CHAPTER 21

Power Supply and Chassis/Case

Considering the Importance of the Power Supply

The power supply is not only one of the most important parts in a PC, but it is unfortunately also the most overlooked. In the words of a famous comedian, the power supply gets no respect! People spend hours discussing their processor speeds, memory capacity, disk storage capacity and speed, video adapter performance, monitor size, and so forth, but rarely even mention or consider their power supply. When a system is put together to meet the lowest possible price point, what component do you think the manufacturer will skimp on? Yes, the power supply. To most people, the power supply is a rather nondescript, unglamorous metal box that sits inside their systems, something to which they pay virtually no attention at all. The few who do pay any mind seem concerned only with how many watts of power it is rated to put out (even though no practical way exists to verify those ratings), without regard as to whether the power being produced is clean and stable, or whether it is full of noise, spikes, and surges.

I have always placed great emphasis on selecting a power supply for my systems. I consider the power supply the core of the system and am willing to spend more to get a better unit. The power supply function is critical because it supplies electrical power to every other component in the system. In my experience, the power supply is also one of the most failure-prone components in any computer system, especially due to the fact that so many system assemblers use the cheapest ones they can find. A malfunctioning power supply can not only cause other components in the system to malfunction, but it also can damage the other components in your computer by delivering an improper or erratic voltage. Because of its importance to proper and reliable system operation, you should understand both the function and limitations of a power supply, as well as its potential problems and their solutions.

This chapter covers the power supply in detail. I focus on the electrical functions of the supply and the mechanical form factors and physical designs that have been used in PC systems in the past, as well as today. Because the physical shape (form factor) of the power supply relates to the case, some of this information also relates to the type of chassis or case you have.

Primary Function and Operation

The basic function of the power supply is to convert the type of electrical power available at the wall socket to the type the computer circuitry can use. The power supply in a conventional desktop system is designed to convert either 115-volt (nominal) 60Hz AC (alternating current) or 230V (nominal) 50Hz AC power into +3.3V, +5V, and +12V DC (direct current) power. Some power supplies require you to switch between the two input ranges, whereas others auto-switch.

Positive DC Voltages

Usually, the digital electronic components and circuits in the system (motherboard, adapter cards, and disk drive logic boards) use the +3.3V or +5V power, and the motors (disk drive motors and any fans) use the +12V power. Table 21.1 lists these devices and their power consumptions.

Table 21.1 Power Consumption Ratings for PC Devices

Voltage	Devices Powered
+3.3V	Chipsets, DIMMs, PCI/AGP cards, miscellaneous chips
+5V	Disk drive logic, SIMMs, PCI/AGP cards, ISA cards, voltage regulators, miscellaneous chips
+12V	Motors, voltage regulators (high output)

The power supply must deliver a good, steady supply of DC power so that the system can operate properly. Devices that run on voltages other than these must be powered by onboard voltage regulators. For example, RIMMs run on 2.5V that is supplied by an onboard regulator, and processors are supplied by a voltage regulator module (VRM) that normally is built into the motherboard as well.

Note

When Intel began releasing processors that required a +3.3V power source, power supplies that supplied the additional output voltage were not yet available. As a result, motherboard manufacturers began adding voltage regulators to their boards, which converted +5V current to +3.3V for the processor. When other chips began using 3.3V as well, Intel created the ATX power supply specification, which supplied 3.3V to the motherboard. DIMMs (Dual In-line Memory Modules) also run on +3.3V as supplied by the power supply. You would think that having 3.3V direct from the power supply would have eliminated the need for onboard voltage regulators, but by that time, processors began running on a wide variety of voltages lower than 3.3V. Motherboard manufacturers then included adaptable regulator circuits called Voltage Regulator Modules (VRMs) to accommodate the widely varying processor voltage requirements.

◄◄ See "CPU Operating Voltages," p. 97.

Negative DC Voltages

If you look at a specification sheet for a typical PC power supply, you can see that the supply generates not only +3.3V, +5V, and +12V, but also –5V and –12V. The positive voltages seemingly power everything in the system (logic and motors), so what are the negative voltages used for? The answer is, not much! Some of the power supply designs, such as the SFX (Small form factor) design, no longer include the –5V output for that reason. The only reason it has remained in most power supply designs is that –5V is required on the Industry Standard Architecture (ISA) bus for full backward-compatibility.

Although –5V and –12V are supplied to the motherboard via the power supply connectors, the motherboard normally uses only the +3.3V, +5V, and +12V. The –5V is simply routed to the ISA bus on pin B5 so any ISA cards can use it. Today, though, not many do. However, as an example, the analog data separator circuits found in older floppy controllers do use –5V.

The motherboard logic normally doesn't use –12V either; however, it might be used in some board designs for serial port or LAN circuits.

Note

The load placed on the –12V output by an integrated LAN adapter is very small. For example, the integrated 10/100 Ethernet adapter in the Intel D815EEAL motherboard uses only 10mA of +12V and 10mA of –12V (0.01 amps each) to operate.

Although older serial port circuits used +/–12V outputs, today most run on only +3.3V or +5V.

The main function of the +12V power is to run disk drive motors as well as the higher-output processor voltage regulators in some of the newer boards. Usually, a large amount of +12V current is available from the power supply, especially in those designed for systems with a large number of drive bays (such as in a tower configuration). Besides disk drive motors and newer CPU voltage regulators, the +12V supply is used by any cooling fans in the system—which, of course, should always be running. A single cooling fan can draw between 100mA and 250mA (0.1–0.25 amps); however, most newer fans use the lower 100mA figure. Note that although most fans in desktop systems run on +12V, portable systems can use fans that run on +5V, or even +3.3V.

Most systems with newer motherboard form factors, such as the ATX, micro-ATX, or NLX, include another special signal. This feature, called PS_ON, can be used to turn the power supply (and thus the system) on or off via software. It is sometimes known as the *soft-power feature*. PS_ON is most evident when you use it with an operating system, such as Windows 9x, that supports the Advanced Power Management (APM) or Advanced Configuration and Power Interface (ACPI) specification. When you select the Shut Down the Computer option from the Start menu, Windows automatically turns off the computer after it completes the OS shutdown sequence. A system without this feature only displays a message that it's safe to shut down the computer.

The Power_Good Signal

In addition to supplying electrical power to run the system, the power supply also ensures that the system does not run unless the power supplied is sufficient to operate the system properly. In other words, the power supply actually prevents the computer from starting up or operating until all the power supply voltages are within the proper ranges.

The power supply completes internal checks and tests before allowing the system to start. If the tests are successful, the power supply sends a special signal to the motherboard, called Power_Good. This signal must be continuously present for the system to run. Therefore, when the AC voltage dips and the power supply cannot maintain outputs within regulation tolerance, the Power_Good signal is withdrawn (goes low) and forces the system to reset. The system will not restart until the Power_Good signal returns.

The Power_Good signal (sometimes called Power_OK or PWR_OK) is a +5V (nominal) active high signal (with variation from +2.4V through +6.0V generally being considered acceptable) that is supplied to the motherboard when the power supply has passed its internal self tests and the output voltages have stabilized. This normally takes place anywhere from 100ms to 500ms (0.1–0.5 seconds) after you turn on the power supply switch. The power supply then sends the Power_Good signal to the motherboard, where the processor timer chip that controls the reset line to the processor receives it.

In the absence of Power_Good, the timer chip holds the reset line on the processor, which prevents the system from running under bad or unstable power conditions. When the timer chip receives the Power_Good signal, it releases the reset, and the processor begins executing whatever code is at address FFFF:0000 (usually the ROM BIOS).

If the power supply cannot maintain proper outputs (such as when a brownout occurs), the Power_Good signal is withdrawn, and the processor is automatically reset. When the power output returns to its proper levels, the power supply regenerates the Power_Good signal and the system again begins operation (as if you had just powered on). By withdrawing Power_Good before the output voltages fall out of regulation, the system never sees the bad power because it is stopped quickly (reset) rather than being allowed to operate using unstable or improper power levels, which can cause memory parity errors and other problems.

Note

You can use the Power_Good feature as a method of implementing a reset switch for the PC. The Power_Good line is wired to the clock generator circuit, which controls the clock and reset lines to the microprocessor. When you ground the Power_Good line with a switch, the timer chip and related circuitry reset the processor. The result is a full hardware reset of the system. *Upgrading and Repairing PCs, 6th Edition*, which is located on this book's CD, contains instructions for making and installing a reset switch.

◀◀ See "Parity and ECC," p. 443.

On pre-ATX systems, the Power_Good connection is made via connector P8-1 (P8 Pin 1) from the power supply to the motherboard. ATX and later systems use pin 8 of the 20-pin connector, which is normally a gray wire.

A well-designed power supply delays the arrival of the Power_Good signal until all the voltages stabilize after you turn on the system. Badly designed power supplies, which are found in many low-cost systems, often do not delay the Power_Good signal properly and enable the processor to start too soon. (The normal Power_Good delay is 0.1–0.5 seconds.) Improper Power_Good timing also causes CMOS memory corruption in some systems.

Note

If you find that a system consistently fails to boot up properly the first time you turn on the switch, but that it subsequently boots up if you press the reset or Ctrl+Alt+Delete warm boot command, you likely have a problem with the Power_Good timing. You should install a new, higher-quality power supply and see whether that solves the problem.

Some cheaper power supplies do not have proper Power_Good circuitry and might just tie any +5V line to that signal. Some motherboards are more sensitive to an improperly designed or improperly functioning Power_Good signal than others. Intermittent startup problems are often the result of improper Power_Good signal timing. A common example is when you replace a motherboard in a system and then find that the system intermittently fails to start properly when you turn on the power. This can be very difficult to diagnose, especially for the inexperienced technician, because the problem appears to be caused by the new motherboard. Although it seems as though the new motherboard is defective, it usually turns out that the power supply is poorly designed. It either cannot produce stable enough power to properly operate the new board or has an improperly wired or timed Power_Good signal (which is more likely). In these situations, replacing the supply with a higher-quality unit, in addition to the new motherboard, is the proper solution.

Power Supply Form Factors

The shape and general physical layout of a component is called the *form factor*. Items that share a form factor are generally interchangeable, at least as far as their sizes and fits are concerned. When designing a PC, the engineers can choose to use one of the popular standard PSU (power supply unit) form factors, or they can elect to build their own. Choosing the former means that a virtually inexhaustible supply of inexpensive replacement parts will be available in a variety of quality and power output levels. Going the custom route means additional time and expense for development. In addition, the power supply is unique to the system and available only from the original manufacturer.

If you can't tell already, I am a fan of the industry-standard form factors! Having standards and then following them allows us to upgrade and repair our systems by easily replacing physically (and electrically) interchangeable components. Having interchangeable parts means that we have a better range of choices for replacement items, and the competition makes for better pricing, too.

