ITFreeTraining

Universal Serial Bus (USB)

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In this video from ITFreeTraining I will look at the Universal Serial Bus or USB. USB standardized the connections to peripherals and has become very popular. Due to its popularity, it is essential for the IT technician to have a good understanding of how USB works.

Universal Serial Bus (USB)

- Released in 1996
- Provides connections between peripherals/devices
- Hot swappable (No reboot required)
- Auto configurable

0:19 Universal Serial Bus or USB was released in 1996. It provides connectors and cables to connect peripherals and devices. USB was originally designed to replace the PS/2 plug which was used for the keyboard and mouse.

The PS/2 connector was limited to only being able to be used for keyboard and mouse. USB was designed to support any device that was manufactured to be compatible with USB. For example, USB could be used for USB sticks, connecting printers or even your mobile device.

USB was designed to be hot swappable. This means that you can connect and disconnect devices from your computer without rebooting the computer. USB is also auto configurable. In the old days of computing, interrupts, ports and other settings would need to be configured. However, with USB the resources the device requires are automatically allocated.

Nowadays, USB has become very popular and it would be hard to find a computer that does not have at least one USB port. USB is used to connect every device you could think of to your computer. Let's have a look at how it works.

USB Host Controller

- Provides interface to communicate with hardware
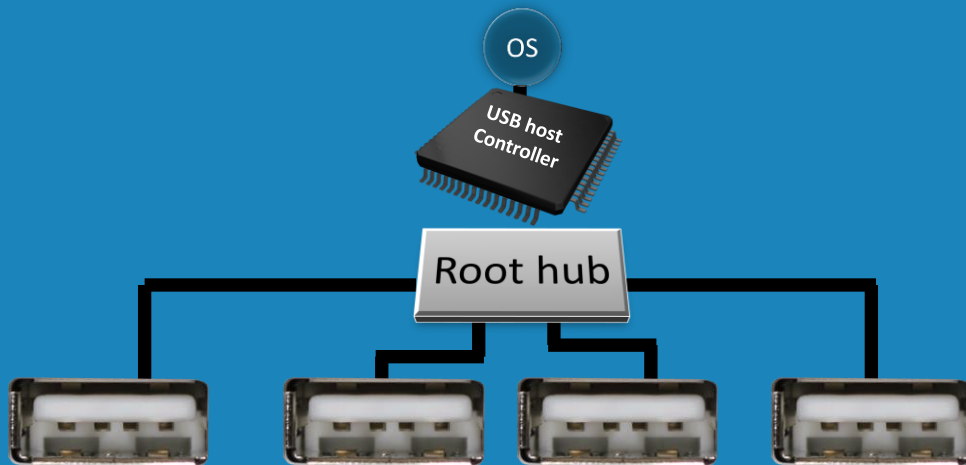
1:33 At the heart of USB is the USB host controller. The USB host controller provides an interface to communicate with the hardware. Each host controller has one root hub. Regardless of how many USB controllers you have, the operating system will communicate with the USB controller using a standard interface.

In this example, there is one chip in the computer that provides a USB host controller. Nowadays, the USB Host Controller will not be a separate chip but will most likely be found in the North Bridge. In some motherboards the newer faster USB 3 controller would be found in the North Bridge and the older slower USB 2 controller would be found in the South Bridge. I will look at the different versions of USB later in the video.

Regardless of how many USB controllers you have on your motherboard, their versions and if they are on one chip or more, they essentially work the same way.

Each USB Host controller can support a maximum of 127 devices. In the real world it is unlikely this maximum will be reached for a number of reasons which I will look at later in the video. To manage a large number of devices using the one USB host controller, each USB host controller has one or more root hubs.

In this example, you can see the USB host controller is connected to the root hub. The root hub is then connected to the physical USB ports. The USB host controller may support more physical ports than what are available on the motherboard. It is up to the manufacturer of the motherboard to determine how many physical ports they are going to support.

Now you may be thinking, if one controller can potentially support 127 devices, there are no motherboards on the market that have anywhere close to 127 USB connectors. There are motherboards that have 16 USB connectors, which should be enough. So, let's have a look at why you would need to support so many.

USB Hub
- Expands single USB port into multiple ports

Upstream port
(Connected to computer)

Downstream ports
(Connected to devices/other hubs)

3:42 USB has the ability for one port to be expanded to many ports. This is the same principal as a power strip. Shown here is a USB hub. This USB hub allows one USB connection to be split into four connections. USB hubs can be separate devices like this one or can be included in devices like computer monitors and keyboards.

The USB hub has an input port which is referred to as an upstream port. This will be connected directly to the computer or another USB hub. In the case of this USB hub, there are four downstream ports which devices or other USB hubs can be connected to. In this case, a USB thumb drive is connected to one of the ports. Another one of the ports is connected to a second hub.

In a previous video, we looked at what would happen if you connected multiple power strips together. Let's have a look at the problem that may occur if you connect multiple USB hubs together.

