Disk and New Storage Devices

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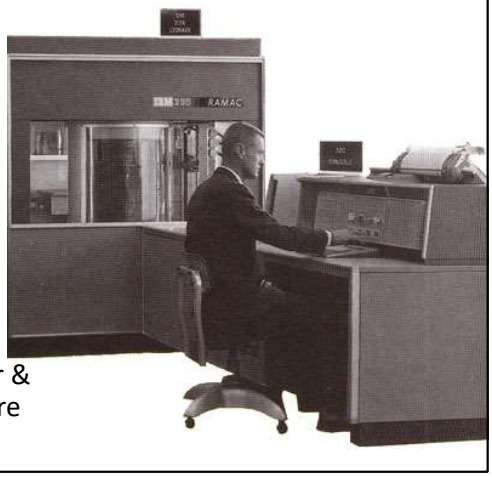
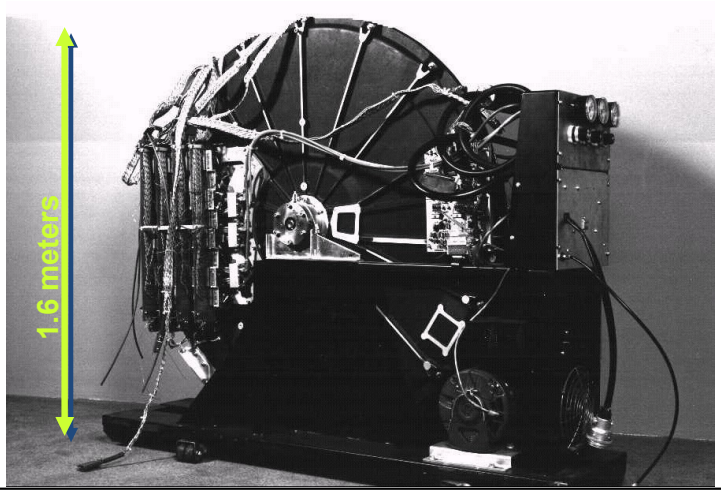
The first HDD (1956)

- IBM 305 RAMAC
- 4 MB
- 50x24” disks
- 1200 rpm
- 100 ms access
- 35k$/y rent
- Included computer & accounting software
  (tubes not transistors)



10 years later

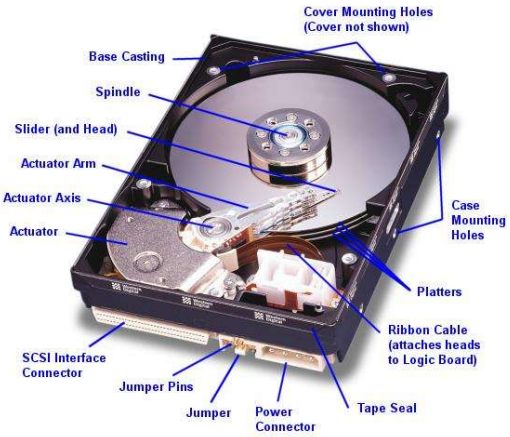


Transportation of HDD

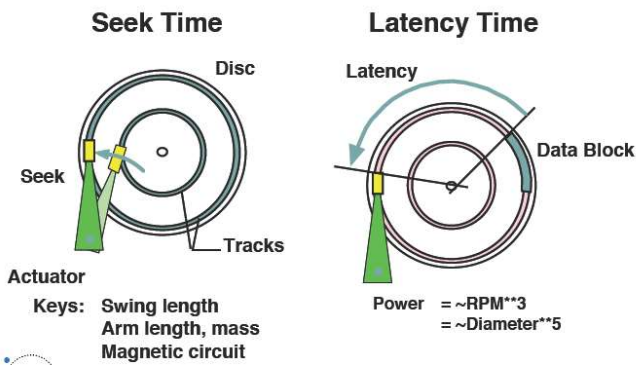
1 inch disk drive!