In the PC market, IBM originally defined the standards, and everybody else copied them. This included power supplies. All the popular PC power supply form factors up through 1995 were based on one of three IBM models, including the PC/XT, AT, and PS/2 Model 30. The interesting thing is that these three power supply definitions all had the same motherboard connectors and pinouts; where they differed was mainly in shape, maximum power output, the number of peripheral power connectors, and switch mounting. PC systems using knock-offs of one of those three designs were popular through 1996 and beyond, and some systems still use them today.

Intel gave the power supply a new definition in 1995 with the introduction of the ATX form factor. ATX became popular in 1996 and started a shift away from the previous IBM-based standards. ATX and the related standards that followed have different connectors with additional voltages and signals that allow systems with greater power consumption and additional features that would otherwise not be possible with the AT style supplies.

Technically, the power supply in your PC is described as a *constant voltage half-bridge forward converting switching power supply*:

- *Constant voltage* means that the power supply puts out the same voltage to the computer's internal components, no matter what the voltage of AC current running it or the capacity (wattage) of the power supply.
- *Half-bridge forward converting switching* refers to the design and power regulation technique used by most suppliers. This design is commonly referred to as a *switching supply*. Compared to other types of power supplies, this design provides an efficient and inexpensive power source and generates a minimum amount of heat. It also maintains a small size and a low price.

Note

Although two power supplies can share the same basic design and form factor, they can differ greatly in quality and efficiency. Later in this chapter, you'll learn about some of the features and specifications to look for when evaluating PC power supplies.

Seven main power supply physical form factors have existed that can be called industry standard. Five of these are based on IBM designs, whereas two are based on Intel designs. Of these, only three are used in most modern systems; the others are pretty much obsolete.

Note that although the names of the power supply form factors seem to be the same as those of motherboard form factors, the power supply form factor is more related to the system chassis (case) than the motherboard. That is because all the form factors use one of only two types of connector designs, either AT or ATX.

For example, all PC/XT, AT, and LPX form factor supplies use the same pair of six-pin connectors to plug into the motherboard and will therefore power any board having the same type of power connections. Plugging into the motherboard is one thing, but for the power supply to physically work in the system, it must fit the case. The bottom line is that it is up to you to make sure the power supply you purchase not only plugs into your motherboard but also fits into the chassis or case you plan to use.

Table 21.2 shows these power supply form factors, their connection types, and associated motherboards.

Table 21.2 Power Supply Connector Types and Form Factors

Obsolete PS Form Factors	Originated From	Connector Type	Associated MB Form Factors
PC/XT style	IBM PC, PC-XT (1981/1983)	AT	PC/XT, Baby-AT
AT/Desk style	IBM PC-AT (1984)	AT	Fullsize AT, Baby-AT
AT/Tower style	IBM PC-AT (1984)	AT	Fullsize AT, Baby-AT
Baby-AT style	IBM PC-AT (1984)	AT	Fullsize AT, Baby-AT
Modern PS Form Factors	**Originated From**	**Connector Type**	**Associated MB Form Factors**
LPX style*	IBM PS/2 Model 30 (1987)	AT	Baby-AT, Mini-AT, LPX
ATX style	Intel ATX, ATX12V (1985/2000)	ATX	ATX, NLX, Micro-ATX
SFX style	Intel SFX (1997)	ATX	Flex-ATX, Micro-ATX

**Note: LPX is also sometimes called Slimline or PS/2.*

Each of these power supply form factors is available in numerous configurations and power output levels. The LPX form factor supply had been the standard used on most systems from the late 1980s to mid-1996, when the ATX form factor started to gain in popularity. Since then, ATX has become by far the dominant form factor for power supplies, with the new SFX style being added as an ATX derivative for use in very compact systems that mainly use Flex-ATX–sized boards. The earlier IBM-derived form factors have been largely obsolete for some time now.

◀◀ See "Motherboard Form Factors," p. 194.

IBM's PC and XT systems (circa 1981 and 1983, respectively) used the same power supply form factor; the only difference was that the XT supply had more than double the power output capability. Because they were identical in external appearance and the type of connectors they used, you easily could install the higher output XT supply as an upgrade for a PC system; thus, the idea of upgrading the power supply was born. The tremendous popularity of the original PC and XT systems led a number of manufacturers to begin building systems that mimicked their shapes and layouts. These clones—or compatibles—as they have been called, could interchange virtually all components with the IBM systems, including the power supply. Numerous manufacturers then began producing components that followed the form factor of these systems. The PC/XT power supply and connectors are shown in Figure 21.1. This form factor, however, is not used in modern systems today.

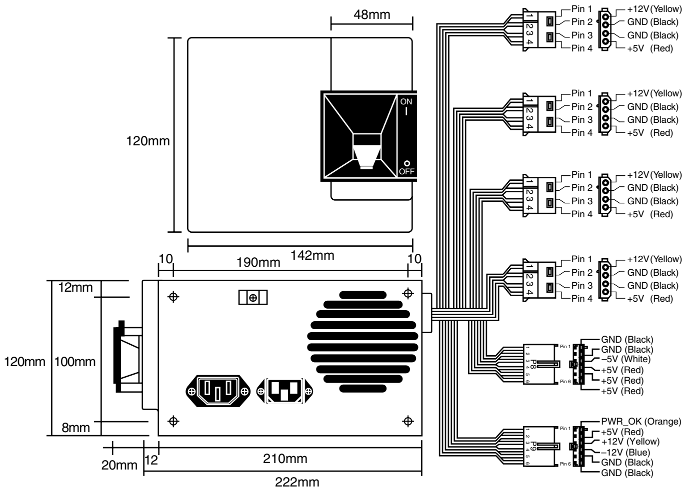

Figure 21.1 PC/XT form factor power supply.

AT/Desk Style

The AT desktop system introduced by IBM in August 1984, had a larger power supply and a form factor different from the original PC/XT. This system was rapidly cloned by other manufacturers and represented the basis for many subsequent IBM-compatible designs. The power supply used in these systems was called the AT/Desktop-style power supply (see Figure 21.2). Hundreds of manufacturers began making motherboards, power supplies, cases, and other components that were physically interchangeable with the original IBM AT. This form factor is no longer used today.

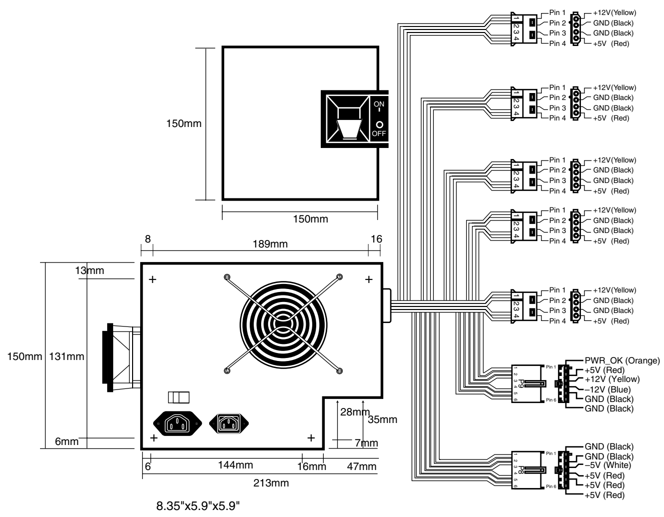

Figure 21.2 AT/Desktop form factor power supply.

AT/Tower Style

The AT/Tower configuration was basically a full-sized, AT-style desktop system running on its side. The tower configuration was not new; in fact, even IBM's original AT had a specially mounted logo that could be rotated when you ran the system on its side in the tower configuration.

The type of power supply used in most of the AT tower systems was identical to that used in a desktop system, except for the location of the power switch. On the original AT/Desktop systems, the power switch was built into the side of the power supply (usually in the form of a large toggle switch). AT/Tower systems instead used an external switch attached to the power supply through a four-wire cable. A full-sized AT power supply with a remote switch is called an AT/Tower form factor power supply and is identical to the AT/Desktop supply in size and dimensions. The only difference is the use of an external switch (see Figure 21.3). This form factor is still used today in large server chassis that run AT form factor motherboards.

Baby-AT Style

Another type of AT-based form factor is the so-called Baby-AT, which is a shortened version of the full-sized AT form factor. The power supply in these systems is shortened in one dimension but matches the AT design in all other respects. Baby-AT–style power supplies could fit in place of the larger AT/Desktop style supply; however, the full-sized AT/Tower supply would not fit in the Baby-AT chassis (see Figure 21.4). Because the Baby-AT PSU performed the same functions as the AT-style power supply but was in a smaller package, it became a common form factor until it was overtaken by later designs. This form factor is rarely used today.

LPX Style

The next power supply form factor to gain popularity was the LPX style, also called the PS/2 type, Slimline, or slim style (see Figure 21.5). The LPX-style power supply has the exact same motherboard and disk drive connectors as the previous standard power supply form factors; it differs mainly in the shape. LPX systems were designed to have a smaller footprint and a lower height than AT-sized systems. These computers used a different motherboard configuration that mounts the expansion bus slots on a "riser" card that plugs into the motherboard. The expansion cards plug into this riser and are mounted sideways in the system, parallel to the motherboard. Because of its smaller case, an LPX system needed a smaller power supply. The power supply designed for LPX systems is smaller than the Baby-AT style in every dimension and takes up less than half the space of its predecessor.

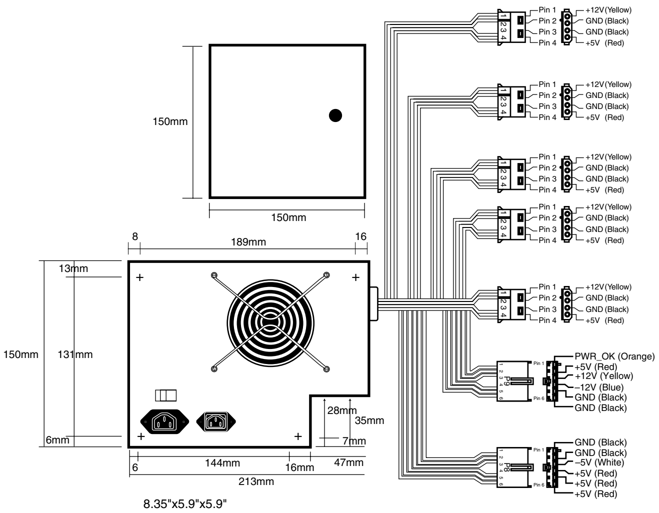

Figure 21.3 AT/Tower form factor power supply.