Multiple USB Hubs
- Allows up to five tiers (Maybe)
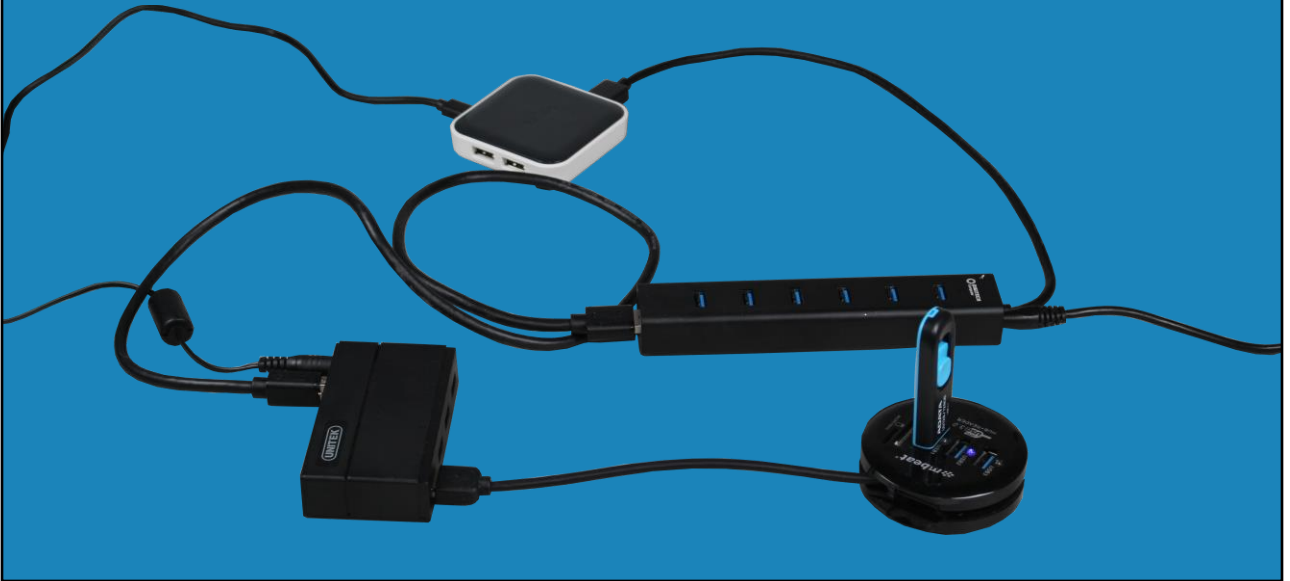
4:45 USB is designed to allow up to five tiers. In this example, you can see that I have connected four USB hubs together. When I did this, the computer was able to access the USB stick plugged into the last USB hub. The point to remember is that the computer contains a root hub. This root hub is essentially the first hub in the chain. So essentially this means that a maximum of four USB hubs can be added, the one inside the computer, plus four additional ones making a total of five.

USB officially supports five tiers, but this may or may not work. I would not recommend daisy chaining USB hubs together like this. Computers nowadays come with a lot of USB connectors. If you need more USB connectors then you increase the number with a USB hub. If you need two or more USB hubs, consider plugging each USB hub into different USB ports rather than daisy chaining them together. Let's have a closer look at how USB works and thus why we may have problems daisy chaining devices together.

USB Power

- 500mA power supplied from computer

One port can use 100mA to 500mA
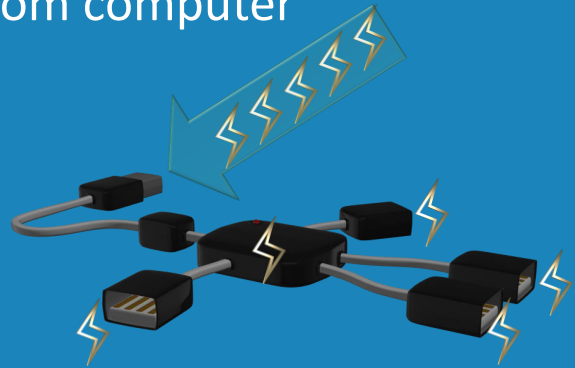
USB Hub uses 100mA

Each port uses 100mA (Max four ports)

5:55 The first problem you may encounter when daisy chaining USB devices together is power. A single USB port on your computer will supply 100 to 500 milliamps of power. Essentially when you plug devices into your computer, the device will use a minimum of 100 milliamps but can draw up to 500 milliamps if it requires it.

The device that is used will determine how much power it will require. Devices that do not have an external power supply will most likely require more power. For example, a USB hard disk that draws power from the USB is most likely going to use more power than a USB stick, as it needs power to spin the hard disk platters.

Now let's consider what happens when you use a USB hub. Like before, the USB can draw up to 500 milliamps of power from the computer. In order to power the USB hub, 100 milliamps are required. Each port will use a further 100 milliamps. This essentially means that a basic USB hub is limited to four ports as power is divided up as follows: 100 milliamps for the hub, 100 milliamps for each port making 400 which is a total of 500 milliamps.
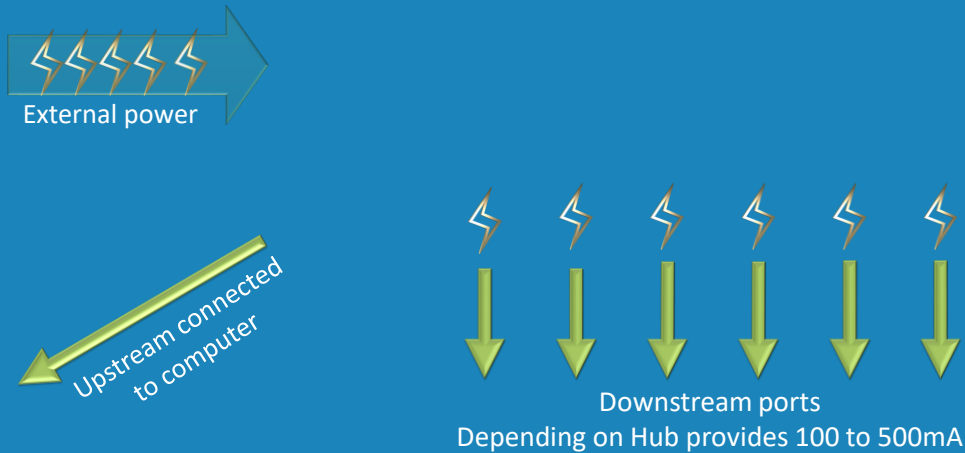
You may remember, from a previous video, we looked at what would happen if you combine multiple power strips together. However, unlike power strips, USB will not draw more power than the maximum amount. So, by combining multiple USB hubs together, you won't risk overloading the power in the computer. What then happens when you plug in a device that requires more power than the USB hub can deliver? Unlike a power strip which will draw more power and potentially overload a circuit, a USB device will simply not work. The operating system you are using will give you a message telling you there is not enough power to operate

