**Overlook on SSD and HDD**

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# Abstract

The standard hard drive (HDD) has been the predominant storage device for computers, both desktops and laptops, for a long time. The main draw is the storage size and low cost. Computer manufacturers can include large hard drives at a small cost, so they've continued to use HDDs in their computers. The solid state drive (SSD) is available and can replace an HDD relatively easily. This paper will compare these two kinds of drive. Then it will give users a suggestion to choose the right drive when building a computer. Because the price of the solid state drive is high though it provides excellent performance, there is still necessity to consider which drive to select.

For most computer users, SSD will be suggested as a primary drive for operating system and most important programs and then having either one or more HDD inside the same computer or an external HDD to store files like pictures and music, which doesn't need the fast access times of SSD. In this paper, readers can find most answers to the problem why they should use this strategy when building a computer.

# 1 Hard disk drive

### 1.1 Introduction of HDD

A hard disk drive (HDD) is a data storage device used for storing and retrieving digital information using rapidly rotating disks coated with magnetic material. An HDD retains its data even when powered off. Data is read in a random-access manner, meaning individual blocks of data can be stored or retrieved in any order rather than sequentially. An HDD consists of one or more rigid rapidly rotating disks with magnetic heads arranged on a moving actuator arm to read and write data to the surfaces.

Introduced by IBM in 1956, HDDs became the dominant secondary storage device for general-purpose computers by the early 1960s. Continuously improved, HDDs have maintained this position into the modern era of servers and personal computers. More than 200 companies have produced HDD units, though most current units are manufactured by Seagate, Toshiba and Western Digital.

### 1.2 Development of HDDs

In September 1956, IBM claimed its first disk storage system of IBM 350 RAMAC to the world. This system can be considered as the earliest hard disk drive in the world. Its magnetic head can move directly to any area of the disk, which implement random storage. However the capacity of this system is only 5MB, totally using 50 disks the diameter of which is 24 inch. The surfaces of these disks are coated with a layer of magnetic material. These disks are stacked and fixed together, which will rotate around a common axis. This RAMAC was mainly designed for flight booking, automatic bank, medical diagnosis and space domain. It can be impossible for ordinary users to take advantage of this. Actually at that time computers are not widespread, also so-called PC (Personal Computer) hasn’t come out.

Due to the bad performance of RAMAC, the large volume, it is quite inconvenient for the users and the manufacturer, in 1968 IBM proposed the "Winchester" technology, discussing the possibility of major modification of technologies used in the hard disk. The principle of "Winchester" technology is: "sealed, fixed and high speed rotating plated disk, magnetic head suspends on the disks, not directly contact with the disk", which is the prototype of most hard disks currently be using. About 5 years later, in 1973, IBM made the first hard disk using "Winchester" technology, from then on the development of hard disk steps onto a correct way, the hard disks what we are most using today are extensions of the technology.

In the following sections, this paper will discuss the history of the techniques used on hard disks.

#### 1.2.1 Technique of magnetic head

One of the important techniques is the technique of magnetic head. Nowadays the capacity of each single platter is larger than 10GB, some may even reach to 20GB. The technology of magnetic may strongly influence the capacity of a single platter, more advanced technology leads to larger capacity of a single platter.

At first the head used magnetic materials, which don’t work well both in the sensitiveness of the head and the precision, so the early hard disks had low capacity of a single platter. Thus, the total capacity of the hard disk is limited because of the limited number of platters in one hard disk (currently drives has about 3~5 platters). Meanwhile, the volume of the head is small at that time, which makes the volume of hard disks relatively large, inconveniencing users.

In 1979, IBM invented the thin film head, providing the possibility of reducing the volume of the hard disk, increasing the capacity, and the speed of reading and writing. Then in the late 80's, IBM company made an important contribution the development of hard disks, the development of MR (Magneto Resistive) head, which has better sensitiveness to the change of signals when reading the data, which makes the density of storage increases by several times. This naturally increases the capacity of a single platter. And this finally increases the entire capacity of the hard disk.

