Computer Fundamentals

Lecture 13: Computer Organization: Part II

Lecture Objectives

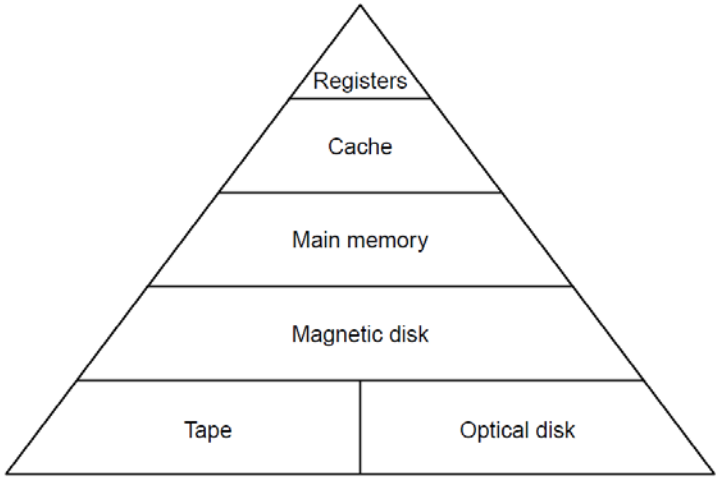
- At the end of this lecture you will be able to explain
  - Devices that help to store instruction, their speed, cost and sizes
  - The function of the memory and different types of storage devices
  - Computer hard disk and its important features

Lecture Outline

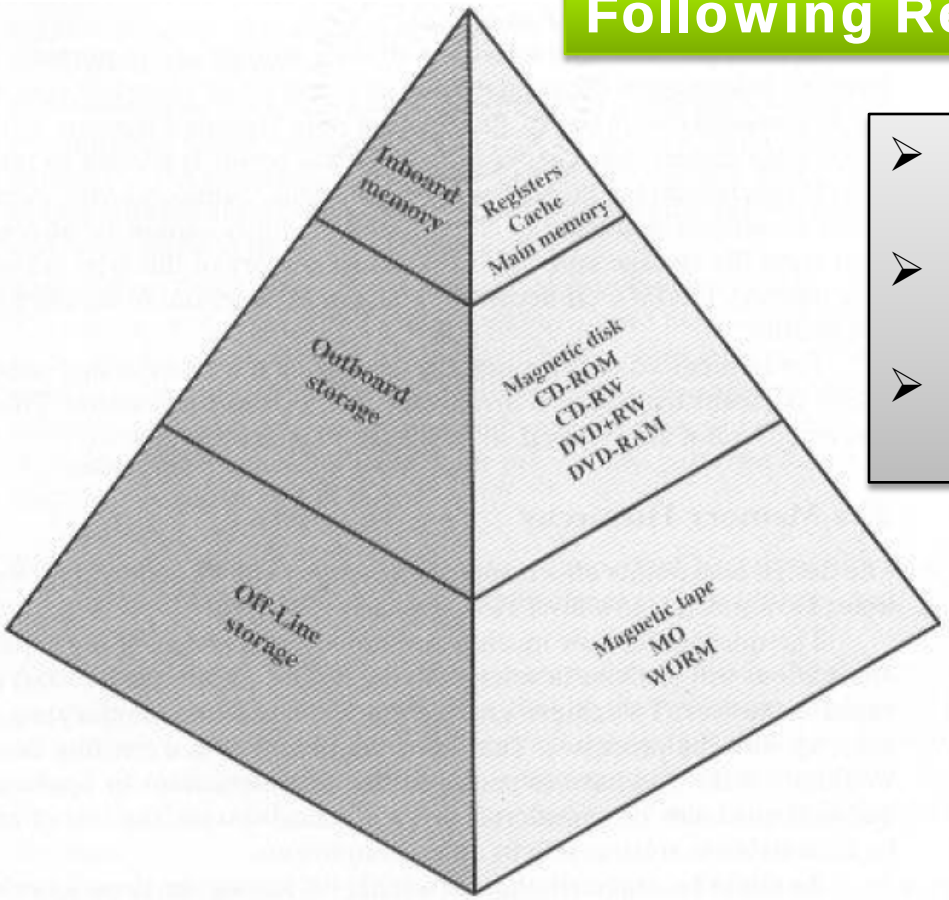
- Memory hierarchy.
- Internal and External Memory
- Registers, Cache, and Main Memory
- How cost, performance, and capacity changes through hierarchy.
- Different types of semiconductor memories and their use
- Hard disk and its parameters

