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# The Measure of an Enclosure

## Five Factors to Consider When Choosing External Data Storage

### Introduction

When it comes to finding good, fast external storage for your data, figuring out which hardware provides the optimal data transfer speed for your buck can be daunting. In this paper, we hope to simplify the exercise for you by digesting it into five simple factors that should be taken into account.

### CHAIN OF COMMAND: THE MOST IMPORTANT THING TO KEEP IN MIND

With any kind of storage, whether it's the hard drive inside of your computer, an external hard drive enclosure, or a networked attached storage device that is accessed via your network, there will always be a chain of components that data must pass through in order to get to its intended destination.

What is this data chain? While there's no official industry name for it, it's comprised of those acronyms and words that you see on the specifications sheets of storage products you're considering purchasing; SATA, SAS, SCSI, USB Type-C, Thunderbolt™, or a combination of letters and numbers like "7200 RPM". This chain starts with the location where your data is stored and ends at the computer or workstation that it's plugged into.

It's not necessary to understand all of the ins and outs of each of these acronyms. All you really need to know is a general overview of how data is read and saved to hard drives and how fast each component in the data chain is.

## GLOSSARY OF TERMS

**Buffer –** memory used to temporarily store data while it is in the process of being transferred.

**Buffer-to-Host Rate –** The rate at which a device receives data from or sends data to its host machine.

**Cache –** see *buffer*.

**Disk-to-Buffer Rate -** The rate at which a device reads data from and writes data to the device's data storage location.

**Host –** The computer, workstation, or other device that requests data from or writes data to the peripheral devices attached to it.

**NAND Flash Memory –** A type of non-volatile storage technology used in most solid state drives that contains data.

**Platter –** A spinning disc inside of a rotational hard drive that contains data.

**Rotational Hard Drive –** A device with platters that rotate at a high rate of speed. Data is read from and written to the platters as they rotate.

**RPM –** revolutions per minute.

**Solid State Drive –** A device with no moving parts that stores data in interconnected flash memory chips.

**Throughput –** the rate at which data is sent or received.

So let's say that you have an external hard drive enclosure plugged into your computer. When you want to access the data on the external hard drive enclosure, how does it get from there to your computer where you can manipulate it? First, it is important to keep in mind that the external hard drive enclosure is not itself a "hard drive". Instead, there is a hard disk drive inside the enclosure that is separate from the enclosure itself. This hard drive first must access the data stored in itself and transfer the data into its cache. The speed at which it does so is its disk-to-buffer rate.

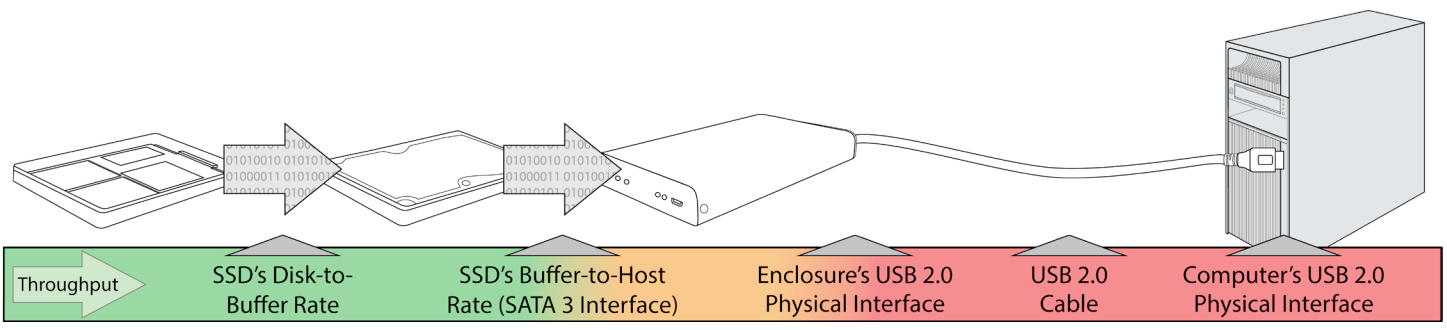
Next, the enclosure needs to send that data in the buffer through the physical interface that it uses to connect to your computer. The physical interface isn't something you would see unless you open up the external hard drive enclosure. The speed at which the enclosure sends the data through its physical interface is called the buffer-to-host rate.

