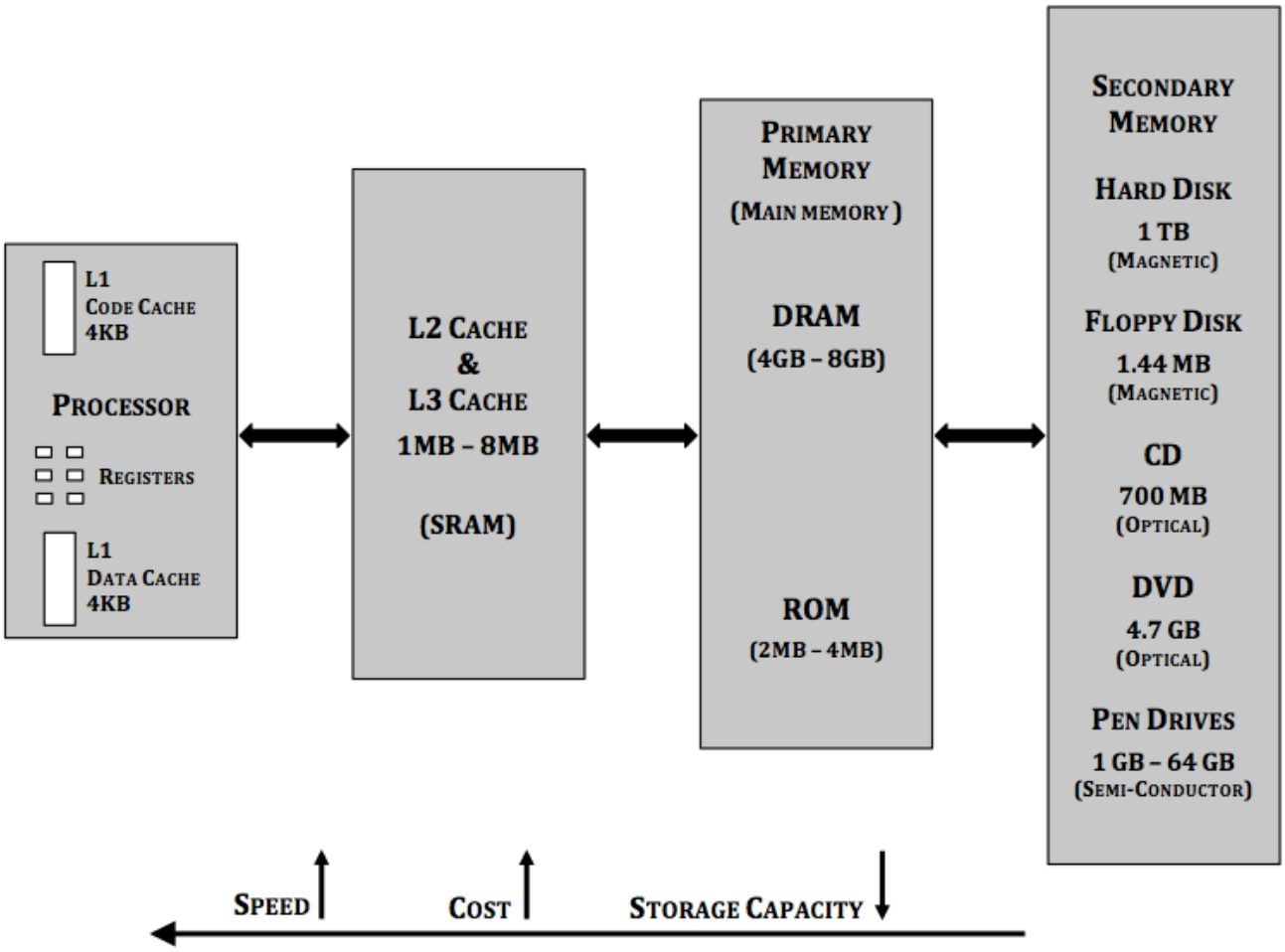
MEMORY

MEMORY HIERARCHY

1) The purpose of any memory device is to **store programs and data**.
2) **Several types** of memory devices are used in the computer forming a **Memory Hierarchy**.
3) Each plays a specific role contributing to the **speed, cost effectiveness, portability** etc.



