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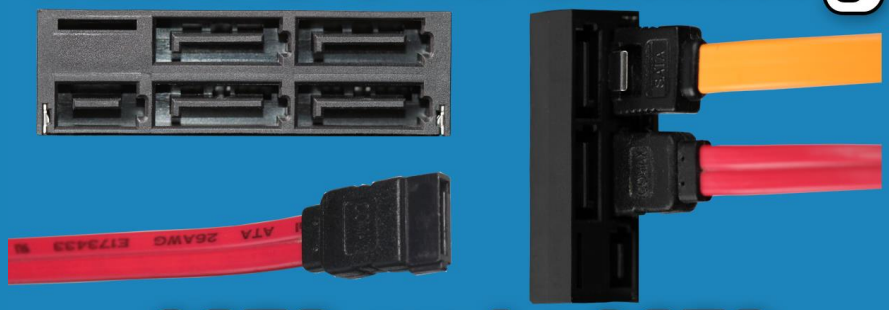

SATA and eSATA

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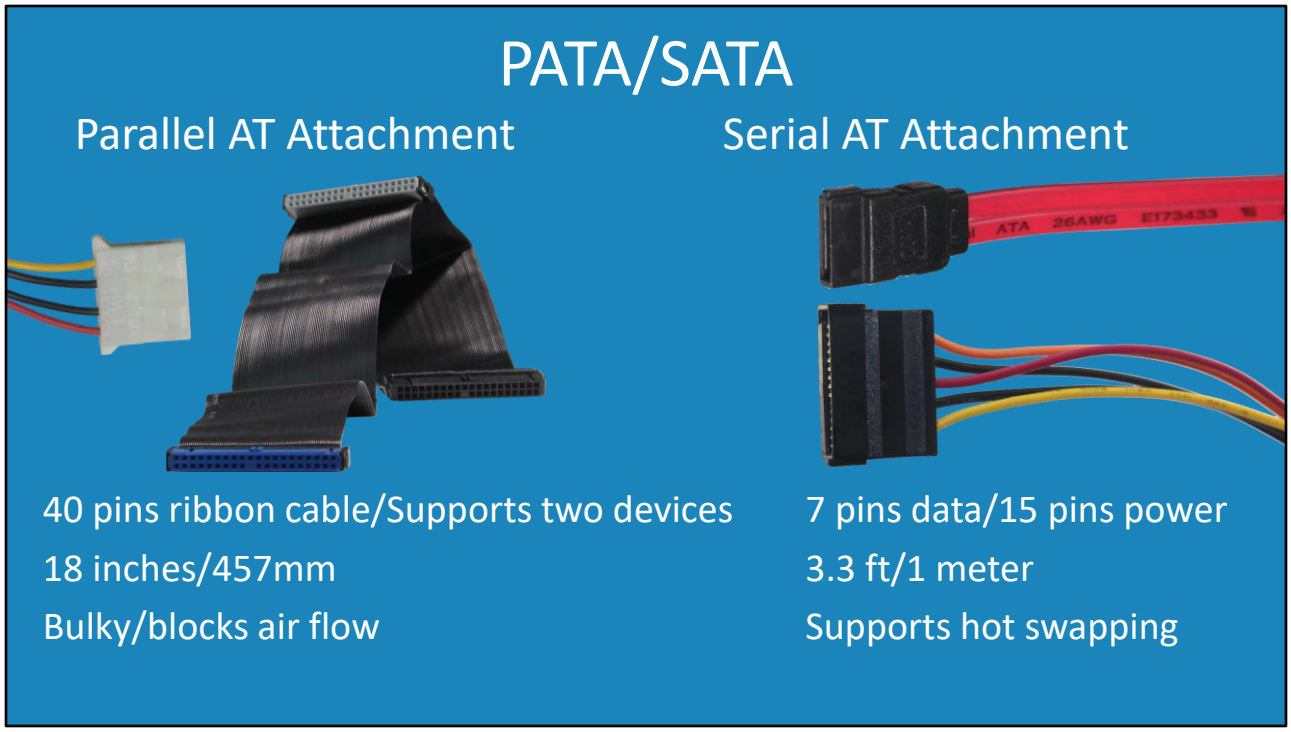
In this video from ITFreeTraining I will look at SATA and eSATA. SATA has become the dominant connection used to connect internal storage devices in computers so it is important to know about it.