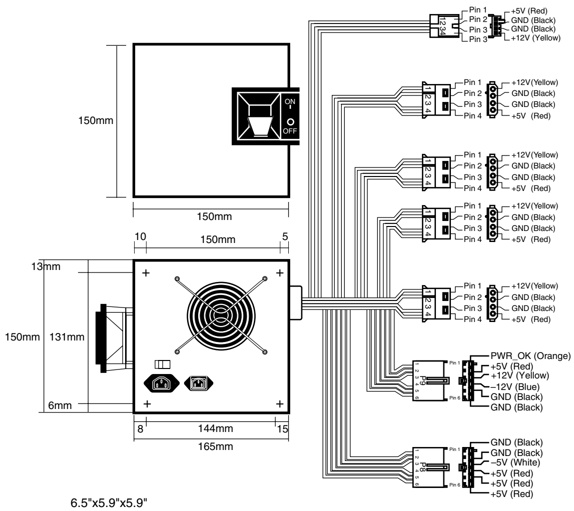

Figure 21.4 Baby-AT form factor power supply.

Note

IBM used this type of power supply in some of its PS/2 systems in the late 1980s; hence it is sometimes called a PS/2-type supply.

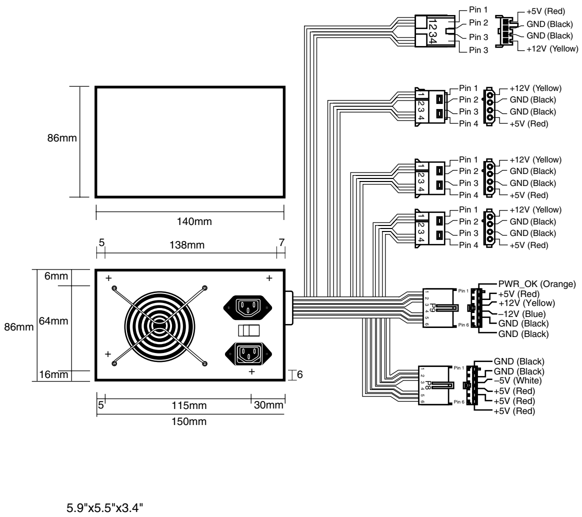

Figure 21.5 LPX form factor power supply.

As with the Baby-AT design in its time, the LPX power supply does the same job as its predecessor but comes in a smaller package. The LPX power supply quickly found its way into many manufacturers' systems, soon becoming a de facto standard. This style of power supply became the staple of the industry for many years, coming in everything from low-profile systems using actual LPX motherboards to full-size towers using Baby-AT or even full-size AT motherboards. It still is used in some PCs produced today; however, since 1996 the popularity of LPX has been overshadowed by the increasing popularity of the ATX design.

ATX Style

One of the newer standards in the industry today is the ATX form factor (see Figure 21.6). The ATX specification, now in version 2.03, defines a new motherboard shape, as well as a new case and power supply form factor.

The shape of the ATX power supply is based on the LPX design, but some important differences are worth noting.

One difference is that the ATX specification originally called for the fan to be mounted along the inner side of the supply, where it could draw air in from the rear of the chassis and blow it inside across the motherboard. This kind of airflow runs in the opposite direction as most standard supplies, which exhaust air out the back of the supply through a hole in the case where the fan protrudes. The idea was that the reverse flow design could cool the system more efficiently with only a single fan, eliminating the need for a fan (active) heatsink on the CPU.

Another benefit of the reverse-flow cooling is that the system would run cleaner, more free from dust and dirt. The case would be pressurized, so air would be continuously forced out of the cracks in the case—the opposite of what happens with a negative pressure design. For this reason, the reverse-flow cooling design is often referred to as a positive-pressure-ventilation design. On an ATX system with reverse-flow cooling, the air would be blown out away from the drive because the only air intake would be the single fan vent on the power supply at the rear. For systems that operate in extremely harsh environments, you can add a filter to the fan intake vent to further ensure that all the air entering the system is clean and free of dust.

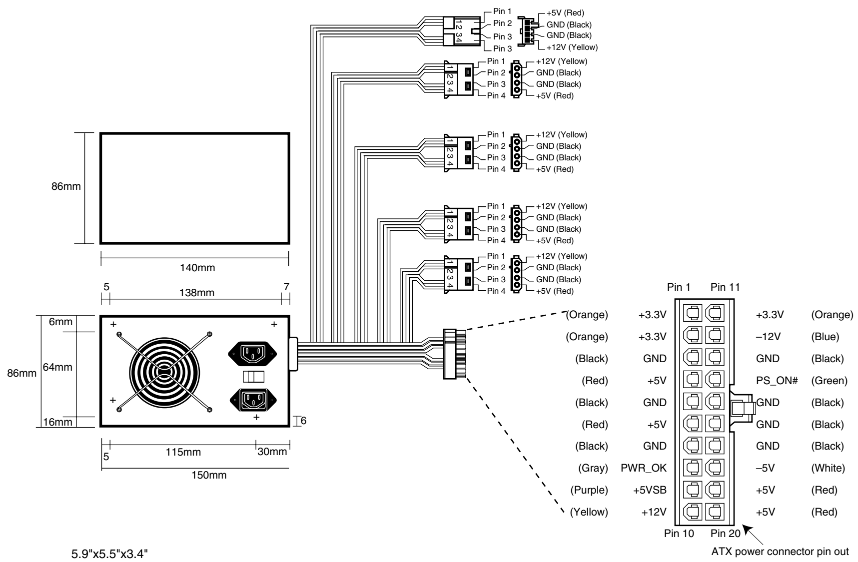

Figure 21.6 ATX form factor power supply, used with both ATX and NLX systems.

Although this sounds like a good way to ventilate a system, the positive-pressure design needs to use a more powerful fan to pull the required amount of air through a filter and to pressurize the case. Also, if a filter is used, it must be serviced on a periodic basis—depending on operating conditions, it can need changing or cleaning as often as every week. In addition, the heat load from the power supply on a fully loaded system heats up the air being ingested, blowing warm air over the CPU, reducing overall cooling capability. As newer CPUs create more and more heat, the cooling capability of the system becomes more critical. In common practice, it was found that using a standard negative-pressure system with an exhaust fan on the power supply and an additional high-quality cooling fan blowing cool air right on the CPU is the best solution. For this reason, the ATX power supply specification has been amended to allow for either positive- or negative-pressure ventilation.

Because a standard negative-pressure system offers the most cooling capacity for a given fan airspeed and flow, most of the newer ATX-style power supplies use the negative-pressure cooling system.

The ATX specification was first released by Intel in 1995. In 1996, it became increasingly popular in Pentium and Pentium Pro–based PCs, capturing 18% of the motherboard market. Since 1996, ATX has become the dominant motherboard form factor, displacing the previously popular Baby-AT. ATX and its derivatives are likely to remain the most popular form factor for several years to come.

The ATX form factor addressed several problems with the power supplies used with Baby-AT and mini-AT form factors. One is that the power supplies used with Baby-AT boards have two connectors that plug into the motherboard. If you insert these connectors backward or out of their normal sequence, you will fry the motherboard! Most responsible system manufacturers "key" the motherboard and power supply connectors so that you cannot install them backward or out of sequence. However, some vendors of cheaper systems do not feature this keying on the boards or supplies they use. The ATX form factor includes different power plugs for the motherboard to prevent users from plugging in their power supplies incorrectly. The ATX design features up to three motherboard power connectors that are definitively keyed, making plugging them in backward virtually impossible. The new ATX connectors also supply +3.3V, reducing the need for voltage regulators on the motherboard to power the chipset, DIMMs, and other +3.3V circuits.

Besides the new +3.3V outputs, another set of outputs is furnished by an ATX power supply that is not normally seen on standard power supplies. The set consists of the Power_On (PS_ON) and 5V_Standby (5VSB) outputs mentioned earlier, known collectively as *Soft Power*. This enables features to be implemented, such as Wake on Ring or Wake on LAN, in which a signal from a modem or network adapter can actually cause a PC to wake up and power on. Many such systems also have the option of setting a wake-up time, at which the PC can automatically turn itself on to perform scheduled tasks. These signals also can enable the optional use of the keyboard to power the system on—exactly like Apple systems. Users can enable these features because the 5V Standby power is always active, giving the motherboard a limited source of power even when off. Check your BIOS Setup for control over these features.

NLX Style

The NLX specification, also developed by Intel, defines a low-profile case and motherboard design with many of the same attributes as the ATX. In fact, for interchangeability, NLX systems were designed to use ATX power supplies, even though the case and motherboard dimensions are different.

As in previous LPX systems, the NLX motherboard uses a riser board for the expansion bus slots. Where NLX differs is that it is a true (and not proprietary) standard. See Chapter 4, “Motherboards and Buses,” for more information on the NLX form factor.

For the purposes of this discussion, NLX systems use ATX power supplies. The only real difference is that the supply plugs into the riser card and not the motherboard, enabling NLX motherboards to be more quickly and easily removed from their chassis for service.

SFX Style

Intel released the smaller Micro-ATX motherboard form factor in December of 1997, and at the same time also released a new smaller SFX (Small form factor) power supply design to go with it (see Figure 21.7). Even so, most Micro-ATX chassis used the standard ATX power supply instead. Then in March of 1999, Intel released the Flex-ATX addendum to the Micro-ATX specification, which was a very small board designed for low-end PCs or PC-based appliances. At this point, the SFX supply has found use in many new compact system designs.

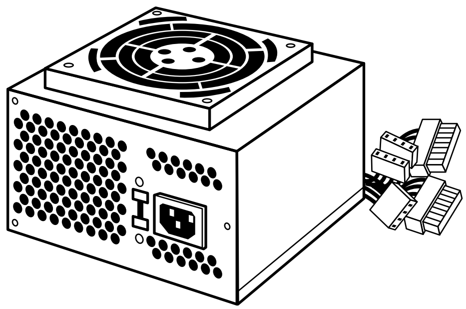

Figure 21.7 SFX style power supply (with 90mm top-mounted cooling fan).

The SFX power supply is specifically designed for use in small systems containing a limited amount of hardware and limited upgradability. Most SFX supplies can provide 90 watts of continuous power (135 watts at its peak) in four voltages (+5, +12, –12, and +3.3V). This amount of power has proved to be sufficient for a small system with a processor, an AGP interface, up to four expansion slots, and three peripheral devices—such as hard drives and CD-ROMs.

Although Intel designed the SFX power supply specification with the Micro-ATX and Flex-ATX motherboard form factors in mind, SFX is a wholly separate standard that is compliant with other motherboards as well. SFX power supplies use the same 20-pin connector defined in the ATX standard and include both the Power_On and 5V_Standby outputs. Whether you will use an ATX or SFX power supply in a given system is dependent more on the case or chassis than the motherboard. Each has the same basic electrical connectors; the main difference is which type of power supply the case is physically designed to accept.

