CHAPTER 5

Power Supplies and System Cooling

"Do I Know This Already?" Quiz

The "Do I Know This Already?" quiz allows you to assess whether you should read this entire chapter or simply jump to the "Exam Preparation Tasks" section for review. If you are in doubt, read the entire chapter. Table 5-1 outlines the major headings in this chapter and the corresponding "Do I Know This Already?" quiz questions. You can find the answers in Appendix A, "Answers to the 'Do I Know This Already?' Quizzes and Troubleshooting Scenarios."

Table 5-1 "Do I Know This Already?" Foundation Topics Section-to-Question Mapping

Foundations Topics Section	Questions Covered in This Section
Power Supplies	1–8
Power Protection Types	9–11
Troubleshooting Power Problems	12
System Cooling	13, 14

1. Which of the following would you use to keep the power supply working properly? (Choose two.)
   a. Surge protector
   b. Extra power supply
   c. UPS units
   d. Multimeter
2. Power supplies are rated using which of the following units?
   a. Amps
   b. Volts
   c. Watts
   d. Output

3. Newer computers' power supplies typically have which of the following power output ratings?

   a. 300 watts
   b. 400 watts
   c. 250 watts
   d. 500 watts or higher

4. Most power supplies in use today are designed to handle which two voltage ranges? (Choose two.)

   a. 115
   b. 300
   c. 230
   d. 450

5. Which of the following are causes of power supply overheating?

   a. Overloading the power supply
   b. Fan failure
   c. Dirt or dust
   d. All of these options are correct

6. How many pins are used for the main power connection by recent ATX/BTX motherboards with ATX12V 2.2 power supplies?

   a. 24
   b. 48
   c. 32
   d. 16

7. Which of the following steps would you use to remove a power supply?

   a. Shut down the computer. If the power supply has an on-off switch, turn it off as well
   b. Disconnect the AC power cord from the computer
   c. Disconnect power connections from the motherboard, hard drives, and optical drives
   d. All of these options are correct

8. To avoid power supply hazards you must never do which of the following? (Choose two.)
   a. Disassemble the power supply
   b. Put metal tools through the openings
   c. Switch the voltage to 220
   d. Put a smaller power supply in the computer
9. What device provides emergency power to a computer in case of a complete power failure?
   a. UTP
   b. UPS
   c. Power strip
   d. Surge protector
10. What is the minimum time recommendation for a UPS to supply power for an individual workstation?
    a. 30 minutes
    b. 45 minutes
    c. 1 hour
    d. 15 minutes
11. What is the major difference between a UPS and a SPS? (Choose all that apply.)
    a. The battery is only used when the AC power fails
    b. They are on all the time
    c. A momentary gap in power occurs between loss of AC power
    d. They are far less expensive
12. If a system is dead and gives no signs of life when you turn on the computer, which of the following might be the cause? (Choose all that apply.)
    a. Defects in AC power to the system
    b. Power supply failure or misconfiguration
    c. Temporary short circuits in internal or external components
    d. Power button or other component failure

13. All processors require a finned metal device to help with cooling. What is this device called? (Choose two.)

- **a.** Passive heat sink
- **b.** Thermal compound
- **c.** Active heat sink
- **d.** Chassis heat sink

14. What is the purpose of thermal compound?

- **a.** Provides the best possible thermal transfer between a component and its heat sink
- **b.** Provides the best possible thermal transfer between a component's heat sink and its fan
- **c.** To negate the effects of thermal contraction and expansion in adapter cards
- **d.** Provides the best possible thermal transfer between the northbridge and its fan

Foundation Topics

Power Supplies

Power issues are largely ignored by most computer users, but a properly working power supply is the foundation to correct operation of the system. When the power supply stops working, the computer stops working, and when a power supply stops functioning properly—even slightly—all sorts of computer problems can take place. From unexpected system reboots to data corruption, from unrecognized bus-powered USB devices to system overheating, a bad power supply is bad news. The power supply is vital to the health of the computer. So, if your computer is acting "sick," you should test the power supply to see if it's the cause. To keep the power supply working properly, use surge suppression and battery backup (UPS) units.

The power supply is really misnamed: It is actually a power converter that changes high-voltage alternating current (AC) to low-voltage direct current (DC). There are lots of wire coils and other components inside the power supply that do the work, and during the conversion process, a great deal of heat is produced. Most power supplies include one or two fans to dissipate the heat created by the operation of the power supply; however, a few power supplies designed for silent operation use passive heat sink technology instead of fans. On power supplies that include fans, fans also help to cool the rest of the computer. Figure 5-1 shows a typical desktop computer's power supply.

Power Supply Ratings

Power supply capacity is rated in watts, and the more watts a power supply provides, the more devices it can safely power.

You can use the label attached to the power supply, shown in Figure 5-2, to determine its wattage rating and see important safety reminders.

NOTE The power supply shown in Figure 5-2 is a so-called "split rail" design with two separate 12V outputs ($+12V_1$ and $+12V_2$). This type of design is frequently used today to provide separate 12V power sources for processors (which reduce 12V power to the power level needed) and other devices such as PCI Express video cards, fans, and drive). Add the values together to get the total 12V output in amps (36A).

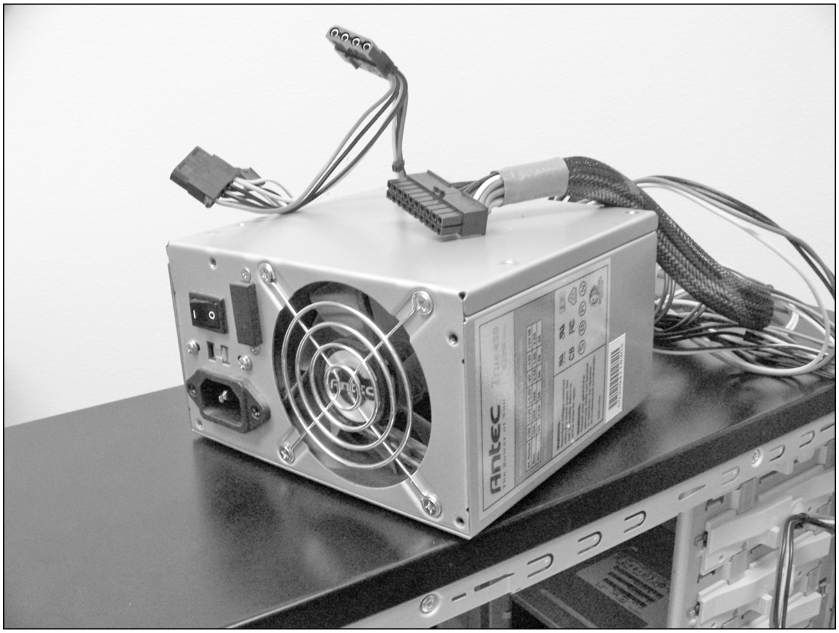
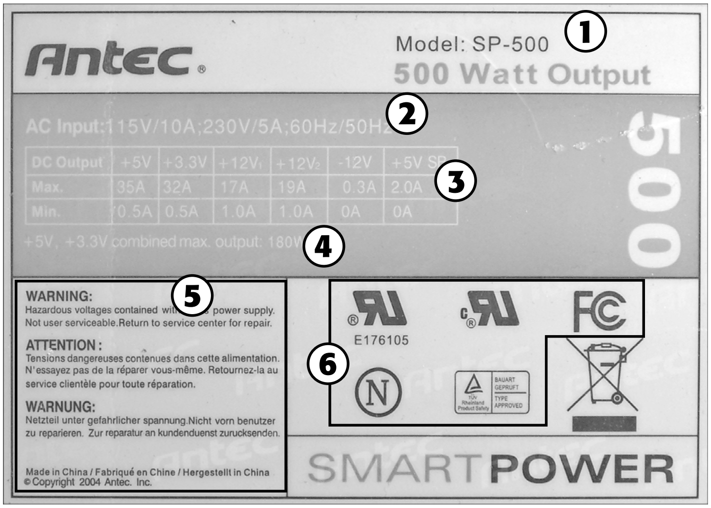


Figure 5-1 A typical ATX power supply.

Key Topic



1. Power supply rating
2. AC Input voltage levels
3. DC output levels by type
4. 3.3V and 5V output and peak output
5. Hazard warnings
6. Product certifications

Figure 5-2 A typical power supply label.

How can you tell if a power supply meets minimum safety standards? Look for the appropriate safety certification mark for your country or locale. For example, in the U.S. and Canada, the backward UR logo is used to indicate the power supply has the UL and UL Canada safety certifications as a component (the familiar circled UL logo is used for finished products only).

CAUTION Power supplies that do not bear the UL or other certification marks should not be used, as their safety is unknown. For a visual guide to electrical and other safety certification marks in use around the world, visit the Standard Certification Marks page at www.technick.net/public/code/cp_dpage.php?aiocp_dp=guide_safetymarks.

Typically, power supplies in recent tower-case (upright case) machines use 500-watt or larger power supplies, reflecting the greater number of drives and cards that can be installed in these computers. Power supplies used in smaller desktop computers have typical ratings of around 300 to 400 watts. The power supply rating is found on the top of the power supply, along with safety rating information and amperage levels produced by the power supply's different DC outputs.

What happens if you connect devices that require more wattage than a power supply can provide? This is a big problem called an *overload*. An overloaded power supply has two major symptoms:

- Overheating
- Spontaneous rebooting (cold boot with memory test) due to incorrect voltage on the Power Good line running from the power supply to the motherboard

Here's a good rule of thumb: If your system starts spontaneously rebooting, replace the power supply as soon as possible. However, power supply overheating can have multiple causes; follow the steps listed in the section "Causes and Cures of Power Supply Overheating," later in this chapter, before replacing an overheated power supply.

To determine whether Power Good or other motherboard voltage levels are within limits, perform the measurements listed in the section "Determining Power Supply DC Voltage Levels" later in this chapter.

Multivoltage Power Supplies

Most power supplies are designed to handle two different voltage ranges:

- 110–120V/60Hz
- 220–240V/50Hz

Standard North American power is now 115–120V/60Hz-cycle AC (the previous standard was 110V). The power used in European and Asian countries is typically 230–240V/50Hz AC (previously 220V). Power supplies typically have a slider switch with two markings: 115 (for North American 110–120V/60HzAC) and 230 (for European and Asian 220–240V/50Hz AC). Figure 5-3 shows a slider switch set for correct North American voltage. If a power supply is set to the wrong input voltage, the system will not work. Setting a power supply for 230V with 110–120V current is harmless; however, feeding 220–240V into a power supply set for 115V will destroy the power supply.