Since this drive resides in an external hard drive enclosure, the data must travel from the hard drive's physical interface to the external drive enclosure's physical interface. External enclosure interfaces come in a variety of connection types, each with their own throughput rate, although the most common you are likely to find these days is some variant of the Universal Serial Bus (USB). The external enclosure's interface is the data connection port that you can see on the outside of the external hard drive enclosure. From there the data travels through a cable to a port on your computer, both of which have their own individual throughputs as well. From there the computer's motherboard ingests your data for display on your monitor. If you save data to the external hard drive enclosure, the path the data takes is reversed.

Ultimately, there is one basic rule to keep in mind: the slowest component sets the pace. In other words, your data transfer speed, or throughput, is bottlenecked by the speed of the slowest component in your data chain.

Let's show an example. But first, it is important to emphasize difference between megabit and megabyte. A megabit is 1/8th of a megabyte . They are often abbreviated as Mb/s and MB/s, respectively, but because these terms are easily confused, CRU® uses the longer abbreviation "Mbps" to represent how many "megabits per second" a device can transfer and the shorter "MB/s" to

**Figure 1.** Illustration of a data chain from a solid state drive through a USB 2.0 cable and into a computer workstation.



represent how many "megabytes per second" a device can transfer.

Let's say you have a SATA 3 solid state drive (or 'SSD') installed in an external USB 2.0 hard drive enclosure. The data chain goes from the data on your SSD, to the SSD's SATA 3 interface, to the USB 2.0 interface in the enclosure, and from there through a USB 2.0 cable to the USB 2.0 interface on your computer.

The disk-to-buffer rate of an SSD is very fast and will probably be the fastest component in your data chain. Next, take a look at the chart in the sidebar, and you will see that the throughput for the SSD's SATA 3 interface is 6 Gbps, which means that the SATA 3 interface determines how fast your SSD will perform. The drive's SATA 3 throughput is also the SSD's buffer-to-host rate.

If you look at the throughput for the external hard drive enclosure's USB 2.0 interface, you'll see that it is 480 megabits per second (Mbps), which limits your data throughput to a tenth of what it could be! Since both the cable and the port on the computer are USB 2.0, those speeds are also 480 Mbps. This speed downgrade is drastic, so you'd never want to put an SSD into a USB 2.0 enclosure. But it serves as a prime example of why getting the fastest, newest technology out there may not be a wise use of resources if you can't also upgrade the plumbing.

After all, sometimes you may have to use something slow like USB 2.0, especially on older computers. Adding a USB 3 adapter won't help you either if anything in your data chain still uses USB 2.0 components. That's because a faster adapter can't speed up a data transfer that's coming into it at a slower speed. So when you are choosing storage for your business or project, investigate all of the interfaces in the data chain you're constructing and keep in mind that the slowest interface sets the pace!

## MAKING SENSE OF USB

Today there are many types of USB connectors and standards available. USB 1.0 is the slowest version, and along with USB 1.1 are obsolete. USB 2.0 uses connectors that are identical in shape to USB 1.0 and 1.1, but is able to transfer data at 480Mbps and is the most widely adopted USB standard to date. USB 3.0 connectors are easily distinguished by their blue markings and can transfer data at up to 5 Gbps when connected to a USB 3.0 compatible host. USB 3.1 is able to transfer data at 10Gbps, double the speed of USB 3.0, and its connectors can be mechanically identical to USB 3.0.

## CHART OF DATA THROUGHPUT RATES

| INTERFACE | THEORETICAL THROUGHPUT (in MB/s) | THEORETICAL THROUGHPUT (in Mbps/Gbps) |
|---|---|---|
| FireWire 800 | 100 MB/s | 800 Mbps |
| Fibre Channel | 2000 MB/s | 16 Gbps |
| eSATA (SATA 2) | 300 MB/s | 3 Gbps |
| eSATA (SATA 3) | 600 MB/s | 6 Gbps |
| PCI Express® 1.0 | 250 MB/s per lane* | 2 Gbps |
| PCI Express 2.0 | 500 MB/s per lane* | 4 Gbps |
| PCI Express 3.0 | 985 MB/s per lane* | 7.88 Gbps |
| PCI Express 4.0 | 1959 MB/s per lane* | 15.672 Gbps |
| SAS 6 Gbps ** | 600 MB/s | 6 Gbps |
| SAS 12 Gbps** | 1200 MB/s | 12 Gbps |
| SATA | 150 MB/s | 1.5 Gbps |
| SATA 2 | 300 MB/s | 3 Gbps |
| SATA 3 | 600 MB/s | 6 Gbps |
| USB 1.0 | 1.5 MB/s | 12 Mbps |
| USB 1.1 | 1.5 MB/s | 12 Mbps |
| USB 2.0 | 80 MB/s | 480 Mbps |
| USB 3.0 | 625 MB/s | 5 Gbps |
| USB 3.1 | 1250 MB/s | 10 Gbps |
| USB Type-C | 1250 MB/s | 10 Gbps |
| Thunderbolt | 1250 MB/s | 10 Gbps |
| Thunderbolt 2 | 2500 MB/s | 20 Gbps |
| Thunderbolt 3 | 5000 MB/s | 40 Gbps |
| | | |
| 7200 RPM Rotational Drive Disk-to-Buffer Rate | 180 MB/s | 1.44 Gbps |
| SSD Drive Disk-to-Buffer Rate | Really Fast***[5] | Really Fast*** |

