SSD

(Solid State Disk)

http://en.wikipedia.org/wiki/Solid-state_drive

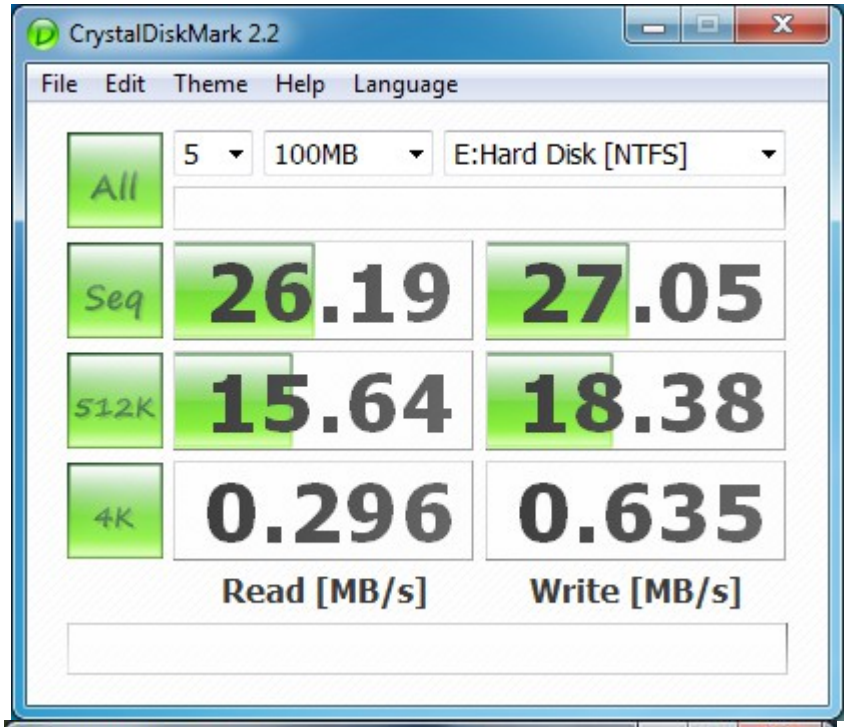
SSD (Solid State Disk) drives

- Most SSD drives gives very good performance 4x ~ 100x
  - No noise, low weight, power and heat generation
  - Extremely low seek times and good resistance to shock
- SSD revolution (2008?)..., now evolution
  - Still expensive but will probably own a lot of the market in the next years to come
- Many different brands (> 50)
  - Intel, Samsung,OCZ, Corsair, Kingston...
- Especially well suited for laptops and RAID 0 since it scales well
  - Power consumption
  - Less wear and tear on cells
- A big step in the computer history!

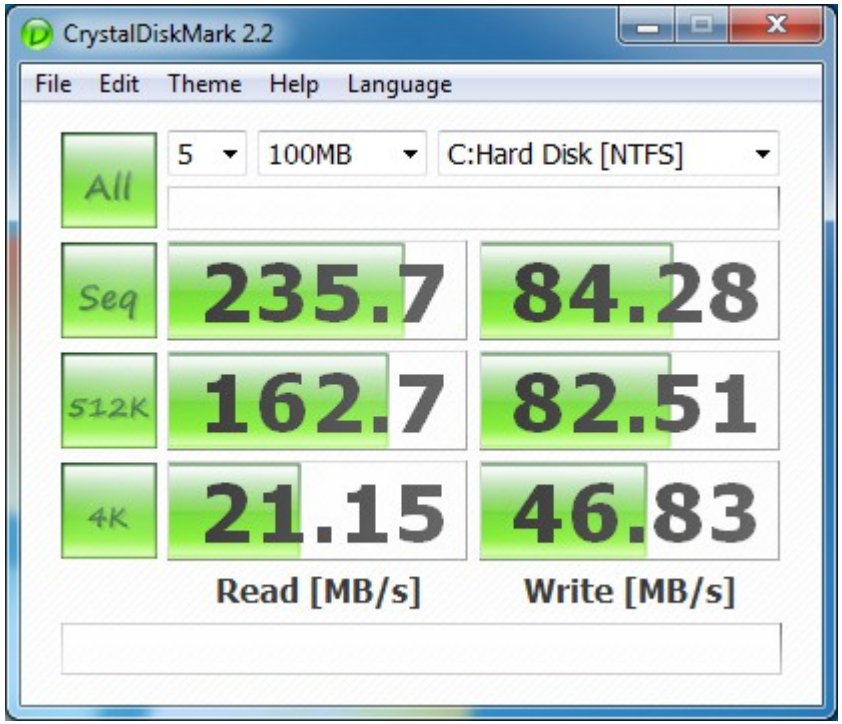
http://en.wikipedia.org/wiki/Category:Solid-state_computer_storage_media

