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DEVELOPMENT OF THE HARD DRIVES IN A PORTABLE COMPUTER DEVICES

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Purpose: The aim of this article is to present the history of hard drive development over the last few decades. The structure and principle of operation of disks made in various technologies was also presented. Particular attention has been paid to SSDs (Solid State Drives) due to their dominant position in the market.
Design/methodology/approach: The article presents the possibilities of using mass storage devices. In the article we also covered the base structure of main mass storage computer device available commercially nowadays.
Findings: During the work we found connections and main differences beetwen main types of mass storage computer devices and how they evolved during last 70 years.
Originality/value: Paper presents whole history of developing of mass storage devices. This approach may be helpfull for engineers who work on designing and refining mass storage technologies.

Keywords: hard drive disk, solid state drive, mass storage.

Category of the paper: Research paper.

1. Introduction

The beginnings of designing hard drives date back to the 1950s. The disk was constructed by IBM on September 14, 1956. This disk was a 20 inch device in an IBM 305 RAMAC computer. It can be said that this drive ushered in the era of hard mass storage. To this day, hard drives are the best way to store data. They are magnetic type disks (Horowitz, Hill, 2019). They are installed in all types of computers, in mobile devices, laptops, PCs, servers, etc.

The hard disk contains a movable system with a sliding reading or writing head on a magnetic plate. So it is a mechanical device. For this reason, for the correct operation of the disk, the stability of the position without any shocks is essential. The computer devices that are most often exposed to shocks are laptops and various types of mobile devices. Each shock exposes the hard drive to irreparable damage and loss of functionality. This may result in the loss of data stored on the disk. Any such data loss can expose the user to significant costs.

The article presents the development trends of hard drives used in portable computers.

2. Design of hard drives and their development

A hard disk is made of a set of rotating plates or a single rotating plate, which are usually made of aluminum alloys, with a polished surface and covered with a magnetic carrier. There are heads next to the plates that enable data recording and reading. There is one read and write head assigned to each surface of the disc. The heads are placed on guides. They are in contact with the plate when they are at rest. However, they float during work. The distance between the head and the platter is stabilized thanks to the aerodynamic effect. This phenomenon is based on the production of a whirl of air resulting from the operation of the plates (Metzger, 2011).

In order to read or write data, the arm of the disk head is positioned at an appropriate distance from the axis of rotation of the disk. The first designs of this type of disk were equipped with a stepper motor. Technological advances related to the increase in the number of cylinders on a disk along with the need to increase the speed of the disks resulted in launching of many other solutions. They used the phenomenon of a strong magnetic field generated by a magnetic coil. As a result, the transition time between successive paths was reduced to less than 1 milisecond. There, the information is recorded on a disk by transmitting an electromagnetic flux through a recording head. This information can be read back in the opposite way. This is because the alternating magnetic field induces an electrical voltage in the head coil. Electronics on board of the hard disk control the movement of the heads and the rotation of the disk. It also prepares read and write processes on the command of the disk controller.

It is obvious that one of the most important features of mass storage devices is their capacity, i.e. the amount of data that can be stored on one indivisible medium. In magnetic type disks, the capacity depends on several factors. The first is the number of plates placed in a unit. The second is the technology of their implementation. The smoother the disk surface, the closer the read/write head can be placed, and thus the density of magnetic memory cells can be increased (Mueler, 2005). The rotational speed of the discs also has an indirect effect on the disks. For those with a lower rotational speed of 5000 rpm, the distribution of available capacities is greater. However, for drives that reach speeds of 7000 rpm, the maximum capacities available on the market are twice as small. This is probably because the

manufacturers, by focusing on the speed of operation in specific models, put the capacity in second place. Otherwise, the price could prevent the release of such models on the market.

The second most important feature is the speed of data transfer. It depends primarily and directly on the rotational speed of the platters and the size of the cache. The former is directly responsible for the speed with which access to a specific sector is made possible. Hence, the faster the platter's rotation speed, the faster the drive responds to commands (SSD and HDD, 2022). On the other hand, a larger and faster cache is needed to transfer and temporarily store larger data packets in this memory. Such temporary retention is needed so that data that is needed more often is not reposited on disk, but in a faster cache (What is a cache, 2022). Hence, the larger it is, the more data can be processed simultaneously.

3. Hard drives evolution strategy

From the invention of the magnetic hard disk to the present day, engineers have made great strides in improving them both in terms of performance and price.