One limiting factor on the SFX design is that it lacks the –5V and so shouldn't be used with motherboards that have ISA slots (most Micro-ATX and Flex-ATX boards do NOT have ISA slots). SFX power supplies also won't have the Auxiliary (3.3V and 5V) or ATX12V power connectors, and therefore shouldn't be used with full-size ATX boards that require those connections.

On a standard model SFX power supply, a 60mm diameter cooling fan is located on the surface of the housing, facing the inside of the computer's case. The fan draws the air into the power supply housing from the system cavity and expels it through a port at the rear of the system. Internalizing the fan in this way reduces system noise and results in a standard negative-pressure design. In many cases, additional fans might be needed in the system to cool the processor (see Figure 21.8).

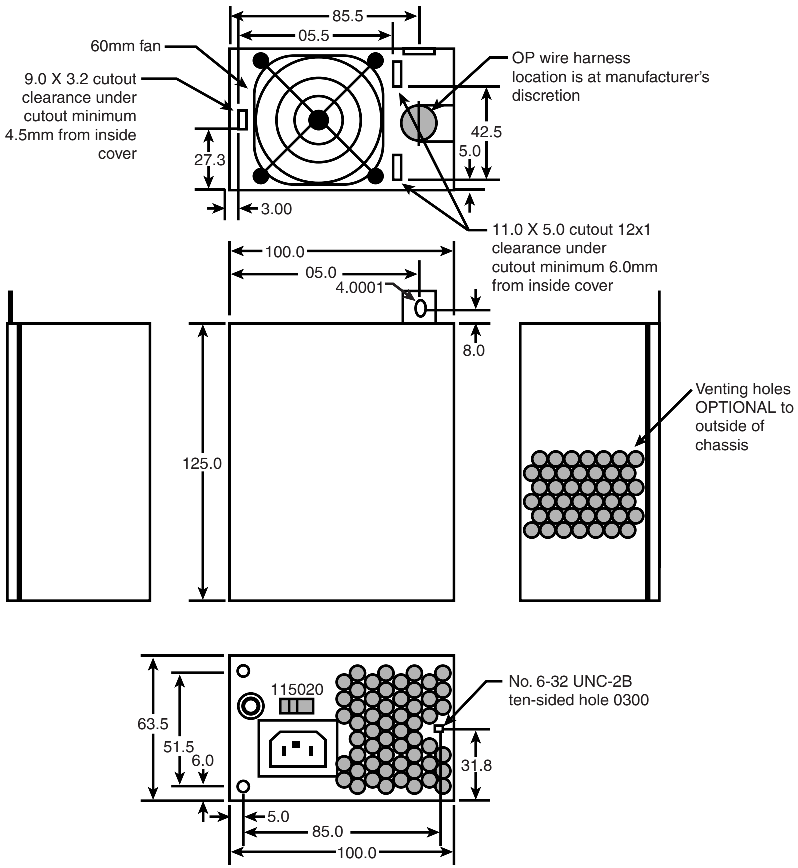

Figure 21.8 SFX form factor power supply dimensions with a standard internal 60mm fan.

For systems that require more cooling capability, a version that allows for a larger 90mm top-mounted cooling fan also is available. The larger fan provides more cooling capability and airflow for systems that need it (see Figure 21.9).

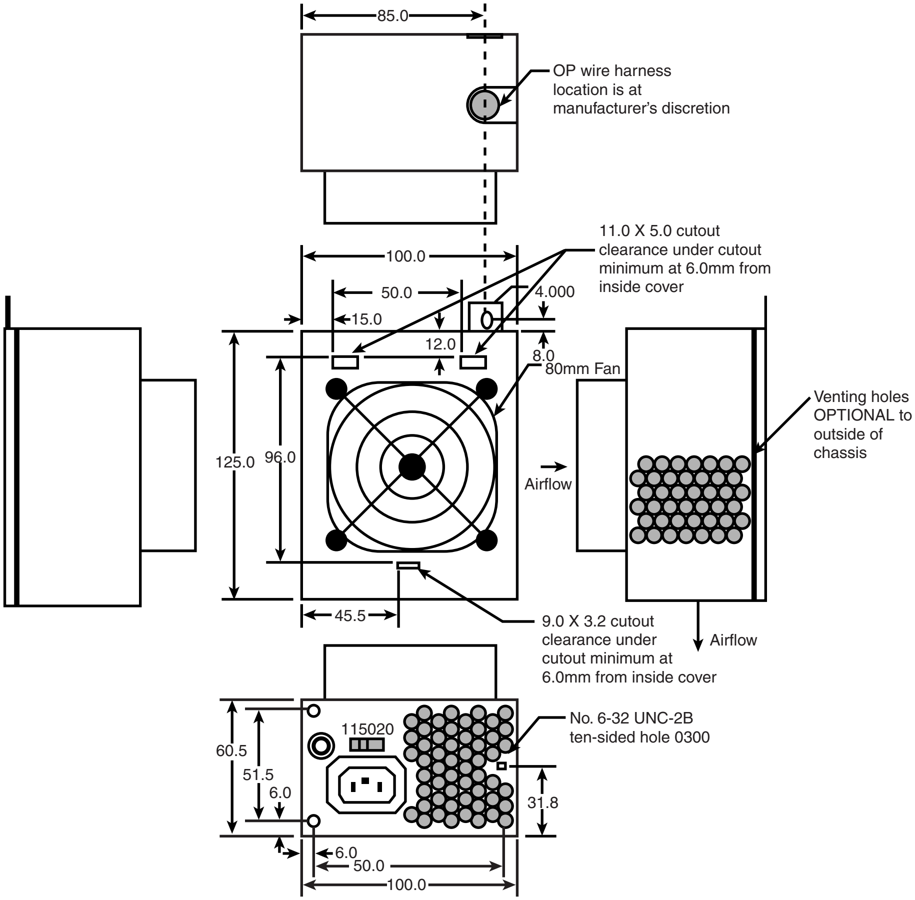

Figure 21.9 SFX form factor power supply dimensions with an internal 90mm top-mounted fan.

Motherboard Power Connectors

Every PC power supply has special connectors that attach to the motherboard, giving power to the system processor, memory, and all slotted add-on boards (ISA, PCI, AGP). Attaching these connectors improperly can have a devastating effect on your PC, including burning up both your power supply and motherboard. The following sections detail the motherboard power connectors used by various power supplies.

AT Power Supply Connectors

Industry standard PC, XT, AT, Baby-AT, and LPX motherboards all use the same type of main power supply connectors. These supplies feature two main power connectors (P8 and P9), each with 6 pins that attach the power supply to the motherboard. Those two connectors are shown in Figure 21.10.

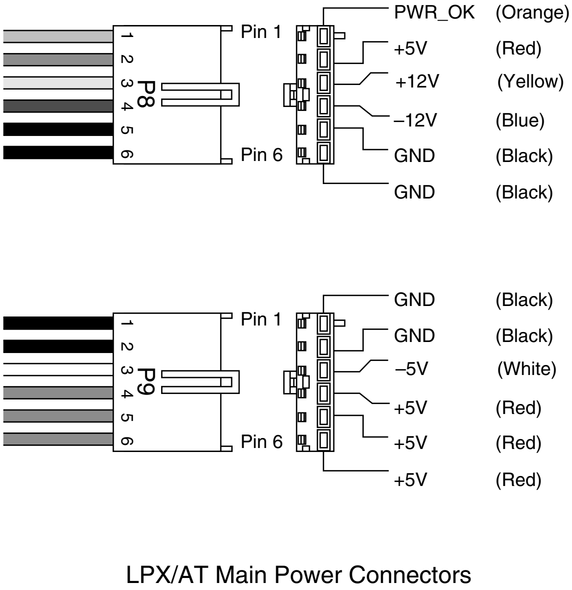

Figure 21.10 AT/LPX main P8/P9 (sometimes also called P1/P2) power connectors.

All standard PC power supplies that use the P8 and P9 connectors have them installed end to end so that the two black wires (ground connections) on both power cables are next to each other. Note the designations P8 and P9 are not fully standardized, although most use those designations because that is what IBM used on the originals. Some power supplies have them labeled as P1/P2 instead. Because these connectors usually have a clasp that prevents them from being inserted backward on the pins on the motherboards, the major concern is getting the two connectors in the correct orientation side by side and also not missing a pin offset on either side. Following the black-to-black rule keeps you safe. You must take care, however, to make sure that no remaining unconnected motherboard pins exist between or on either side of the two connectors after you install them. A properly installed connector connects to and covers every motherboard power pin. If any power pins are showing on either side of the connectors, the entire connector assembly is installed incorrectly, which can result in catastrophic failure for the motherboard and everything plugged into it at the time of power-up. Figure 21.11 shows the P8 and P9 connectors (sometimes also called P1/P2) in their proper orientation when connecting.

Table 21.3 shows typical AT and LPX power supply connections.

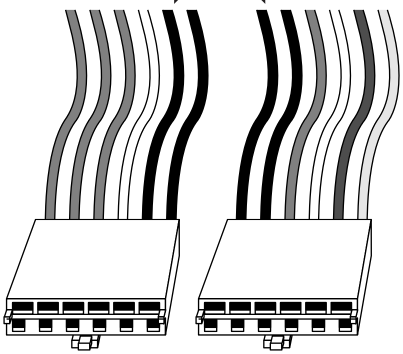

Figure 21.11 The P8/P9 power connectors (sometimes also called P1/P2) that connect an AT/LPX power supply to the motherboard.

Table 21.3 AT/LPX Power Supply Connectors

Connector	Pin	Signal	Color	Connector	Pin	Signal	Color
P8 (or P1)	1	Power_Good (+5V)	Orange	P9 (or P2)	1	Ground	Black
	2	+5V*	Red		2	Ground	Black
	3	+12V	Yellow		3	–5V	White
	4	–12V	Blue		4	+5V	Red
	5	Ground	Black		5	+5V	Red
	6	Ground	Black		6	+5V	Red

**Older PC/XT motherboards and power supplies did not use this output (P8 pin 2).*
Color codes can vary from manufacturer to manufacturer;, the ones shown here are typical.

Tip

Although older PC/XT power supplies do not have any connection at connector P8 pin 2, you still can use them on AT-type motherboards, or vice versa. The presence or absence of the +5V on that pin has little or no effect on system operation because the remaining +5V wires usually can carry the load.

Note that all the power supplies from the AT/Desk through the Baby-AT and LPX power supplies use the same pin configuration.

