COL216
Computer Architecture

Input/Output – 5

Secondary Storage

28th March 2022

Hard Disk Drive Example

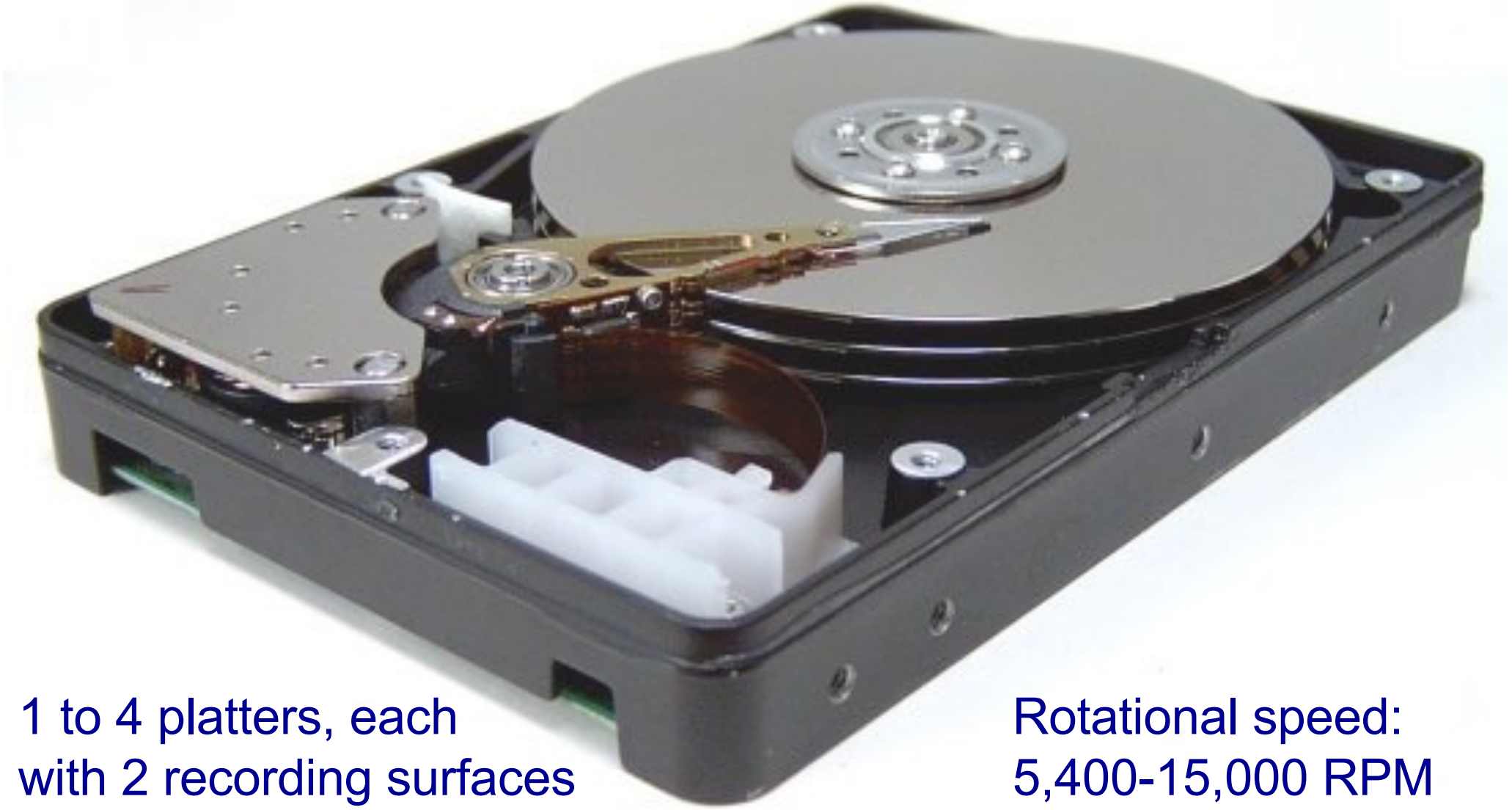
Capacity:	14TB
Size:	3.5”
RPM:	7200
Data rate:	250 MB/s
Disks:	8 (16 heads)
Sector:	512B (logical)
	4096B (physical)
Density:	2426 Kb/in
	436 Ktracks/in
Cache:	256 MB

