ALBERT-LUDWIGS-
UNIVERSITÄT FREIBURG

Distributed Storage Networks and Computer Forensics

3. Solid State Disks

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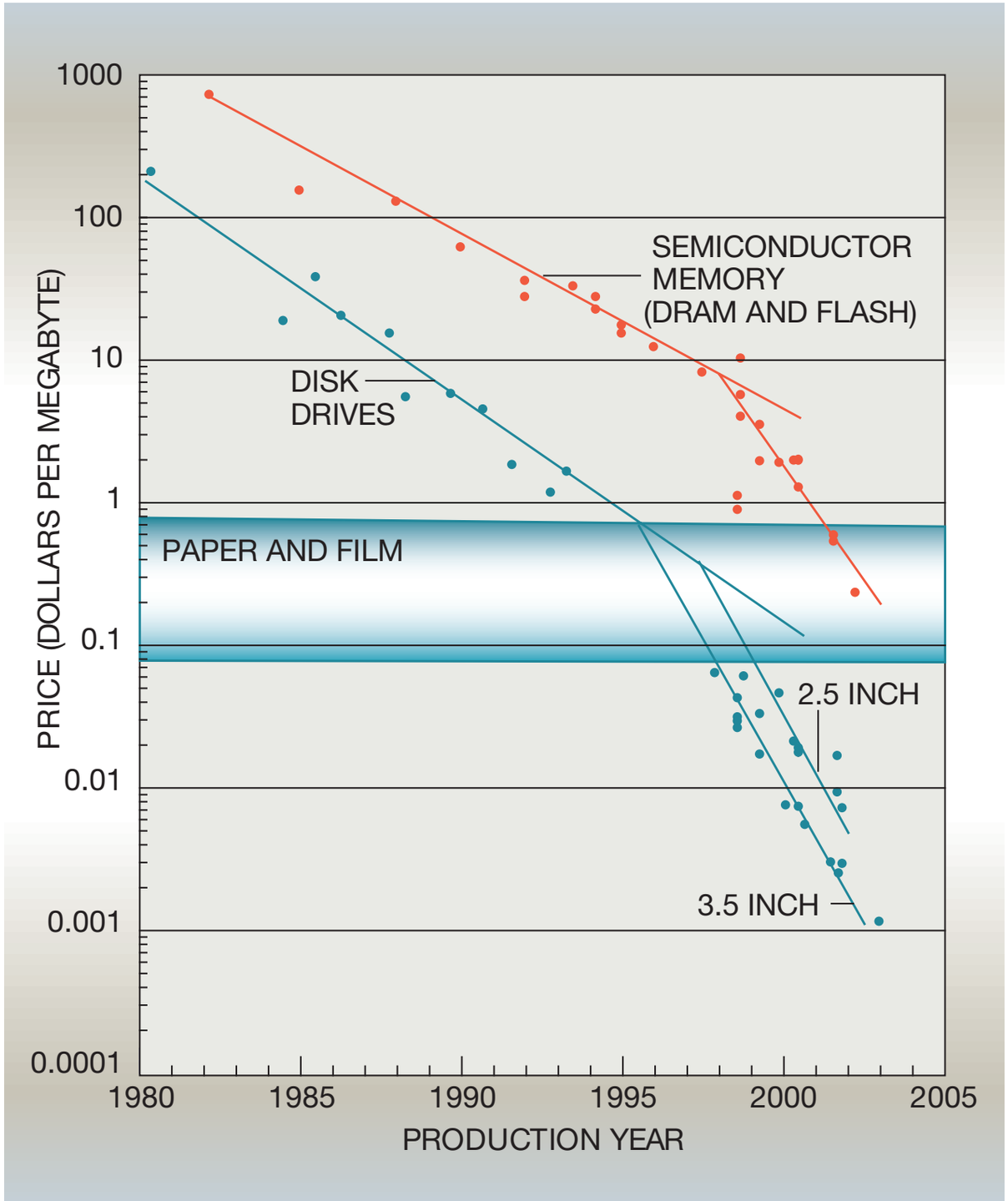
Solid State Disks

Motivation

Price Fall of RAM and Disk Storage

Figure 7 Cost of storage for disk drive, paper, film, and semiconductor memory



Technological impact of magnetic hard disk drives on storage systems, Grochowski, R. D. Halem
IBM SYSTEMS JOURNAL, VOL 42, NO 2, 2003