SSD (2009) performance laptop

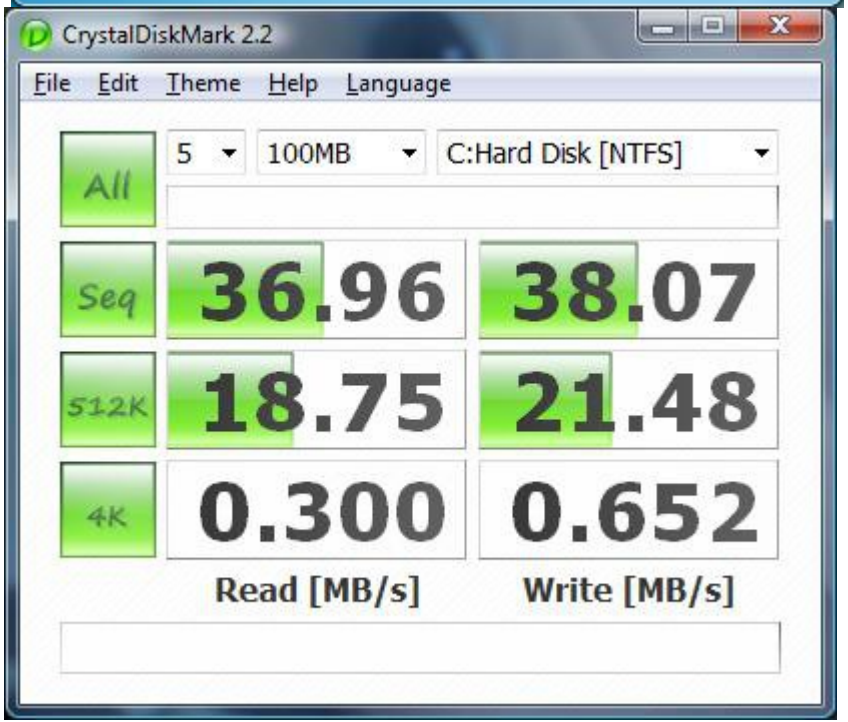
USB-disk



SSD, Intel G2 – SATA 2



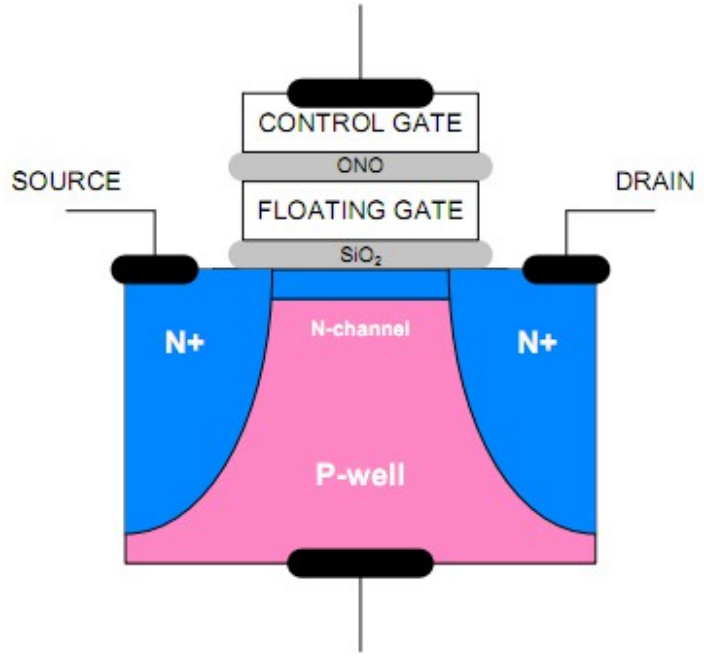
HD



How SSD work I

http://en.wikipedia.org/wiki/Flash_memory

- The building block of NAND flash is the N-channel MOSFET transistor cell
- Voltage levels
  - 2, 4 and 8 levels of voltage
- SLC (Single-Level Cell)
  - Holds 1 bit of data
- MLC (Multi-Level Cell)
  - Holds 2 bits of data
- TLC (Triple-Level Cell)
  - Holds 3 bits of data



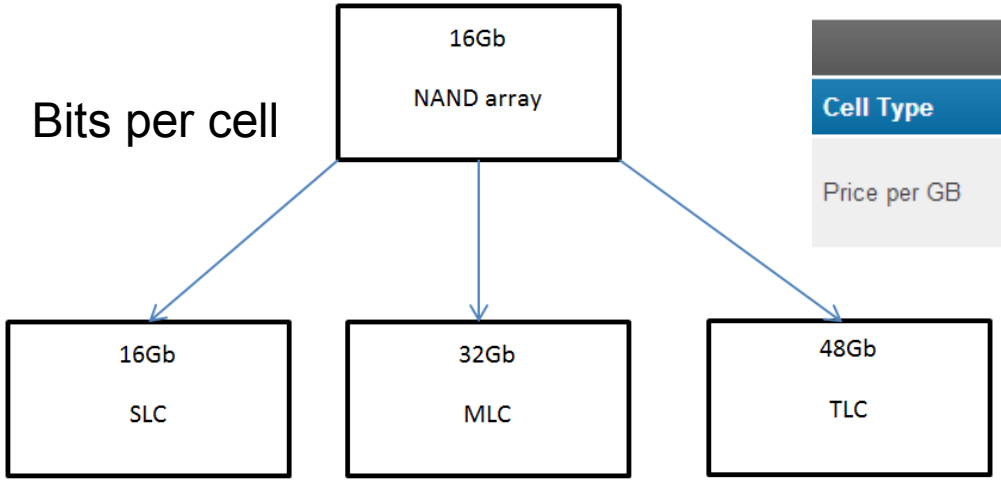
When you program a cell, you are placing a voltage on the control gate, while source and drain regions are held at 0V.
The voltage forms an electric field, which allows electrons to tunnel through the silicon oxide barrier from the N-channel to the floating gate.

