As you study this section, answer the following questions:

* Why must the case be matched to the motherboard?
* How does the ATX form factor differ from the ITX form factor?
* What are the characteristics of the ATX form factor?
* What is the main difference between a Micro-ATX tower and a Micro-ATX slim tower case?
* What is the most common ITX form factor?

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Motherboards | Adhere to design specifications called form factors. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| CompTIA 220-1001 | 3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * Motherboard form factor   + ATX   + mATX   + ITX   + mITX |

3.1.1 Cases and Form Factors

**Cases and Form Factors**0:00-0:45

Computer cases come in many different shapes and sizes. Each computer case is designed to fit a specific motherboard size called the form factor.

The form factor is a specification that determines the motherboard's dimensions. It defines the width and height, the locations of mounting holes, back panel ports, and expansion slots.

Having these specifications makes pairing a motherboard with a case extremely easy. If the case has the same form factor as a motherboard, then you know they will be compatible.

In this lesson, we're going to look at the most common form factors and how they affect the size and dimensions of computer cases. Let's start with the ATX form factor.

**ATX Form Factor**0:46-1:37

The ATX form factor, also called Standard ATX, is the most commonly used form factor. Standard ATX motherboards are 9.6 inches by 12 inches. While the type and number of ports on the back panel of an ATX motherboard can vary, they need to fit within the ATX form factor's specified dimensions. The dimensions for the back panel are 6.25 inches by 1.75 inches.

Another characteristic of the ATX form factor is the number of expansion slots and their spacing. Standard ATX motherboards have between six and seven expansion slots. These are spaced 0.8 inches apart.

There are several variants of the ATX form factor. They are considered variants because they adhere to certain specifications such as mounting hole locations, back panel port arrangement, and expansion slot spacing. However, they have entirely different dimensions.

**microATX**1:38-1:51

One variant is the microATX form factor. The typical dimensions of a microATX motherboard are 9.6 inches by 9.6 inches. The reduced length of this form factor is achieved by having only four expansion slots instead of seven.

**Extended ATX**1:52-2:24

Another variant is the Extended ATX (EATX) form factor. Instead of reducing its size, the EATX form factor adds up to three and a half inches to the Standard ATX form factor. This extra space is used for extra slots for memory modules.

Remember, these are all ATX variants. This means that even though they are different sizes, the mounting holes, back panel ports, and expansion slots are all in the same location. If we were to stack all three ATX variants on top of each other, everything would line up.

**ITX**2:25-3:09

Another common form factor is the ITX form factor. The ITX form factor is primarily used with small form factor computers. There are several variants of the ITX form factor, the most common of which is the mini-ITX form factor.

Mini-ITX motherboards measure 6.7 inches by 6.7 inches and have only one expansion slot. They're pretty small. They were designed to be a low power, low temperature motherboard that could be used in smaller computers.

Even though it's a different form factor than ATX, Mini-ITX was designed so that the mounting holes and back panel arrangement matches the ATX form factor. This allows Mini-ITX motherboards to be used with ATX cases.

Other ITX form factors include Nano-ITX, Pico-ITX, and Mobile-ITX.

**BTX and NLX**3:10-3:51

There are two more form factors we should mention. These form factors are rarely used, but you still might encounter them.

The first is the BTX form factor. This form factor was intended to replace the ATX form factor. The BTX form factor has roughly the same dimensions as ATX form factor. However, BTX motherboards have a completely different back panel orientation.

The second is the NLX form factor. NLX motherboards use a unique back panel design. They also use what's called a riser card. This attaches to the motherboard, allowing expansions to be installed parallel to the motherboard.

**Case Types**3:52-4:17

Now that we've looked at all the different motherboard form factors, let's take a look at how they affect a case's size and dimensions.

Cases are identified by both their type and the form factor they are compatible with. So let's take a look at the most common types of cases.

Computer cases come in all different shapes and sizes. Remember, they are designed to fit a specific motherboard form factor.

**ATX Full-tower**4:18-4:39

The ATX full-tower is probably the largest case you'll see. ATX full-towers are made to be compatible with all ATX form factors, including EATX. Full-tower cases usually have several external bays for things like DVD ROM drives. They also have a lot of room inside the case for hard drives, large graphics cards, and power supplies.

**ATX Mid-tower**4:40-4:59

Next is an ATX mid-tower. ATX mid-towers are slightly smaller than ATX full-towers. However, they are still compatible with all the ATX form factors. Some ATX mid-towers are even compatible with the Mini-ITX form factor. ATX mid-towers have fewer external bays. They also have less internal space.

**microATX Tower**5:00-5:36

There are two types of microATX towers. The first one is a traditional microATX tower. It has a single external bay and it's considerably smaller than the ATX mid-tower or full-tower.

This second one is a microATX slim tower. These cases can either stand upright or lie flat on a desk. Both of these towers are compatible with the microATX form factor as well as the Mini-ITX form factor.

One big difference between these two towers is that due to its slim design, the microATX slim tower requires a riser card to install expansion cards.

**Mini-ITX Tower**5:37-5:48

The last case is a Mini-ITX tower. These cases are compatible with only the Mini-ITX form factor. Because of this, they are smaller than the microATX towers.

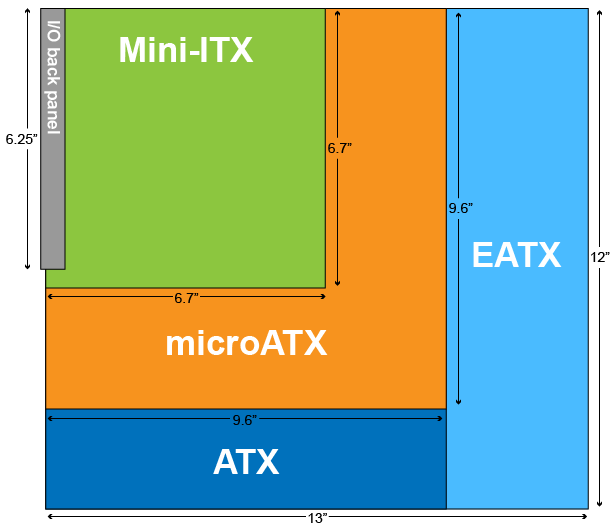
**Summary**5:49-6:16

Those are the different form factors used by motherboards and cases. Remember, the form factor identifies the dimensions and specifications of a motherboard. It also determines which type of case the motherboard is compatible with.

By knowing the different form factors, you can make informed decisions when deciding which motherboard and case will best suit a specific need. And when selecting a case, you need to consider not only the size and the number of external and internal bays, but also the motherboard form factor you are going to use.

3.1.2 System Case Facts

Motherboards adhere to design specifications called form factors. The form factor determines the physical characteristics of a motherboard, including its dimensions, number of expansion slots, and mounting hole locations, as well as the back panel dimensions, arrangement, and orientation. The following graphic and table describe the characteristics of the most common motherboard form factors:



|  |  |  |
| --- | --- | --- |
| **Form Factor** | **Characteristics** | |
| ATX | The ATX (advanced technology extended) form factor is the most commonly used form factor. Because of its popularity, several variants of the ATX form factor exist. Each variant has different specifications for dimensions and number of expansion slots. However, all ATX variants share the following characteristics:   * Back plate measurements (6.25" × 1.75") * Power supply specifications:   + 24-pin ATX power connector   + On/off switch runs from the case to the motherboard   + Soft-power control (OS can turn the computer off) * Expansion slot locations and spacing (0.8" between slots) * Mounting hole locations * CPU location (top of board near power supply)   Below are the most common ATX variants and their unique characteristics: | |
| Standard ATX | The standard ATX form factor is the form factor that all other variants are modeled after. ATX motherboards:   * Measure 12" × 9.6" * Have up to seven expansion slots * Have between six and nine mounting holes |
| Extended ATX (EATX) | The EATX form factor is the largest ATX variant. EATX:   * Measures 12" × 13" * Typically uses extra space for additional memory slots |
| microATX | The microATX form factor is a smaller version of the ATX form factor. The microATX form factor:   * Measures 9.6" × 9.6" * Has four expansion slots |
| ITX | The ITX form factor was designed for low-power, small form factor (SFF) computers. The most common ITX form factor is the Mini-ITX form factor. The Mini-ITX form factor:   * Specifies a maximum motherboard size of 6.7" × 6.7" * Has only one expansion slot * Allows for small (100 watt) power supplies * Is typically used with a home theater PC (HTPC)   Other ITX form factors include the following:   * Nano-ITX (4.7" × 4.7") * Pico-ITX (3.9" × 2.85") * Mobile-ITX (2.9" × 1.7")   The Mini-ITX form factor uses the same mounting locations and back panel specifications as the ATX form factor, allowing Mini-ITX motherboards to fit in ATX cases. | |
| NLX | NLX (new low profile extended) is an old form factor that was designed for use in slimline desktop computers. NLX:   * Uses a detachable riser card to provide expansion slots (the motherboard itself has no expansion slots). * Allows the motherboard to slide in or out of the system case easily. * Was replaced by microATX and Mini-ITX. | |
| BTX | The BTX (balanced technology extended) form factor was designed as a replacement for the ATX form factor. However, it did not gain widespread adoption. With BTX:   * The CPU is positioned in such a way that air flow is increased. * There is no heatsink fan. Instead, a thermal module or shroud fits over the CPU to move heat directly out of the system. * The back panel orientation and mounting location is reversed.   BTX was implemented mainly by computer manufacturers such as Dell. | |

Computer cases are designed to fit motherboard form factors. The following table describes the most common types of computer cases:

|  |  |
| --- | --- |
| **Type** | **Description** |
| ATX Full-tower | ATX full-tower cases are the largest computer cases. Full-tower cases have a lot of space for external and internal components. ATX full-tower cases are compatible with the following form factors:   * Standard ATX * EATX * microATX |
| ATX Mid-tower | ATX mid-tower cases are slightly smaller than full-tower cases. Mid-tower cases have fewer external and internal bays. ATX mid-tower cases are compatible with the following form factors:   * Standard ATX * microATX * Mini-ITX * EATX (some) |
| microATX Tower | microATX towers are smaller cases designed to be placed on desktops. microATX towers typically have only one drive bay and are compatible with the following form factors:   * microATX * Mini-ITX   Some microATX towers have a slim design. These cases are typically half the width of a microATX tower and are designed to lie flat or upright. |
| Mini-ITX Tower | Mini-ITX towers are designed to house mini-ITX motherboards. They are typically smaller than microATX towers. |
| HTPC | Home theatre PC (HTPC) cases are designed to connect to TVs and be used as a home media computer. HTPC cases are compatible with microATX and Mini-ITX form factors. |
| Notebook | Notebook cases are generally proprietary and often vary among models. |

Some small form factor cases (e.g., microATX and Mini-ITX towers) use riser cards for installing expansion boards. Riser cards are installed in an expansion slot and allow the expansion board to be installed parallel to the motherboard, instead of perpendicular.

When you purchase a computer case, it will usually come with the following components::

* Computer case
* Power supply (although the power supply might also be separate)
* Case fans
* Plastic or rubber feet that attach to the bottom of the case
* Metal screws and standoffs for attaching the motherboard
* Additional external connectors (such as audio, USB, and FireWire) that connect to motherboard headers

Chapter 3: System Components

3.2 Power Supplies

As you study this section, answer the following questions:

* How does the case form affect the type of power supply you purchase?
* What is the function of the red toggle switch on a power supply? Why is this important?
* What rating determines the number of internal components a computer can handle?
* What is soft power?
* Why must you be careful when using a proprietary power supply?

In this section, you will learn to:

* Install a power supply

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| SATA power | A power connector that has 15 pins and provides 3.3, 5, and 12 volts. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| TestOut PC Pro | 1.1 Given a scenario, select and install PC components  1.1.1 Install and connect a power supply |
| CompTIA 220-1001 | 3.2 Identify common connector types.   * Molex   3.7 Summarize power supply types and features.   * Input 115V vs. 220V * Output 5.5V vs. 12V * 24-pin motherboard adapter * Wattage rating * Number of devices/types of devices to be powered |

3.2.1 Power Supplies

**Power Supplies**0:00-0:16

Computers need electricity to function. Without it a computer is nothing more than a really expensive paperweight. In this lesson, we're going to look at the hardware component responsible for powering a computer, the power supply.

**Back Panel**0:17-1:11

This is a typical ATX power supply. The ATX tells us that the power supply adheres to the ATX form factor specifications. Right now, we're looking at the back panel of the power supply. This is the part of the power supply that's exposed when it's installed in the computer case.

Here you'll typically see a power switch like this one that turns the power supply on and off. You might also see a voltage selector switch. It's used to toggle the input voltage between 115 or 230 volts, depending on which is being used.

Some power supplies are able to automatically switch between voltages, eliminating the need for the switch. These types of power supplies specify a voltage range that they are compatible with, which is usually between 100 volts and 240 volts.

Most power supplies also have air holes on the back. Some models have a fan here instead of on the top.

**AC Power to DC Power**1:12-1:50

On the back panel of all power supplies is a C14 connector. This is where the power cord from the wall plugs into. Now, the electricity that comes in here from the power cord is 120 volt AC power. However, the components inside a computer use DC power.

This means the AC power from the outlet need to be converted to DC power. This is one of the main functions of a power supply.

The 120 volt AC power from the wall flows into the power supply where it's converted into three DC voltage levels, 12 volts, 5 volts, and 3.3 volts. This is because different components have different voltage requirements.

**Wire Bundle & Connectors**1:51-2:20

The converted DC power flows out the power supply's wire bundle which is on the opposite side of the power supply here. The power supply's wire bundle contains a variety of wired connectors that plug into components and provide them with the correct voltage of DC power.

Now, it's important to know that the number of components a power supply can handle isn't based on the number of its connectors. For example, a power supply could have 10 hard drive connectors but this doesn't mean it can power 10 hard drives.

**Watts**2:21-3:10

Instead, power supplies use a power rating called watts, which is a measurement of its maximum power output. Now, for most desktop computers a 350 watt power supply should be sufficient.

However, when you start adding hard drives, optical drives, and high end video cards, your power needs increase substantially. As such, it's usually best to invest in a more powerful one such as a 500 or 650 watt power supply.

If necessary, you can identify your exact power needs by adding up the wattage requirements for each component you need to power. There are also several websites you can use to calculate specific power needs.

Remember, one of the power supply's main functions is to provide power to components, but if the connected components draw more power than the power supply can handle, they will shut off.

**Thermal Management**3:11-3:44

Another part of the power supply is its fan. Most ATX power supplies will have a large fan on it that helps to cool the unit, however, this fan serves a secondary purpose. When installed in a case, a power supply's fan aids in thermal management.

Power supplies are typically installed in the back, top of a computer case, directly above the CPU. This positioning allows the power supply's fan to pull hot air out of the computer case allowing cooler air from the front of the case to flow in. This helps to maximize cooling by creating a wind tunnel effect inside the case.

**Summary**3:45-4:04

Those are the basics of computer power supplies. Remember, power supplies have two primary functions. First, they convert AC power to DC power and second, they provide 12, 5, and 3.3 volts of DC power to components. Power supplies also provide a secondary function which is to aid in thermal management.

3.2.2 Power Supply Facts

Power supplies are responsible for powering every component in a computer system. Power supplies perform the following functions:

* Convert AC power to DC power
  + AC (alternating current) is the type of current distributed through wall sockets. The voltage alternates between a negative and a positive charge, which is good for appliances requiring a high current.
  + DC (direct current) is the type of current used inside a computer. Negative particles are drawn toward a positive charge, creating a unidirectional current flow. This type of predictable reliable current is ideal for an application where a lower current is required.
* Provide components with the correct levels of DC voltage
  + Standard ATX power supplies provide + 3.3 volts, +/- 5 volts, and +/- 12 volts of DC power. Most modern components require +12 volt output.
  + Each separate voltage output circuit is referred to as a *rail* and can power multiple devices. To avoid overloading one circuit, many newer power supplies have two or more +12 volt rails. These are known as dual rail power supplies. Separate rails balance the power load between multiple circuits, preventing any one circuit from becoming overloaded.
* Aid in thermal management
  + All ATX power supplies have a fan that cools the unit.
  + The fan direction pulls cooler air from the front of the case and blows hot air out the back.

Older ATX units use a reverse air flow that blows air directly over the CPU. This method is not as efficient.

You should be aware of the following facts about power supplies:

* Power supplies should be matched to the motherboard and case form factor (i.e., match an ATX power supply with an ATX motherboard or a microATX power supply with a microATX motherboard).
* Most power supplies have a voltage switch that toggles between 115 and 230 volt electricity.
  + 115 volts is used in North America.
  + 230 volts is used in Europe.

Some power supplies eliminate the voltage switch and instead automatically switch between voltages as necessary. These power supplies specify a voltage range they can function in.

* Many power supplies have a switch on the back that turns the power on or off.
* Power supplies are rated in watts. A power supply's watt rating determines its maximum power output. To determine a computer's power requirements, use the following method:
  + Find the watt requirement for each component by multiplying volts by amps (*W = V × A*).
  + Add each value together to find the total watt requirements.

Alternatively, there are several online tools you can use to estimate a computer's watt requirements.

* ATX power supplies provide soft power, even when the computer is turned off, the motherboard has power. Soft power allows the computer to be turned on and off by the operating system or over the network.

When selecting a power supply, make sure it has all the necessary connectors for your components. The following table shows the common power supply connectors:

|  |  |
| --- | --- |
| **Connector** | **Description** |
| 24-pin (20+4 pin) ATX connector | The 24-pin ATX power plug supplies power to the motherboard.   * Some 24-pin connectors have one 20-pin plug and a detachable 4-pin plug. This allows for backwards compatibility with 20-pin motherboards. * You can plug a 24-pin ATX power plug into a 20-pin motherboard connector, leaving the four pins unconnected.   Older motherboards used 20-pin power plugs. With a 24-pin ATX power plug, the four extra pins supply an additional 3.3, 5, and 12 volts of DC power. |
| 4-pin 12 V (P4) power | Starting with the Pentium 4 (P4) processor, CPUs required more power than could be provided through the ATX power plug. The 4-pin 12 V connector:   * Connects to the motherboard * Provides two dedicated 12 V wires to the CPU (Older processors only used 5 V power)   The 4-pin 12 V CPU connector is not the same as the 20+4-pin ATX power connector. |
| 8-pin EPS12V CPU power | Modern processors consume even more power. The 8-pin EPS12V connector provides four lines of 12 V power.   * The 8-pin EPS12V was originally used with some older dual processor systems. * All modern multi-core processors use this connector. * Some power supplies have two 4-pin connectors (4+4) that are meant to be used side-by-side in the 8-pin plug. |
| 6+2-pin PCIe | Newer video cards require more power than can be supplied through the PCI Express bus. The 6+2-pin PCIe connector plugs directly into the video card to supply additional, dedicated power. The 6+2-pin PCIe:   * Provides up to 150 watts * Is also known as a PEG6+2 (PCI Express Graphics 6+2 pin) * Some motherboards have only a 6-pin PCIe connector. These connectors provide up to 75 watts. |
| 4-pin peripheral power | The 4-pin peripheral power connector (colloquially called a 4-pin Molex connector) is used by legacy components (e.g., IDE hard drives and PATA optical drives), case fans, and other accessory devices. The connector provides both 5 V (red wire) and 12 V (yellow wire).   * Each power supply cable typically has multiple 4-pin connectors on the same cable. * When connecting devices, try to balance the devices connected to each cable. |
| SATA power | The SATA power connector has 15 pins and provides 3.3, 5, and 12 volts. As its name implies, it powers SATA devices.   * You can use a special adapter to convert a 4-pin peripheral power connector to a SATA connector. * When using an adapter, or on some power supplies, the connector supplies only 5 and 12 volts. |
| 4-pin mini-Molex | The 4-pin mini-Molex connector provides both 5 and 12 volts and is used by floppy drives.  Most modern power supplies do not have a 4-pin mini-Molex connector. |

If your power supply does not have some of the required connectors (such as for the CPU, video card, or SATA device), you can purchase adapters to convert from one connector to another.

When troubleshooting a power supply, keep the following in mind:

* Symptoms of bad power supply include:
  + The computer does not turn on
  + The computer sporadically shuts off or reboots
  + A broken or noisy fan
* Before opening up the computer, rule out the obvious. Make sure:
  + The power cord is plugged into the wall.
  + The power switch is in the on position.
  + The voltage switch is set to the correct voltage.
* Test the power supply using a multimeter or power supply tester. Voltage levels should be within +/- 5% of normal. If they aren't, the power supply is bad or failing and should be replaced.
  + 12 V rail should be between 11.4 and 12.6 volts.
  + 5 V rail should be between 4.7 and 5.25 volts.
  + 3.3 V rail should be between 3.1 and 3.4 volts.
* Because power supplies carry dangerous levels of electrical current, always take proper safety precautions.
  + Never ground yourself when working on a power supply.
  + Never open or disassemble a power supply. Always replace the entire unit.

Some computer manufacturers, such as Dell or HP, produce proprietary power supplies. These power supplies might have a unique shape or use different wiring schematics on connectors. When replacing a power supply, identify whether a standard ATX or a proprietary power supply is required.

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3.2.2 Power Supply Facts

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* Provide components with the correct levels of DC voltage
  + Standard ATX power supplies provide + 3.3 volts, +/- 5 volts, and +/- 12 volts of DC power. Most modern components require +12 volt output.
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* Aid in thermal management
  + All ATX power supplies have a fan that cools the unit.
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Older ATX units use a reverse air flow that blows air directly over the CPU. This method is not as efficient.

You should be aware of the following facts about power supplies:

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  + 115 volts is used in North America.
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Some power supplies eliminate the voltage switch and instead automatically switch between voltages as necessary. These power supplies specify a voltage range they can function in.

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* Power supplies are rated in watts. A power supply's watt rating determines its maximum power output. To determine a computer's power requirements, use the following method:
  + Find the watt requirement for each component by multiplying volts by amps (*W = V × A*).
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|  |  |
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| 4-pin 12 V (P4) power | Starting with the Pentium 4 (P4) processor, CPUs required more power than could be provided through the ATX power plug. The 4-pin 12 V connector:   * Connects to the motherboard * Provides two dedicated 12 V wires to the CPU (Older processors only used 5 V power)   The 4-pin 12 V CPU connector is not the same as the 20+4-pin ATX power connector. |
| 8-pin EPS12V CPU power | Modern processors consume even more power. The 8-pin EPS12V connector provides four lines of 12 V power.   * The 8-pin EPS12V was originally used with some older dual processor systems. * All modern multi-core processors use this connector. * Some power supplies have two 4-pin connectors (4+4) that are meant to be used side-by-side in the 8-pin plug. |
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| SATA power | The SATA power connector has 15 pins and provides 3.3, 5, and 12 volts. As its name implies, it powers SATA devices.   * You can use a special adapter to convert a 4-pin peripheral power connector to a SATA connector. * When using an adapter, or on some power supplies, the connector supplies only 5 and 12 volts. |
| 4-pin mini-Molex | The 4-pin mini-Molex connector provides both 5 and 12 volts and is used by floppy drives.  Most modern power supplies do not have a 4-pin mini-Molex connector. |

If your power supply does not have some of the required connectors (such as for the CPU, video card, or SATA device), you can purchase adapters to convert from one connector to another.

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  + The power switch is in the on position.
  + The voltage switch is set to the correct voltage.
* Test the power supply using a multimeter or power supply tester. Voltage levels should be within +/- 5% of normal. If they aren't, the power supply is bad or failing and should be replaced.
  + 12 V rail should be between 11.4 and 12.6 volts.
  + 5 V rail should be between 4.7 and 5.25 volts.
  + 3.3 V rail should be between 3.1 and 3.4 volts.
* Because power supplies carry dangerous levels of electrical current, always take proper safety precautions.
  + Never ground yourself when working on a power supply.
  + Never open or disassemble a power supply. Always replace the entire unit.

Some computer manufacturers, such as Dell or HP, produce proprietary power supplies. These power supplies might have a unique shape or use different wiring schematics on connectors. When replacing a power supply, identify whether a standard ATX or a proprietary power supply is required.

3.2.3 Identify Power Supply Components

**Identify Power Supply Components**0:00-1:26

Like motherboards and cases, power supplies adhere to form factor specifications. This makes matching a power supply to a particular motherboard or case very simple. All you need to do is make sure they're the same form factor.

For example, if you have an ATX case, purchase an ATX power supply. Likewise if you have a microATX case, purchase a microATX power supply.

There's a bit of shared compatibility with power supplies. ATX power supplies are compatible with most microATX motherboards and some Mini-ITX motherboards.

However, the inverse isn't necessarily true. Mini-ITX and microATX power supplies are designed for lower power consumption computers. They might not be sufficient for a standard ATX motherboard.

Also know that microATX and Mini-ITX power supplies are smaller in size than ATX power supplies because they are made to fit in smaller cases. This makes it impossible to use an ATX power supply with a Mini-ITX case.

When it comes to form factor compatibility and power supplies, a good rule of thumb is that larger form factors are almost always compatible with smaller form factors. However, small form factors are rarely compatible with larger form factors.

Therefore, it's important for you to be able to identify the different types of power supplies.

**Types of Power Supplies**1:27-2:04

We'll discuss the three most common types of power supplies you'll encounter. The ATX power supply, microATX power supply, and Mini-ITX power supply.

Notice the size and shape of the Mini-ITX power supply. These are made to fit in Mini-ITX cases and also some proprietary computers such as Dell or HP.

ATX and microATX power supplies are very similar. However, ATX power supplies are slightly larger and usually won't fit in microATX cases. If they do, it might be a very tight fit that can effect air flow and thermal cooling.

**Power Supply Connectors**2:05-2:32

In addition to being able to identify these three power supplies, you also need to be able to identify the different types of connectors and the components they power. Even though these three power supplies are different types, they all have the same types of connectors on them. Let's take a look at the connectors on the ATX power supply.

On the back of a power supply is the wire bundle. It's composed of all the various connectors used to power components.

**ATX Power Plug**2:33-3:05

The first connector we'll look at is the ATX power plug which is the defining characteristic of an ATX power supply. The ATX power plug has 24 pins, two rows of 12.

Depending on the power supply, this plug might be a solid 24-pin plug or it might be split into one 20-pin plug and one 4-pin plug. The ATX power plug connects to the motherboard and provides several functions. First and most important, it provides 3.3, 5, and 12 volts of DC power to the motherboard.

**Power Good Signal**3:06-3:32

The second function is that the ATX power plug sends a power good signal to the motherboard. When a power supply first turns on, it does a series of self-tests. These tests insure that the power supply can provide a consistent flow of the correct voltages.

If the tests pass, then the power supply sends a 5-volt current called the power good signal to the motherboard on one of its wires. When the motherboard receives the signal, the motherboard allows the computer to turn on.

**5-Volt Standby**3:33-3:51

A third function that the ATX power plug provides is standby power. As long as the power supply is plugged in, one of the wires supplies the motherboard with a constant 5-volt current even when the computer is turned off. This constant current powers the circuitry that enables the fourth function which is to provide soft power.

**Soft Power**3:52-4:18

An ATX power plug wire carries what's called the power on signal. This signal allows the computer to be turned on or off by the operating system or remotely over the network. This is called soft power.

Older computers had to be turned on or off using a hard switch that physically broke the electrical connection. Soft power sends a signal to turn the power supply on or off. The electrical connection is never broken.

**CPU Connectors**4:19-4:41

These next two connectors also plug in to the motherboard and are used to provide auxiliary power to the CPU. Auxiliary power is necessary because most processors require more power than the ATX power plug can provide. Less power hungry CPU's use a ATX 12-volt 4-pin connector.

Newer CPU's require more power. They use this 8-pin connector called an EPS 12-volt connector.

**PCIe Connector**4:42-5:01

Next is the PCIe connector. This connector's used to provide dedicated power to high-end video cards. Because some video cards use 6-pin connectors and some use 8-pin connectors, these connectors usually have a 6 plus 2 configuration and are compatible with both types.

**SATA Connector**5:02-5:06

The next type of connector is the SATA power connector. It's used by SATA hard drives and SATA optical drives.

**Adapters**5:07-5:24

In some situations, you may encounter power supplies that don't have some of these connectors. Luckily you can purchase adapters to convert, say a 4-pin accessory connector into a SATA connector or 6-pin PCIE connector into an 8-pin PCIe connector.

**Summary**5:25-5:54

That's it for this lesson. Remember there are three types of power supplies you should be familiar with: ATX, microATX, and Mini-ITX. When selecting a power supply, matching the power supply with the case and motherboard form factor is the best way to ensure compatibility.

Be sure to know the different types of connectors used by power supplies. This will help you ensure that a power supply has all the necessary connectors and enough of them for the computer's components.

3.2.4 Change the Power Supply

**Change a Power Supply**0:00-0:14

Power supplies are considered field-replaceable units. If one goes bad, you should replace it with a known good spare. So, we're going to cover how to identify and replace a bad power supply.

**Identify a Bad Power Supply**0:15-1:49

When you're identifying a bad power supply, there are a couple of key symptoms you should look for. The first is the computer not turning on. If you check the obvious—make sure the power cord is plugged in and the switch on the power supply is turned on—and the computer still doesn't start up, there's a good chance the power supply is bad.

Another symptom is the computer spontaneously shutting off or restarting. While this might be caused by something else, it's usually the result of a faulty power supply. And the culprit is actually the Power Good signal on the ATX power plug.

The Power Good signal is a 5-volt signal that tells the motherboard the correct power levels that can be sustained by the power supply. If this signal stops at any point during operation, the motherboard will turn off the computer to prevent damage to components. If the signal drops below 5 volts and then goes back up to 5 volts, then the computer will restart.