Key Topic

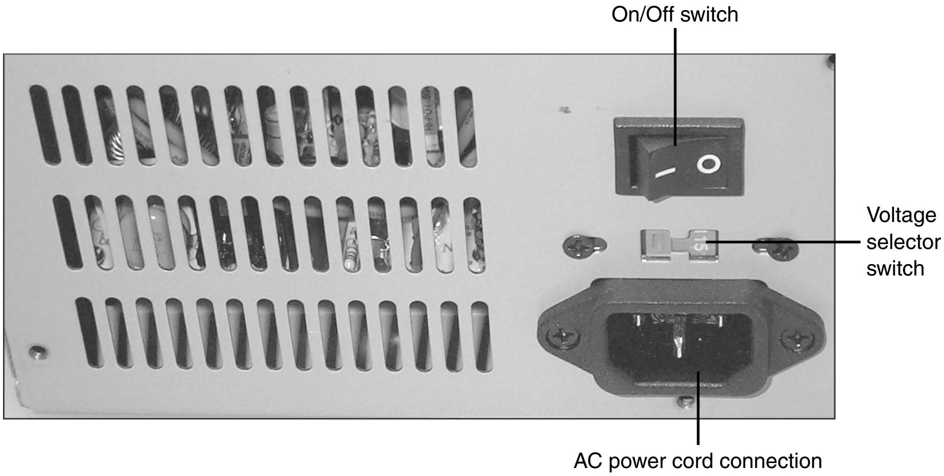


Figure 5-3 A typical power supply's sliding voltage switch set for correct North American voltage (115V). Slide it to 230V for use in Europe and Asia.

NOTE Note that some power supplies for desktop and notebook computers can automatically determine the correct voltage level and cycle rate. These are referred to as *autoswitching power supplies*, and lack the voltage/cycle selection switch shown in Figure 5-3.

The on/off switch shown in Figure 5-3 controls the flow of current into the power supply. It is not the system power switch, which is located on the front of most recent systems and is connected to the motherboard. When you press the system power switch, the motherboard signals the power supply to provide power.

CAUTION Unless the power supply is disconnected from AC current or is turned off, a small amount of power can still be flowing through the system, even when it is not running. Do not install or remove components or perform other types of service to the inside of a PC unless you disconnect the AC power cord or turn off the power supply. Wait a few seconds afterward to assure that the power is completely off. Some desktop motherboards have indicator lights that turn off when the power has completely drained from the system.

Causes and Cures of Power Supply Overheating

Got an overheated power supply? Not sure? If you touch the power supply case and it's too hot to touch, it's overheated. Overheated power supplies can cause system failure and possible component damage, due to any of the following causes:

- Overloading
- Fan failure
- Inadequate air flow outside the system
- Inadequate air flow inside the system
- Dirt and dust

Use the following sections to figure out the possible effects of these problems in any given situation.

Overloading

An overloaded power supply is caused by connecting devices that draw more power (in watts) than the power supply is designed to handle. As you add more card-based devices to expansion slots and install more internal drives in a system, the odds of having an overloaded power supply increase.

If a power supply fails or overheats, check the causes listed in the following sections before determining whether you should replace the power supply. If you determine that you should replace the power supply, purchase a unit that has a higher wattage rating.

Use the following methods to determine the wattage rating needed for a replacement power supply:

- Whip out your calculator and add up the wattage ratings for everything connected to your computer that uses the power supply, including the motherboard, processor, memory, cards, drives, and bus-powered USB devices. If the total wattage used exceeds 70% of the wattage rating of your power supply, you should upgrade to a larger power supply. Check the vendor spec sheets for wattage ratings.
- If you have amperage ratings instead of wattage ratings, multiply the amperage by the volts to determine wattage and then start adding. If a device uses two or three different voltage levels, be sure to carry out this calculation for each voltage level, and add up the figures to determine the wattage requirement for the device. Table 5-2 provides calculations for typical AMD and Intel–based systems.

Table 5-2 Calculating Power Supply Requirements

MicroATX system with integrated video		**Full-size ATX system with SLI (dual graphics cards)**	
Components	**Wattage**	**Components**	**Wattage**
AMD Athlon 64 X2 4000+ Socket AM2	65	Intel Core 2 Quad Q6700 Socket 775	95
microATX motherboard	60	ATX motherboard	100
2GB RAM	30	3GB RAM	45
Rewritable DVD drive	30	Rewritable DVD drive	30
SATA hard disk	20	SATA hard disk	20
Two case fans	6	Three case fans	9
CPU fan	3	CPU fan	3
Integrated Video	—	High-end SLI video cards (2)	210 (105×2)
Estimated Wattage	214	Estimated Wattage	472
Minimum Power Supply Size Recommended (70% efficiency assumed)	300	Minimum Power Supply Size Recommended (70% efficiency assumed)	700

- Use an interactive power supply sizing tool such as the calculators provided by eXtreme Outervision (www.extreme.outervision.com) or PC Power and Cooling (www.pcpowercooling.com)

Note that the recommended power supply shown for each example in Table 5-2 is considerably larger than the estimated wattage rating to make up for the reduced efficiency of some power supplies.

NOTE Some power supplies now feature power factor correction (PFC), which uses special circuitry to achieve an efficiency of 95% or more, as opposed to the 70%–75% efficiency of standard power supplies. Thus, when comparing two power supplies with the same wattage rating, the power supply with PFC makes more wattage available to the system.

Fan Failure

The fan inside the power supply cools it and is partly responsible for cooling the rest of the computer. If the fan fails, the power supply and the entire computer are at risk of damage. The fan also might stop turning as a symptom of other power problems.

A fan that stops immediately after the power comes on usually indicates incorrect input voltage or a short circuit. If you turn off the system and turn it back on again under these conditions, the fan will stop each time.

To determine whether the fan has failed, listen to the unit; it should make less noise if the fan has failed. You can also see the fan blades spinning rapidly on a power supply fan that is working correctly. If the blades aren't turning, the fan has failed or is too clogged with dust to turn.

NOTE Note that if the fan has failed because of a short circuit or incorrect input voltage, you will not see any picture onscreen because the system cannot operate.

If the system starts normally but the fan stops turning later, this indicates a true fan failure instead of a power problem.

CAUTION Should you try to replace a standard power supply fan? No. Because the power supply is a sealed unit, you would need to remove the cover from most power supplies to gain access to the fan. The wire coils inside a power supply retain potentially *lethal* electrical charges. Instead, scrap the power supply and replace it with a higher-rated unit. See the section "Removing and Replacing the Power Supply" later in this chapter.

Inadequate Air Flow Outside the System

The power supply's capability to cool the system depends in part on free airflow space outside the system. If the computer is kept in a confined area (such as a closet or security cabinet) without adequate ventilation, power supply failures due to overheating are likely.

Even systems in ordinary office environments can have airflow problems; make sure that several inches of free air space exist behind the fan output for any computer.

Inadequate Air Flow Inside the System

As you have seen in previous chapters, the interior of the typical computer is a messy place. Wide ribbon cables used for hard and floppy drives, drive power cables, and expansion cards create small air dams that block air flow between the heat sources—such as the motherboard, CPU, drives, and memory modules—and the fan in the power supply.

You can do the following to improve air flow inside the computer:

- Use cable ties to secure excess ribbon cable and power connectors out of the way of the fans and the power supply.
- Replace any missing slot covers.
- Make sure that auxiliary case fans and CPU fans are working correctly.
- Use Serial ATA drives in place of conventional ATA hard drives (assuming the system supports Serial ATA); Serial ATA drives use very narrow data cables.

For more information about cooling issues, see the section "System Cooling," later in this chapter for details.

Dirt and Dust

Most power supplies, except for a few of the early ATX power supplies, use a cooling technique called *negative pressure*; in other words, the power supply fan works like a weak vacuum cleaner, pulling air through vents in the case, past the components, and out through the fan. Vacuum cleaners are used to remove dust, dirt, cat hairs, and so on from living rooms and offices, and even the power supply's weak impression of a vacuum cleaner works the same way.

When you open a system for any kind of maintenance, look for the following:

- Dirt, dust, hair, and gunk clogging the case vents
- A thin layer of dust on the motherboard and expansion slots
- Dirt and dust on the power supply vent and fans

Yuck! You never know what you'll find inside of PC that hasn't been cleaned out for a year or two. So how can you get rid of the dust and gunk? You can use either a vacuum cleaner especially designed for computer use or compressed air to remove dirt and dust from inside the system. If you use compressed air, be sure to spread newspapers around the system to catch the dirt and dust. If possible, remove the computer from the computer room so the dust is not spread to other equipment.

Replacing Power Supply Form Factors and Connectors

When you shop for a power supply, you also need to make sure it can connect to your motherboard. There are two major types of power connectors on motherboards:

- 20-pin, used by older motherboards in the ATX family
- 24-pin, used by recent ATX/BTX motherboards requiring the ATX12V 2.x power supply standard

Some high-wattage power supplies with 20-pin connectors might also include a 20-pin to 24-pin adapter.

Some motherboards use power supplies that feature several additional connectors to supply added power, as follows:

- The four-wire ATX12V connector provides additional 12V power to the motherboard; this connector is sometimes referred to as a “P4” or “Pentium 4” connector.
- Many recent high-end power supplies use the eight-wire EPS12V connector instead of the ATX12V power connector.
- Some older motherboards use a six-wire AUX connector to provide additional power.

Figure 5-4 illustrates most of these connectors.

Key Topic

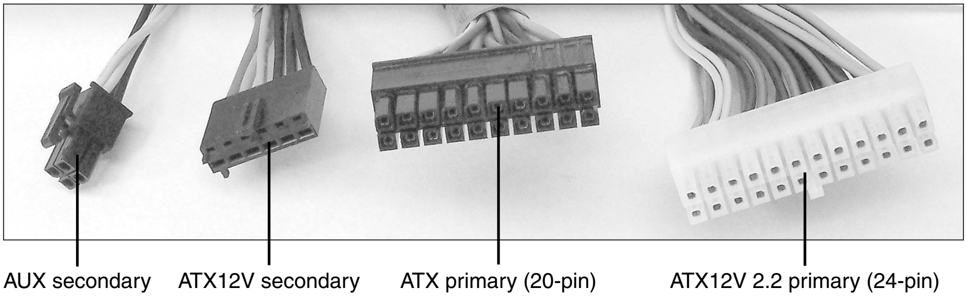
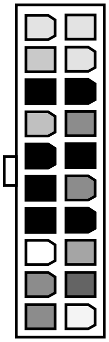


Figure 5-4 Typical power supply connectors to the motherboard.