Price Development of Solid State Disks (SSD)

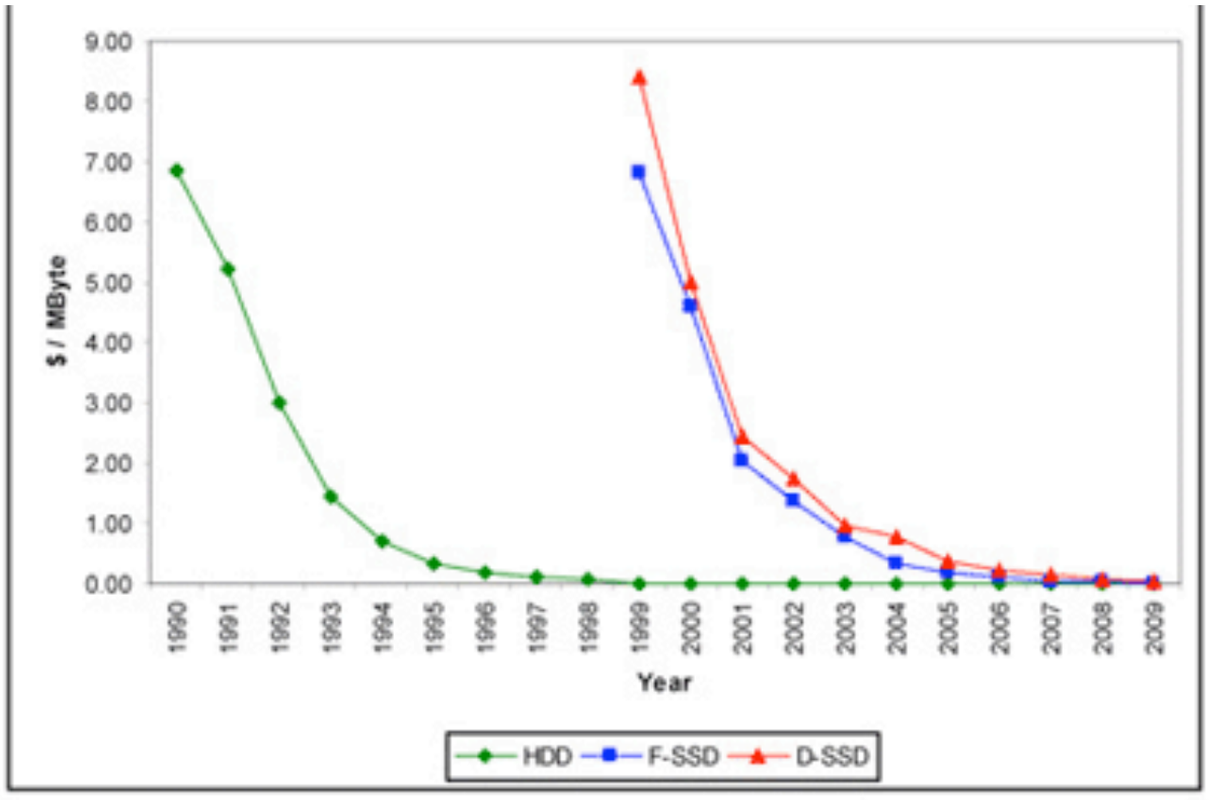
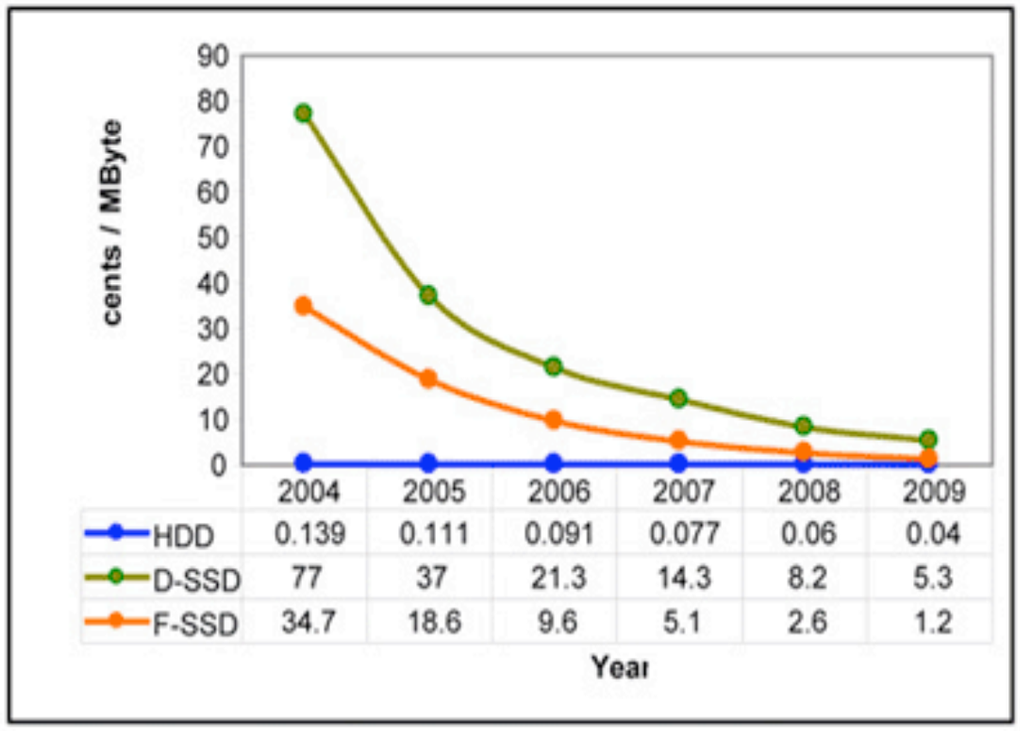