The silicon oxide acts as an insulator and will not allow electrons to enter or escape the floating gate unless an electrical field is formed.
To erase a cell, you apply voltage on the silicon substrate (P-well in the picture) and keep control gate voltage at zero.
An electric field will be formed which allows the electrons to get through the silicon oxide barrier.

Understanding SLC/MLC/TLC NAND

http://www.anandtech.com/show/5067/understanding-tlc-nand

Bits per cell



Comparison of NAND Wholesale Prices			
Cell Type	**SLC**	**MLC**	**TLC**
Price per GB	$3.00	$0.90	$0.60

Price

	SLC	MLC	TLC
Bits per Cell	1	2	3
Random Read	25 µs	50 µs	100 µs
Erase	2ms per block	2ms per block	?
Programming	250 µs	900 µs	?

Performance

Degradation

	5Xnm	3Xnm	2Xnm
SLC	100,000	100,000	N/A
MLC	10,000	5,000	3,000
TLC	2,500	1,250	750

Understanding SLC/MLC/TLC NAND

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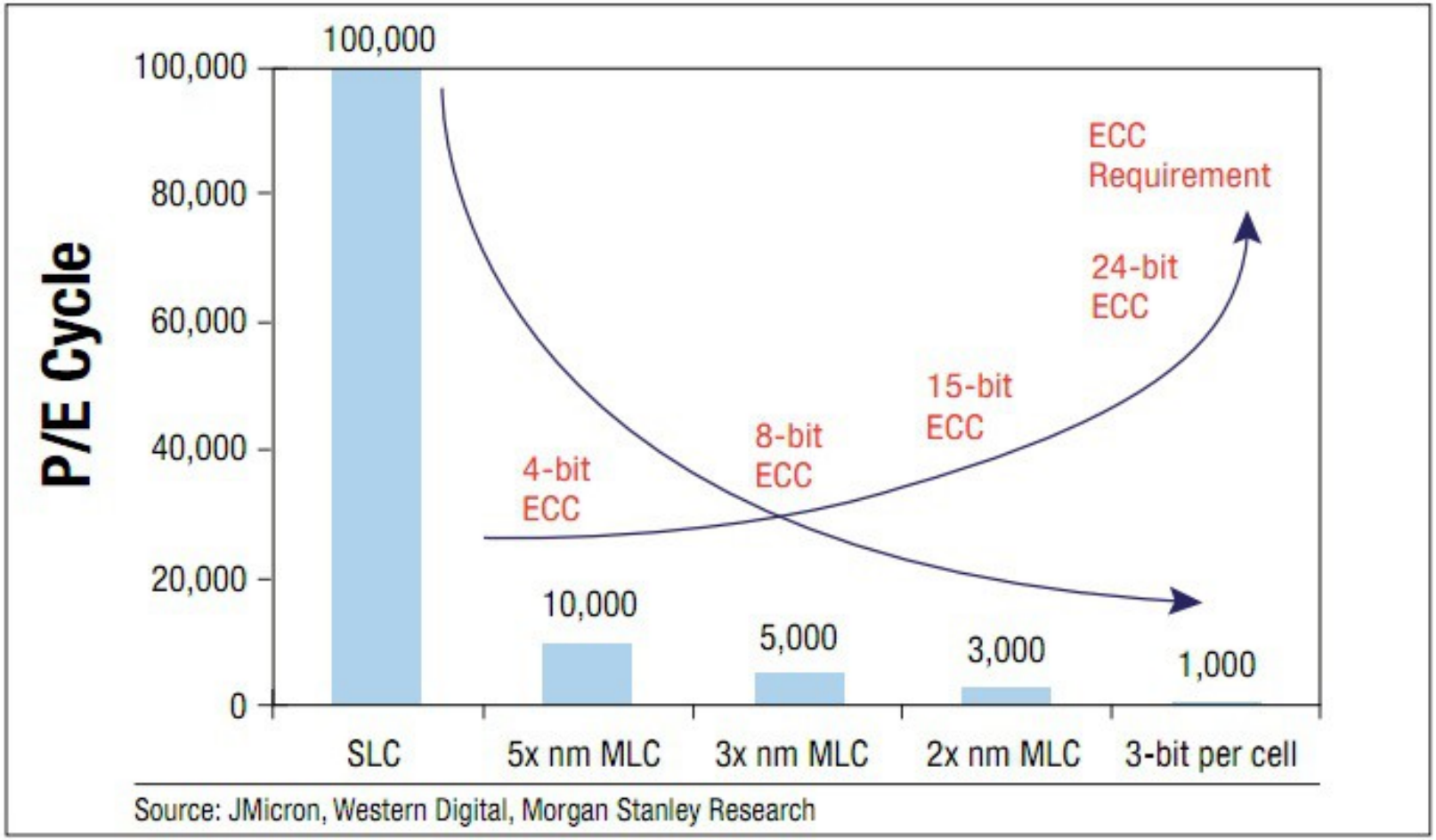
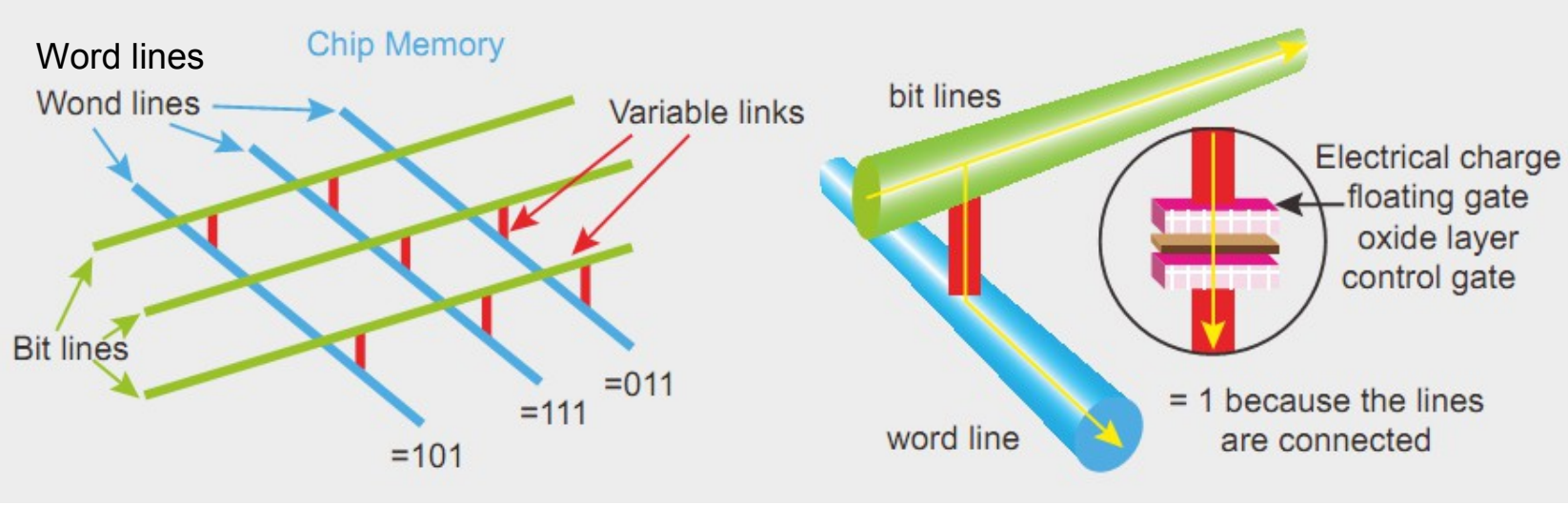
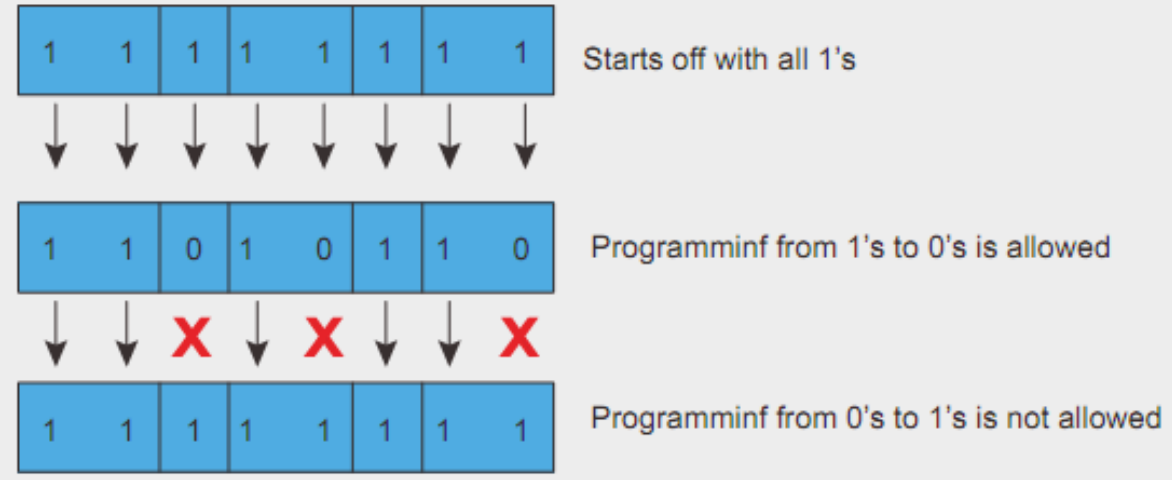


Figure 1 | A life cycle and ECC comparison of NAND flash by process node shows how an increase in correction capability is not enough to maintain endurance of the memory cell.

