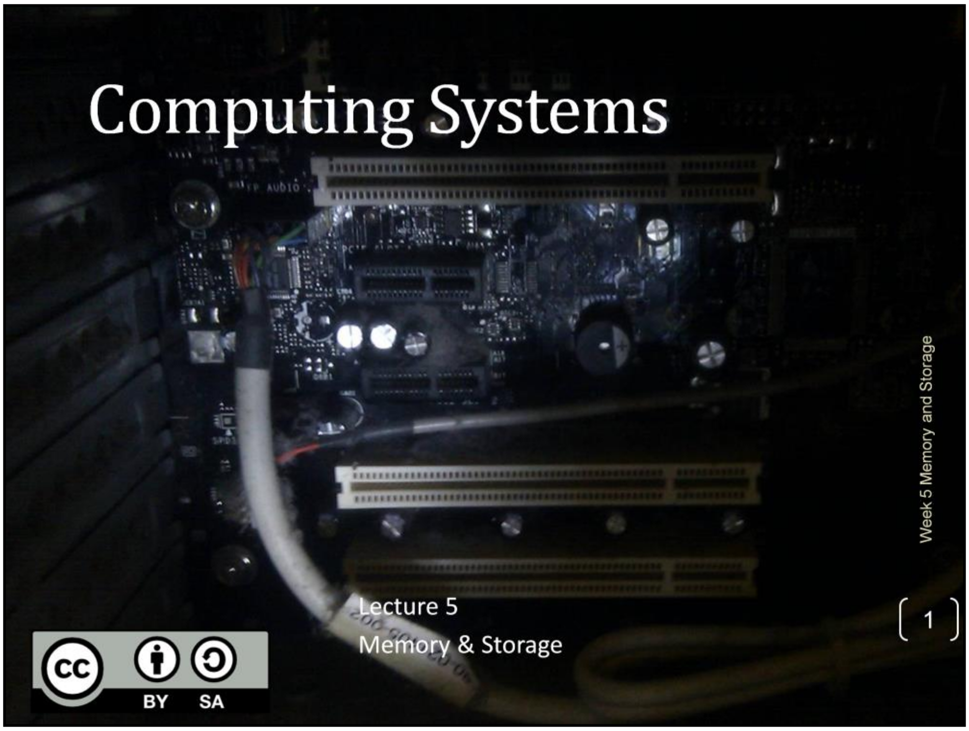
Computing Systems
Week 5 Memory and Storage
Lecture 5
Memory & Storage
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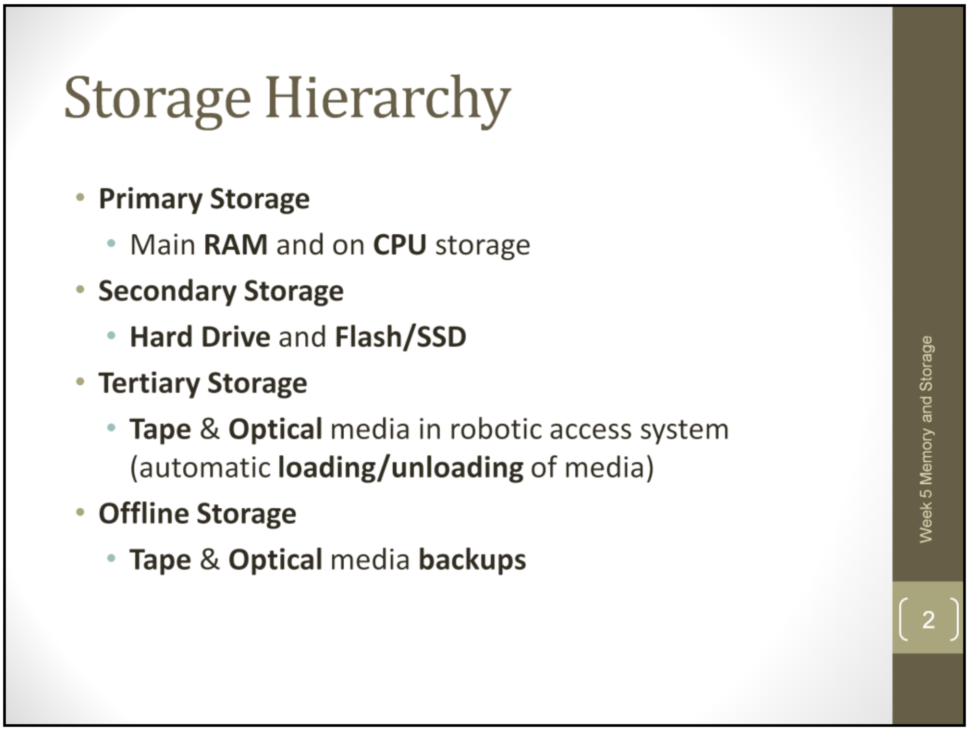
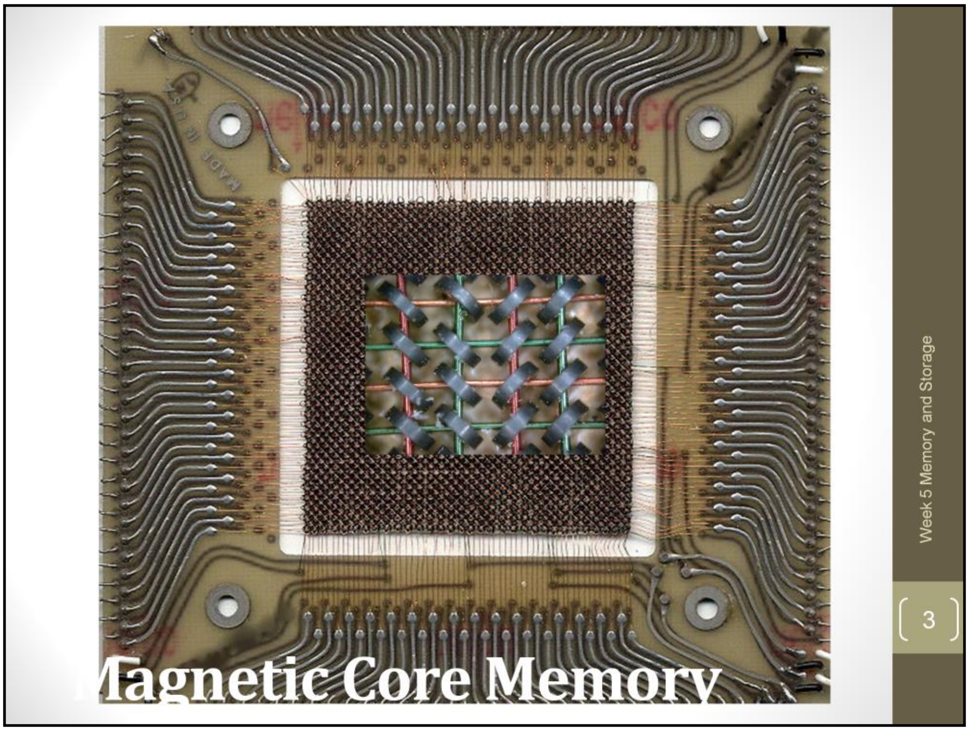
BY SA