It's important to know that this isn't always caused by a faulty power supply. It could be that it's just not powerful enough. If the components are drawing more watts than the power supply can handle, then the Power Good signal will cut out, and the computer will turn off.

So, to rule this out and verify that the power supply is bad, you need to test it. And can you do this using a power supply testing tool.

**Use a Power Supply Tester**1:50-4:31

This is a power supply testing tool. Notice all the connectors. With this tool, all you do is plug in the various connectors, starting with the ATX power plug, here. When you do, the voltage output is displayed on the LCD, here.

We can see that the 12-volt yellow wire has an output of 12 volts DC. This is good. On this wire, we should see between 11.4 and 12.6 volts. Anything below this means the power supply is bad and should be replaced.

And we can see that the red 5-volt wire has an output of 5.2 volts. This is good, too.

If voltages are too low, then the tool will let you know with a message on the display or a beeping noise.

Let's connect the ATX power plug to this tester. The power supply turns on, and we can see the voltage levels on the display. Notice the beeping and this flashing light. The tester is telling us that the CPU power connector is either bad or not connected. So let's connect the CPU power over here. The beeping stopped, and the tester now displays the readings from this connector, down here.

This device also tests the power good wire. We can see the status down here. The rating is in milliseconds. A value between 100 milliseconds and 900 milliseconds is ideal. Anything outside this range will prevent the power supply from running. As you can see, using a power supply tester is much easier and faster than using a multimeter.

Based on our tests, we know this power supply is good. But for our purposes, let's say we got some bad readings from our tools, and we need to remove and replace the power supply.

**Remove a Power Supply**4:32-5:30

The first thing we need to do is turn off the power supply by disconnecting the tool. After that, we want to unplug the power supply from the wall.

Next, we need to remove all these connectors in here. If the computer you're working on has a lot of connectors, it's sometimes a good idea to take a picture of the case with a phone or digital camera. That way, when you install the new power supply, you can reference the photo to make sure everything gets reconnected in the right place.

Be sure to disconnect everything—optical drives, SATA hard drives, CPU, fans. You can make sure everything is disconnected by gently grabbing the wire bundle and placing all the wires over the side of the case.

After that, we need to unscrew the four mounting screws on the back of the case. These four screws are the only thing holding the power supply in the case. While you unscrew these, you should hold on to the power supply itself, so it doesn't fall out of the case and damage components.

With all the screws removed, we can remove the power supply from the case.

**Install a New Power Supply**5:31-6:18

Now we're ready to install the new power supply. First, we need to mount it, so we slide it back in and screw in all four mounting screws.

With that done, we're ready to reconnect all the power connectors. We'll start with the ATX power plug, which is the 24-pin connector here. Now, the connectors on all ATX motherboards are keyed. This means they can only be inserted in one way. Older AT power supplies didn't have keyed connectors, and if they were inserted wrong, they would actually fry the motherboard. Luckily, we don't have to worry about that.

Next, we connect the CPU power. After that, we connect all our peripheral devices and any case fans. And that's it. We've successfully tested, removed, and replaced a power supply.

**Cable Management**6:19-6:52

If we want, we can go one step further and organize all these cables. This is known as cable management. Cable management doesn't just make the inside of the case look pretty; it also helps with air flow and potential problems. For example, an unused connector could make its way into the CPU fan. At the very least, this would make a really loud noise, but it could stop the fan from moving altogether—and that would be bad.

To fix this, we can use rubber bands or cable ties to bundle wires together or anchor them to the case to prevent them from moving around.

**Summary**6:53-7:10

That's it for this lesson. To review, we started by talking about the key symptoms to look for to identify the power supply as the problem. Then we looked at how to use a power supply tester. And finally, we removed the bad power supply and installed a new one.

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Chapter 3: System Components

3.3 Motherboards and Buses

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As you study this section, answer the following questions:

* What factors should you consider when selecting a motherboard?
* What chipset functionalities have moved to the CPU on newer systems?
* What are the basic steps of installing a motherboard?
* How can you add peripheral devices to a system?
* How are PCI and PCIe different?

In this section, you will learn to:

* Select an appropriate motherboard and install it in a desktop computer

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| AC (alternating current) | The type of current distributed through wall sockets. |
| DC (direct current) | The type of current used inside a computer. |
| Motherboard | A circuit board that either houses or is connected to all of the components operating in the computer. |
| CPU socket | Houses the CPU. |
| Expansion slots | Allow you to expand the capabilities of your computer. |
| Firmware | Is stored on integrated flash memory, on a motherboard. |
| Chipset | A group of chips that facilitates communication between the processor, memory, and peripheral devices. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| TestOut PC Pro | 1.1 Given a scenario, select and install PC components  1.1.2 Install and connect a motherboard |
| CompTIA 220-1001 | 3.4 Given a scenario, select, install and configure storage devices.   * Magnetic hard drives   + Sizes:     - 2.5     - 3.5   3.5 Given a scenario, install and configure motherboards, CPUs, and add on cards.   * Motherboard connectors types   + Front panel connector   + Internal USB connector * CMOS battery * Expansion cards   + Video cards     - Onboard |

3.3.1 Motherboard Components

**Motherboard Components**0:00-0:33

Components in a computer need to be able to communicate with each other. Data needs to be retrieved from the hard-drive, structures need to be read from the CPU, and graphic information needs to be sent to the video card. The component that allows all this to happen is the motherboard.

In this lesson, we're going to take a closer look at the different parts of a motherboard.

Here's a typical ATX motherboard. The first thing we want to look at are all these connection areas. Because every component connects to the motherboard, there's a lot of different connectors.

**CPU Socket**0:34-0:49

The first one you might notice is the CPU socket here. This is where the CPU is installed. Depending on the type of CPU the motherboard is made for, this socket might look a little different, but for the most part, it's very easy to identify the CPU socket.

**Memory Slots**0:50-1:00

Next to the CPU socket are the memory slots. This is where the computer's memory modules are installed. Four memory slots is standard for most motherboards but some might have more or less.

**ATX and CPU Power**1:01-1:11

Right here is the ATX power connector for the power supply and over here is the CPU power connector. This supplies the CPU with additional power.

**Case and CPU Fans**1:12-1:33

Also on the motherboard are connectors for case fans, which are these pin connectors. Most motherboards have around three case fan connectors.

In addition, there's a CPU fan connector up near the CPU socket. Even though this uses the same connector as the case fans, it's a bit different. It actually gathers information about the CPU fan such as its RPMs.

**Expansion Slots**1:34-1:43

Over here are the motherboard's expansion slots. This is where expansion boards, which expand the functionality of the computer, are installed.

**Front Panel and Case Connectors**1:44-1:57

Down by the expansion slots is where you'll find the motherboard's front panel connectors. If your case has front panel audio or USB, you connect the cables for them down here. There's also connection areas for the case's buttons and lights.

**SATA**1:58-2:11

Right here are the SATA connectors. Most new motherboards will have several of these. Their configuration will be different between motherboards. Sometimes the connections are upright and sometimes they are parallel with the board.

**Firmware and CMOS Battery**2:12-2:58

In addition to all these connectors, motherboards also have integrated flash memory that stores the motherboard's firmware. Motherboards use one of two different types of firmware. The first is the Basic Input/Output System, or BIOS. The second is the Unified Extensible Firmware Interface, or U-E-F-I.

Over here is the CMOS battery. Older motherboards store BIOS configuration settings in the CMOS chip, which uses volatile memory. The CMOS battery supplies power to this memory so that the settings aren't erased when the computer is turned off.

However, modern motherboards store the BIOS configuration settings in what's called non-volatile BIOS memory. The CMOS battery on these motherboards is used to retain accurate day and clock times when the computer is unplugged.

**Chipset**2:59-3:30

Another integrated component is the motherboard's chipset. The chipset is responsible for managing communications among the CPU, memory, and various connector components. Older chipsets were split into two integrated circuits called the northbridge and the southbridge. The northbridge handled communication between the CPU, memory, and graphics controller. The southbridge handled all other communications.

However, newer chipsets use only a southbridge, which is this chip here. The northbridge functionality has migrated to the CPU.

**I/O Connectors**3:31-3:56

Motherboards also have integrated peripheral connectors called I/O connectors. The type of connectors here depend on the motherboard. Some motherboards have onboard components such as a network card, video card, or a sound card.

If this is the case, then those connectors would be here. For example, we know this motherboard has an integrated network card and sound card because of its Ethernet and audio ports.

**Traces**3:57-4:23

There's one more, often overlooked, motherboard component you should know about. Let's flip the motherboard over. Notice the lines that run all over the back here? These are called traces.

Remember, motherboards allow all the connected devices to communicate with each other. Those communications are transmitted along these traces which connect to every chip and connector on the motherboard.

**Summary**4:24-4:35

As you can see, the motherboard plays a huge role in a computer system. It's where all the computer components connect, including the CPU, memory, hard-drives, and expansion boards. It handles the communications between each of those devices.

3.3.2 Motherboard Facts

A *motherboard* (also called system board, logic board, or mainboard) is a circuit board that either houses or is connected to all of the components operating in the computer. When selecting a motherboard, consider the following motherboard specifications:

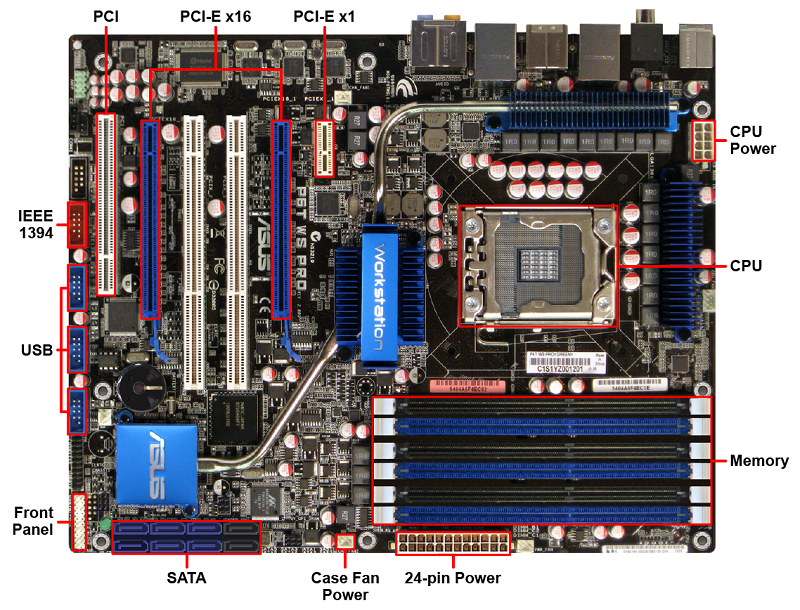
* CPU socket type
* Memory module compatibility
* Number of memory slots
* Maximum supported memory
* Expansion slot count and type
* Onboard devices (video, audio, or network)

A typical motherboard includes the following components:

|  |  |
| --- | --- |
| **Component** | **Function / Characteristic** |
| CPU Socket | The CPU socket houses the CPU. There are a variety of CPU socket types, each of which have unique shapes, pin arrangements, or mounting configurations. Because of this, it's important to match the motherboard socket type with the processor socket type. Some motherboards support multiple processors and have a socket for each CPU. |
| Memory Slots | Most motherboards have multiple memory slots. Memory slots are designed to be compatible with a specific type of memory module. |
| Expansion Slots | Expansion slots (also called expansion buses) allow you to expand the capabilities of your computer by installing expansion cards. There are a number of different expansion slot types:   * PCI (Peripheral Component Interconnect) * PCI-X (Peripheral Component Interconnect Extended) * PCIe (Peripheral Component Interconnect Express) * Accelerated Graphics Port (AGP) |
| Onboard Components | Many motherboards include onboard components (such as network cards, audio cards, video cards, or USB and FireWire connections). Selecting a motherboard with onboard devices is typically cheaper than buying separate expansion cards for each feature. However, the quality of these onboard devices might not be as high as dedicated expansion cards. |
| I/O Connectors | I/O connectors for onboard components are located on the back of the motherboard. These connectors typically include the following:   * PS/2 mouse and keyboard ports * USB ports * Serial ports (COM 1, 2, 3, and 4) * Parallel port * Audio jacks * Ethernet port   An I/O shield fits over the connectors to secure them and protect the inside of the computer from dust and debris. |
| Internal Connectors | There are a number of connectors on motherboards for components such as power supplies, fans, and LED lights. Computer cases often have front panel ports (e.g., USB, FireWire, or audio ports) that need to be connected to the motherboard. These ports are connected to the motherboard's front panel connectors, which are also called headers.  External ports that are not available on the motherboard are often added using expansion cards. |
| Firmware | The firmware on a motherboard is stored on integrated flash memory. Motherboards use one of two firmware implementations:   * BIOS (Basic Input/Output System) * UEFI (Unified Extensible Firmware Interface)   Older motherboards stored the BIOS on removable, read-only memory (ROM) chips. |
| CMOS Battery | The CMOS battery is used to keep an accurate date and time, even when the motherboard has no power. In older motherboards, the CMOS battery was also used to retain BIOS configuration settings, which were stored in volatile memory called the CMOS chip. |
| Chipset | The *chipset* is a group of chips that facilitates communication between the processor, memory, and peripheral devices.  With chipsets:   * The memory controller and graphics controller are on the CPU. * The remaining functionality is combined into a single controller chip.   + Intel processors use the Platform Controller Hub (PCH).   + AMD processors use the Fusion Controller Hub (FCH). * The front-side bus is replaced by the Direct Media Interface (DMI). |
| Support manual | A motherboard's support manual is an excellent source of information. Support manuals contain technical specifications as well as diagrams that identify the motherboard's components. If you are missing a motherboard's support manual, check the manufacturer's website. |

Selecting a motherboard with the same form factor as the case and power supply is an easy way to assure compatibility.

A typical motherboard includes the common connectors shown in the following diagram:



3.3.4 Motherboard Installation Facts

Repairing a motherboard is beyond the skill of most technicians and it is almost always cheaper and faster to purchase a new one. You might also need to replace your motherboard to add new features or to upgrade the processor. Use the following process when installing or replacing a motherboard:

1. If you are replacing an existing motherboard, document the current CMOS settings. You might need these settings to configure the new motherboard.
2. Install the CPU, heat sink, and memory before installing the motherboard in the case.
3. Insert the I/O shield into the case.
4. Fasten standoffs to the case, being sure to match the hole pattern on the motherboard. The standoffs prevent the motherboard circuits from touching the system case.
5. Install the motherboard, securing it to the standoffs with insulated washers and screws.
6. Connect the power and accessory cables:
   * Connect the ATX power cable and the CPU power cable.
   * Connect the CPU fan power cable.
   * Connect case wires (e.g., power switch, reset switch, and drive activity and power lights).
   * Connect any case fan cables.
7. Connect drives to SATA connectors.
8. Install additional devices in expansion slots.
9. Connect wires for front/top panel ports (e.g., USB, audio, or eSATA).
10. Document the settings of the new motherboard.

Consult the motherboard's documentation to identify the location and configuration of front/top panel ports and case wires.

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Chapter 3: System Components

3.5 Processors

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As you study this section, answer the following questions:

* What are the differences between the four levels of cache memory?
* What is the biggest limitation of using a 32-bit processor?
* What factors should be considered when comparing the speed of computers?
* What are the benefits of using a smaller processor size during CPU manufacture?
* What is the difference between hyper-threading and multithreading?
* Under what circumstances might you choose to use throttling?
* What is virtualization? Which CPU features enable advanced virtualization support?
* Which components are used with a CPU to dissipate heat?

In this section, you will learn to:

* Select and install a processor

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Multi-core | A processor that has multiple processors within a single processor package. |
| Throttling | The process of modifying the operating characteristics of a processor based on current conditions. |
| Overclocking | Pushing a CPU beyond its designed specifications. |
| Virtualization | The ability to install and run multiple operating systems simultaneously on a single physical machine. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| TestOut PC Pro | 1.1 Given a scenario, select and install PC components  1.1.3 Install a CPU and CPU fan |
| CompTIA 220-1001 | 3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * CPU features   + Single-core   + Multicore   + Virtual technology   + Hyperthreading   + Speeds   + Overclocking   + Integrated GPU * Motherboard connectors types   + Socket types * Compatibility   + AMD   + Intel |
| CompTIA 220-1002 | 1.1 Compare and contrast common operating system types and their purposes.   * 32-bit vs. 64-bit   + RAM limitations   + Software compatibility |

3.5.1 Processor Concepts

**Processor Concepts**0:00-1:42

In this lesson, we're going to spend some time discussing the brains of any computer system, and that's the central processing unit, which we call the CPU, or processor. Let's begin this lesson by discussing the role and function of the CPU.

The CPU is an integrated circuit that's built on a slice of silicon and contains millions of microscopic circuits called logic gates. They're all connected by hairline strands of aluminum that work together to store and manipulate data.

A CPU can accept instructions, or programs, and execute those instructions to perform both arithmetic and logical operations. These instructions may tell the CPU to perform tasks. It could prompt the user to enter a series of numbers, read the input from the system keyboard as the user types them, store those numbers in specific memory locations in the system RAM, use arithmetic functions to add all those numbers together and then write the result to a new location in the system RAM, write a message on the screen explaining the result and then open a file on the hard drive and write the result to that file, or to save the file and then close it.

So, when we say the CPU is the brains of the computer, we really aren't kidding. Without a CPU, none of the other components in the system would be able to do anything.

The CPU connects to the rest of the system using a special socket on the motherboard. This socket contains a series of many small connectors into which you plug the CPU. And by doing this, electric connections are established with the motherboard bus, which, in turn, connects the CPU to other components in your system, like the system RAM, your storage devices, your video interface, and other expansion cards that are installed in the expansion slots.

**Clock Speed**1:43-2:24

You also need to be familiar with the CPU's clock speed. The clock speed identifies the rate at which the CPU can execute instructions. The clock speed is measured in gigahertz.

The CPU requires a fixed number of clock ticks to execute each instruction. Generally speaking, the faster the CPU's clock speed, the more instructions it can execute per second.

The clock speed is very important. Understand that for all the components connected to the motherboard to communicate with each other, such as the RAM, the CPU, and the expansion cards, the components must be synchronized to the same clock. Therefore, your CPU's clock speed must be supported by the motherboard, and vice versa.

With that in mind, we need to talk about overclocking.

**Overclocking**2:25-3:24

Beware that, with most systems, the CPU, the RAM, and the motherboard can be overclocked to a degree.

Overclocking is pushing a CPU beyond its designed specifications. You can gain a marginal increase in performance by doing this. Intel's Turbo Boost technology allows the processor to dynamically run above its rated speed. It also allows a CPU to overclock as needed.

Overclocking basically increases the speed that the clock runs. Because the clock runs faster, the CPU, the memory, and the motherboard all run faster too. In theory, this provides better performance. However, beware that the improved performance comes at a price.

Overclocked systems tend to run much hotter and consume more electricity. And the increased temperature can significantly reduce the lifespan of the CPU, as well as the other components in the system.

In addition, if you push the CPU too fast, you'll probably experience system instability. So you must decide whether the increased performance is worth the shortened lifespan of the device, as well as the potential instability of the system overall.

**Cache Memory**3:25-3:55

With that in mind, let's shift gears and talk about CPU cache memory. The important thing to understand here is that the CPU has its own built-in memory. We call it the CPU cache.

CPU cache is different from the system RAM. The CPU cache is made up of static random access memory chips, or SRAM, which are very fast. In fact, they're much faster than the DRAM chips that system RAM chips are made from.

The CPU cache is used to store a copy of frequently accessed information from the system RAM. This can significantly increase performance.

**Multi-Core Processors**3:56-4:44

Now let's talk about the concept of a core.

In early CPUs, there was one processor within each CPU package. In other words, it only had a single core. If you wanted really great performance from a computer system, you could purchase a special motherboard that had two or more CPU sockets, allowing you to implement multiple CPUs at the same time.

Today, however, most CPUs have multiple processors, or cores, within the same CPU package. Implementing multiple cores dramatically improves the system performance.

The key thing to remember is that a multi-core CPU can execute more than one instruction at a time. For example, if you have four cores within your CPU, each core can execute an instruction concurrently. So, instead of processing just one single instruction, the CPU can execute four instructions at the same time.

**Multithreading**4:45-5:08

In addition to multiple cores, some CPUs also support multi-threading. Multithreading allows a single core within a CPU to execute two instructions at the same time.

Multithreading can also increase system performance, especially if it's implemented within a multi-core CPU. For example, if you have a CPU that has four cores and each one of those cores is a multithreading core, that CPU can run eight instructions concurrently.

**Hyper-Threading**5:09-5:45

Some CPUs also support hyper-threading. In 2002, Intel introduced the hyper-threading technology. This technology is owned by Intel. Hyper-threading is a form of simultaneous multithreading technology.

With hyper-threading, one physical core appears to the operating system as two processors. This allows one core to process two instructions at the same time. The two processes can also use the same resources, so if resources for one process aren't available, then another process can continue if its resources are available.

Hyper-threading gives you about a 20 percent increase in performance. Hyper-threading is not to be confused with multi-core or multithreading technology.

**Integrated GPU**5:46-6:15

There's always a wide variety of CPUs available to you, and some are better for creating graphics, crunching numbers, playing games, and so on.

A GPU, or graphics processing unit, is a programmable logic processor specialized for display functions. The GPU renders images, animations, and video for the computer's screen. GPUs are located on plug-in cards, in a chipset on the motherboard, or in the same chip as the CPU. If it's on the same chip as the CPU, it's called an integrated GPU.

**Virtualization**6:16-7:09

Let's discuss virtualization technology.

Virtualization is the ability to install and run multiple operating systems simultaneously on a single physical machine.

Let's say we have a data center with four servers and four physical platforms, each running an application. There's a database server, an application server, an email server, and a file server.

Now, suppose we combine these services virtually onto one server platform. These servers still exist, but they exist as virtual machines running under a single host OS on a single hardware platform. That's the concept of virtualization.

The virtual machines appear as self-contained and separate physical systems.

Each virtual machine looks and acts like a traditional computer system. If your computer will be used as a virtualization system, then you need to make sure that the CPU you want to implement supports virtualization.

**Cooling**7:10-9:28

Now, let's discuss cooling. When you work with modern CPUs, you have to keep cooling foremost in your mind. Sometimes people turn their systems on for testing purposes without the CPU cooler installed. This is a bad idea because modern CPUs generate a lot of heat.

Heat is bad for your computer systems. An uncooled CPU will burn up in less than a minute. CPUs use a heat sink, fan, thermal paste, liquid, or fanless cooling system to transfer heat from the CPU to the cooling unit.

Install a heat sink and fan before you ever turn the system on.

There are several different CPU cooling options available. The first one is to use a heatsink. This can be a more passive form of CPU cooling. The heatsink makes physical contact with the CPU, which, essentially, increases the CPU's surface area, allowing more heat to be dissipated.

A heatsink alone can't adequately cool a CPU. If you're going to use a heatsink, then you should always use it in conjunction with a fan. The fan blows air over the heatsink to increase the airflow. By doing this, we remove more heat from the heatsink more quickly. This is an example of active cooling.

Another option available is to use heat pipes. Heat pipes are usually implemented in conjunction with a heat sink. The heat pipes are filled with a liquid that absorbs heat from the CPU. As they do, liquids within the pipe evaporate. Because that vapor is less dense than the liquid around it, it rises towards the heat sink on the other end of the heat pipe.

Then the heat sink and a fan cool the vapor, causing it to condense back into a liquid. When it does, it drops back down to the CPU, on the other end of the heat pipe. The system keeps cycling that way to remove heat from the CPU.

This system is usually much more efficient at cooling the CPU than the traditional heat sink and fan, and it's a good example of active cooling.

There's a fourth option available that's more expensive and not as widely implemented, the radiator. This option uses a coolant, a fan, a pump, and a radiator, much like your car's cooling system.

The coolant cycles through the system, exchanging heat from the CPU to the radiator, where it's dissipated by the fan.

No matter which cooling option you use, you need to make sure that you use thermal paste. Thermal paste is critical because it facilitates heat transfer from the CPU to the CPU cooler.

**Select A CPU**9:29-11:10

With all of this information in mind, let's end this lesson by discussing several key criteria to remember when you're selecting an appropriate CPU in a new implementation. First, you need to identify the purpose of the system. You need to be sure that the CPU you select can perform the task that you want the system to perform.

Also, you need to make sure that the CPU is supported by the motherboard. Two considerations need to be taken into account. First of all, is the CPU compatible with the socket on the motherboard? And second, will the motherboard's BIOS or UEFI firmware support that CPU? A CPU may fit into the socket, but that doesn't mean the motherboard itself will support it.

You also need to identify the appropriate CPU speed. However, don't rely solely on the CPU's clock speeds when you're making comparisons between processors. There are many other factors that need to be taken into account, such as the CPU architecture, the number of cores, whether multi-threading is supported, and the amount of cache memory that has been implemented with the CPU.

One way to get around this is to use websites, such as cpubenchmark.net. These websites objectively assign a benchmark score to your CPUs that allows you to compare to see which one is fastest.

You also need to take cost into account when you're selecting a CPU. You need to decide how much performance you need versus how much money you're willing to spend.

Generally speaking, CPUs that are manufactured by Intel tend to provide the best performance. But they also come at a premium price.

CPUs manufactured by AMD, on the other hand, tend to be much less expensive, but they also don't perform quite as well. So you must make that choice between cost and performance.

**Summary**11:11-11:27

That's it for this lesson. In this lesson, we introduced you to the CPU. We talked about the role and function of the CPU, clock speeds, overclocking, cache memory, multi-cores, multithreading, and hyper-threading.

Then we talked about virtualization, cooling, and the factors you should keep in mind when selecting a CPU.