HDD comparison – then and now

Parameter	1957	2018-20	Improvement
Capacity	3.75 MB	18 TB	4.8×10^6
Volume	1.9 m^3	34 cm^3	5.6×10^4
Weight	910 kg	62 g	1.5×10^4
Access Time	600 ms	2.5 – 10 ms	2×10^2
Price	USD 9.2 / KB	USD 24 / TB	3×10^6
Density	2K b / in^2	1.3 TB / in^2	6.5×10^8
MTBF	2000 hrs	285 yrs	1.25×10^3

Source: Wikipedia

Hard Disk Drive



1 to 4 platters, each
with 2 recording surfaces

Rotational speed:
5,400-15,000 RPM

https://www.pctechguide.com/wp-content/uploads/2011/09/31harddrive.jpg

Hard disk drive close-up

Tracks:
10-50 K
Sector/track
100-500
Bytes/sector
512
Seek time:

- Track to track
  .5-2 ms
- Average
  ~10 ms

Disk Latency

Disk Latency =

Seek time + Rotational Latency + data transfer time + controller overhead

Average rotational latency =

time for ½ rotation =

(.5 x 60 x 1000 / rpm) msec

Transfer rate = 10^1 – 10^2 MB/sec

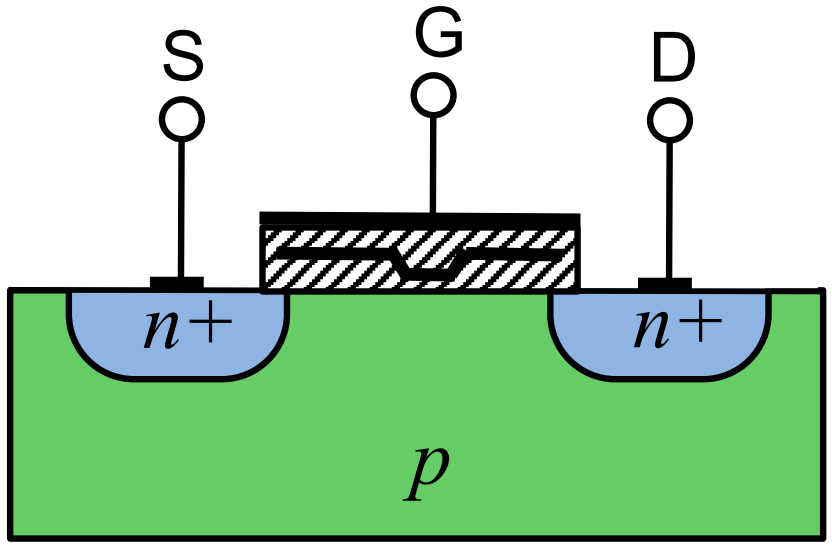
Bulk storage without moving parts

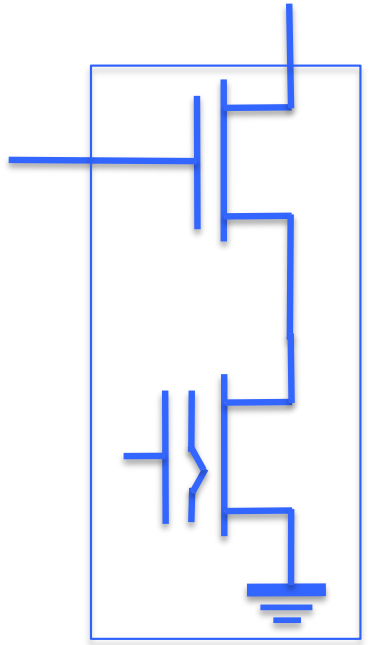
- Flash: semiconductor memory like SRAM, DRAM, but non-volatile like magnetic disks
- Latency is 100–1000 times less than disk
- Smaller, lighter, more power efficient, and more shock resistant than disk
- Has caught up with HDD in capacity, but more expensive
- SSD wears out faster than HDD