the device.

So, how do we get around the power issue while also being able to have a USB hub with more than four ports?

Powered Hub

- Supplies power to ports from external power

External power

Upstream connected to computer

Downstream ports
Depending on Hub provides 100 to 500mA

7:59 When purchasing a hub, you can choose from powered and non-powered. A powered hub supplies power to its ports from external power. Powered hubs cost more than non-powered hubs.

A powered hub, generally will be plugged into a power plug, but it could be powered in other ways. For example, a hub inside a monitor will draw its power from the monitor.

You can see, in this example, the power plug is at the top of the hub. This supplies power to the hub and is used to provide power to each of the downstream ports on the hub. Depending on the hub, the power delivered to each port will be between 100 to 500 milliamps. The better hubs will be able to deliver 500 milliamps to all ports. Cheaper hubs may only be able to deliver 500 milliamps to a few ports and then the output will be reduced for the other ports. For this reason, it is important to check the packaging before buying a hub to make sure it will deliver full power to all ports.

The hub will be connected to the computer or another USB hub via a single upstream connection. If there is a problem powering a device on the hub, the computer should give you a message indicating this. When this occurs, check your hub is powered. Most likely the power plug has come out or the hub cannot provide enough power to power the device.

The downside of using a USB hub is that since the hub is always powered, this can cause devices connected to it to also be always powered up. For example, a hard disk connected to a USB powered hub will always be powered up even if the computer is not switched on. Some

devices will go into standby if not used for a period of time. This is something to consider when plugging a device into a USB powered hub, or you can switch off the powered hub when you switch off the computer. If you leave the USB hub on, and if the device does not go into standby, it may keep operating even when the computer is switched off.

Bandwidth

- Uses packets to transmit data

USB host Controller

Root hub

Bandwidth falls down to 1/5
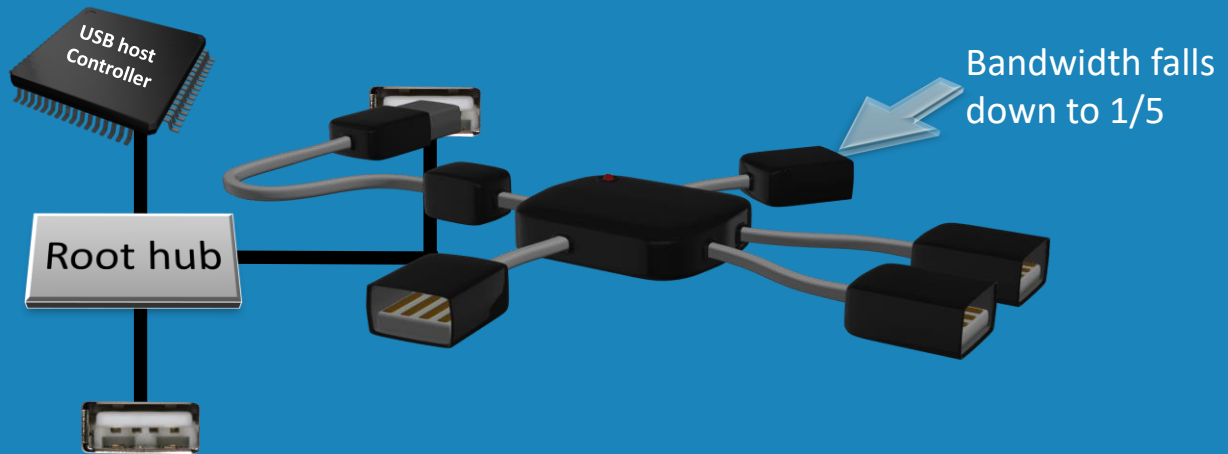
10:05 The next thing to consider with USB is bandwidth. USB uses packets to transmit data. It works in a similar way to how networks transmit packets. If you consider a USB controller, as I covered in a previous video, it is connected to one or more USB root hubs. Each USB root hub can be connected to one or more ports. In this example, this root hub is connected to two USB ports.

What this means is that, essentially, the bandwidth from this root hub is shared between two ports. If you have high bandwidth on one port and a low bandwidth device on the other this will not be a problem. However, if you put a high bandwidth device on both ports this can cause bandwidth problems.

Now consider what happens when you install a USB hub. The USB hub has four ports, which increases the number of ports connected directly or indirectly to the root hub to five. This essentially means that a port on the USB hub can use almost all the bandwidth, more on that in a moment, or be limited to one fifth of the bandwidth. It all depends on how much bandwidth the other devices are using - which will determine how much bandwidth that port will get.