3.5.2 CPU Facts

When selecting a Central Processing Unit (CPU), you will need to match the motherboard and the CPU. Either select a CPU supported by the motherboard, or select a motherboard that will support the processor you have chosen. The following table lists several considerations for choosing a processor:

|  |  |
| --- | --- |
| **Feature** | **Description** |
| CPU Manufacturer | Intel and AMD are the two major producers of processors used in modern PCs.   * Both Intel and AMD processors work in PC systems and support Windows software. * Intel has a larger market share, while AMD processors generally cost less. * Processor performance and special features vary between models and manufacturers. |
| 32-Bit or 64-Bit | A 32-bit processor can process 32-bits of information at a time; a 64-bit processor can process 64-bits of information.   * The biggest advantage of 64-bit processors over 32-bit processors is in the amount of memory they can use. 32-bit processors have a limit of 4GB. 64-bit processors have a theoretical limit of 16 EB, although operating system and current hardware limitations impose a much lower practical limit. * The operating system and applications must be written for 64-bits to take full advantage of 64-bit processing. * The processor instruction set identifies all instructions (operations) that a processor can perform.   + 32-bit processors use the IA-32 instruction set (also referred to as x86).   + Itanium processors from Intel use the IA-64 instruction set.   + AMD64 and Intel 64 processors use the x86-64 instruction set (also referred to as x64). * 32-bit applications can run on 64-bit processors using the following methods:   + Itanium processors use a software layer to translate between IA-32 and IA-64.   + x64 processors execute both 32-bit and 64-bit instructions in the hardware.   + You can run a 32-bit operating system on a computer with a 64-bit processor. * Applications typically perform better on 64-bit systems.   + 64-bit applications typically perform better than 32-bit applications.   + In some cases, 32-bit applications might perform better on 64-bit systems. |
| Multi-Core | A multiple core processor has multiple processors within a single processor package.   * Dual-core, triple-core, and quad-core processors are typical in desktop systems. * Multi-core systems enable the operating system to run multiple applications simultaneously. Without multiple processors, applications appear to run at the same time, but must wait their turn for processing time from the single processor. * Some applications can be written to execute on multiple processors at the same time. * Some motherboards use two (or more) processor sockets to provide a multiple processor solution. Multi-core processors use a single motherboard socket to support multiple processors. |
| Speed | Processors operate using an internal clock that is the same as, or is a multiple of, the motherboard bus speed. The speed is represented in megahertz (MHz) and is also referred to as the frequency.   * You can purchase processors of the same type but with different speed ratings. * When selecting a processor, make sure the motherboard supports the processor speed by reading the motherboard documentation first. * Most motherboards automatically detect the processor speed. If not, you might need to use jumpers or edit the CMOS to configure the processor speed. |
| Cache | *Cache* is memory that the processor can access directly without using the system RAM. There are four types of processor cache:   * Level 1 (L1) cache is integrated on the processor die itself and stores instructions for the processor. On multi-core systems, each processor typically has its own L1 cache. Some processors might have two L1 caches, one for instructions and one for data. * Level 2 (L2) cache is additional cache used for both instructions and data. Depending on the processor, L2 cache might be shared between two or more cores, or exclusive to a single core. * Level 3 (L3) cache is additional cache beyond the level 2 cache. For multi-core systems, L3 cache is shared between all cores. * Level 4 (L4) cache is shared dynamically between the on-die graphics processor unit (GPU) and CPU.   Be aware of the following regarding processor cache:   * The size of the cache increases as you move from L1 to L4, with L1 cache being the smallest. * As a general rule, a processor with more cache performs better than a processor with less cache (all other things being equal). * Originally, only L1 cache was on the processor die, with L2 cache being on the motherboard between the CPU and the RAM. As processor technology has advanced, L2 cache moved to the processor die, with L3 cache being on the motherboard. Today, all three cache levels are located on the processor. * The L4 cache acts an overflow cache for the L3. Information evicted from L3 is dumped into L4. |
| Process Size | The *process size* refers to the manufacturing process used to etch transistors onto the silicon wafer that will become the CPU. A smaller process size means smaller transistors, which translates into a smaller CPU die with more transistors and less power consumption. Process size is expressed in microns (such as .25 microns) or nanometers (90 nm which equals .09 microns). |
| Hyper-Treading | *Hyper-threading* is a feature of some Intel processors that allows a single processor to run threads (instructions) in parallel, as opposed to processing threads linearly. Hyper-threading enables a processor to execute two threads at the same time. For example, on a quad-core Intel system that supports hyper-threading, the processor can execute 8 threads at a time (2 on each core).  Hyper-threading is not the same as multithreading. *Multithreading* is a feature of an application that allows it to send multiple threads at the same time. Applications are typically written to support multithreading to take advantage of multiple cores (executing threads on two or more processors at the same time) or hyper-threading features. |
| Throttling | *Throttling* is the process of modifying the operating characteristics of a processor based on current conditions.   * Throttling is often used in mobile processors to change the operating frequency to minimize power consumption and heat output. * Throttling can also be used in low memory conditions to slow down the processing of I/O memory requests, processing one sequence at a time in the order the request was received. * Related to throttling, processors or the operating system can shut down unused cores in multi-core systems to conserve energy. |
| Overclocking | *Overclocking* is pushing a CPU beyond its designed specifications. Overclocking can give you a marginal increase in performance, but will decrease your CPU's life. Some Intel processors include a Turbo Boost feature. Turbo Boost, the opposite of throttling, allows the processor to dynamically run above its rated speed to improve performance. *Unlocked* processors are processors whose speed can be changed above their rated speed through overclocking.   * With overclocking, you increase the speed and often the voltage to increase the performance of the processor. * Overclocking typically voids the CPU warranty and could lead to shorter component lifetimes. * Some multi-core processors (such as a triple-core CPU) have additional cores that have been disabled. With the appropriate motherboard support, you might be able to unlock and use the additional core(s). However, stability of the extra cores is not guaranteed. |
| Mobile Processors | Mobile CPUs are used in mobile computers and cell phones where portability and mobility are a concern. Special versions of processors are built to minimize power consumption and the amount of heat generated. |
| Virtualization | Virtualization is the ability to install and run multiple operating systems simultaneously on a single physical machine. Virtualization typically includes the following components: a physical machine, hypervisor, virtual machine, and virtual hard disk (VHD). The virtual machines appear as self-contained and separate physical systems.   * Virtualization is performed by adding a thin layer of software, called a hypervisor, between the physical system and the operating system. A hypervisor allows virtual machines to interact with the hardware without going through the host operating system. * Early virtualization was performed using software only. Newer virtualization uses special instructions supported by the processor to improve performance. * There are several different types of hypervisor software.   + VMware Workstation and ESX (made by VMware)   + Hyper-V (made by Microsoft)   + XEN (open source) * If you are planning on implementing a virtual solution, check to see whether hardware support in the CPU is required. Hardware support is provided by processors with the following features:   + Intel's Virtualization Technology (VT)   + AMD's AMD Virtualization (AMD-V) |
| Integrated Memory Controller | To improve performance, some processors include the memory controller with an integrated graphics processing unit (GPU) on the processor die, resulting in faster memory access by the processor. |
| Cooling | Processors require some form of heat dissipation system to function properly. Without a heat dissipation system, a processor will overheat and burn out in less than a minute. CPUs use a heat sink, fan, thermal paste, liquid, or fanless cooling system to transfer heat from the CPU to the cooling unit. |

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3.5.2 CPU Facts

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3.5.3 CPU Performance Facts

For a long time, processor clock speed was used as a measure of processor performance. This is not necessarily true for newer processors for the following reasons:

* If two processors are of the same type, higher speed typically means higher performance. With processors of different types, speeds might not be comparable.
* It is important to make sure your motherboard can support the speed of your processor.
* Many processors use a performance rating, instead of speed. A higher number indicates a better-performing processor. However, performance ratings are typically applicable only between models of the same manufacturer.
* In some cases, buying a processor with double the cache can nearly double the performance.
* Dual core processors offer better performance, but typically not double. Software must be specially written to take best advantage of the dual core processors.
* Special instruction sets supported by a processor can increase performance. For example, hyper-threading support on Intel processors can boost performance for specific types of operations.
* Performance can also be increased by modifying other system components such as adding more RAM, using a faster disk, or improving cooling and ventilation.
* *Overclocking* is a feature that causes the processor to operate at a higher speed. Overclocking is typically performed by those who want to get the maximum performance from their systems. Some important things to know about overclocking are:
  + Overclocking can cause system instability, component damage, and can void your warranty.
  + Motherboard bus, processor, and memory settings should be adjusted to match the overclock speed.
  + Overclocking may require more voltage.
  + Overclocking often increases heat output. For this reason, it may be necessary to upgrade your cooling devices.

3.5.4 CPU Socket Facts

When choosing a motherboard, you need to ensure that the board is compatible with the system CPU that you intend to use.

Your motherboard has a socket that accepts the processor. The processor socket on the motherboard must match the socket type used by the processor. Some motherboards support multiple processors and will have a socket for each one.

Processor sockets can be categorized according to how the processor makes contact with the leads in the processor socket.

* Pin Grid Array (PGA): PGA processors implement a series of pins on the underside of the processor package in an array. The pins are inserted into corresponding receptacles within the processor socket on the motherboard.
* Land Grid Array (LGA): The LGA socket moves the connecting pins from the processor package to the socket itself. Conducting pads are implemented on the bottom of the processor that contact the protruding pins from the processor socket.

Some commonly-implemented processor sockets include the following:

* Intel:
  + 775: Used with the Intel Pentium 4, Celeron D, Intel Pentium 4 Extreme Edition, Pentium D, Pentium Dual-Core, Core 2 Duo, Core 2 Extreme, Core 2 Quad, Xeon, and Celeron processors.
  + 1155: Used with the Intel Pentium 4, Celeron, Core i3, Core i5, Core i7, Core i7 Extreme, and Xeon processors.
  + 1156: Used with the Intel Pentium 4, Celeron, Core i3, Core i5, Core i7, and Xeon processors.
  + 1366: Used with the Intel Celeron, Core i7, and Xeon processors.
  + 1150: Used with the Intel Celeron Dual-Core, Pentium Dual-Core, Core i3, Core i5, Core i7, Core i7 Extreme, and Xeon processors.
  + 2011: Used with the Intel Core i7 and Xeon processors.
* AMD:
  + AM3: Used with the AMD Phenom II, Athlon II, Sempron, and Opteron processors.
  + AM3+: Used with the AMD Phenom II, Athlon II, Sempron, and Opteron processors.
  + FM1: Used with the AMD Athlon II processor along with the A-series APUs.
  + FM2: Used with the AMD A4 series, A6 series, A8 series, A10 series, Athlon X2, Athlon X4, FirePro, and Sempron processors.
  + FM2+: Used with the AMD A4 series, A6 series, A8 series, A10 series, Athlon X2, and Athlon X4 processors.

3.5.6 CPU Installation Facts

Remember the following when installing a CPU:

|  |  |
| --- | --- |
| **Installation Step** | **Description** |
| Prepare for Installation | Preparing for a CPU installation will help to ensure that your new components are not damaged before installation.   * Use anti-static protection when installing a CPU. * Ensure that the CPU and motherboard socket type match. The socket identifies the number and layout of pins. * Verify that the motherboard supports the processor speed. * Verify how heat connectivity will be established between the CPU and heatsink. |
| Insert CPU | Inserting the CPU is simple.   * Handle the CPU by the edges without touching the underneath connectors. * Drop the processor into place, then push down on the lever to lock the processor into place when using a Zero Insertion Force (ZIF) socket that uses a lever to allow installation of the processor. * Be sure to orient the CPU appropriately with the socket.   + In most cases, the pin array is keyed so that the CPU can be inserted in only one way.   + For processors that can be inserted multiple ways, be sure to line up pin 1 on the processor with pin 1 in the processor slot. Pin 1 is typically identified with a dot or a triangle. * Fill unused processor slots with a special terminating resistor when installing a processor in a multi-processor system. * Be sure that the speed of the processors are the same when adding multiple processors in a multi-processor system, . |
| Install Heat Sink and Fan | The heat sink and fan are installed on top of the CPU.   * CPUs require a heat sink and most desktop systems also use a fan for cooling. * When installing a heat sink, use thermal grease or a thermal pad between the processor die and the heat sink. This maximizes heat transfer between the processor and the CPU. |
| Connect Fan Power | When the CPU includes a fan, be sure to connect the fan power to the motherboard. |
| Configure CMOS Settings | Most motherboards automatically detect the processor speed. If not, you might need to use jumpers or edit the CMOS to configure the processor speed. For newer processors released after the motherboard, you might be able to add support for the processor by updating the BIOS.   * Typically, the processor will run at a speed lower than its rating if the motherboard does not support the higher speed. * As a best practice, you should update the BIOS shortly after installing the processor (you must have a processor and memory installed to update the BIOS).   An important feature in the BIOS/UEFI is the Execute Disable Bit. Execute Disable Bit (EDB) is an Intel hardware-based security feature that can help reduce system exposure to viruses and malicious code. EDB allows the processor to classify areas in memory where application code can or cannot execute. When a malicious worm attempts to insert code in the buffer, the processor disables code execution, preventing damage and worm propagation.  To use Execute Disable Bit, you must have a PC or server with a processor with Execute Disable Bit capability and a supporting operating system. EDB-enabled processors by Intel are indicated by a "J" after the CPU model number. Execute Disable Bit is abbreviated as EDB (by Intel) or XDB. |
| Troubleshoot | Use the following troubleshooting tips if you are having problems with your installation:   * **Spontaneous reboot or intermittent system crashes**: An overheated CPU will cause a spontaneous reboot or intermittent system crashes. A spontaneous reboot can also be caused by a bad power supply or device driver. A clicking noise when reading or writing data from the hard disk is an early sign of a failing drive. * **System lockups and restarts**: Because you have just replaced the processor, the most likely cause of the problem is related to the CPU. System lockups and restarts can be caused by an overheated processor. Make sure the CPU fan is running, and that you have used thermal paste between the CPU and the heat sink. * **System beeps regularly, nothing is shown on the screen and it doesn't start**: Flashing the BIOS is often required to upgrade system components that are part of the motherboard, such as to upgrade to a faster processor. If the motherboard lists the processor as supported but it is not correctly recognized, update the BIOS to the latest version. Before you can do this, you must reinstall the old processor in the system to get it back up and running again. Press F8 while booting to enter the advanced boot menu when Windows loads. However, this option assumes the BIOS has loaded correctly and the computer passed the POST tests. Replacing the motherboard is likely not required as the motherboard was working correctly and the documentation states the CPU is compatible with the motherboard. Replace the CPU only after you have determined that it is faulty. |

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Chapter 3: System Components

3.7 Memory

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As you study this section, answer the following questions:

* What is the difference between SRAM and DRAM?
* What are two advantages of using DDR3 memory over DDR2 memory?
* What is the difference between SODIMM and UniDIMM?
* How does DDR4 differ from DDR3?
* What does the IMC do?

In this section, you will learn to:

* Classify different types of RAM
* Distinguish between different standards of DRAM

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Static RAM (SRAM) | Stores data using four transistors for every bit of data. |
| Dynamic RAM (DRAM) | Stores data using a single transistor for every bit of data. |
| DDR | Double-Data Rate Synchronous Dynamic RAM |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| CompTIA 220-1001 | 3.3 Given a scenario, install RAM types.   * RAM types   + SODIMM   + DDR2   + DDR3   + DDR4 * Error correcting * Parity vs. non-parity |
| CompTIA 220-1002 | 1.7 Summarize application installation and configuration concepts.   * System requirements   + RAM |

3.7.1 Random Access Memory

**Random Access Memory**0:00-0:29

In this video, we're going to talk about random access memory, or RAM.

RAM is a type of computer memory. Its name comes from the way you can access it randomly. The CPU can access any memory cell without accessing any of the preceding bytes. It goes directly to the memory cell containing the information it needs.

RAM is the most common type of memory in computers and peripheral devices like printers.

There are two main types of RAM. The first is called DRAM.

**DRAM**0:30-2:14

DRAM stands for dynamic random access memory. DRAM is the most common type of RAM used in the computer.

In a PC system, RAM is implemented as a series of DRAM chips soldered onto an interface board. We call this a stick of RAM.

DRAM stores each bit of binary data in a memory cell made of a capacitor and a transistor.

The capacitor stores the electrical charge. If there's a charge in the capacitor, it could be represented by a 1. A lack of a charge could be represented by a 0. The transistor regulates the current and acts like a switch for the electronic signals coming into the memory cell, a little gate that opens and closes. The transistors and capacitors for RAM are extremely small. Billions can fit on a single memory chip.

There's a problem with DRAM. The capacitors lose their charge quickly and have to be recharged. So if we want to keep our data in RAM, we have to refresh that charge every now and then, or we'll lose it. Capacitors need a new electronic charge every few milliseconds.

Each DRAM chip is made up of a bunch of memory cells, and each of these cells is assigned an address using hexadecimal notation.

The address of each memory cell is a number selected by the integrated memory controller, or IMC, for a byte of data. An integrated memory controller, or IMC, is a digital circuit that manages the flow of data going to and from the RAM. This address is used to write and retrieve data. The IMC keeps track of the addresses of all the cells, where they're at, and what's in them.

The IMC and the CPU are connected to a set of wires called an address bus. The address bus allows the CPU to communicate with the IMC. The CPU sends requests to read or write to a certain memory cell in the RAM through the address bus.

DRAM is most often the main memory in your computer.

**SRAM**2:15-2:45

There's also static random access memory, or SRAM. SRAM is primarily used for the cache in the CPU in PC systems, LCD screens, and printers.

A typical SRAM chip is composed of six transistors, a capacitor, and a switched buffer. When the switched buffer is open, data moves in and out of the cell. When the switched buffer is closed, no data moves in and out of the cell. The switched buffer can retain the value of one or zero without having to be refreshed. By doing this, SRAM provides faster access to data.

**DRAM vs SRAM**2:46-3:25

DRAM and SRAM have different strengths that suit them to different situations. If your priority is speed, SRAM is your best choice. DRAM needs to be refreshed thousands of times per second, while SRAM does not need to be refreshed.

DRAM access time is about 60 nanoseconds. SRAM provides access time as low as 10 nanoseconds.

DRAM is volatile or non-persistent, which means that it loses its contents when the power is turned off. SRAM comes in both volatile and nonvolatile types. Nonvolatile SRAM is used in many situations, like networking, aerospace, and medical, where preserving data is critical and batteries are impractical. But you'll encounter DRAM more often since it's more affordable.

**DDR2**3:26-3:49

Sometimes you'll see synchronous DRAM, or SDRAM, synchronized with the clock speed that the microprocessor is optimized for. Doing this increases the number of instructions the processor can perform.

DDR2 is a double data rate SDRAM interface. On top of double-pumping the data bus, DDR2 allows higher bus speed and requires a lower power by running the internal clock at half the speed of the data bus.

**DDR3**3:50-3:59

DDR3 has a high-bandwidth interface and different signaling voltages and timings from other RAMs. It transfers data at twice the rate of its predecessors.

**DDR4**4:00-4:11

DDR4 is not compatible with any earlier RAM due to different signaling voltages and physical interface. It has higher module density, lower voltage requirements, and higher data rate transfer speeds.

**Summary**4:12-4:22

To review, we discussed RAM and how it works. We introduced you to the two types of RAM, DRAM and SRAM. DRAM is used as the main memory, and SRAM is primarily used for cache memory in the CPU.

3.7.1 Random Access Memory

**DRAM Types**0:00-0:22

In this lesson we'll talk about the different types of DRAM. When installing or upgrading memory for your computer, it's important that you get the right type. You should be able to recognize each type of DRAM by sight.

But, to identify the memory in your computer, you'll probably run a utility or use the internet to look up a serial number for the memory modules. Let's take a look at each memory type.

**DDR**0:23-1:23

Let's start with DDR, or sometimes called DDR1. Here's a DDR module. Notice that there is a single notch, slightly off-center.

You'll notice that for each memory module that we look at, the slot positions are slightly different to prevent you from installing the wrong memory. One way to tell the type of memory you have is to look at the stickers on the memory module.

In this case, the sticker identifies this as DDR 266 memory. The 266 is the operating frequency. And DDR identifies it as DDR memory.

If the memory module doesn't have any stickers, try installing the memory into a given slot. If the notch is in the correct location for the slot, then you have the correct memory for your machine.

DDR accepts one command per clock cycle followed by two data sets. So, for each clock cycle the DDR RAM can accept two 64-bit words of data. DDR operates at 2.5 volts at bus frequencies between 100 and 200 MHz.

Although DDR is no longer used in motherboards, you might encounter this type of memory in older systems.

**DDR2**1:24-2:03

So it's important to know it.

The next memory module is DDR2. DDR2 has a single slot. If I look at the sticker on the memory, I can see that it's labeled as PC2 with the 2 identifying DDR2, instead of the previous DDR.

DDR2 doubles the bandwidth of DDR. It accepts four data sets per clock cycle. It operates at 1.8 volts, with a frequency of 200 to 533 MHz, making the frequency faster and doubling the amount of data submitted in a single clock cycle.

Another improvement with DDR2 is the addition of a buffer between the data bus and the memory. The buffer allows movement of the four data sets and the increased speed per clock cycle.

**DDR3**2:04-2:24

The next memory module is DDR3. DDR3 has a single slot. However, this notch is off to the left.

DDR3 is an improvement on previous versions. It doubles the data rate of DDR2, allowing it to accept eight data sets per clock cycle. DDR3 also has a buffer and operates at 1.5 volts with a frequency between 400 and 1,000 MHz.

**DDR4**2:25-3:18

The newest member of the RAM family is DDR4. Notice the notch on a DDR4 module is left of center.

DDR4 supports a number of power saving enhancements, including a power down mode to reduce power consumption when the system is in standby. The lower operating voltage and power enhancements allow DDR4 RAM to draw less power and run cooler than DDR3 RAM.

With DDR4, you have a lower operating voltage of 1.2 volts. In addition, DDR4 chip densities have increased. DDR4 chips are manufactured in densities of up to 2 to 16 GB per chip. That is double the density of DDR3.

So you can see that as we move from DDR to DDR2 to DDR3 and DDR4, we lower the voltage in each case while increasing the operating frequency. We also take the amount of data submitted in each cycle and double that.

**Memory Modules Comparison**3:19-4:14

Now let's look at a sample of each memory module.

If you compare DDR and DDR2 memory, you will notice that the notch on DDR is slightly closer to the center. You can also see that the DDR2 memory has more pins across the bottom. The easiest way to distinguish between the two is to look at the pins. DDR memory has pins that are rather wide. DDR2 memory has pins that are not as wide, allowing you to fit more pins within the same space.

When you compare DDR2 and DDR3, you might be able to tell that both DDR2 and DDR3 have an equivalent number of pins. In other words, the connectors across the bottom are similarly spaced. Comparing that to DDR memory, you'll notice that the notch on DDR3 is to the left of DDR.

Now let's add DDR4 to our group. The notch on DDR4 is closer to the center than DDR3. DDR4 has a greater pin density.

**Memory Form Factors**4:15-4:32

There are 288 pins, compared to the 240 pins on DDR3.

In addition to the various standards we have discussed, memory can be packaged into different form factors depending on the memory type and the use for the memory. So, let's look at the different memory modules that you can purchase and install on your computer.

**DIMM**4:33-4:42

A DIMM refers to any variation of the DDR RAM. You might see motherboard documentation that would say this motherboard accepts a total of four DIMMs, or it has a total of four DIMM slots.

**SO DIMM**4:43-5:19

Another term you might see is SO DIMM, or Small Outline Dual In-line Memory Module. These are used in laptops. The difference between a DIMM and a SO DIMM is the size and the number of memory chips on the module itself. DIMMs typically contain eight memory modules, but SO DIMMs are about half the size with maybe four memory chips.

The capacity may be the same, but the number of chips required to reach that capacity is different. The smaller size allows the chip to fit within the smaller form factor of the laptops. SO DIMMs use any type of DDR RAM depending on how the memory has been packaged.

**UniDIMM**5:20-5:35

UniDIMM, or Universal DIMM, is an upgrade to the current SO DIMM standard and allows mobile platform users to use both DDR3 and DDR4 in the same slot. Because of this, the computer's memory controller must support both DDR3 and DDR4 memory standards.

**Memory Size Comparison**5:36-5:54

If I compare the SO DIMM and UniDIMM memory modules to the DIMM modules that fit in a desktop system, you'll notice a size difference. This difference is due to the fact that these smaller modules are used in laptop systems. Also, notice that there are different pin densities and notch positions between these modules.

**Summary**5:55-6:07

That's it for this lesson. We looked at the different types of DRAM you may encounter and discussed their frequency and bandwidths. If you're putting together a new computer, you will likely use DDR3 or DDR4 DIMMS for desktop computers or UniDIMMS for laptop computers.

3.7.3 RAM Facts

Random Access Memory (RAM) can be classified as one of two types:

|  |  |
| --- | --- |
| **Type** | **Description** |
| Static RAM (SRAM) | SRAM stores data using four transistors for every bit of data. SRAM does not require constant power to maintain the contents of memory.   * SRAM is more complex and less dense (e.g., lower storage capacity) than DRAM. * SRAM is faster and requires less power than DRAM. * Regular SRAM still requires periodic power to maintain the state of memory, but the rate of refresh is less than with DRAM. Non-volatile SRAM (nvSRAM) is able to maintain memory contents when the power is turned off. * SRAM is typically used in cache memory, such as CPU cache, hard disk cache, and cache in networking devices. |
| Dynamic RAM (DRAM) | DRAM stores data using a single transistor for every bit of data (a 0 or a 1). To maintain the state of the transistor, DRAM must continually supply power to the transistor; when the power is turned off, the data is lost.   * DRAM is simple to implement. * DRAM can have a very high density (e.g., high storage capacity). * Because of the simplicity, DRAM is relatively inexpensive. * DRAM is used in the main system memory on a computer. |

All system memory used in personal computers is DRAM. Individual DRAM chips are packaged onto a board that contains circuitry for reading and writing to the memory. You should be aware of the following standards for DRAM:

|  |  |  |
| --- | --- | --- |
| **Hardware** | **Standard** | **Description** |
|  | DDR | DDR (Double-Data Rate Synchronous Dynamic RAM) is a variation of the original synchronous DRAM (SDRAM).   * All variations of DDR are synchronized with the system clock and accept 64-bit words. * DDR accepts a single command and two consecutive data sets per bus clock cycle. * Operating at the same frequency, DDR has twice the bandwidth of SDRAM. * DDR operates at 2.5 volts at bus frequencies between 100-200 MHz.   DDR memory has a single notch, slightly off center. DDR memory has 184 pins. |
|  | DDR2 | DDR2 doubles the data transfer rate of DDR, for four times the bandwidth of SDRAM.   * DDR2 accepts four consecutive 64-bit words per bus clock cycle. * DDR2 includes a buffer between the data bus and the memory. * DDR2 operates at 1.8 volts at bus frequencies between 200-533 MHz. The internal memory frequency is half that of the bus frequency (100-266 MHz).   DDR2 memory differs from DDR memory as follows:   * The notch is slightly closer to the middle. * It has 240 pins. While you don't need to count the pins, you should notice that the pins are smaller because they have to fit in the same space as the DDR memory. |
|  | DDR3 | DDR3 doubles the data transfer rate of DDR2, for eight times the bandwidth of SDRAM (twice that of DDR2).   * DDR3 accepts eight consecutive 64-bit words per bus clock cycle. * DDR3 operates at 1.5 volts at bus frequencies between 400-1000 MHz. The internal memory frequency is one-fourth that of the bus frequency (100-266 MHz).   DDR3 memory has a single notch more left of center than the notch for DDR or DDR2. Like DDR2, DDR3 has 240 pins. |
|  | DDR4 | DDR4 doubles the data transfer rate of DDR3 for ten times the bandwidth of SDRAM.   * DDR4 accepts eight consecutive 64-bit words per bus clock cycle. * DDR4 operates at 1.2 volts at bus frequencies between 1066-2133 MHz. The internal memory frequency is about one-tenth that of the bus frequency (100-266 MHz). * DDR4 reduces the demand for power. * DDR4 is not compatible with earlier types of random access memory (RAM) because of the different signaling voltages, physical interface, and other factors. * DDR4 theoretically allows for DIMMs of up to 512 GB in capacity, compared to the DDR3's theoretical maximum of 128 GB per DIMM.   DDR4 memory has a single notch slightly right of center. DDR4 has 288 pins. |

DDR is no longer used in modern motherboards, although you might encounter DDR memory in older systems.

Memory comes in various form factors (or packages), with the form factor determining the number of pins and the size of the memory module. Generic form factor labels that you should be familiar with are:

|  |  |  |
| --- | --- | --- |
| **Hardware** | **Form** | **Description** |
| DDR DIMM | DIMM | A DIMM (dual in-line memory module) has pins on both sides of the module, with each pin being unique.   * DIMMs have a 64-bit data path that matches the system bus width. * RDRAM and DDR/2/3/4 are packaged into DIMMs, with each specification having a unique number of pins and notch position. * DDR4 allows for DIMMs of up to 512 GB in capacity. |
| 144-pin SODIMM  200-pin SODIMM | SODIMM | A SODIMM (small outline dual in-line memory module) is a smaller DIMM used in laptops.  SODIMMs are much smaller than other memory, perfect for notebook computers. Notice the notch slightly off center in the 144-pin SODIMM. 144-pin SODIMMs are used by SDRAM, DDR, and DDR2 memory. On the 200-pin SODIMM, notice that the notch is farther off center than the 144-pin SODIMM. You might also be able to notice the higher pin density. 200-pin SODIMMs are used by DDR2 and DDR3 memory. |
|  | UniDIMM | UniDIMM (Universal DIMM) is a specification for DIMMs and is designed to carry DRAM chips. UniDIMMs can be populated with either DDR3 or DDR4 chips, but do not support any additional memory control logic. Because of this, the computer's memory controller must support both DDR3 and DDR4 memory standards. UniDIMM:   * Is an upgrade to the current SODIMM standard * Allows mobile platform users to use both DDR3 and DDR4 |

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3.7.3 RAM Facts

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3.7.4 Memory Speed

**Memory Speed**0:00-0:26

Computers use RAM for storing data that's currently used by the processor. RAM is the fastest storage type in a personal computer. When comparing memory modules of different types like SD RAM, DDR2, or DDR3, remember that memory is not created equal. Some memory modules are faster than other modules.

As we talk about the speed of a memory module, you need to be aware of the following terms.

**Frequency**0:27-2:23

The first term that is sometimes used to designate the speed is the frequency. Frequency describes how fast the clock cycle runs. When talking about the clock cycle, there are two different measurements that we need to be aware of. The first is the bus clock and the other is the internal clock of the memory module.

When you think of the clock cycle, think of people playing jump rope. They have the ropes strung between them and a third person is jumping. The clock cycle refers to how fast the rope rotates. As memory operates, it need to send and receive data in time with the rotation of the clock cycle.

For example, if the person jumping the rope were to jump at the wrong time, the rope would hit that person. The same thing happens with the clock cycle. The bus is operating at a certain cycle and certain timing.

You might even think about it as a rhythm, like a beat in music. As the memory operates, the communication between the memory and the bus needs to occur on these regular cycles. The bus is set to operate at a certain frequency.

For example, 1,000 MHz. Memory often has a lower internal frequency than the bus frequency. But it is always a multiple of the bus frequency. For instance, let's say that the memory module operates at only 200 MHz, so it's operating slower than the bus speed. In this case, the bus clock is operating at five times the speed of the internal memory clock.

This is important because with every cycle of the internal memory, I can send five different instructions from the system bus. So when we talk about the speed of the memory, the memory is often matched to the bus clock.

However, the internal operating speed of the memory might be slower, as a multiple of the bus clock. The memory must match the bus clock but also have its own internal frequency.

What makes this confusing is that when you ask how fast the memory is, some specifications may refer to the bus clock that the memory matches, and some specifications may refer to the internal clock that the memory uses.

**Bandwidth**2:24-4:10

The second term we use to describe the speed of the memory is bandwidth. The bandwidth describes the amount of data that can be sent. It's typically expressed as megabytes per second (MBps).

So, for example, one memory module might be rated at 100 MBps. And a different module might be able to receive 200 MBps worth of data. The increase in the bandwidth of the memory is often received by increasing the bus speed so that more multiples of the internal speed can be received on a single cycle.

Remember that DDR2 memory doubles the bandwidth of DDR memory by doubling the amount of data that is sent within a clock cycle. DDR3 doubles the bandwidth of DDR2, and DDR4 doubles the bandwidth of DDR3.

When we talk about the speed of memory, we might be talking about the frequency at which it operates, or we might be talking about the amount of data that can be sent.

In most cases, the term "speed" better describes the bandwidth, because bandwidth is always comparable. A memory module that can accept 200 MBps of data is always faster than one that can accept 100 MBps.

However, when you're talking about frequency, sometimes a memory module with a frequency of 166 MHz might actually outperform a memory module that operates at 200 MHz. This can happen if the bus speed is higher or the amount of data it accepts per memory cycle is higher.

But on some certification exams, the questions may be referring to the frequency and not the overall bandwidth, when they ask about the speed of the memory module.

**Match Memory Speed to Motherboard Speed**4:11-7:57

Let's look at how to match the memory module speed to the motherboard speed. The speed of the memory module is typically identified by a rating number. There are several designations for identifying the memory speed.

When DDR RAM was introduced, they kept the PC designation for a while. However, to communicate the idea that DDR RAM doubles the bandwidth of SD RAM, the PC designation was doubled to designate twice the speed of the bus.

So a PC designation was the bus speed times two. The two coming from the doubling of the multiple instructions per clock cycle. For instance, a PC200 designation operates at a bus speed of 100 MHz, but it was called 200 to illustrate that double the amount of data was being sent within that same bus cycle.