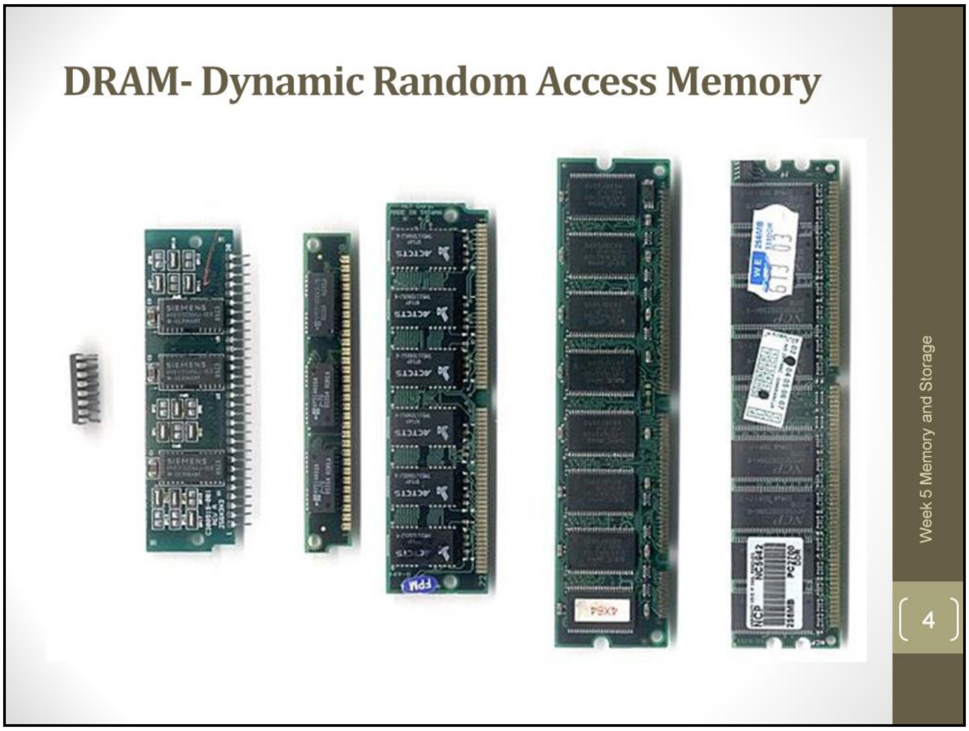


Primary storage has (more or less) direct access from CPU, Secondary storage requires use of I/O channels and interfaces.

Tertiary storage requires automated media loading and unloading facilities



Early Computer memory uses Magnetic Core Memory, this card would be about 10cms a side. In the centre there is little magnetic cores, magnets, with wires in between them. Magnets would store a charge, and you set a magnets charge to store or clear a charge stored in the magnet. This gave a basic storage capability. It was still used in the early space shuttle as it was very reliable, well understood technology. Very resistant to damage and could maintain it contents for a long period of time even when power was switched off. Not really used in modern systems.

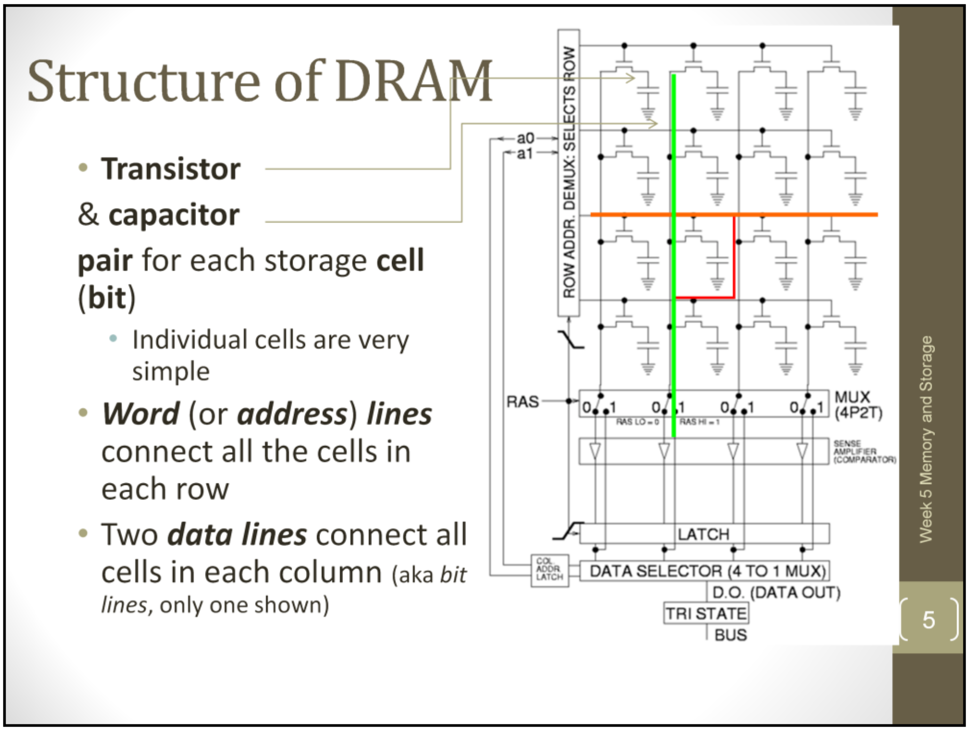


DRAM – is used in modern computer systems. Different chips from various eras.

More recent on the right, contain a number of different DRAM chips on one circuit board which slots into the computer. Modern DRAM modules might contain quite large capacities up to several Gigabytes in one module, whereas earlier memory modules chips may have contains only a few KB of RAM-.

DRAM memory: At left is a Dual in-line Package (DIP) dynamic RAM chip – the other memory modules are more modern. From left to right: DIP, SIPP, SIMM (30-pin), SIMM (72-pin), DIMM (168-pin), DDR DIMM (184-pin).

http://commons.wikimedia.org/wiki/File:RAM_n.jpg



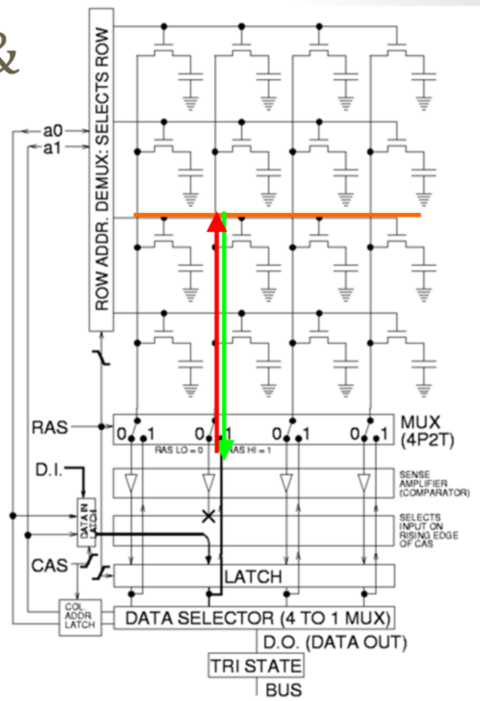
Capacitor is an electrical device that is able to store a charge for a period of time. Memory cell is simple it has a transistor and a capacitor. A row of these components are connected along a word or address line CONNECTING ALL CELLS IN EACH ROW. Two data lines connect all cells in each column, only one is shown. By setting a value to activate an address line and another to address a column, you can address an individual memory cell or BIT. Each cell stores a single 0 or 1 value. We can refer to cell if we know it's address line and column. For reading and writing the signal makes one address line active at the same time. A whole word would normally be read at the same time. Cell value is copied down to the sense amplifier (buffer). Write operation it is the same idea, values are put into buffer, the line is activated, a charge is sent up the address line to the memory cells.