REGISTERS

1) Registers are **present inside the processor**.
2) They are basically a **set of flip-flops**.
3) They store **data and addresses** and can **directly take part** in **arithmetic and logic operations**.
4) They are very small in size typically **just a few bytes**.

PRIMARY MEMORY

1) It is the original form of memory also called as **Main memory**.
2) It comprises of **RAM and ROM**, both are **Semi-Conductor** memories. (chip memories)
3) **ROM is non-volatile**.
   It is used is storing permanent information like the **BIOS program**.
   It is typically of **2 MB - 4 MB** in size.
4) **RAM is writable** and hence is used for **day-to-day operations**.
   Every file that we access from secondary memory, is **first loaded into RAM**.
   To provide large amount of working space RAM is **typically 4 GB - 8 GB**.

SECONDARY MEMORY

1) The main purpose of Secondary Memory is to **increase the storage capacity, at low cost**.
2) Its biggest component is the **Hard Disk**.
   This is where all the files inside a computer **are stored**.
3) It is **writeable as well as non-volatile**.
4) Typical size of a **HD is 1 TB**.
5) Disk memories are much **slower than chip memories** but are also **much cheaper**.

PORTABLE SECONDARY MEMORY

1) These are required to **physically transfer files** between computers.
2) **Floppy Disk**: It is a **magnetic form** of storage. Typical **Size is 1.44 MB**.
3) **CD**: It is an **optical form** of storage. Typical **Size is 700 MB**.
4) **DVD**: It is an **optical form** of storage. Typical **Size is 4.7 MB**.
5) **Pen Drives & Memory Cards**: It is a **semi-conductor form** of storage.
   It is composed of FLASH ROM.
   It's a special type of ROM that's writable as well as non-volatile.
   Typical **Size ranges form 1 GB - 64 GB** depending upon the cost.

CACHE MEMORIES

1) It is the **fastest form of memory** as it uses SRAM (Static RAM).
2) The Main Memory uses DRAM (Dynamic RAM).
3) **SRAM uses flip-flops and hence is much faster than DRAM which uses capacitors.**
4) But SRAM is also **very expensive** as compared to DRAM.
5) Hence **only the current portion of the file** we need to access is copied from Main Memory (DRAM) to Cache memory (SRAM), to be directly accessed by the processor.
6) This gives **maximum performance and yet keeps the cost low**.
7) Typical size of Cache is around **2 MB – 8MB**.
8) If **code and data** are in the **same cache** then it is **unified cache** else its **called split cache**.
9) Depending upon the location of cache, it is of three types: L1, L2 and L3.
10) **L1** cache is **present inside the processor** and is a **split cache** typically **4-8 KB**.
11) L2 is present on the **same die as the processor** and is a **unified cache** typically **1 MB**.
12) L3 is present **outside the processor**. It is also **unified** and is typically of **2-8 MB**.

MEMORY CHARACTERISTICS

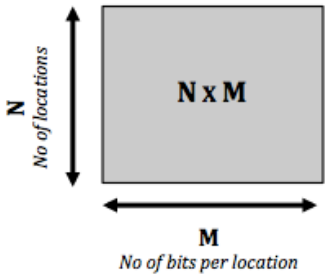
1) Location

Based on its physical location, memory is classified into three types.

- **On-Chip:** This memory is present **inside the CPU**. E.g.:: Internal Registers and **L1 Cache**.
- **Internal:** This memory is present **on the motherboard**. E.g.:: **RAM**.
- **External:** This memory is **connected to the motherboard**. E.g.:: **Hard disk**.