For example, a PC100 designation for SD RAM operates at the same frequency as a PC200 designation. However, the PC200 memory can now move twice the amount of data within the same bus cycle.

To further complicate things, as DDR memory evolved, the PC designation was changed to no longer identify twice the bus speed, but rather to identify the bandwidth. So a PC designation of PC1600 does not mean that the bus is operating at 800 MHz. Instead, it means that it's capable of sending 1600 MBps worth of data and in fact, a PC200 rating is equivalent to a PC1600 rating.

To tell the difference, ask yourself, does the number designate twice the bus speed? Or does it designate the bandwidth? Currently, all modules that are rated with the PC rating identify the bandwidth. However, as you're mixing and matching older modules and trying to compare the speeds, you need to be aware that current designations identify the bandwidth, whereas older specifications identify frequency.

With the introduction of the new PC rating that identifies the bandwidth, they use a new rating of DDR to identify the frequency. So an older designation of PC200 is equivalent to the newer designation of DDR 200, which is equivalent to the PC1600 designation.

Newer memory modules won't use this older style. So you may see a PC3200 memory module, which also has a designation of DDR 400. 3200 identifies the bandwidth, whereas DDR 400 identifies the bus speed multiplied by two. In this case, the bus speed would be 200 MHz.

Designations for DDR2, DDR3, and DDR4 memory follow these same conventions. The PC designation identifying bandwidth and the DDR, either DDR2, DDR3 or DDR4, identifying the frequency. So with these memory modules, you can take the PC number in every case and compare it between DDR2, DDR3, and DDR4.

For instance, if I had a DDR3 module that operates at PC3 6400, or if I had a DDR2 module that operates at PC2 6400, you might ask yourself which memory module is faster. In this case, we're comparing bandwidth, and the bandwidth is equivalent.

Let's say, for instance, I'm comparing PC3 6400 with PC2 8500. In this case, I have an older standard of memory module, PC2 or DDR2 that can move 8500 MBps of data, which makes it faster than the PC3 designation of 6400.

Frequency is further complicated. Looking at my frequency designations, if I have a DDR2 module with an 800 designation, this means that the bus clock is operating at 400 MHz. Again, the designation is double the bus clock. If I have a DDR3 module, also operating at 800, these are equivalent in speed because they are operating at the same frequency.

**Frequency Comparison**7:58-8:29

So let's look at a couple of examples. Let's say we have PC166 memory and we want to compare that with PC266 memory. We're also going to compare it to DDR2 400 memory, and DDR3 400 memory.

So the question is, which of these memory modules is the fastest? Well, in this case, all of these designations are identifying the frequency of the system bus. So a straight number comparison will tell me that DDR2 and DDR3 are equivalent in speed and both are faster than the other two designations.

**Bandwidth to Frequency Conversion**8:30-10:19

Now let's say my second memory module has a PC rating of PC1600. In this case, if I were simply comparing the values, I might think that PC1600 is faster than the DDR2 400. But remember, this is a case where the PC designation is now identifying bandwidth instead of a frequency, I'm not doing an apples to apples comparison. Instead, I'm comparing the bandwidth in one case to the frequency in the other cases.

So to make this comparison, I need to convert the bandwidth into a frequency value. And I do that by dividing the bandwidth by eight, which gives me a PC200 rating, also called a DDR 200 rating.

Now I can make my frequency comparisons and see that DDR 200 is slower than the DDR 400.

Now, let's replace my last memory module with a PC3 8500 designation. Here, I need to answer the question, which memory is faster? Again, in some cases, I'm using frequency and in other cases, I'm using bandwidth.

I can immediately identify that the bandwidth of the PC3 module is higher than the bandwidth of the PC1600 module, but to make these comparisons, I need to convert the bandwidth to a frequency value, which is dividing it by eight, which gets me a DDR3 designation of 1066.

So in this case, when comparing the frequency, my DDR3 module is faster than my DDR2 400 module. Or in other words, a memory module with a PC3 8500 designation is faster than the DDR2 400 designation.

Now, the main thing to remember when comparing memory modules, is to ask yourself, am I comparing the frequency or the bandwidth? Or is there some odd combination of the two? Ideally, all ratings will be either frequency or bandwidth. But if you need to convert between one and the other, simply divide the bandwidth by eight to get the equivalent frequency.

**Multiple Channel Memory Configurations**10:20-12:48

We've seen how DDR memory increases the bandwidth of memory by sending multiple datasets in a single clock cycle. Another method for increasing memory bandwidth is by using multiple channels.

A typical system configuration has a single memory controller that sends data to multiple memory modules. All data that is intended for the RAM must pass through this single memory controller.

Dual channel memory adds a second, or even a third memory controller to the motherboard. In this case, my memory modules are assigned to one of the memory controllers. So, for instance, if I have dual channel memory, I would assign one memory module to one controller and the second module to the second controller.

Triple channel memory has three memory controllers and the chance to assign three different memory modules to three different memory controllers. With dual and triple channel, you can often assign multiple chips per channel.

For example, if I had a dual channel system, I could have, perhaps, four memory modules with two modules assigned for each controller. With triple channel, I would complete the configuration by assigning a total of six modules across the three controllers.

Using dual or triple channel in this manner doesn't replace the DDR configuration, or the DDR2 or DDR3 capabilities of the memory, because I can send multiple instruction sets at a time for each clock cycle during a single clock cycle, through this controller.

The only difference between dual and triple channel is that with the triple channel, I can divide the data between multiple memory controllers, so that instead of having a single pipeline to all memory modules, I have multiple pipelines that handle the load to the memory modules.

When using dual and triple channels like this, you might think that by splitting the workload between multiple controllers, I would be able to double the bandwidth. However, in most cases, the actual increase is five to fifteen percent when using dual and triple channel memory configurations.

It's also important to note that using dual and triple channel memory configuration is a configuration specific to the motherboard and not to the memory itself. The memory you purchased is still DDR2 or DDR3 memory. The dual and triple channel capabilities typically come from the motherboard and not from the memory module itself.

You can use DDR2, DDR3, and DDR4 memory in a dual channel configuration. With triple channel and quadruple channel, you can use DDR3 and DDR4 memory. All this is dependent on the memory type supported by your motherboard.

**Summary**12:49-13:10

That's it for this lesson. When we talk about memory speed, we need to identify what we mean. Are we talking about the frequency or the bandwidth? In most cases, an exam question is looking at the frequency. However, the frequency is often inadequate when identifying the real performance of the memory. The best measure of performance is the bandwidth. Lastly, we talked about increasing memory bandwidth by using multiple channels.

3.7.5 Memory Speed Facts

Memory is rated based on its guaranteed stable operating frequency and bandwidth (the rate at which data can be read or written). Memory ratings help you to differentiate between slower and faster RAM. The following rating systems are used:

* For all DDR memory (DDR, DDR2, and DDR3), a new designation was introduced to identify that twice the data was being transferred with each bus clock cycle.
  + The number following the DDR-, DDR2-, and DDR3- prefixes is the data transfer rate (twice the bus frequency).
  + For example, DDR-400 matches a bus frequency of 200 MHz; DDR2-800 has a bus frequency of 400 MHz; and DDR3-1600 has a bus frequency of 800 MHz.
* For DDR past 150 MHz (and for all DDR2 and DDR3 memory), the PC- designation was changed to identify the *bandwidth* instead of a number derived from the bus frequency.
  + The bandwidth is 16 times the bus frequency, or 8 times the DDR- designation.
  + For example, DDR-400 has a bandwidth of 3200 MB (PC-3200); DDR2-800 has a bandwidth of 6400 MB (PC-6400); and DDR3-1600 has a bandwidth of 12800 MB (PC-12800).
  + For a brief time, the double-frequency designation used the PC- prefix for early DDR modules. For example, PC-200 used with DDR indicates a bus frequency of 100 MHz, not a bandwidth of 100 MB (PC-200 is equivalent to DDR-200 which is equivalent to PC-1600).

When listing the frequency, the frequency value usually indicates the bus speed, not the internal frequency (DDR designation) used by the memory.

The following table lists the various memory speed designations for the most common memory types:

|  |  |  |
| --- | --- | --- |
| **Memory Type** | **Bus Speed** | **Designations** |
| DDR | 100 MHz | PC-200 or PC-1600 or DDR-200 |
| 133 MHz | PC-266 or PC-2100 or DDR-266 |
| 166 MHz | PC-2700 or DDR-333 |
| 200 MHz | PC-3200 or DDR-400 |
| DDR2 | 200 MHz | PC2-3200 or DDR2-400 |
| 266 MHz | PC2-4200/4300 or DDR2-533 |
| 333 MHz | PC2-5300/5400 or DDR2-667 |
| 400 MHz | PC2-6400 or DDR2-800 |
| 533 MHz | PC2-8500/8600 or DDR2-1066 |
| DDR3 | 400 MHz | PC3-6400 or DDR3-800 |
| 533 MHz | PC3-8500 or DDR3-1066 |
| 667 MHz | PC3-10600/10666 or DDR3-1333 |
| 800 MHz | PC3-12800 or DDR3-1600 |
| 900 MHz | PC3-14400 or DDR3-1800 |
| 1000 MHz | PC3-16000 or DDR3-2000 |
| DDR4 | 800 MHz | PC4-12800 or DDR4-1600 |
| 933 MHz | PC4-14900 or DDR4-1866 |
| 1066 MHz | PC4-17000 or DDR4-2233 |
| 1200 MHz | PC4-19200 or DDR4-2400 |
| 1333 MHz | PC4-21300 or DDR4-2666 |
| 1600 MHz | PC4-25600 or DDR4-3200 |

When comparing the speed of memory modules, be aware of the following:

* The most useful way to compare most DDR modules will be to compare the amount of data that can be transferred per second (bandwidth), as indicated by the PC- designations. For example, PC-3200 will always indicate a "faster" memory module than one with a PC-2700 rating.
* PC- numbers up to PC-266 identify the frequency (or double the frequency), not the bandwidth. For example, a PC-266 module has a greater bandwidth than a PC-1600 module (PC-266 = PC-2100).
* Comparing DDR- numbers can also give you an idea of the relative bandwidth. For example, DDR-600 can transfer more data than a DDR2-400 module.
* The bandwidth identifies a theoretical maximum that the memory can transfer in a given time period, and is directly related to the front size bus frequency.
* If you can derive the bus frequency, you can also get a relative idea of the amount of data a module can handle.
  + When comparing DDR modules, the frequency is relative to the bandwidth.
  + For example, a DDR2 module operating on a 533 MHz bus is faster than a DDR3 module on a 400 MHz bus.
* Other memory characteristics besides the frequency could affect the effective bandwidth or actual speed of the memory module.

Another method for increasing memory bandwidth is by providing multiple channels within the memory controller.

* Dual-channel systems use two memory controllers, while triple-channel systems use three memory controllers. Quadruple-channel (quad-channel) systems use four memory controllers. Each memory controller can communicate with one or more memory modules at the same time.
* To operate in dual-channel mode, install memory in pairs; to operate in triple-channel mode, install memory in sets of three. To operate in quad-channel mode, install memory in sets of four
* Dual-channel systems theoretically double the bandwidth. However, in practice, only a 5–15% increase is gained.
* Dual-channel, triple-channel, and quad-channel support is mainly a function of the motherboard (e.g., the memory controller), not the memory itself. DDR, DDR2, DDR3, and DDR4 can all work in dual-channel systems (depending on the memory supported by the motherboard); both a triple-channel and a quad-channel system use DDR3 and DDR4.

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Chapter 3: System Components

3.10 BIOS/UEFI

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As you study this section, answer the following questions:

* What are the functions of the BIOS?
* What is the role of CMOS? How does it differ from the BIOS?
* Why does the CMOS require a battery?
* What might be some common reasons for editing the CMOS settings?
* What determines the keystroke to open a CMOS editor? How can you find this information?
* What functions are performed in the POST process?

In this section, you will learn to:

* Find and edit BIOS settings
* Clear CMOS settings

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Unified Extensible Firmware Interface  (UEFI) | I/O firmware that will, eventually, completely replace BIOS. |
| Basic Input Output System  (BIOS) | Firmware that controls input and output operations. |
| Electrically Erasable Programmable Read-Only Memory  (EEPROM) | A RAM chip that replaced the CMOS chip. |
| Complementary Metal-Oxide Semiconductor  (CMOS) | A technology for constructing integrated circuits. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| TestOut PC Pro | 1.2 Given a scenario, configure hardware components  1.2.2 Configure BIOS/UEFI settings |
| CompTIA 220-1001 | 3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * BIOS/UEFI settings   + Boot options   + Security   + Drive encryption   + TPM   + LoJack   + Secure boot |

3.10.1 BIOS/UEFI

**BIOS/UEFI**0:00-2:38

In this lesson, we're going to talk about BIOS and CMOS. For the sake of clarification, when we say BIOS and CMOS we're really talking about four things: UEFI, legacy BIOS, CMOS, and EEPROM.

UEFI stands for Unified Extensible Firmware Interface and is a firmware interface for PCs. It was designed to replace the BIOS. The UEFI design improves the software interoperability and the address limitations of BIOS. It also provides better security to protect against bootkit attacks.

UEFI provides faster start-up time, support for drives larger than 2.2 TB, support for 64-bit firmware device drivers, and compatibility with both BIOS and UEFI hardware.

Most PCs use UEFI but some still use a legacy BIOS. Because of this, the term BIOS has become a generic term referring to both UEFI and legacy BIOS.

The term CMOS has also become a generic term because CMOS chips have been replaced by Electrically Erasable Programmable Read-only Memory or EEPROM chips. Yet, many people still call them CMOS.

EEPROM is a type of non-volatile memory used in computers and other electronic devices to store relatively small amounts of data.

EEPROM also replaced EPROM chips and have been used for computer BIOS since 1994. EEPROM allows individual bytes to be erased and reprogrammed. Meaning that you can update the BIOS in your computer without having to open the computer and remove any chips.

Now that we've cleared that up, in this lesson we'll use the generically accepted terms of BIOS and CMOS because it will be important for you to know them both.

To understand the BIOS, the CMOS, and the role that they play in a PC system, you need to understand that the CPU inside the PC doesn't know how to directly communicate with the other devices that are installed on the motherboard. Furthermore, the CPU doesn't know how to contact RAM or the storage devices connected to the motherboard.

In order for the CPU to do this, it needs software. It needs programming. And it needs a set of instructions that tell it how to communicate with these devices. The problem is that the CPU can't store the software in the RAM or disk because it doesn't know how to communicate with the RAM or the hard disk natively. So, it can't load the software it needs to communicate with these devices from these devices.

So, what do we do?

**ROM**2:39-4:04

Well, what we do is implement a special chip in the motherboard called a ROM chip. ROM stands for Read-only Memory. A ROM chip is kind of like a RAM chip, a Random Access Memory chip. However, a ROM chip retains its contents even if the system is powered off. This is called persistent data.

A RAM chip loses its content when the PC is turned off. However, ROM chips, unlike RAM chips, can't be written to. Whatever was written on that ROM chip when it left the factory, is what's there. You can't add information to it.

ROM chips installed in the motherboard contain hundreds of little programs that were burned into the ROM before it left the factory. These little programs allow the CPU to communicate with various devices attached to the motherboard like the keyboard, the disk drives, and the memory. The CPU reads the information from the ROM chip the same way it reads information from the RAM.

All of the hundreds of little programs stored on the ROM chip are collectively referred to as the basic input-output services or BIOS chip. Most of the ROM chips used by PC systems with a BIOS vary from 365 KB to 1 MB in size. Now, in the industry, we say BIOS chip, but the BIOS is not really the ROM chip itself. The BIOS is really the software on the ROM chip.

**Devices**4:05-4:29

Devices that are connected to or a part of the motherboard can be categorized into three different categories. We have devices that have non-configurable parameters and aren't likely to ever be replaced. We have devices that have configurable parameters or that are likely to be changed from time-to-time. And then we have custom devices that may or may not be present in any given system.

**Non-configurable Devices**4:30-4:57

Let's first talk about non-configurable devices. These types of devices can be handled by the BIOS alone. Because the parameters don't change, nothing has to be changed in the programming that allows the CPU to communicate with that given device. These are devices such as the keyboard, or the system speaker, not audio speakers that you listen to music through, but the speaker that is built into the PC case that provides a simple beeping sound.

**Configurable Devices**4:58-5:58

The second category are configurable devices with parameters that can be changed or upgraded from time-to-time. The BIOS can't handle these parameters alone because the presence of the device, the quantities, or parameters may change from system to system.

For example, we can have 1 GB of memory in one machine and 4 GB in another machine. We can have a 40 GB or 250 GB hard drive installed in the system. If we had only a BIOS, then theoretically, if we changed anything in the system like adding more memory or adding a bigger hard drive, then we'd have to install a new BIOS chip that supported the new parameters associated with those new devices because the BIOS isn't re-writable.

Instead, PCs use a second RAM chip in conjunction to the ROM chip that can be written to and read from. These chips are called EEPROM chips. However, most people still refer to them as CMOS. I'll introduce you to CMOS in a minute.

**Custom Devices**5:59-7:41

This brings us to the third category of devices present in the PC system. These include devices like sound cards, network adapters and video cards. There's an endless variety of different types of cards that can be inserted into the expansion slots of the PC.

Within each category like sound boards, there's an endless variety of different models that can be installed. You can buy a sound card from this manufacturer or that manufacturer. They all do the same thing, but they're built slightly differently.

The problem with custom devices is that there's no feasible way to build a BIOS ROM chip or a CMOS RAM chip that's extensive enough to accommodate every last different type of device that you could possibly put in the PC. So, your PC system uses one of two strategies to allow the CPU to communicate with these types of devices.

The first strategy is to put Option ROM or OPROM into the devices. OPROM is firmware run by the PC BIOS during platform initialization. Option ROM is usually stored on a plugin card but it can also reside on the system board. Devices like video cards, network adapters, and storage drivers for RAID modules contain OPROM. Option ROM also provides firmware drivers to the PC.

A second strategy is to use device drivers. This is the more common strategy used for sound cards, network adapters, and all kinds of other devices. In this case, we aren't really using the BIOS to address these devices. Instead, we're using a device driver which is a piece of software that's loaded by the operating system. It tells the CPU how to address the sound card or how to address the network board.

**CMOS**7:42-9:44

Now, let's talk about CMOS. CMOS stands for Complementary Metal Oxide Semiconductor. The CMOS is RAM, Random Access Memory. The CMOS contains the parameters that BIOS programs need in order to access certain devices.

The BIOS, on the other hand, contains programs that the CPU needs in order to communicate with various devices on the motherboard. The BIOS is hard-wired ROM memory, read-only memory, so it cannot be rewritten.

For example, let's say we add a new hard drive into our system. Because this new hard drive has different parameters from the one that was there before, we need to update the CMOS with the new parameters for the new hard drive so that the CPU can access the hard drive.

The CPU loads the appropriate programs from the BIOS. Since these programs need the parameters that the CMOS already has, these programs contact the CMOS and ask it for the location where data can be stored on the new hard drive.

Whenever you add a new component, you can change the values that are stored in the CMOS and the CMOS will relay these configuration changes to the BIOS.

The CMOS is also where your system clock runs from. Have you ever looked down to the bottom right corner of your screen to see what time it is? Your operating system pulls that time from the CMOS.

On older systems, the CMOS would lose its BIOS settings if it lost power, so a coin battery was used to provide a small amount of power to the CMOS while the computer was off. This battery is called the CMOS battery.

However, since we use EEPROM chips instead of CMOS chips, the configuration information is not lost at shut down. EEPROM is a type of flash memory and won't lose any BIOS settings when the power is off.

Despite that, we still need a CMOS battery. The CMOS battery is used to keep the clock running even when the computer is turned off. Otherwise, you would have to reset the clock every time you turned on the computer.

**BIOS Settings vs. CMOS Settings**9:45-11:14

Before we end our discussion on BIOS and CMOS, you need to know about two different terms that are used interchangeably in this context in the industry. You might hear someone say, "I'm going to edit my BIOS settings." Or you might hear someone say, "I'm going to edit my CMOS settings." They're talking about the same thing but using the terms CMOS and BIOS interchangeably is not technically correct.

In the past, the BIOS chip and the CMOS chip were physically separate. They were two separate chips implemented on your motherboard. Today, they're both implemented within the same chip package even though they are still separate entities. Because they are implemented within the same chip package, we tend to use both terms, BIOS and CMOS interchangeably.

But, the BIOS is still not re-writable and we can't save any custom parameters to it. That's the job of the CMOS chip. To modify the parameters, we can run a small program out of the BIOS called the CMOS setup program that provides us with a user interface where we can specify the various parameters that the BIOS program needs to communicate with the hardware in our system.

For example, we can store information about our hard drive geometry in the CMOS chip. We can customize the speed in which the CPU and the memory runs in the system and so on. We enter this information using the CMOS setup program which in turn saves it in the CMOS chip. That information is also used by the programs running on the BIOS to allow the CPU to perform its work.

**Summary**11:15-11:56

Let's review what we've discussed in this lesson. We learned that the CPU can't directly access other devices that are installed on the motherboard. To do that, we have to have software and that software is stored in the BIOS or the UEFI of the motherboard. These programs allow the chip to communicate with these other devices.

For some devices, we have to use the CMOS to store various parameters that the software in the BIOS needs to give to the CPU so that the CPU can access them. We also talked about devices that have their own BIOS or device drivers loaded into the system so that the CPU can use them. Lastly, we talked about the CMOS battery, it's purpose and the difference between BIOS settings and CMOS settings.

3.10.2 PC Boot Process

**PC Boot Process**0:00-0:14

One of the main jobs of the UEFI or legacy BIOS is to help you start the system. Several different processes occur when you first turn the computer on. Let's take a look at what they are.

**Power to CPU**0:15-0:36

First, power is supplied to the CPU. The CPU is hard coded to look at a special memory address for code that it can execute. This memory address contains a pointer or a jump program that tells the processor where to find the UEFI or legacy BIOS program. After it does, the CPU loads the legacy BIOS or UEFI program.

**Run POST**0:37-2:14

After the UEFI or BIOS starts, the first process run is the POST process. POST stands for Power-On Self Test. POST does several different jobs. First, it verifies the integrity of the UEFI BIOS code to make sure it's uncorrupted.

After the POST is satisfied that the integrity of the code is good, it then looks for the BIOS and the video card. The BIOS and the video card are checked and loaded. This allows the display signal to be sent to your monitor so that you can see what's happening during the power on process.

Once that's done, POST checks to see if there are other add-in cards with BIOS programs. Not all add-in cards have their own BIOS, but some do.

The last process that occurs during POST is a device check. The POST program goes through the system and checks all of the basic devices that are needed for the system to run, such as memory, the keyboard, and so on.

Perhaps you've powered on a PC and gotten a keyboard error because you were leaning up against the keyboard or holding down a key during system boot up. POST was sending that error.

The POST was trying to check the keyboard and determined that something was wrong because it was receiving a signal for one particular key character over and over again. POST knew that the keyboard wasn't supposed to do that. So it assumed that something was wrong with the keyboard and displayed the error on the screen.

Also, you may have noticed the little memory counter up in the top left corner of the screen when you first turn on your PC. That's the POST program running. It's testing your computer's memory to see how much memory is installed in the system.

**Identify System Devices**2:15-2:36

After the POST tests are complete, the UEFI or legacy BIOS identifies other system devices. It uses the information contained in your EEPROM as well as the information supplied by the devices themselves to identify and configure hardware devices. This is where your plug-and-play devices are allocated system resources.

**Identify the Boot Drive**2:37-3:20

At this point, the UEFI or legacy BIOS searches for a boot drive using the boot order specified in the CMOS setup program. You can go in to your CMOS setup program and specify which device you want to boot off of.

For example, do you want to boot off of your DVD drive first? Or do you want to boot off of your hard drive first? Maybe you want to boot off of a flash drive.

You can configure those things in your CMOS setup program. The BIOS will search for that boot drive using that boot order. Then on that boot device, the BIOS searches for the master boot loader and loads the boot loader program.

At this point, the BIOS stops controlling the system. Control is passed to the boot loader program.

**Load the Operating System**3:21-3:41

The boot loader program is configured to locate and load an operating system off of your boot device, whether it's a CD, DVD, or hard disk. When it finds the operating system, it loads the kernel for that operating system.

As the operating system loads, additional steps are taken to load all of the additional programs and configure the devices that are needed by the operating system.

**Summary**3:42-3:59

So let's review. In this lesson we discussed how the boot process works. First, power is supplied to the CPU. The CPU loads the BIOS. The POST process begins and the BIOS identifies other system devices and identifies the boot drive. And lastly, the operating system is loaded.

3.10.3 BIOS/UEFI Facts

You should know the following facts about the UEFI, BIOS, EEPROM, and CMOS:

|  |  |
| --- | --- |
| **Component** | **Description** |
| Unified Extensible Firmware Interface (UEFI) | The UEFI was designed to replace the BIOS. Important things about UEFI are:   * The UEFI is firmware. * The UEFI program controls the startup process and loads the operating system into memory. * The UEFI design improves the software interoperability and the address limitations of BIOS. * The UEFI provides better security to protect against bootkit (malware attacks on the boot process) attacks. * The UEFI provides faster startup times. * The UEFI supports drives larger than 2.2 terabytes. * The UEFI supports 64-bit firmware device drivers. * The UEFI is compatible with both BIOS and UEFI hardware. * You should frequently check for UEFI updates from the manufacturer. Updating the UEFI (called flashing the UEFI) makes new features available. |
| Basic Input/Output System (BIOS) | The BIOS is a legacy program stored in a read-only memory (ROM) chip that the CPU automatically loads and executes when it receives power. Important things to know about the BIOS are:   * The BIOS program controls the startup process and loads the operating system into memory. * The BIOS is firmware. * You should frequently check for BIOS updates from the manufacturer. Updating the BIOS (called flashing the BIOS) makes new features available, such as allowing the BIOS to recognize newer hardware devices. * Most BIOS chips vary from 265 KB to 1 MB in size. * Video cards include a BIOS chip on the device. These devices have their own ROM chip called an option ROM (OpROM). |
| Electrically Erasable Programmable Read-Only Memory (EEPROM) | The EEPROM is a RAM chip that replaced the CMOS chip. Important things about EEPROM are:   * EEPROM is a type of non-volatile memory used in computers and other electronic devices to store relatively small amounts of data. * EEPROM allows individual bytes to be erased and reprogrammed. * EEPROM replaced EPROM chips and are used for computer BIOS built after 1994. * EEPROM chips allow you to update the BIOS/UEFI in your computer without having to open the computer and remove any chips. |
| Complementary Metal-Oxide Semiconductor (CMOS) | CMOS is legacy computer chip technology that has become a general term used for the program that stores important system information related to the starting of a computer. It is often used synonymously with BIOS. Data held in CMOS includes the hard disk type and configuration, the order of boot devices, and other configurable settings related to the system hardware. The following are important things to know about CMOS:   * You changed the data stored in CMOS using a CMOS editor program that was part of the BIOS. * CMOS used to refer to the real-time clock and the CMOS chip that stored system information. Both were powered by a CMOS battery. Now, the EEPROM chip stores the system information that used to be stored on the CMOS chip. EEPROM requires no power to maintain data storage. * The CMOS battery is still used to keep the real-time system clock running when the computer is powered off. It can be a low-voltage dry cell, lithium mounted on the motherboard, or even AA batteries in a housing clipped on a wall inside of the case. The electric current is about 1 millionth of an amp and can provide effective power for years. |

During the computer's startup procedure, you can press one or more keys to open a CMOS editor so you can change the data stored in CMOS memory. This CMOS setup program is part of the BIOS program. The key or keys you press to open the CMOS editor depend on the BIOS manufacturer. The easiest way to find out which key to press is to read the screen as it boots or to consult the motherboard documentation. The most common keys are Delete, Insert, F1, and F2.

Common reasons for editing the CMOS settings are:

* To change the boot device order.
* To enable or disable motherboard devices.
* To add a password to the setup program to prevent unauthorized access.

If you set a BIOS/UEFI password and then forget it, you will be unable to edit CMOS settings.

To remove the password for most motherboards, move or remove a jumper, then replace it after a specific period of time.

* To configure processor or memory settings (e.g., when you need to set operating speeds or when you want to overclock hardware settings).
* (In rare cases) To manually configure device properties for legacy devices.

One of the main jobs of the BIOS/UEFI is to help start the system. The following process is used when you turn a computer on:

1. Power is supplied to the processor. The processor is hard-coded to look at a special memory address for the code to execute.
2. This memory address contains a pointer or jump program which instructs the processor where to find the BIOS program.
3. The processor loads the BIOS program. The first BIOS process to run is the power-on self-test (POST) process. POST does the following:
   1. Verifies the integrity of the BIOS/UEFI code.
   2. Looks for the BIOS on the video card and loads it. This powers the video card and results in information being shown on the monitor.
   3. Looks for BIOS programs on other devices, such as hard disk controllers and loads those.
   4. Tests system devices, such as verifying the amount of memory on the system.
4. After POST tests complete, the BIOS identifies other system devices. It uses CMOS settings and information supplied by the devices themselves to identify and configure hardware devices. Plug-and-play devices are allocated system resources.
5. Then the BIOS searches for a boot drive using the boot order specified in the CMOS.
6. On the boot device, the BIOS/UEFI searches for the master bootloader, then loads the bootloader program. At this point, the BIOS/UEFI stops controlling the system and passes control to the bootloader program.
7. The bootloader program is configured to locate and load the operating system.
8. As the operating system loads, additional steps are taken to load all additional programs and configure devices for use by the operating system.