ATX Main Power Connector

The industry standard ATX power-supply–to–motherboard main connector is the Molex 39-29-9202 (or equivalent) 20-pin ATX style connector (see Figure 21.12). First used in the ATX form factor power supply, it also is used in the SFX form factor or any other ATX-based variations. This is a 20-pin keyed connector with pins configured as shown in Table 21.4. The colors for the wires listed are those recommended by the ATX standard; however, they are not required for compliance to the specification, so they could vary from manufacturer to manufacturer. Note that I like to show these connector pinouts in a wire side view, which shows how the pins are arranged looking at the back of the connector (from the wire and not terminal side). This is because it shows how they would be oriented if you were back-probing the connector with the connector plugged in.

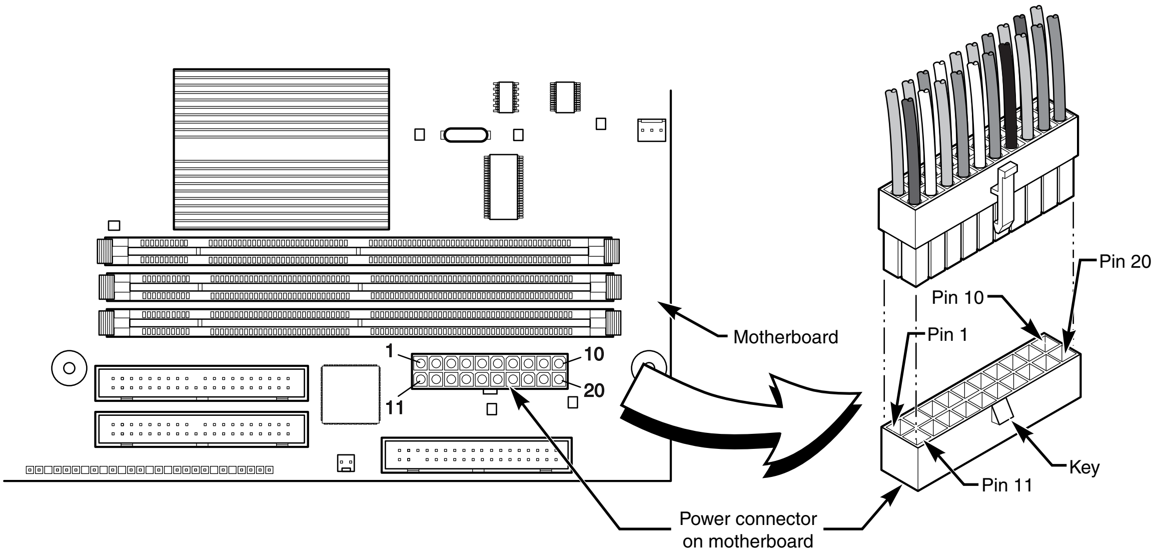

Figure 21.12 ATX style 20-pin motherboard main power connector, perspective view.

Figure 21.13 shows a view of the connector as if you were looking at it facing the terminal side.

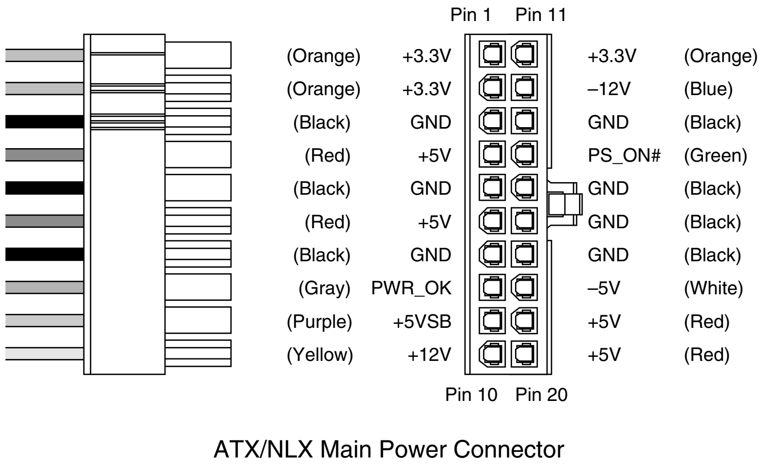

Figure 21.13 ATX/NLX 20-pin main power connector, terminal side view.

Table 21.4 ATX Main Power Supply Connector Pinout (Wire Side View)

Color	Signal	Pin	Pin	Signal	Color
Orange*	+3.3V	11	1	+3.3V	Orange
Blue	–12V	12	2	+3.3V	Orange
Black	GND	13	3	GND	Black
Green	PS_On	14	4	+5V	Red
Black	GND	15	5	GND	Black
Black	GND	16	6	+5V	Red
Black	GND	17	7	GND	Black
White	–5V	18	8	Power_Good	Gray
Red	+5V	19	9	+5VSB (Standby)	Purple
Red	+5V	20	10	+12V	Yellow

**Might have a second orange or brown wire, used for +3.3V sense feedback—used by the power supply to monitor 3.3V regulation.*

Note

The ATX supply features several voltages and signals not seen before, such as the +3.3V, PS_On, and +5V_Standby. Therefore, adapting a standard LPX form factor supply to make it work properly in an ATX system, is difficult—if not impossible—even though the shapes of the power supplies themselves are virtually identical.

However, because ATX is a superset of the older AT standard, you can use an adapter to allow an ATX power supply to connect to an older Baby-AT style motherboard. PC Power and Cooling (see the vendor list) sells this type of adapter.

ATX Auxiliary Power Connector

As motherboards and processors evolved, the need for power became greater. In particular, chipsets and DIMMs were designed to run on 3.3V, increasing the current demand at that voltage. In addition, most boards included CPU voltage regulators designed to convert +5V power into the unique voltage levels required by the processors the board supported. Eventually, the high current demands on the +3.3V and +5V outputs were proving too much for the number and gauge of the wires used. Melted connectors were becoming more and more common as these wires overheated under these loads.

Finally, Intel modified the ATX specification to add a second power connector for ATX motherboards and supplies. The criteria was that if the motherboard needed more than 18A of +3.3V power, or more than 24A of +5V power, an auxiliary connector would be defined to carry the additional load. These higher levels of power are normally necessary in systems using 250-watt to 300-watt or greater supplies.

The auxiliary connector (shown in Figure 21.14) is a 6-pin Molex-type connector, similar to one of the motherboard power connectors used on AT/LPX supplies. It is keyed to prevent misconnection.

The pinouts of the auxiliary connector are shown in Table 21.5.

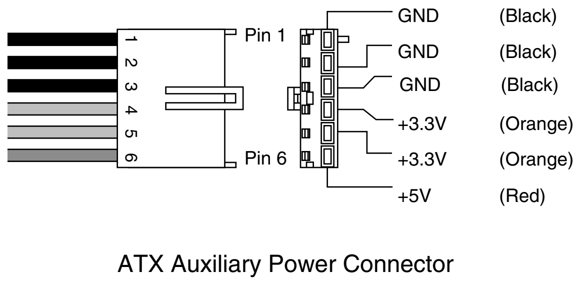

Figure 21.14 ATX auxiliary power connector.

Table 21.5 ATX Auxiliary Power Connector Pinout

Pin	Signal	Color	Pin	Signal	Color
1	Gnd	Black	4	+3.3V	Orange
2	Gnd	Black	5	+3.3V	Orange
3	Gnd	Black	6	+5V	Red

If your motherboard does not feature a mating auxiliary connector, it probably wasn't designed to consume a large amount of power, and the auxiliary connector from the power supply can be left unconnected. If your power supply is rated at 250 watts or larger, you should ensure that it has this connector and that your motherboard is capable of accepting it. This eases the load on the main power connector.

ATX12V Connector

Power for the processor comes from a device called the voltage regulator module (VRM), which is built into most modern motherboards. This device senses the CPU voltage requirements (usually via sense pins on the processor) and calibrates itself to provide the proper voltage to run the CPU. The design of a VRM enables it to run on either 5V or 12V for input power. Most have used 5V over the years, but many are now converting to 12V because of the lower current requirements at that voltage. In addition, the 5V already might be loaded by other devices, whereas, typically, only drive motors use the 12V. Whether the VRM on your board uses 5V or 12V depends on the particular motherboard or regulator design. Many modern voltage regulator ICs are designed to run on anything from a 4V to a 36V input, so it is up to the motherboard designer as to how they will be configured.

For example, I studied a system using an FIC (First International Computer) SD-11 motherboard, which used a Semtech SC1144ABCSW voltage regulator. This board design uses the +5V to convert to the lower voltage needed by the CPU. Most motherboards use voltage regulator circuits controlled by chips from Semtech (`http://www.semtech.com`) or Linear Technology (`http://www.linear.com`). You can visit their sites for more data on these chips.

That motherboard accepts an Athlon 1GHz Cartridge version (Model 2), which according to AMD has a maximum power draw of 65W and a nominal voltage requirement of 1.8V. 65W at 1.8V would equate to 36.1A of current at that voltage (volts×amps = watts). If the voltage regulator used +5V as a feed, 65W would equate to only 13A at +5V. That would assume 100% efficiency in the regulator, which is impossible. Therefore, assuming 75% efficiency (it might be better, but I like to think conservatively), there would be about 17A actual draw on the +5V due to the regulator and processor combined.

When you consider that the motherboard itself also uses some +5V power—plus ISA or PCI cards are drawing power as well—you can see how easy it is to overload the +5V lines from the supply to the motherboard.

Although most motherboard VRM designs up through the Pentium III and Athlon/Duron use 5V-based regulators, a transition is underway to use 12V-powered regulators. This is because the higher voltage will significantly reduce the current draw. As an example, using the same 65W AMD Athlon 1GHz CPU, you end up with the levels of draw at the various voltages shown in Table 21.6.

Table 21.6 Levels of Draw at Various Voltages

Watts	Volts	Amps	Amps at 75% Regulator Efficiency
65	1.8	36.1	—
65	3.3	19.7	26.3
65	5.0	13.0	17.3
65	12.0	5.4	7.2

As you can see, using 12V to power the chip results in only 5.4A of draw, or 7.2A assuming 75% efficiency on the part of the regulator.

So, modifying the motherboard VRM circuit to use the +12V power feed would seem simple. Unfortunately, the standard ATX 2.03 power supply design has only a single +12V lead in the main power connector. The auxiliary connector has no +12V leads at all, so that is no help. Pulling up to 8A more through a single 18ga. wire supplying +12V power to the motherboard is a recipe for a melted connector.

To augment the supply of +12V power to the motherboard, Intel created a new ATX12V power supply specification. This adds a third power connector, called the ATX12V connector, specifically to supply additional +12V power to the board. This connector is shown in Figure 21.15.