DRAM Read & Write

Signal sent to make one **address line** active at a time

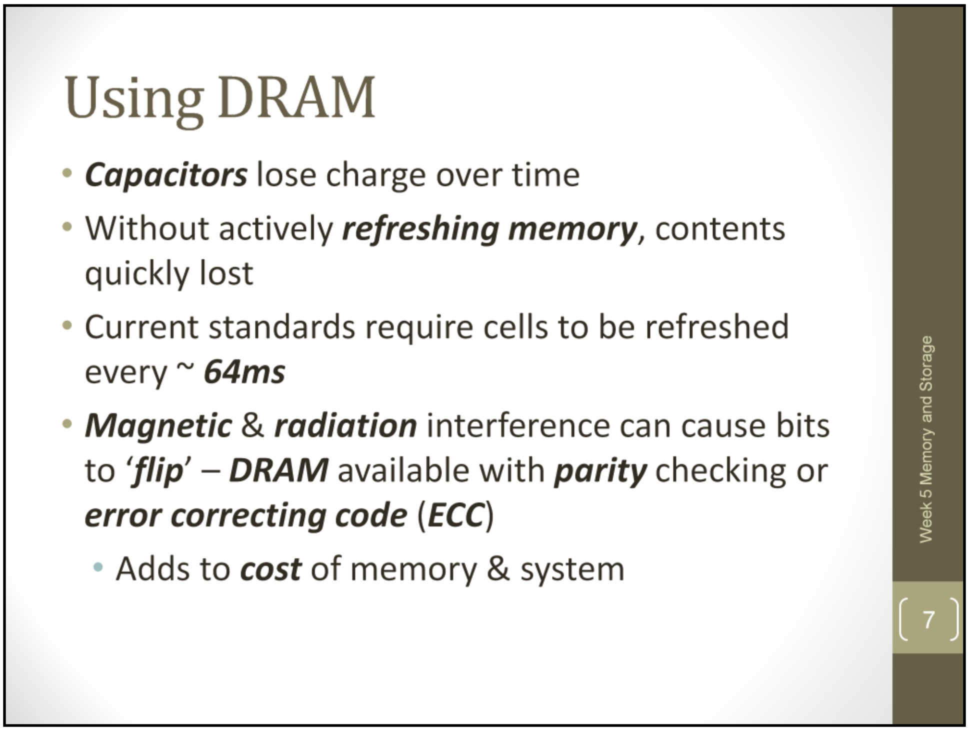
For **read**, active cell from each column copied **to** a ***buffer*** (the *sense* ***amplifier***)

For **write** operation, bits **from** the ***buffer*** are sent via the ***data lines*** to reset the values in the ***current address line***



Week 5 Memory and Storage

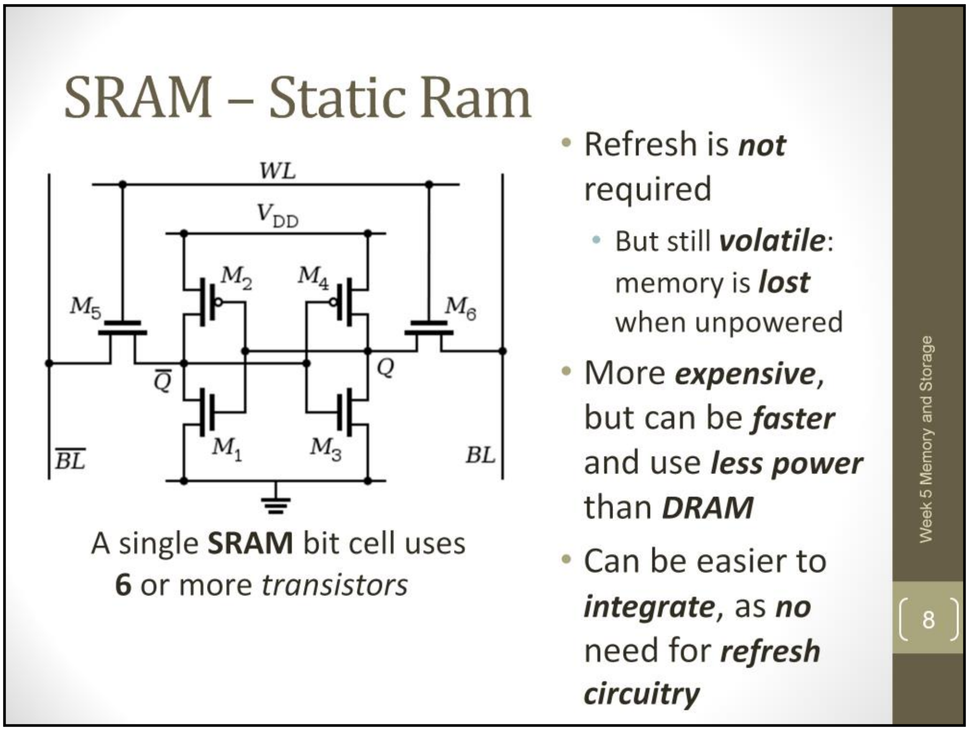
6



64 ms – milliseconds – 1/1,000th of a second. Thousandth.

You can buy DRAM with / without ECC.

For most home computer use normal to use the DRAM without ECC as random BIT flip is not very common. Some business uses need DRAM with ECC.



A long as power is on it keeps it’s value. Use less power than DRAM as they do not need refreshed.

More circuitry is involved therefore it is more expensive. It can be faster. Can be easier to integrate into some systems as there is no need to have special circuitry to refresh the memory.