Figure A: 2.5-inch and 3.5-inch Flash-SSD, $ / Mbyte
Source: Web-Feet Research



	2004	2005	2006	2007	2008	2009
HDD	0.139	0.111	0.091	0.077	0.06	0.04
D-SSD	77	37	21.3	14.3	8.2	5.3
F-SSD	34.7	18.6	9.6	5.1	2.6	1.2

Figure B: HDD and SSD Storage Price Trend (2004-2009), cents / MByte
Source: Web-Feet Research

http://www.embeddedstar.com/articles/2005/2/article20050207-3.html

Speed Development of Solid State Drive (SSD)

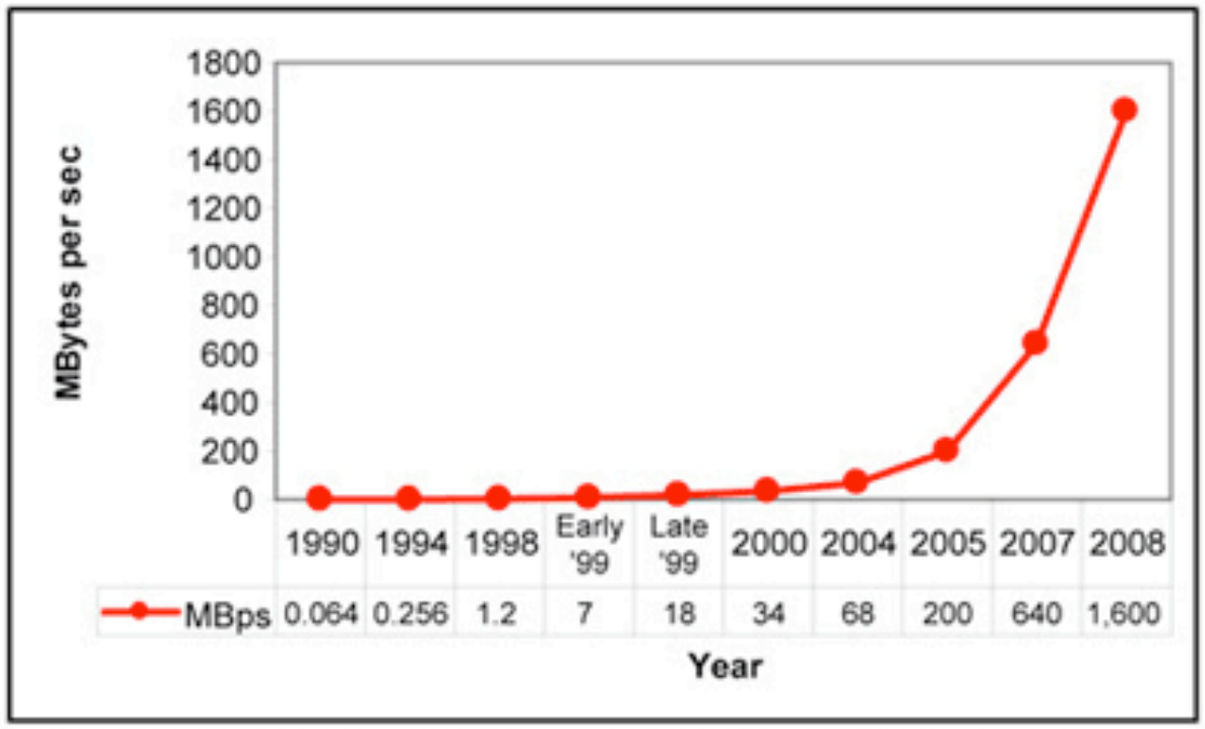


Figure C: 3.5-inch Flash-SSD Sustained Random Read/Write Rates Trend

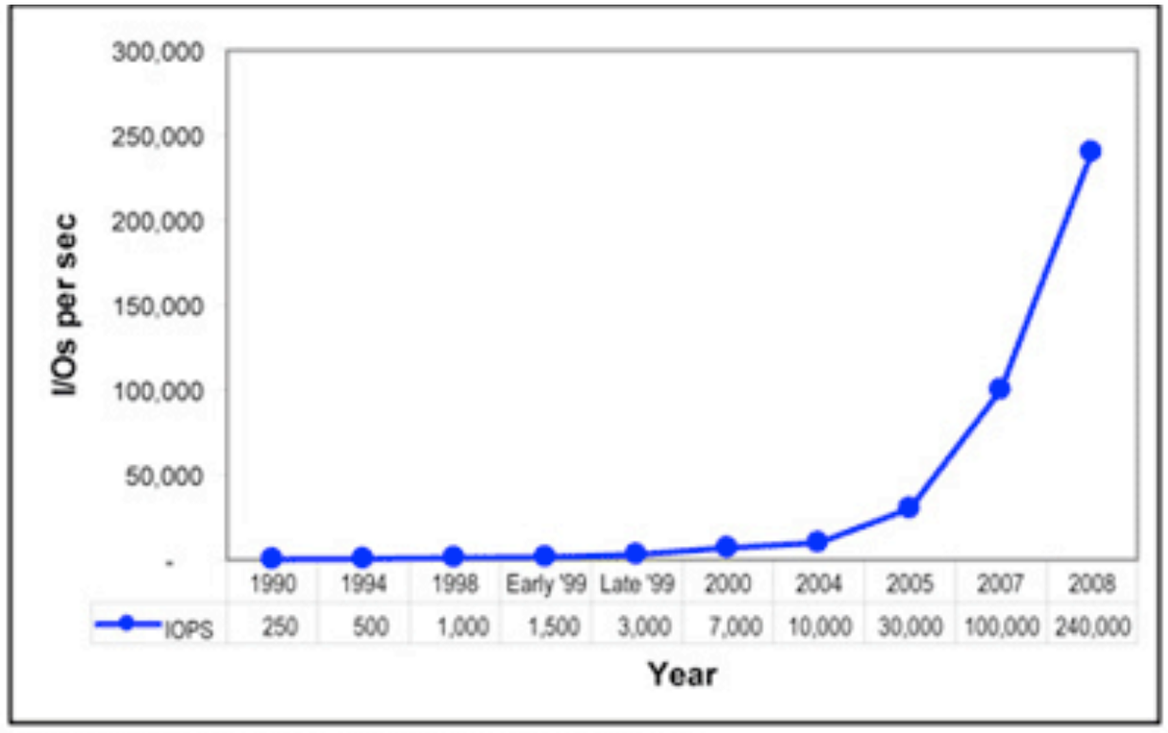


Figure D: 3.5-inch Flash-SSD Random IOPS Trend

http://www.embeddedstar.com/articles/2005/2/article20050207-4.html

Non-Volatile RAM

- **EEPROM**
  - EPROM
  - non-flash EEPROM
  - Flash memory
- **Battery powered RAM**
  - **SRAM**
  - **DRAM**