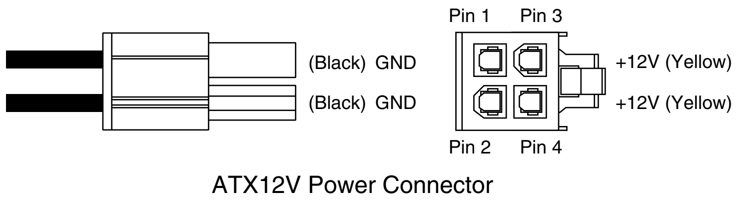

Figure 21.15 An ATX12V power connector.

The pinout of the +12V power connector is shown in Table 21.7.

Table 21.7 ATX +12V Power Connector Pinout (Wire Side View)

Color	Signal	Pin	Pin	Signal	Color
Yellow	+12V	3	1	Gnd	Black
Yellow	+12V	4	2	Gnd	Black

If you are replacing your motherboard with a new one that requires the ATX12V connection for the CPU voltage regulator, and yet your existing power supply doesn't have that connector, an easy solution is available. Merely convert one of the peripheral power connectors to an ATX12V type.

PC Power and Cooling has released just such an adapter that can instantly make any standard ATX power supply into one with an ATX12V connector. The issue is not whether the power supply can generate the necessary 12V—that has always been available via the peripheral connectors. The ATX12V adapter shown in Figure 21.16 solves the connector problem quite nicely.

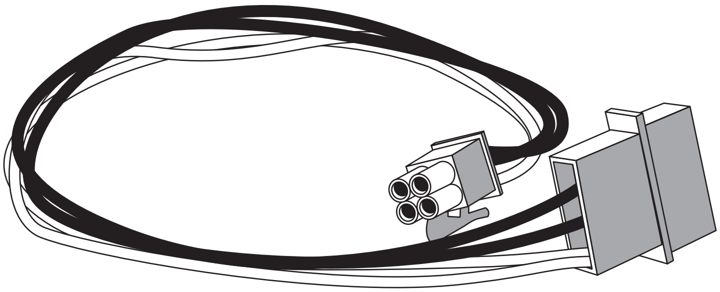

Figure 21.16 ATX12V adapter from PC Power and Cooling.

ATX Optional Connector

The ATX specification also defines an optional six-pin connector. This connector has two rows of three pins each to provide the signals and voltages. The computer can use these signals to monitor and control the cooling fan, monitor the +3.3V power to the motherboard, and provide power and grounding to IEEE 1394 (FireWire) devices.

This connector has gone through several revisions in pinout since first being published, and I have yet to see any motherboards or power supplies on the market that actually support it. In fact, the latest *ATX/ATX12V Power Supply Design Guide* published by Intel states "Details of the 2x3 'Optional Power Connector' mentioned in the ATX 2.03 Specification are omitted from this design guide until such time as the signals on that connector are more rigidly defined."

Table 21.8 lists the pinout of the optional connector as defined in the ATX 2.03 Specification.

Table 21.8 ATX Optional Power Supply Connections

Color	Signal	Pin	Pin	Signal	Color
White/Black Stripe	1394R	4	1	FanM	White
White/Red Stripe	1394V	5	2	FanC	White/Blue Stripe
	Reserved	6	3	+3.3V sense	White/Brown Stripe

The FanM signal enables the operating system to monitor the status of the power supply's cooling fan so that it can take appropriate actions, such as shutting down the system if the fan fails.

The motherboard (under operating system control) can use the FanC signal with variable voltages to control the operation of the power supply's fan, shifting it into a low power state or shutting it off completely when the system is in sleep or standby mode. The ATX standard specifies that a voltage of +1V or less indicates that the fan is to shut down, whereas +10.5V or more instructs the fan to operate at full speed. The system designer can define intermediate voltages to operate variable-speed fans at various levels. If the power supply does not include a variable-speed fan circuit, any voltage level higher than +1V on the FanC signal is interpreted as a command to run the fan at its full (and only) speed.

The 1394 connectors are for powering an optional IEEE1394 (FireWire or iLink) bus on a motherboard. The 1394V pin provides voltages from 8 to 40V to run FireWire peripherals off the bus, and the 1394R pin is a return or ground line for this power circuit. This separate power rail keeps the 1394 bus power separate from the system main power to prevent interference.

Note

The SFX specification also defines the use of a six-pin control connector, but uses it only to provide a fan control signal on one pin. The other five pins are all reserved for future use.

Dell Proprietary (Nonstandard) ATX Design

If you currently own or are considering purchasing a desktop system from Dell, you will definitely want to pay attention to this section. A potential booby trap is waiting to nail the unsuspecting Dell owner who decides to upgrade either the motherboard or power supply in his system. This hidden trap can cause the destruction of the motherboard, power supply, or both! OK, now that I have your attention, read on….

As those of you who have attended my seminars or read previous editions of this book will know, I have long been a promoter of industry-standard PCs and components and wouldn't think of purchasing a desktop PC that didn't have what I consider an industry-standard form factor motherboard, power supply, and chassis (ATX, for example). I've been down the proprietary road before with systems from Packard Bell, Compaq, IBM, and other companies that used custom, unique, or proprietary components. For example, during a momentary lapse of reason in the early '90s, I purchased a Packard Bell system. I quickly outgrew the capabilities of the system, so I thought I'd upgrade it with a new motherboard and a faster processor. It was then to my horror that I discovered that LPX systems were nonstandard. Additionally, because of riser card differences, virtually no interchangeability of motherboards, riser cards, chassis, and power supplies existed. I had what I now refer to as a "disposable PC"—the kind you can't upgrade but have to throw away instead. Suddenly, the money I thought I had saved when initially purchasing the system paled in comparison to what I'd now have to spend to completely replace it. Lesson learned.

In a similar experience, I remember paying more than $950 to IBM for a replacement 114W power supply to fit my PS/2 P75 luggable that had a power supply failure out of warranty. The supply had a totally unique shape and a weird connector I had never seen before, and no alternative choices were available from any other companies. The system wasn't even worth that much at the time, but I was using it for work and had no choice but to pay the price to get it replaced. And, of course, the replacement was the same relatively low-output 114W unit because there were simply no other versions available that would fit. Another lesson learned.

After several upgrade and repair experiences like that, I decided *never again* would I be trapped by systems using proprietary or nonstandard components. By purchasing only systems built from industry-standard parts, I could easily and inexpensively upgrade, maintain, or repair the system for many years into the future. I have been preaching the gospel of industry-standard components in my seminars and in this book ever since.

Of course, building your own system from scratch is one way to avoid proprietary components, but often that route is more costly in both time and money than purchasing a prebuilt system. And what systems should I recommend for people who want an inexpensive prebuilt system but one that uses industry-standard parts so it can be inexpensively upgraded and repaired later? Although many system vendors and assemblers exist, I've settled on companies such as Gateway, Micron, and Dell. In fact, those are really the three largest system vendors that deal direct, and they sell mostly systems that use industry-standard ATX form factor components in all their main desktop system product lines. Or so I thought.

It seems that starting after September of 1998, Dell defected from the cause of industry standardization and began using specially modified Intel-supplied ATX motherboards with custom-wired power connectors. Inevitably, they also had custom power supplies made that duplicated the nonstandard pinout of the motherboard power connectors.

An even bigger crime than simply using nonstandard power connectors is that only the pinout is nonstandard; the connectors look like and are keyed the same as is dictated by true ATX. Therefore, nothing prevents you from plugging the Dell nonstandard power supply into a new industry-standard ATX motherboard you installed in your Dell case as an upgrade, or even plugging a new upgraded industry-standard ATX power supply into your existing Dell motherboard. But mixing either a new ATX board with the Dell supply or a new ATX supply with the existing Dell board is a recipe for silicon toast. How do you like your fried chips: medium or well-done?

Frankly I'm amazed I haven't heard more about this because Dell is second only to Compaq in worldwide PC sales. I can only imagine that it is because they started using these nonstandard boards and power supplies in late 1998, and most of those systems haven't yet come due for motherboard upgrades. However, they are now passing 2 years old, which is about the time that many people consider motherboard upgrades. That is why, after discovering this information, I wanted to make it well known. I figure by getting this information out as soon as possible, I can save thousands of innocent motherboards and power supplies from instant death upon installation.

If you've already fallen victim to this nasty circumstance, believe me, I feel your pain. I discovered this the hard way as well—by frying parts. At first, I thought the upgraded power supply I installed in one of my Dell systems was bad, especially considering the dramatic way it smoked when I turned on the system: I actually saw fire through the vents! Good thing I decided to check the color codes on the connectors and verify the pinout on another Dell system by using a voltmeter before I installed and fried a second supply. I was lucky in that the smoked supply didn't take the motherboard with it; I can only surmise that the supply fried so quickly it sacrificed itself and saved the motherboard. You might not be so lucky, and in most cases I'd expect you'd fry the board and supply together.

Call me a fool, but I didn't think I'd have to check the color-coding or get out my voltmeter to verify the Dell "pseudo-ATX" power connector pinouts before I installed a new ATX supply or motherboard. You'll also find that motherboard and power supply manufacturers don't like to replace these items under warranty when they are fried in this manner due to nonstandard connector wiring.

I spoke with one of the engineers at a major power supply manufacturer and asked whether a valid technical reason (maybe some problem in the ATX specification) exists that would require Dell to use unique connector pinouts. Of course, the answer was that, no, the only reason he could imagine they did this is to lock people into purchasing replacement motherboards or power supplies from Dell. In fact, what makes this worse is that Dell uses virtually all Intel boards in their systems. One system I have uses an Intel D815EEA motherboard, which is the same board used by many of the other major system builders, including Gateway, Micron, and others. It's the same except for the power connectors, that is. The difference is that Dell has Intel custom make the boards for Dell with the nonstandard connectors. Everybody else gets virtually the same Intel boards, but with industry-standard connectors.

Tables 21.9 and 21.10 show the nonstandard Dell main and auxiliary power supply connections. This nonstandard wiring is used on Dell systems dating from after September 1998 to the present.