2) Storage Capacity

This indicates the **amount of data stored** in the memory.
Obviously it should be **as large as possible**.
It is represented as N x M.
Here,
N = **Number of memory locations** (no of words)
M = **Number of pits per memory location** (word size)
E.g.:: (4K x 8) means there are 4K locations of 8-bits each.



3) Transfer Modes

Data can be accessed from memory in two different ways.

- **Word Transfer:** Here, if CPU needs some data, it will transfer only that amount of data.
  E.g.:: Data accessed from **L1 Cache.**
- **Block Transfer:** Here, if CPU needs some data, it will transfer an entire block containing that data. This makes further access to remaining data of this block much faster. This is based on Principle of Spatial Locality. A processor is most likely to access data near the current location being accessed.
  E.g.:: On a **cache miss**, processor goes to **main memory** and copies a **block** containing that data.

4) Access Modes

Memories can allow data to be accessed in two different ways.

- **Serial Access:** Here locations are accessed one by one in a **sequential manner**.
  The access time depends on how far the target location is, from the current location.
  Farther the location, **more** will be its **access time**.
  E.g.:: Magnetic tapes.
- **Random Access:** Here **all locations** can be directly accessed in any **random order**.
  This means **all locations** have the **same access time** irrespective of their address.
  E.g.:: Most modern memories like RAM.

5) Physical Properties

There are various Physical attributes to memory.

- **Writeable: Contents** of the memory **can be altered**. E.g.:: **RAM**
- **Non-Writeable: Contents** of the memory **cannot be altered**. E.g.:: **ROM**
- **Volatile: Contents** of the memory are **lost** when power is **switched off**. E.g.:: **RAM**
- **Non-Volatile: Contents** of the memory are **retained** when power is **switched off**. E.g.:: **ROM**

Most secondary memories like Hard disk are Writable as well as non-volatile.

6) Access Time (t_A)

It is the time taken between **placing the request** and **completing the data transfer**.
It should be as **less as possible**.
It is also known as **latency**.

7) Reliability

It is the **time** for which the memory is expected to **hold the data without any errors**.
It is measured as **MTTF: Mean Time To Failure**.
It should be as **high as possible**.

8) Cost

This indicates the **cost of storing data** in the memory.
It is expressed as **Cost/bit**.
It must be **as low as possible**.

9) Average Cost

It is the total cost per bit, for the entire memory storage.
Consider a system having **two memories M_1 (RAM) & M_2 (ROM)**
If **C_1** is the cost of memory M_1 of size **S_1**
& **C_2** is the cost of memory M_2 of size **S_2**

Then the average cost of the memory is be calculated as:
$C_{AVG} = (C_1 S_1 + C_2 S_2)/ (S_1 + S_2)$

Small sizes of **expensive** memory and **large** size of **cheaper** memory **lowers** the **average cost**.

10) Hit Ratio (H)

Consider two memories M_1 and M_2.
M_1 is **closer** to the processor E.g.:: **RAM**, than **M_2** E.g.:: **Hard disk**.
If the **desired data is found in M_1**, then it is called a **Hit**, else it is a **Miss**.
Let **N_1** be the number of **Hits** and **N_2** the number of **Misses**.
The **Hit Ratio** H is defined as **number of hits divided by total attempts**.
$H = (N_1) / (N_1 + N_2)$
It is expressed s a percentage.
H can never be 100%. In most computers it is maintained around 98%.

From the above discussion it is clear that no single memory can satisfy all the characteristics, **hence we need a hierarchy of memories**.
Cache memories are the **fastest** but also the **most costly**.
Hard disk is **writeable** as well as **non volatile** and is also very **inexpensive**, but is much **slower**.
CD/DVD etc. are needed for **portability**.
ROM is **nonvolatile**, and is used for **storing BIOS**.
DRAM is **writable**, f**aster than hard disk** and **cheaper than SRAM** hence forms **most part of Main Memory**.