USB uses a token method for packet transmission. What happens is the host sends out a token to each device to let it know it can communicate. If you are familiar with the old token-based networks, you know the devices on the network controlled a single token moving around the network. If a device had the token, it knows it could send data on the network. The problem occurred when the token was lost and a new one would need to be created. Sometimes a second token would be created and there would be two tokens on the network, then two

devices would try and transmit at once.

USB gets around this problem by the USB host controller sending out a token to each device. Thus, the USB host controller always has control over who is sending and receiving data. If you have more devices on the same USB controller, this is more devices the USB controller has to send tokens to. You can see why you may not get the full bandwidth, because USB has to use some of the bandwidth to check the other devices to make sure they do not wish to send data, even though this is a small amount of time. This method also stops one device taking all the bandwidth and allows the bandwidth to be better shared between devices. A USB device also has the option to go into standby mode if it is not being used and thus will not receive any tokens until it comes out of standby.

When connecting devices to a computer, bandwidth is something I will always consider. For example, for a capture card that requires a lot of bandwidth, I will generally have it plugged directly into the computer rather than connected to a USB hub. Although some computers will only have the one USB root hub, if your computer has multiple root hubs, it is worth connecting different devices to different root hubs. If I am not sure, generally I will plug two high bandwidth devices away from each other. For example, plug one into the front of the case and one in the back. Otherwise, plug both in the back of the case but away from each other. Generally speaking, USB ports that are next to each other are more likely to be on the same root hub.

USB Architecture
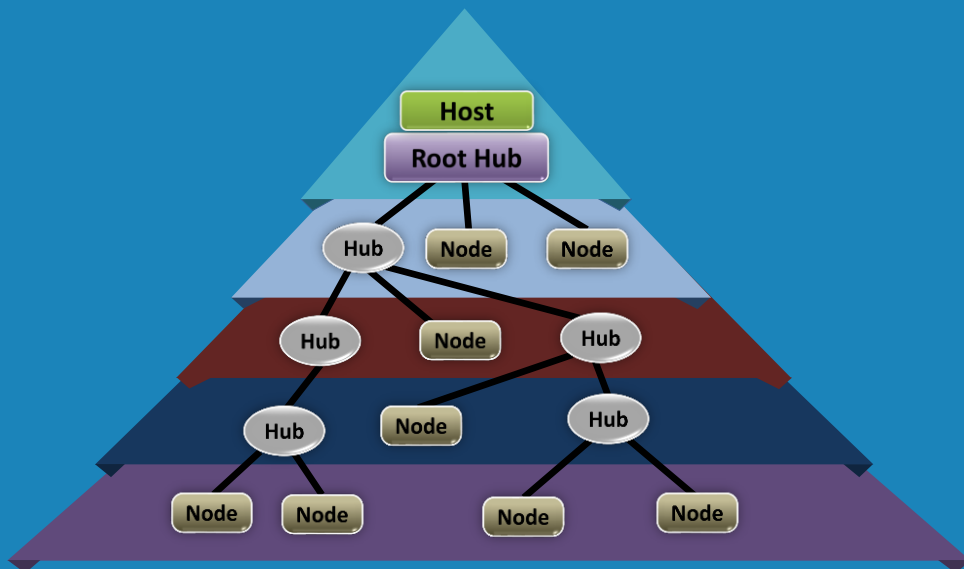
13:39 To put everything I have covered so far into perspective, I will now have a look at the USB architecture. At the top, you have your host, essentially the computer that is providing USB functions. This is called the USB host controller. It may be on its own chip, but generally it will be included inside another chip that provides USB functions. On some motherboards, there may be two or more USB host controllers.

The USB host controller contains the root hub. The root hub essentially performs the same functions as a USB hub connected physically to the computer. It allows one or more USB ports to be connected to the computer. This essentially forms the second tier as the root hub is the first tier.

To increase the number of USB ports, a USB hub can be used. This allows another tier of USB devices to be used. For example, more USB hubs or devices. When you start getting down to tier 2 you will most likely will start having some power problems unless you are using a powered USB hub. The computer will output 500 milliamps of power. Remember that each USB port and hub requires a minimum of 100 milliamps of power. As soon as the number of outgoing ports on a USB hub gets above four you are going to have power problems. Remember the incoming port also requires power which makes five ports at 100 milliamps for a total of 500 milliamps. This effectively limits the number of ports on a USB hub to four if it is not powered.
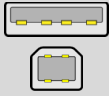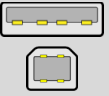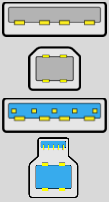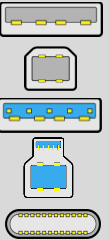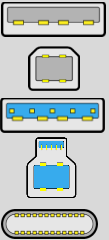
You are free, if you wish, to add more devices and hubs, if you so choose, to form another tier. Most users won't have a need to do this, but later in the video I will go into an example where

it is a useful feature to have.

Lastly you have tier 5. If you really need to, you can add more devices to this tier. In testing I have also added hubs to this tier and it worked. However, if you start daisy chaining too many devices together, you can't expect it to work. You may or may not get lucky if you try doing this. The power problems should be easy to solve using powered hubs. However, when you start getting down to this number of tiers it means more devices that traffic needs to go through and more things that can go wrong. If you need to connect a lot of devices, I would personally attempt to use fewer tiers rather than more. You can purchase a USB hub with seven ports. This may seem a better option than using two USB hubs; however, as we will see later in the video, a seven port USB hub can be essentially two USB hubs connected together.