From time to time, your PC's manufacturer may release updates to your BIOS firmware. To update the BIOS, you will need to download the update along with a utility provided by your PC manufacturer that is used to rewrite data stored in the BIOS chip. This process is called *flashing* the BIOS. The actual steps you follow to flash the BIOS will vary by manufacturer.

You should connect your PC to a UPS before flashing the BIOS. If a power outage occurs during the flash process, it will irrecoverably damage the BIOS and prevent your system from booting.

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Chapter 3: System Components

3.11 Expansion Cards

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As you study this section, answer the following questions:

* What advantage does a PCIe bus have over a PCI bus?
* Which type of devices typically use mini PCI cards?
* Which bus type is commonly used by graphics cards?
* What type of slot can a PCIe x1 expansion card be placed in?

In this section, you will learn to:

* Install an expansion card

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Peripheral Component Interconnect  (PCI) | A connection slot for a 32-bit computer bus. |
| PCI Extended  (PCI-X) | A PCI design that overcomes PCI bandwidth limitations. |
| PCI Express  (PCIe) | The connector that replaced PCI, PCI-X and AGP. |
| Mini PCI | A small form factor used by computers. |
| Legacy Bus | An old bus no longer supported by manufacturers. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| TestOut PC Pro | 1.1 Given a scenario, select and install PC components  1.1.5 Select and install expansion cards |
| CompTIA 220-1001 | 3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * Motherboard connectors types   + PCI   + PCIe   + Riser card |

3.11.1 Expansion Buses and Slots

**Expansion Buses and Slots**0:00-1:26

Technology in the computer world advances extremely fast. This is really cool, but can also be somewhat frustrating. The high-end computer you bought a month ago can suddenly become a thing of the past when the next new technology is released. Luckily, computers have a way to keep up with new technology and features by using expansion cards.

Expansion cards are circuit boards that are designed to fulfill a specific role, such as sound processing or graphics processing. These cards are often called dedicated cards and are installed into a motherboard's expansion slot.

The nice thing about expansion cards is that if the computer doesn't offer a certain type of feature, or if a new technology is released, it can be added without needing to buy a completely new computer.

Expansion cards and slots are designed to use a particular expansion bus standard, which defines the communications specifications and the physical characteristics of the card and the slots.

Now, most expansion bus standards aren't compatible with each other. Because of this, it's important for you to be able to identify the bus type used by a particular expansion card or expansion slot. There are some physical characteristics you can look for to do this.

For expansion cards, we look at the characteristics of the insertion tab. For expansion slots on the motherboard, you look at its length and how it's keyed.

So let's take a look at the first expansion bus type you should be familiar with, the Peripheral Component Interconnect (PCI).

**PCI and PCI-X**1:27-2:27

PCI expansion cards have a connector tab that looks like this. The tab is keyed. It has a notch here, towards the back of the card. This notch corresponds to a notch on the motherboard's PCI expansion slot, which looks like this.

This is where the PCI expansion board is installed. The keyed tab helps prevent installing the wrong type of interface or installing the card in the wrong direction.

There is another type of interface that was built on the PCI standard and was designed to enhance it. This is the PCI-X interface. The X stands for extended. As you can see, PCI-X cards and slots are double the length of the standard PCI interface. PCI-X has double the transfer speeds of standard PCI.

The PCI and PCI-X interfaces are somewhat older interfaces. While you'll still find PCI slots in most desktop computers, PCI-X slots are usually found only in server systems. The interface that's replacing these older types is the PCI Express (PCIe) interface.

**PCI Express**2:28-4:08

The PCI Express interface is much faster than standard PCI and also allows for a lot more functionality and features. The PCIe interface has two main types of connection formats. The first is the PCIe x1 format.

An expansion card that uses the PCIe x1 interface has a keyed tab that looks like this. It almost looks like a miniature PCI tab. This is the PCIe x1 expansion slot on the motherboard. Notice how small it is. The PCIe x1 interface is typically used by network interface cards or dedicated sound cards.

The second type of PCIe is the PCIe x16 interface. As its name suggests, the PCIe x16 interface is longer than the PCIe x1 interface. PCIe x16 cards also have a keyed tab and they look like this. And here's the PCIe x16 expansion slot. Now, the PCIe x16 interface might look the same as the standard PCI interface to you, but they are different.

The notch on the PCIe x16 interface is near the front of the card and slot. The PCI interface's notch is at the back. In addition, PCIe x16 expansion cards have this little hook here at the back of the card. The hook connects to the tab on the PCIe x16 slot on the motherboard right here. It helps secure the expansion card and ensure that it's properly seated.

The PCIe x16 interface is 16 times faster than the PCIe x1 interface. As such, it's primarily used by dedicated video cards.

**Summary**4:09-4:23

As a PC technician, you are going to be removing and installing expansion boards all the time. Because of this, being able to tell a PCI interface from a PCIe x16 interface or a PCIe x1 interface from a PCI-X interface is not just helpful, it's necessary.

3.11.2 Expansion Bus Types

Expansion cards are used to expand a computer's functionality or increase its performance. Expansion cards are installed into the expansion slot on a motherboard. Expansion cards and slots use different expansion bus standards that define communication specifications as well as physical characteristics.

The following table describes the characteristics of the most common expansion bus types:

|  |  |
| --- | --- |
| **Bus Type** | **Characteristics** |
| Peripheral Component Interconnect (PCI) | PCI was developed to replace the obsolete ISA and VESA bus standards. PCI:   * Is processor independent, meaning the CPU and PCI bus can process concurrently * Supports plug-and-play, meaning installed devices are detected and configured automatically * Is used most commonly by devices such as sound cards, modems, network cards, and storage device controllers * Can run at 33 MHz and transfer data at 133 MBps or run at 66 MHz and transfer data at 266 MBps |
| PCI Express (PCIe) | PCIe was developed to replace PCI, PCI-X, and AGP. Instead of a shared bus, each PCIe slot links to a switch that prioritizes and routes data through a point-to-point dedicated connection and provides a serial, full-duplex method of transmission. PCIe uses several different connection types.   * PCIe types are defined by the number of transmission lanes that are used to transfer data. For example, PCIe x1 provides one lane for transmission (x1), while PCIe x16 provides sixteen lanes for transmission. PCIe defines x2, x4, x8, x16, and x32 connection types. * PCIe data rates depend on the protocol version and number of transmission lanes:   + 1.0: 250 MBps (x1); 4 GBps (x16)   + 2.0: 500 MBps (x1); 8 GBps (x16)   + 3.0: 1 GBps (x1); 16 GBps (x16)   + 4.0: 2 GBps (x1); 32 GBps (x16) * In addition to greatly increased speed, PCIe offers higher quality service. * PCIe can run alongside legacy PCI technology (e.g., both PCIe and PCI buses can be in the same system). * PCIe x1 slots are typically used for network cards, USB cards, and sound cards. PCIe x16 slots are primarily used for dedicated video cards.   PCIe cards are cross-size compatible, as long as the slot size is the same or larger than the card size. For example, a PCIe x1 card can be installed in a PCIe x16 slot, but a PCIe x16 card cannot be installed in a PCIe x1 slot. |
| Legacy buses | Buses that have been replaced by newer types are considered legacy buses. Legacy buses are rarely used and include the following:   * AGP (accelerated graphics port) was a dedicated bus type used by dedicated video cards. * AMR (audio/modem riser) was a riser card that attached to the motherboard and allowed additional cards (called daughter cards) to be installed. * CNR (communications network riser) was a riser card slot that allowed for installing network, sound, or modem functions. |

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Chapter 3: System Components

3.12 Video

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As you study this section, answer the following questions:

* How does the video card affect the quality of the image on the monitor?
* Which type of DVI connector sends digital signals only?
* How does the GPU increase the video performance?
* What are the differences between integrated graphics and dedicated video cards?
* What advantages are provided by SLI and CrossFire?
* What is the general function of HDCP? When should you be concerned with an HDCP video card or monitor?

In this section, you will learn to:

* Select the appropriate video card for a computer system
* Upgrade a video card

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Display connectors | Connectors that attach to different displays like VGA, DVI-I, HDMI, DisplayPort. |
| Display quality | The resolution, refresh rate. |
| Processing capabilities | The capacity of the graphics processing unit (GPU). |
| Memory | DDR, DDR2, DDR3, GDDR2, GDDR3, GDDR5. |
| Bus type | PCIe x16, PCI, AGP, VESA. |
| Multi-GPU | SLI, CrossFire. |
| HDMI audio | HDTV out, onboard sound. |
| DirectX/openGL | A collection of APIs that improves graphic, animation, and multimedia creations. |
| TV Input/output | S-video, HDMI, VGA, DVI and connectors. |
| High-bandwidth Digital Content Protection (HDCP) | A digital copy form designed to protect digital media from piracy. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| CompTIA 220-1001 | 3.1 Explain basic cable types, features, and their purposes.   * Video cables   + VGA   + DVI   + HDMI   + Mini-HDMI   + DisplayPort   + DVI-D, DVI-I   3.2 Identify common connector types.   * BNC   3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * Expansion cards   + Video cards   3.6 Explain the purposes and uses of various peripheral types.   * Monitors |

3.12.1 Video Cards

## Video Cards 0:00-0:33

Video cards are responsible for generating a computer's visual output. This visual output can be as basic as a line of text on a screen or as complex as an immersive, 3D PC game. And, as you might guess, processing graphics for a PC game is a lot more demanding than processing graphics for a text program.

In this lesson, we're going to take a look at the different implementations and features of video cards, as well as some video card characteristics you should be aware of. This information will help you select the best video card for any implementation.

## Video Card Components 0:34-1:11

Video cards are composed of two main components: a graphics processing unit, GPU, and video memory. The GPU's job is to process all graphical information and output it to a display. Because that generates a lot of heat, GPU's have heatsinks and fans on them to keep them cool.

The video memory is used to store graphic information that needs to be accessed extremely fast. Video cards can have anywhere between 1 GB and 12 GB of video memory.

Video cards can be implemented in two main ways. The first is for the video card to be integrated with another component. This implementation is called integrated graphics.

## Integrated Graphics 1:12-2:01

The most common integrated graphics solution is to have the video card integrated with the motherboard. Motherboards with integrated graphics are often said to have onboard video cards.

Onboard video cards are usually sufficient for most computer needs. They're also the cheapest and most widely-implemented graphics solution.

One thing to know about onboard video cards is that they share system memory for graphic processing. This means, if you have 4 GB of RAM in your computer, the onboard video card might allocate 512 MB of that RAM for graphic processing.

Motherboards with onboard video cards can be easily identified by having video output ports on the I/O plate.

Another type of integrated graphic solution is to integrate the video card with the CPU. CPU-integrated graphics also share system memory.

## Dedicated Video Cards 2:02-2:43

The second type of implementation is a dedicated video card. Dedicated video cards are installed into expansion slots on the motherboard and contain everything needed for graphic processing. Dedicated video cards have a GPU, as well as very high-speed dedicated graphic memory, known as SGRAM, which can be implemented as VRAM, or much faster GGDR3, 4, or 5 memory.

High-end dedicated video cards have a very large heatsink and multiple fans on the card for thermal management.

Dedicated video cards are the most expensive and the most robust video solution. They're typically used for gaming computers, or computers that deal with a lot of graphic applications, such as 3D rendering software.

## Display Connectors 2:44-3:15

When selecting a video card, there are a few considerations you need to keep in mind. The first is the output connectors on the card. These can be VGA, DVI, S-Video, HDMI, or display port connectors. Some video cards even have coaxial or RCA connectors.

While you can use an adaptor, it's best to select a video card with connectors that match your display device.

Some video cards also have input connectors. These video cards are typically used for capturing video from external devices.

## Display Capabilities 3:16-3:30

It's also important to select a video card that matches or exceeds the capabilities of your display device. Some parameters to consider are resolution, the number of pixels that can be displayed, and refresh rate, which is the number of times per second the screen is redrawn.

## Memory Size 3:31-3:49

Depending on your needs, you might need a video card with a lot of memory. A good way to determine how much memory a video card needs is to look at the recommended requirements of the most demanding application the computer will be running.

For example, if a PC game recommends a video card with 2 GB of memory, then select a video card that has at least 2 GB of memory.

## DirectX/OpenGL 3:50-4:19

Another consideration is specific to PC games. Most PC games use a particular 3D graphics API to communicate with the GPU. The two most common 3D APIs are DirectX and OpenGL. If the computer will be used to play the latest PC games, make sure the video card supports the latest 3D API version.

Now, there are several considerations to keep in mind that involve dedicated video cards only. The first is the bus type.

## Bus Types 4:20-4:40

Because dedicated video cards are installed into expansion slots, you need to make sure your motherboard has the correct bus type. Most dedicated video cards use a PCIe x16 expansion bus. Some video cards might use a PCIe x1, or PCI expansion bus. Whatever's used, make sure the motherboard and video card bus types match.

## Multi-GPU Support 4:41-5:06

The second consideration is multi-GPU support. Some video cards have multi-GPU technology that allows two identical video cards to be linked together and share the graphical processing load. The name of the technology is manufacturer-specific. NVIDIA calls it SLI, and AMD calls it CrossFire.

Multi-GPU configurations can get very expensive and really benefit only high-end PC gaming systems.

## Summary 5:07-5:25

For most computer systems, integrated graphics are a good choice and offer more than enough processing capability. However, if more processing power or memory is required, a dedicated video card is most likely the only solution.

Remember, when selecting a video card solution, be sure to identify recommended requirements, display connector compatibility, and supported bus types.

3.12.2 Video Card Facts

Video cards process graphical information for output to an external display.

This lesson covers the following topics:

* Integrated vs. dedicated video cards
* Characteristics of video cards

### Integrated vs. Dedicated Video Cards

Video cards can be implemented as a dedicated expansion board or integrated with other components (e.g., the motherboard or CPU).

* Dedicated video cards:
  + Are installed in an expansion slot on the motherboard
  + Have a graphics processing unit (GPU) and a dedicated, high-speed video memory bank
  + Are more powerful than integrated video cards, but are also more expensive
* Integrated graphics:
  + Integrate the GPU with another hardware component (e.g., a motherboard or CPU)
  + Share system memory for graphic processing
  + Are much cheaper than dedicated video cards, but are also less powerful

### Characteristics of Video Cards

When selecting a video card, keep in mind the following characteristics:

|  |  |
| --- | --- |
| **Characteristic** | **Description** |
| Display Connectors | Video cards have one or more connectors for attaching an external display. Always try to select a video card with connectors that match your display.   * VGA monitors use a VGA (DB-15) connector. * LCD and LED monitors use one (or more) of the following connectors:   + DVI-Integrated (DVI-I) connector   + HDMI connector (also used by HDTVs)   + DisplayPort connector   DVI-I connectors are able to send either analog or digital signals. Older video cards might use DVI-A (analog) or DVI-D (digital) connectors.  Some video cards have dual heads (two output connectors capable of displaying video simultaneously) and are able to support dual monitors.  If necessary, you can use special connector adapters to convert from one connector type to another (e.g., DVI to HDMI). However, it's usually best to match the connector type of the video card with the display connectors. |
| Display Quality | The quality of images and animations is determined by both the video card and the external display. When selecting a video card, the following specifications should be considered:   * The *resolution* is the number of pixels displayed on screen. A higher resolution means that more information can be shown on the screen. A video card is rated by its max resolution, which is the highest possible resolution it can display (e.g., 1920 × 1080 or 4096 × 2160). * The *refresh rate* is the number of times in one second that the GPU draws a frame. Refresh rates are measured in hertz. A refresh rate of 70 Hz or lower may cause eye fatigue. An optimal refresh rate is between 75 Hz and 85 Hz.   For optimal image quality and graphic performance, it is best to select a display that matches the video card specifications, and vice versa. |
| Processing Capabilities | The graphics processing unit (GPU) handles all video rendering tasks. GPUs are much more efficient at processing graphic data than a traditional CPU.   * Using the GPU to render graphics is often referred to as video hardware acceleration. * Settings in the operating system can be used to control how much video processing is offloaded to the GPU. * GPUs have a clock speed that is rated in MHz. A higher speed means better performance. |
| Memory | Dedicated video cards use high-speed memory to store graphic data. The amount of memory on the card affects performance as well as other characteristics.   * The amount of memory on a card can be as low as 1 GB or as high as 12 GB. * Dedicated video cards use the following types of memory:   + DDR, DDR2, and DDR3 memory are similar to system memory. This type of memory is cheaper, but provides less performance features than special graphics memory.   + GDDR2, GDDR3, and GDDR5 are DDR memory specifically designed and optimized for graphical data. This memory is more expensive, but results in better performance.   Integrated graphics (onboard video cards) share system memory with the CPU for video processing. |
| Bus type | Video cards must be compatible with the expansion slots on the motherboard. Common slot types used by video cards include the following:   * PCIe x16 * PCI * AGP and VESA (used by older video cards)   Motherboards with integrated graphics embed the functionality with the buses on the system (e.g., PCIe, AGP, or PCI). |
| Multi-GPU | Some video cards can be linked together and share the graphic processing load between the two GPUs.   * Multi-GPU configurations are manufacturer-specific:   + NVIDIA uses SLI (Scalable Link Interface).   + AMD uses CrossFire. * Video cards are linked using a special bridge clip or through software (depending on the implementation). * The motherboard and each video card must use the same connection method (SLI or CrossFire). The motherboard must also have multiple PCIe x16 slots. * In most cases, both video cards must be identical.   Some motherboards allow you to link an integrated graphics controller with a video card installed in the expansion slot; however, this offers a negligible performance boost. |
| HDMI audio | HDMI cables are able to carry both video and audio signals; however, most video cards send only a video signal. The following techniques can be used to send an audio signal through the video card:   * With audio pass-through, an audio output cable is connected to the video card. The video card combines the audio signal with the video signal for HDMI output. This option is often called HDTV out. * A graphics card with an onboard audio processor can decode and process audio and send it out the HDMI port. This option is often referred to as onboard sound. |
| DirectX/OpenGL | DirectX is a collection of application program interfaces (APIs) that improves graphic, animation, and multimedia creations.   * DirectX includes multiple components targeted to a different aspect of multimedia. For example, Direct3D is the 3D rendering component of DirectX. * Applications (typically games) are written using features included in specific DirectX versions. * To view content written to a specific DirectX version, your video card must also support that (or a higher) version.   OpenGL is an alternative standard to DirectX that is used by some applications. Most video cards support both DirectX and OpenGL. |
| High-bandwidth Digital Content Protection (HDCP) | HDCP is a method for protecting digital media. The purpose of HDCP is to prevent the interception and copying of protected data streams as they are sent from a playback device to a display device (e.g., from a DVD player to an HDTV).   * When playing protected content from a PC, the DVD player, video card, and display device must all support HDCP. * If you plan on watching protected content on your PC, or playing content from your PC to an external TV, make sure the video card supports HDCP. |

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Chapter 3: System Components

3.13 Audio

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As you study this section, answer the following questions:

* What do you need to do to play AIFF files on a Windows computer?
* What color typically indicates the speaker port on a sound card? What color is used for the microphone?
* Which connectors are used for digital S/PDIF audio?
* Which encoding techniques are used for surround sound audio?

In this section, you will learn to:

* Select and install a sound card

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Sound card | An expansion card that manages sound input and output. |
| ADC | An analog-to-digital converter. |
| DSP | A digital signal processor. |
| DAC | A digital-to-analog converter. |
| Sampling rate | A number of analog signal samples taken in over a period of time. |
| Feature support | DirectSound 3D, EAX, THX, Dolby Digital, DTS, SDDS, MIDI. |
| Analog output | An output that allows sound to be played through external devices. |
| Analog input | An input that allows audio to be recorded through the sound card. |
| Audio file types | WAV, AIFF, AU, MP3, AAC, WMA, MIDI. |
| I/O | Acronym for input/output. |
| Mini TRS | A port that accepts 3.5mm plugs for analog audio I/O. |
| TOSLINK | A digital optical I/O for S/PDIF audio. |
| RCA | A coaxial digital I/O for S/PDIF audio. |
| IEEE 1394 | A FireWire port. |
| HDMI | A port that sends HD audio to an HDMI device. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| TestOut PC Pro | 2.1 Given a scenario, install, update, and configure an operating system  2.1.6 Manage audio device settings |
| CompTIA 220-1001 | 3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * Expansion cards   + Sound cards   3.6 Explain the purposes and uses of various peripheral types.   * Speakers |
| CompTIA 220-1002 | 1.6 Given a scenario, use Microsoft Windows Control Panel utilities.   * Sound |

3.13.1 Digital Audio

**Digital Audio**0:00-1:14

In this lesson we're going to spend some time talking about digital audio. Now digital audio involves taking a standard audio signal and converting it into zeros and ones so that a computer can process and store it.

Understand that the sounds that we hear in our everyday lives such as the sound of my voice or maybe the sound coming from a musical instrument are not digital in nature. Instead they use analog audio signals.

Computers cannot directly process analog audio signals. They use digital signaling to transmit and store data including audio data. Therefore, in order for a computer to store audio data, the analog signals need to be converted into a digital signal first.

Once that's done, the computer can process it and save it. But, later on when we decide we want to play back that same audio signal and listen to it with our ears from the computer, the digital data has to be converted back into an analog signal.

The device that does all of this conversion back and forth is the sound card. To understand how a sound card does this, we first need to understand how analog audio signals work.

**Analog Audio Signals**1:15-3:09

Analog audio signals are transmitted through the air in the form of sound waves. Sounds waves are created by something vibrating the air. This vibration creates alternating regions of high and low air pressure and it moves outward from the source.

For example, audio speakers have big round surfaces called drivers and when this driver moves back and forth it vibrates the air and creates pressure waves and these pressure waves propagate out carrying the sound's signal.

The regions of high and low air pressure can be mapped over time like this. If we were to measure a given point on this wave the values we could assign to this point could occupy an infinite number of potential values.

For example, a given point here could have a value of 2.3, 2.33, 2.333, 2.33333, and so on. When we measure analog signals, we use two different values to describe what this analog wave looks like. We measure amplitude and we measure frequency.

Amplitude measures the strength of the signal and, with audio signals, this determines how loud the sound is. A signal's amplitude is a measurement of the distance from the lowest point to the highest point of the signal from here to here.

Frequency, on the other hand, is a measurement of how many times the signal changes amplitude in one second. That is how many times the signal goes from its starting point to its highest point to its lowest point and then back to its starting point in one single second.

When analog devices record analog signals it's pretty straightforward. They essentially just make a direct copy of this wave on some type of medium.

But remember, computers aren't analog devices. They use digital signals and because of this, the analog signal has to be converted into a digital format before the computer can process and store it. This is done through a process called sampling.

**Sampling**3:10-3:59

When a computer digitizes an analog signal, it'll break this wave into discrete chunks called samples. A sample is a specific value you use to identify the amplitude and frequency of the wave at a given point in time. It does this at specific intervals along the entire analog wave.

By doing this, the computer creates an approximation of what the analog wave looks like but in digital format instead. Now the accuracy of this approximation is known as fidelity.

Fidelity describes how close the approximation is to the real analog wave. There are a couple of different parameters that are used to describe how accurate this approximation will be. The first number is the number of digital bits used to represent the value of each sample. We call this the bits per sample (bps).

**Bits per Sample**4:00-5:35

The bits per sample determines how many possible values one given sample can have to measure the wave at that point. For example, let's say we create a 4-bit digital sample of a guitar being played. Now here's the analog signal of that sound. Because we're using four digital bits to represent each of these samples, there's a maximum of only 16 possible values available to represent each sample.

Notice with only 16 possible values, we really can't match the digital sample very closely to the real analog waveform. We can't match the position of the sample to the exact location of the analog signal. As a result, the sample's only an approximation of the sound. It's not very accurate, so a lot of fidelity is lost.

However, if you were to increase the number of bits that are used to measure each sample, the fidelity will increase.

For example, if we were to sample this same analog signal again but this time we were to use 16 digital bits to measure each sample, well now we've got up to 65,536 possible values that can represent each of these samples, the value of each sample.

By having so many more possible values, we are able to create a much closer approximation of the original analog wave. This results in much higher quality sampling.

The fidelity of the digital signal is much closer to the original analog signal.

**Sampling Rate**5:36-7:48

Another thing that affects the quality of the sample is the sampling rate. The sampling rate measures the number of samples that are taken in one single second and it's measured in Hz. For example, a sampling rate of 8,000 Hz means that 8,000 samples of this analog wave are taken every second.

That sounds like a lot, but in reality an 8,000 Hz sample would result in a very poor quality recording. It would sound similar to somebody talking on a walkie talkie or an old telephone with a bad connection.

For example, let's say this is an analog wave of somebody talking and we sample this wave with only 8,000 samples every second. Instead of a continuous line like this, our sample would have discrete points of data with gaps in between.

The computer will fill in the gaps and create an approximate line between the sample points and as you can see the approximation doesn't really look the same as the original analog source.

But if you were to increase the sampling rate, in other words we were to take more samples every single second, this will add a lot more points to our digital sample and it'll create a much smoother approximation of the original analog wave.

Remember, all this conversion is done by the sound card and as such it's the sound card that dictates the number of bits per sample and the sampling rate. The standard for sound cards is to be able to output at least 16-bit 44 kHz audio. This is considered CD quality.

Now, higher end sound cards are able to produce even higher quality audio using 24-bit 192 kHz audio.

It's important to know that the higher the bit rate and the sampling rate, the better the sound fidelity. But also, you're gonna end up with much larger file sizes.

For example, if you were to create a 24-bit 96 kHz sample it'll use 34 MB of disk space for every one minute of audio. That means if you were to record a six-minute song that song's going to end up being around 200 MB in size.

To get around this several compression schemes have been developed over the years to reduce the size of audio files.

**Compression**7:49-8:44

Now the goal of audio compression is to reduce the file size while still maintaining a certain level of fidelity to the original sound. The most common compression scheme used for audio is Mpeg2 Audio Layer III compression, we just call it MP3.

MP3 compresses audio files to about 9% of the original file size. Therefore, that same 200 MB uncompressed file we looked at earlier will end up being only about 18 MB in size using MP3 compression.

You have to be aware that with any compression scheme you do tend to lose quality. An MP3 is considered a lossy compression algorithm. Which means that some fidelity is lost during the compression and decompression process. However, the reduced file size is an acceptable trade off.

Other common compression schemes used are Windows Media Audio, WMA; Advanced Audio Coding, AAC; as well as Dolby Digital.

**Summary**8:45-9:01

That's it for this lesson. In this lesson we talked about digital audio. Remember, the process of converting analog audio into digital audio is called sampling. The device that does this in the computer is the sound card. It's also responsible for converting digital audio back into analog signals that can be played through headphones or computer speakers.

3.13.2 Sound Cards

## Sound Cards 0:00-0:11

Whenever you're purchasing or evaluating sound cards, there are a lot of factors that you need to keep in mind. We're going to talk about those in this lesson.

## Input/Output Ports 0:12-0:55

First of all, you need to look at the types of input and output ports that the sound card has. Almost all sound cards will have at least three analog jacks: Line Out, Speaker Out, and Microphone. These are 3.5mm jacks and for traditional home use they're usually sufficient.

However, there are some users who require higher-end sound cards with better quality sound. These sound cards may have an S/PDIF port which stands for Sony Philips Digital Interface. An S/PDIF port is used to transfer digital audio without converting it to analog first. This results in higher quality sound as the Digital to Analog conversion process usually causes some loss of quality.

## Channels 0:56-1:42

In addition to the input and output ports, you also need to be aware of the number of channels the sound card supports. Understand that each speaker in a sound system is considered to be one channel. Almost all sound cards will support a minimum of two channels, and this is stereo sound. It gives you a left and a right channel.

However, some sound cards support even more channels. Sound cards that are used with standard surround sound systems, for example, support 5.1 channels.

This gives you front left, center, front right, rear left and rear right channels as well as a low frequency effect or LFE channel which is the .1 in the 5.1 channel designation. This channel is usually used to connect a bass, a sub-woofer.

## Software and Hardware Decoding 1:43-2:26

Surround sound audio uses encoding and compression techniques to separate the sound into distinct channels. It also reduces the size of the audio stream. This can be done using either software decoding or hardware decoding.

Software decoding often results in lower quality sound. Hardware decoding on the other hand results in very high quality sound. Because of this, you need to see which type of encoding is supported by the sound cards that you're looking at. Some common hardware decoding technologies are: Dolby Digital and DTS-ES.

Another feature that higher-end sound cards provide is called 3D Audio. 3D Audio is typically used by computer gamers to create an immersive experience using sound.

## Onboard vs. Dedicated 2:27-3:24

A popular 3D audio technology currently in use is EAX.

One last thing to consider is whether you want to purchase a dedicated sound card as an expansion card that's installed in an expansion slot, or whether you want to use an onboard sound card that's integrated into the motherboard. There are obviously benefits and drawbacks to both.

For example, there are onboard sound cards that do support Dolby Digital 5.1 Surround Sound, and because it's integrated into the motherboard, it's free. It doesn't cost anything to implement.

However, onboard sound cards do tend to have lower quality sound output and provide fewer features than the more expensive dedicated sound cards that are installed in an expansion slot.

So, the more features you want in a sound card, the more expensive it's going to be. When you're looking at sound cards, you need to weigh the cost versus the benefit of the features. Remember you need to make sure that the sound card you select has the necessary input and output ports, channels, and hardware features.

## Summary 3:25-3:28

That's it for this lesson. In this lesson, we talked about some factors you need to keep in mind as you pick a sound board for a PC System.

3.13.3 Sound Card Facts

A *sound card* is an expansion card (or an integrated component on the motherboard) that manages sound input and output.