Long Term Storage

- **RAM** is relatively ***expensive*** & ***power hungry***
- **Good** for storing ***active programs*** in a running computer
- **Wasteful** for storing ***inactive programs*** and ***data***
- Totally ***useless*** for storage when computer is switched ***off***

Storage

- **Disks**
  - **Floppy Disks** – removable & portable media
  - **Hard Drives** – fixed & portable
  - **Optical media** – **CD**, DVD & **Blu-Ray**
- **Tape** storage
  - **Large capacity archive media**
- **Flash memory**
  - **USB** flash drives
  - **Solid-State Drive**s (**SSD**)

Cache Memory

- Will look in this in more detail later
- General principle:
  - Use a small amount of **high performance memory** as a **local copy** of data stored in some **cheaper** but **lower performing memory**
- Examples:
  - **CPU** may have a cache storing copy of some data from main memory (**RAM**)
  - Disk drives may have **RAM** chips to cache data recently used

Limits dependency on using the disk itself to read and write data to allow faster access.

Quick quiz

- Join the 'Socrative' app 'Room 642124' and try the quick quiz.

3 ½ - used widely up to 7 years ago or so.

Note: A wide range of data formats and capacities existed for each of these standard disk sizes.

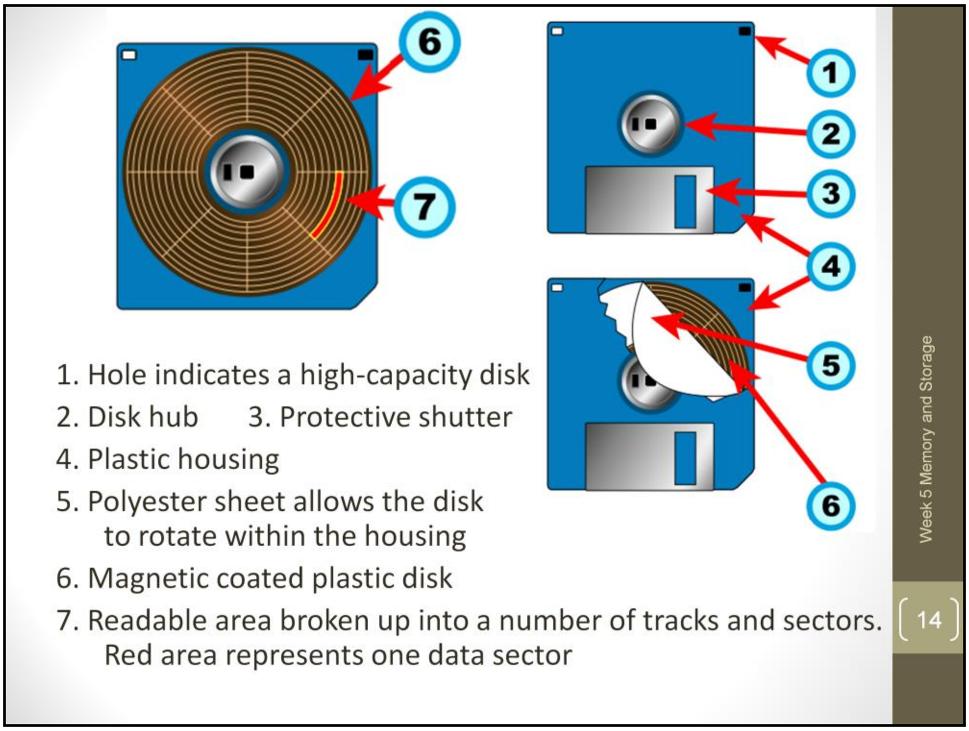
Lots of detail and tables at http://en.wikipedia.org/wiki/Floppy_disk

More important for us are the common features of all of these:

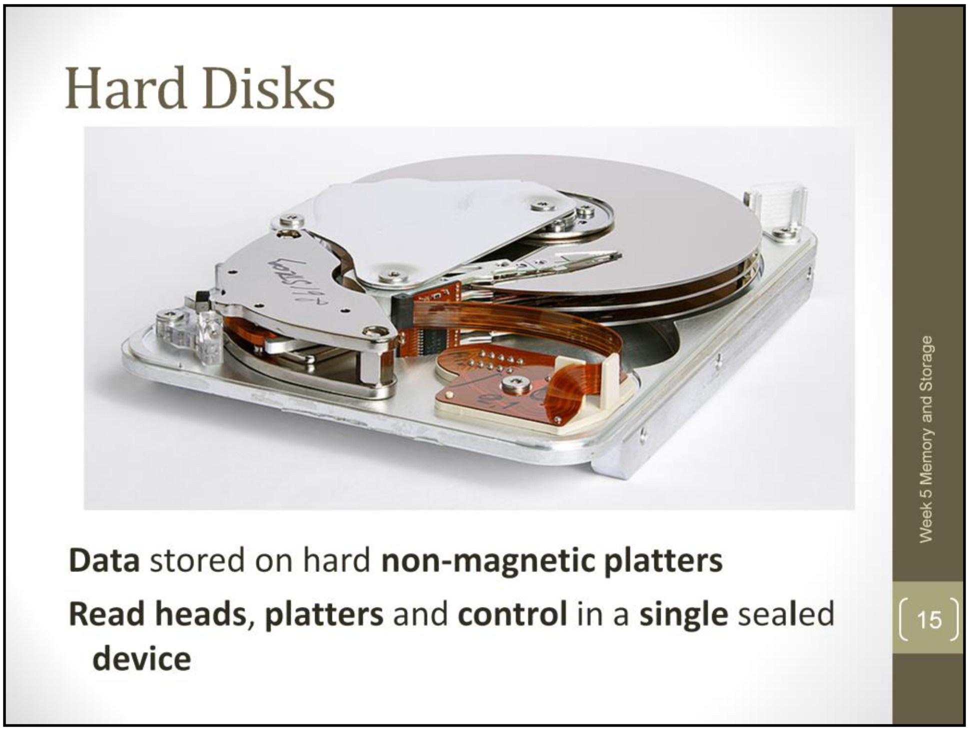
Larger unformatted capacity, smaller usable formatted capacity, flexible disk in either flexible or rigid case.

3½" disk also featuring sliding cover to protect the disk from damage.

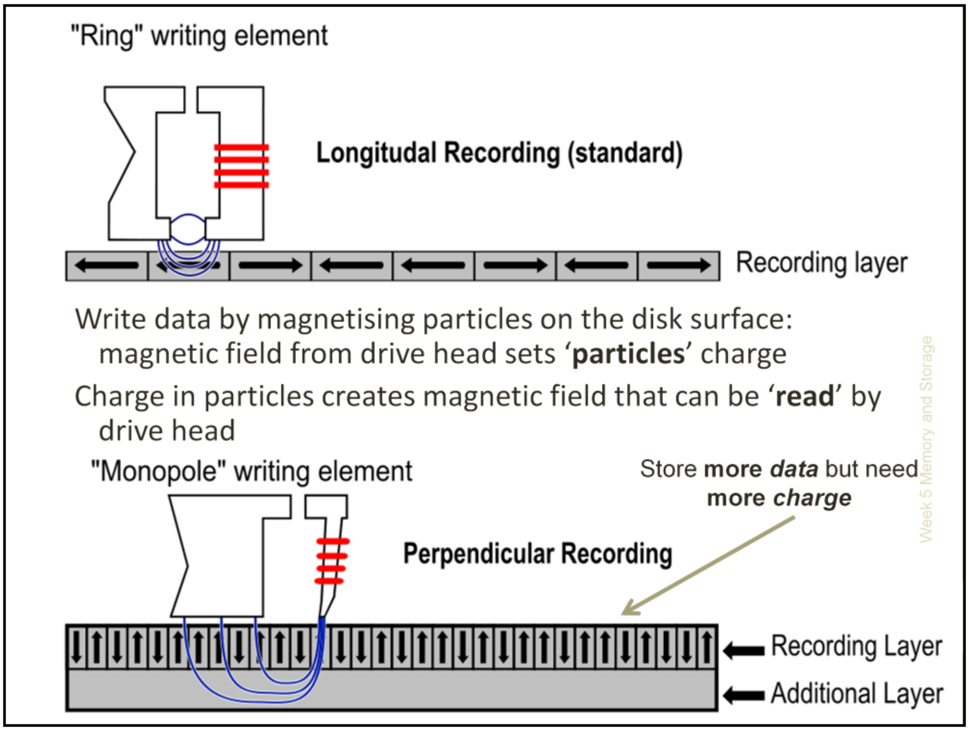
If possible bring disks to class – even allow them to be broken open if possible...