USB has different versions which run at different speeds. Now that we understand how we can connect devices together, let's see what happens when we connect devices of different speeds together. Before we can do that, however, we first need to understand the different versions of USB.

USB Versions

	1.1	2.0	3.0	3.1	3.2
	12 Mbit/s 1.5 Mbit/s	480 Mbit/s	5 Gbit/s*	10 Gbit/s*	20 Gbit/s**
Release date	1998	2000	2008	2013	2017
Connectors					

* Requires SuperSpeed Type A connector for max speed
** Requires Type C connector for max speed

16:44 There have been a lot of different versions of USB over the years. Not all were adopted, so I will only cover the commonly used ones. The first widely adopted version of USB was 1.1. USB 1.1 supports a high and low speed mode. High speed runs at 12 Megabits per second and low speed runs at 1.5 Megabits per second.

Although you won't be able to purchase a computer that has a USB 1.1 port, USB 1.1 devices are still sold on the market. Devices like a keyboard or a mouse don't need to send a lot of data and thus don't need to run at high speed. These devices still use USB 1.1.

The next USB standard was version 2 released in the year 2000. These used the same connectors as USB 1 and so are backward compatible. This is why there can still be USB 1.1 devices on the market even though USB 1.1 ports are no longer used.

USB 2 increased the speed to 480 Megabits per second. This is a fairly decent speed for a lot of devices. So, you will find that devices like keyboards, mice and headphones use the USB 2 standard. This is unlikely to change anytime soon.

The next version released was USB 3. This was released in the year 2008. This increased the speed to 5 Gigabits per second. To get this increased speed, the SuperSpeed Type A connector is required. The connector is generally blue in color so it is easy to tell apart from the USB 1 and 2 connectors. If you have the right connector, it will run at USB 3 speed, otherwise it will run at USB 2 speed.

The next version released was USB 3.1. This was released in 2013. The version runs at 10 Gigabits per second. Like before, to get the higher speed you need the SuperSpeed Type A connector. This version however does support the Type C connector. This connector, unlike any of the other USB connectors, can be inserted in any direction. You don't have to worry about it being plugged in upside down as it will work regardless of which way it is plugged in.

The last version I will look at is USB 3.2 released in 2017. This increases the speed to 20 Gigabytes per second. In order to get this speed, however, you need to use the Type C connector. The Type C connector has an additional data lane. Without this extra data lane USB 3.2 cannot get the extra speed. So, this is why the SuperSpeed connectors will be backward compatible, but will not run at 20 Gigabits per second.

I think the different USB versions are pretty easy to understand, so let's have a look at how manufacturers have made some changes to make things really confusing.

USB Naming

Original name	New name	Marketing Name
USB 3.0 USB 3.1 Gen 1	USB 3.2 Gen 1	SuperSpeed USB
USB 3.1 USB 3.1 Gen 2	USB 3.2 Gen 2	SuperSpeed USB 10 Gbps
USB 3.2	USB 3.2 Gen 2 x 2	SuperSpeed USB 20 Gbps

19:42 This information you don't need to know for the CompTIA exam; however, if you are purchasing USB products, it is good to know. So essentially what happened is there have been a number of name changes to USB 3.

To start with, USB 3.0 was also called USB 3.1 gen 1 (Gen meaning generation). They then decided to change the name to USB 3.2 gen 1. So, if you purchase a motherboard which has USB 3.2 Gen 1 ports, this essentially means that it is a USB 3.0 port.

To make things more complicated, the marketing name used was 3.0 SuperSpeed USB for USB 3.0. So if you purchase a USB device you may see it called SuperSpeed USB rather than USB 3.0. Confused yet? I would suggest referencing this table if you are buying a USB device so you know what you are buying as the name could be any of the ones listed.

To make things more complicated, USB 3.1 was also called USB 3.1 gen 2. This later changed to USB 3.2 Gen 2. The marketing name however is SuperSpeed USB 10 Gigabits. For the CompTIA exam you only need to know the version numbers. That is, version 3, 3.1 and 3.2.

Lastly, USB 3.2 was changed to USB 3.2 Gen 2 x 2. This is because it has two data lanes, so the name references this fact. Lastly the marketing name for this is SuperSpeed USB 20 Gigabits per second.

You will be happy to know that this is the last time that I will reference this table in this course. I will simply use the names USB 3, USB 3.1 and USB 3.2. For the CompTIA this all you need to

know. The only time you will need reference this information is when you purchase a device or when buying a motherboard so you know what you are purchasing.

Compatibility

- USB 2 backward compatible with USB 1
- USB 3 backward compatible with USB 2
 - Max speed needs SuperSpeed Type A or Type C

21:57 The next topic I will look at is compatibility. USB 2 is backward compatible with USB 1. If you plug a USB 1 device into a USB 2 port it will work.

USB 3 devices are backward compatible with USB 2. When I say USB 3, I mean 3.0, 3.1 and 3.2, that is all the different versions of USB 3. Since USB 2 is compatible with USB 1 then USB 3 is also compatible with USB 1.

To get the max speed you will require the SuperSpeed or Type C cable. If you plug in a USB 2 cable it will still work, you just won't get the max speed. You may find that some USB 3 devices won't work with USB 2. This won't be a hardware problem it will be a problem with the software. For example, digital capture devices require a lot of bandwidth and the software won't work with USB 2 because it is not fast enough. This won't prevent the device installing, but when you run the software, it will say it needs the extra speed of USB 3 to work. In most cases, you will find the device will still work, it will just run at a lower speed.