- 2000 IBM MicroDrive:
  - 1.7” x 1.4” x 0.2”
  - 1 GB, 3600 RPM, 5 MB/s, 15 ms seek
  - Digital camera, PalmPC?
- 2006 MicroDrive
  - 8 GB, 50 MB/s!

The internal look of HDD (now)



Data access of HDD



Access Time = Seek Time + Rotational Delay + Transfer Time

Redundant Array of Inexpensive Disks (RAID): 1987-1993

The RAID paper

- D. A. Patterson, G. Gibson, and R. H. Katz, "*A case for redundant arrays of inexpensive disks (RAID)*," in SIGMOD'88 Proceedings of the 1988 ACM SIGMOD International Conference on Management of Data, 1988, vol. 17, no. 3, pp. 109-116.

https://www.cs.cmu.edu › RAIDpaper › Patterson88 PDF

A Case for Redundant Arrays of Inexpensive Disks (RAID)

by DA Patterson · Cited by 4490 — 1 Background: Rlsrng CPU and Memory Performance. The users of computers are currently enJoymg unprecedented growth m the speed of computers…

8 pages

- One of the important publications in computer science. http://en.wikipedia.org/wiki/List_of_important_publications_in_computer_science
- EMC, HP, IBM, NetApp… have produced so many RAID-related storage products.

Better Storage?

- Capacity?
- Performance?
- Availability?
- ……

RAID Levels

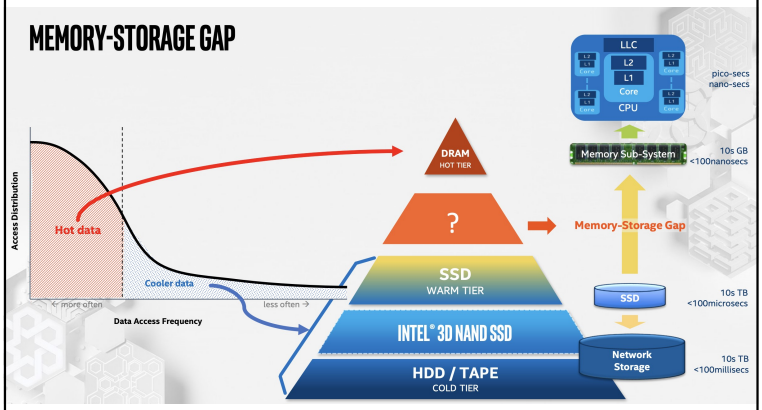
RAID	Min Disks	Storage Efficiency %	Cost	Read Performance	Write Performance
0	2	100	Low	Very good	Very good
1	2	50	High	Better than a single disk	Slower than a single disk
4	3	(n-1)*100/n	Moderate	Good for reads	Poor for small random writes
5	3	(n-1)*100/n	Moderate	Good for reads	Poor for small random writes
6	4	(n-2)*100/n	Moderate	Good for reads	Poor for small random writes