0:11 To understand SATA better, let's first look what was used before SATA. Parallel AT Attachment or PATA was first developed in 1986. It used a 40-pin ribbon cable that could support two devices on the same cable. The cable transferred 16 bits at a time in parallel. It was powered by the Molex power plug. Traditionally the Molex connectors were white in color. Generally, you will find that power supplies sold on the market today will have a few Molex power connectors.

The cable itself has a maximum length of 18 inches or 457mm. Although not a bad length, in modern computers with large expansion cards and other objects in the way, this can make it difficult to connect devices to the cable. This gets more complex if you want to remove a device from a computer. Due to its short length, you may need to disconnect the cable from the computer or disconnect the cable from another device to remove the device from the computer. This makes it harder to plug in and unplug devices.

The ribbon cable is also quite bulky and thus can block air flow. The PATA cables were the dominant cable until the year 2000 when the SATA cable was released. SATA stands for Serial AT Attachment.

The SATA connection uses a 7-pin data connector and a 15-pin power connector. It increases the length of the cable to 3.3ft or 1 meter. There were a lot of small improvements; the biggest improvement was that SATA supports hot swapping. Hot swapping is being able to plug in an unplug storage devices without having to switch the computer on or off.

Hot swapping requires a few things. First, the computer or the device not being damaged when it is installed. This can occur with electronics when something is first plugged in, as there may be a rush of power to the device. The second thing hot swapping requires is for the device and the operating system to be able to recognize a device was installed or removed. Although hot swapping is officially supported, it sometimes won't work. For hot swapping to work, it requires the motherboard, BIOS and operating system to support it. You won't damage anything by plugging it in and giving it a go, and if it fails to work, give the computer a restart and it should detect the device.

Let's have a closer look at how SATA works.

Data Connector

- L-shaped connector
- Uses differential signaling

Plug

Connector

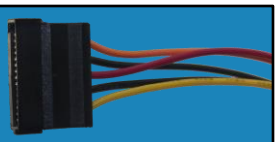
Pin	Function
1	Ground
2	A+ (Transmit)
3	A- (Transmit)
4	Ground
5	B- (Receive)
6	B+ (Receive)
7	Ground
-	Keying notch

2:35 The SATA data connector is an L-shaped connector. This prevents it from being plugged in the wrong way. The data connector has seven pins. The data is transmitted using differential signaling. Differential signaling uses two wires to transfer data. This helps reduce noise and data corruption at high speeds – something that is essential when you are using serial communication. The other pins in the cable are ground pins.

Since two pins are used for transmitting data and two for receiving data, this essentially means that SATA has one data channel. When differential signaling is used and there is bi-directional transfer like this, it is often referred to as a lane of data. So essentially SATA supports one lane.

There are other data cables on the market that use more than one lane. This is one of the reasons, which I will cover in more detail later in the video, why it is unlikely in the long term that SATA will continue to be used.

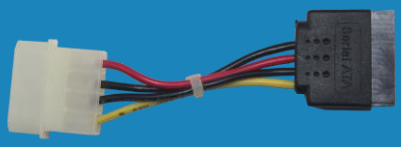
SATA Power Connector



- L-shape connector
- Adds 3.3 volts

Plug

Connector



Does not include 3.3v
(Very few storage devices use it)

Pin	Function
-	Keying notch
1	3.3V Power
2	
3	Enter/Exit power disable
4	Ground
5	
6	
7	5V pre-charge
8	5V power
9	
10	Ground
11	Staggered spinup/activity
12	Ground
13	12V pre-charge
14	12V Power
15	