To summarize, USB is backward compatible. If you are using the wrong cable, it will still work but the speed will be lower. Next, I will have a look at how USB supports compatibility.

USB Buffering
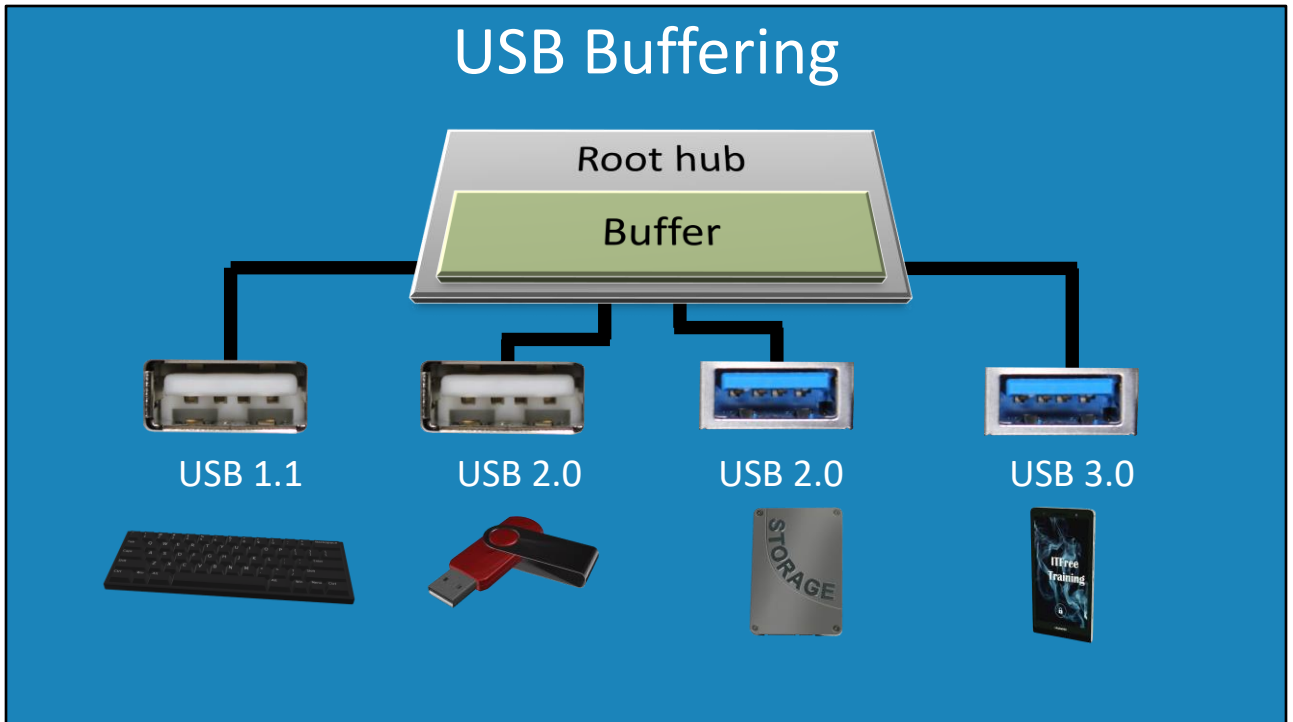
23:26 To understand how USB handles different versions, consider this root hub that is connected to four physical ports. The root has USB 2 and USB 3 ports attached to it. On the first port, a keyboard is attached. The port is a USB 2 port. The keyboard is a USB 1.1 device, so the port will set its speed to USB 1.1.

The next port has a USB stick that supports USB 2. For this reason, the USB 2 port will run at USB 2 speed. The next port is USB 3 which has a USB 2 storage device attached so the port will run at USB 2 speed.

The last port is USB 3 and has a USB 3 mobile device attached, so it will run at USB 3 speed. So essentially the port has matched the speed of the device attached. If you are familiar with networking, this is the same principal when you plug a network card into a network switch. The network switch will change the speed of the port to match the network card that is attached. Like network equipment, the root hub uses a buffer.
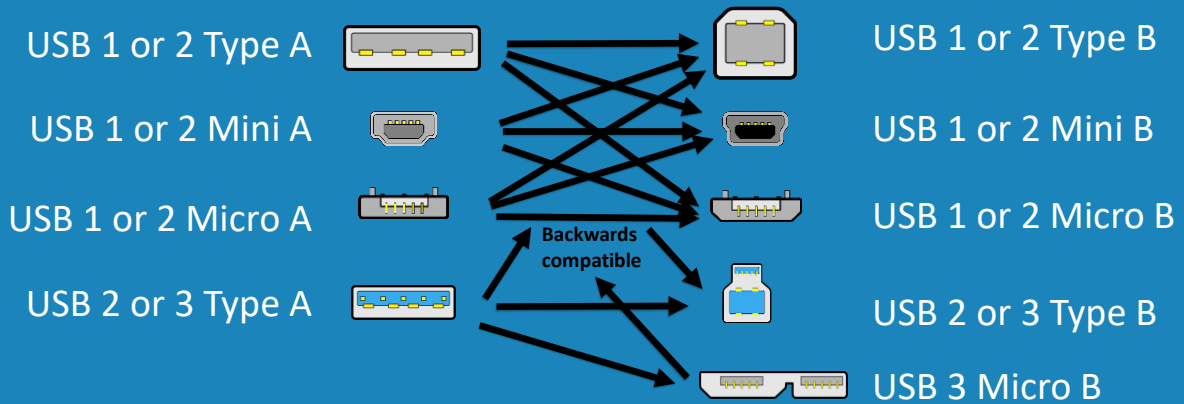
The buffer is what allows the port to run at different speeds. Remember that a root hub has a single upstream port. The buffer is used to manage the different speeds so the data can be packaged into the upstream port. This is a little different from a networking device as the root hub polls the device and tells it when to transmit. A network device, in contrast, cannot control this; however, it can ask a device to slow down if it is transmitting too fast.