3 ½ - protective shutter, hard outer case. Disk is coated in magnetic particles. Most floppy disks have the sectors arranged so that the sector angle is the same. There is the same amount of data on each sector so that the disk rotates at the same speed. There could be more data on the sectors at the outside of the disk but that would slow things down as the disk would have to rotate at different speeds. It was complicated earlier on.



Hard disks can slow down and speed up therefore more data can be stored in the outer sectors. Disk head float a miniscule distance above the disk. Disks are normally sealed.



This applies to both floppy and hard disks. Magnetic particles are lined up one way or another representing 0 or 1. Perpendicular is more recent and allows more data to be stored / packed but needs more charge, current.

Hard Disk Technology

- Platters coated with thin layer of **magnetic material (10-20nm)**
- Typical **rotation speed** of **7,200 RPM**
- Heads float **nano-meters** above **platter**
- Modern hard disks are hermetically sealed units including ***read/write*** heads and controller
  - **1970's** hard disks had **removable packs** consisting of the platters themselves. **Drives** would be about the size of a **washing machine**

Week 5 Memory and Storage

17

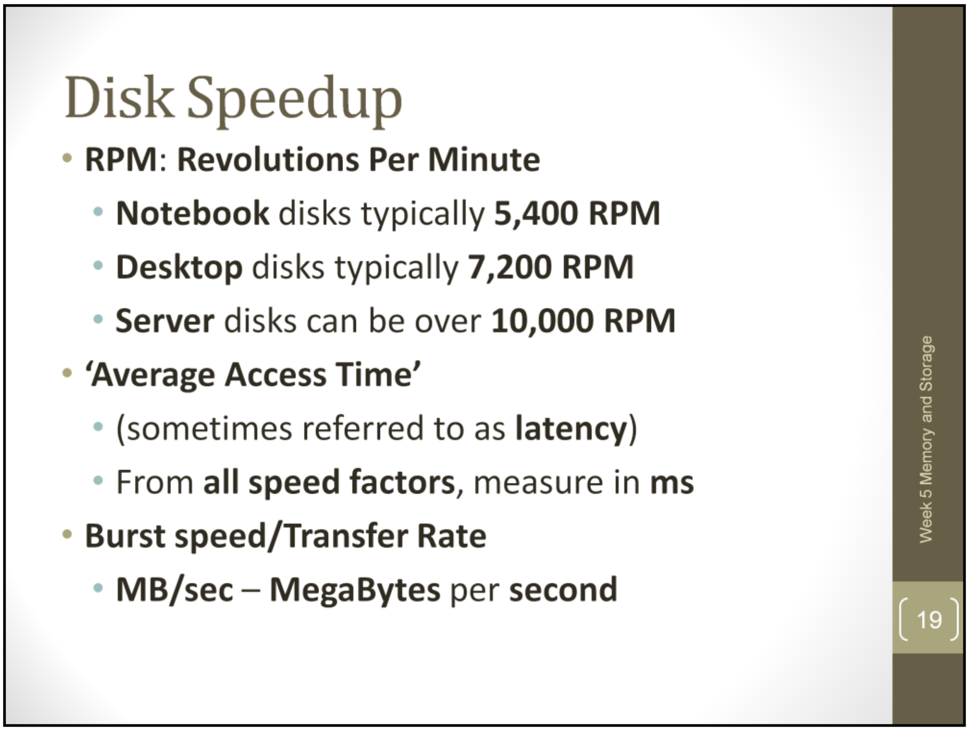
10-20nm (nanometre -- equal to one billionth of a metre) thick coating of magnetic material compare to typical sheet of copier paper will be 70,000-180,000nm thick! Particles of smoke could not fit between the gap.

Disk Slowdown causes

- **Spin-up time**
  - Many drives will switch off automatically to save power; takes time to **restart**
- **Seek time**
  - **Data** may be **anywhere** on **disk**; Time to **move** read **head** into **correct position**
- **Latency**
  - **Time** for **disk** to **rotate** until **correct sector** is **present** at *read/write* head
- **Fragmentation**
  - Single **file** may exist in **sections** scattered over **disk**; Time to **move** between **sections**