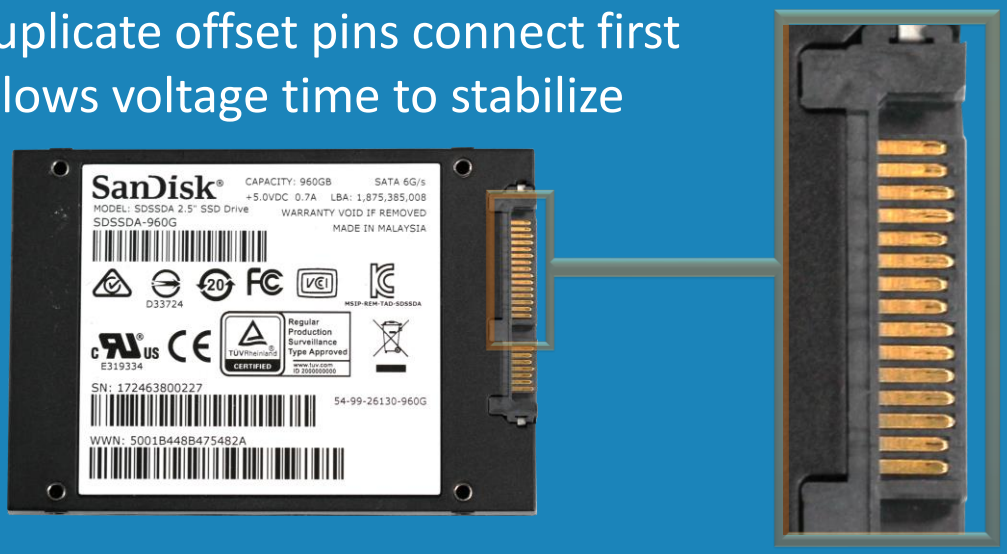
3:36 The SATA drives use a new power connector. Like the data connector, this connector is an L-shaped connector, so you won't be able to plug it in the wrong way. This power connector has 15 pins. It contains 12 and 5 volt pins that were traditionally provided by the Molex power connector. However, it also adds a 3.3 volt pins.

Since it contains an extra voltage, if an adapter is used to convert Molex to SATA power, it will not include the 3.3 voltage. However, this is generally not a problem because very few storage devices use the 3.3 voltage option.

We know that SATA supports hot swapping, so next I will look at how this is supported, particularly now that we have up to three different voltages on the one power connector.