Flash Memory

- Semiconductor memory made up of “Floating gate” transistors – these store information in a non-volatile manner
- Reading is fast, but writing is slow as it requires large current
- Writing involves one way state change (e.g. 0 to 1), therefore needs erasing first (make all bits 0 first)
- Block erase, unlike byte erase of EEPROM

Floating gate transistor





Programming: pass high current through channel
Electrons are trapped on the floating gate

Before trapping: like a normal NMOS transistor
After trapping: transistor remains OFF

NOR and NAND flash

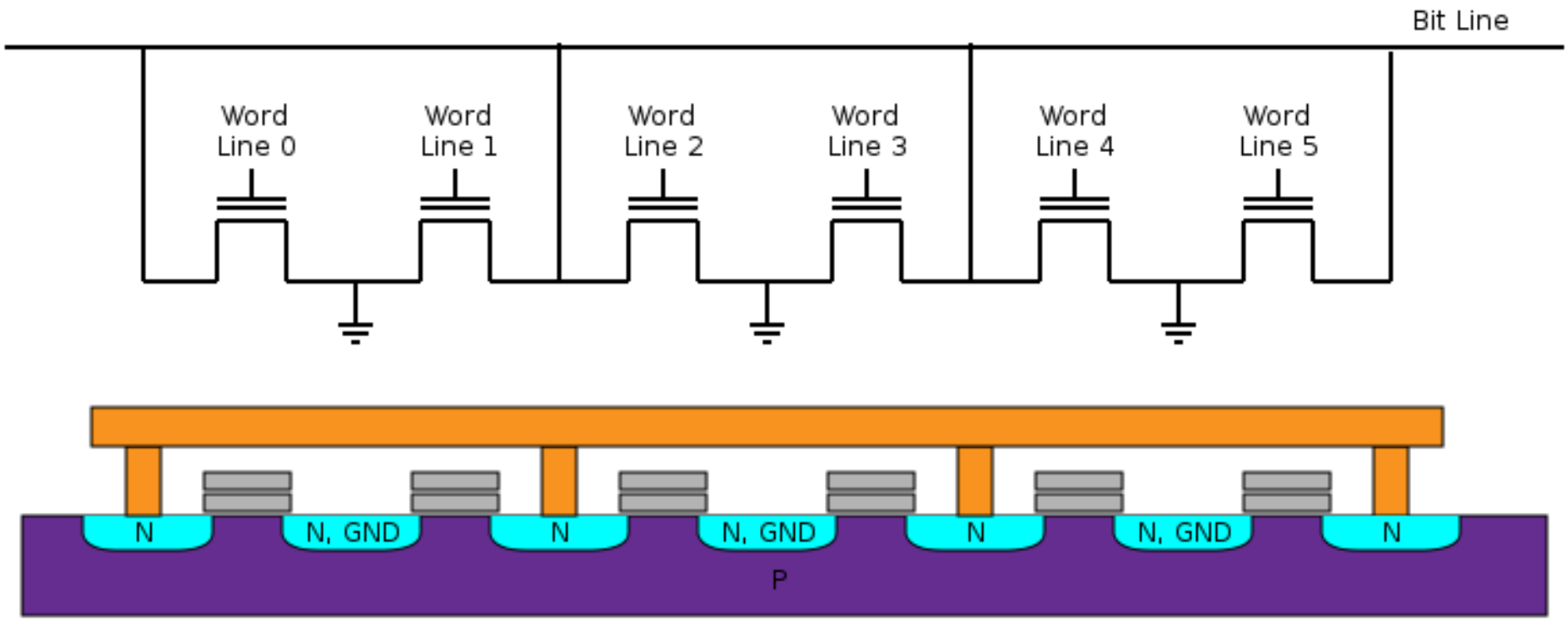
NOR flash

- Structure like NOR gate
- Random access
- Lower density
- More expensive
- Used for BIOS memory