Week 5 Memory and Storage

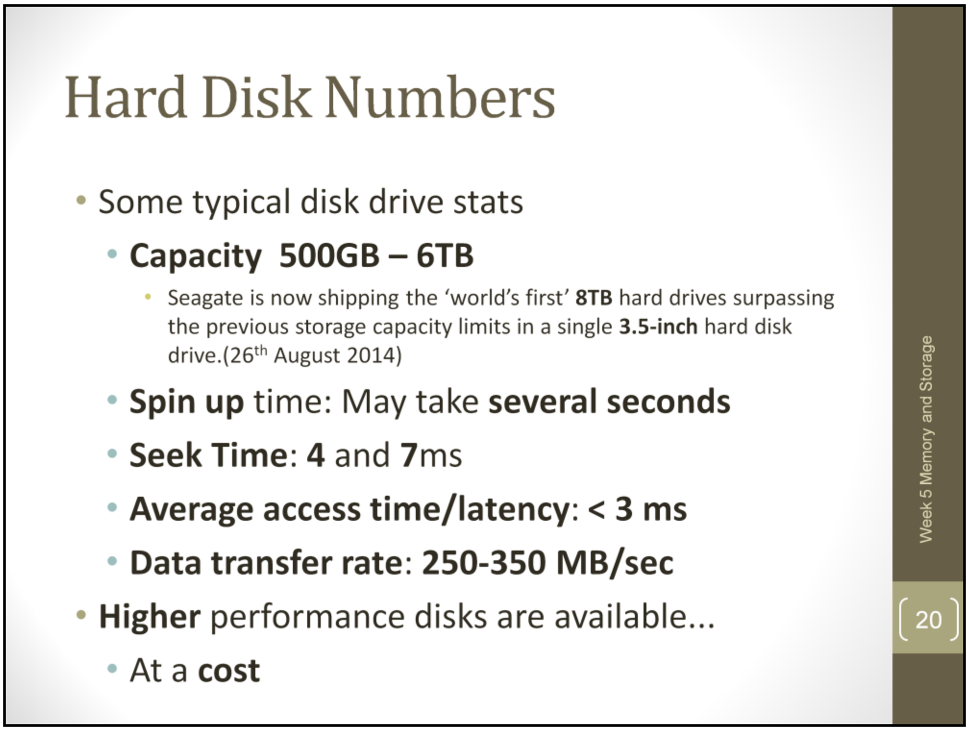
18



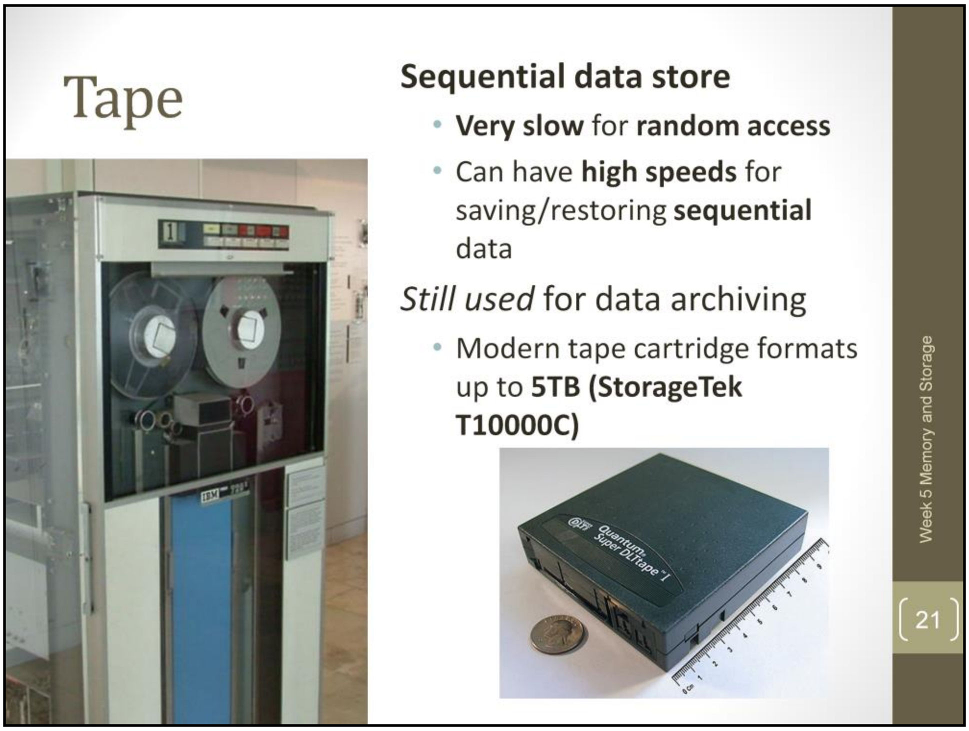
To speed up.

Average Access Time → all delay times added together.

Burst speed –> maximum speed from a hard disk, when you have taken out the seek time delays.



2 TB – terabyte → One trillion (1,000,000,000,000) bytes



See them in 70s films, Bond film.

Tape gives a sequential data store, very slow for random access, but have very high speed for saving and restoring data in order. Tape is still used for data archiving servers and by ISPs. It is very cheap, one cartridge can store up to 3TB, therefore can store more than and is cheaper than a comparable hard disk.

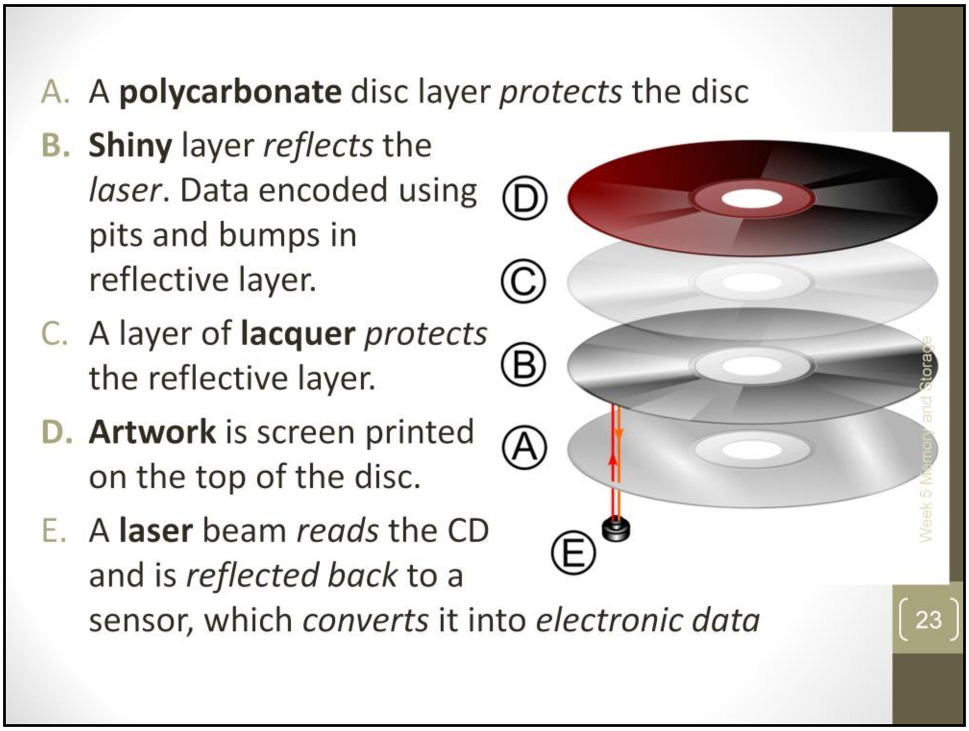
Optical Disks

- **CD, DVD** and **Blu-Ray disks** are forms of *optical* media
- **Lasers** used to *etch* and *scan microscopic holes* on the internal *surface* of disks
- **Transparent layer** protects read/write surface
  - Resistant to minor scratches
- **700MB (CD), 4.7GB (DVD), 25/50GB (Blu-Ray)**

Week 5 Memory and Storage

22

Optical Disks → possibly have a limited life span left.



All have similar layout to above.

Note: The wikipedia original states that the data is burned into the polycarbonate layer. In contrast the text book (HCW) and other sources claim that the pits and burned into the reflective material instead of the top of the polycarbonate layer. I've gone with the latter...

