Categories

In detailing **I***nput***->P***rocessing***->O***utput*, a key section of **P***rocessing* is **Storage**.

Storage, as defined for the whole system, is the broad category encompassing the internal data storage methods and systems for containing data that are either: about to be used or have just resulted from processing.

But is must be stated that this definition of *storage* does not include the data in transfer (from device to device via the bus) or data in process (in the CPU). Some of this transition and process data exist temporarily for the sake of processing, but being related neither to *Input* nor *Output*.

> See text, **Chapter 11**.

Storage Categories

All storage devices can be viewed as belonging to one of two (2) categories: primary storage or secondary storage.

Although both are used for storage, these categories have fundamental differences that are defined by which devices the CPU (or the bus) can access directly.

Primary Storage

- memory (storage) that is directly accessible by the CPU through the internal system bus (Primary Storage sits on, or is connected to, the internal bus)
  - the width of the internal address bus limits the potential amount of primary storage due to the memory addressing techniques of the CPU and bus ("wider" the bus, more addressable memory, see Lecture 15); also, practical limits are imposed by the mainboard/chipset manufacturer
- [usually] very *temporary*: lost when the power is off! although this limitation is being redefined with high-speed SRAM (static RAM), CMOS (complementary metal-oxide semiconductor), and Flash Memory (EEPROM) that require little (or no) power to retain data
- Cache memory and Video RAM (VRAM) fall into this category
- term is commonly interchangeable with RAM (Random Access Memory); [Primary Storage ≡ RAM]
  - by definition, since it is directly accessible by the CPU, ROM (Read Only Memory) is also part of Primary Storage although it is not lost when power is off

Secondary Storage

- memory (stored data) that is not directly accessible by the CPU, and must be accessed through a peripheral bus and intermediate device (via a “controller”)
- considered *permanent* if data can never be modified (such as CD-ROM); *semi-permanent* if data does not change unless intentionally modified (magnetic disk, tape).
- most removable storage devices are considered secondary storage
- used for long-term storage of data as the *result of processing* or the *anticipation of further processing*.

The Grey Line

Much like input and output devices, a grey line exists that blurs the distinction between the categories of *primary* and *secondary* storage. Devices that can be seen by the CPU, yet offer long-term storage and removeability are becoming more popular because of large storage options and high data security (i.e., "store a lot, and store it securely").

The blending of the categories is directed towards completely stable and secure, long-term storage that used for both active storage (running of programs and their data) and inactive storage (saved files)—such as the Flash memory of removable memory cards used in handhelds, digital cameras, and memory drives.

Examples of Primary and Secondary Storage

For the following descriptions, you are strongly encouraged to consult the textbook for detailed information.

Primary *(short-term storage)*

- RAM comes in many forms, from the original DIP (dual-inline pin) to the most recent DIMMs (dual-inline memory module: SD-RAM, DDR-RAM, RD-RAM), but it all serves the same purpose: CPU-directly accessibly storage
- common forms of RAM: DRAM – dynamic RAM (SIMM, DIMM, VRAM), and SRAM – static RAM (Cache)

Secondary *(long-term, permanent (or semi-permanent) storage)*

Image

- paper, or other hardcopy form, using a direct binary printing technique that can be scanned by the system
- this form has not been used since the late 80's; is very portable, but lacks the dependability and speed of other, newer "electronic" storage methods
- new forms of *image storage* are being designed for use with personal computer scanners (examples from **Xerox**: *Xreader*, and *Dataglyphs)*
- example of image storage: *punch cards* and *paper tape* (the first Microsoft BASIC Interpreter for the Altair computer was stored on a reel of paper tape)

Magnetic Tape

- metal-oxide coated mylar (flexible, durable plastic) like audio- or video-tape
- represents binary data as magnetic signatures (charges): positive (+, 1) and negative (–, 0)
- logically described as "rewriteable": write the data, erase all data, and write again (although the drive head could, theoretically, change data immediately after it reads it…but this would cause too many problems)
- the data storage is *sequential* in nature, "always start at the beginning and read until item found, or the end"
- unlimited in capacity (just add more physical tape!), but physically limited by the tape container
- unlike older 9-track tape (where parallel columns of 9 bits (8-data + 1 parity) are recorded), modern streaming tape records data on a diagonal (angle) to increase recording and reading speed while writing data in a continuous stream of bits, and therefore not limited to 9 bit words (a technique also used in VCR recording)
- example of use: backup, long term storage, "streaming" video or audio content

