A Bit of History

- My first computer was an Ohio Superboard II imported from USA in 1978.
- It had 4kB of RAM which I upgraded to 8kB.
- It had no case, no monitor, no power supply.
- It had no disk drive, programs and data were stored on an audio cassette tape.
- A modified TV was used as a monitor.

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- In 1980, the year before the IBM PC first appeared, I moved up to a Hitachi Peach.
- It came in a case, with power supply, and I got my first monitor.
- It had 32kB of memory which I expanded to 48kB.
- It started with the tape storage but I later added twin 5¼” floppy drives, 320kB each!

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- Next came my first IBM clone, in 1986.
- It had a huge memory of 640kB.
- Storage was still floppy drives but I added my first hard drive a couple of years later, a whopping 10MB!
- In less than 40 years internal computer memory has increased from kilobytes to gigabytes and storage capacity has increased from megabytes to terabytes.
- A book will typically have about 2,500 characters on a page so a 200 page book will need about half a megabyte of storage.
- A 1 terabyte hard drive can store 2 million such books.

Computer Memory

- Computer memory is of two kinds:
  - Volatile – only retained while there is power, commonly referred to as RAM.
  - Non-volatile – retains without power.
- NV memory can be tape, disk, ROM, or flash.
- Floppy drives use plastic disks with a magnetic coating, basically the same technology as audio tapes and cassettes.
- Hard drives use metal disks with a magnetic coating.
- Hard drives started with the same form factors as floppy drives, ie 5¼" and 3½", then went to smaller sizes to suit laptops.
- Flash memory evolved in various forms to suit different applications; e.g. Compact Flash, USB, SD, xD for computers, cameras and phones.

Solid State Drives

- Solid state drives are basically a variation of flash memory intended as replacements for rotating disk hard drives in computers.
- Early versions used the same interface connections as hard drives but new standards have emerged, such as the ’M2’ interface which is becoming a common feature on motherboards.
- There are also SSD cards which plug into the expansion slots on motherboard in the same way as video cards.

- Compared with the electromechanical drives, SSDs are typically more resistant to physical shock, run silently, and have faster access time and lower latency.
- SSDs store data by electrical charge in semiconductor cells. As of 2019, cells can contain between 1 and 4 bits of data.
- SSD storage devices vary in their properties according to the number of bits stored in each cell, with single-bit cells ("SLC") being generally the most reliable, durable, fast, and expensive type.
- 2- and 3-bit cells ("MLC" and "TLC"), and finally quad-bit cells ("QLC") being used for consumer devices that do not require such extreme properties, are the cheapest of the four.
- 3D XPoint memory (sold by Intel under the Optane brand), stores data by changing the electrical resistance of cells instead of storing electrical charges in cells.

- Hybrid drives or solid-state hybrid drives (SSHDs), combine features of SSDs and HDDs in the same unit using both flash memory and a HDD in order to improve the performance of frequently-accessed data.
- SSDs based on NAND Flash will slowly leak charge over time if left for long periods without power.
- Therefore, SSDs are not suitable for archival storage.
- The key components of an SSD are the controller and the memory to store the data.
- The controller is an embedded processor that executes firmware-level code and is one of the most important factors of SSD performance. Some of the functions performed by the controller include:

- Bad block mapping
- Read and write caching
- Encryption
- Crypto-shredding
- Error detection and correction via error-correcting code (ECC)
- Garbage collection
- Read scrubbing and read disturb management
- Wear leveling

Wear leveling

- If a particular block is programmed and erased repeatedly without writing to any other blocks, that block will wear out before all the other blocks — thereby prematurely ending the life of the SSD. For this reason, SSD controllers use a technique called wear leveling to distribute writes as evenly as possible across all the flash blocks in the SSD.
- In a perfect scenario, this would enable every block to be written to its maximum life so they all fail at the same time. The process to evenly distribute writes requires data previously written and not changing (cold data) to be moved, so that data which are changing more frequently (hot data) can be written into those blocks.
- Relocating data increases write amplification and adds to the wear of flash memory. Designers seek to minimize both.
- Defragmentation programs are not needed for SSDs and should be avoided.

SSD failure

- SSDs have very different failure modes from traditional magnetic hard drives.
- Because solid-state drives contain no moving parts, they are generally not subject to mechanical failures.
- Instead, other kinds of failure are possible (for example, incomplete or failed writes due to sudden power failure can be more of a problem than with HDDs, and if a chip fails then all the data on it is lost, a scenario not applicable to magnetic drives).
- However, on the whole statistics show that SSDs are generally highly reliable, and often continue working far beyond the expected lifetime as stated by their manufacturer