Table 21.9 Dell Proprietary (Nonstandard) ATX Main Power Connector Pinout (Wire Side View)

Color	Signal	Pin	Pin	Signal	Color
Gray	PS_On	11	1	+5V	Red
Black	Gnd	12	2	Gnd	Black
Black	Gnd	13	3	+5V	Red
Black	Gnd	14	4	Gnd	Black
White	–5V	15	5	Power_Good	Orange
Red	+5V	16	6	+5VSB (standby)	Purple
Red	+5V	17	7	+12V	Yellow
Red	+5V	18	8	–12V	Blue
KEY (blank)	—	19	9	Gnd	Black
Red	+5V	20	10	Gnd	Black

Table 21.10 Dell Proprietary (Nonstandard) ATX Auxiliary Power Connector Pinout

Pin	Signal	Color	Pin	Signal	Color
1	Gnd	Black	4	+3.3	Blue/White
2	Gnd	Black	5	+3.3	Blue/White
3	Gnd	Black	6	+3.3	Blue/White

At first I thought that if all they did was switch some of the terminals around, I could use a terminal pick to remove the terminals from the connectors (with the wires attached) and merely reinsert them into the proper connector positions, enabling me to use the Dell power supply with an upgraded ATX motherboard in the future. Unfortunately, if you study the Dell main and auxiliary connector pinouts I've listed here and compare them to the industry-standard ATX pinouts listed earlier, you'll see that not only are the voltage and signal positions changed, but the number of terminals carrying specific voltages and grounds has changed as well. You could modify a Dell supply to work with a standard ATX board or modify a standard ATX supply to work with a Dell board, but you'd have to do some cutting and splicing in addition to swapping some terminals around. Usually, it isn't worth the time and effort.

If you do decide to upgrade the motherboard in your Dell system (purchased on or after 09/98), a simple solution is available—just make sure you replace both the motherboard AND power supply with industry-standard ATX components at the same time. That way nothing gets fried, and you'll be back to having a true industry-standard ATX system. If you want to replace just the Dell motherboard, you're out of luck unless you get your replacement board from Dell. On the other hand, if you want to replace just the power supply, you do have one alternative. PC Power and Cooling now makes a version of its high-performance 300W ATX power supply with the modified Dell wiring for about $110. Note that the internals are identical to their industry-standard, high-performance 300W ATX supply (approximately $84), only the number and arrangement of wires has changed.

For the time being, I'm suspending any Dell purchase recommendations until Dell moves back into the fold of true industry standardization. Fortunately, others, such as Gateway and Micron, have remained true to the industry standard.

Power Switch Connectors

Three main types of power switches are used on PCs. They can be described as follows:

- Integral Power Supply AC switch
- Front Panel Power Supply AC switch
- Front Panel Motherboard Controlled switch

The earliest systems had power switches integrated or built directly into the power supply, which turned the main AC power to the system on and off. This was a simple design, but because the power supply was mounted to the rear or side of the system, it required reaching around to the back to actuate the switch. Also, switching the AC power directly meant the system couldn't be remotely started without special hardware.

Starting in the late '80s systems began using remote front panel switches. These were essentially the same power supply design as the first type. The only difference is that the AC switch was now mounted remotely (usually on the front panel of the chassis), rather than integrated in the power supply unit, and connected to the power supply via a four-wire cable. The ends of the cable are fitted with spade connector lugs, which plug onto the spade connectors on the power switch. The cable from the power supply to the switch in the case contains four color-coded wires. In addition, a fifth wire supplying a ground connection to the case might be included. The switch was usually included with the power supply and heavily shrink-wrapped or insulated where the connector lugs attached to prevent electric shock.

This solved the ergonomic problem of reaching the switch, but it still didn't enable remote or automated system power-up without special hardware. Plus, you now had a 120V AC switch mounted in the chassis, with wires carrying dangerous voltage through the system. Some of these wires are hot anytime the system is plugged in (all are hot with the system turned on), creating a dangerous environment for the average person when messing around inside her system.

Caution

At least two of the remote power switch leads to a remote mounted AC power switch in an AT/LPX supply are energized with 115V AC current at all times. You could be electrocuted if you touch the ends of these wires with the power supply plugged in, even if the unit is turned off! For this reason, always make sure the power supply is unplugged before connecting or disconnecting the remote power switch or touching any of the wires connected to it.

The four or five wires are color-coded as follows:

- *Brown and blue.* These wires are the live and neutral feed wires from the 110V power cord to the power supply. These are always hot when the power supply is plugged in.
- *Black and white.* These wires carry the AC feed from the switch back to the power supply. These leads should be hot only when the power supply is plugged in and the switch is turned on.
- *Green or green with a yellow stripe.* This is the ground lead. It should be connected to the PC case and should help ground the power supply to the case.

On the switch, the tabs for the leads are usually color-coded; if not, you'll find that most switches have two parallel tabs and two angled tabs. If no color-coding is on the switch, plug the blue and brown wires onto the tabs that are parallel to each other and the black and white wires to the tabs that are angled away from each other. If none of the tabs are angled, simply make sure the blue and brown wires are plugged into the most closely spaced tabs on one side of the switch and the black and white wires on the most closely spaced tabs on the other side.

See Figure 21.17 as a guide.

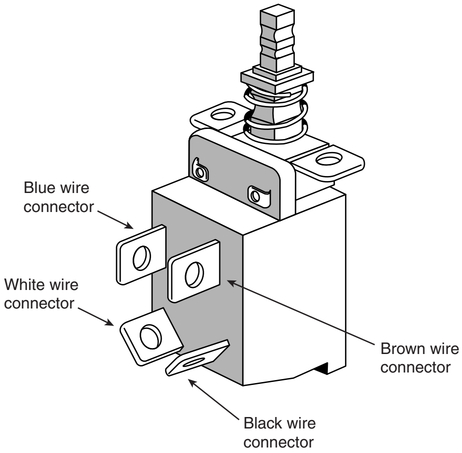

Figure 21.17 Power supply remote push button switch connections.

Caution

Although these wire color-codings and parallel/angled tabs are used on most power supplies, they are not necessarily 100% universal. I have encountered power supplies that did not use the same coloring or tab placement scheme described here. One thing is sure: Two of the wires will be hot with AC wall current anytime the power supply is plugged in. No matter what, always disconnect the power supply from the wall socket before handling any of these wires. Be sure to insulate the connections with electrical tape or heat shrink tubing so you won't be able to touch the wires when working inside the case in the future.

As long as the blue and brown wires are on the one set of tabs and the black and white leads are on the other, the switch and supply will work properly. If you incorrectly mix the leads, you will likely blow the circuit breaker for the wall socket because mixing them can create a direct short circuit.

All ATX and subsequent power supplies that employ the 20-pin motherboard connector use the PS_ON signal to power up the system. As a result, the remote switch does not physically control the power supply's access to the 110V AC power, as in the older-style power supplies. Instead, the power supply's on or off status is toggled by a PS_ON signal received on pin 14 of the ATX connector.

The PS_ON signal can be generated physically by the computer's power switch or electronically by the operating system. PS_ON is an active low signal, meaning that the power supply voltage outputs are disabled (the system is off) when the PS_ON is high (greater than or equal to 2.0V). This excludes the +5VSB (standby) on pin 9, which is active whenever the power supply is connected to an AC power source. The PS_ON signal is maintained by the power supply at either 3.3V or 5V. This signal is then routed through the motherboard to the remote switch on the front of the case. When the switch is pressed, the PS_ON signal is grounded. When the power supply sees the PS_ON signal drop to 0.8V or less, the power supply (and system) is turned on. Thus, the remote switch in an ATX-style system (which includes NLX and SFX systems as well) carries up to only +5V of DC power, rather than the full 115–230V AC current like that of the older AT/LPX form factors.

Caution

The continuous presence of the +5VSB signal on pin 9 of the ATX connector means that the motherboard always is receiving standby power from the power supply when connected to an AC source, even when the computer is turned off. As a result, it is even more crucial to unplug an ATX system from the power source before working inside the case than it is on an earlier model system.

Peripheral Power Connectors

In addition to the motherboard power connectors, power supplies include a variety of peripheral power connectors for everything from floppy and hard drives to internal case fans. The following sections discuss the various types of connectors you're likely to find in your PC.

Peripheral and Floppy Drive Power Connectors

The disk drive connectors on power supplies are fairly universal with regard to pin configuration and even wire color. Figure 21.18 shows the peripheral and floppy power connectors.

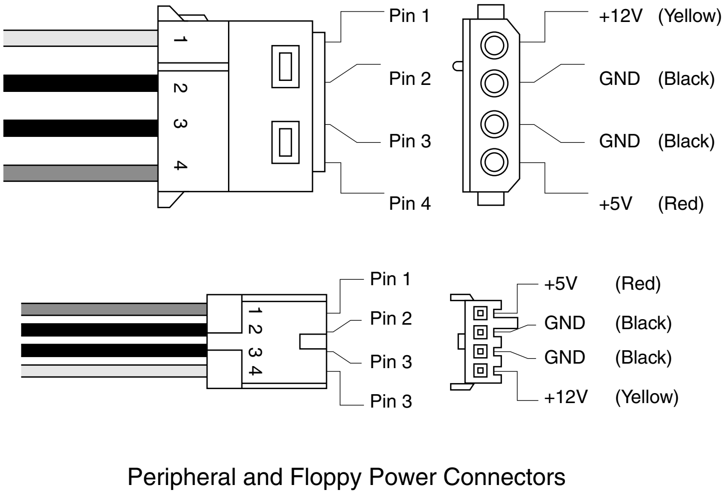

Figure 21.18 Peripheral and floppy power connectors.

Table 21.11 shows the standard disk drive power connector pinout and wire colors, whereas Table 21.12 shows the pinouts for the smaller floppy drive power connector.

Table 21.11 Peripheral Power Connector Pinout (Large Drive Power Connector)

Pin	Signal	Color	Pin	Signal	Color
1	+12V	Yellow	3	Gnd	Black
2	Gnd	Black	4	+5V	Red

Table 21.12 3 1/2-Inch Floppy Power Connector Pinout (Small Drive Power Connector)

Pin	Signal	Color	Pin	Signal	Color
1	+5V	Red	3	Gnd	Black
2	Gnd	Black	4	+12V	Yellow

Note that the pin numbering and voltage designations are reversed on the two connectors. Be careful if you are making or using an adapter cable from one type of connector to another. Reversing the red and yellow wires will fry the drive or device you plug into.

To determine the location of pin 1, look at the connector carefully. It is usually embossed in the plastic connector body; however, it is often tiny and difficult to read. Fortunately, these connectors are keyed and therefore difficult to insert incorrectly. Figure 21.19 shows the keying with respect to pin numbers on the larger drive power connector.

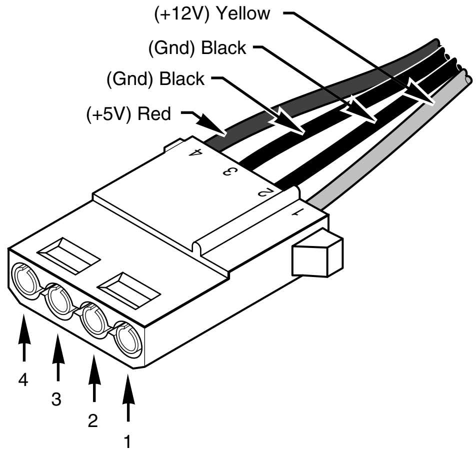

Figure 21.19 A peripheral female power supply connector.