NAND flash

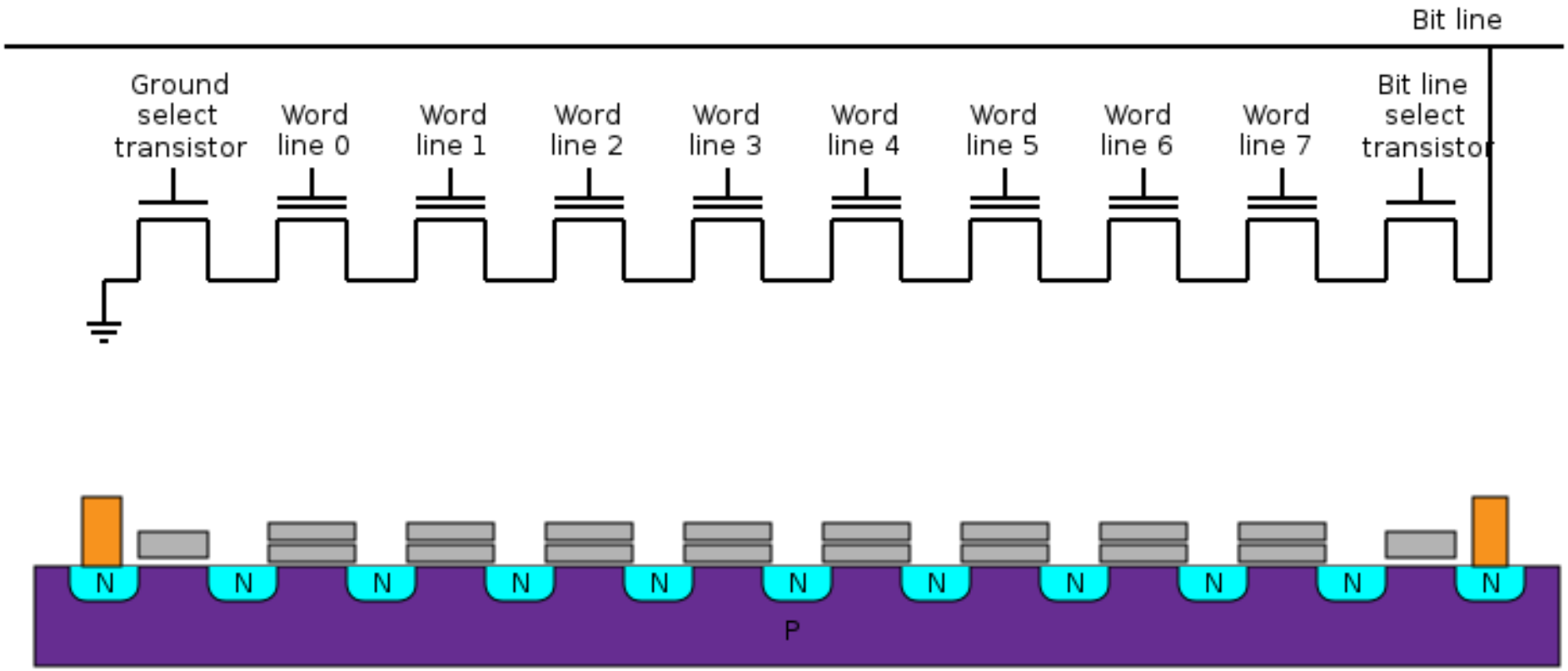
- Structure like NAND gate
- Random plus sequential access
- Higher density
- Less expensive
- Used for pen drive, SD card, SSD
- 32 Mb on BASYS 3