In 1991, IBM used MR technique for 3.5-inch hard disk, so that the capacity of hard disks which ordinary users have reached 1GB, then the hard disks we use can be discussed on the order of GB. GMR is a new generation of technique IBM invented based on MR technique, it is the latest technique of the head, the current hard disks all take advantage of GMR technique.

#### 1.2.2 Technique of electric motor

The technique of electric motor is also essential, which directly affect the rotation rate of hard disks. The recent fastest hard disk Cheetah X15 is manufactured by Seagate, the rotation rate of which is up to 15000rpm. Nowadays, the rotation rate of the most used IDE hard disks is 7200rpm. While the rotation rate of SCSI hard disks are 10000rpm. There are still many IDE hard disks whose rotation rate are 5400rpm, which aim at the market of low price.

There is a relatively good motor technology owned by Seagate, the Fluid Dynamic Bearing (FDB) motor, which can reduce noise effectively, reduce vibration, prolong life and strengthen the resistance of shock. Technology of motor directly affects the speed of hard disks, and the speed determines the seek time of hard disks. Of course, in the improvement of speed, the quantity of heat and the problem of vibration and noise should be examined. So the technology of the motor directly determines the speed of hard disks, working temperature and the working noise etc.

#### 1.2.3 Interface technology

The interface of hard disks are always what people concerned about, with the development of the performance of other computer accessories (subsystems such as CPU, memory, display), the transmission rate of an interface slowly becomes the bottleneck of the entire computer system, the interface of hard disks has attracted more and more attention.

The earliest interface of hard disks is the ST-506/412 interface developed by Seagate, Seagate’s ST506 and ST412 first used this interface. The ST506 interface is quite easy to use, not requiring any special cables and connectors, but its transmission rate is very low, so about in 1987 this interface is nearly eliminated. Hard disks with this interface have capacities less than 200MB.

IDE (Integrated Drive Electronics) intended to actually refers to the hard drive which integrate the controller and the body of disk, IDE interface what we often say is also called ATA (Advanced Technology Attachment) interface, current PCs’ hard disks are majority compatible with the IDE interface. It just requires one cable to connect with the motherboard or interface card. The scheme reduces the amount and length of cables the interface has, the reliability of data transmission is enhanced. It becomes easier to manufacture hard disks, because manufacturers do not have to worry about whether their hard disks are compatible with other manufacturers’ controllers. As for users, installation of hard disks is more convenient.

Serial ATA, was released by Intel in 2013 in Intel Developer Forum, which will be used in the interface type of the next generation of peripheral products, as the name suggests, it transmits the data serially and continuously, but will have only 1 bits to transmit data at the same time, this approach can reduce the number of pins in an interface, all the work can be finished using four pins (1st pin to send, 2nd pin to receive, 3rd pin to supply the power, 4th pin to connect the ground wire). This approach can reduce the consumption of power and the heat emit from the hard disk.

#### 1.2.4 Technique of platter

As the magnetic head, motor and interface are constantly updated, platter stores data also keeps updating, in general, the early hard disks use plastic materials as the substrate of the platter, then coated with magnetic materials to form the platter of hard disks.

IDE hard drives on the market are generally using aluminum material as the substrate. While the latest hard disk is using glass materials as the substrate, glass material can make the hard disk much smoother and more rugged, in addition glass material has higher stability when the hard disks rotate in high speed.

### 1.3 Parameters of hard disk drive

When selecting a hard disk, customers should consider some parameters such as the capacity, rotational speed, average access time etc.

#### 1.3.1 Capacity

As the data storage of computer system, the capacity of hard disks play the most important role in parameters.

Capacity is measured in MB/MiB, GB/GiB or TB/TiB. The common conversion is 1TB=1024GB, 1GB=1024MB and 1MB=1024KB. But what the hard disk manufacturers usually use is GB, and the Windows system also uses GB to represent GiB (1024 conversions), so what can be seen when formatting the hard disk shows the capacity will be lower than the nominal value manufacturers claim. Generally speaking, larger capacity means cheaper unit price, but there are exceptions when the capacity is quite large.