Figure 5-5 lists the pinouts for the 20-pin and 24-pin ATX power supply connectors shown in Figure 5-4.

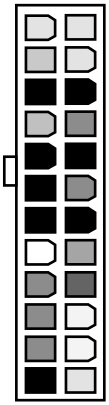
ATX 20-pin power connector (top view)



11	+3.3v	Orange	Orange	+3.3v	1
12	-12v	Blue	Orange	+3.3v	2
13	Ground	Black	Black	Ground	3
14	PS-On	Green	Red	+5v	4
15	Ground	Black	Black	Ground	5
16	Ground	Black	Red	+5v	6
17	Ground	Black	Black	Ground	7
18	-5v	White	Gray	Power Good	8
19	+5v	Red	Purple	+5v Standby	9
20	+5v	Red	Yellow	+12v	10

Figure 5-4 Typical power supply connectors to the motherboard.

ATX 12V version 2.x 24-pin power connector (top view)



13	+3.3v	Orange	Orange	+3.3v	1
14	-12v	Blue	Orange	+3.3v	2
15	Ground	Black	Black	Ground	3
16	PS-On	Green	Red	+5v	4
17	Ground	Black	Black	Ground	5
18	Ground	Black	Red	+5v	6
19	Ground	Black	Black	Ground	7
20	NC	White	Gray	Power Good	8
21	+5v	Red	Purple	+5v Standby	9
22	+5v	Red	Yellow	+12v	10
23	+5v	Red	Yellow	+12v	11
24	Ground	Black	Orange	+3.3v	12

Figure 5-5 Pinouts for standard ATX 20-pin and 24-pin power connectors.

The power supply also powers various peripherals, such as the following:

- PATA hard disks, CD and DVD optical drives, and case fans that do not plug into the motherboard use a four-pin Molex power connector.
- 3.5-inch floppy drives use a reduced-size version of the Molex power supply connector.
- Serial ATA (SATA) hard disks use an L-shaped thinline power connector.

- High-performance PCI Express x16 video cards that require additional 12V power use a PCI Express six-pin power cable.

Figure 5-6 illustrates these connectors compared to the 20- and 24-pin ATX primary motherboard power connectors.

Key Topic

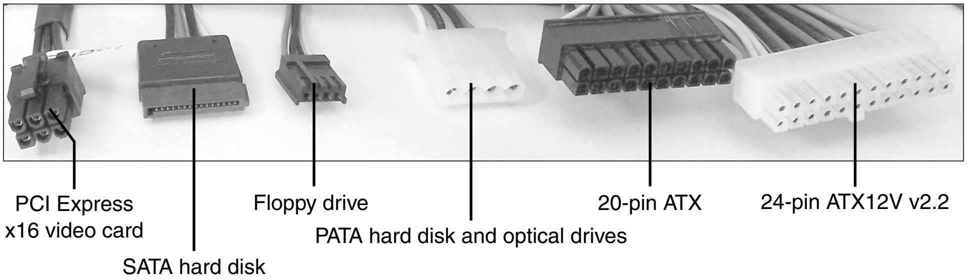


Figure 5-6 Typical peripheral power connectors.

If your power supply doesn't have enough connectors, you can add Y-splitters to divide one power lead into two, but these can short out and can also reduce your power supply's efficiency. You can also convert a standard Molex connector into an SATA or floppy drive power connector with the appropriate adapter.

CAUTION Many recent and older Dell computers use proprietary versions of the 20-pin or 24-pin ATX power supply connectors. Dell's versions use a different pinout that routes voltages to different wires than in standard power supplies. Consequently, if you plug a standard power supply into a Dell PC that uses the proprietary version, or use a regular motherboard as an upgrade for a model that has the proprietary power supply, stand by for smoke and fire! To determine if a particular Dell computer model requires a proprietary power supply, see the Dell Upgrade Power Supplies section of the PC Power and Cooling website www.pcpower.com/products/power_supplies/dell/.

If your wattage calculations or your tests (covered later in this chapter) agree that it's time to replace the power supply, make sure the replacement will meet the following criteria:

- Have the same power supply connectors and the same pinout as the original.
- Have the same form factor (shape, size, and switch location).
- Have the same or higher wattage rating; a higher wattage rating is highly desirable.

- Support any special features required by your CPU, video card, and motherboard, such as SLI support (support for PCI Express 6-pin connectors to power dual high-performance PCI Express x16 video cards), high levels of +12V power, and so on.

TIP To assure form factor connector compatibility, consider removing the old power supply and taking it with you if you plan to buy a replacement at retail. If you are buying a replacement online, measure the dimensions of your existing power supply to assure that a new one will fit properly in the system.

Removing and Replacing the Power Supply

If you have done your homework (checked compatibility and size and dug up the case-opening instructions for your PC), installing a new power supply is one of the easier repairs to make. You don't need to fiddle with driver CDs or Windows Update to get the new one working. But, you do need to be fairly handy with a screwdriver or nut driver.

Typical power supplies are held in place by several screws that attach the power supply to the rear panel of the computer. The power supply also is supported by a shelf inside the case, and screws can secure the power supply to that shelf. To remove a power supply, follow these steps:

Step 1. Shut down the computer. If the power supply has an on-off switch, turn it off as well.

Step 2. Disconnect the AC power cord from the computer.

Step 3. Open the case to expose the power supply, which might be as simple as removing the cover on a desktop unit, or as involved as removing both side panels, front bezel, and case lid on a tower PC. Consult the documentation that came with your computer to determine how to expose the power supply for removal.

Step 4. Disconnect the power supply from the motherboard (refer to Figure 5-7). The catch securing the power supply connector must be released to permit the connector to be removed.

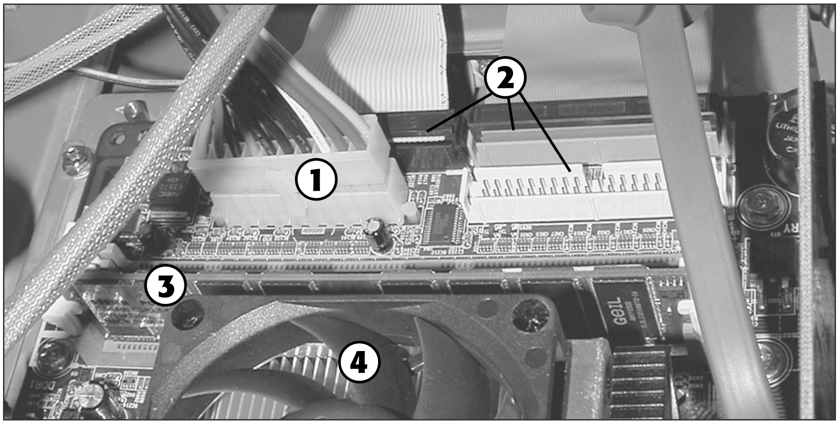
Step 5. Disconnect the power supply from all drives.

Step 6. Disconnect the power supply from the case and CPU fans.

Step 7. Remove the power supply screws from the rear of the computer case (see Figure 5-8).

Step 8. Remove any screws holding the power supply in place inside the case. (Your PC might not use these additional screws.)

Step 9. Disconnect the power supply switch from the case front (if present).



1. Catch securing power supply connector
2. PATA/IDE drive connectors
3. Memory module
4. Active heat sink for processor

Figure 5-7 Disconnecting the power supply from the motherboard.

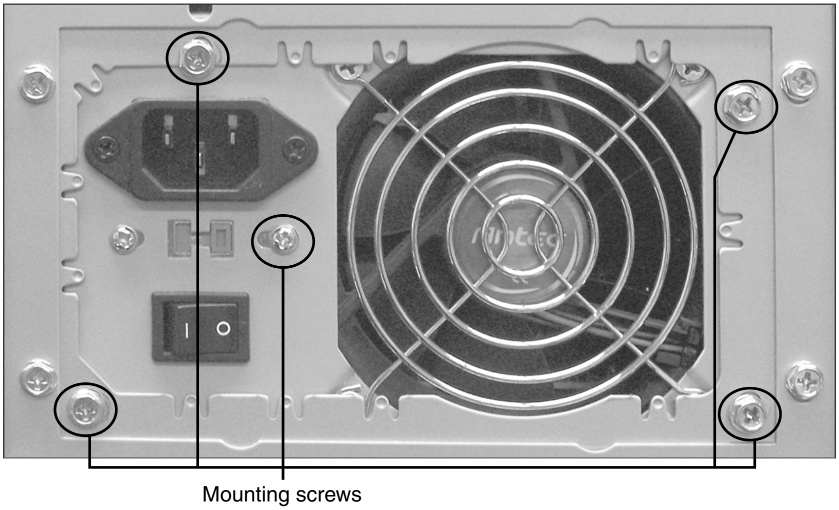


Figure 5-8 Removing the mounting screws from a typical power supply.

Step 10. Lift or slide the power supply from the case.

Before installing the replacement power supply, compare it to the original, making sure the form factor, motherboard power connectors, and switch position match the original.

To install the replacement power supply, follow these steps:

Step 1. Lower the power supply into the case.

Step 2. Attach the power supply to the shelf with screws if required.

Step 3. Attach the power supply to the rear of the computer case; line up the holes in the unit carefully with the holes in the outside of the case.

Step 4. Connect the power supply to the case, CPU fans, drives, and motherboard. Note that some power supplies provide a two-wire cable for use by motherboards that can monitor the power supply fan speed. Be sure to connect this cable as well as the main power cable and additional power cables as required.

Step 5. Check the voltage setting on the power supply. Change it to the correct voltage for your location.

Step 6. Attach the AC power cord to the new power supply.

Step 7. Turn on the computer.

Step 8. Boot the system normally to verify correct operation, and then run the normal shutdown procedure for the operating systems. If necessary, turn off the system with the front power switch only.

Step 9. Close the case and secure it.

Testing Power Supplies with a Multimeter

How can you find out that a defective power supply is really defective? How can you make sure that a cable has the right pinouts? Use a multimeter. A *multimeter* is one of the most flexible diagnostic tools around. It is covered in this chapter because of its usefulness in testing power supplies, but it also can be used to test coaxial, serial, and parallel cables, as well as fuses, resistors, and batteries.

Multimeters are designed to perform many different types of electrical tests, including the following:

- DC voltage and polarity
- AC voltage and polarity
- Resistance (Ohms)
- Diodes
- Continuity
- Amperage

All multimeters are equipped with red and black test leads. When used for voltage tests, the red is attached to the power source to be measured, and the black is attached to ground.