Hot Swapping

- Duplicate offset pins connect first
- Allows voltage time to stabilize

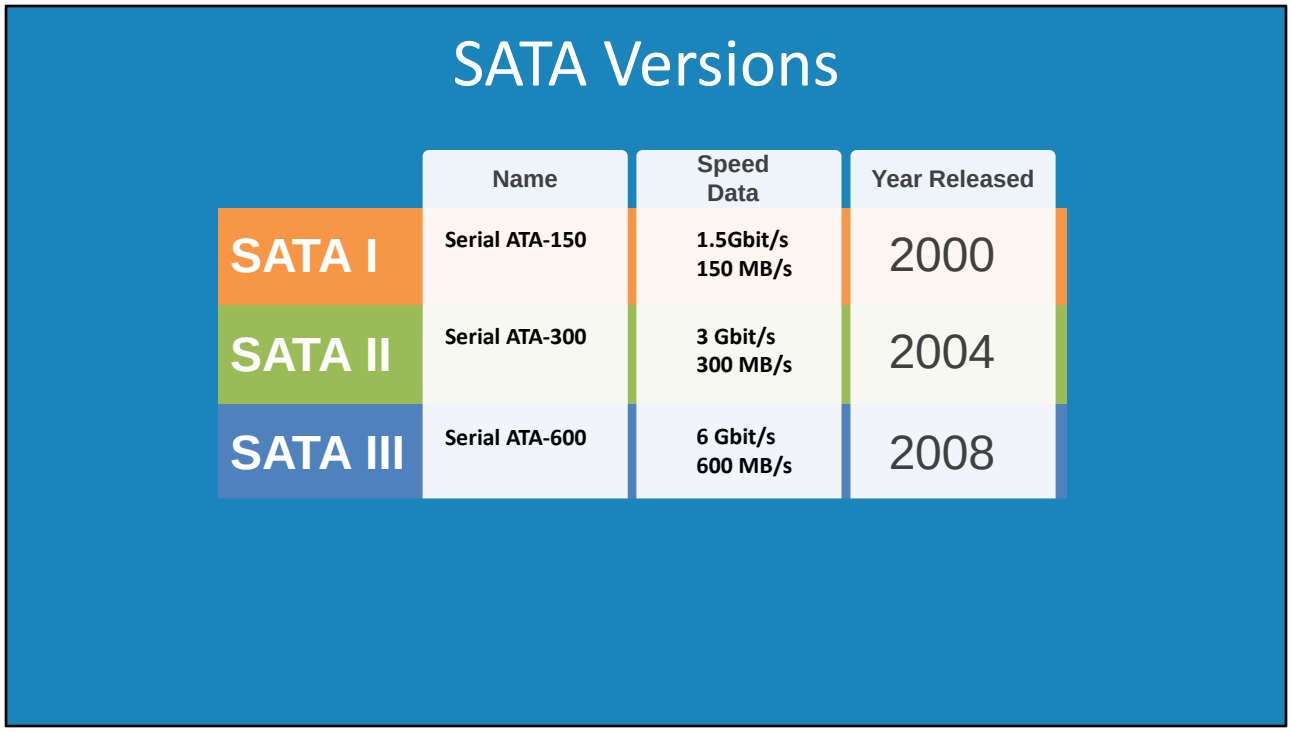


4:24 The main issue with hot swapping is the potential for the device to be damaged when it is plugged in, due to an unstable voltage. To prevent this occurring, the SATA connectors have duplicate offset pins which connect first when the device is plugged in.

You can see that the pins on the SATA connector are two different lengths. The long pins connect first. These long pins are connected to different circuits in the device which are designed to handle power spikes and unstable voltages. This can be a problem when the device is first plugged in. Having these longer pins gives the device a small amount of time to allow the voltage to stabilize.

The shorter pins connect next and are connected to the electronics in the device itself. You can understand why there are duplicate pins on the connector. The duplicate pins are there to simply give the device a split second to stabilize the voltage. If this was not done, potentially when the device is plugged in, a power spike could damage the electronics in the device.

Since SATA first started being used, there have been three different versions released. I will next have a look at the different versions of SATA.



5:34 The first version of SATA was released in the year 2000. This version operated at speeds of 1.5 Gigabits per second. Although it can transfer 1.5 Gigabits per second, SATA uses an encoding scheme to transfer data to help reduce the chance of errors. This encoding scheme takes about 20% of the bandwidth. When this overhead is taken into account, the actual maximum data that can be transferred per second is 150 Megabytes per second.

Although everyone calls it SATA I, its official name is Serial ATA 150. Sometimes on product documentation you may see it referred to as this. If you have not guessed, the 150 in the name is named after its speed which is 150 Megabytes per second.

In 2004, the second version of SATA was released. This doubled the speed to 3 Gigabits per second and transferred data at 300 Megabytes per second. The committee that worked on the specification was called the SATA II committee. Thus, the marketing name used was SATA II. The official name for SATA II is Serial ATA 300. For your information, the SATA committee now has the name SATA-IO so as not to cause any more confusion in the future.

The next version of SATA was released in 2008. This version, commonly called SATA III, once again doubled the speed to 6 Gigabits per second, and allowing data transfers of 600 Megabytes per second.

At this stage, you are probably expecting the next version to be SATA IV, however it is actually SATA Express or SATAe. SATA Express interfaces directly into PCI Express. It allows access to two PCI Express lanes and thus gives a maximum speed of 16 Gigabits per second or close to 2000

Megabytes of data per second. If you want to be precise, max speed is 1969 Megabytes of data per second.

To use SATA, you just need to plug in the data cable and the power. SATA I, II and III use the same plugs and are backwards compatible; however, SATA Express is a little different. Let's have a close look at SATA Express.

