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From 20 Megabytes to 20 Terabytes: 40 years of hard disk drive technology

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About 40 years ago, the first PCs were equipped with hard disk drives (HDDs) – large drives that had a storage capacity of just 20 Megabytes. However, the technology shrank rapidly in terms of physical size, while storage capacities grew. The very smallest models have since disappeared from the market, but the demand for ever-increasing capacity continues unabated. Current HDDs can hold up to 20 Terabytes – a million times as much memory as those early PCs.

The history of the hard disk goes back to the 1950s. Even the drives of that time share their base technology with today's models – rotating magnetic discs between which arms with read/write heads move and magnetise or scan bits. The first HDDs were like small cabinets and weighed almost a ton. They were used in selected computer and mainframe systems and revolutionised data processing, because more immediate access to information was suddenly possible.

The triumph of the hard disk began in the 1980s with the advent of PCs. The drives measured 5.25 inches in diameter and held only a few Megabytes of data at the time – more storage was not necessary, because applications had no graphical user interfaces, and no document scans, digital videos or other storage-hungry data needed to be stored. The 20 Megabyte models were very popular, and many users started the PC era with them.

In the years that followed, storage capacities rose into the triple-digit Megabyte range and interfaces were standardised. For power supply, the Molex connector with four pins prevailed; for data transfer, ATA became the standard. This standard was previously known as IDE, and with the introduction of Serial ATA (SATA) it was usually referred to as Parallel ATA (PATA) for better differentiation. Typical of PATA were the ribbon cables with three 40-pin connectors that connected two drives to the

Today, as 40 years ago, hard disk drives with rotating magnetic discs are the storage medium of choice when it comes to storing large amounts of data. (Source: Toshiba Electronics Europe)

mainboard of the computer. By means of small plug-in jumpers on special contact points on the hard drives, it was determined which drive was the primary and which was the secondary.

The boom that the new storage technology triggered is shown by the fact that there were 75 hard disk manufacturers in 1985. Over time, more than 200 companies tried to produce the drives, of which only three are still active today. Consolidation began in the second half of the 1980s, as production was only economically attractive with large quantities.

Hard disk sizes keep getting smaller

The 3.5-inch HDDs became widespread from the end of the 1980s; the form factor was based on the size of floppy disk drives in order to fit into the same drive bays. In servers and storage systems, too, the 3.5-inch form factor quickly became the standard – and it still is today. However, manufacturers also developed ever smaller form factors, starting with 2.5-inch hard drives for notebooks. Today, these models are really only found in external USB drives, as SSDs are more usually used in notebook computers. Particularly in low-cost devices, manufacturers only install low-capacity SSDs for cost reasons, so the demand for external hard drives as storage expansion remains high. However, the drives are hardly being developed further technologically, so no significant increases in capacity are to be expected.

A lower limit was reached, and the very smallest hard disk models have now disappeared completely from the market. However, around the turn of the millennium, for example, there were 1.8-inch HDDs for the PCMCIA slot of notebooks. Since the devices usually had neither an internal modem nor a network connection or WLAN and the connection to the outside world also required a plug-in card, notebook owners at the time had to make difficult decisions. In 2001, the first MP3 players also had a HDD – a model with a 1.0 inch format and 5 Gigabytes of storage capacity.

Because flash memory was expensive and memory cards only had small capacities, 1-inch disks were also developed that could fit into the CompactFlash slot of digital cameras. HDDs hardly bigger than a thumbnail were found in some smartphones at the beginning of the 2000s. Some of these 0.85-inch models held an impressive 4 Gigabytes. However, they did not get any smaller, as flash outstripped the hard disk in mobile devices.