Multimeters use two different readout styles: digital and analog. Digital multimeters are usually *autoranging*, which means they automatically adjust to the correct range for the test selected and the voltage present. Analog multimeters, or non–autoranging digital meters, must be set manually to the correct range and can be damaged more easily by overvoltage. Figure 5-9 compares typical analog and digital multimeters.

Figure 5-9 Typical analog (left) and digital (right) multimeters. Photos courtesy of Colacino Electric Supply (www.colacinoelectric.com/).

Multimeters are designed to perform tests in two ways: in series and in parallel. Most tests are performed in parallel mode, in which the multimeter is not part of the circuit but runs parallel to it. On the other hand, amperage tests require that the multimeter be part of the circuit, so these tests are performed in series mode. Many low-cost multimeters do not include the ammeter feature for testing amperage (current), but you might be able to add it as an option.

Figure 5-10 shows a typical parallel mode test (DC voltage for a motherboard CMOS battery) and the current (amperage) test, which is a serial-mode test.

Table 5-3 summarizes the tests you can perform with a multimeter.

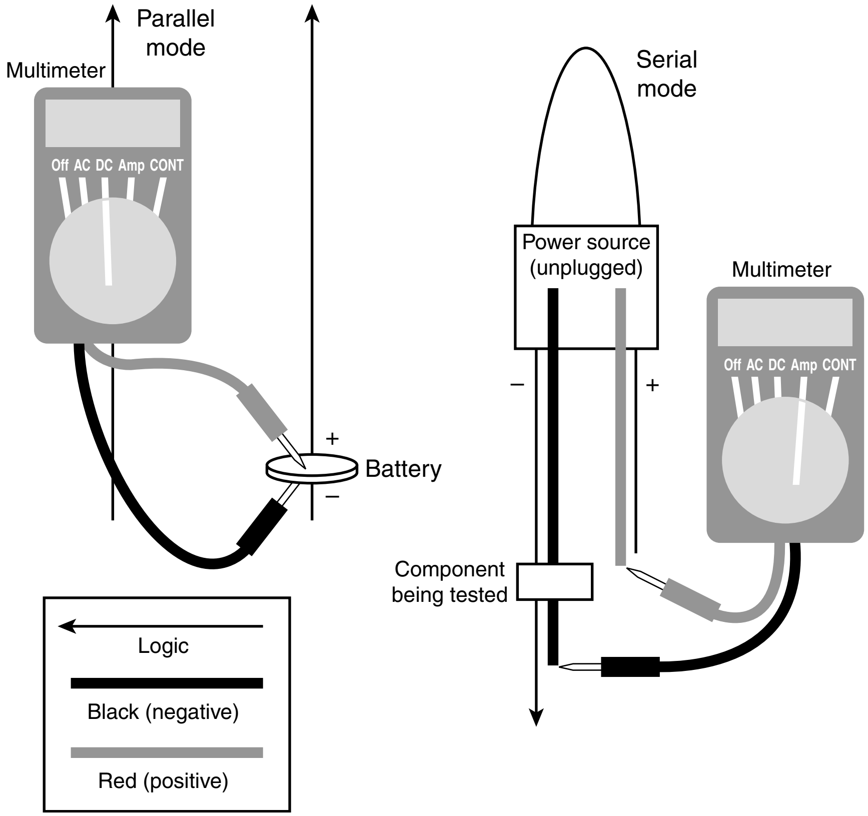


Figure 5-10 A parallel-mode (DC current) test setup (left) and an amperage (current) serial-mode test setup (right).

The following section covers the procedure for using a multimeter to diagnose a defective power supply.

Determining Power Supply DC Voltage Levels

You can use a multimeter to find out if a power supply is properly converting AC power to DC power. Here's how: Measure the DC power going from the power supply to the motherboard. A power supply that does not meet the measurement standards listed in Table 5-4 should be replaced.

You can take the voltage measurements directly from the power supply connection to the motherboard. Both 20-pin and 24-pin power connectors are designed to be back-probed as shown in Figure 5-11; you can run the red probe through the top of the power connector to take a reading (the black probe uses the power supply enclosure or metal case frame for ground).

Key Topic

Table 5-3 Using a Multimeter

Test to Perform	Multimeter Setting	Probe Positions	Procedure
AC voltage (wall outlet)	AC	Red to hot, black to ground.	Read voltage from meter; should be near 115V in North America
DC voltage (power supply outputs to motherboard, drives, batteries)	DC	Red to hot, black to ground (see next section for details).	Read voltage from meter; compare to default values
Continuity (cables, fuses)	CONT	Red to lead at one end of cable; black to corresponding lead at other end. For a straight-through cable, check the same pin at each end. For other types of cables, consult a cable pinout to select the correct leads.	No CONT signal indicates bad cable or bad fuse Double-check leads and retest to be sure
Resistance (Ohms)	Ohms	Connect one lead to each end of resistor.	Check reading; compare to rating for resistor A fuse should have no resistance
Amperage (Ammeter)	Ammeter	Red probe to positive lead of circuit (power disconnected!); black lead to negative lead running through component to be tested.	Check reading; compare to rating for component tested

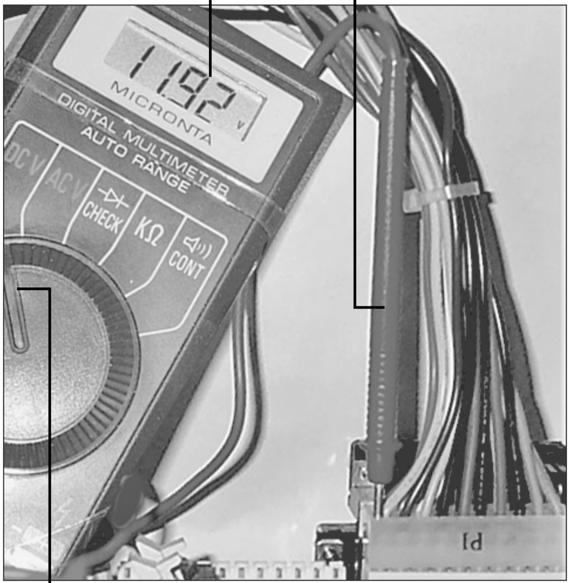
Key Topic

Table 5-4 Acceptable Voltage Levels

Rated DC Volts	***Acceptable Range***
+5.0	+4.8–5.2
–5.0	–4.8–5.2
–12.0	–11.4–12.6
+12.0	+11.4–12.6
+3.3	+3.14–3.5
Power Good	+3.0–6.0

Red probe from multimeter back-probing +12V line

DC voltage readout



Multimeter's mode selector switch set to DV voltage

Figure 5-11 Testing the +12V line on an ATX power supply. The voltage level indicated (+11.92V) is well within limits.

The multimeter also can be used to check the Power Good or Power OK line by pushing the red lead through the open top of the power connector. See Table 5-4 for the acceptable voltage levels for each item.

If a power supply fails any of these measurements, replace it and retest the new unit.

Avoiding Power Supply Hazards

To avoid shock and fire hazards when working with power supplies, follow these important guidelines:

- **Never disassemble a power supply or push metal tools through the openings in the case—** Long after you shut off the system, the wire coils inside the power supply retain potentially fatal voltage levels. If you want to see the interior of a power supply safely, check the websites of leading power supply vendors such as PC Power and Cooling.
- **If you are replacing the power supply in a Dell desktop computer, determine whether the computer uses a standard ATX or Dell proprietary ATX power supply—** Many Dell computers built from September 1998 to the present use a nonstandard version of the ATX power supply with a different pinout for the

power connector. Install a standard power supply on a system built to use a Dell proprietary model, or upgrade from a Dell motherboard that uses the Dell proprietary ATX design to a standard motherboard, and you can literally cause a power supply and system fire!

The proprietary Dell version of the 20-pin ATX connector has no 3.3V (orange) lines, and its Power Good (gray wire) line is pin 5, not pin 8 as with a standard ATX power supply. The 3.3V (orange) wires are routed to the 6-pin Dell proprietary auxiliary connector. The proprietary Dell version of the 24-pin ATX connector also uses pin 5 for Power Good, and provides 3.3V power (blue/white) through pins 11, 12, and 23, rather than through 1, 2, 12, and 13 as with a standard 24-pin ATX power supply. Make sure you buy a power supply made specifically for your Dell model.

- **Always use a properly wired and grounded outlet for your computer and its peripherals—** You can use a plug-in wiring tester to quickly determine if a three-prong outlet is properly wired; signal lights on the tester indicate the outlet's status (see Figure 5-12).

Power Protection Types

How well can a power supply work if it has poor-quality AC power to work with? Answer**.** Not very well.

Because computers and many popular computer peripherals run on DC power that has been converted from AC power, it's essential to make sure that proper levels of AC power flow to the computer and its peripherals. There are four problems you might run into:

- Overvoltages (spikes and surges)
- Undervoltages (brownouts)
- Power failure (blackouts)
- Noisy power (interference)

Extremely high levels of transient or sustained overvoltages can damage the power supply of the computer and peripherals, and voltage that is significantly lower than required will cause the computer and peripherals to shut down. Shutdowns happen immediately when all power fails. A fourth problem with power is interference; "noisy" electrical power can cause subtle damage, and all four types of problems put the most valuable property of any computer, the data stored on the computer, at risk. Protect your computer's power supply and other components with appropriate devices:

- Surge suppressors, which are also referred to as surge protectors
- Battery backup systems, which are also referred to as UPS or SPS systems
- Power conditioning devices

Key Topic

Figure 5-12 An outlet tester like this one can find wiring problems quickly. This outlet is wired correctly.

Surge Suppressors

Stop that surge! While properly designed surge suppressors can prevent power surges (chronic overvoltage) and spikes (brief extremely high voltage) from damaging your computer, low-cost ones are often useless because they lack sufficient components to absorb dangerous surges. Surge suppressors range in price from under $10 to close to $100 per unit.

Both spikes and surges are overvoltages: voltage levels higher than the normal voltage levels that come out of the wall socket. *Spikes* are momentary overvoltages, whereas *surges* last longer. Both can damage or destroy equipment and can come through data lines (such as RJ-11 phone or RJ-45 network cables) as well as through power lines. In other words, if you think of your PC as a house, spikes and surges can come in through the back door or the garage as well as through the front door. Better "lock" (protect) all the doors. Many vendors sell data-line surge suppressors.

How can you tell the real surge suppressors from the phonies? Check for a TVSS (transient voltage surge suppressor) rating on the unit. Multi-outlet power strips do not have a TVSS rating.