#### 1.3.2 Rotational Speed

Rotational Speed, is the rotational speed of the motor in the hard disk drive, in other words the maximum revolutions the hard disk can finish in a minute. The rotational speed is one of important parameters to indicate the rank of a hard disk, it directly decides the transfer rate of the hard disk. The higher the rotational speed is, the less the time to find files will be, the transmission speed is also improved. The rotational speed is measured by RPM which is short for revolutions per minute. The bigger the RPM value is, the better the performance can be.

#### 1.3.3 Average access time

The average access time refers to the time the head moves from a starting position to the target track, and the time the head spends to find the area to read or write data. The average access time reflects the reading and writing speed, it includes average seek time and the average waiting time, i.e. the average access time = average seek time and average waiting time.

Average seek time of a hard disk refers to the time the head spends to move to the track asked. The average seek time of a hard disk is usually 8ms to 12ms, while the average seek time of SCSI hard disk should be less than or equal to 8ms.

Waiting time of a hard disk, is also called latency. When the head is already on the track to visit, it should wait for the section to rotate below the head. This is the waiting time. Average waiting time is half of time the platter rotate one revolution. The general should be below 4ms.

#### 1.3.4 Data transfer rate

The data transfer rate refers to the rate the hard disk reads and writes data, measured by megabits per second (MB/s). Hard disk’s data transfer rate includes internal data transfer rate and the external data transfer rate.

Internal transfer rate is also known as the sustained transfer rate, which reflects the performance of the hard disk when the buffer is not used. The internal transfer rate depends mainly on the rotational speed of the hard disk.

External data transfer rate is also known as the burst data transfer rate or interface transfer rate, it is the data transmission rate between the system bus and hard disk buffer, the external data transfer rate depends on the types of the interface and the size of the disk’s cache.

Cache is a memory chip on the controller of hard disks. It has fast access speed. It is the buffer between internal hard disk storage and the outside interface. Due to the different transmission speeds between internal hard disk and the external interface, cache plays a role as a buffer. The size and speed of the cache are important factors which directly relate to the transmission speed of the hard disk. Cache can greatly improve the overall performance of the hard disk. When the hard disk needs to constantly exchange data between disk and memory, a large cache can store some fragmented data temporarily, which reduces the load on the external system, also improves the speed of data transmission.

### 1.4 How hard disks work



Figure 1.1 Hard Disk Drive

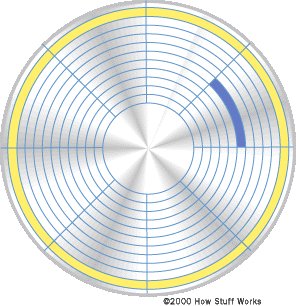


Figure 1.2 A typical track is shown in yellow; a typical sector is shown in blue. A sector contains a fixed number of bytes -- for example, 256 or 512. Either at the drive or the operating system level, sectors are often grouped together into clusters.

The process of low-level formatting a drive establishes the tracks and sectors on the platter. The starting and ending points of each sector are written onto the platter. This process prepares the drive to hold blocks of bytes. High-level formatting then writes the file-storage structures, like the file-allocation table, into the sectors. This process prepares the drive to hold files.

Underneath the board are the connections for the motor that spins the platters, as well as a highly-filtered vent hole that lets internal and external air pressures equalize:

Removing the cover from the drive reveals an extremely simple but very precise interior:



Figure 1.3 Beneath the board of the hard disk

This picture shows:

The platters - These typically spin at 3,600 or 7,200 rpm when the drive is operating. These platters are manufactured to amazing tolerances and are mirror-smooth.

The arm - This holds the read/write heads and is controlled by the mechanism in the upper-left corner. The arm is able to move the heads from the hub to the edge of the drive. The arm and its movement mechanism are extremely light and fast. The arm on a typical hard-disk drive can move from hub to edge and back up to 50 times per second -- it is an amazing thing to watch!

# 2 Solid State Disk

A solid-state drive (SSD) is a data storage device that uses integrated circuit assemblies as memory to store data persistently. SSD technology uses electronic interfaces compatible with traditional block input/output (I/O) hard disk drives, thus permitting simple replacement in common applications. Additionally, new I/O interfaces, like SATA Express, have been designed to address specific requirements of the SSD technology.