How SSD work II

- Flash memory design and programming the cells





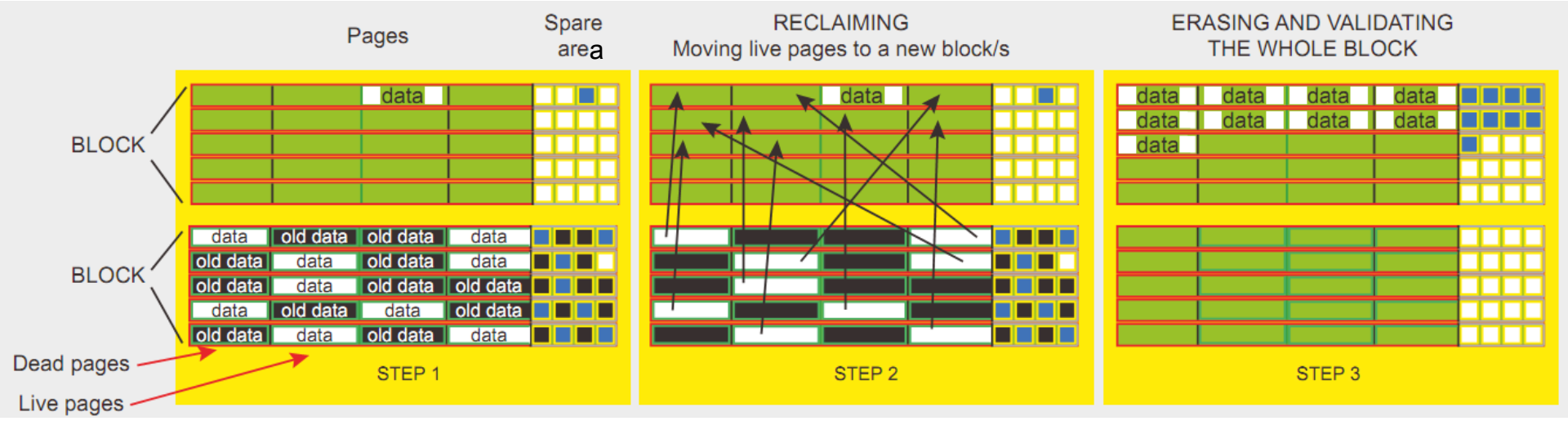
How SSD work III

- A group of cells is called a **page** which is the smallest structure that is programmable (writeable)
  - Usually 2 or 4 kB
- A **block** consists of a number of pages
  - Usually 64-128 pages, example: 128 * 4kB = 0.5 MB
- A block is the smallest structure you can erase!
- Just now the MLC flash disks can do around 10 000 erase/program cycles
  - With SLC it's around 100 000 because of the simplicity
- Remember - reading does not “wear” the cell!
- Creating a small file and deleting it is not possible, controller will wait until a certain percent of pages are marked as invalid (dirty) within a block before copying valid pages to other blocks

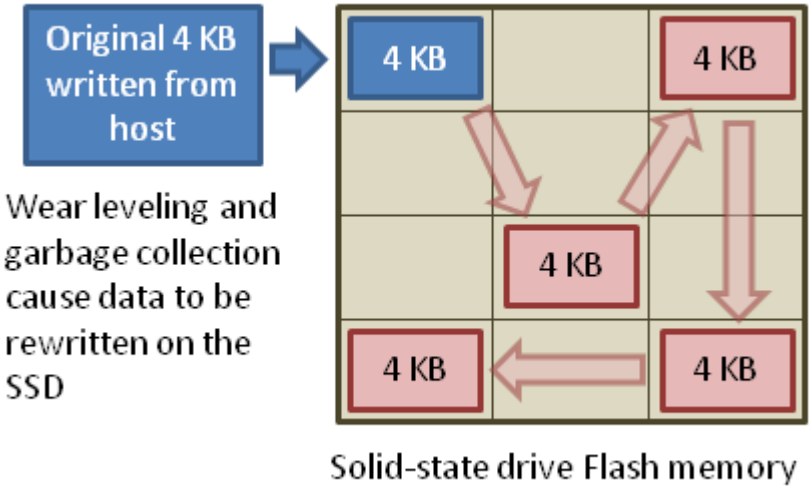
$$\text{Expected lifetime} = \frac{\text{Size of NAND flash x number of erase cycles x FAT overhead}}{\text{Bytes written per day}}$$

How SSD work IV

- The reclaim process as part of the wear levelling policy
  - The garbage collection is a background process
  - Example: 2 blocks in 3 steps
- Spare or OOB (Out Of Band) area
  - Cannot be addressed, it is used to store page status (valid or dirty) and ECC data etc.