Beyond the TVSS rating, look for the following features to be useful in preventing power problems:

Key Topic

- A low TVSS let-through voltage level (400V AC or less). This might seem high compared to the 115V standard, but power supplies have been tested to handle up to 800V AC themselves without damage.
- A covered-equipment warranty that includes lightning strikes (one of the biggest causes of surges and spikes).
- A high Joule rating. Joules measure electrical energy, and surge suppressors with higher Joule ratings can dissipate greater levels of surges or spikes.
- Fusing that will prevent fatal surges from getting through.
- Protection for data cables such as telephone/fax (RJ-11), network (RJ-45), or coaxial (RG6).
- EMI/RFI noise filtration (a form of line conditioning).
- Site fault wiring indicator (no ground, reversed polarity warnings).
- Fast response time to surges. If the surge suppressor doesn't clamp fast enough, the surge can get through.
- Protection against surges on hot, neutral, and ground lines.

If you use surge protectors with these features, you will minimize power problems. The site-fault wiring indicator will alert you to wiring problems that can negate grounding and can cause serious damage in ordinary use.

A surge suppressor that meets the UL 1449 or ANSI/IEEE C62.41 Category A (formerly IEEE 587 Category A) standards provides protection for your equipment. You might need to check with the vendor to determine if a particular unit meets one of these standards.

NOTE To learn more about UL 1449 and the other UL standards it incorporates, see ulstandardsinfonet.ul.com/scopes/scopes.asp?fn=1449.html.

In preparing for the A+ Certification exam, you should pay particular attention to the UL standard for surge suppressors and the major protection features just listed.

CAUTION If you're looking for a way to negate the protection provided by high-quality surge protectors, plug them into an ungrounded electrical outlet. You'll still find them in older homes and buildings.

The two- to three-prong adapter you use to make grounded equipment plug into an ungrounded outlet is designed to be attached to a ground such as a metal water pipe (that's what the metal loop is for). If you can't ground the adapter, don't use a computer or other electronic device with it. If you do, sooner or later you'll be sorry.

Battery Backup Units (UPS and SPS)

A UPS (uninterruptible power supply) is another name for a battery backup unit. A UPS provides emergency power when a power failure strikes (a blackout) or when power falls below minimum levels (a brownout).

There are two different types of UPS systems: true UPS and SPS systems. A true UPS runs your computer from its battery at all times, isolating the computer and monitor from AC power. There is no switchover time with a true UPS when AC power fails because the battery is already running the computer. A true UPS inherently provides power conditioning (preventing spikes, surges, and brownouts from reaching the computer) because the computer receives only battery power, not the AC power coming from the wall outlet. True UPS units are sometimes referred to as line-interactive battery backup units because the battery backup unit interacts with the AC line, rather than the AC line going directly to the computer and other components.

An SPS (standby power supply) is also referred to as a UPS, but its design is quite different. Its battery is used only when AC power fails. A momentary gap in power (about 1ms or less) occurs between the loss of AC power and the start of standby battery power; however, this switchover time is far faster than is required to avoid system shutdown because computers can coast for several milliseconds before shutting down. SPS-type battery backup units are far less expensive than true UPSs, but work just as well as true UPSs when properly equipped with power-conditioning features.

NOTE In the rest of this section, the term *UPS* refers to both true UPS or SPS units except as noted, because most backup units on the market technically are SPS but are called UPS units by their vendors.

Make sure you understand the differences between these units for the exam.

Battery backup units can be distinguished from each other by differences in the following:

- **Run times—** The amount of time a computer will keep running on power from the UPS. A longer runtime unit uses a bigger battery and usually will cost more than a unit with a shorter run time. Fifteen minutes is a minimum recommendation for a UPS for an individual workstation; much larger systems are recommended for servers that might need to complete a lengthy shutdown procedure.
- **Network support—** Battery backup units made for use on networks are shipped with software that broadcasts a message to users about a server shutdown so that users can save open files and close open applications and then shuts down the server automatically before the battery runs down.
- **Automatic shutdown—** Some low-cost UPS units lack this feature, but it is essential for servers or other unattended units. The automatic shutdown feature requires an available USB (or RS-232 serial) port and appropriate software from the UPS maker. If you change operating systems, you will need to update the software for your UPS to be supported by the new operating system.
- **Surge suppression features—** Virtually all UPS units today have integrated surge suppression, but the efficiency of integrated surge suppression can vary as much as separate units. Look for UL-1449 and IEEE-587 Category A ratings to find reliable surge suppression in UPS units.

Figure 5-13 illustrates the rear of a typical UPS unit.

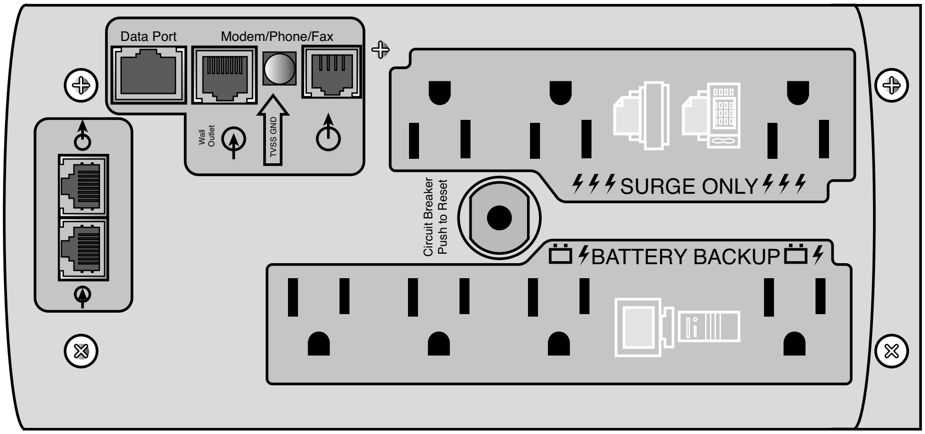


Figure 5-13 A typical UPS with integrated surge suppression for printers and other AC powered devices, 10/100 Ethernet (including VoIP), and conventional telephony devices.

NOTE Always plug a UPS directly into a wall outlet, not into a power strip or surge suppressor.

Buying the Correct-Sized Battery Backup System

Battery backups can't run forever. But then, they're not supposed to. This section describes how you can make sure you get enough time to save your files and shut down your computer.

UPS units are rated in VA (volt-amps), and their manufacturers have interactive buying guides you can use online or download to help you select a model with adequate capacity. If you use a UPS with an inadequate VA rating for your equipment, your runtime will be substantially shorter than it should be.

Here's how to do the math: You can calculate the correct VA rating for your equipment by adding up the wattage ratings of your computer and monitor and multiplying the result by 1.4. If your equipment is rated in amperage (amps), multiply the amp rating by 120 (volts) to get the VA rating.

For example, my computer has a 450W power supply, which would require a 630VA-rated UPS (450×1.4) and a 17-inch monitor that is rated in amps, not watts. The monitor draws 0.9A, which would require a 108VA-rated UPS (0.9×120). Add the VA ratings together, and my computer needs a 750VA-rated battery backup unit or larger. Specifying a UPS with a VA rating at least twice what is required by the equipment attached to the UPS (for example, a 1500VA or higher rating, based on a minimum requirement of 750VA) will greatly improve the runtime of the battery.

In this example, a typical 750VA battery backup unit would provide about five minutes of runtime when used with my equipment. However, if I used a 1500VA battery backup, I could increase my runtime to more than 15 minutes because my equipment would use only about half the rated capacity of the UPS unit.

If you need a more precise calculation, for example, if you will also power an additional monitor or other external device, use the interactive sizing guides provided by battery backup vendors, such as American Power Conversion (www.apc.com).

CAUTION You should *not* attach laser printers to a UPS because their high current draw will cause the runtime of the battery to be very short. In most cases, only the computer and monitor need to be attached to the UPS. However, inkjet printers and external modems have low current draw and can be attached to the UPS with little reduction in runtime.

Power Conditioning Devices

Although power supplies are designed to work with voltages that do not exactly meet the 120V or 240V standards, power that is substantially higher or lower than what the computer is designed for can damage the system. Electrical noise on the power line, even with power at the correct voltage, also causes problems because it disrupts the correct sinewave alternating-current pattern the computer, monitor, and other devices are designed to use.

Better-quality surge protectors often provide power filtration to handle electromagnetic interference (EMI)/radio frequency interference (RFI) noise problems from laser printers and other devices that generate a lot of electrical interference. However, to deal with voltage that is too high or too low, you need a true power conditioner.

These units take substandard or overstandard power levels and adjust them to the correct range needed by your equipment. Some units also include high-quality surge protection features.

To determine whether you need a power-conditioning unit, you can contact your local electric utility company to see if it loans or rents power-monitoring devices. Alternatively, you can rent them from power consultants. These units track power level and quality over a set period of time (such as overnight or longer) and provide reports to help you see the overall quality of power on a given line.

Moving surge- and interference-causing devices such as microwaves, vacuum cleaners, refrigerators, freezers, and furnaces to circuits away from the computer circuits will help minimize power problems. However, in older buildings, or during times of peak demand, power conditioning might still be necessary. A true (line-interactive) UPS provides built-in power conditioning by its very nature (see the previous discussion).

Troubleshooting Power Problems

A dead system that gives no signs of life when turned on can be caused by the following:

- Defects in AC power to the system
- Power supply failure or misconfiguration
- Temporary short circuits in internal or external components
- Power supply or other component failure

With four suspects, it's time to play detective. Use the procedure outlined next to find the actual cause of a dead system. If one of the test procedures in the following list corrects the problem, the item that was changed is the cause of the problem. Power supplies have a built-in safety feature that shuts down the unit immediately in case of short circuit. The following steps are designed to determine whether the power problem is caused by a short circuit or another problem:

Step 1. Check the AC power to the system; a loose or disconnected power cord, a disconnected surge protector, a surge protector that has been turned off, or a dead AC wall socket will prevent a system from receiving power.

If the wall socket has no power, reset the circuit breaker in the electrical service box for the location.

Step 2. Check the AC voltage switch on the power supply; it should be set to 115V for North America. Turn off the power, reset the switch, and restart the system if the switch was set to 230V.

Step 3. Check the keyboard connector; a loose keyboard connector could cause a short circuit.

Step 4. Open the system and check for loose screws or other components such as loose slot covers, modem speakers, or other metal items that can cause a short circuit. Correct them and retest.

Step 5. Verify that the cable from the front-mounted power switch is properly connected to the motherboard.