NOR Flash



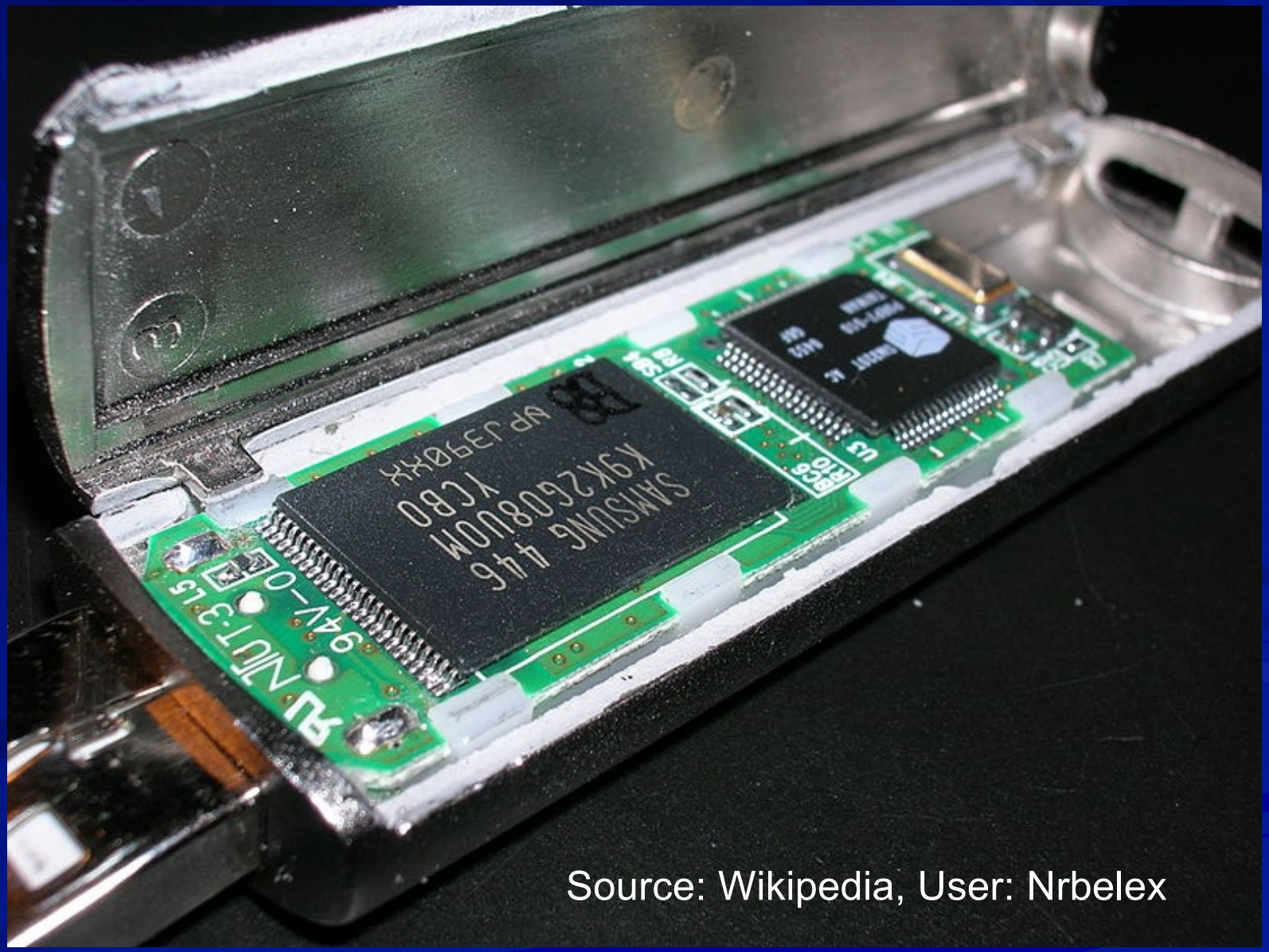
Source: Wikipedia, Author: Cyferz

NAND Flash



Source: Wikipedia, Author: Cyferz

A USB Flash Drive



Source: Wikipedia, User: Nrbelex