So far, we have looked at USB in a master slave configuration. That is, the computer or the root hub is the master device with slave devices attached. However, this may not always be the case.

Connection Types

Master			Slave
USB 1 or 2 Type A			USB 1 or 2 Type B
USB 1 or 2 Mini A			USB 1 or 2 Mini B
USB 1 or 2 Micro A		Backwards compatible	USB 1 or 2 Micro B
USB 2 or 3 Type A			USB 2 or 3 Type B
			USB 3 Micro B

25:23 Before I have a look at how this is achieved, I will first have a look at the different connector types used by USB. The first type is the master connection type, the second type is the slave connection. Devices like keyboards and mice use these kinds of connections because they never need to access other devices. The device is essentially a slave device which is controlled by the device it is plugged into.

The most common connection is the type A connection. This supports USB 1 or USB 2. Having a different plug means it cannot be plugged in the wrong way. The plug itself is quite large so not practical for smaller devices. For this reason, the mini plug and the micro plug were created.

These plugs were smaller and thus useful for smaller devices like mobile devices and cameras. Both support USB 1 or 2. The plugs essentially use the same wires in the cable and do not change. Only the shape of the plug changes. For this reason, any of the master plugs can be connected to the slave plugs.

With the introduction of USB 3, more wires were needed, however it was desirable to be compatible with USB 2. Thus, a connection was designed that was the same size and shape as USB 2, however contained more wires inside. If a USB 2 device was plugged into a USB 3 plug, it would not have all the connections and thus only use the USB 2 wires. Thus, USB 2 and USB 3 were compatible with each other. Of course, if you connect USB 2 to USB 3 the speed will drop.

Although USB 3 can use the micro and mini connection, with a speed drop to USB 2, a small, full-speed connection was still required. In order to support the extra pins for USB, but still

allow for compatibility with USB 2, a flat micro B connection was created.

This connector is essentially a USB micro B connector on the left with the extra pins required for USB 3 on the right. This allows a USB 2 micro B connector to be plugged in a USB 3 micro B connector making it compatible with USB 2 and USB 3.

This system makes it easy to work out which is the master and the slave side, since the connector is different and prevents it being plugged in the wrong way. So, how do we allow a device to either act as a master or slave?
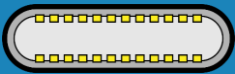
USB on the Go (OTG)

- Allows device to function as Master or Slave
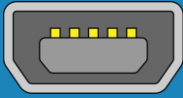
Mini AB. Supports Mini A and B plugs (USB 2)

Micro AB. Supports Micro A and B plugs (USB 2)

Type C (USB 3)

27:57 USB on the Go allows a device to either function as a master or slave. To understand why this would be important, consider a device like a mobile device. You may want to plug the mobile device into a computer in order to access the storage on the device or you may want to plug an external keyboard into the device. In order to access the storage, the mobile device needs to work as a slave, but in order to access the keyboard, the device needs to act as a master.

To achieve this, a different type of plug needed to be designed. The first example is the mini AB. The mini AB allows either a micro A or micro B plug to be plugged into it. This makes sense since the device could either be a master or a slave; you want to be able to plug both in.

Following this, you probably guessed it, is the micro AB plug. Once again, this allows a micro A or micro B plug to be plugged in. Both these plugs were designed for USB 2. For USB 3, a new type of plug the Type C was developed. The Type C plug is designed for USB 3, however it is backward compatible with USB 2.

The Type C connection is a little different from the other two connections in that it is found on both ends. Generally, AB connectors are not found on a computer, but only devices like mobile devices. The Type C connection however, can be found on computers although it is not common place yet.

USB on the Go was first supported back in 2001. Essentially it was added on to the USB protocol to allow the device to detect what the device on the other side is. Essentially, when

both devices are connected, they will negotiate with each other to determine which device is the master.

Now that we understand what different types of USB there are on the market, let's consider what is the maximum length of the cables that we can use.

Cable Length

USB 1/Low speed
1   2   3m/10ft

USB 2/High speed
1   2   3   4   5m/16ft

USB 3/Super speed (Recommended not official)
1   2   3m/10ft

30:01 For a low speed or USB 1 cable, the maximum length is 3 meters or 10 feet. For high speed or USB 2 the distance increases to 5 meters or 16 feet. For super speed or USB 3, there is no official length for the cables. However, it is recommended to use cables that are 3 meters or 10 feet or shorter.

There are manufacturers of cables that will make cables that are longer than these. These cables may or may not work correctly. Also, the quality of the cable can make a difference to the length of the cable. If you need a cable that is longer than the maximum length, consider purchasing an active cable. I will cover these in another video but essentially an active cable uses power to re-transmit or boost the signal to allow the cable to be of a longer length.

Let's now have a look at what happens when you put multiple USB devices together which run at different speeds.