Step 6. Check for fuses on the motherboard (mainly found in very old systems). Turn off the power, replace any blown fuse on the motherboard with a fuse of the correct rating, and retest. Never try to short-circuit or bypass fuses on the motherboard or anywhere else.

Step 7. Remove all expansion cards and disconnect power to all drives; restart the system and use a multimeter to test power to the motherboard and expansion slots per Table 5-4, earlier in this chapter.

Step 8. If the power tests within accepted limits with all peripherals disconnected, reinstall one card at a time and check the power. If the power tests within accepted limits, reattach one drive at a time and check the power.

Step 9. If a defective card or drive has a dead short, reattaching the defective card or drive should stop the system immediately upon power-up. Replace the card or drive and retest.

Step 10. Test the Power Good line at the power supply motherboard connector with a multimeter.

It's a long list, but chances are you will track down the offending component before you reach the end of it.

System Cooling

Today's computers often run much hotter than systems of a few years ago, so it's important to understand how to keep the hottest-running components running cooler. The following sections discuss the components that are most in need of cooling and how to cool them.

Passive and Active Heat Sinks

All processors require a heat sink. A heat sink is a finned metal device that radiates heat away from the processor. In almost all cases, an *active heat sink* (a heat sink with a fan) is required for adequate cooling, unless the system case (chassis) is specially designed to move air directly over the processor and a passive heat sink.

Although aluminum has been the most common material used for heat sinks, copper has better thermal transfer properties, and many designs mix copper and aluminum components. Traditional active heat sinks include a cooling fan that rests on top of the heat sink and pulls air past the heat sink in a vertical direction. However, many aftermarket heat sinks use a horizontally mounted cooling fan and heat pipes to cool the process. Figure 5-14 compares typical examples of passive and active processor heat sinks used in ATX chassis.

Key Topic

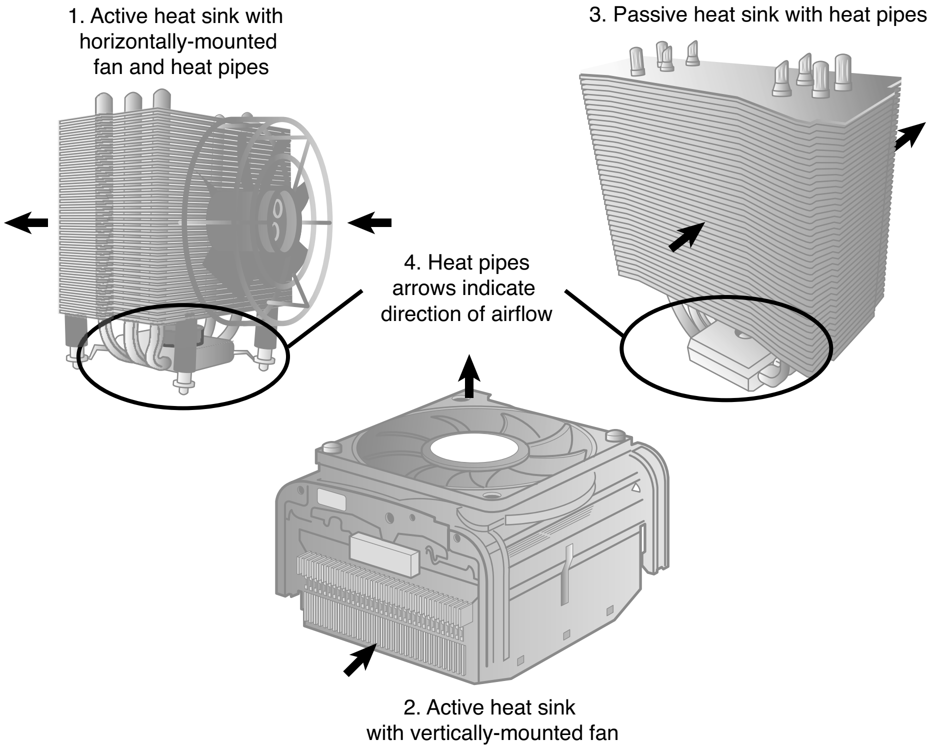


Figure 5-14 Active and passive processor heat sinks. Note that the passive heat sink has more fins than the active heat sinks to enable it to provide adequate cooling.

BTX chassis use a different approach to processor cooling. These chassis use a thermal duct that fits over the processor and its heat sink. A cooling fan at one end of the duct directs air past the processor. Figure 5-15 illustrates this type of processor cooler.

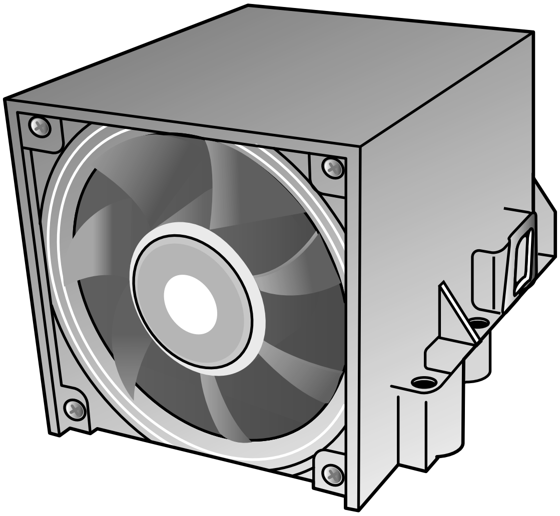


Figure 5-15 A typical BTX thermal duct.

Processor fans typically plug into a specially marked three-prong jack on the motherboard that provides power and fan speed monitoring capabilities (see Figure 5-16).

North/Southbridge Cooling

Most motherboards use a two-chip chipset to route data to and from the processor. The northbridge or Memory Controller Hub (MCH) chip, because it carries high-speed data such as memory and video to and from the processor, becomes hot during operation, and, if the component overheats and is damaged, the entire motherboard must be replaced. For this reason, most motherboards feature some type of cooler for the northbridge chip.

Although the southbridge or I/O Controller Hub (ICH) chip carries lower-speed traffic, such as hard disk, audio, and network traffic, it can also become overheated. As a result, most recent motherboards also feature cooling for the southbridge chip. Some chipsets combine both functions into a single chip, which also requires cooling.

Three methods have been used for cooling the motherboard chipset. Passive heat sinks are inexpensive, but do not provide sufficient cooling for high-performance systems. Active heat sinks provide better cooling than passive heat sinks, but low-quality sleeve-bearing fans can cause premature fan failure and lead to overheating. The latest trend in chipset cooling uses heat pipes, which draw heat away from the chipset and dissipates it through high-performance, very large passive heat sinks located away from the chipset itself.

Figure 5-17 illustrates passive and active heat sinks for north and southbridge chips.

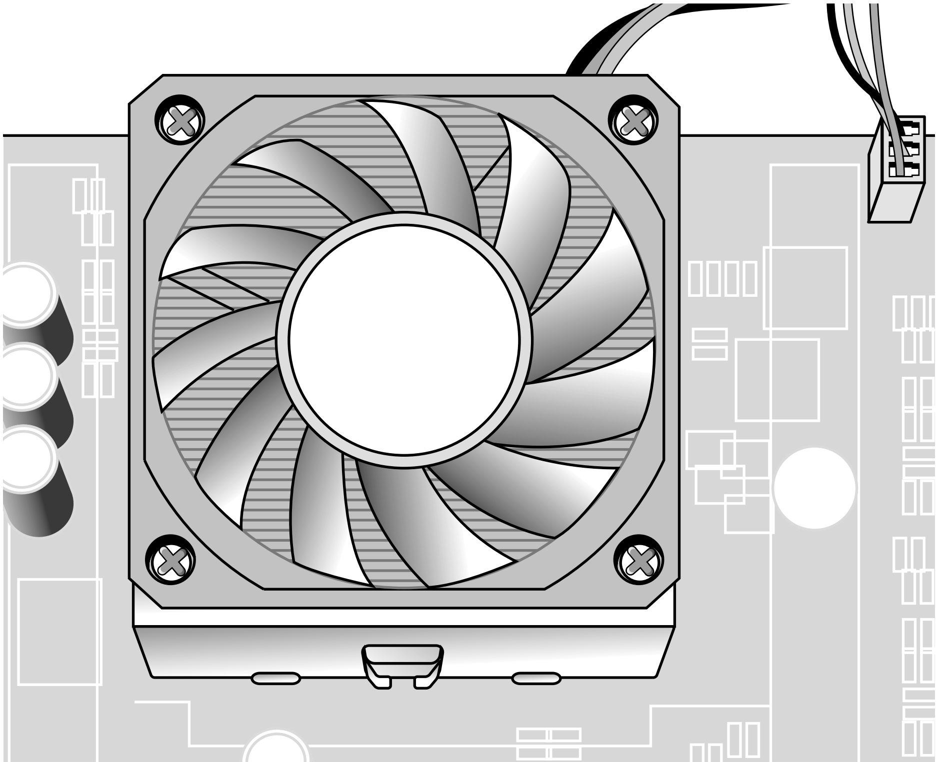


Figure 5-16 A typical processor active heat sink plugged into the motherboard.

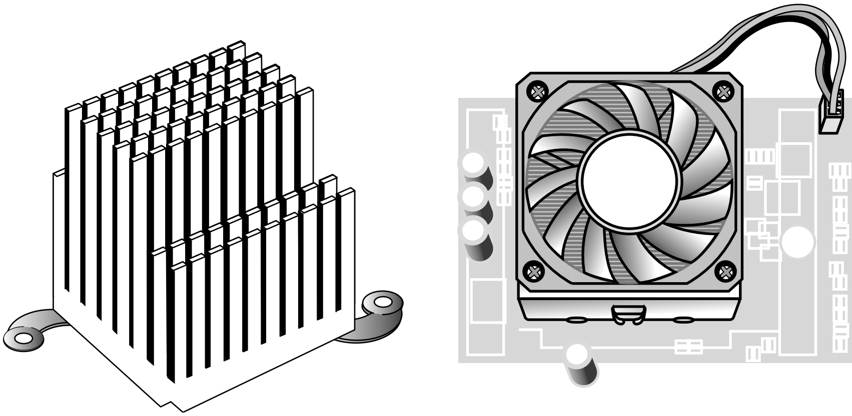


Figure 5-17 Passive and active heat sinks for chipsets.

Figure 5-18 illustrates a motherboard that uses heat pipes for chipset cooling.