SSDs have no moving components. This distinguishes them from traditional electromechanical magnetic disks such as hard disk drives (HDDs) or floppy disks, which contain spinning disks and movable read/write heads. Compared with electromechanical disks, SSDs are typically more resistant to physical shock, run silently, have lower access time, and less latency. However, while the price of SSDs has continued to decline over time, consumer-grade SSDs are still roughly six to seven times more expensive per unit of storage than consumer-grade HDDs.

As of 2014, most SSDs use NAND-based flash memory, which retains data without power. For applications requiring fast access, but not necessarily data persistence after power loss, SSDs may be constructed from random-access memory (RAM). Such devices may employ separate power sources, such as batteries, to maintain data after power loss. Hybrid drives or solid-state hybrid drives (SSHDs) combine the features of SSDs and HDDs in the same unit, containing a large hard disk drive and an SSD cache to improve performance of frequently accessed data.

### 2.1 Development and history

SSDs had origins in the 1950s with two similar technologies: magnetic core memory and charged capacitor read-only storage. These auxiliary memory units emerged during the era of vacuum-tube computers. But with the introduction of cheaper drum storage units their use ceased.

Later, in the 1970s and 1980s, some early supercomputers of IBM, Amdahl and Cray used SSDs as semiconductor memory. But SSDs were seldom used because of their high price. In the late 1970s, General Instruments produced an electrically alterable ROM which operated somewhat like the flash memory. Unfortunately, many companies abandoned the technology due to the short life which is only ten years. In 1978, Texas Memory Systems introduced a 16 kilobyte RAM solid-state drive to be used by oil companies for seismic data acquisition. Then in 1979, StorageTek developed the first RAM solid-state drive.

In 1983, Psion MC 400 Mobile Computer included four slots for removable storage in form of flash-based solid-state disks. The flash modules did have the limitation of needing to be re-formatted entirely to reclaim space from deleted or modified files; old versions of files which were deleted or modified continued to take up space until the module was formatted.

In 1991 SanDisk Corporation created a 20MB solid state drive (SSD) which sold for $1,000. In 1994, STEC, Inc. bought Cirrus Logic's flash controller operation, allowing the company to enter the flash memory business for consumer electronic devices.

In 1995, M-Systems introduced flash-based solid-state drives. They had the advantage of not requiring batteries to maintain the data in the memory (required by the prior volatile memory systems), but were not as fast as the DRAM-based solutions. Since then, SSDs have been used successfully as HDD replacements by the military and aerospace industries, as well as for other mission-critical applications. These applications require the exceptional mean time between failures (MTBF) rates that solid-state drives achieve, by virtue of their ability to withstand extreme shock, vibration and temperature ranges.

In 1999, BiTMICRO made a number of introductions and announcements about flash-based SSDs, including an 18 GB 3.5-inch SSD.

In 2007, Fusion-io announced a PCIe-based SSD with 100,000 input/output operations per second (IOPS) of performance in a single card, with capacities up to 320 gigabytes.

At Cebit 2009, OCZ Technology demonstrated a 1 terabyte flash SSD using a PCI Express ×8 interface. It achieved a maximum write speed of 654 megabytes per second (MB/s) and maximum read speed of 712 MB/s.

In December 2009, Micron Technology announced an SSD using a 6 gigabits per second SATA interface.

Enterprise flash drives are designed for applications requiring high I/O performance, reliability, energy efficiency and, more recently, consistent performance. In most cases, an EFD is an SSD with a higher set of specifications, compared with SSDs that would typically be used in notebook computers. The term was first used by EMC in January 2008, to help them identify SSD manufacturers who would provide products meeting these higher standards. There are no standards bodies who control the definition of EFDs, so any SSD manufacturer may claim to produce EFDs when they may not actually meet the requirements.

In the fourth quarter of 2012, Intel introduced its SSD DC S3700 series of drives, which focuses on achieving consistent performance, an area that had previously not received much attention but which Intel claimed was important for the enterprise market. In particular, Intel claims that at steady state the S3700 drives would not vary their IOPS by more than 10–15%, and that 99.9% of all 4 KB random IOs are serviced in less than 500 µs.