*PCI Express cards contain one to 32 lanes. To determine the total possible transfer speed of a PCI Express card in your data chain, multiply the transfer speed rating listed above by the number of lanes the card has.

**There are many types of SAS interface connectors, each beginning with "SFF-" and then a number to denote the connection type. Like PCI Express, some connectors combine more than one SAS lane. The measurement listed here shows the throughput for a single lane.

***There is no solid measurement that we could find for an SSD's disk-to-buffer rate. The closest we could find was a study that measured the performance of various NAND flash memory devices, which is the same type of memory that most SSDs use. Device performance was measured in microseconds. This basically means that an SSD's disk-to-buffer rate will outperform any known buffer-to-host interface like SATA, SAS, and so on, and thus the SSD's overall throughput will be limited by the SSD's buffer-to-host rate.

## USB 3.1: THE NEXT FRONTIER

The USB 3.1 specification defines three aspects that are going to change how we think of data connectors, or interconnects. The first is the data transfer rate of 10Gbps, twice as fast as USB 3.0.

Next is the ability to deliver power to any device that it's plugged into. In its fullest implementation, USB 3.1 can deliver up to 100W of power in either direction, depending on what the controller in the cable is sensing. For example, a USB 3.1 hard drive plugged into an AC power source can deliver power to a laptop that needs it. Likewise, power can be provided to a bus powered hard disk drive or printer, eliminating the need for a separate power brick to power each device.

Finally, USB 3.1 also brings with it the flippable Type-C universal connector. The Type-C connector has no up or down orientation, so there is no more guesswork on which way to plug in your USB Type-C cable.

Because these three elements can be implemented independently, there is potential for confusion in the marketplace early in the rollout of USB 3.1. However, since it is an open standard, it has the possibility of greatly influencing and changing how we think about external storage and other devices connected to our computers.

For example, Intel's Thunderbolt 3 standard makes use of the Type-C connector, but will also deliver a transfer rate of up to 40 Gbps. This will allow a single Thunderbolt 3 Type-C cable to drive up to two 4K displays at 60 Hz. Thunderbolt 3 can also be used with USB 3.1 devices[1].

## DATA TRANSFER RATINGS ARE A "BEST GUESS"

Further complicating the issue is the fact that throughput ratings are theoretical and do not take into account the overhead of the information transfer protocol being used, among other factors. The transfer protocol is the code that allows data transfers to take place, and it must be sent along with the data being transferred, which decreases how much of your data can be sent at a time. For example, the fastest SSDs measured today top out around 550 MB/s[2], or 4.4 Gbps, even though they theoretically could max out at the 6 Gbps throughput of their SATA 3 interface. This mismatch between theoretical throughput and real-world performance is due to factors such as this.

While each throughput rating for each interface is fairly accurate in comparison to other interfaces, you should always keep in mind that they are optimistic approximations of the performance you will get in a best-case scenario.

## OTHER FACTORS THAT IMPACT TRANSFER RATE

Among the factors that affect the speed of your data transfer rate, the biggest is the difference between a rotational hard drive and an SSD. The fastest 7200 RPM rotational hard drives—which are the most common type of rotational hard drive used in consumer-grade computers today—will top out around 180 MB/s, whereas the fastest SSDs top out around 550 MB/s.