Solid State Disks

RAM

Battery Powered RAM

- **Combination of DRAM or SRAM with external energy source**
  - DRAM = dynamic random access memory
    - memory needs to be refreshed
    - fast, small, energy-consuming
    - DDR-SDRAM (Double Data Rate Synchronous Dynamic Random Access Memory)
  - SRAM = static random access memory
    - memory needs continuous power supply
    - slower, still energy-consuming
- **Usage**
  - RAM Disks
- **Advantages**
  - high speed
  - direct addressing
  - long lifetime of memory
- **Disadvantages**
  - more expensive than hard disks
  - lifetime restricted by battery size
- **Hybrid hard disks**
  - combine large RAM with hard disk as Cache memory
  - when hard disk is shutdown RAM memory is saved to the disk
- **Hybrid flash memory**
  - DRAM used as a Cache for Flash memory
  - RAM is 80 times faster than Flash memory

Solid State Disks

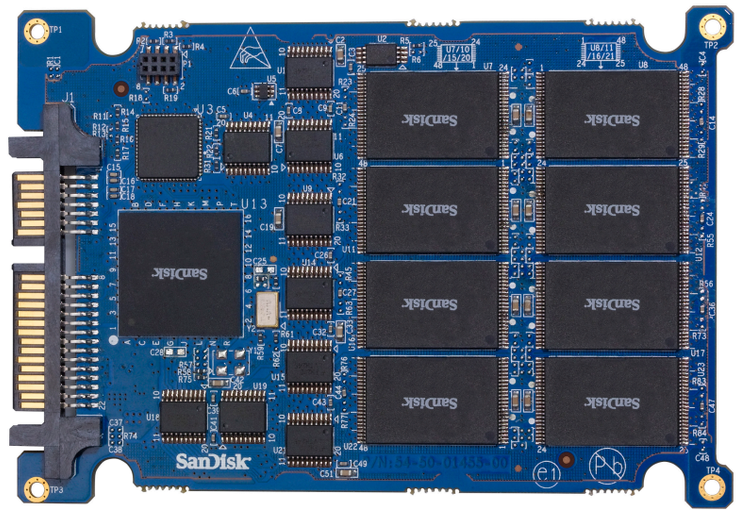
Flash

E*PROM

- **PROM (Programmable Read-Only Memory)**
  - can be programmed only once
  - „blowing fuses“ using extra high power when programming
- **EPROM (Erasable PROM)**
  - can be reprogrammed by exposing it to ultraviolet light
- **EEPROM (Electrically EPROM)**
  - non-volatile memory
  - Categories: Flash and Non-flash memory
    - difference: addressing for erasure
    - Non-flash erases units
    - Flash erases full blocks

Flash Memory

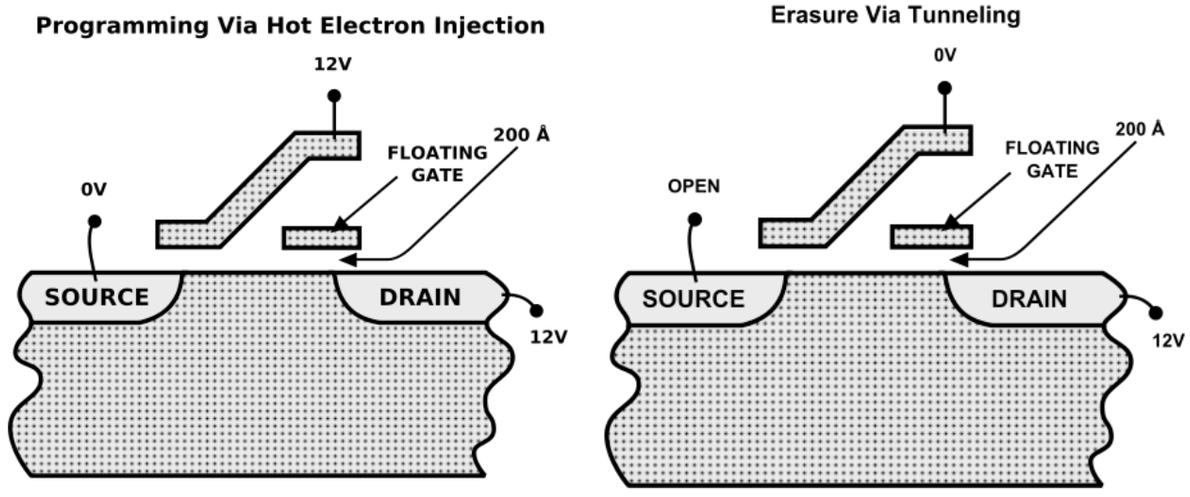
- **Special form of EEPROM**
  - Random access
  - Fast access times
    - faster than hard disk, slower than SRAM
  - Block-wise erasure
- **Invented 1980 at Toshiba**
- **Types**
  - NOR
    - long erase and write times
    - random access
    - last 10^4-10^6 erase cycles
    - used as replacement for ROM
    - Originally CompactFlash was based on NOR-Flash
  - NAND
    - faster erase and write times
    - block-wise read access
    - used as secondary storage
      - solid state disk
    - used as portable memory
      - Memory cards, USB flash drives,