This lesson covers the following topics:

* Sound card components
* File types

### Sound Card Components

Because computers use digital data, sound cards must convert analog sound into digital data, and digital data into analog sound. The following components are used to do this:

* The Analog-to-Digital Converter (ADC) converts analog sound into digital data.
* The Digital Signal Processor (DSP) is an onboard processor that handles analog and digital conversion.
* The Digital-to-Analog Converter (DAC) converts digital data into analog sound (in preparation to be played on speakers).

When purchasing a sound card, be aware of the following considerations:

|  |  |
| --- | --- |
| **Component** | **Description** |
| Bus Support | Sound cards can be installed via an expansion slot (e.g., PCI or PCIe x1) on the motherboard. When selecting a sound card, make sure the bus type is compatible with your motherboard.  Most new motherboards have an onboard sound card. |
| Channels | Audio can be split into multiple channels, which increases the sound quality and makes it more realistic. Some standard channel configurations are as follows:   * 2 channel audio is stereo. Examples of 2 channel audio include standard TV and radio. * 4 channel audio is quadraphonic audio and was an early attempt at surround sound. * 5.1 channel audio, also known as surround sound, has 6 audio channels: five speakers and one low-frequency effects subwoofer (LFE) channel. * 7.1 channel has 8 audio channels: 7 speakers and one LFE subwoofer channel. This is the first technology providing error correction. |
| Sampling Rate | The *sampling rate* is the number of analog signal samples taken in over a period of time. Sample rates are expressed in cycles per second, called hertz (1,000 hertz (Hz) = 1 kilohertz (kHz)). A high sampling rate gives a more accurate representation of the sound. Examples of different sampling rates include:   * 8 kHz (telephone) This is adequate for conversation because the human voice's full range is about 4 kHz. * 22 kHz (radio quality). * 44 kHz (CD quality) This sample rate can accurately reproduce the audio frequencies up to 20,500 hertz, covering the full range of human hearing. * 48 kHz (Digital TV, DVD movies). * 96 kHz (DVD audio). * 192 kHz, used by:   + LPCM (Linear Pulse Code Modulation), a DVD-music production format.   + BD-ROM (Blu-ray Disc-ROM).   Higher sample rates require more bits of data per sample.   * 8-bit sound cards use a sampling size of 256. * 16-bit sound cards use a sampling size of 65,536. * 20-bit sound cards use a sampling size of 1,048,576. * 24-bit sound cards use a sampling size of 16,777,216. * 32-bit sound cards use a sampling size of 4,294,967,296.   The bit portion of a sound card's sampling size *does not* correspond with the bus size. |
| Feature Support | Additional features on sound cards provide higher quality sound or additional functionality.   * DirectSound 3D allows a computer to play audio in surround sound. * EAX is a high-definition sound technology originally developed for video games. This technology provides such realistic nuances that audio can actually cue gamers. * THX is a sound quality standard, originally created for film, now available on sound cards. This is a sound card feature that allows computers to present theater quality sound output. * Dolby Digital is a technology that broadcasts sound at a frequency the human ear can hear and diminishes collateral sound. This is a sound card feature that allows computers to present higher quality sound output. * DTS (Digital Theater Systems) Digital requires an optical reader to decode physical data and send it to a computer for processing. This is a sound card feature that allows computers to present theater quality sound output. * SDDS (Sony Dynamic Digital Sound) was originally developed for theater sound. SDDS decoders provide error correction. * MIDI (Musical Instrument Digital Interface) is a protocol for recording and playing audio created on digital synthesizers. This feature allows the computer to become an integrated component to a musical instrument. |
| Analog Input and Output | Analog output jacks allow you to play sound on your computer through external devices:   * The speaker out connector sends signal to external speakers. This signal is amplified and the computer controls the sound level that is sent. * The line out connectors send audio to other sound devices. This signal is unamplified.   Analog input jacks allow you to record audio through the sound card.   * The line-level (line-in) connector receives signals from CD players and musical instruments coming from the line out port of the other device. * The mic-level (mic in) connector receives signals from a microphone. |
| Digital Audio | Most audio devices, such as stereo consoles, TVs, and speakers require analog audio. Newer devices, such as some CD players, DVD players, and HDTVs, are capable of processing digital audio signals. Digital audio support in a sound card:   * Allows you to play digital audio directly from an internal CD player * Allows for compression of audio data to support Dolby Digital or DTS surround sound * Can use fiber optic cables to eliminate electrical interference   Sound cards support digital audio in the following ways:   * An internal connector on the sound card connects to a digital audio output connector on a CD/DVD drive. Through this connection, you can play CDs directly through the sound card. * An internal connector on the sound card sends HD audio, such as from a DVD or Blu-ray disc, to an audio pass-through on a video card. This allows the HD audio signal to be combined with the video signal through an HDMI connector. * Sony/Philips Digital Interface Format (S/PDIF) is a consumer standard for digital audio. These are either optical or coaxial external connectors and allow input and output between other digital audio-capable devices. |
| Additional Ports | In addition to audio input and output ports, some sound cards also include the following ports:   * MIDI port to interface with MIDI sound devices * FireWire * Some high-end audio cards include HDMI video processors and video output, combining the features of an audio card with a video card. The sound card might have 1 or 2 HDMI ports (for input and/or output). |

### File Types

Sound card drivers and other software save digital audio into several different file types. Common file types include:

* WAV (Windows standard), a widely used and compatible file type
* AIFF (Audio Interchange File Format), the Macintosh equivalent of the WAV
* AU (UNIX standard), supported by most web browsers
* MP3 (MPEG-2 Layer III), a highly effective audio compression standard
* AAC (Advanced Audio Coding), also known as MPEG-2, a compression expected to replace MP3
* WMA (Windows Media Audio), a highly compatible standard developed to compete with Real Audio
* MIDI, not a true audio file, but contains data to reproduce sounds through electronic synthesis

3.13.5 Sound Card Installation Facts

Sound cards should be treated with care. Below are tips and suggestions for installing, configuring and troubleshooting sound cards.

This lesson covers the following topics:

* Configure the system sound
* Troubleshoot sound problems

### Configure the System Sound

Be aware of the following when configuring system sound:

* Many motherboards include an onboard sound card. Use the connectors on the motherboard's I/O plate to connect components to the onboard sound card.
* Sound cards are typically added to a computer using PCI or PCIe slots. Some sound cards also connect through USB. External sound cards for laptops can use an ExpressCard slot.
* When installing a sound card using an expansion slot, make sure to disable the onboard sound card in the CMOS configuration.
* After installing the sound card, install the drivers and other software that came with the sound card.
* In Control Panel, use the Sound applet to:
  + Configure settings for sound card connections such as speakers, audio input, and microphone.
  + Identify the sources that you want to record.
  + Configure sounds to play with system events or to play a sound to test your configuration.
* An audio *codec* is a specific method of formatting sound files. Common codecs include WAV, WMV, AIFF, and MP3. To play sounds saved using these formats, your computer must have the corresponding codec installed.
  + You can see the list of installed codecs in System Information.
  + By default, Windows comes with common codecs installed. Other codecs might be installed as you add other software.

### Troubleshoot Sound Problems

To troubleshoot sound problems, try the following:

* Make sure that the speakers are connected to the sound card and that the speakers have power.
* Check the volume setting on the speaker and the back of the sound card (if present).
* Check software sound settings. Verify that the sound is not muted and check mixer settings.
* If some files play but others do not, make sure you have the right codecs installed for playing that file type.
* If you are working with a built-in audio interface, verify that it is correctly configured in the BIOS. If you have installed an add-in card, make sure the built-in audio is disabled.
* If no sound plays, make sure the card is seated, check for resource conflicts, and update the drivers if necessary.
* Ensure that the sound card is not experiencing electromagnetic interference (EMI) from the disk drive or power supply. To remedy this problem, move the affected card to an expansion slot located away from the source of EMI.

3.13.6 Sound Card Connectors

Sound cards provide input and output (I/O) ports for connecting external, audio-related devices to the computer.

The most commonly found ports are described in the following table:

|  |  |
| --- | --- |
| **Port** | **Description** |
| **Mini TRS** | Mini TRS ports on the sound card accept 3.5mm plugs for analog audio I/O. The number of ports on the sound card depends on the type of I/O support (e.g., the number of speaker channels, microphone, or line-in support).  Ports are often labeled with text or graphics to identify its function. Standardized color coding might also be helpful in determining the proper connection.   * Pink = Mic in (mic-level) * Light blue = Line in (line-level) * Lime green = Line out (front speakers or headphones) * Black = Line out (rear speakers) * Orange = Line out (center and subwoofer)   Although these colors are standard, be sure to consult the sound card documentation for specific details. |
| **TOSLINK** | A TOSLINK (or optical audio cable) connector is used with digital optical I/O for S/PDIF audio. |
| **RCA** | An RCA connector on a sound card is used for coaxial digital I/O for S/PDIF audio.  While RCA connectors can be used for analog audio, RCA connectors on a sound card are normally used for S/PDIF digital audio. |
| **IEEE 1394** | Some sound cards include one or more IEEE 1394 (FireWire) ports. These ports function as normal IEEE 1394 ports. |
| **HDMI** | A sound card with an HDMI port is capable of sending HD audio to an HDMI device. Some sound cards are able to output video or combine a video signal from a video card and output the combined audio/video signal through the HDMI port. |

3.14.2 System Cooling Facts

The normal operation of computer components produces heat. Overheated components can cause intermittent errors and reduce component life. If components are overheated for an extended period of time, they will fail. To keep component temperatures optimal, computer cases maintain a consistent, one-way flow of air through the case.

This lesson covers the following topics:

* Airflow in a computer case
* Cooling system components
* Cooling system recommendations

### Airflow in a Computer Case

The following diagram shows how air should flow through a computer case:

Test Out Logo

**TestOut PC Pro***English 6.0.4*

Home

Outline

**Actions**

Click to View Actions Menu

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Chapter 4: Peripheral Devices

4.1 Peripheral Devices

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As you study this section, answer the following questions:

* What are the three types of peripheral devices?
* Which connector is used by most peripheral devices?
* Which peripheral devices require little to no configuration?
* How can you verify that a device is compatible with a particular computer?
* Which peripheral devices require special software or drives to function?
* What is the difference between an input device and an output device?

In this section, you will learn to:

* Understand the various functions of different peripheral devices
* Connect a KVM to multiple computers
* Connect peripheral devices using the appropriate cables and connectors

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Digitizer | A device that captures an analog signal and turns it into digital data. Examples include graphics tables, document scanners, and 3D scanners. |
| Input device | A device that sends data to a computer. |
| Input & output (I/O) device | A device that can input data to a computer and accept output data from a computer. Example include CD-ROMs, DVD-ROMS, USB flash drives, hard disk drives, network adapters, and Bluetooth adapters. |
| KVM (keyboard, video, mouse) switch | A switch that allows multiple computers to use a single keyboard, mouse, and monitor. |
| Lumen | A unit of measurement that indicates an amount of light. |
| Near-field communication (NFC) | A set of communication protocols that allow devices to communicate when they are within 1.6 inches of one another. NFC devices are commonly used in retail stores and restaurants with Tap Pay phone apps. |
| Output device | A device used to send or display data from a computer. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| CompTIA 220-1001 | 1.2 Given a scenario, install components within the display of a laptop.   * Types   + LCD   3.6 Explain the purposes and uses of various peripheral types.   * KVM * VR headset * Mouse * Keyboard * ADF/flatbed scanner * Barcode scanner/QR scanner * Game controllers * Touchpad * Camera/webcam * Microphone * Signature pad * Magnetic reader/chip reader * NFC/tap pay device * Projector   + Lumens/brightness   + OLED |
| CompTIA 220-1002 | 4.1 Compare and contrast best practices associated with types of documentation.   * Inventory management   + Barcodes |

4.1.1 Peripheral Devices

**Peripheral Devices**0:00-0:32

A peripheral device is any external component that either sends information to or retrieves information from a computer. Peripheral devices can be as simple as a USB keyboard or as complex as an entire security system complete with cameras, motion sensors, and bio-metric devices.

Some peripheral devices are required for a computer to function properly. Others are used to expand the functionality of a computer. Peripheral devices are divided into three categories.

**Input Devices**0:33-0:48

The first category is input devices. These are devices that send information into a computer. Input devices come in a lot of different forms. The most common input devices are a keyboard and a mouse. Other less common input devices include bar code scanners or bio-metric scanners.

**Output Devices**0:49-1:06

The second category is output devices. These are devices that retrieve information from a computer and display it somehow. For example, both a computer monitor and a printer are output devices. One outputs graphical information using light. The other uses ink and paper.

**Input & Output Devices**1:07-1:34

The third category of peripheral devices combines both input and output functions and they're called input/output devices or I/O devices.

The most common I/O device is a touchscreen. Touchscreens combine the output of a monitor and the input of a mouse into a single device. Another I/O device is a KVM switch. A KVM switch is a device that allows multiple computers to use a single keyboard, mouse, and monitor.

**Peripheral Device Connection**1:35-3:02

Connecting peripheral devices to a computer is relatively straight forward. Once connected, most peripheral devices require little or no configuration. They are plug and play. However, there are still a few things you should keep in mind.

The first is the connection type used by the peripheral device. Most peripheral devices use common connection types such as USB or FireWire. However, some peripheral devices use connectors that are specific to their device type. For example, display devices use display specific connection types. Other peripheral devices connect wirelessly using Wi-Fi, Bluetooth or Infrared. Whatever the connection type, make sure it's compatible with the computer it will be used with.

The next thing you should keep in mind is system compatibility. Some peripheral devices have system requirements such as minimum CPU speed, memory size, or OS version. In addition, some peripherals should be paired with specific hardware components. For example, some displays work better with specific video cards.

The last thing to keep in mind is the steps that need to be taken after the device has been connected. A lot of peripheral devices need little or no configuration. However, some devices require specialized software, drivers, or configuration steps in order to function. For example, a bar code scanner might need drivers and software installed in order for it to work. And a game controller or joystick might need its buttons configured and mapped.

**Summary**3:03-3:19

As you can see peripheral devices perform a lot of different functions. Some are essential to everyday computer use and some offer very specific functionality. Remember there are three types of peripheral devices: input devices, output Devices, and I/O devices that combine both input and output functions.

4.1.2 Peripheral Device Facts

A peripheral device is any external component that either sends information to or retrieves information from a computer. There are three categories of peripheral devices:

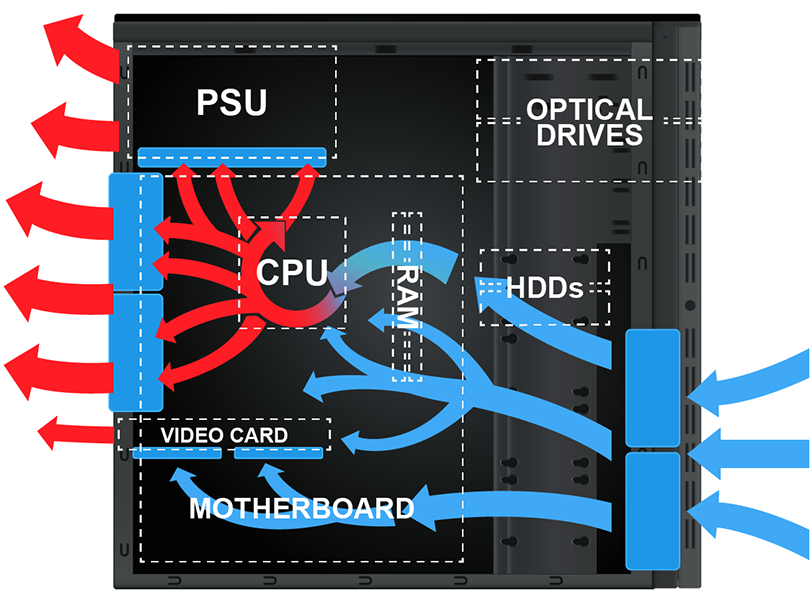
* Input devices
* Output devices
* Input & Output (I/O) devices

The following table describes some of the most common peripheral devices:

|  |  |
| --- | --- |
| **Device** | **Considerations** |
| Keyboard | Keyboards connect through a USB port. Many keyboards include special function keys that simplify playing music or browsing the internet. Some keyboards include a built-in USB port that can be used to connect other peripheral devices.  Almost every desktop computer requires at least a keyboard to function. Most computers require a keyboard, mouse, and display device in order to function properly. |
| Mouse | A mouse can be either wired or wireless.   * A wired mouse uses a USB port to connect to the computer. * A wireless mouse uses an internal battery for power and uses RF signals (e.g., Bluetooth) to connect to a receiver, which is either connected to a USB port or integrated with the computer.   When selecting a mouse, consider the following:   * Because optical mice use light rays to detect motion, they don't work on some surfaces. * Some mice have internal motion sensors, allowing them to detect movements while in the air. This particular device can attach to a user's head and move the cursor when the head moves. * You can select mice with additional buttons or a scroll wheel to add functionality. * High-end gaming mice use a rating of dots per inch (DPI). The rating denotes how many steps (cursor movements) are counted in a single inch. |
| Digitizer | A digitizer captures some type of analog signal and converts it into digital data. Some common types of digitizer devices include:   * Graphics Tables—Graphics tablets capture analog stylus strokes written on a pad and convert them to digital data. These are mostly used by graphic artists to capture hand-drawn images. * Document Scanners—Document scanners are specifically designed to convert paper documents into digital documents, such as PDFs or Rich Text Format files. Document scanners use optical character recognition (OCR) to create editable word processor documents. There are two types of document scanners. Automatic Document Feeder (ADF) scanners automatically scan a stack of papers. Flatbed scanners require that you place each page on a scanning surface one by one. * 3D Scanners—3D scanners use either physical contact or lasers to map the size and shape of a physical object and convert it into a 3D digital model. |
| Game controllers | *Game controllers* are input devices designed specifically for computer gaming. There are two main types of game controllers:   * Gamepads are handheld controllers with directional controls on the left and buttons on the right. * Joysticks consist of a stick that pivots on a base. Both the stick and the base have several input buttons. Joysticks are typically used with flight simulator games.. |
| Scanner | Scanners are used to scan hard-copy images and documents and convert them into digital input for the PC. For example, film photos can be scanned and saved as image files.  Some scanners combine the functionality of a document scanner and are able to create editable documents. |
| Motion sensor | Motion sensors are devices that are able to detect the slightest amount of movement in an area. They are typically used with security systems and require special software and configuration. Two types of motion sensors exist:   * Active motion sensors use ultrasonic sound waves to detect movement in an area. If movement is detected, something happens (e.g., a door opens or an alarm triggers). * Passive motion sensors detect infrared energy, which is emitted by humans and animals. Passive motion sensors ignore small changes in infrared energy in order to avoid false alarms. Passive motion sensors are sometimes called passive infrared sensors (PIR). |
| Touch pad | Touch pads are typically found on notebook computers and are used in place of a mouse. Users slide their finger on the touch pad to manipulate the cursor. Touch pads can also be used with desktop computers. These touch pads connect to the computer through a USB port and are used instead of a mouse. |
| Card reader | A card that contains an embedded microchip or a magnetic strip is inserted into the reader. The reader then scans the chip or strip, verifies its contents, and authenticates the user. Card readers can be stand-alone devices or integrated with other peripherals (e.g., a keyboard or workstation). |
| Biometric scanner | Biometric scanners are used as a form of authentication. They are able to scan users' unique physical features and use them to verify their identity. Common physical features used by biometric scanners include:   * Retina (eyes) * Fingerprint * Face * Heart beat |
| Barcode reader | A barcode reader is a device that can scan barcodes.   * Barcodes are most commonly used in retail environments at checkout stands. Shipping companies, hospitals, and other organizations use barcodes to track or inventory items. * Most bar code readers use a laser to scan the barcode. Some use cameras or optical scanners. * Barcode readers include software that interprets the meaning of the barcode.   By installing a special app, smart phones are able to function as a barcode reader by using the phone's built-in camera. |
| Near Field Communication (NFC)/ Tap Pay Device | NFC is a set of communication protocols that allows devices to communicate when they are within 1.6 inches of one another. NFC technology is most often employed between a base and a smart phone to allow Tap Pay transactions at stores and restaurants; the user places their phone within proximity of the base and uses an app to make an electronic transactions from their mobile phone. NFC is also used to share contacts, photos, videos, and documents, such as identity documents and key cards. |
| Virtual Reality (VR) Headset | A device worn on the head that covers the eyes and provides separate images for each eye, stereo sound, and motion tracking sensors to create a virtual reality experience for the user. Some headsets also have eye tracking sensors and work with handheld gaming controllers. Virtual reality is widely used to train medical and military professionals. As it becomes more affordable, it is being widely adopted in many fields. |
| Microphone | A microphone converts sound into an electrical signal. Some computers have a built-in microphone, and many headsets and camera systems that connect to computers include microphones. |
| Signature Pad | Signature pads are used to obtain signatures for transactions and agreements. The user uses a stylus on a touch screen to sign his or her name. The signature is captured and stored digitally. Signature pads are commonly used in retail stores and restaurants. |
| Projector | Projectors are display devices that use light to project display output onto a wall or screen. Projectors are often used in classrooms and meetings to display information for a large audience. The brightness of light from projectors and other output devices is measured in *lumens*. Projectors may use light-emitting diodes (LEDs), organic light-emitting diodes (OLEDs), or other hardware. |
| KVM Switch | A KVM (keyboard, video, mouse) switch allows multiple computers to use a single keyboard, mouse, and monitor. KVM switches have multiple input groups, with each group accepting keyboard, video, and mouse connections from one computer. A single output group connects to the shared peripheral devices. Buttons on the KVM switch are used to toggle between each connected computer.   * Rackmount KVM switches can support up to 16 computers and are typically used in data centers to manage servers from a central console. * Desktop KVM switches typically support two or three computers, which must be within about 5 meters. * Networked or remote KVM switches use special hardware devices that send keyboard, mouse, and video content through a network connection. |

When connecting peripheral devices, consider the following recommendations:

* Make sure the computer supports the connection type used by the device.
  + Most peripheral devices use USB connectors.
  + Older peripheral devices can use PS/2, serial, or parallel connectors. For these devices, you can use an adapter (e.g., a PS/2 to USB adapter).
  + An expansion card can be added to provide the necessary connections.
* Identify the system requirements of the peripheral device. Some peripheral devices specify a minimum CPU speed, memory size, or OS version.
* Install any necessary drivers or software.
* Configure the device in the OS and verify it is working correctly.



### Cooling System Components

The following table identifies several components that are used to help regulate a computer system's internal temperature:

|  |  |
| --- | --- |
| **Component** | **Description** |
| Case fans | Case fans create a pressurized system that allows air to flow through the case in a specific way.   * Intake fans (at the front) pull air inside the case to cool components. * Outtake fans (at the back and top) exhaust warm air from inside the case. * Some cases have intake fans on the side case cover. * Fan filters can be installed to keep dust and debris inside the case to a minimum. |
| Power supply | ATX power supplies aid in cooling by exhausting hot air out the back of the case. |
| Heat sink | Heat sinks are made of a heat conductive material (usually aluminum or copper) and are attached to components using a thermal paste or pad. Heat sinks are designed with fins to increase the surface area exposed to air, allowing heat to dissipate from the component much faster. Heat sinks can be either active or passive.   * Active heat sinks have an attached fan that helps cool off the component at a faster rate. Active heat sinks are used with the following components:   + CPUs   + High-end video cards   + Some motherboard chipsets with integrated graphics * Passive heat sinks do not have a fan and instead rely on increased surface area and passive air movement to cool the component. Passive heat sinks are used with the following components:   + Most motherboard chipsets   + Low-end video cards   + Memory modules (heat sinks on memory modules are also called heat spreaders)   Because passive heat sinks do not use a fan, they are 100% reliable. However, active heat sinks can dissipate heat much faster than passive ones. |
| Heat sensors | Most motherboards include the following heat sensors:   * CPU sensor (located on the circuit board underneath the processor) * System case sensor (located either on the motherboard or on a cable attached to the motherboard) * Room temperature sensor (usually connected to the motherboard by a cable and mounted on a case slot)   Special software can monitor the temperature levels and be configured to send warnings when high temperature conditions exist. The BIOS in most motherboards can also be configured to automatically shut the system down when a specified thermal threshold is exceeded. |
| Liquid cooling | Liquid cooling systems are used when air cooling is not sufficient. Liquid-based cooling systems are composed of tubes, cooling plates, a reservoir, and a radiator. Cooling plates have tubes connected to them and are attached to components. Liquid coolant is then circulated through the system, cooling it. Because liquid cooling can dissipate heat much faster than air cooling, it is primarily used for high-end gaming computers and high-performance systems. |

Issues related to insufficient cooling are sometimes difficult to identify. They usually manifest as random errors or system lockups. One tool that can be used to troubleshoot cooling problems is freeze spray. If a system is starting to fail due to overheating, spraying it with freeze spray reduces the temperature and could restore it to normal functionality. If the problem goes away after spraying a suspected component, implement additional cooling solutions for that component.

### Cooling System Recommendations

Because proper airflow is necessary to keep components cool, consider the following recommendations to ensure optimal system cooling:

* Keep the case free of dust and debris. Excess dust can restrict airflow and prevent proper heat transfer.
* Reduce the number of airflow obstructions.
  + Employ proper cable management (e.g., bundle cables together and secure unused cables to the case).
  + Space out multiple hard disk drives instead of stacking them next to each other.
  + Do not use an excess number of expansion cards.
* Maintain appropriate ambient temperatures. Optimal ambient temperatures are between 60 and 80 degrees Fahrenheit. For server rooms, the ambient temperature might be as low as 45 degrees.
* Ensure proper ventilation.
  + Keep air intakes and exhausts free from obstructions.
  + Leave space between the computer and any walls or desks.
* Preserve negative pressure inside the case by keeping all covers and shields installed (e.g., unused expansion cards, I/O shield, front drive bays).

4.2.2 USB Facts

The Universal Serial Bus (USB) is the most commonly used connection interface. Almost every device (e.g., laptops, smart phones, tablets, desktop computers) uses USB in some capacity. USB:

* Uses serial communication (bits are sent sequentially)
* Supports plug-and-play and hot plugging (adding and removing devices without rebooting)
* Allows up to 127 devices to be connected to a single bus, directly to the host or via hubs (hubs are limited to five tiers)
* Shares the bandwidth among all devices connected to a single bus
* Provides 5 V of power through the cable

USB has several versions, all of which are backwards compatible. The following table describes the specifications of each version:

|  |  |  |  |
| --- | --- | --- | --- |
| **Version** | **Speed** | **Data Rate** | **Max Cable Length** |
| 1.1 | Low Speed | 1.5 Mbps | 3 m |
| Full Speed | 12 Mbps | 5 m |
| 2.0 | Hi-Speed | 480 Mbps | 5 m |
| 3.0/3.1 | SuperSpeed | Up to 5 Gbps | 3 m |
| SuperSpeed+ | Up to 10 Gbps | 5 m |

Data transfer rates are limited by the slowest USB version being used. For example, a USB 2.0 device connected to a USB 3.0 port will run at USB 2.0 speeds.

USB uses several connector types for various peripheral devices. The following table describes the most common USB connector types:

|  |  |
| --- | --- |
| **Connector** | **Description** |
| Type-A | A rectangular connector that generally plugs directly into the computer or a hub. Almost all USB cables have one Type-A connector on one of the ends. |
| Type-B | A square connector with two beveled corners. Type-B connectors are mostly used with printers. Some networking devices, such as hubs and modems, also use this connector.  Most USB cables that use this connector have a Type-A connector on one end that plugs into the computer. |
| Type-C | A long, thin oval connector designed to be a universal USB port that works with many devices and connectors. |
| miniUSB | This connector is used by portable electronic devices, such as digital cameras and some portable storage devices. |
| microUSB | microUSB connectors are designed for smart phones and tablet devices. microUSB connectors are approximately half the thickness of miniUSB connectors, making them more appropriate for smaller devices. |

USB 3.0 introduced several new connector types. The following table describes the connectors used by USB 3.0:

|  |  |
| --- | --- |
| **Connector** | **Description** |
| Type-A | The blue tab indicates that the connector is a USB 3.0 Type-A connector and capable of USB 3.0 speeds. USB 3.0 Type-A connectors are backwards compatible with all previous USB versions. |
| Type-B | The USB 3.0 Type-B connector is larger in size and designed to carry both data and power. Due to their increased size, USB 3.0 Type-B connectors cannot be plugged into older USB Type-B ports. However, USB 3.0 peripherals that use this port are able to accept older USB Type-B connectors. |
| Micro-B | The USB 3.0 Micro-B connector is used by portable devices, such as compact external storage devices, digital cameras, or smart phones. |

USB devices are connected to computers in one of two ways:

* Directly to a USB port located on the motherboard or on the front panel of a case
* To an external USB hub that is connected to the computer

USB hubs can be chained together to provide even more USB ports.

USB devices can be classified according to how they receive power.

|  |  |
| --- | --- |
| **Type** | **Description** |
| Self-Powered | Devices that rely on their own power supply (i.e., they are plugged into an AC outlet) are *self-powered* devices (sometimes called *active* devices). USB 2.0 devices that draw more than 500 mA of power are required to be self-powered; USB 3.0 devices that draw more than 900 mA of power are required to be self-powered. |
| Bus-Powered | USB cables have wires to carry both power and data. Bus-powered (sometimes called passive) devices get their power via the USB cable. Bus-powered devices are classified as low-powered or high-powered devices, depending on the amount of power they draw from the USB bus.   * Low powered devices use 100 mA or less * High-powered devices use between 100 and 500 mA (up to 900 mA for USB 3.0)   Like USB devices, USB hubs can be bus-powered or self-powered. You cannot connect high-powered devices to a bus-powered hub (you can connect only low-powered or self-powered devices to a bus-powered hub). Therefore, self-powered hubs that provide 500 mA per port are recommended to ensure an adequate power supply to all bus-powered devices that you may wish to connect to the hub. |

To install a USB device, you typically install the software driver before attaching the device. When you plug in the device, it will be automatically detected and configured.