Memory Hierarchy

- When we go down the hierarchy
  - Cost per bit is decreasing
  - Capacity is increasing
  - Access time is increasing
  - Frequency of access of the memory by the processor is decreasing.
- Why is there a hierarchy instead of having a single memory



Memory Hierarchy (Contd.)



Following Relationships can be found:

- Faster access time , greater cost per bit
- Greater capacity, smaller cost per bit
- Greater Capacity, slower access time

Internal and External Memory

- **Internal memory** : Directly accessible by the processor
  - Registers
  - Cache
  - Main memory
- **External Memory** : Accessible by the processor via an I/O module
  - Hard disks
  - Magnetic tapes
  - CD/DVDs
  - Floppy disks
  - USB thumb drives
  - Etc..

Key Characteristics of Computer Memory System

Location
- Processor
- Internal (main)
- External (secondary)

Capacity
- Word size
- Number of words

Unit of Transfer
- Word
- Block

Access Method
- Sequential
- Direct
- Random
- Associative

Performance
- Access time
- Cycle time
- Transfer rate

Physical Type
- Semiconductor
- Magnetic
- Optical
- Magneto-optical

Physical Characteristics
- Volatile/nonvolatile
- Erasable/nonerasable

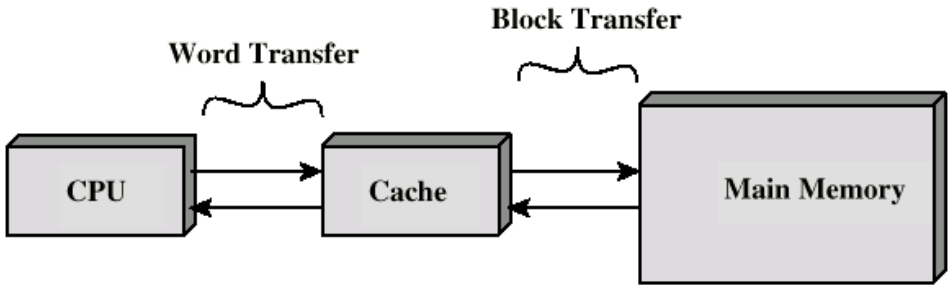
Organization

Registers

- CPU must have some working space (temporary storage)
- Called registers
- Number and function vary between processor designs
- Top level of memory hierarchy
- Fastest memory in computer (why)
- Why registers are needed?
- What are the registers available in Intel Pentium CPUs

Cache Memory

- Small amount of fast memory(Faster than RAM, static memory)
- Sits between normal main memory and CPU
- May be located on CPU chip or module.
- Cache works on the principal of locality of reference.



Elements of Cache Design

Cache Size	**Write Policy**
Mapping Function	Write through
Direct	Write back
Associative	Write once
Set associative	**Line Size**
Replacement Algorithm	**Number of caches**
Least recently used (LRU)	Single or two level
First in first out (FIFO)	Unified or split
Least frequently used (LFU)	
Random	

How cache memory works

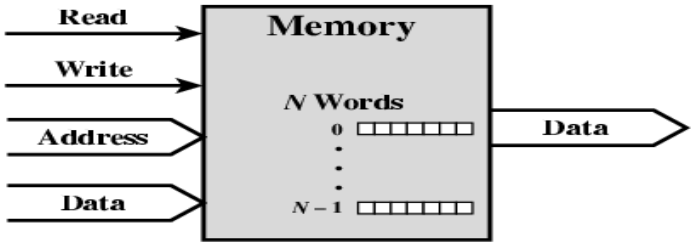
- CPU requests contents of memory location
- Check cache for this data
- If present, get from cache (fast)
- If not present, read required block from main memory to cache
- Then deliver from cache to CPU
- How cache memory speed up the computer
- Locality of reference- During the course of the execution of a program, memory references tend to cluster(limited to a small area in the memory)