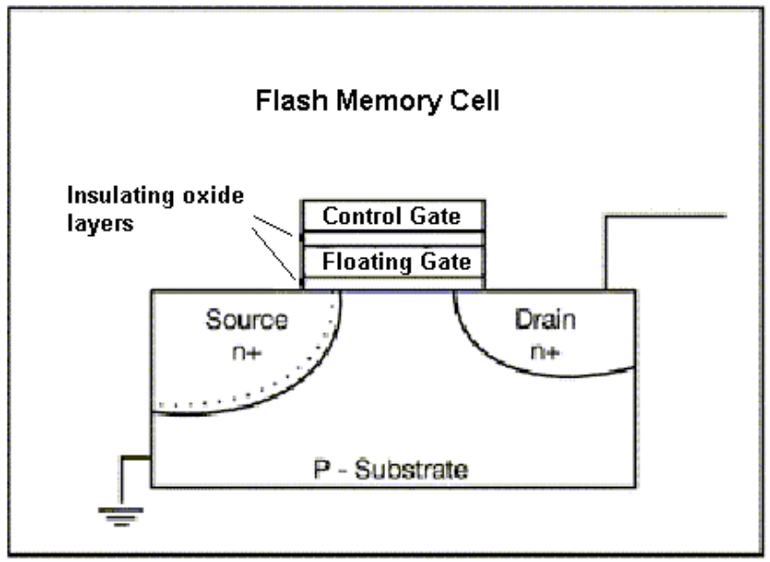
(c) SanDisk

Nor Flash Memory Cell

- **A memory cell is a transistor**
  - with an insulated floating gate (trapping electrons)
- **Reading**
  - If floating gate is charged then the threshold voltage is modified
- **Programming/Erasure**
  - Apply elevated voltage
  - Electrons jump through the insulated layer by quantum tunneling
- **Memory wear**
  - After some 100,000 cycles the floating gate cannot be erased



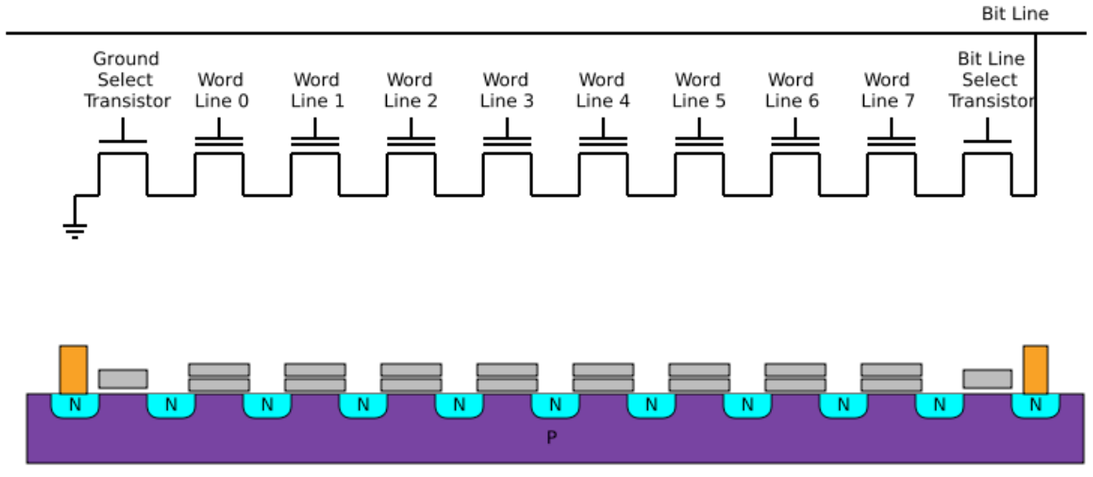
http://en.wikipedia.org/wiki/NOR_flash



http://www.lascon.co.uk/dh00300.htm

Solid State Disk Architectrue

- **NAND Flash**
  - address blocks for read and write access
    - block size 16KB-512 KB
  - Erase block sets all bits to 1
  - Successive writes can add 0s to each block