SATA Express (SATAe)

- Connects directly to PCIe

PCI Express version	Introduced	Transfer speed	Encoding	Throughput
PCI Express 1	2003	2.5 GT/s	8b/10b	250 MB/s
PCI Express 2	2007	5.0 GT/s	8b/10b	500 MB/s
PCI Express 3	2010	8.0 GT/s	128b/130b	984.6 MB/s
PCI Express 4	2017	16.0 GT/s	128b/130b	1969 MB/s
PCI Express 5	2019	32.0 GT/s	128b/130b	3938 MB/s
PCI Express 6	2021 (Estimate)	64.0 GT/s	128b/130b	7877 MB/s

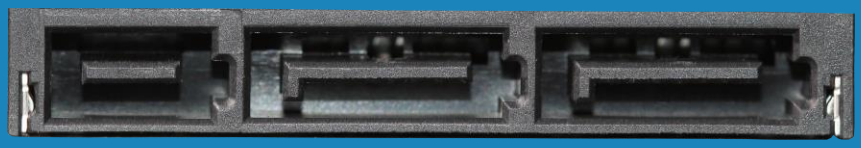
7:53 SATA Express differs from traditional SATA in that it connects directly into the PCI Express bus. Devices like the M.2 solid-state drives utilize this in order to communicate with the motherboard. This allows the device to communicate at PCI Express speed. Shown here are the PCI Express speeds. SATA 3 allows for speeds of 600 Megabytes per second. You can see that PCI Express 3 allows for speeds of over 600 Megabytes per second when compared with SATA 3.

Since there have been power and other related problems creating a specification for SATA 4, it is possible a SATA 4 specification will never be released. We will probably see SATA using PCI Express more and more. You can see that with each version of PCI Express, in most cases, the speed is double that of the previous version. If more speed is required than the version allows, multiple lanes can also be used. However, generally solid-state devices only require the one lane as PCI Express provides enough speed for solid-state drives. You can see how much potential there is using PCI Express.

Devices like M.2 were created to be used inside a computer. However, there was a version of SATA Express that was designed to be used outside the computer, so let's have a look at that.

SATA Express Connector

- Introduced in SATA 3.2
- Allows 16 Gbit/s speeds utilizing two lanes



Utilized both plugs as one connection

Two SATA connectors can be used for SATA

9:16 Back in 2013, high end consumer solid-state drives had reached the limit of what SATA 3 interfaces could transfer data at. With the technical problems of implementing SATA 4, and also a lack of other alternative technology, there was, for a short time, a need for something else to bridge the gap.

With the introduction of SATA 3.2, a SATA Express connector was also introduced. Essentially it has a plug, shown on the left, that adds some additional pins required for PCI Express. Next to this are two SATA plugs.

To use the SATA Express connector at full speed, a cable is plugged in which uses all three of these ports. SATA and PCI Express both use differential signaling to transmit data. This means, to support both directions, a minimum of four data pins and four ground pins are required. In order to get higher speeds, SATA Express uses two lanes. This allows for speeds of up to 16 Gigabits per second. Since one SATA connection does not have enough pins to support two lanes, two SATA connectors are used. One lane essentially travels over each SATA connector. The third connector provides some additional wires required by PCI Express.

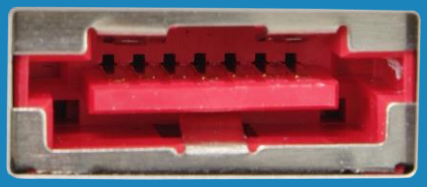
To allow for backwards compatibility, the two SATA plugs can also be used for SATA connectors. The SATA Express connector, at the time, allowed for faster speeds than what SATA 3 could provide. However, as time passed, other alternatives started coming onto the market. In particular, improvements to external connectors like USB allowed for higher speed devices to be connected outside the computer. The end result, SATA express connectors only appeared briefly on high-end motherboards. Nowadays, the SATA Express connectors are no longer

included on motherboards. Essentially, the SATA Express connector provided increased speed when the market required it; However, as other technologies improved, it was no longer needed.