Storage capacity goes up and up

The flash boom meant that HDDs could only succeed with high capacities at favourable costs. Perpendicular magnetic recording (PMR), a new recording method, led to a real leap in capac-

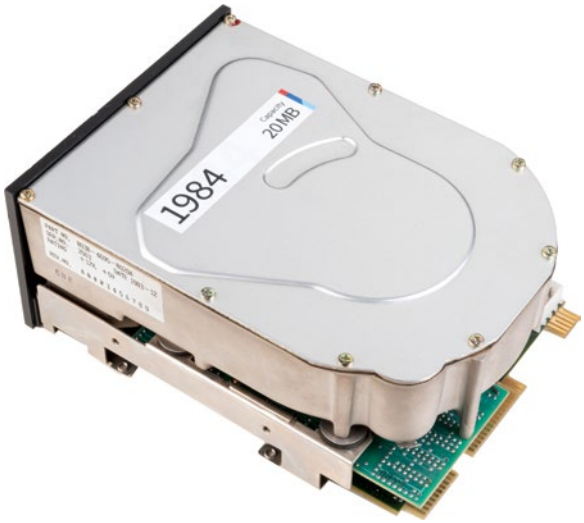

Figure 1: A hard disk model from 1984 that stores 20 Megabytes. At that time, the drives were increasingly being installed in PCs, but at 5.25 inches they were still much larger than today's hard disks. The interfaces were also not yet standardised – PATA came later. (Source: Toshiba Electronics Europe)

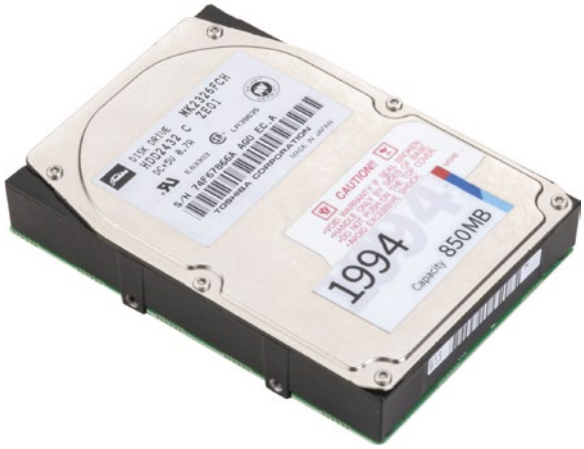

Figure 2: At the end of the 1980s, 3.5-inch drives became popular; here is a model from 1994 with 850 Megabytes. The form factor is still standard in PCs, servers and storage systems today. (Source: Toshiba Electronics Europe)

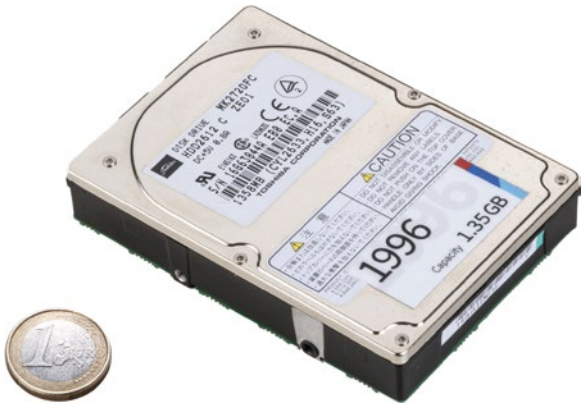

Figure 3: The increasing demand for notebooks led to a boom in 2.5-inch hard disks, and in the mid-1990s the Gigabyte limit was passed. Since mobile computers are now mainly equipped with SSDs, 2.5-inch drives are now used almost exclusively in external USB enclosures. (Source: Toshiba Electronics Europe)

ity. Until the mid-2000s, the drives only held a few Gigabytes, but shortly after that more than 100 Gigabytes and soon even 1 Terabyte became completely normal.

With the previously used longitudinal magnetic recording (LMR), the bits on the magnetic discs were aligned horizontally, whereas PMR allowed a vertical arrangement and thus a much higher storage density. The big challenge here was the positioning of the magnetic poles on the recording head, as the magnetisation had to take place through the disc, but the recording head could not be built around it. The solution was ultimately a reflecting and scattering layer underneath the disc, which led the magnetic flux back to the second pole located above.