The history of the evolution of hard drives is as follows:

- September 4, 1956 - IBM's construction of the first 20-inch hard drive, named RAMAC 350, in the IBM 305 RAMAC computer.
- 1983 - the appearance of IBM PC/XT computers with mounted disks with a capacity of 5 and 10 MB,
- 1986 - development of the IDE (Integrated Drive Electronics) controller,
- 1987 - start of production of 3.5-inch drives,
- 2003 - hard drives produced at that time could collect from 60 to 500 GB of data, their platters rotated at a speed from 5400 to 15 000 rpm and had an average data transfer speed of 30MB/s - some servers and workstations used disks with rotational speeds of 15 000 revolutions per minute,
- 2006 - a new perpendicular recording technology was used, which made it possible to store over 1 TB of data on the disk; SATA and SAS (Serial Advanced Technology Attachment and Serial Attached SCSI (Small Computer Systems Interface)) have become a standard; USB sticks began to displace floppy drives,
- 2009 - production of disks with a capacity of 2 TB; the appearance of disks with a dynamic change in rotational speeds; the SATA 3 standard was developed for SSDs,
- 2013 - the first Ultrastar He6 disk with a hermetic housing and filled with helium is launched commercially. It reduced energy consumption by 49% in the category of watts per terabyte (WD releases 6TB, 2022),

- 2014 - the company Western Digital (WD) announces the release of new hard drives with a capacity of 10 TB filled with helium and with a new recording technology SMR (shingled magnetic recording) (Western Digital unveils, 2022),
- 2018 - Seagate announces a 16 TB hard drive thanks to the HAMR (heat-assisted magnetic recording) recording technology (HAMR Milestone, 2022),
- 2022 - Western Digital (WD) at its inaugural What's Next Western Digital event in San Francisco presented new 22 TB hard drives called Ultrastar DC HC570 and 26 TB called Ultrastar DC HC670. At the same time, it presented a path that will make it possible to achieve even higher capacities (Orchestrating, 2022).

Nowadays, the leading manufacturers of hard drives are: Seagate, Western Digital, Samsung, Hitachi, Fujitsu.

In the next chapter we will deal with disks made in the latest commercially available SSD (solid state drive) technology. It is a direct successor to magnetic hard drives. It is worth emphasizing, however, that the SSD technology has not replaced the magnetic technology, but is used alongside the latter, which gives enormous benefits and allows to use the advantages of both technologies and compensate for the disadvantages of each of them.

4. Solid state drive (SSD)

Solid state disks get their name from the part of physics that deals with solid-state physics. One of the most important parts of this branch of physics is the study of semiconductor properties and their application (Skorko, 1982). This is where the name and construction of SSD drives come from.That is because these disks do not contain moving (mechanical) parts, but their main data storage material is a semiconductor. In order to obtain the greatest possible capacity, FLASH type semiconductor memory chips are constructed (Wawrzyski, 2003), which are arranged in the disk.

This approach to construction allows the use of any connector for data transfer, and even to integrate such a disk directly with the motherboard (such solutions can be found in small laptops, where great emphasis is placed on their minimum physical size, especially thickness). However, due to backward compatibility with older motherboards, SSDs contain a SATA or ATA type connector.

Since the launching of the new solid state drive (SSD) technology, the massive development of this type of memory has begun. The constantly cheaper components lead to the production of more and more new types of SS (Solid State) memories with much greater capacity, which makes them more and more available and finding newer and newer applications. This trend is driving waves of applications and generating newer and newer product groups. Examples include: small earbuds, smart watches and sports bands (smartwatch and smartband), smart rings, smart glasses (the latter two, however, are not common today) and the like.

SSDs have a number of advantages that cannot be achieved with magnetic disks. First of all, these disks are extremely resistant to shocks and mechanical damage. They are also characterized by low power consumption. This is again due to the lack of mechanical components. The entire process of data storage in an SSD takes place at the level of the atom and electron shells, hence the energy needed for the operation of such a system is much smaller than that needed to power the moving head system, the disk and the electronics controlling them. For the same reason, SSDs are completely silent and generate no noise at all. Also, depending on the type of semiconductor used, they have a much wider operating temperature range than hard drives, i.e. from -40°C to 85°C.

Finally, it is probably the greatest advantage of SSD drives that should be mentioned, i.e. their data transfer speed. Due to the elimination of the need to physically move the head over the appropriate sector to write or read data, it has been possible to shorten the data access time many times over. Currently, the data transfer speed in semiconductor memories in the latest models reaches even 5000 MB/s! This means that the mass memory on which the operating system and user data are located is equal to and even beats the RAM operating memory with its speed. This creates, first of all, the possibility of creating smooth and fast-operating computer units (personal or for industrial applications), but also the possibility of creating fast and efficient servers and data centers.

