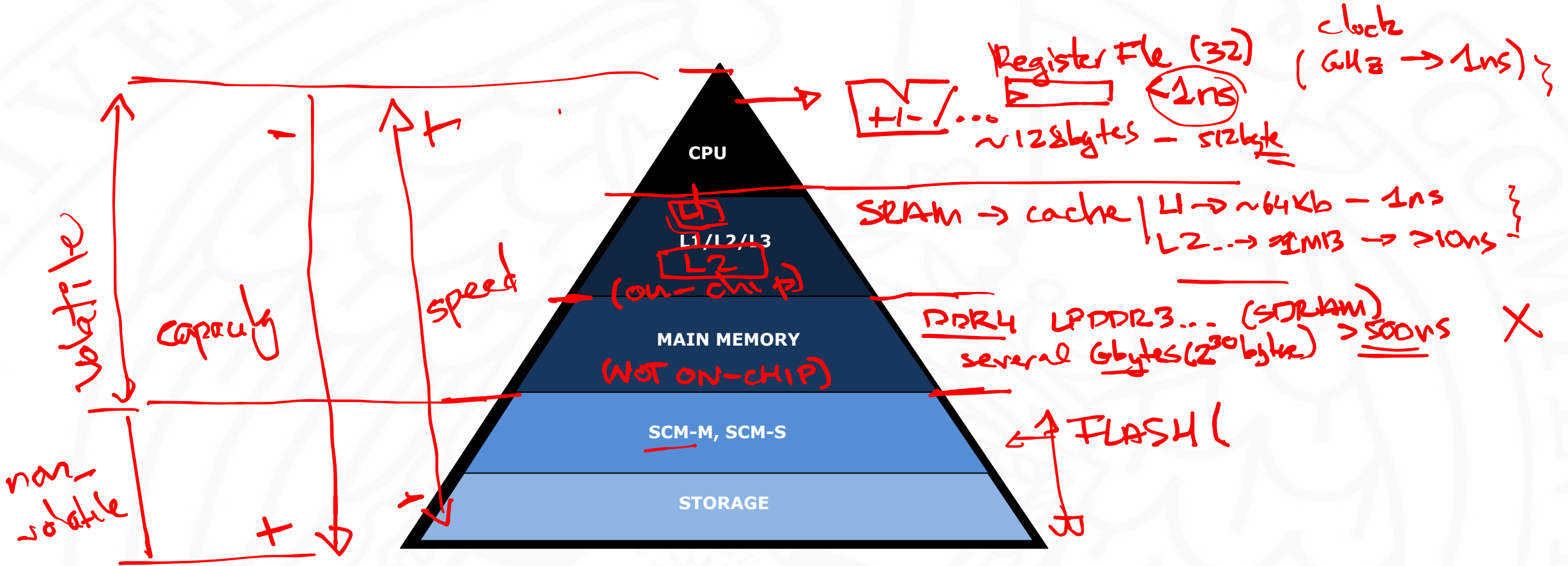




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MADRID

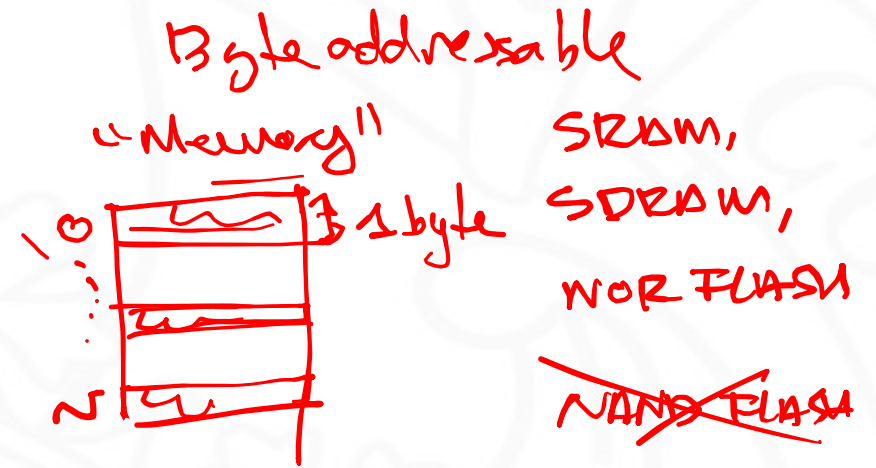
Memory and storage

Memory Hierarchy



NOR FLASH

- ❑ Slow writes/erase
 - "Fast" ~~writes~~ ~~en~~ ~~lecturas~~ read (ms)
 - Very slow writes
- ❑ Very reliable (ROM → NOR FLASH)
- ❑ Flexible addressing
 - Random
 - Byte level
- ❑ Good for code storage (instructions)
 - Boot, application, OS...
- ❑ Serial and parallel interfaces (SPI)