课堂练习（姓名+学号）

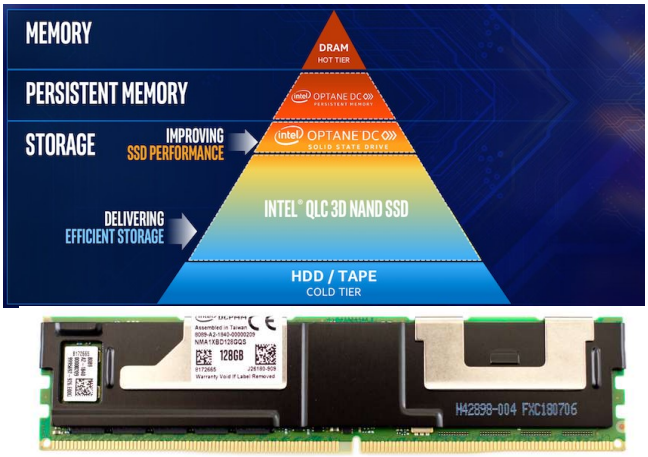
假设每个磁盘的容量为10GB，根据RAID技术的相关知识填表：

级别	盘个数	容量（GB）	存储效率
RAID0		60	100%
RAID1	8		50%
RAID5	8	70	
RAID6	6		66.7%

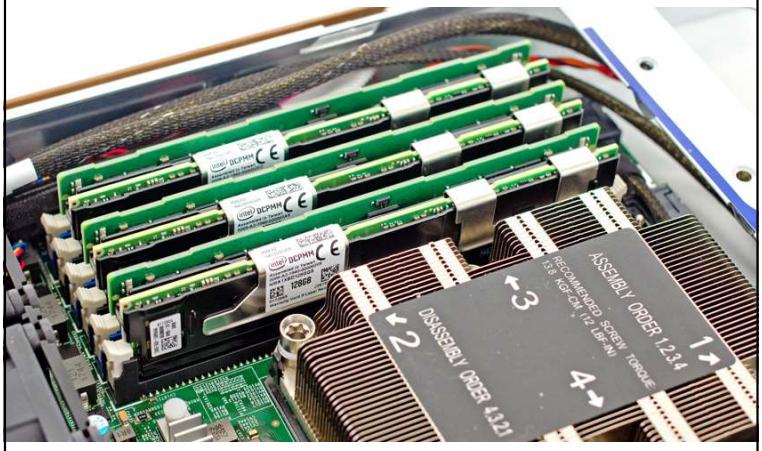
Storage Hierarchy



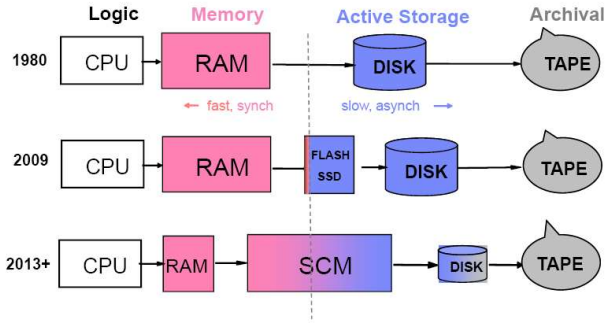
Storage Hierarchy



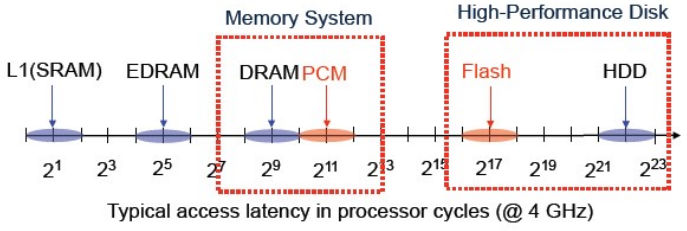
Intel Optane PM



New Storage Devices



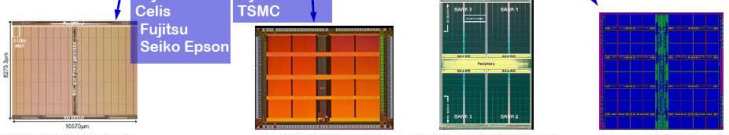
New Storage Devices



Emerging Memory Technologies

Memory technology remains an active focus area for the industry

FLASH Extension	FRAM	MRAM	PCRAM	RRAM	Solid Electrolyte	Polymer/ Organic
Trap Storage Saifun *NROM* Tower Spansion Infineon Macronix Samsung Toshiba Spansion Macronix NEC Nano-x³tal Freescale Matsushita	Ramtron Fujitsu STMicro TI Toshiba Infineon Samsung NEC Hitachi Rohm HP Cypress Matsushita Oki Hynix Celis Fujitsu Seiko Epson	IBM Infineon Freescale Philips STMicro HP NVE Honeywel Toshiba NEC Sony Fujitsu Renesas Samsung Hynix TSMC	Ovonyx BAE Intel STMicro Samsung Elpida IBM Macronix Infineon Hitachi Philips	IBM Sharp Unity Spansion Samsung	Axon Infineon	Spansion Samsung TFE MEC Zettacore Roltronics Nanolayer