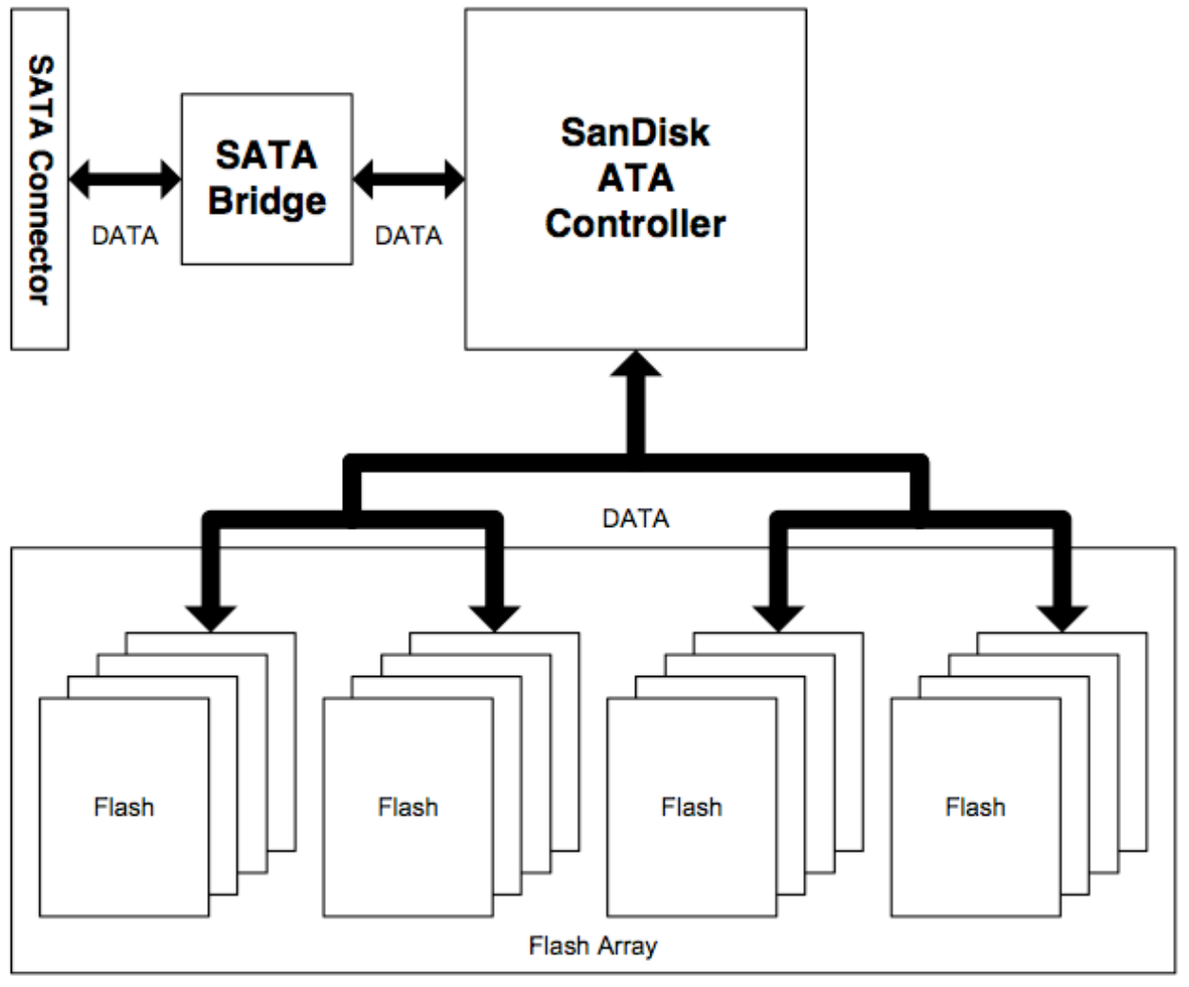
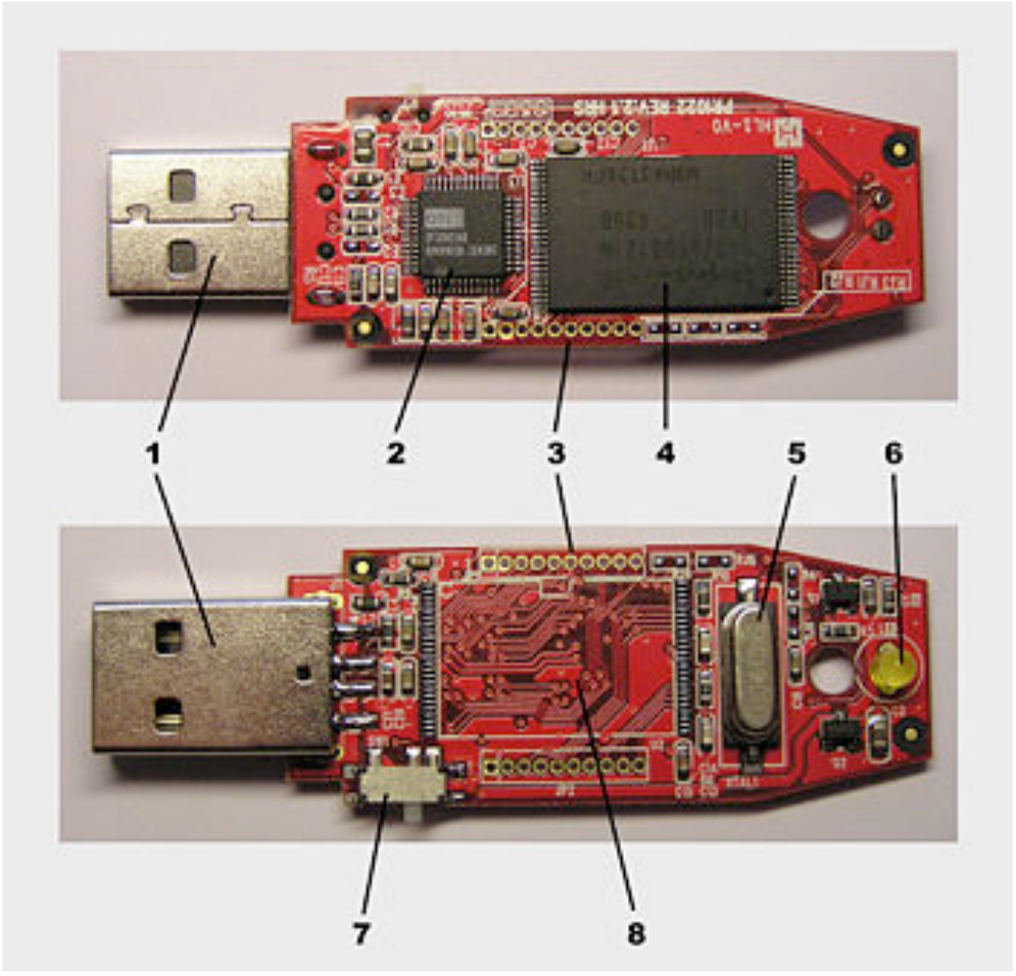


Figure 1: SanDisk SSD SATA 5000 2.5" Block Diagram

http://www.sandisk.com/Assets/File/pdf/industrial/SanDisk_SSD_SATA_5000_2.5_DS_Rev0.2.pdf

USB flash drive

- **NAND flash memory with USB interface**
- **File system**
  - most flash drives FAT or FAT 32



1 USB connector
2 USB mass storage controller device
3 Test points
4 Flash memory chip
5 Crystal oscillator
6 LED
7 Write-protect switch
8 Space for second flash memory chip

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

Wear Levelling

- **Techniques to prolong the lifetime of flash storage**
  - Error-correcting codes
  - Pool of reserve spaces to redirect read/writes after failure
  - Blocks are tracked in a least recently used queue
    - microcontroller
    - minimizes the number of uses of each block
  - Copy-on-write
    - mark memory and copy it if the write actually occurs
- **Special purpose file systems supporting it**
  - JFFS (Journalling Flash File System Version 2)
  - YAFFS (Yet Another Flash File System)

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