Memory

- Programmes and data are stored in memory prior to execution.(This is called Stored Programme Concept proposed by Von Neumann).
- Memory is a semiconductor device in modern computers (Magnetic core memories were used earlier)
- Main memory, primary storage are synonyms to memory. (RAM also denotes the same)
- Memory is volatile.(it can’t retain data when electric power is not supplied)

Memory Connections

- Receives and sends data
- Receives addresses (of locations)
- Receives control signals
  - Read
  - Write
  - Timing



Main Memory

- This is a semi conductor memory.
- This is also called RAM(misnamed because all semiconductor memory is random access
- volatile
- Main memory is made of dynamic memory- therefore slower than cache memory
- Main Memory can be made faster by using static memory. Then why don't we do that?

Structure of Main Memory

- Memory is byte addressable
- Each byte has a unique address
- Memory addresses start from zero and increment sequentially.

- Exercise: what is the memory address of the last byte of a 1GB memory.
- Write a C++ programme to create an integer array. Print the addressees of each element in the array.
- Get a memory dump using debug command and observe how memory locations are addressed.

Memory Refresh

- Memory refresh is the process of periodically read information from an area of computer memory and immediately writing the read information to the same area with no modifications.

Memory Types

- Dynamic RAM (DRAM)
  - Synchronized DRAM (SDRAM)
- Static RAM (SRAM)

Dynamic Memory

- Bits stored as charge in capacitors
- Charges leak
- Need refreshing even when powered
- Simpler construction
- Smaller per bit
- Less expensive
- Need refresh circuits
- Slower
- Main memory is a dynamic memory
- Essentially analogue
  - Level of charge determines value

Static Memory

- Bits stored as on/off switches
- No charges to leak
- No refreshing needed when powered
- More complex construction
- Larger per bit
- More expensive
- Does not need refresh circuits
- Faster
- Cache memories are made of static memory
- Digital
  - Uses flip-flops

A Faster Computer

- It is possible to build a computer which uses only static RAM (see later)
- This would be very fast
- This would need no cache
  - How can you cache cache?
- This would cost a very large amount

Semi-conductor Memory Types

Memory Type	Category	Erasure	Write Mechanism	Volatility
Random-access memory (RAM)	Read-write memory	Electrically, byte-level	Electrically	Volatile
Read-only memory (ROM)	Read-only memory	Not possible	Masks	Nonvolatile
Programmable ROM (PROM)			Electrically	
Erasable PROM (EPROM)	Read-mostly memory	UV light, chip-level		
Electrically Erasable PROM (EEPROM)		Electrically, byte-level		
Flash memory		Electrically, block-level		

ROM

- Main memory is volatile
- Therefore a device is needed to keep the instructions for the start up process (booting up) the computer
- Potential applications that include in ROM
  - Library subroutines for frequently wanted functions
  - System Programs
  - Function Tables