4.2.3 Install USB Devices

You work at a computer repair store. You are in the process of connecting several devices to a computer.

In this lab, your task is to complete the following:

* Connect the USB hub to the computer.
* Connect the inkjet printer to a USB port.
* Connect the laser printer to a USB port.
* Connect the scanner to a USB port.
* Connect the external hard drive to a USB port.

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Chapter 4: Peripheral Devices

4.3 Display Devices

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As you study this section, answer the following questions:

* What are some of the specifications used by display devices?
* What are the benefits of a higher resolution?
* What is the refresh rate?

In this section, you will learn to:

* Identify digital and analog connectors by sight
* Select the appropriate display device based on customer requirements and system support
* Configure display properties (including dual monitor support) in Windows, macOS, and Linux

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Color depth | The number of bits used for each color component of a single pixel. |
| Resolution | A measurement of an image's sharpness and clarity. The more pixels that make up an image, the higher its resolution. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| CompTIA 220-1002 | 1.6 Given a scenario, use Microsoft Windows Control Panel utilities.   * Display/Display Settings   + Resolution   + Color depth   + Refresh rate |

4.3.1 Configure Display Settings in Windows

**Configure Display Settings in Windows**0:00-0:27

In this demonstration, we're going to practice working with display settings. We're going to do this on a Windows 10 system.

Now in Windows 10, there's two ways to get to Display settings. One is to right-click the Windows icon, go to System > Display.

You can also come over to the desktop, right-click and click Display settings. It will launch the Settings app and will take you to Display under System. And here, you can customize your display settings.

**Display Settings**0:28-2:56

Now on this main screen, there are a few things you can configure.

You can specify what display resolution you want to use. Currently, I'm working on monitor 1 and my resolution is set to 1280 by 720. If I need to change that for some reason, I click this drop-down list and then select the appropriate display resolution from the list provided.

Now, there's an important thing you need to understand here. If you're working on older CRT monitors, then you can pick from many different display resolutions as long as that monitor supports it. Most CRT monitors are multisync monitors, which allows them to support a wide range of different resolutions. You can try whichever ones you like and pick the ones that suit you best.

That's not the case with newer LCD and LED monitors. LCD and LED monitors have a fixed resolution. They have a fixed number of pixels across and a fixed number of pixels down. This is called the native resolution of the monitor. What you need to do is check the monitor documentation and then select the resolution displayed in this drop-down list that matches the native resolution of that monitor.

Now, is the world going to end if you pick something different? No, it just won't look very good because your video board will have to calculate the pixels and kind of stretch and squeeze things to get it to fit within the native resolution of the monitor itself. It will work, it just won't look very good.

If you see a screen display that is blurry and out of focus or looks distorted or stretched in one way or the other, more than likely the resolution is set incorrectly. So once again, check the monitor documentation. Find out what the native resolution of the monitor is, come over here to Resolution and pick the appropriate setting.

In addition to setting the display resolution, you can also extend your desktop between multiple monitors. Now the system I have supports three monitors. It's a notebook system on a docking station. So I have my main screen and I can plug in two additional monitors. And I've done that right here.

I'm currently working on monitor one, but if I wanted to, I could extend my desktop over here onto monitor number three, which is currently inactive. If you want to verify which monitor you're using, you can come over here to the Identify link. Click it. When you do, you see a number displayed on each monitor. So in this case, when I click Identify, I see the number one displayed here, which tells me I am indeed working on monitor one.

Now if you have multiple monitors connected to your video board but you're not seeing all those monitors displayed here, you may come down here and click the Detect link. Detect will query your video board and try to detect any monitor that may have been connected to it.

**Extended Desktop**2:57-5:46

In this case, all my monitors were detected correctly, so we get the response, "Did not detect another display."

Once your monitors have been connected, they've been detected, and you've identified which one is which, you can then extend your display across those monitors. You can do that down here with the multiple displays drop-down list. If I click this, I can specify how I want to handle the additional displays.

One option is to duplicate these displays. If I select this option, then the video output that I see in monitor number one will also be displayed on monitor number two. There are some situations where that is a useful thing.

For example, if you're working in a classroom setting and the instructor's computer displays his or her desktop and the output from that computer is also been being displayed on an overhead display for the students to see, then you'll probably want to mirror the displays. You duplicate them so that what the instructor sees is the same thing that the students are seeing.

If, on the other hand, the computer system is being used by say an accountant who needs multiple displays going so that she can put some information on one screen and other information on the other screens, then you may want to select the Extend these displays option.

In this case, the desktop will extend across all the monitors. That's a very useful feature, one that is very commonly used. It gives you a lot more real estate for your Windows working environment. I'm extending my desktop and I have all my monitors active.

Now I can manage the display resolution for each of these monitors independently. For example, monitor number 1 that I'm working on has a display resolution of 1280 by 720. But display number 2 is an older 4:3 LCD monitor and it uses a completely different geometry. It uses 1024 by 768. So I can go through and select the appropriate resolution for each of these monitors.

Now as I do this, more than likely I'm going to have my monitors sitting right next to each other, which is the case on the workbench that I'm working on right now. So when I move my mouse cursor between these monitors, for example, if I take my mouse cursor and move it off the screen, I want it to show up over here on my other monitor, at roughly the same point where it left this monitor.

For example, if the mouse cursor leaves monitor one, right down here, I want it to appear on monitor three in roughly the same location so it tracks a straight line across between the two.

Now if I want to change that, all I do is click and drag the monitors and arrange them to match the way they are physically oriented on my work bench.

So in this situation, I want my monitor to be even at the top. When I move my mouse cursor off of the screen, it shows up in the right place on monitor 3 which of course you can't see right now. And actually, I got it just a little off. I need to put it right about there. When I do that, everything looks perfect.

Now to make these changes stick, I need to come over here and click the apply button. And now I have my monitor setup configured and working properly.

**Summary**5:47-5:56

That's it for this demonstration. In this demo, we talked about how to configure display settings on a Windows 10 system. We looked at how to change screen resolution as well as how to extend our desktop across multiple screens.

4.3.2 Configure Advanced Display Settings in Windows

**Configure Advanced Display Settings in Windows**0:00-0:11

In this demonstration, we're going to explore some advanced display settings that you can use to optimize the performance of your video on a Windows system.

**Optimize Adapter Settings**0:12-2:34

To do this, I'm going to right-click my Desktop and select Display Settings. Once we launch our Display Settings, you see that we have some basic settings that we can configure. We can set our resolution, our orientation, and configure multiple displays. However, notice that there's another link called Advanced display settings. This is what we want to focus on in this demonstration.

Once we are in our Advanced display settings, you can see information about each of our monitors. This is helpful, but we want to go just a little deeper. So, let's click Display adapter properties for Display 1. Now, this is what we want to focus on for this demonstration.

The first tab I see is the Adapter tab. This tab displays a lot of very useful information about the video adapter that's installed in the system.

First of all, up here it tells us what type of video adapter is installed in this system. This system has an NVIDIA NVS 3100M installed. If I come over here to Properties and click it, I see the properties of this device in Device Manager.

In fact, we can come over here to the Driver tab where we can view driver details and update the driver. If we need to, we can disable the device or even uninstall the driver completely. Now please be aware that sometimes, the information you see under Adapter Type is not entirely accurate. Basically, the value you see displayed here under Adapter Type is based on the driver that's been loaded for the video hardware.

Here's what happens on occasion. You install a new Windows system. When you do, Windows doesn't recognize the video hardware that you have installed in the system. When this happens, in order to just get something on the screen, Windows will load, by default, a basic Microsoft display video driver. It's not a very good driver, but it works across a wide range of different hardware devices.

If that happens, instead of seeing the actual adapter type listed here, what you'll see is something to the effect of Microsoft Basic Display Adapter listed. So just be aware that if you see that output here under Adapter Type, it means you need to go out and find the right video driver for the hardware in your system.

Down here under Adapter Information, we can view additional information about the adapter itself, such as the Chip Type. We can view the BIOS version information. Down here, we can also see how much video memory is installed on the device.

**Optimize Monitor Settings**2:35-5:49

Next, we have the Monitor tab. The value displayed under Monitor Type works in much the same way as the value displayed under Adapter Type. It's based upon the driver that's been loaded for the monitor itself.

In this case, we do not have the correct driver loaded for the monitor that I have connected to the system. If Windows doesn't recognize the monitor, it'll load a generic driver, in which case you'll see this generic type of monitor listed here under Monitor Type.

And just as with the adapter, I can come over here and hit Properties, and the Device Manager interface for the monitor is displayed. And I can come over here and manage the driver, just like I did with the display adapter.

Down here, under monitor settings, we can manage the screen refresh rate. Now back in the old days when we were using CRT monitors that were multisync, meaning they supported multiple synchronization rates, you would come down here and pick the fastest screen refresh rate that the monitor could handle, because it reduced flicker and it reduced eyestrain.

With LCD monitors, this is no longer the case. For an LCD monitor, you need to set the screen refresh rate to the recommended value for the specific monitor. Check your monitor documentation and find out what refresh rate you should use. That is what you should specify. Usually, Windows is able to probe the monitor and automatically determine the correct screen refresh rate, but not always.

Notice down here there's an option called Hide modes that this monitor can't display. It's usually checked by default. The idea behind this option is that Windows wants to prevent you from selecting a refresh rate that's not supported by the monitor. This is very important because if you select a refresh rate that is not compatible with your monitor, you could end up damaging the monitor.

Now let's go back over to the Adapter tab. There's a really important option down here called List All Modes. If I click this button, I see a list of all the valid configuration modes for the video board and the monitor connected to the system. Notice that it's composed of three different settings.

First of all, we have the screen resolution. We also have the color depth parameter which defines how many colors can be displayed on the screen. And, we have the monitor refresh rate over here. Currently, this system is set to use 1280 by 720 display resolution, using true color, 32-bit color depth at 60 hertz.

If we scroll through the list, we can see the many different display options are available for this monitor. If you're using a CRT monitor, you have a great deal of flexibility in choosing the display settings you want to use. Because they're multisync monitors, they can use different refresh rates and they support different screen resolutions.

That is not the case with LCD and LED monitors. With LCD and LED monitors, you need to check your monitor documentation and find out what the native resolution of that monitor is. Unlike a CRT monitor, LCD and LED monitors have a fixed number of pixels vertically and horizontally.

Now, does that mean you cannot pick a different display resolution? No, you can if you want, but it's not going to look very good because the video board is going to have to try to figure out how to display a non-native resolution on that monitor. And if you do, basically things are going to look either blurry and/or blocky on the screen. I'm going to click Cancel here.

**Optimize Color Management**5:50-6:30

Notice also that we have a tab called Color Management. The Color Management tab allows you to adjust the colors that you see on the screen to make sure they match the color that you see in documents that are scanned or printed.

Color management is performed by loading profiles. I'll click the Color Management button and notice up here we have several different devices. Each of these devices has a color profile associated with it. By choosing a profile, we ensure that the colors that we see on the screen will match the colors that are seen in the output.

If you see an image on the screen and when you print it, the colors are slightly off and they don't quite match, you could go in and try to use a different color profile to try and correct the problem.

**Performance Options**6:31-8:21

Now another thing you can do to manage the performance of your video output is to adjust your visual effects. We'll go ahead and get out of this interface.

Now let's go to Control Panel by coming down here and typing Control Panel in our search field. And then within Control Panel, we click System and Security > System > Advanced system settings.

Under Performance, on the Advanced tab, we want to click Settings. Here we see many different settings that govern the way the video output is formatted on the monitor. Some of these settings require more processing power on the part of the video board and the CPU than others do. In this interface, you can turn different video elements off or on in order to optimize performance.

Now notice up here, by default, the selection is to let Windows decide what will work best on this computer, which options it should turn on and which options it should turn off. Notice that with Let Windows choose what's best for my computer, most of the options are turned on, with the exception of these two in the middle.

If I'm having trouble with the output of this system and I'm not happy with the way things look, I can change things. One option is to reconfigure it for best appearance. In this case, notice that all the options are turned on. But again, that's going to require more processing power on the system and could slow things down.

If I'm having those types of issues, I could go here and click this option, Adjust for best performance. Notice when I do that, all of these options get turned off. That will require less processing power on the part of the video board and the processor, and the video display should respond a little bit more quickly.

You can also click Custom and then manually come in and select which of these options you want to use and which you don't. I'm going to go ahead and leave this option set to Let Windows choose what's best for my computer. I'm going to click Cancel so I don't make any changes that I don't want.

**Summary**8:22-8:34

That's it for this demonstration. In this demo, we talked about how to optimize video settings. We first talked about how to optimize adapter settings and monitor settings. We ended this lesson by looking at how to optimize color management.

4.3.3 Select and Configure Dual Monitors

You are the IT administrator for a small corporate network. The employee in Office 2 is setting up a virtualization environment for software development. To make the system easier to use, she has requested dual monitors. You need to upgrade the computer in Office 2 to support dual monitors. You have purchased a second monitor and placed it in the Workspace (the monitor on the left). The video card in the computer currently only supports a single monitor, so you will need to upgrade the video card to support dual monitors.

In this lab, your task is to configure dual monitors as follows:

* Select and install a video card that provides you with dual monitor support for both monitors using a digital connection to the video card.
* Connect the new monitor using an HDMI cable to the computer. The new monitor is already plugged in to the surge protector.
* Connect the original monitor to the new video card using the DVI-I cable.
* Turn on the computer.
* Turn on the new monitor.
* Make sure Extend these displays is selected.
* Configure the display properties to show the Start menu and taskbar on the left monitor.
* Configure the relationship of the two monitors to reflect the physical placement of both monitors. By default, Windows places monitor 1 on the left. Because of the way the monitors connect to the video adapter, this configures the monitor on the left as your right monitor.

4.3.4 Configure Display Settings in Linux

**Configure Display Settings in Linux**0:00-0:47

In this demonstration, we're going to discuss how to configure display settings on a Linux system.

Most Linux distributions come with an applet that you can use to configure your display settings properly. For example, on this Fedora system, I can come up to Activities and then type 'display' in the search field and press Enter. Notice that there's an app here called Displays. If I click it, a list of all the displays configured on the system are shown.

Note that I have only one display configured. You can tell which one it is by this number on the display. We have a number one on the display icon and a one in the box under Activities. That tells me that the display shown is the display that I'm currently using. If I had multiple displays, there would be another one listed that had a two on it. If I had three displays, there would be a third one with a three and so on.

**Setting the Screen Resolution**0:48-1:47

For our purposes, we can configure only this display we're using. I click the display and I can specify which display resolution I want to use. Right now it's set to 1280 x 768, which is a (16:10) display ratio. If I need to use a different display resolution, I could click the drop-down list and then pick the one I want to use.

For example, I could set this to 1440 x 900, which is also a (16:10) ratio. I click Apply. I click Keep Changes. And now my screen is much bigger than it was before. In fact, it's so big that it's off the side of the edge of the recording window, so we can't see it.

Let's set it back to what it was before. Click 1280 x 768 and then click Apply. Keep our changes. And now we're back within the recording window.

There are a couple of other display settings that you can configure as well. They're not as commonly used as the resolution we just looked at.

**Setting the Screen Rotation**1:48-2:17

If I click the display, notice that I have three buttons under the display picture. These are rotation buttons. The left button will rotate the screen 90 degrees counterclockwise. The middle button will rotate the screen a full 180 degrees, basically making it upside down. The right button will rotate it 90 degrees clockwise.

For example, if I click the right button, notice that the screen is rotated. I can click Apply. And notice that my screen is rotated 90 degrees to the right which is not what we want to use. So I'm going to press the Tab button and click Revert Settings.

**Managing Color Profiles**2:18-3:19

I press the < icon in the upper, left corner of the screen and go back to All Settings.

Now, the last thing I want to show you before we end this demonstration is this Color applet. Just as with Windows, we can manage the color profiles that the display uses so it looks the way we want.

You can see on the right side of the window that this monitor is not calibrated. To calibrate it, I can click Add profile. In the Add Profile window, I can specify the color profile that I want to use. For example, I'm going to click the color space compatible with Adobe RGB color profile and click Add.

If the profile that I want to use is not listed here, for example maybe I have a profile that came with a particular printer that I have connected to the system. I can come down here and click Import File and pull that profile in and then select it.

I'm going to click Add. I now have the standard space compatible with Adobe RGB color profile loaded and it's set to on. I can turn it off if I wanted to. Let's leave it on. By doing this, the colors that I see on the screen will match this color profile.

**Summary**3:20-3:31

That's it for this demonstration. In this demo, we talked about how to manage display settings. We first looked at how to set the screen resolution. We talked about how to set the screen rotation. And then we ended this lesson by talking about how to manage color profiles.

4.5.2 Install Device Drivers

## Install Device Drivers 0:00-0:11

In this demonstration, we're going to spend some time talking about managing plug-and-play device drivers for plug-and-play devices that you connect to your Windows system.

## Load a Device Driver for a Storage Device 0:12-0:40

Now, you basically have two different options for loading a driver for these devices. The first option is to rely on Windows to identify the device and load the correct driver for you. The other option is to manually download and install the appropriate device driver before you connect the plug-and-play device.

We'll take a look at both of those scenarios in this demonstration. Let's begin by connecting a plug-and-play device to this Windows system and let Windows determine the appropriate device driver to use and automatically load it for us.

## Load a Device Driver Automatically 0:41-1:44

I have an external USB flash drive that I'm going to connect to the system. Notice when I do, down in the lower right of the screen, Windows automatically found the appropriate device driver to support the USB flash drive. Windows had the appropriate driver. I didn't really have to do anything.

If I come down here to my notification area, notice that the Safely Remove Hardware option displays the device that I just connected. Here it is right here. If I come over here to File Explorer, here is the drive that I just connected to the system.

Now why did this work? It's because Windows had the necessary drivers within its driver store to support this particular make and model of USB flash drive. So, I didn't have to manually install a driver for it.

We can verify this by going over to our Windows icon, right-clicking, selecting Device Manager, expanding Disk Drives, and here is the USB flash drive that I just connected to the system. If we right-click it, go to Properties, and then go to Driver, we can see the device driver that was loaded to support this device, and it came from Microsoft.

## Load Drivers Manually 1:45-2:25

There may be situations where you connect the device to the system and Windows probes it to find out what kind of device it is and determines that it does not have the appropriate driver for that device. If this happens, then you're going to have to manually load the appropriate device driver to support that device.

If this happens, one option you can use in Device Manager to get more information about the device is to come over here, click Action, and then click Scan for Hardware Changes. This will cause Windows to go out and reprobe the system to try to find any new devices that have been connected to the system.

Now in this case that didn't happen because all the devices we have connected to the system are working properly.

## Remove a Connected Storage Device 2:26-4:37

Now please be aware of how Windows saves data. Say you have connected an external device to the Windows system and Windows has loaded the drivers for it. If you begin saving files on that external storage device, such as this E: drive right here, you must stop that device before you remove it from the system.

Here's what happens. Windows uses the concept of what's called a delayed write. To make the system more efficient, pending disk writes are queued up in system RAM and stay there until the storage device isn't busy. When the storage device isn't busy, then those pending write operations are executed and the data is written to the disk.

When we move the pending disk writes out of cache and commit them to disk, it's called flushing the cache. Here's the issue. You don't know how long it's going to take for those pending writes to occur.

So, if I save some data to this E: drive right here and then pull it out before those pending disk writes have been committed to disk, then I'm going to end up with corrupted data. Before you do that, you need to come down here to your notification area, locate the Safely Remove Hardware and Eject media button, right-click it, and then click the option to eject the storage device.

When you do this, Windows will check and see if there are any queued up pending disk writes. If there are, it will write those. When that's done, it will tell you, okay, now you can go ahead and remove the device.

There's another option for doing that, too. With most removable storage devices, you right-click the device itself in File Explorer and then click the Eject option. Both will do the exact same thing.

If I were to come down here, right-click, and then select Eject USB Flash Drive, it would fail. Why? Because I have File Explorer open and I'm looking at the E drive.

Let's close File Explorer. Now if I come over to my Safely Remove Hardware and Eject media icon, I can click Eject USB Flash Drive, and now I can remove it from the system.

When I did that, Windows checked to see if there were any pending disk writes and committed them to disk. Then it told me, go ahead and remove the device from the system. So that's one way to load a device driver or a plug-and-play device. Let Windows take care of it for us.

## Load Drivers before Connecting Device 4:38-7:46

Now, please understand that the Windows driver store, both the drivers that are stored locally on your system here and those that are available online from Microsoft site, are by no means all-inclusive. There are many plug-and-play devices that you can connect to your system that do not have a corresponding driver in Microsoft's driver store.

For these devices, you must manually load a device driver. And here's the key mistake a lot of folks make. They assume that just because you can plug a thumb drive into the system and Windows will automatically load the drivers for you, that you should be able to plug any plug-and-play device into the system and rely on Windows to load the appropriate drivers. That just isn't true.

The best practice for loading a driver for one of these types of devices is to install a driver first, before you connect the device to the system. That way, when we plug the device in, Windows will then probe the device and recognize right away that it already has the appropriate device driver to support that device.

Now, is it all lost if you don't do that? If you plug it in first? No. More than likely what will happen is the device will show up as either unrecognized or Microsoft will load some generic driver to provide a minimal level of support for the device.

Then you're going to have to go into Device Manager and manually select the driver you want to use. Let's not make that mistake on this system. I have a USB plug-and-play network adapter here that I want to connect to the system. I happen to know that the appropriate drivers are not available in the Microsoft driver store.

So, the first thing I'm going to do is install the appropriate device drivers on this system. Okay, so I already downloaded the drivers from the manufacturer's website. I'm going to launch the exe and install the driver.

Okay, the driver installation routine is complete. I'll exit out of the installation interface. And now I'm going to connect the device to an open USB port on the system. When I do, because Windows already has the device driver installed, it should be able to query the device, see what kind of device it is, recognize that it already has the appropriate device driver, and load it.

You can see that it detected that this was a network adapter. And the device has been successfully added to the system. As you go through this process, understand that there are two different places where Microsoft stores device drivers.

There is a driver store that's included within your Windows installation. The drivers are stored locally. There's a whole bunch more that are stored out on the internet. So the first thing that Windows is going to do when it detects a device like this, is it will query the local driver store to see if a device driver exists there.

If a driver is not in the local driver store, then Windows will go out onto the internet to the Microsoft site and see if Windows Update has the necessary driver for that piece of hardware. If it does, it will download and install it. Understand that process takes a while to complete.

If that fails to happen, then you will end up with an unknown device in Device Manager and you'll have to manually install a device driver for it from there. To do this, you would come over here to your Windows icon, right-click, and go to Device Manager. Then we can locate the appropriate device that's having problems.

## Update Device Drivers Manually 7:47-10:00

For example, let's suppose that I was having problems with my display adapter. To manage the drivers for this device, I can right-click it, select Properties and then go to the Driver tab. Here I have several different options.

For example, I could use the Update option to find a newer device driver or to manually load a device driver. Or, I can come down here to Uninstall to completely remove the device driver, in which I case I can try loading it again manually. Let's click the Update Driver option. I have two different options for looking for a better device driver.

One is to search automatically for updated device drivers, in which case Windows will first query its local drivers store. If it can't find a better driver there, it will then access the Windows update site and look for a better driver in the online driver store.

The other option is to manually select the appropriate driver. Let's try the first option first, Search Automatically for Updated Driver software. Notice that it first looked locally, now it's looking online for a better device driver.

When I did this, it tells me that the best driver for my device is already installed, meaning that there was not a newer driver stored locally in the local drivers' store, nor was there a better driver available in Microsoft's online driver store. If I went out to Microsoft's website and located a better driver for this video board and downloaded it, I could click this option to manually download the appropriate driver.

For example, this is a Dell computer I am working on. I could go to Dell's website and I could download the latest video driver from there. After doing so, I can use the Browse button here to browse to and select that newer driver. It happens to be located in this folder right here. Then, I could go ahead and click Next and it would pull that driver from the hard drive and load it on the system.

Now I'm not going to do this, because I happen to know that this is the very latest driver for my video board and the one that I've downloaded isn't any newer, so it won't accomplish anything.

You do have another option down here. That is to pick from a list of device drivers on the computer. If you know the make and model of the device, you can browse to and select the appropriate driver for that particular device. And again, the best device for this particular piece of hardware has already been selected.

## Summary 10:01-10:23

That's it for this demonstration. In this demo, we talked about how to manage device drivers for plug-and-play devices. We first walked through the process of letting Windows automatically load a device driver for a storage device. Then we walked through the process of manually loading a device driver prior to connecting a plug-and-play device. We ended this demonstration by talking about how to manually update device drivers.

4.5.7 Device Driver Installation Facts

This lesson covers the following topics:

* Device installation considerations
* Device Manager

### Device Installation Considerations

Be aware of the following when installing devices:

* Before purchasing or installing the device, verify that the device is compatible with the version of Windows you are running. You can:
  + Check the product documentation and look for the Certified for Windows logo.
  + Check the Microsoft Hardware Compatibility List (HCL).
  + Contact the manufacturer to see if the device is compatible.
* Obtain the latest driver before installation. Instead of using the driver included on the installation disc, check the manufacturer's website for the latest driver.
* Read the product documentation and follow the instructions for installation. Always follow the manufacturer's instructions for installing and configuring a device.
* For USB devices, you will typically install the driver prior to connecting the device.
* For internal and non-hot swappable devices, turn off and unplug the system before installing the device.
* Windows will automatically configure a device if:
  + The device is fully plug and play capable.
  + There are no resource conflicts or other problems.
  + Windows finds a suitable driver in its driver database.
  + The driver is signed and from a trusted publisher.
* On Windows, unsigned and self-signed drivers must be manually approved. However, you cannot install unsigned drivers on x64 versions of Windows.

### Device Manager

Use Device Manager to view installed devices and their status.

* To open Device Manager:
  + Right-click **Start** and select **Device Manager**.
  + In the search field on the taskbar, type **Device Manager**.
  + Press the **Windows** key + **R** and type **devmgmt.msc**.
* Use the device icon to identify the status of the device:
  + If the icon for the device is not there, then Windows did not detect the device. Try scanning for new hardware or rebooting the system to detect the device.
  + A normal icon means the device was configured, the appropriate driver was installed, and the device is working properly.
  + An icon with a yellow exclamation mark means the device was detected, but could not be configured properly. In this case, make sure you have the latest driver for the device.
  + An icon with a black down-arrow means the device is disabled.
* To identify the system resources used by a device:
  + Right-click the ***device*** and select **Properties**.
  + Select the **Resources** tab.
* To view all resources used by the computer:
  + On the file menu in Device Manager, select **View** > **Resources by type** (or **Resources by connection**).
  + Alternatively, press the **Windows** key + **R**, type **Msinfo32**.

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Chapter 5: Storage

5.1 Storage Devices

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As you study this section, answer the following questions:

* What are the advantages of hard disks over all other forms of storage media?
* How do optical drives store and read data from a disc?
* How does a flash device differ from a hard disk?
* Which storage device types are magnetic media? Which are optical? Which are solid state?

In this section, you will learn to:

* Select the appropriate storage solution

Key terms for this section include the following:

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Flash memory | Electronic non-volatile memory that is easy to erase and reprogram. |
| Hard disk | A long-term storage device; a thick magnetic disk made of several aluminum platters in a protective shell. |
| Integrated Drive Electronics (IDE) | An electronic interface that allows communication between a motherboard's data pathos or bus and a computer's hard disks. |
| Non-Volatile Memory Express (NVMe) | A memory storage device designed to allow access to non-volatile storage media through a PCI express (PCIe) bus. |
| Optical disc | A storage device that records binary information through pits in a reflectively-coated disc. Optical discs use lasers for reading and writing information. |
| M.2 | A popular solid state drive often used in portable electronics. |
| SD card | A flash memory device is often used in digital cameras. |
| Solid state drive | A flash device with a large storage capacity comparable to a hard disk drive's. |

This section helps you prepare for the following certification exam objectives:

|  |  |
| --- | --- |
| **Exam** | **Objective** |
| CompTIA 220-1001 | 1.1 Given a scenario, install and configure laptop hardware and components.   * Hardware/device replacement   + Hard drive     - SSD vs. hybrid vs. magnetic disk   3.4 Given a scenario, select, install and configure storage devices.   * Solid-state drives   + M2 drives   + NVME * Hybrid drives   + Flash   + SD card   + CompactFlash   + Micro-SD card   + Mini-SD card   + xD   3.5 Given a scenario, install and configure motherboards, CPUs, and add-on cards.   * Motherboard connectors types   + IDE |

5.1.1 Storage Devices

**Storage Devices**0:00-0:14

In this lesson, we're going to look at long-term storage devices. We'll cover five devices: hard disk drives, solid state drives, flash memory devices, Non-Volatile Memory Express, and optical discs.

**Hard Disk Drive**0:15-2:35

Let's start with hard disk drives. This is what the inside of one looks like.

The hard disk drive is composed of many different platters, aluminum disks coated with magnetic material that's magnetized and demagnetized to encode binary data.

Over here, we have our read/write heads. These heads read and write information to and from the platter's surface. Data is stored on both sides of the platter, so there's a head on the bottom and top of each disk.

The heads are connected to this armature, which has an electric motor that moves the heads in and out so that they can access every part of the disk.

These platters spin at a very high speed. As they spin, a little cushion of air is created on the surface of the disk, which keeps the heads from writing right on top of the platter. This is called the Bernoulli Effect.

If you were to look at the platter edge straight on, you would see that there's just a tiny little cushion of air between the surface of the platter and the surface of the head. It's still close enough that the magnetism in the head can magnetize or demagnetize a certain area of the hard disk drive to create zeros and ones, but the heads don't actually touch the surface of the platter.