CD/DVD/Blu-Ray

- All use a spiral track with constant track size
- The **smaller** the **wavelength** of the **light**, the **more tracks** can be **packed** onto the **disk**
- **Blue light** has **shorter wavelength** than **Red**
- **DVD** & **Blu-Ray** may be **dual** layer, with **two layers** on a **single disc**
- Focussing the **light beam** allows either **layer** to be **read/written**

Week 5 Memory and Storage

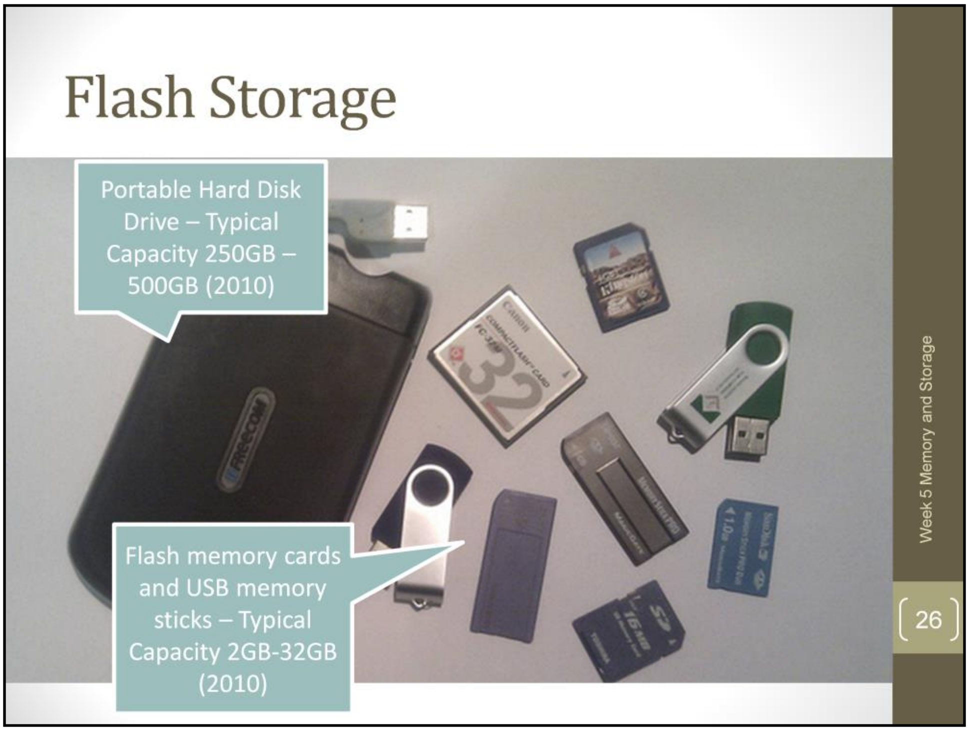
24

Data spirals out from the centre of the disk. Blue light has shorter wavelength than Red. CD used red layer.

Read/Write Optical Media

- Special **dye** layer before **reflective** layer can have **pits burned** in it by **writer**
- Normal drives can read as usual
  - **Write drives** can produce **higher power beams** to **mark**, **melt** or **distort** the **dye layer**
- *Lots of formats* –write once **(+/-R)** and rewritable **(+/-RW/RE)**
- Dye can decay – affecting lifespan of disc
  - But modern discs should last **10s** to **100s** of years

Lots of formats –write once (+/-R) and rewritable (+/-RW/RE)



Portable drive shown is actually several years old, with an 80GB capacity – it is now possible to buy USB memory sticks with greater capacity (though at time of writing they tend to be rather chunky!)

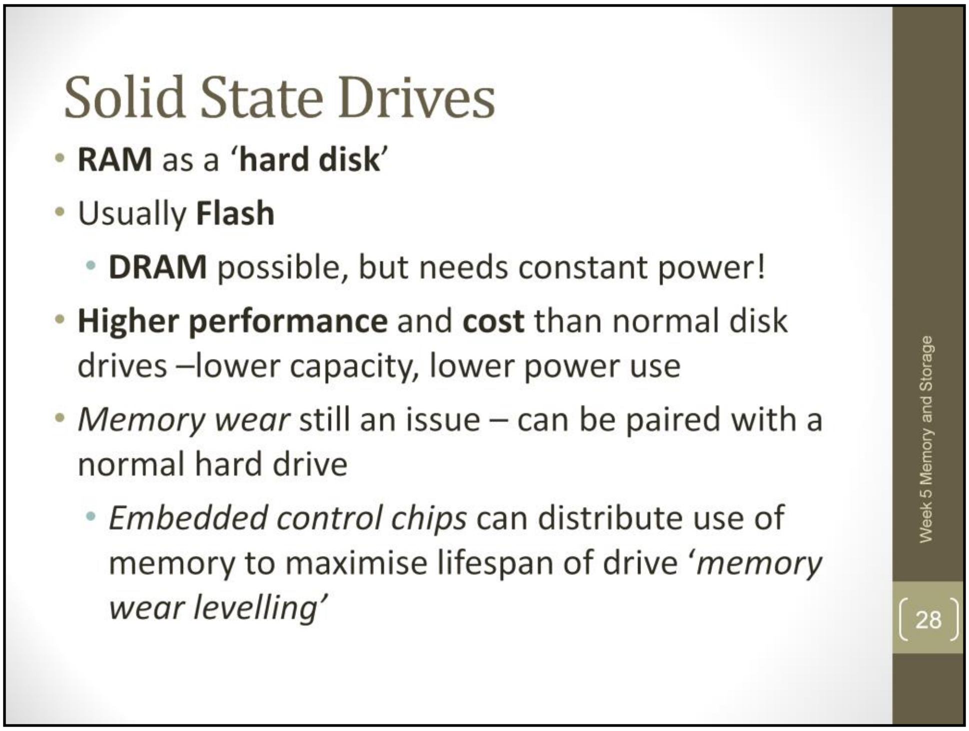
Memory cards shown (Compact Flash, SD, SDHC, Memory Stick, Memory Stick Pro and Memory Stick Pro Duo) have been collected over many years – with capacity ranging from 16MB (!) to 4GB. The Compact Flash card (the largest card) has just 32MB capacity. USB memory sticks were free with conference attendance or membership gifts.

Flash Memory

- Transistors with a **fourth** *insulated connection*
  - Additional gate can hold charge for many years, allowing flash **RAM** to store data without power
- Memory cells ***fail*** over time – ***Memory Wear***
  - 100,000 to 1,000,000 program/erase cycles
  - ***Wear levelling*** and memory block management can extend lifetime
  - Using flash for memory cache or **frequent compiling** can cause serious damage!
- Range of **speeds** & **lifetimes** – and **costs**