Magnetic Disk

- circular metal-oxide coated substrate/layer (metal or ceramic for hard disks, mylar for floppies)
- physically stores data in the same way as tape--with magnetic signatures
- fully read/write: any disk section can be written, read, erased, and rewritten at any time
- data storage is *direct-access* in nature: any point on the disk surface can be accessed, regardless of the current location (spin disk and move the head radially in or out)
- areas of disks identified within unchanging magnetic signatures (result of "formatting") that shape concentric, divided rings representing *cylinders (stacked tracks), sectors, and clusters*
- capacity limited by disk surface area, size of the read/write head, and byte-size of cluster (cluster can hold only one file segment; segments smaller than the cluster size waste space—smaller clusters are always preferable)
- common physical sizes: 5.25" and 3.5" for regular drives (in standard towers and desktop computers), 2.5" for laptops and notebooks, "thumb-size" for handheld computers, mp3 players, and mobile phones
- examples of type: floppy, hard disks, removable magnetic disks (ZIP, JAZ, SparQ, LS-120)

Optical Disk (CD-compact disk, DVD-digital versatile disk, -ROM, -RAM, -R-recordable, -RW-rewritable)

- light reflective surface, read and changed with laser optics
- (CD-ROM/DVD-ROM) stores data in the form of points of *high-reflectivity* (land = 1) and *low-reflectivity* (pit = 0); physical surface is permanently distorted with a laser-burned pit (a "burn" on the surface)
- (CD-R/-RW, DVD-R/-RW/-RAM) stores data similar to –ROM formats, except that the surface is not permanently changed, but rather colour-shifted between *full-colour-reflectivity* and *low-colour-reflectivity* through a chemical reaction between the laser and dye material on surface (-RW requires erasure of existing data before writing again, whereas as –RAM can function almost like magnetic media)
- most modern CD-ROM drives can read CD-ROM, -R, and -RW disks; DVD-ROM drives can read these along with certain forms of DVDs, although not all -R, -RW, or –RAM can be read by all DVD-ROM drives
- unlike magnetic disks, optical disks record data in a long, continuous, single spiral *track* going from the inner edge of the disk to the outer edge; the single track is divided into equally-sized *sectors*
- DVDs come in different forms (and capacities): single-layer/single-side, double-layer/single-side, single-layer/double-side, and double-layer/double-side, for capacities from 4 GB to 17 GB
- [**special case**] WORM (Write-Once, Read-Many) disk is optical, but organised into *tracks, sectors* and *clusters* as is a magnetic disk; WORM offers the *random-access* efficiency of magnetic disks but in optical media
- examples of type; CD-ROM/R/RW, DVD-ROM/RAM (and other DVD variants), WORM

Magneto-Optical Disk

- malleable magnetic surface; laser optics used for positioning, heating, and reading; magnetics used for writing: particle alignment (north/south) represents binary data
- writing data:
  - using permanent disk markers, laser tracks and positions the disk surface below the magnetic "write" head
  - another laser "heats" (melts) a section of the disk containing magnetic particle (the Curie effect)
  - while area is soft and the particle floats freely, the "write" head aligns the particle, waiting until the disk surface "cools," the particle alignment is now permanent
- reading data:
  - again using makers, laser tracks and positions the disk surface below the magnetic "read" head
  - a laser hits the magnetically aligned particle, reflecting with a specific polarised "spin" (to represent a binary value), a optical sensor reads the polarisation (the Kerr effect)
- although optical, the magnetic nature makes it as flexible as a magnetic disk
- like a magnetic disk (or WORM) it is fully-read/write and organised into *tracks*, *sectors*, and *clusters*…
  sort of, or at least as far as the computer and OS are concerned (the drive's BIOS handles the translation)
- current capacities have yet to exceed larger magnetic hard disks or optical disks (DVD);
  storage limitation due to,
  a) the sizes of the magnetic particles,
  b) spaces required between the particles, and
  c) distance between the surface and the "read/write" head
- examples: common MO disk capacities are 230 & 650 MB and 1 GB, and the Sony Music MiniDisc format

Flash Memory Devices

- uses EEPROM (Electronically Erasable Programmable Read-Only Memory), or small-charged SRAM, chips on circuits; behaviour is similar to hard disks, but much faster, fewer moving parts, and use less energy
- used widely in handheld computers, palmtops, digital cameras, mobile phones, and USB removable memory
- for the moment, the *cost per megabyte* is still too expensive to have wide-spread use of multi-gigabyte storage systems to replace hard disk drives (for *read/write* access) and CDs/DVDs (for permanent storage)
- examples of type: Secure Digital (SD), Compact Flash (CF), Smart Media (SM), Memory Stick (MS), (xD) USB Flash Drives