The increasing storage capacities made new, serial interfaces with a higher throughput necessary: in the client area the already-mentioned SATA, and in the data centre area SAS, which replaced SCSI. In the data centres, SSDs subsequently began to displace the fast-spinning hard disks with 10k and 15k more and more – and what remained were 3.5-inch HDDs with 7,200 revolutions, which offer an optimal balance of capacity and performance. They were filled with helium from the mid-2010s. This lightweight inert gas causes less friction and turbulence than air, so using thinner discs created space for additional discs in the enclosure. With nine discs and PMR, 16 Terabytes could be realised. Ten and more discs seem possible, and further increases in capacity can be realised with alternative recording technologies.

A new generation of hard disks with microwave technology

With microwave-assisted magnetic recording (MAMR), a new recording method has been developed in recent years that uses microwaves to control and focus the magnetic flux at the write head. This means that less energy is needed to magnetise the bits, so that the recording head is smaller and can write data more densely. Toshiba launched hard drives last year that featured a new form of MAMR, called flux-controlled MAMR (FC-MAMR). This technology has boosted data storage capacity and enhanced power efficiency. Building on the great market response that these drives received, the MG10 Series was released in 2022. These advanced HDDs, with a 10-disk helium-sealed design, push capacity values still further. This allows them to store 20 Terabyte of data, while still keeping to the 3.5-inch form factor.

In the next development stage, microwave-assisted switching MAMR (MAS-MAMR), the microwaves will activate the material of the magnetic discs to further reduce energy input and enable a further reduction in the size of the write head. However,

Figure 4: The audio players, digital cameras and smartphones that emerged at the end of the 1990s were initially equipped with hard disk drives – flash memory was far too expensive at that time. Manufacturers developed HDD drives with 1.8 inches, 1 inch and also this tiny one from 2004, which measures only 0.85 inches and holds 4 Gigabytes. (Source: Toshiba Electronics Europe)

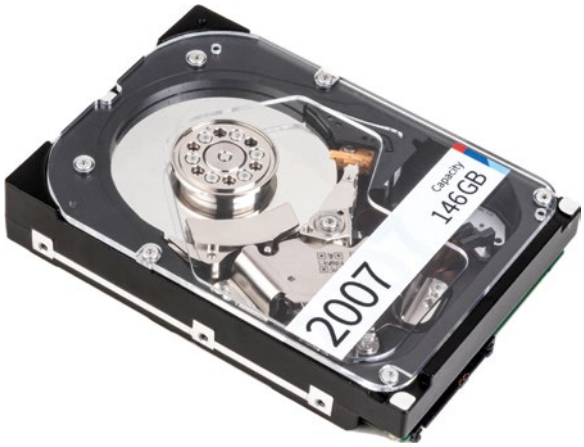

Figure 5: In the mid-2000s, the new recording method PMR (perpendicular magnetic recording) caused enormous leaps in capacity. Hard disks could suddenly hold well over 100 Gigabytes. The high data volumes made new interfaces necessary: SATA replaced PATA in the client area and SAS followed SCSI in the data centre. (Source: Toshiba Electronics Europe)

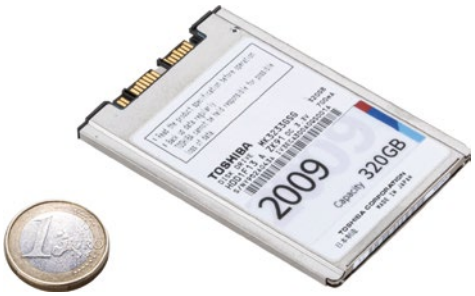

Figure 6: This flat 1.8-inch hard drive from 2009 is equipped with a single magnetic disk that can store 320 Gigabytes and is used in compact notebooks, among other things. (Source: Toshiba Electronics Europe)