### C:\Users\ZhenyuHan\Desktop\recover-data-hard-drive-1.jpg2.2 How solid-state drives work

Figure 2.1 It's easy to see this hard drive's platters, which look a bit like CDs stacked one on top of another, and an actuator arm.

SSD uses semiconductor chips, not magnetic media, to store data. Computers already comes with chips, of course. The motherboard contains some that house the device's system memory, or RAM, which is where information is stored and processed when a computer is running. The chips used in a solid-state drive deliver non-volatile memory, meaning the data stays put even without power. SSD chips aren't located on the motherboard, either. They have their own home in another part of the computer. In fact, users could remove the hard drive of their laptop and replace it with a solid-state drive, without affecting any other essential components.

On the outside, solid-state drives look just like HDDs. They're rectangular in shape, covered in a brushed-metal shell and sized to match industry-standard form factors for hard drives -- typically 2.5 and 3.5 inches (6.4 and 8.9 centimeters). But beneath the silver exterior, there are an array of chips organized on a board, with no magnetic or optical media in sight. Much of that stuff could fit into a smaller space, but SSD manufacturers dress up their components in extra "housing" to make sure they fit into existing drive slots of laptops and desktop PCs.

Compared to the stark simplicity of a solid-state drive, the innards of a hard drive are a marvel of motion, sound and activity. Round platters, arranged on a spindle, can spin at 7,200 revolutions per minute. An actuator arm, branching into multiple read-write heads, races across the platters in too-fast-to-be-seen bursts of speed. The arm connects to the actuator block, which holds the instructions for moving the read-write heads. As those instructions are called up, sometimes up to 50 times a second, the arm pivots at one end and moves the heads in unison over the platters. Once a head arrives at a certain location on a platter, an electromagnet produces a magnetic field, which aligns data-carrying domains in the underlying track. Each domain can be aligned in one of two possible directions -- 1 or 0. As these alignments change, they form patterns that correspond to discrete chunks of digital information.

The NAND flash of a solid-state drive stores data differently. Recall that NAND flash has transistors arranged in a grid with columns and rows. If a chain of transistors conducts current, it has the value of 1. If it doesn't conduct current, it's 0. At first, all transistors are set to 1. But when a save operation begins, current is blocked to some transistors, turning them to 0. This occurs because of how transistors are arranged. At each intersection of column and row, two transistors form a cell. One of the transistors is known as a control gate, the other as a floating gate. When current reaches the control gate, electrons flow onto the floating gate, creating a net positive charge that interrupts current flow. By applying precise voltages to the transistors, a unique pattern of 1s and 0s emerges.

NAND flash comes in two flavors based on how many 1s and 0s can be stored in each cell. Single-level cell (SLC) NAND stores one bit -- either a 1 or a 0 -- per cell. Multi-level cell (MLC) NAND stores two bits per cell. MLC flash delivers higher capacity, but it wears out more quickly (yes, wears out -- we'll cover that more in a couple of pages). Still, it's less expensive per gigabyte than SLC and, as a result, is the preferred technology in almost all consumer-level SSDs.

Cost has been one of the biggest hurdles of flash memory and, consequently, of solid-state drives. But in recent years, costs have dropped significantly. At the same time, advances in NAND flash development have taken what's good about the technology and made it even better. Up next, this paper will look at the advantages of solid-state drives.

### 2.3 Advantages of solid-state drives

Assume one was invested in a top-of-the-line laptop with a 500-gigabyte hard drive, and it is working great. This hard drive contains all his photos and videos, his entire music library, five half-finished novels and applications galore packed onto the drive's platters. Why would he consider swapping the HDD for a solid-state drive? Didn't Dad always say, "If it ain't broke, don't fix it"?