PC systems generally use hard disk drives for long-term storage because they're fast and they can store huge amounts of information. Hard disks work with Integrated Drive Electronics, or IDE, an electronic interface that allows communication between a motherboard's data paths or bus and a computer's hard disks. Data is accessed in a random order, meaning that the individual blocks of data can be stored or retrieved in any order. And HDDs are a type of non-volatile memory, so they retain stored data when powered off.

Inexpensive hard disk drives spin at about 5400 revolutions per minute, or RPMs. A good-quality HDDs spins at about 7200 RPMs. High-end drives spin at 10,000 to 15,000 RPMs. The higher the revolutions per minute, the faster you can access your data.

Hard disk drives do have a few disadvantages. The biggest issue is that they're not very portable. An Hard Disk Drive has to be installed inside of the computer, so it can be time consuming to take it out and move it to another computer. There are portable HDDs that have a USB interface, which lets you unplug the drive from a USB port on one system and plug it into a USB port on another system, and then the information from the drive is immediately available. But they're still large enough that they're an awkward portable storage device.

**Solid State Drive**2:36-3:15

Now let's move on to solid state drives, a competitor with hard disk drives.

Solid state drives are another type of long-term storage device, but they use flash memory instead of platters. Solid state drives are designed to replace a standard hard disk drive.

A video editing workstation might use a solid state drive because it can read and write information faster than a standard hard disk drive.

Solid state hard drives are also found in smart phones, laptops, cameras, watches, and fitness trackers. They're smaller and lighter than a hard disk drive. And because they don't have any mechanical parts, they don't create as much heat or consume as much energy, and they're more reliable. But they're more expensive and generally have a smaller storage capacity.

**M.2**3:16-5:12

M.2 is a popular solid state drive. M.2 used to be called Next Generation Form Factor (NGFF). It's for internally mounted expansion cards. It replaced the mSATA standard, which used the PCI Express Mini Card. M.2 is useful because it allows different module widths and lengths. It's often used for solid state storage in ultrabooks and tablets. It supports legacy Advanced Host Controller Interface, AHCI, and NVM Express, NVMe, a technology we'll talk about in just a minute.

M.2 drives feature PCI Express 3.0, Serial ATA, or SATA, 3.0, and USB 3.0 ports, and they're backwards compatible with USB 2.0. They can integrate with Wi-Fi, Bluetooth, satellite navigation, near field communication, digital radio, Wireless Gigabit Alliance, WiGig, wireless WAN, and other solid state drives.

Non-Volatile Memory Express (NVMe)

One more memory device you'll encounter in PCs is NVM Express, or NVMe. It's sometimes called Non-Volatile Memory Host Controller Interface Specification, or NVMHCIS. It's made for accessing non-volatile storage media through a <mnu>PCI Express bus.

NVM Express is designed to work well with the low latency and internal parallelism of solid-state storage devices. By allowing host hardware and software to utilize the level of parallelism possible in modern SSDs, NVM Express reduces I/O overhead and improves functionality.

NVM Express devices come in three forms. The most common are standard-size PCI Express expansion cards and 2.5-inch form-factor devices that provide a four-lane PCI Express interface through the U.2 connector. There are also storage devices that use SATA Express and the M.2 specification and support NVM Express as the logical device interface.

**Flash Memory Device**5:13-6:49

There are other types of long-term storage devices that are more portable. These devices use flash memory. This is a flash drive, sometimes called a thumb drive.

If you opened up this device, you would see rows of memory chips.

The memory chips inside of a flash device are different from the memory chips used inside your system RAM because they're programmable. You can write information to the memory locations in the memory chips and then remove power from these chips, and the memory will remain intact. You can't do that with the standard dynamic RAM used on a system memory board.

Because of this, you can take a flash memory device, plug it into the appropriate port on a PC, and have it function like a standard hard disk drive. You can store, read, and format data just like a regular hard disk drive, but you're writing and rewriting data to a location on a memory chip instead of a spinning platter.

This particular flash drive uses a USB interface, so all I have to do is unplug the flash drive from one USB port and plug it into another USB port on another system, and I've got access to all my data.

Flash memory is also used in digital cameras, smart phones, and digital camcorders. The SDHC memory cards often used in cameras are flash devices.

If you have a card reader installed in your PC or laptop, you can remove the memory card from the digital camera, put it in the card reader in your machine, and use it just like a hard disk drive or thumb drive.

Flash devices are relatively fast. They can read and write information as fast as a standard hard disk drive. Flash devices also provide a lot of storage space in a very small physical device. You can buy flash storage as small as four gigabytes and as large as two terabytes.

**Optical Disk**6:50-8:11

Now let's look at optical discs as long-term storage.

Optical drives are for CDs, DVDs, and Blu-Ray discs, and you'll find one on most PC systems. They're called optical drives because they don't use magnetism to encode binary data; they use light.

If you look at the bottom of an optical disc, you will see a rainbow effect as the light hits it. That rainbow effect is caused by the encoding on the bottom of the disk that stores data in binary.

Using an optical disc to store data has many advantages. First of all, optical discs are very portable, and they have good storage capacity. A single layer DVD will hold 4.7 gigabytes of information. A double layer DVD will hold twice that amount, and high-definition DVDs holding between 15 and 30 gigabytes of data. In addition, a single layer Blu-Ray disc can hold up to 25 gigabytes of data, while a dual layer Blu-Ray disc can hold between 50 and 128 gigabytes of data.

Optical discs are great for the long-term storage of read-only data. For example, if you have a bunch of files that you've been working on, and you want to make a backup so that you can retrieve them later, an optical disc is a great way to store your files.

Unfortunately, optical discs are susceptible to damage. Normal wear and tear can scratch up the surface of the disc, making your data unreadable. For that reason, many people are beginning to prefer flash drives or cloud storage to optical discs.

**Summary**8:12-8:32

At this point, you might be asking, which type of long-term storage is best? My answer is, it depends on what you want to do. If you want quick access to a large amount of data, then you should probably look at a hard disk drive or a solid state drive. If you need information to be portable so you can move it from one system to another, then you should look at a flash drive or a rewriteable optical disc.

5.1.2 Storage Device Facts

The following table describes common storage devices:

|  |  |
| --- | --- |
| **Device Type** | **Description** |
| Hard Disk Drive (HDD) | A hard disk is a thick magnetic disk encased in a thicker protective shell. A hard disk consists of several aluminum platters, each of which requires a read/write head for each side. All of the read/write heads are attached to a single access arm to prevent them from moving independently. Each platter has circular tracks that cut through all of the platters in the drive to form cylinders. The spinning of the platters is referred to as revolutions per minute (RPM). The higher the revolutions per minute, the faster the data can be accessed. Standard hard drives are categorized as follow:   * 5400 rpm (inexpensive HDD) * 7200 rpm (good quality HDD) * 10,000 rpm (expensive HDD)   Some of the advantages of hard disks are:   * They have lots of storage (starting at 16 GB up to several TB). * They are significantly faster than floppy disks. * The cost per MB is cheap.   Some of the disadvantages of hard disks are:   * Many hard disks are internal devices, though you can get external enclosures. * They are prone to failure. * They are vulnerable to physical damage (e.g., when dropped).   SCSI is a standard for transferring data between devices on internal and external computer buses. Though SCSI devices are most commonly used for tape storage devices and hard disks, they can also be used for devices such as CD-ROM drives, scanners, and printers. |
| Solid State Drive (SSD) | A solid state drive is a flash device with a storage capacity similar to a small hard drive. Solid state drives are used as replacements for hard disk drives for storing operating system, application, and data files.  Some advantages of solid state drives:   * They are faster than hard drives. * They have no moving parts. * They have lower power consumption than hard drives (good for laptops). * They are less susceptible to physical damage (from dropping) and immune from magnetic fields. * They are smaller and lighter than hard drives   The main disadvantage currently for solid state drives is cost. They are several times more expensive than comparable hard drives. However, their advantages make them a good choice, especially for portable devices. M.2 is a popular SSD for portable devices. |
| Non-Volatile Memory Express (NVMe) | A memory storage device designed to allow access to non-volatile storage media through a PCI express (PCIe) bus.  NVM Express is designed to work well with low latency and internal parallelism of solid-state storage devices. By allowing host hardware and software to utilize the level of parallelism possible in modern SSDs, NVM Express reduces I/O overhead and improves functionality.  NVM Express devices come in three forms. The most common are standard-sized PCI Express expansion cards and a 2.5-inch form-factor devices that provide a four-lane PCI Express interface through the U.2 connector. There are also storage devices that use SATA Express and the M.2 specification, which support NVM Express as the logical device interface. |
| Flash Devices | Flash memory cards store information using programmable, non-volatile flash memory. Some of the advantages of flash devices are:   * The memory is re-programmable. * They can retain content without power. * They are optimal for use in devices like cameras. * They are highly portable. * They have a larger capacity than CDs and DVDs. * They have relatively fast memory access.   Some of the disadvantages of flash devices are:   * Their storage capacity is not yet comparable to the capacity of modern hard disks. * Different memory card formats require different readers.   Common flash memory cards include:   * CompactFlash cards * SD cards * SSD cards * MiniSD cards * MicroSD cards * xD cards * Hybrid cards (combines SSD and HDD technology) * Memory sticks |
| Optical Disc | Optical discs such as CDs, DVDs, and Blu-ray discs are a storage medium that uses lasers for both reading and writing information. Optical discs store information through pits in their reflective coating. As the disc spins, the optical drive sends laser optics to the disk and receives the stored information through the deflected output.  Some of the advantages of optical discs are:   * They are great for music and video (they play in audio or video devices that aren't computers). * They are portable and universal. * They are cheap. * You can buy discs that are recordable. * They have a long shelf life and are relatively sturdy. * Blu-ray discs can store a large amount of data (25 GB or more, depending upon the format).   Some of the disadvantages of optical discs are:   * They are slower than hard disks. * They have a small capacity (650 MB for CDs, 4.7 GB for DVDs). * There are some compatibility issues between disc formats and readers. |
| Integrated Drive Electronics (IDE) | An electronic interface allows communication between a motherboard's data paths or bus and a computer's hard disks. |

Removable storage refers to the ability to easily connect and disconnect storage devices or storage media from a computer (as compared to internal or fixed storage). Optical discs, flash devices, eSATA drives, and tapes are examples of removable media. Hard disks and solid state drives are typically not removable media as they are installed internally in the computer.

5.3.4 Optical Media Facts

*DVD* (Digital Video Disc or Digital Versatile Disc) is an optical media standard that can be used to store large amounts of different types of data (computer data, video, audio).

|  |  |
| --- | --- |
| **Optical Media** | **Characteristics** |
| Compact Disc (CD) | CDs were first developed to store digital music. Later, the CD technology was adapted to store digital computer data. A CD:   * Can hold 74 to 80 minutes of audio * Is 120 millimeters in diameter * Is 1.2 millimeters thick   CD-ROM stands for compact disc read-only memory. CD-ROMs are identical in appearance to audio CDs, and data is stored and retrieved in a very similar manner. CD-ROMs:   * Have lands and pits and use reflective light to interpret the data on the disc. * Hold about 737 MB of data with error correction or 847 MB total. * Transfers data at a rate of 150 KBps. * Drive speeds are measured as multiples of this original speed. To calculate an estimate of your CD-ROM drives transfer rate, multiply its speed by 150 kilobyte (1x = 150 KBps, 2x drive = 300 KBps, 4x drive = 600 KBps, 72x = 10,800 KBps).   CD-RW stands for Compact Disc-ReWritable.   * CD-RW can be written, read many times, erased, and rewritten. * CD-RW has a capacity of about 650 MB. * CD-RW is a removable hard drive, because you can insert the disc into the disc drive on one PC, add and delete data, eject it, and insert it into another disc drive on another system and have all your data immediately accessible. * CD-RW drives can burn or write to CD-RW discs, erase CD-RW discs, and read a CD-ROM disc. * CD-RW drive speed rating includes three parameters: a write speed, a rewrite speed, and a CD-RW read speed. All of these are multiples of the original 150 KBps 1x speed defined by the first CD-ROM drives. For example, if you have an 8x4x32 CD-RW drive, this means that it can write at 1,200 KBps, it can rewrite to a CD-RW disk at 600 KBps, and it can read at 4,800 KBps. * The bottom surface of a CD-RW drive is coated with a photo reactive crystalline coating. A red laser causes a crystal to form which creates the reflective and non-reflective areas on the bottom of the CD-RW disc. * A CD-RW drive has a second, high power write laser. When this laser hits the bottom of this photo reactive material on the bottom of the CD-RW disc, it causes crystals to form. This is called phase shifting or a phase shifting media. A crystal forming on the bottom of a CD-RW disc is like a land on a CD-ROM disk, because it reflects light. |
| Digital Versatile Disc (DVD) | DVD (Digital Versatile Disc) is an optical media standard that can be used to store large amounts of different types of data (computer data, video, audio).   * Most DVD drives can read and write. Older drives or older DVD players might only support DVD-R. * A DVD with a single side of data can hold about 4.7 GB. * A DVD-ROM is read-only memory. * DVD-RW is a rewritable DVD format. * DVD-RW uses a crystal encoding on the bottom of the DVD disc. * A DVD-RW DL employs two recordable dye layers, each capable of storing about 4.7 GB; the total disk capacity is 8.5 GB. * Some DVDs can store data in two different layers on the same side.   + The outer layer is semi-transparent, allowing the laser to read data from the inner layer.   + Dual-layer discs can hold up to 8.5 GB of data.   + Dual-layer recordable discs cost more than single layer discs.   + Dual-layer DVDs are recorded using Opposite Track Path (OTP).   + Most newer drives can read both single and dual layer discs. However, older drives might not support dual layer discs. * DVD speeds use a multiple of 1.35 MBps (1x = 1.35 MBps, 2x = 2.7 MBps, etc.) or 11 Mbps (1x = 11 Mbps, 2x = 22 Mbps, etc.). |
| Blu-ray Disc (BD) | Blu-ray Disc (BD) is a newer optical disc format that is capable of greater storage capacity than DVDs.   * Blu-ray was originally developed for high definition video (and expanded content on movie discs), but can also be used for data storage. * Blu-ray uses a blue laser instead of the red laser used with CDs and DVDs. The blue laser light has a shorter wavelength, which allows data to be packed more tightly on the disc. * A single layer Blu-ray disc holds 25 GB; a double layer disc holds up to 50 GB. Experimental 20 layer discs can hold up to 500 GB. * Blu-ray discs can be read-only (BD-ROM), recordable (BD-R), or rewritable (BD-RE). * A 1x Blu-ray drive reads data at 4.5 MBps. * Most Blu-ray drives include a second read laser for reading CDs and DVDs. Without this additional laser, Blu-ray drives would not be able to read CDs or DVDs. * Blu-ray is intended to eventually replace DVD. * Blu-ray has become the accepted HD video standard as the last movie studio stopped distributing HD DVD movies. |

Be aware of the following when working with optical drives:

* When you place a disc in the drive, it can take several seconds for the drive to recognize the new disc and spin up to speed. If you receive a message saying that the drive is not accessible after trying to access a recently inserted new disc, wait a few seconds and try again..
* If you install a new hard drive, the drive letter for your optical drive might change. Software programs or shortcuts that rely on the old drive letter will likely not run properly until they have been told the correct drive letter for the drive.
* Access time is a general measure of drive performance. Like hard drives, average access time includes average seek time and average latency time. However, it also includes average spin up/down time. This is the time required for a drive to spin up or down to the proper speed to read the data from that particular location of the disc.
* If the drive tray won't open for some reason, you can insert a straightened paper clip in the small hole beneath the drive door to push the drive tray out of the drive.

Use the following precautions to protect discs:

* Some recordable discs use a foil placed on the top of the disc instead of imbedding the foil inside the plastic. Be very careful when working with these types of discs. A scratch or even some types of markers can damage this layer..
* To help prevent scratching, keep the disc in its case when not being used.
* To minimize the effect of scratches that might be generated while wiping a disc, wipe the disc in straight lines from the center to the edge (like the spokes of a wheel).
* Keep the disc away from direct sunlight and other sources of heat.

5.5.2 View File System Components

## View File System Components 0:00-0:12

In this demonstration, we are going to talk about how to view and manage file system components. Specifically, we are going to use Device Manager and Disk Management to do this.

## Device Manager 0:13-1:44

Let's take a look at Device Manager first. Let's go down to the Start menu, right-click, and select Device Manager. From here, let's go ahead and click the drop-down next to Disk drives.

This shows a list of all the drives installed on the system. To see more specific information, go ahead and right-click a drive and select Properties. From here in the General tab, we can see various pieces information regarding this drive.

We can see a device type, that it is a hard drive. The manufacturer will be listed here in some scenarios. We can also see that this is a SCSI drive because it has a bus number and a Target ID.

Additionally, we can see the device's current status. Note that it is working properly, currently. If there's any errors with the device, it will show up here.

Now, there's one tab that shows up under Disk drives in Device Manager that doesn't show up for any other type of devices. That is the Volumes tab. The Volumes tab will show us various pieces of information regarding the disk and the volumes contained on it.

Note that you first must select Populate in order for it to obtain that information. We can see here various bits of information, including a Partition style, the Capacity, Disk number, and the Status.

We also see down here, the different volumes that are contained on the drive. Since this is our primary hard drive, we can see that the C volume is contained on it. The one thing you can't do in Device Manager is manage these components.

So what you want to do is use a different utility called Disk Manager. To get there, we can cancel out of this and close Device Manager.

## Disk Management 1:45-2:21

There are two ways to get to Disk Management. One way is to go up here to Computer Management and then select Disk Management in the left-hand column. Additionally, we can just select Disk Management in this menu.

We expand this to make it easier to see. You can see Disk Management is divided into sections. The upper part shows a listing of all the different volumes that have been defined on the system on all storage devices.

For example our C: drive, E: drive, and F: drive. Additionally we have some partitions that do not have letters. These are ones generally created by the operating system when it's installed.

## Graphical Depiction 2:22-5:13

Down here in the lower part of the Disk Management interface, you will see a geographical depiction of how the volumes up here have been defined on the various hard disk drives.

You can see we have one for each of the storage devices that has been installed on the system. We have Disk 0, Disk 1, and Disk 2. On each disk, there's a listing of the partitions that have been defined on that disk.

Now, I want to come over here to this part of the screen and click a particular volume. In this case, I want to click the C volume where Windows is installed.

When I do, I see that the C volume is defined on Disk 0 and that it is the third partition on the drive. Notice down at the bottom the screen, that different types of volumes are identified with different colors.

First of all, any space on a drive that is shown in black indicates that is unallocated space. That space has not been allocated to any partition yet, so it's free space that we could use if we wanted it for a new volume.

Down here, on Disk 2 at the very end, we have about 9 to 10 GB of unallocated space that we could use for new volume. In addition, the blue partitions are primary partitions.

As you can see up here on Disk 0, I have three different partitions. I have my Recovery, and I have my C: drive. I also have an unlabeled amount of an unlabeled partition used for operating system functions.

If you see a volume here that's identified with the light green color, that indicates it is a simple volume has been defined on a dynamic disk. Notice that we have two dynamic disks on the system and one basic disk.

On Disk 1, we have a simple volume here that is named Stats. It has been assigned the drive letter of F:. We also have a simple volume down here on Disk 2, but you'll notice that there's something different. There's no volume name and there's no letter assigned to it. That's because this volume, while has been defined does not have a file system on it, and it doesn't have a drive letter assigned.

In addition, the system also has spanned volumes. Spanned volumes are indicated by purple. Notice up here, that I have a volume called Art assigned a drive letter of E:. But if you look down at the bottom of the display, we see that the Art volume is composed of space on the two separate hard disk drives.

We've got about 15ish GB off of Disk 1 and about 15 GB off Disk 2. Now the Windows operating system is going to use space on this drive and space on this drive together to form the Art volume. It will treat the Art volume as if it were one big hard disk drive.

It basically allocates space and creates a logical spanned volume from the space on these two hard disks. So if I were to saved a file on my Art volume, the E: drive, it could be saved on Disk 1 or it could end up being saved on Disk 2, depending on which blocks with an Art volume that Windows decides to save the file to.

## Explore 5:14-8:10

Now, if you select a volume up at the top here, right-click and select Explore. We see that we can view all the different files and folders are contained within that volume. Additionally, if we select This PC, we can see all the different volumes that are accessible within Windows.

Notice that we have our C: drive, which is our operating system drive found on Disk 0. We have our Art or E drive which is spanned across Disk 1 and Disk 2. We also have our stats for F: drive, which is found on Disk 1.

Notice the unlabeled volume here does not show up in the list. That is because it does not have a drive letter, nor does it have a partition on. To add those, we first want to come here, right-click and select Change Drive Letter and Paths.

Click Add. And then we want to choose a drive letter. I'm going to select G, click OK. Now, if we come back to Windows Explorer, we can see that it has shown up here. Notice if you try and access it, we get a message stating that we must format the disk on drive G before we can use it.

So I'm just going to go ahead and select Format disk. Now it's going to give us a few different options here. By default, it's going to use all of the available space on the volume. Then additionally, it's going to want have us select a file system.

By default, it's going to use NTFS. But you can alternatively use FAT32 if you wanted to. But typically when dealing with internal storage devices on a Windows system, we will always use NTFS because NTFS allows us to implement users and permissions on the files and folders in the system, allowing us to control access to data on the drive. It also allows us to create much bigger volumes that have files that are much larger than FAT32.

FAT32 is a very old file system and does not support users and permissions assignment. You can't implement access controls on it, so there is a security issue there. It also has pretty severe file size limitations. So really, unless you're dealing with an external flash drive connected to a USB port, you are probably going to use NTFS on internal storage devices.

Let's come down here and give it a Volume label of Data. Then, click Start. Notice it does warn us that "Hey, when I format this, you're going to erase everything that's currently on this partition. Are you sure you want to do that? We say, "yeah, that's fine because there's nothing there." So we select OK.

We'll wait a moment. We'll wait until it is formatted and it will complete. We can see over in File Explorer that we can now save data on our G drive. So we can do that by opening it up. Notice that we can right-click and create a new folder. Then we can open that folder and within that folder, I can right-click on empty space. Then I can create a new bitmap image.

I can come up here, right-click, and edit the image. We can create some beautiful artwork on here. I can save my data. All because I have a file system now on this volume which allows you to create and save data on it.

## Summary 8:11-8:32

That's it for this demonstration. In this demo, we talked about how to view and manage file system components. We first looked at managing file system components in Device Manager and then we talked to how to manage file system components with Disk Management. We ended this demonstration by creating files and folders inside a volume using file Explorer.

5.5.3 File System Facts

This lesson covers the following topics:

* File system components
* Formatting
* NTFS
* ExFAT

### File System Components

A *file system* is a means for organizing and storing data and information on a storage device. The file system and the operating system work together to ensure data availability, integrity, and accessibility. The following table gives a description for the four main components of a file system:

|  |  |
| --- | --- |
| **Component** | **Description** |
| Partition | A *partition* is a logical division of a storage device associated with a hard disk drive. Multiple partitions can be assigned to a single device, in which case a drive letter is assigned to represent each partition. Multiple letters do not always mean that there are multiple devices, just multiple partitions. Some reasons why you may consider partitioning your hard drive are:   * Assigning the boot system to a different partition than application and data files can help many computers run more smoothly and minimize damage in a system crash. * Storing the swap file on its own partition is sometimes necessary or useful. * Creating a separate partition for your operating system can help it run properly. Some operating systems can't run on a large partition. * Assigning log files to be stored on distinct partitions can help minimize the effects of a system crash due to excessively large log files. * Assigning distinct operating systems to run on assigned partitions allows a dual boot system setup.   Unallocated space is space on a partition that has not been assigned to a volume. You cannot store or read data in unallocated space |
| Volume | A *volume* is a single accessible storage area within a file system. A volume can encompass a single partition or span across multiple partitions depending on how it is configured and what operating system you are using. Volumes are identified by drive letters. |
| Directory | A *directory* (also called a *folder*) is a container in a volume that holds files or other directories. It is used to logically sort and organize data to keep related files grouped together. Most operating systems use a hierarchal filing structure. |
| File | A *file* is a one-dimensional stream of bits treated as a logical unit. Files are the most basic component that a file system uses to organize raw bits of data on the storage device itself. The file name is made up of the directory path plus the file name. An extension can also be added to the filename to identify the file type and the program used to create, view, and modify the file. |

File systems take many forms. Some common ones beside exFAT, FAT32, and NTFS include:

* Compact Disk filing system (CDFS), a virtual file system used with Linux.
* Network File System (NFS), a distributed file system that allows client computers to access files over a computer network.
* Ext4, the default Linux file system (and its predecessor ext3, which is still in use).

### Formatting

*Formatting* is the process of preparing a partition to use a specific file system. Be aware of the following facts regarding formatting:

* When you format a disk, you identify the file system type and identify the cluster size used to store data.
* Reformatting removes the existing file system and replaces it with the new file system type. Reformatting a drive deletes all existing data.
* If your system or disk supports multiple operating systems, be sure to select a file system supported by all necessary operating systems.
* NTFS is not recommended for disks smaller than 10 MB.
* When using NTFS on removable devices, you must use Safely Remove Hardware before removing the flash device to prevent file corruption.
* If you run a Full Format, files are removed from the volume you scan and the system checks the hard disk for bad sectors. If you run a Quick Format, the system removes files from the partition, but does not scan the disk for bad sectors.

When configuring your hard drive, you must choose a file system that will be implemented on your computer. The following table explains the characteristics of the file systems supported in Windows systems:

|  |  |  |
| --- | --- | --- |
| **Property** | **FAT32** | **NTFS** |
| Partition size | 2 terabytes\* | 256 terabytes |
| Volume size | 2 terabytes\* | 256 terabytes |
| File name length | Long File Names (255 characters, spaces) | Unicode (255 characters, anything but /) |
| File size | 4 gigabytes | 16 terabytes |
| Amount of files | 268,435,437 | 4,294,967,295 |

\*FAT32 partitions/volumes can be up to 2 terabytes in size. Windows can read partitions up to the 2 terabyte size, but cannot create them.

### NTFS

For Windows systems, you will likely choose NTFS over FAT for hard drives to take advantage of additional features not supported by FAT such as:

* The ability to format larger partition sizes in Windows.
* Smaller cluster sizes for more efficient storage with less wasted space.
* File and folder permissions to control access to files.
* Encryption to hide the contents of a file.
* Compression to reduce the amount of space used by files.
* Disk quotas to restrict the amount of disk space that files saved by a user can use.
* Volume mount points that allow you to map disk space on another partition into an existing volume.

### ExFAT

The Extended File Allocation Table (exFAT, sometimes called FAT64) file system is a special file system that is designed to support large flash drives. Using NTFS on flash drives is usually not a good idea due to its high overhead and risk of corruption if the device is not stopped properly prior to removal. However, many flash drives exceed the 32 GB limit discussed above. Microsoft introduced native exFAT support in Windows 7 to allow large removable flash storage devices to continue to use a FAT-type file system.

5.7.3 Shrink and Split Partitions

**Shrink and Split Partitions**0:00-0:07

In this demonstration, we're going to spend some time looking at how you shrink a volume on Windows.

**Loading Disk Management**0:08-0:24

Of course, to do this, you'll need to be in Disk Management, so I'll right-click on my Windows icon and then select Disk Management. You could also select Computer Management and then select the Disk Management option on the left. But in this case, it's better to use Disk Management here. Maximize, and here it is.

**Shrink Volume**0:25-2:19

Notice that we have disks 0, 1, and 2. There's no unallocated space available on any of these disks. Suppose, for some reason, we need to create an additional drive. Maybe we need to store some sensitive documents on that drive, so I want to restrict access to the information. An easy way to do that is to create a separate volume and implement those permissions at the volume level. Well, I don't have that option because I don't have any volumes available. One option I do have, however, is to take one of these volumes and shrink it, and then create another volume out of the available unallocated space, effectively splitting the volume.

For example, notice that the data volume here is 32 gigs in size, and it encompasses all of Disk 1. Well, we could shrink data down to where it encompasses about 16 gigs, about half the hard disk drive, freeing up an additional 16 gigs that we can use for new volume, where we're going to store that confidential information.

So, let's right-click on this Data volume, and then we're going to select Shrink Volume. Disk Management decided how much we can shrink this volume. Notice that, because Data doesn't isn't storing a lot of information, the shrink process can be fairly aggressive. Here's the size before shrinking, about 32 gigs. Here's the size of available shrink space, 29 to 30 gigs.

So, if we go with the default, the data volume is going to be cranked down to just under three gigs in size. That's a little bit more than we currently want. Let's just shrink it to about half the size. Let's change this part, here, to about 16, 384 MB, which is roughly 16 gigs. This is how much space will be unallocated after the shrink. And here's how big the data volume will be after the shrink process, as well. Let's click the Shrink button, and we'll wait just a minute while the shrink process occurs.

All right. The volume has been shrunk. Data is now roughly 16 gigs in size, and we have 16 gigs of unallocated space.

**Create Simple Volume**2:20-2:59

Let's go ahead and create a new simple volume in the unallocated space. Right-click and select New simple volume. Hit Next. By default, we'll use all of the available space. Next. Give it a drive letter of D. Hit Next. And let's label this one ‘Secure', and we'll ensure that Perform a quick format is selected to speed things up. Hit Next and Finish.

Okay. A new secure volume has been created. We've effectively split the data volume into two different volumes. We have our DATA volume here and secure volume here, which, if you check This PC, we can see has been assigned drive letter D.

**Summary**3:00-3:03

That's it for this demonstration. In this demo, we talked about shrinking and splitting a volume in Windows.