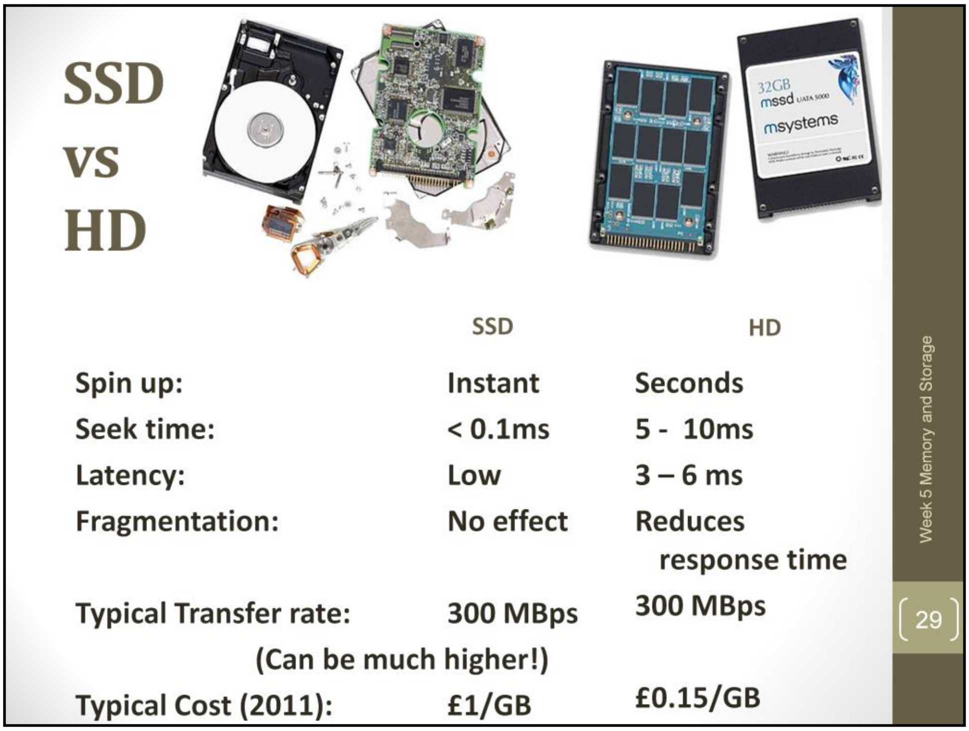
Note: Not all flash memory is the same; Flash memory with longer expected lifetime or higher rated performance can cost 2 to 4 times as much as basic flash memory for the same capacity. Flash RAM can store data without power.

Wear levelling and memory block management can extend lifetime by saving the data on a different are when resaving it. Bargain Flash memory for good prices may have a shorter life time.



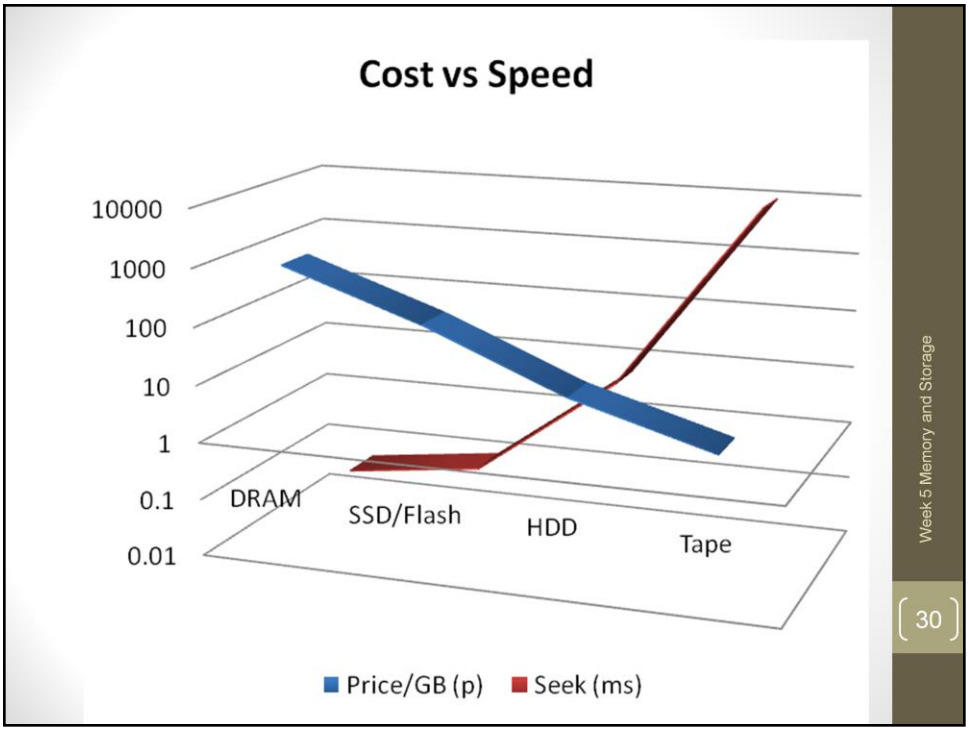
Solid State Drives → Relatively recent → use RAM as Hard disk → used for Lap tops.

Place o/s files on SSD but user files and memory cache on the Hard Disk



Comparison of SSD to HD.

SSD data will be fragmented but will have no effect.



DRAM is most expensive but has fastest seek time.

Scale on left is logarithmic.

Hacking MicroSD Cards

- For the full blog on this topic go to http://www.bunniestudios.com/blog/?p=3554
- Some **SD cards** contain *vulnerabilities* that allow arbitrary **code execution** — on the memory **card its**elf.
- On the dark side, code execution on the memory card enables a class of ***MITM (man-in-the-middle)*** attacks, where the card seems to be behaving one way, but in fact it does something else.
- On the light side, it also enables the possibility for hardware enthusiasts to gain access to a **very cheap** and **ubiquitous** source of **microcontrollers**.

Hacking MicroSD Cards cont.

- **Flash** memory is really **cheap**. So cheap, in fact, that it's **too** good to be **true**.
- In reality, all flash memory is **riddled** with **defects** — without exception. The **illusion** of a contiguous, **reliable storage media** is crafted through **sophisticated error correction** and **bad block management functions**. This is the result of a constant arms race between the engineers and mother nature; with every **fabrication process shrink**, **memory** becomes **cheaper** but more **unreliable**.
- Likewise, with every generation, the engineers come up with more **sophisticated** and **complicated algorithms** to **compensate** for mother nature's propensity for entropy and **randomness** at the atomic scale.

Hacking MicroSD Cards cont.

- The quality of the flash **chip(s)** integrated into **memory cards** varies widely.
- It can be anything from **high-grade factory-new** silicon to material with over **80% bad sectors**.
- Those concerned about **e-waste** may (or may not) be pleased to know that it's also common for **vendors** to use **recycled flash chips** salvaged from **discarded parts**.
- **Larger vendors** will tend to offer more **consistent quality**, **but** even the largest players staunchly **reserve** the **right** to **mix** and **match flash chips** with **different controllers**, yet sell the **assembly** as the **same** part **number** — a nightmare if you're dealing with implementation-specific bugs.

Quick quiz

- Join the ‘Socrative’ app ‘Room 642124’ and try the quick quiz.

Required Reading For Next Week

- HCW:
  - Part 7 How the Internet Works: Introduction and Chapters 24-28, p 308-357
  - (Skip 322/323,326/327, skim 338-349)
  - *P319 – Bus topology comments not quite right!*

Further Reading

- Wikipedia:
  - Computer Data Storage & related articles
- PCH
  - Chapter 12 – Computer Memory

Week 5 Memory and Storage

36

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