Putting it All Together

| USB 3.0 | USB 2.0 Active extender | USB 3.0 Powered Hub | USB 2.0 KVM | USB 1.1 Keyboard and mouse |

30:59 For this example, I have my USB 3.0 port. I want to have my computer on the other side of the room so I have used a USB active extender. An active extender is a long USB cable that uses a chip in the cable that retransmits the USB data. This uses some power from the computer, but allows the USB cable length to be longer.

Since the USB extender only gives me one port, I am going to connect it to a USB 3.0 powered hub. This will give me additional ports that I can use. Connected to the USB hub I will connect my KVM switch. This will allow me to share my keyboard and mouse to different computers.

So, you can see I have multiple devices connected together which run at different speeds. Let's see how this is handled.

Demonstration

- USBView (Views USB devices and connections)
- Available in Windows SDK
  - Select option "Debugging Tools for Windows"

31:48 To have a look at my setup, I am going to use the software USBView. USBView is available in Windows SDK which is a free download from Microsoft. When you install it, you just need to select the option "Debugging Tools for Windows". This will install the executable for USBView and you just need to run it.

I will now run USBView. You can see on this computer it has two USB host controllers. Some computers will have more than one. You can see under the first USB controller there is a root hub. There should only be the one. In theory you could have more than one, but generally manufacturers will only have the one. To have more than one would not provide any advantage at this level. Essentially the traffic at some stage will still need to be combined together into a single upstream channel to be used by the computer.

You can see the root hub is connected to four USB ports. Since this computer has two USB host controllers, one is 3.2 and the other is 3.1. This one is the faster one and thus only has the four ports. A faster device needs more bandwidth and thus a computer will generally only have a few of them.

The fourth ports is connected to a USB hub. You will notice on the right side of the screen the connection is USB 2. Even though this has appeared as a USB hub, I know this device is my active extender. Sometimes devices you don't expect will appear as hubs.

The device will appear with four ports. However, since it is a cable, only one port will ever be used. When I expand the fourth port, notice that there are four ports and another USB hub.

This does not make sense as I am using a seven port USB hub.

What has occurred is that the seven port USB hub appears as two hubs, one connected to the other. Thus, this accounts for the odd number of ports (seven) as one port is lost to connect the hubs together.

When I expand the second hub, you will notice another hub on port 1. You will notice on this hub there are two composite devices. These devices are my keyboard and mouse so this hub is my KVM switch. You will notice that when I select one of the devices it is running at USB 1.1 speed.

So essentially what has happened is, in order to connect my keyboard and mouse, the traffic needs to go through five hubs including the root hub. It did not take much effort to reach this. If you want to go beyond five tiers, you can always try but it is not guaranteed to work. You will also notice that if I choose a different port on the seven port USB hub, I could have reduced the number of hubs by one. You will find that sometimes by changing a port to a different USB port you may get the device to work.

The USB hub is also running at USB 2 rather than USB 3. It is possible from a hardware perspective to have it run at USB 3 even though it is connected via a USB 2 connection, but in the real world this does not occur. The reason for this is that the USB 2 connection will create a bottleneck for the USB 3 devices, essentially slowing the devices down to what it can handle which is USB 2 speed, so there is no point running at USB 3 speed. By contrast, in networking this does not occur because devices on the network can communicate with each other. In USB, all devices communicate to and from the computer and not to each other, so there is no need for this to occur.

To put it in simple terms, when you connect a low speed device, all devices after that device will need to reduce to the speed of that device. So, if I want my device in this case to run faster, I will need to replace my active USB 2 extender with an active USB 3 extender.

I will now have a look at the second USB host controller. Notice that this controller has 26 ports connected to it. Only the fast USB connectors were on the first host controller; for example, this motherboard has a Type C connector.

On this computer, I have a pair of headphones connected which you can see has appeared as a USB 1.1 device.

You will notice further down there is another hub. This hub is connected at USB 3 speed. This is an interesting one. These ports are the USB ports on the front of my

computer. So, in my previous example, if I connected my USB extender to this port, this would have added to the number of tiers by one. Something else to consider when connecting USB devices. You never quite know how they are connected in the computer. Sometimes a physical connection on the computer will be connected not directly to the root hub but to a hub that is connected to the root hub.

You will notice that there is another hub with a mass storage device connected. On this computer, I have a card reader attached. This card reader has a memory card in the reader which has been detected as a mass storage device. You willotice that this device has also appeared as a USB 3 device. Since there are no USB 2 connections between it and the computer, it can run at full speed.

There is one more property of USB 3 that I want to look at. To see this, I will disconnect my USB 3 hub and plug it into this USB host controller. You will notice the USB 3 hub has appeared connected to port 3. However, notice that it is working at USB 2 speed. That should not be the case since it is connected directly to the computer.

You will notice that there is another USB hub connected to port 19 which is at USB 3 speed. What happens with USB 3 devices is that they have USB 2 and USB 3 hardware in them. They appear as both USB 2 and USB 3 devices. Essentially the hub is connected to the computer via a USB 2 and a USB 3 connection running over the same cable. USB 2 devices will be connected to the USB 2 hub, and devices will be connected to the USB 3 hub. When I connected it using the USB 2 active extender, essentially the USB 3 hub did not install because the connection did not support it. This is how USB 3 supports USB 2 and USB 1.1 devices. Essentially USB 3 hardware supports both in the device, and it is up to the computer to connect to which one it wants to use. In the case of USB hubs it will connect to both.

I hope you have enjoyed this video from ITFreeTraining on USB. Hopefully we helped you understand it better. Until the next video from us, I would like to thank you for watching.

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