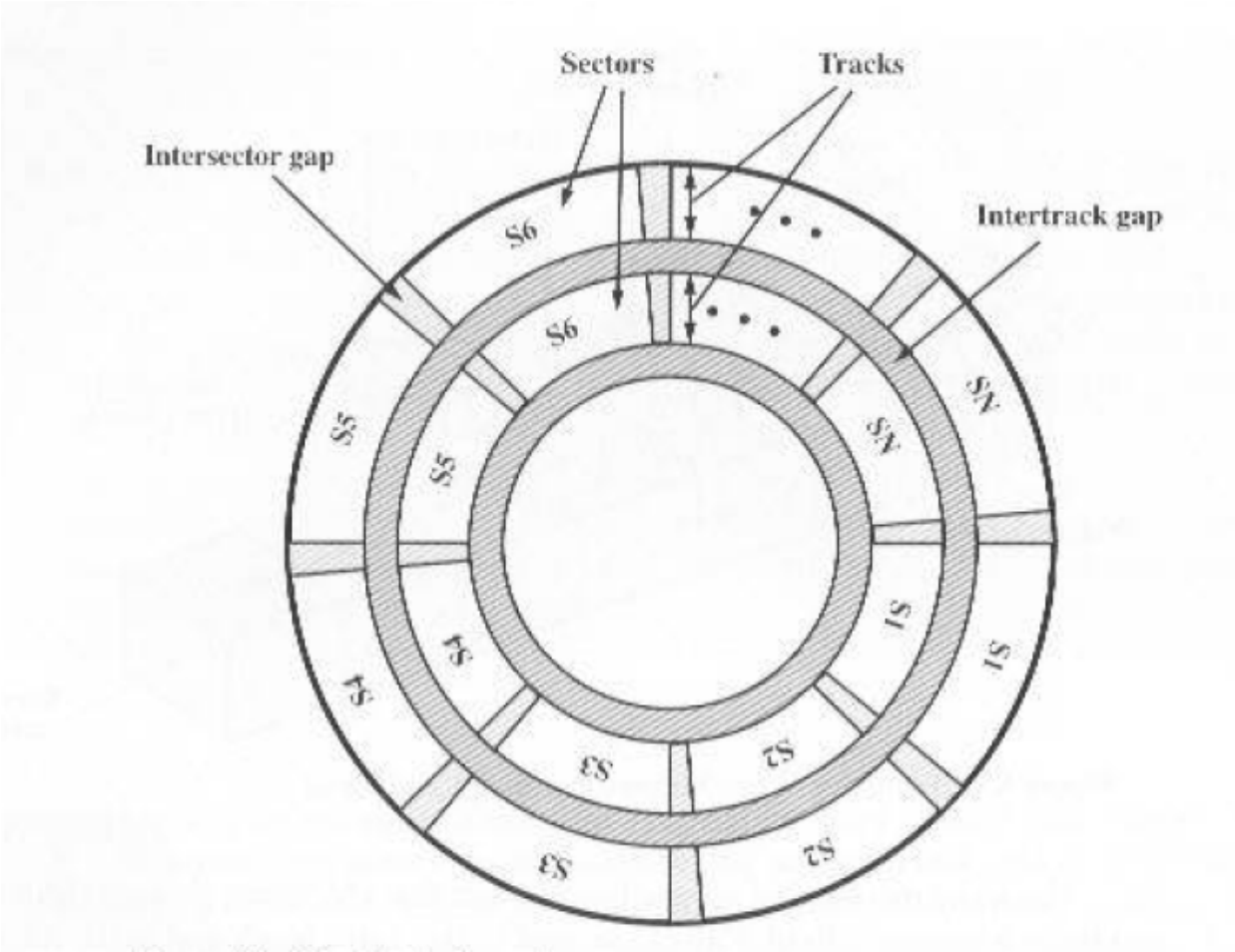
ROM (Contd.)

- There are three common forms ROM
  - PROM – Programmable ROM
  - EPROM – Erasable Programmable ROM
  - EEPROM – Electrically Erasable Programmable ROM
  - Flash Memory