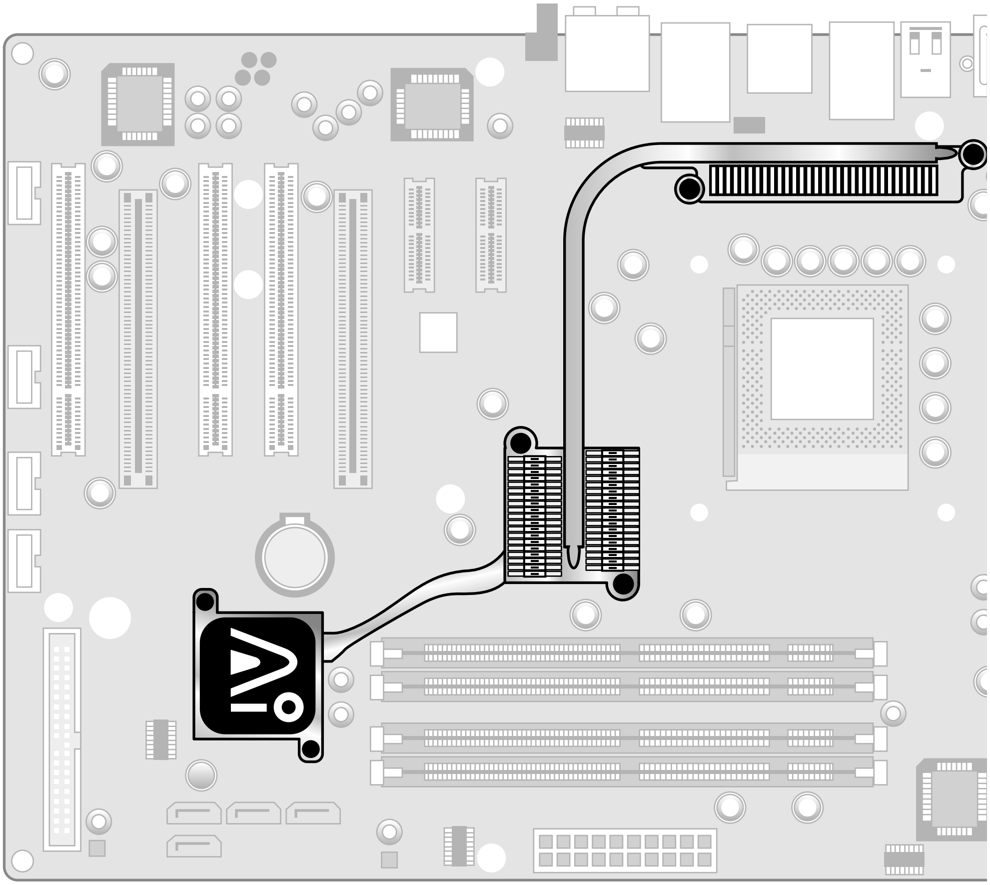


Figure 5-18 Motherboard with heat pipe cooling for the chipset.

The following sections discuss the role that video card cooling, case fans, thermal compound for heat sinks, and liquid cooling systems have in system cooling.

Video Card Cooling

Another major heat source in modern systems is the video card's graphics processing unit (GPU) chip, which renders the desktop, graphics, and everything else you see on your computer screen. With the exception of a few low-end video cards, almost all video cards use active heat sinks to blow hot air away from the GPU.

However, the memory chips on a video card can also become very hot. To cool both the GPU and video memory, most recent mid-range and high-end video card designs use a fan shroud to cool both components. Fan shrouds often require enough space to prevent the expansion slot next to the video card from being used.

Figure 5-19 illustrates a typical video card with a two-slot fan shroud.

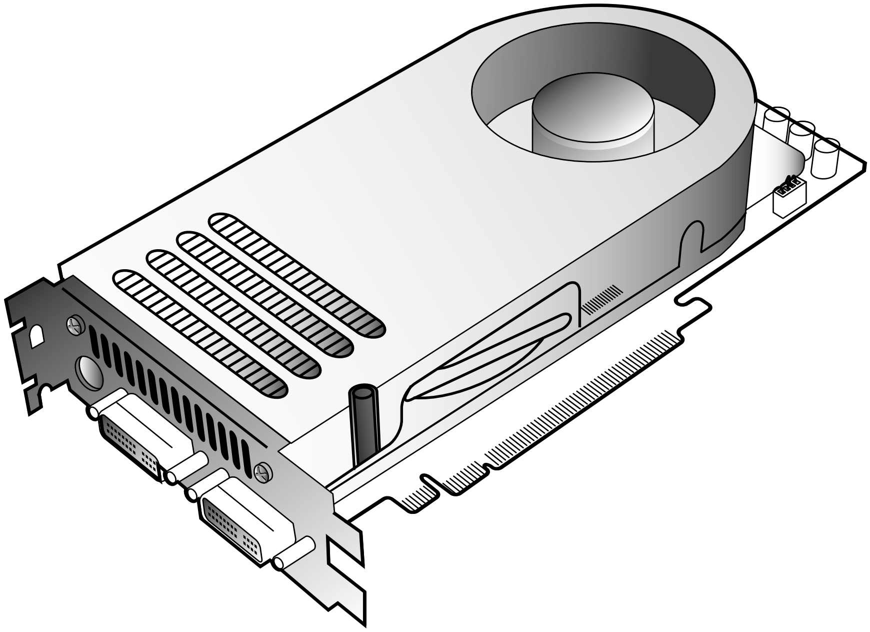


Figure 5-19 The GeForce 8800 GTS is a high-performance PCI Express x16 video card that requires a two-slot fan shroud.

Case Fans

Most ATX chassis have provisions for at least two case fans: one at the front of the system, and one at the rear of the system. Case fans can be powered by the motherboard or by using a Y-splitter connected to a four-pin Molex power connector. Case fans at the front of the system should draw air into the system, while case fans at the rear of the system should draw air out of the system.

Figure 5.20 shows a typical rear case fan. You can plug fans like this into the three-prong chassis fan connection found on many recent motherboards or into the 4-pin Molex drive power connector used by hard drives. If the motherboard power connector is used, the PC Health or hardware monitor function found in many recent system BIOS setup programs can monitor fan speed. See Chapter 4, "BIOS," for a typical example.

NOTE Some case fans that can be powered by a Molex power connector include a special power cable that permits the fan speed to be monitored by the motherboard, even though the motherboard is not used to power the fan.

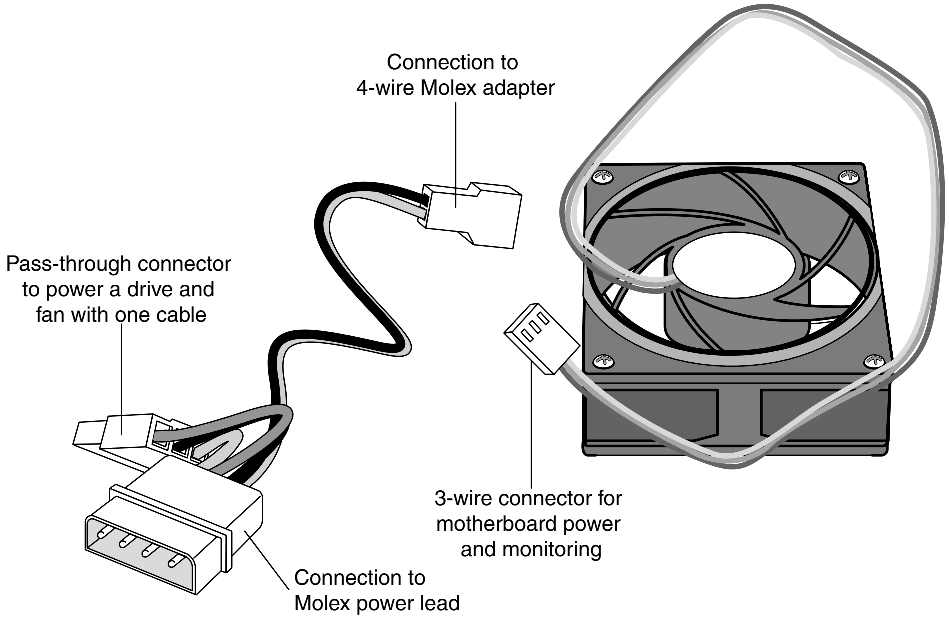


Figure 5-20 A rear case fan that can be plugged into the motherboard or into a Molex power connector.

Rear case fans are available in various sizes up to 120mm. The fan shown in Figure 5-20 is an 80mm model; measure the opening at the rear of the case to determine which fan size to purchase. Some recent systems, such as the one shown in Figure 5-21, might feature two rear fans. The system shown in Figure 5-21 also has a video card that uses a two-slot fan shroud.

Case fans as well as processor fans and other fans that are connected to the motherboard can be monitored by the hardware monitor display in the system BIOS as shown in Figure 5-22 or by system monitoring software running after system startup. If a case fan fails or runs too slowly, it can cause the system to overheat.

Thermal Compound

When passive or active heat sinks are installed on a processor, north or southbridge chip, GPU or other component, thermal compound (also known as thermal transfer material, thermal grease, or phase change material) must be used to provide the best possible thermal transfer between the component and the heat sink.

Heat sinks supplied with boxed processors might use a preapplied phase-change material on the heat sink, whereas OEM processors with third-party heat sinks usually require the installer to use a paste or thick liquid thermal grease or silver-based compound. Coolers for northbridge or southbridge chips might use thermal grease or a phase-change pad.

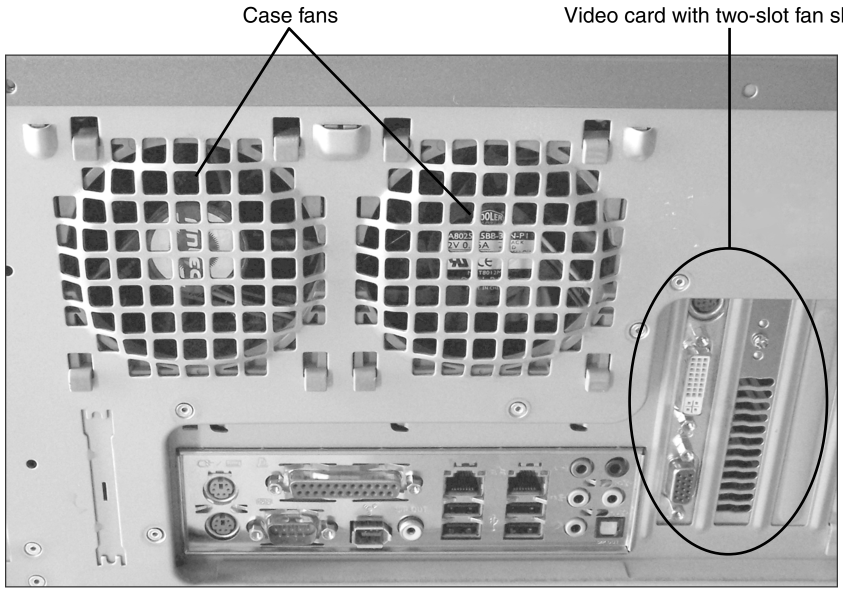


Figure 5-21 A system with two rear case fans.