How SSD work V

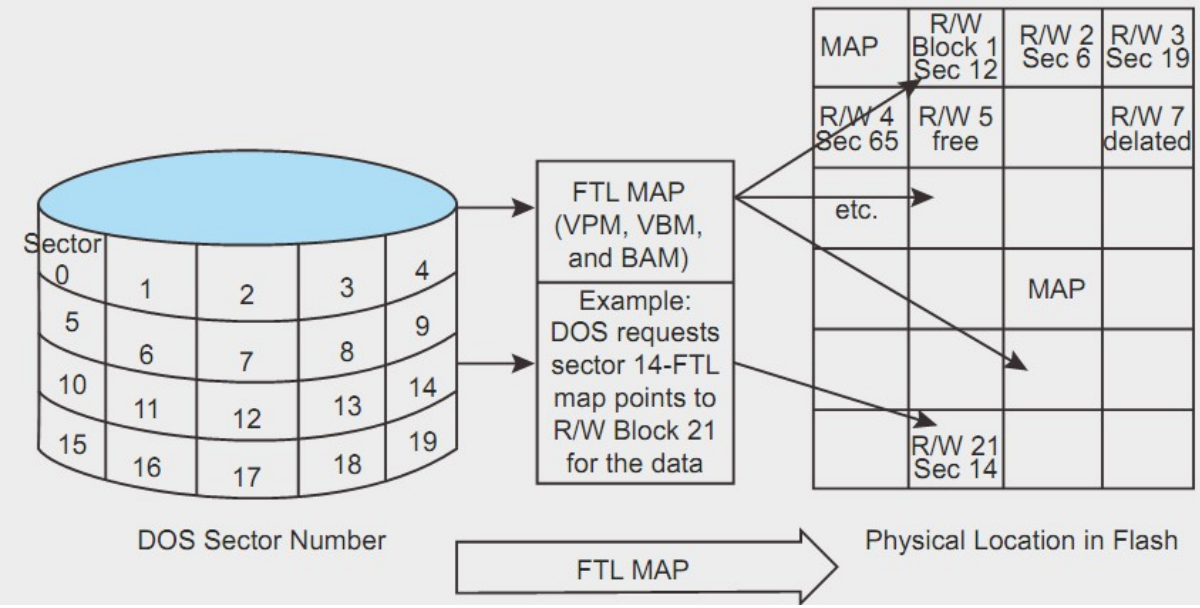


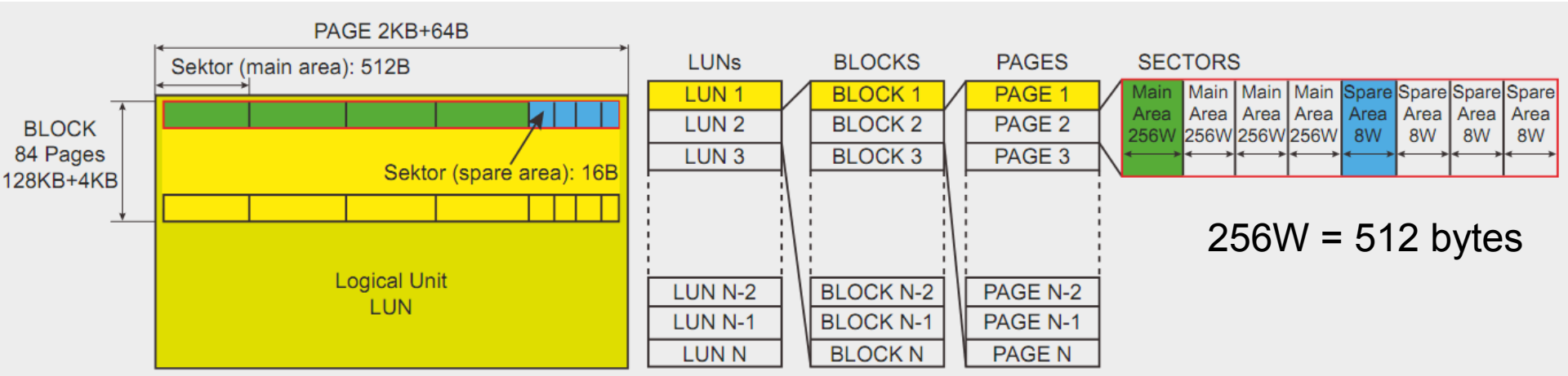
- Write amplification is the amount of NAND write performed for a requested amount of write from the host
  - Best controllers have a write amplification factor less than 1.1x
- Uses intelligent wear leveling algorithms in order to prolong the life of the drive
  - Spreading the usage of blocks over whole drive and limiting the damage – even moving non changed data to other blocks
  - Will actually reuse a “dirty” block when all other blocks on the drive have been written to once
  - There are a certain extra percent of space on the drive left meant for reliability purposes which may be adjustable!
- Many different algorithms exists handling SSD disks and new ones will probably pop up
- Sources

http://www.anandtech.com/cpuchipsets/intel/showdoc.aspx?i=3403
http://www.anandtech.com/storage/showdoc.aspx?i=3531
http://en.wikipedia.org/wiki/Write_amplification

How SSD work VI

- FTL (Flash Translation Layer) sector relocation MAP
  - VPM (Virtual Page Map)
  - VBM (Virtual Block Map)
  - BAM (Block Allocation Map)
- A logical unit (LUN) is the minimum unit that can independently execute commands and report status