The SATA Express connector is sometimes referred to as SATAe.

eSATA

- External non-powered connection
- Cable length of two meters (Shielded)
- Standardized 2004/Almost gone by 2017



Plug

Connector

11:26 The next connector that I will look at is eSATA, not to be confused with SATA Express. The 'e' stands for external and essentially is an external non-powered SATA connection. The plug is different from the SATA connection as it does not use the L-shaped connector. However, electrically the plug is compatible with the standard SATA connection.

The difference is that the plug is designed to allow storage devices external to the computer to be connected. The cable length is increased to two meters and uses a shielded cable. If you compare the cable with a standard SATA cable you will notice that the eSATA cable is thicker than the standard SATA cable. This reduces the interference that may affect the cable, making it more reliable over a longer distance. The disadvantage is, that since the cable is thicker, it is less flexible than the standard SATA cable.

eSATA was standardized in 2004 and it started to appear on some computers. Standardization essentially means a standard for manufacturer has been agreed on. Until standardization occurs, different manufacturers may be following different standards, leading to compatibility problems.

With the release of USB 3, this replaced the need for eSATA so it started disappearing. By 2017, it was pretty rare to see an eSATA port on a computer.

In the real world you will rarely come across an eSATA port, but you may get asked a question on it in the exam.

eSATAp

- Power over eSATA
- Hybrid supports eSATA or USB

eSATA cable

USB cable

12:54 The last SATA port I will look at is the eSATAp. This is also known as power over eSATA as essentially it provides power over the cable. You may also see a hybrid version of this port which supports USB as well. This plug allows you to plug in an eSATA cable in the port or a USB cable.

The port is keyed in such a way that either cable can be put in. The computer will auto detect the connection and then use the required interface controller depending on what is plugged in. Generally, this type of connection can be seen on laptops, but given how popular USB has become, you are more likely to have a USB plug rather than a hybrid plug like this.

Well that covers it for all the different plugs and versions of SATA.

AHCI

- Advanced Host Controller Interface
- Replaces Parallel ATA (IDE Mode)
- Extra features like hot swapping/queuing

Designed for spinning drives

Not optimal for solid-state drives

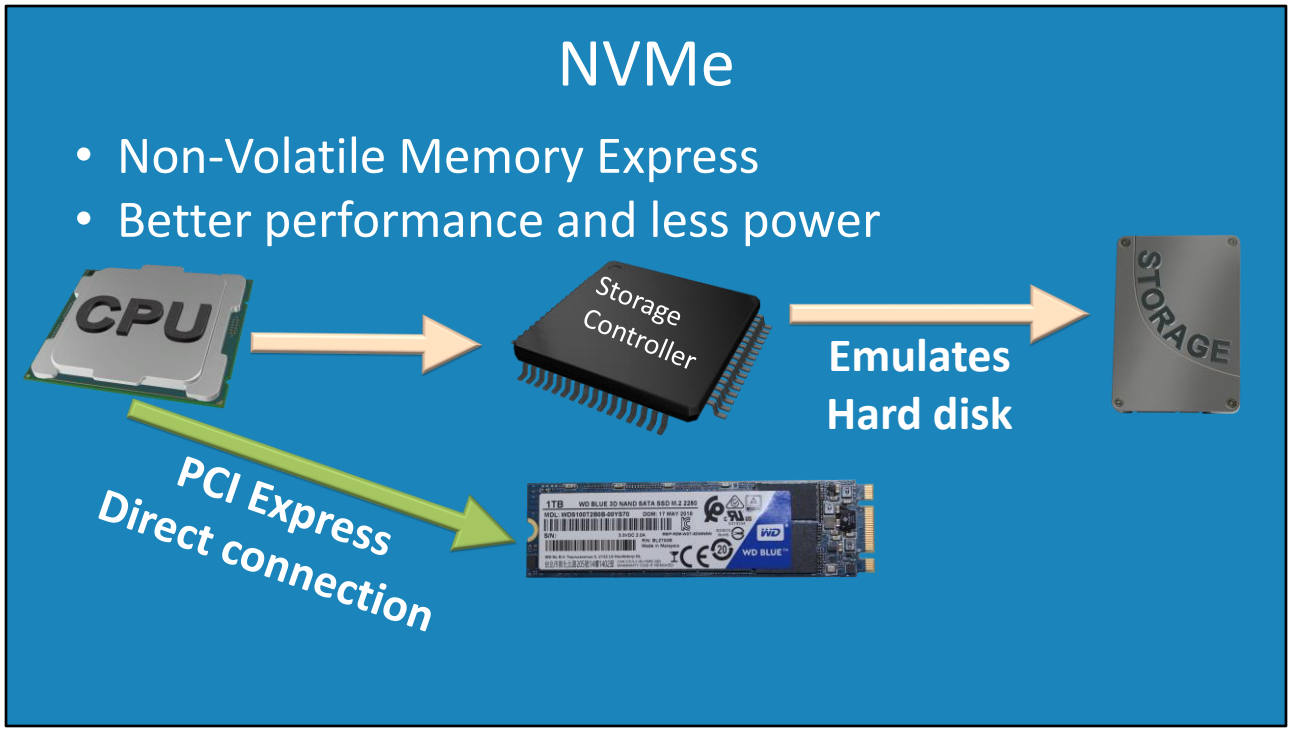
13:41 I will now have a look at what controls SATA. This will allow us to have a better understanding of the limitations of SATA and why it is unlikely that we will see SATA IV in the future.