Key Topic

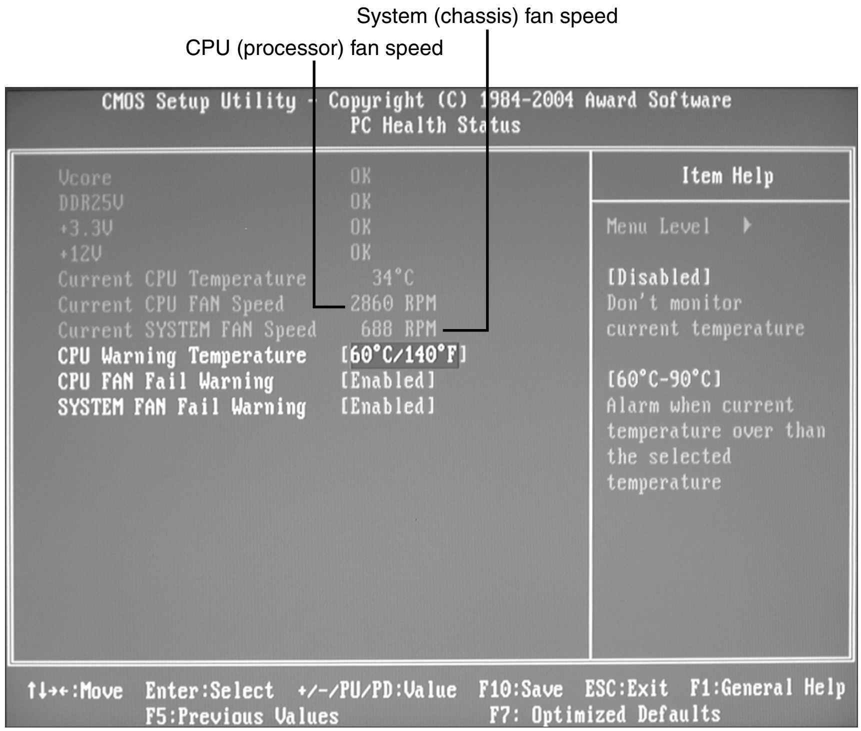


Figure 5-22 The PC Health (system monitor) dialog in a typical system BIOS.

If the thermal material is preapplied to the heat sink, make sure you remove the protective tape before you install the heat sink. If a third-party heat sink is used, or if the original heat sink is removed and reinstalled, carefully remove any existing thermal transfer material from the heat sink and processor die surface. Then, apply new thermal transfer material to the processor die before you reinstall the heat sink on the processor.

Figure 5-23 illustrates the application of thermal compound to a northbridge chip before attaching a heat sink.

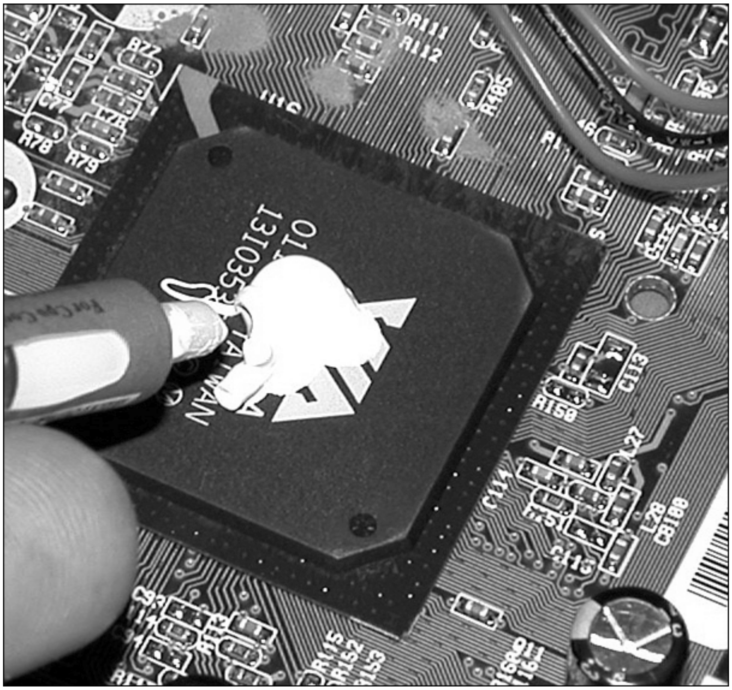


Figure 5-23 Applying thermal grease to the Northbridge chip.

CAUTION Never operate a system before attaching the heat sink to the processor with the appropriate thermal transfer material. The processor could be destroyed by overheating in just a few moments. Most recent systems have thermal safeguards that shut down the system in the event of processor overheating, but if these safeguards fail, there could also be damage to the processor.

Liquid Cooling Systems

Liquid cooling systems for processors, motherboard chipsets, and GPUs are now available. Some are integrated into a custom case, whereas others can be retrofitted into an existing system that has openings for cooling fans.

Liquid cooling systems attach a liquid cooling unit instead of an active heat sink to the processor and other supported components. A pump moves the liquid (which might be water or a special solution, depending upon the cooling system) through the computer to a heat exchanger, which uses a fan to cool the warm liquid before it is sent back to the processor. Liquid cooling systems are designed primarily for very high-performance systems, especially overclocked systems. It's essential that only approved cooling liquids and hoses be used in these systems (check with cooling system vendors for details); unauthorized types of liquids or hoses could leak and corrode system components.

Figure 5-24 illustrates a typical liquid cooling system for cooling the processor.

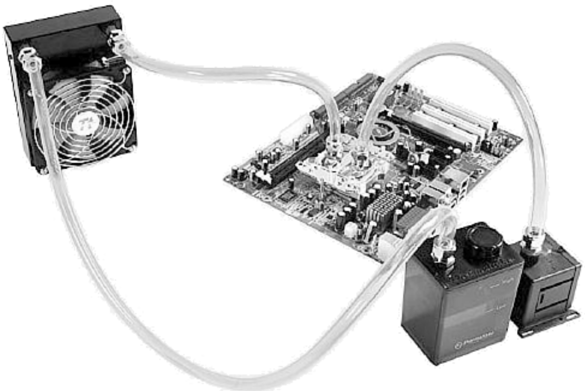


Figure 5-24 A typical liquid cooling system.

Exam Preparation Tasks

Review All the Key Topics

Review the most important topics in the chapter, noted with the key topics icon in the outer margin of the page. Table 5-5 lists a reference of these key topics and the page numbers on which each is found.

Table 5-5 Key Topics for Chapter 5

Key Topic Element	Description	Page Number
Figure 5-2	A typical power supply label.	162
Figure 5-3	A typical power supply's sliding voltage switch set for North American voltage (115V).	164
Figure 5-4	Typical power supply connectors to the motherboard.	169
Figure 5-6	Typical peripheral power connectors.	171
Table 5-3	Using a Multimeter.	177
Figure 5-11 and Table 5-4	Testing the +12V line on an ATX power supply, and acceptable voltage levels.	177-178
Figure 5-12	An outlet tester can find wiring problems quickly.	180
List	This list of features are useful in preventing power problems.	185-186
Figure 5-14	Active and passive processor heat sinks.	187
Figure 5-22	The PC Health (system monitor) dialog in a typical system BIOS.	193

Definitions of Key Terms

Define the following key terms from this chapter, and check your answers in the glossary.

AC

DC

Power Supply

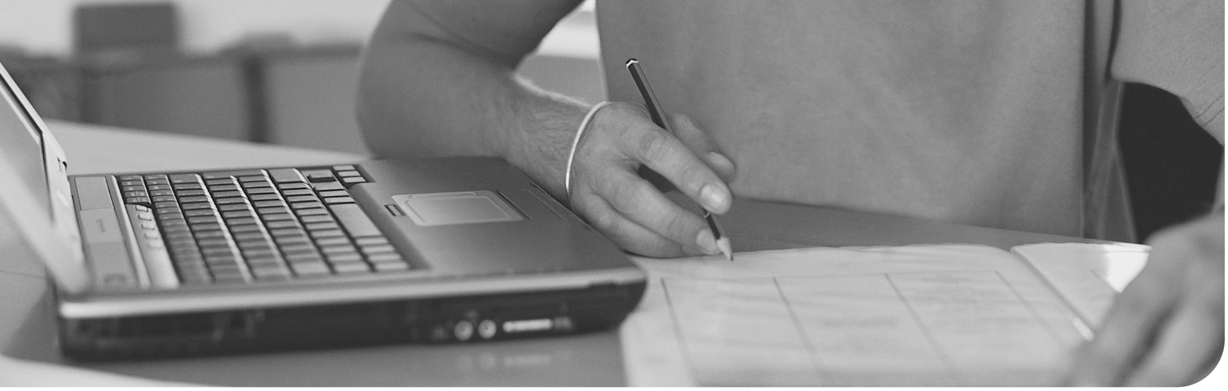
Surge Protector

UPS

Troubleshooting Scenario

You are working on a computer that is overheating. What steps should you take to make sure the power supply is not being overloaded?

Refer to Appendix A, "Answers to the 'Do I Know This Already?' Quizzes and Troubleshooting Scenarios," for the answer.



This chapter covers the following subjects:

- **RAM Basics—** This section talks about what RAM does, how it works, and how it relates to the rest of the computer system.
- **RAM Types—** In this section you learn about the various types of RAM available, including SDRAM, DDR, and Rambus. Their architecture, capacity, and speed will also be described.
- **Operational Characteristics—** This section describes the features of memory modules and types of memory like ECC, EDO, registered, and unbuffered.
- **Installing Memory Modules—** This section demonstrates how to install SIMMs and DIMMs properly.
- **Troubleshooting Memory—** This section covers some issues you might encounter with RAM due to incompatible memory speeds and types.
- **Preventative Maintenance for Memory—** Due to the possibility of memory overheating, this section describes some measures you can take to keep your memory modules clean and protected.

This chapter covers a portion of the CompTIA A+ 220-701 objectives 1.2 and 1.6 and CompTIA A+ 220-702 objectives 1.1 and 1.2