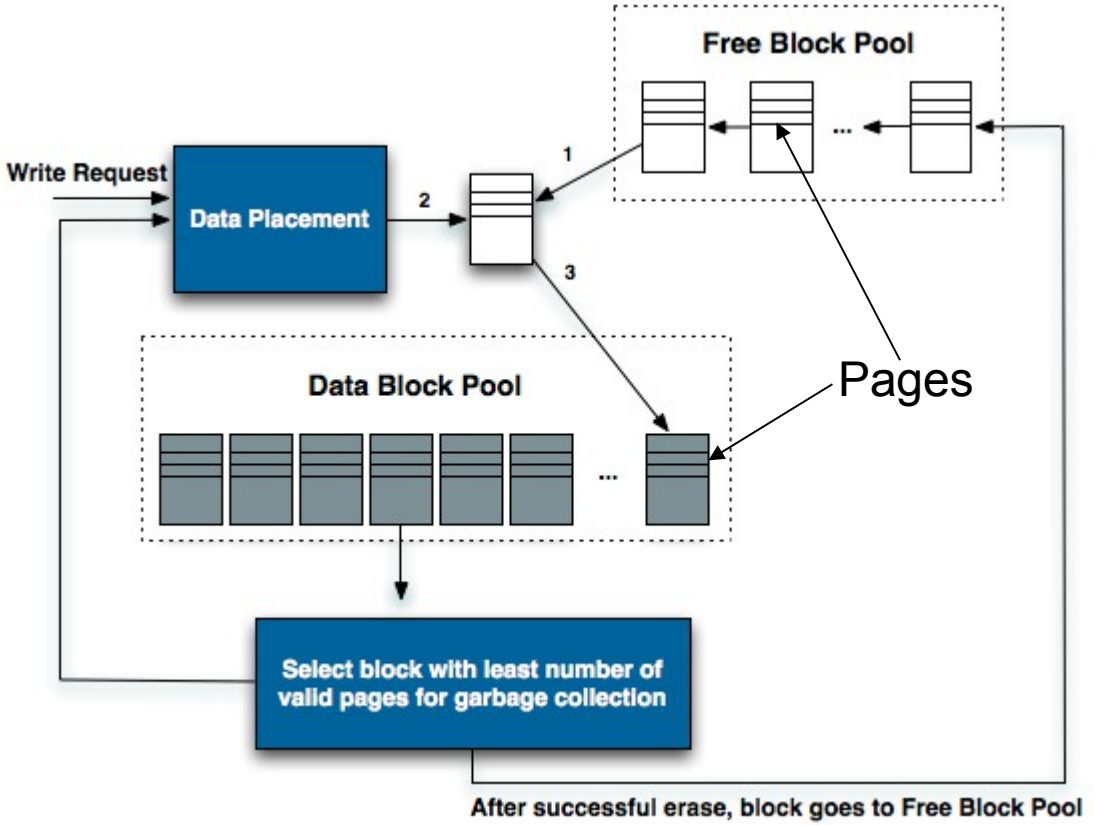




How SSD work VII

Windows* 7 ATA Data Set Management Command (TRIM)

- TRIM command (only enabled on certain OS:es)
  http://en.wikipedia.org/wiki/TRIM_(SSD_command)
- SSDs do not know if a file is deleted until it want to use that adress again
- SSDs needs to keep track of **every** bit that has been written to it
- Deleteing with the ATA-TRIM instruction attaches addresses that are to be erased with the TRIM command
- SSD can free those addresses (blocks) when it ”got time” in advance - speeding up future writes
- Sources



http://www.anandtech.com/storage/showdoc.aspx?i=3631

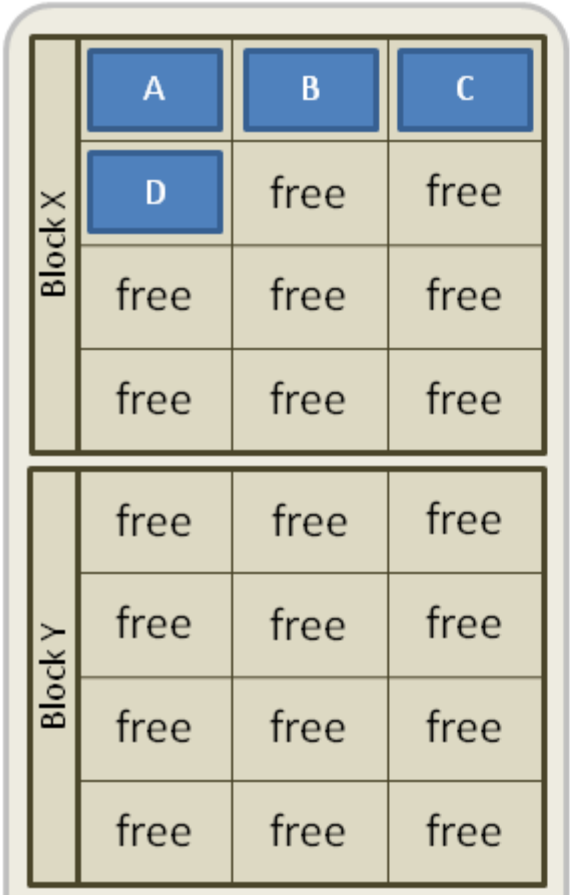
http://anandtech.com/storage/showdoc.aspx?i=3667