The standard that is designed to control SATA is AHCI or Advanced Host Controller Interface. When it was created, hard disks were the dominant storage technology used, and solid-state was not on the market yet. For this reason, AHCI was designed with spinning drives in mind. It can be used with solid-state drives; however, it will not give optimal performance.

AHCI replaces the older standard used for Parallel ATA. This will often be called IDE mode in the BIOS. If you have this mode selected in the BIOS, your hard disks and solid-state drives will still work, but they will underperform. AHCI also adds additional options like hot swapping and queuing.

Nowadays, you should just leave it on the AHCI option unless you are having problems. Be careful, if you decide to change the option after installing Windows, Windows may fail to start up or blue screen.

With the number of solid-state drives increasing, you can start to see why SATA IV is unlikely to ever be released. For SATA IV to stay compatible with other versions of SATA it would need to support AHCI, and AHCI was never designed to run with solid-state-drives. As solid-state drives get faster and faster, this become more of a performance problem.



15:17 For this reason, with newer motherboards, you are starting to see NVMe or Non-Volatile Memory Express. Since this was designed with solid-state drives in mind, the performance is better and it also uses less power. If a SATA IV standard were to be created, it would not be able to perform at the same level. This is because SATA IV would be limited by the older AHCI protocol, and in order to get higher speeds, the power would need to be increased. It became clear that with solid-state drives, to get the best performance, a new way of accessing the solid-state drive needed to be designed.

I won't go into much detail about this, since this video is about SATA drives, but the process is like this. The CPU using NVMe connects directly to storage using a PCI Express direct connection. Since PCI Express supports multiple lanes, the storage device can transfer multiple data streams to the CPU at the same time. Hard disks, in contrast, have a head that needs to be positioned to read and write data. Thus, only one command on the hard disk could be actioned at one time. Solid-state technology can potentially handle multiple read and write commands at the same time.

If we compare this to SATA, the CPU must first connect to a storage controller. The storage controller then connects to the storage device. If the storage controller is connecting to a solid-state drive, this means that the solid-state drive needs to effectively emulate how a hard disk works since either could be connected.

You can start to see what the performance problems are. The CPU cannot directly connect to the storage device which slows the process down. The storage controller protocol is not

designed to perform multiple reads and writes at the same time, which solid-state drives are able to do; thus the performance will be less. To get the best performance, we will most likely see more NVMe connections in the future. Will this replace SATA in the long term? Time will tell, but most likely as time passes, you will see less and less SATA connections on a motherboard. These SATA connections will get replaced with NVMe or something else, but I doubt very much they will be replaced with SATA IV.

That covers it for SATA. I hope you have found this video helpful. Until the next video from us, I would like to thank you for watching.

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