Maybe Dad didn't own any hard drives. The harsh reality is that HDDs can and do fail, often more frequently than their technical specs would seem to suggest. For example, hard drive manufacturers rate the reliability of their products using a measurement known as mean time between failures, or MTBF. A typical consumer hard drive has a MTBF rating of 500,000 hours, meaning that, in a sample of drives tested, there would be one failure every 500,000 hours of testing. That's one failure every 57 years, which sounds pretty good, right? Unfortunately, MTBF scores are misleading. They come from a statistical evaluation based on a small sample size and a short amount of time. In reality, you'd also want to consider a typical HDD's warranty and service life (three to five years or so), along with the MTBF score. Because they have no moving parts, SSDs can deliver improved reliability. They can rate up to 2.5 million hours MTBF, which probably means a few more years added to the lifespan of the device.

An even bigger deal is the performance of solid-state drives compared to HDDs. With no moving heads and spinning platters, SSDs can access one piece of data as quickly as any other piece, even if they aren't in the same proximity. The speediness of the device manifests itself in all key CPU tasks, from booting up system software to opening files to reading and writing data. The following bullets compare SSDs and HDDs on these critical activities:

Boot-up time (Windows 7): 22 seconds (SSD), 40 seconds (HDD)

Data read-write speed: 510-550 megabytes per second (SSD), 50-150 megabytes per second (HDD)

Excel file open speed: 4 seconds (SSD), 14 seconds (HDD)

All of this adds up. Even a casual user will notice a significant increase in the performance of a computer equipped with an SSD. But a power user will really feel the difference. Game designers, animators and other folks rendering huge output files were early adopters of SSDs just because of the cumulative time they could save reading and writing large files. Today, gamers, photographers and anyone editing graphics or video files will appreciate the boost in speed a solid-state drive delivers.

Finally, SSDs consume far less power than traditional hard drives, which means they preserve battery life and stay cooler. They're also super quiet, with none of the whirring and clicking you get with HDDs. Users will appreciate this more if they are frequent travelers and often have their computer perched on their knees, but even if their laptop remains docked most of the time, a cooler, quieter machine can make a noticeable difference in the comfort of their workspace.

Of course, no technology is perfect, and SSDs are far from it. On the next page, this paper will examine the negatives of NAND flash and why a combination of technologies may be the best solution.

### 2.4 Disadvantages of solid-state drives

Trading out the hard drive for a solid-state drive seems like a no-brainer. But before making the switch, one should understand the limitations of SSDs. Like cost. Even though prices have decreased steadily, NAND flash memory is still expensive. To get 240 gigabytes of storage on a PNY Prevail SSD, for example, one might shell out $280. That's $1.17 per gigabyte. The Western Digital Scorpio Blue HDD, on the other hand, gives him 250 gigabytes of storage for roughly $65. That works out to be $0.26 per gigabyte.

Then there's the issue of longevity. The NAND flash used in SSDs can only be used for a finite number of writes. Why? Because SSDs can't write a single bit of information without first erasing and then rewriting very large blocks of data at one time. Each time a cell goes through an erase cycle, some charge is left in the floating-gate transistor, which changes its resistance. As the resistance builds, the amount of current required to change the gate increases. Eventually, the gate can't be flipped at all, rendering it useless. This decaying process doesn't affect the read capabilities of SSD, because reading only requires checking, not changing, the voltages of cells. As a result, NAND flash can "rot" into a read-only state.

Some manufacturers use something called wear-leveling to counteract the degradation of NAND flash. This technique distributes data writes across all blocks to make sure the flash memory wears evenly, but even with that, SSDs will decay over time. NAND flash memory of the single-level cell variety generally delivers 50,000 program/erase cycles. Flash of the multi-level cell variety -- the kind used in consumer-level products -- wears out after about 5,000 cycles.

For this reason, many data centers and techies use a combination of SSD and HDD. One approach is to use a solid-state drive in a laptop and a traditional hard drive as external storage holding music, photos and other files. This combines the best of both worlds -- the ultrafast, random data access of SSD with the relatively inexpensive, high capacity of HDD. If this sounds good to consumers, they'll want to start shopping for a suitable solid-state drive. Leading manufacturers include Samsung, Seagate, SanDisk, PNY, Toshiba and OCZ Technology. And don't forget about Intel, which offers a robust line of drives, as well as several tools to help them choose the right technology and calculate how much time and money they can save if they make the switch to SSD.

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