SSD and forensics

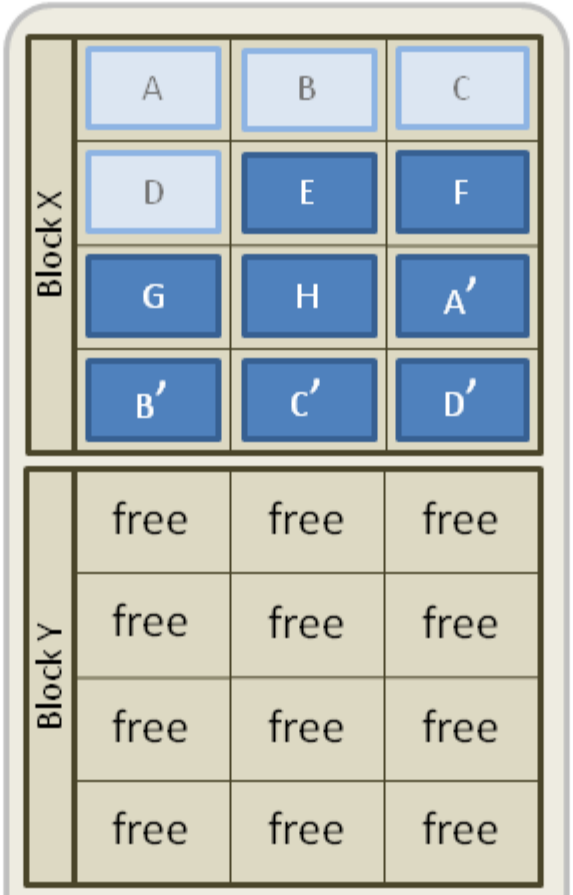
- DEFCON 16 presentation - http://www.defcon.org/
  - Data Recovery and Information about Solid State Devices and NAND Flash Memory
    - This is about two years of research about how these devices work and what will change with forensics and data recovery...
  - Solid State Drives will Ruin Forensics (5 parts)

  http://www.youtube.com/watch?v=WcO7xn0wJ2I
  - Very good view - also info about “old world” disks!
  - Summary
    - SSD is virtualized using translation drivers for “old world” disks
    - The SSD drive is intelligent (you don’t know what it does)
    - There will be less (or no) slack space and unallocated space
    - There is a lot of unknown functions and manufacturer specific stuff which need to be reverse engineered
    - Repairs is very hard to perform

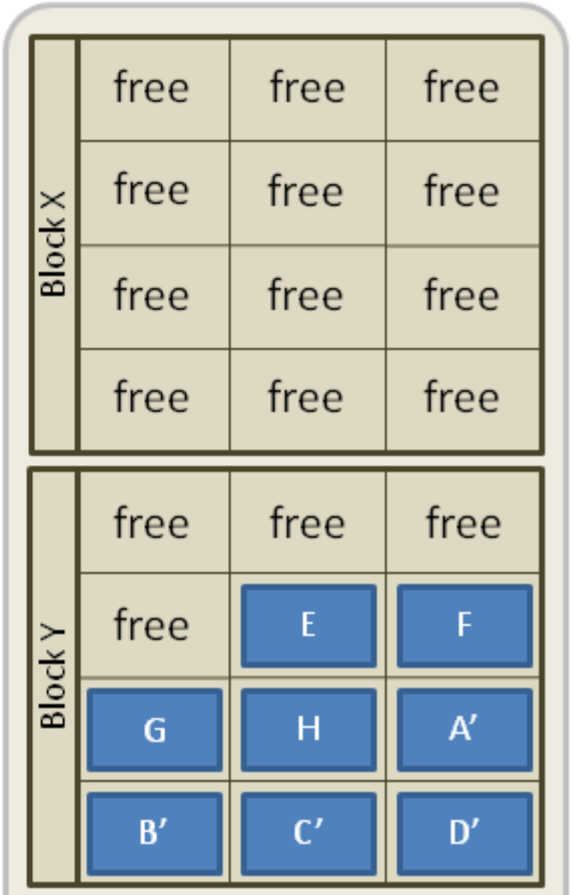
SSD reference 1 - garbage collection



1. Four pages (A-D) are written to a block (X). Individual pages can be written at any time if they are currently free (erased).



2. Four new pages (E-H) and four replacement pages (A′-D′) are written to the block (X). The original A-D pages are now invalid (stale) data, but cannot be overwritten until the whole block is erased.



3. In order to write to the pages with stale data (A-D) all good pages (E-H & A′-D′) are read and written to a new block (Y) then the old block (X) is erased. This last step is *garbage collection*.

SSD reference 2
TRIM

Works more or less as garbage collection but the NAND block is temporarily kept in a memory cache