Table 1 shows the storage media available on the market for data storage. You can easily compare these products with each other. Semiconductor storage media clearly exceed the data transfer speed compared to other media

Table 1.
Memory medias available at the market

Kind of memory	**Memory card MicroSDXC**	**Memory card Compact Flash**	**Disk USB Flash Drive (Pendrive)**	**Hard drive HDD 3.5 inch**	**Disk SSD 2.5 inch**	**Disk SSD M.2**
Manufacturer and the model of device	SanDisk Ultra microSDXC 32	SanDisk EXTREME CF 32	SanDisk Ultra Flair USB 3.0 FlashDrive	Seagate Barracuda ST1000DM010	SanDisk SSD Plus	WD_BLACK SN770 NVMe SSD
Size	15 x 11 x 1 mm	43 x 36 x 3,3 mm	6.6 x 42 x 13 mm	147 x 101 x 26 mm	7 x 100 x 70 mm	80 x 22 x 2.38 mm
Weight	2 grams	10 grams	About 30 grams	400 grams	100 grams	5,5 grams
Nominal capacity	32 GB	32 GB	256 GB	1 TB	240 GB	250 GB
Price	32 PLN	164 PLN	169 PLN	200 PLN	210 PLN	283 PLN
Price per 1 GB	1 PLN	5 PLN	0.66 PLN	0.20 PLN	0.88 PLN	1.1 PLN
Read speed	Up to 100 MB/s	Up to 120 MB/s	Up to 150 MB/s	Up to 210 MB/s	Up to 530 MB/s	Up to 4 GB/s
Write speed	30 MB/s (min 10MB/s)	Up to 85 MB/s	50 MB/s	Up to 100 MB/s	Up to 400 MB/s	Up to 2 GB/s
The maximum available capacity for this media type	516GB	128GB	512 GB	8 TB	2 TB	2 TB

Source: own work.

Apple was the first company to massively use SSD disks in its devices. It offered the possibility of mounting an SSD drive in place of standard storage media in laptops it produced. Lenovo was the first manufacturer to equip its series of products with SSD drives. In addition, there were no devices containing magnetic disks in the computers of these series. Asus was also a pioneer in applying the new SSD disk technology. These were low-cost, small mobile computers. SSD disks in these computers were permanently installed on the motherboard.

5. Solid state drive evolution strategy

SSDs have grown rapidly over the past few decades. At the beginning, their main disadvantage was the price. In addition, from today's perspective, we can say that this price was in no way disproportionate to their parameters. However, this is usually how the development of something good and useful looks like.

This is the story of the evolution of SSD storage drives:

- 1991 - the launch of the first SSD drive with a capacity of 20 MB, which cost $ 1000 at the same time (The evolution, 2022),
- 2006 - Samsung introduces a 32 GB SSD drive, which is built into their computer models: Sens Q30PLUS Samsung Note PC and Sens Q1 ultra-mobile PC, (Leading the transition, 2022),
- 2016 - Samsung introduces a 16 TB SSD called PM1633a (Westlake, 2022),
- 2018 - Samsung has created a 30 TB SSD called PM1643 (Snoch, 2022),
- 2022 - a 30 TB drive from Samsung can be purchased for PLN 40,000.

6. Security of data contained on solid state drive disks

The new SSD hard drives are much more reliable than the previously developed magnetic drives. They are much more shock-resistant and guarantee effective work with the data. In modern computer systems, security and reliability issues take priority over other properties. Hence, in computer systems, SSD storage media are an ideal product that meets the needs of system users. No wonder that these drives have been used in large corporations, concerns and organizations for which reliability and security are priorities. Organizations such as the armed forces and governmental organizations should be mentioned in particular. It is worth mentioning that computers have been involved in hostilities for decades and have helped in these areas. SSD drives can meet the requirements of working in harsh military conditions and are therefore widely chosen by such organizations.

7. Summary

A significant reduction in the production costs of storage media is noticeable in comparison with the years of introducing individual types of storage media to the market. There is considerable interest in new storage technologies. Especially with SSD technology due to its high energy and transfer efficiency. The prices of storage media are highly dependent on the manufacturing technology, capacity and speed of data transfer. Hence, manufacturers, in order to ensure the availability of their products for as many users as possible, design the same types of carriers adapted to specific applications. That is, in certain models, they focus on speed, and on other models, capacity.

In recent years, however, the development of computer memories of both technologies has reached the limits of its development. It is about cells that are shrinking, in which bits of data are saved, and which are getting closer and closer in size to the size of a single atom. This leads to the fact that in the next several years, magnetic and semiconductor technology will reach the limit where memory cells will no longer be able to become smaller. Hence, there is a need to invent other methods of storing information, which will be appropriate to the ever-increasing amount and intensity of its processing by people around the world.

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