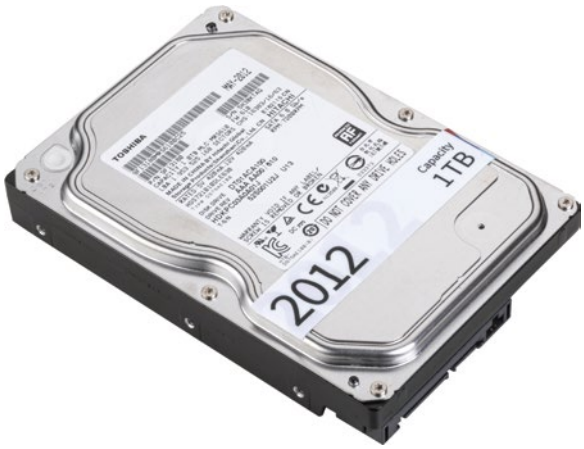

Figure 7: Flash is displacing hard drives from many devices, so HDDs can only succeed with large capacities. The drives broke the Terabyte barrier in the early 2010s, catching the rapidly swelling data wave of the information age in data centres and cloud environments. (Source: Toshiba Electronics Europe)

this will require a new coating for the discs, which the hard disk manufacturers are currently developing. According to experts, MAS-MAMR will increase the capacity of 3.5-inch HDDs to up to 50 Terabytes in the next few years. This sets the course for hard disks to continue to bear the brunt of data storage in the information age.

However, it seems unlikely that the next 40 years will see another leap in capacity like the one from 20 Megabytes to 20 Terabytes. Hard drives in the early 2040s would then have to offer 20 Exabytes of storage capacity – ten times that of a modern cloud data centre. On the other hand, the proud owner of a 20 Megabyte hard disk in the early 1980s probably never dreamed of models with 20 Terabytes.

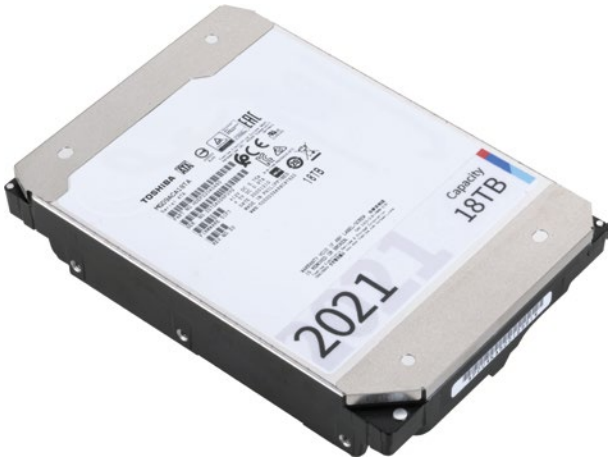

Figure 8: In 2021, a new generation of hard disk drives entered the scene, relying on the new MAMR (microwave-assisted magnetic recording) method. The first model had a capacity of 18 Terabytes, and its successor in 2022 has already brought it to 20 Terabytes. (Source: Toshiba Electronics Europe)

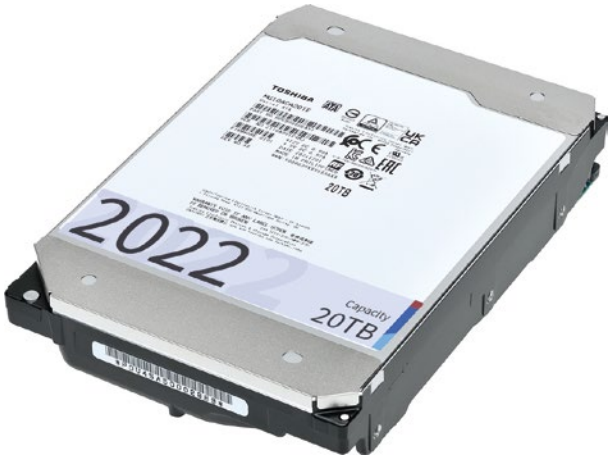

Figure 9: The advanced MG10 Series is the answer on the data growing at an explosive pace, Announced in 2022, these HDDs, boost the capacity up to 20 Terabytes which is 11.1% more than its predecessor. With its improved power efficiency and increased capacity, these HDDs help cloud-scale service providers and storage solution designers to achieve higher storage densities for cloud, hybrid-cloud and on-premises rack-scale storage.

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