When it comes to choosing a hard drive, you can also consider how much cache memory it has, its rotational speed, and its access time. Most people will want the largest amount of cache memory and rotational speed as well as the lowest access time. However, these considerations are not as important as the overall transfer rate of your data chain. Therefore the simplest way to ensure that you purchase a CRU product that performs the way you want is to pay attention to the transfer rates of the interfaces you'll be using in your data chain. Here is a brief overview of these factors:

### Cache Memory

The cache memory is its "buffer". It's where the data is stored temporarily until it is sent on to the host

computer. We referred to this earlier when discussing the hard drive's disk-to-buffer and buffer-to-host rates.

**Rotational Speed**

Rotational speed refers to how fast the platters on a rotational hard drive spin and is measured in revolutions per minute (RPM). The most common consumer-grade rotational drive types today are 7200 RPM drives and 5400 RPM drives, although the fastest available are 15,000 RPM drives, which are typically used in high-end servers. The higher the rotational speed, the lower the access time and the better the drive performance.[3] SSDs do not have platters, and so they do not have a rotational speed rating. Instead most SSDs in use today have NAND flash memory.

**Access Time**

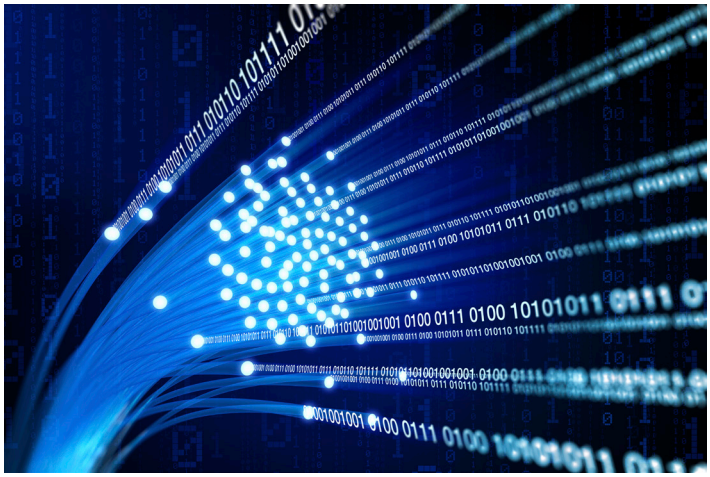
A hard drive's access time describes in milliseconds how fast the drive can locate data on the disk. For rotational drives, this rate fluctuates between 5 and 10 ms[4] depending on whether the data is located toward the inside or the outside of the disc platters. An SSD's NAND flash memory allows nearly instantaneous data access.

## CONSIDER THE APPLICATION

Lastly, and while certainly not least, you will have to decide or at least note how you are going to be using your external storage. Not all applications of external storage require the most complex interfaces or the fastest speeds available. For example, if you're backing up your laptop overnight, then you may not need an enterprise-level solution like a SAS host interface connected to your computer in order to do so. A standard USB 3 host interface with rotational hard drives deployed a mirrored RAID configuration, like what can be found in several of our RTX® and RAX® products, will serve most small business requirements.

The advantages provided by a SAS interface, which include transferring data to and from a device by multiple users simultaneously, are not typically needed for most backups, but may sometimes be useful in larger enterprise applications such as online transaction processing.

Furthermore, purchasing SSDs for a backup solution may prove too costly compared to purchasing rotational drives, since an SSD's blazing speed is not needed if your backups occur overnight or in the background as you work. The capacity of an SSD is also smaller than the average rotational hard drive, and so the cost per megabyte is much higher than that of a rotational hard drive.



In short, you can save yourself some cash and perhaps a few IT headaches by purchasing the simplest solution that covers your bases.

## FIVE FACTORS TO CONSIDER

Your data is important to us, and our business is to help you find solutions that help you retain that data and to access it in a way that best serves your particular needs.

- You should always consider the throughput of each component that makes up the data chain connecting the data on your drives to your computer workstation or network. The slowest component in the chain "sets the pace" and will determine your overall data transfer rate.
- Choose the correct interface for your requirements, keeping in mind that there are many types of USB, and that each one performs differently.
- Keep in mind that although the transfer ratings of each product, component, or interface are roughly accurate relative to each other, they are based on theoretical best-case scenarios.
- SSDs are much faster than rotational drives. Other factors such as each hard drive's cache memory,

rotational speed, and access time can also slightly impact performance.

- You should also consider what your external storage will be used for, as this will allow you to determine what to purchase without wasting money on features that will give you little to no benefit for their cost.

Keep these five factors in mind, especially that the slowest transfer rating sets the pace, and you will be well on your way to finding the best external storage solution for your needs.

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