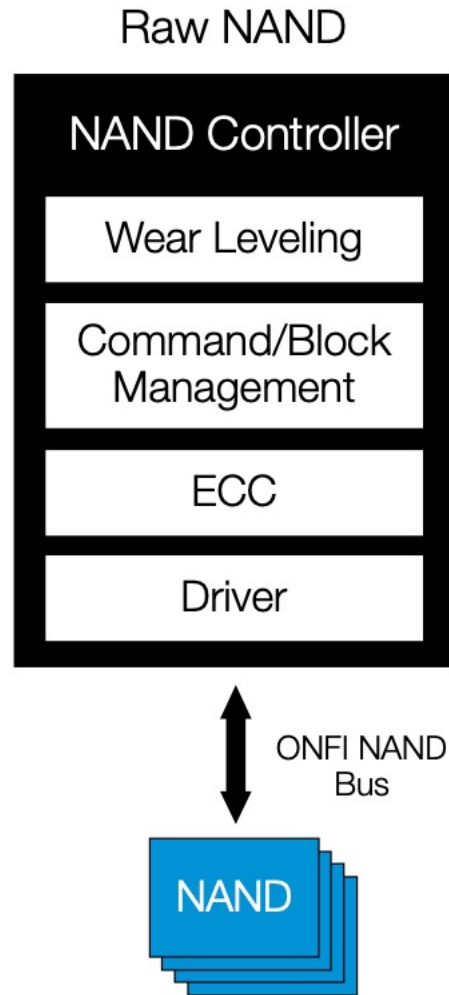


- ❑ Denser than NOR Flash
 - Less area per bit
- ❑ Used to store data
 - NON random access provide. Block wise (*≈ 512 bytes per word*)
 - Writes and erase operations faster than NOR flash
 - But write operations use to include erase a whole block. Page level writing (Block > page)
- ❑ Many research to decrease cost/GB
 - Less lifetime: finite number of program/erase cycles per block
- ❑ Needs a controller
 - External or internal
 - Error Code Correction (ECC), manage damage blocks, wear leveling (*trying to use blocks equally*)
- ❑ Density alternatives
 - SLC - MLC - TLC - QLC *bits per cell* → good balance performance / density
 - 3D TLC / 3D QLC are the most competitive

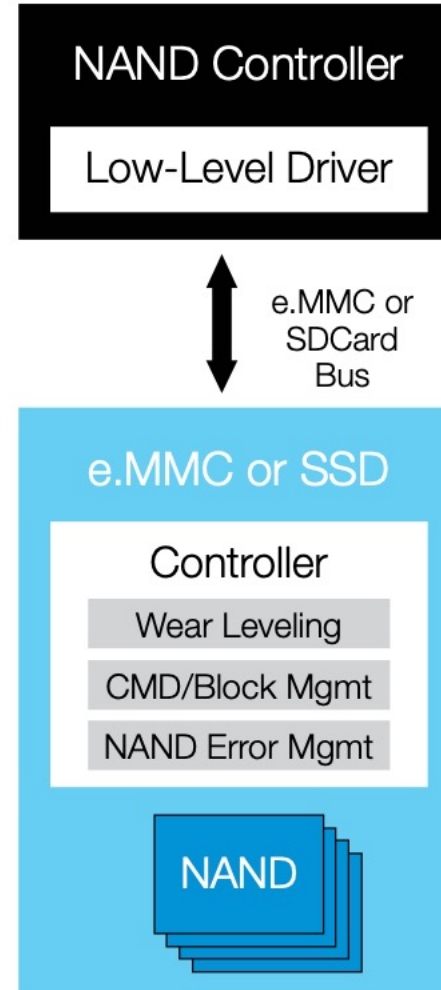
Raw vs managed NAND Flash

Raw NAND

- Less cost per bit
- It requires external controller



Fully Managed NAND



Managed

- Simple, less development time
- Several interfaces
 - eMMC
 - On-die ECC NAND → *GP32*
 - Solid State Drives (SDDs)
 - SD / microSD cards

NAND Relative Attributes

Device	<u>(lifetime)</u> Endurance	ECC Compatibility	Performance	Price/GB	Interface Complexity
SLC NAND	•••••	•	•••••	\$\$\$\$	••
Serial (SPI) NAND <i>ESP-32</i>	•••••	•	•••••	\$\$\$\$	•
Enterprise NAND – MLC ¹	•••	•••••	•	\$\$\$	•••••
MLC NAND	•••	••	•••	\$\$\$	•••
TLC NAND	•	•••	•	\$	•••
QLC NAND		•••		\$	•••
MCPs – NAND with LPDRAM	•••	•	•••	\$\$\$	••
e.MMC/UFS	••	None	••	\$\$	•
eMCP – e.MMC with LPDRAM	••	None	••	\$\$\$	•
Embedded USB (eUSB)	•••••	None ²	•••	\$\$\$\$	•
SSD	•••••	None	•••	\$\$\$\$	•
SD and microSD cards	••	None	••	\$	•

Fuente: <https://www.micron.com/products/nand-flash/choosing-the-right-nand>