64Mb FRAM (Prototype)
0.13um 3.3V

4Mb MRAM (Product)
0.18um 3.3V

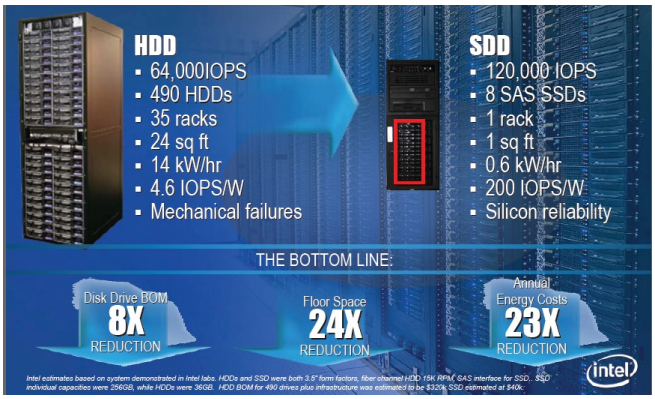
512Mb PRAM (Prototype)
0.1um 1.8V

4Mb C-RAM (Product)
0.25um 3.3V

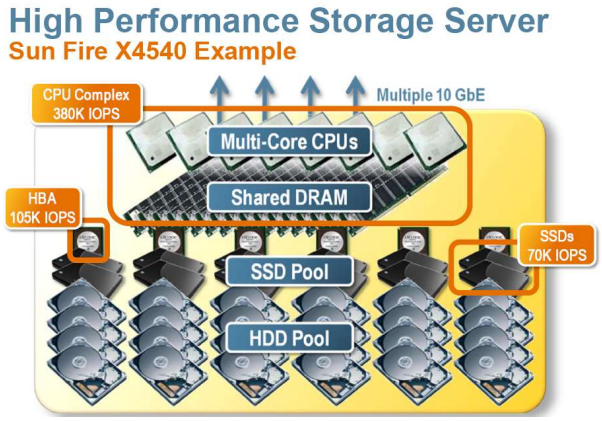
New Storage Devices

	SRAM	DRAM	Flash (NOR)	Flash (NAND)	FeRAM	MRAM	PRAM	RRAM	STT-RAM
Non-volatile	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cell size (F^2)	50–120	6–10	10	5	15–34	16–40	6–12	6–10	6–20
Read time (ns)	1–100	30	10	50	20–80	3–20	20–50	10–50	2–20
Write / Erase time (ns)	1–100	15	1 µs / 10 ms	1 ms / 0.1 ms	50 / 50	3–20	50 / 120	10–50	2–20
Endurance	10^{16}	10^{16}	10^5	10^5	10^{12}	$>10^{15}$	10^8	10^8	$>10^{15}$
Write power	Low	Low	Very high	Very high	Low	High	Low	Low	Low
Other power consumption	Current leakage	Refresh current	None	None	None	None	None	None	None
High voltage required	No	3 V	6–8 V	16–20 V	2–3 V	3 V	1.5–3 V	1.5–3 V	<1.5 V
	Existing products						*Prototype*		

New Storage Devices



New Storage Devices



Performance Comparison

Table 1: Comparison among SRAM, DRAM, Flash, and PCRAM

	SRAM	DRAM	NAND Flash	PCRAM
Cell size	$> 100F^2$	$6 - 8F^2$	$4 - 6F^2$	$4 - 20F^2$
Read time	$\sim 10ns$	$\sim 10ns$	$5\mu s - 50\mu s$	$10ns - 100ns$
Write time	$\sim 10ns$	$\sim 10ns$	$2 - 3ms$	$100 - 1000ns$
Standby power	leakage	leakage & refresh	zero	zero
Write endurance	10^{18}	10^{15}	10^5	$10^8 - 10^{12}$
Non-volatility	No	No	Yes	Yes