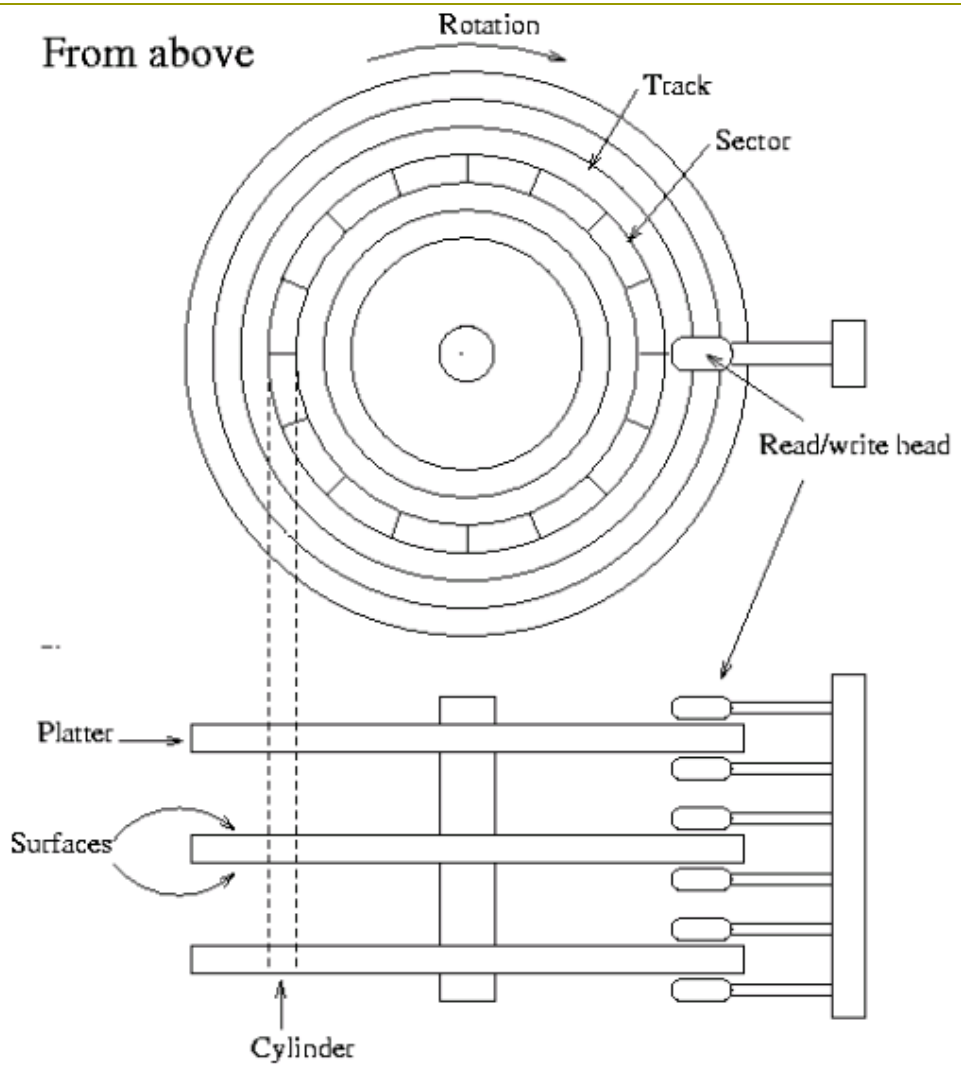
External Memories

- Magnetic Disks
- CD-ROMs
- DVDs
- Magnetic Tapes

Disk Data Layout

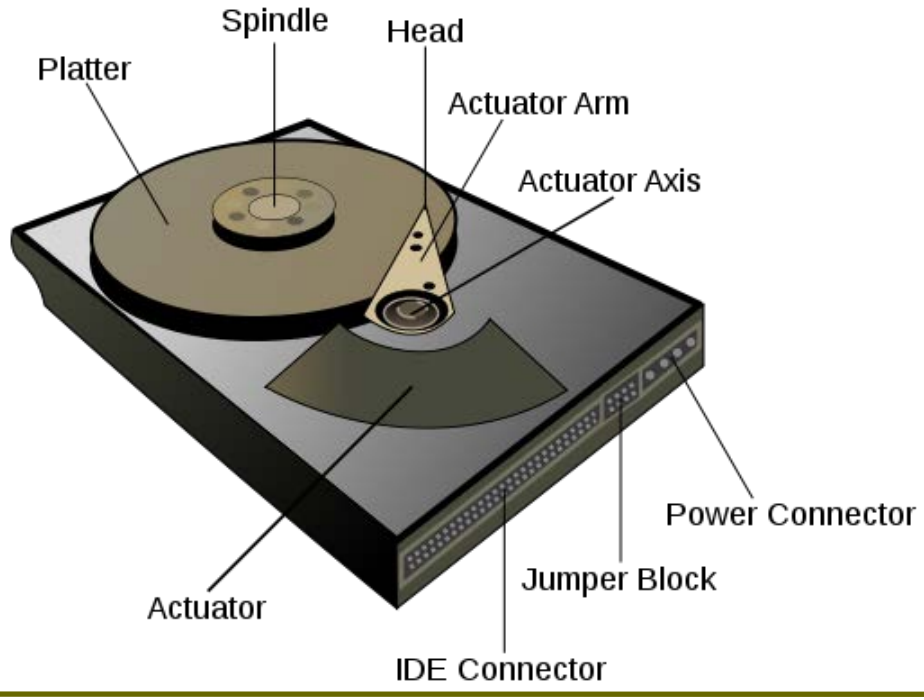


Hard Disk: Important Features



Hard Disk

- HDDs first introduced by IBM and were originally developed for the use with general purpose computers
- HDDs record data by magnetizing ferromagnetic material directionally, to represent 0 and 1 binary digits.

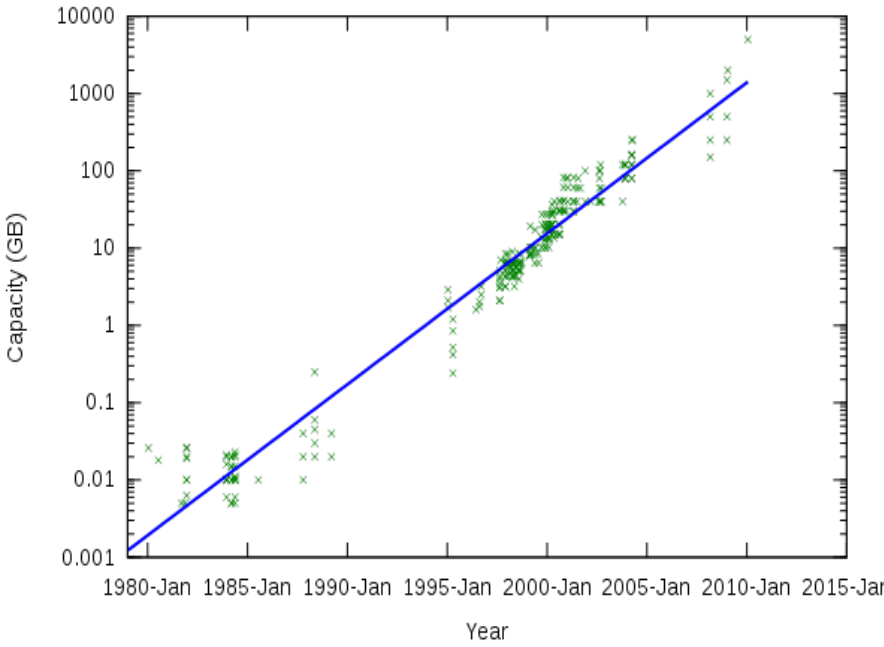


Anatomy of a Hard Disk Drive

Figure: http://en.wikipedia.org/

Capacity and Access Speed

- As of February 2010, the highest capacity consumer HDDs are 2TB
- Typical Desktop HDD stores between 120GB and 2TB, rotates at 5400rpm to 15000rpm, and has a media transfer rate of 0.5 Gbit/s or higher.
- The fastest “enterprise” HDDs spin at 10000 or 15000rpm and achieve sequential media transfer speed above 1.6Gbit/s.



Disk Performance Parameters

- Access time – seek time + rotational delay
  - Seek time – track selection time (moving the head on the desired sector on the track)
  - Rotational delay – the time it takes for the beginning of the sector to reach the head.
- Transfer time – the time required to transfer data.

External Storages

- CD-Recordable - The write-once-read-many CDs
- CD-RW – Optical disk that can be repeatedly written and overwritten, as with a magnetic disk.
- Digital Versatile Disk (DVD) – can store huge storage capacity and vivid quality

Thank You