Note

Some drive connectors might supply only two wires—usually the +5V and a single ground (pins 3 and 4)—because the floppy drives in most newer systems run on only +5V and do not use the +12V at all.

Early power supplies featured only two large style drive connectors, normally called peripheral connectors today. Later power supplies featured four or more of the larger peripheral (drive) connectors, and one or two of the smaller 3 1/2-inch floppy drive connectors. Depending on their power ratings and intended uses, some supplies have as many as eight peripheral/drive connectors.

If you are adding drives and need additional disk drive power connectors, Y splitter cables (see Figure 21.20), as well as large to small drive power connector adapters (see Figure 21.21), are available from many electronics supply houses (including Radio Shack). These cables can adapt a single power connector to service two drives or enable you to convert the large peripheral power connector to a smaller floppy drive power connector. If you are using several Y-adapters, make sure that your total power supply output is capable of supplying the additional power.

Physical Connector Part Numbers

The physical connectors used in industry-standard PC power supplies were originally specified by IBM for the supplies used in the original PC/XT/AT systems. They used a specific type of connector between the power supply and the motherboard (the P8 and P9 connectors) and specific connectors for the disk drives. The motherboard connectors used in all the industry-standard power supplies were unchanged from 1981 (when the IBM PC appeared) until 1995 (when Intel released the ATX standard). The original PC's four-pin disk drive connector was augmented by a smaller (also four-pin) power connector when 3 1/2-inch floppy drives appeared in 1986. Table 21.13 lists the standard connectors used for motherboard and disk drive power.

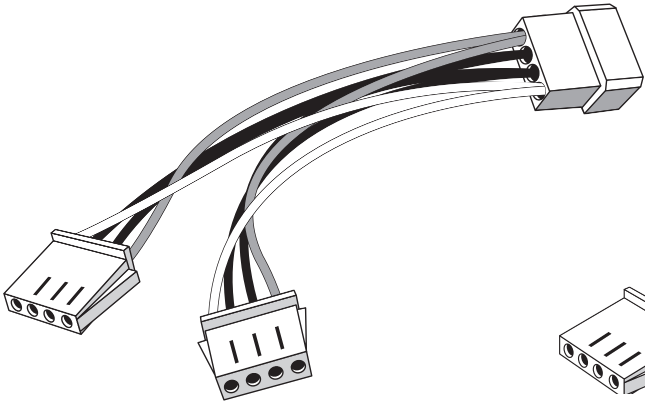

Figure 21.20 A common Y-adapter power cable.

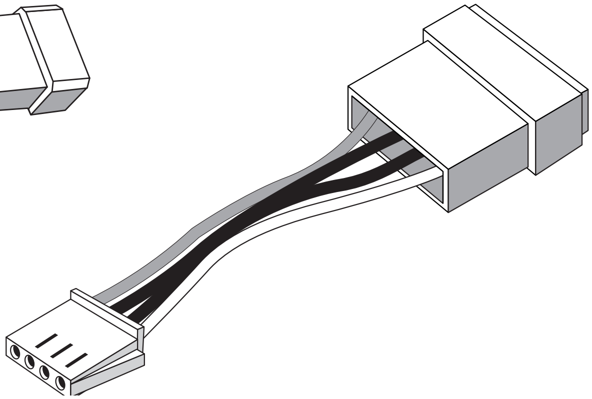

Figure 21.21 A peripheral–to–floppy-drive power adapter cable.

Table 21.13 Physical Power Connectors

Connector Description	Female (on Power Cable)	Male (on Component)
ATX/NLX/SFX (20-pin)	Molex 39-29-9202	Molex 39-01-2200
ATX Optional (6-pin)	Molex 39-01-2960	Molex 39-30-1060
PC/AT/LPX Motherboard P8/P9	Burndy GTC6P-1	Burndy GTC 6RI
Disk drive (large style)	AMP 1-480424-0	AMP 1-480426-0
Floppy drive (small style)	AMP 171822-4	AMP 171826-4

You can get these raw connectors through the electronics supply houses (Allied, Newark, and Digi-Key, for example) found in the Vendor List on the CD. You also can get complete cable assemblies, including drive adapters that convert the large connectors into small connectors; disk drive Y splitter cables; and motherboard power extension cables from a number of the cable and miscellaneous supply houses, such as Ci Design and Key Power, as well as PC Power and Cooling.

Caution

Before you install additional connectors to your power supply using Y splitters or any other type of connector, be sure your power supply is capable of delivering sufficient power for all your internal peripherals. Overloading the power supply can cause damage to electrical components and stored data.

▶▶ See "Power Supply Ratings," p. 1134.

Power Factor Correction

Recently, the power line efficiency and harmonic distortion generation of PC power supplies has come under examination. This generally falls under the topic of what is called the power factor of the supply. Interest in power factor is not only due to an improvement in power efficiency, but also a reduction in the generation of harmonics back on the power line. In particular, new standards are now mandatory in many European Union (EU) countries that require harmonics be reduced below a specific amount. The circuitry required to do this is generally called power factor correction (PFC).

Power factor measures how effectively electrical power is being used, and it is expressed as a number between 0 and 1. A high power factor means that electrical power is being used effectively, whereas a low power factor indicates poor utilization of electrical power. To understand power factor, you need to understand how power is used.

Generally, two kinds of loads are placed on AC power lines:

- *Resistive.* Power converted into heat, light, motion, or work.
- *Inductive.* Sustains an electromagnetic field, such as in a transformer or motor.

A resistive load is often called *working power* and is measured in kilowatts (KW). An inductive load, on the other hand, is often called *reactive power* and is measured in kilovolt-amperes-reactive (KVAR). Working power and reactive power together make up *apparent power*. Apparent power is measured in kilovolt-amperes (KVA). The power factor is measured as the ratio of working power to apparent power, or working power / apparent power (KW/KVA). The ideal power factor is 1, where the working power and apparent power are the same.

The concept of a resistive load or working power is fairly easy to understand. A light bulb, for example, that consumes 100W of power generates 100W worth of heat and light. That is a pure resistive load. An inductive load, on the other hand, is a little harder to understand. Think about a transformer, which has coil windings to generate an electromagnetic field, and then induce current in another set of windings. A certain amount of power is required to saturate the windings and generate the magnetic field, even though no work is being done. A power transformer that is not connected to anything is a perfect example of a pure inductive load. There would be an apparent power draw to generate the fields but no working power because no actual work is being done.

When the transformer is connected to a load, it would use both working power and reactive power. In other words, power would be consumed to do work (for example, say the transformer is powering a light bulb), and apparent power would be used to maintain the electromagnetic field in the transformer windings. What can happen in an AC (alternating current) circuit is that these loads can become out of sync or phase, meaning they don't peak at the same time, which can generate harmonic distortions back down the power line. I've seen examples where electric motors caused distortions in television sets plugged into the same power circuit.

Power factor correction (PFC) usually involves adding capacitance to the circuit to be able to maintain the inductive load without drawing additional power from the line. This makes the working power and apparent power the same, which results in a power factor of 1. It usually isn't just as simple as adding some capacitors to a circuit, although that can be done and is called *passive* power factor correction. *Active* power factor correction involves a more intelligent circuit designed to match the resistive and inductive loads so they are seen as the same by the electrical outlet.

A power supply with active power factor correction draws low distortion current from the AC source and has a power factor rating of 0.9 or greater. A nonpower factor corrected supply draws highly distorted current and is sometimes referred to as a *nonlinear* load. The power factor of a noncorrected supply is normally 0.6–0.8. This means that only 60% of the apparent power consumed is actually doing real work!

Having a power supply with active PFC might or might not improve your electric bill (it depends on how your power is measured), but it will definitely reduce the load on the building wiring. With PFC, all the power going into the supply will be converted into actual work, and the wiring will be less overworked. For example, if you ran a number of computers on a single breaker-controlled circuit and found that you were blowing the breaker every so often, by switching to systems with active PFC power supplies, you'd reduce the load on the wiring by up to 40%, meaning you would be less likely to blow the breaker.

The International Electrical Committee (IEC) has released standards dealing with the low frequency public supply system. Initial standards were 555.2 (Harmonics) and 555.3 (Flicker), which have since been refined and are now available as IEC 1000-3-2 and IEC 1000-3-3, respectively. As governed by the EMC directive, most electrical devices sold within the member countries of the European Union (EU) must meet the IEC standards. The IEC1000-3-2/3 standards became mandatory in 1997 and 1998.

Even if you don't live in a country where PFC is required, I highly recommend specifying PC power supplies with active PFC. The main benefits of PFC supplies is that they do not overheat building wiring or distort the AC source waveform, causing less interference on the line for other devices.

Power Supply Loading

PC power supplies are of a *switching* rather than a *linear* design. The switching type of design uses a high-speed oscillator circuit to convert the higher wall-socket AC voltage to the much lower DC voltage used to power the PC and PC components. Switching type power supplies are noted for being very efficient in size, weight, and energy in comparison to the linear design, which uses a large internal transformer to generate various outputs. This type of transformer-based design is inefficient in at least three ways. First, the output voltage of the transformer linearly follows the input voltage (hence the name *linear*), so any fluctuations in the AC power going into the system can cause problems with the output. Second, the high current-level (power) requirements of a PC system require the use of heavy wiring in the transformer. Third, the 60Hz (hertz) frequency of the AC power supplied from your building is difficult to filter out inside the power supply, requiring large and expensive filter capacitors and rectifiers.

The switching supply, on the other hand, uses a switching circuit that chops up the incoming power at a relatively high frequency. This enables the use of high-frequency transformers that are much smaller and lighter. Also, the higher frequency is much easier and cheaper to filter out at the output, and the input voltage can vary widely. Input ranging from 90 volts to 135 volts still produces the proper output levels, and many switching supplies can automatically adjust to 220V input.

One characteristic of all switching-type power supplies is that they do not run without a *load*. This means that you must have the supply plugged into something drawing power for the supply to work. If you simply have the power supply on a bench with nothing plugged into it, either the supply burns up or its protection circuitry shuts it down. Most power supplies are protected from no-load operation and shut down automatically. Some of the cheap clone supplies, however, lack the protection circuit and relay. They are destroyed after a few seconds of no-load operation. A few power supplies have their own built-in load resistors, so they can run even though no normal load is plugged in.

According to IBM specifications for the standard 192-watt power supply used in the original AT, a minimum load of 7.0 amps was required at +5V and a minimum of 2.5 amps was required at +12V for the supply to work properly.

Because floppy drives present no +12V load unless they are spinning, systems without a hard disk drive often do not operate properly. Some power supplies have a minimum load requirement for both the +5V and +12V sides. If you fail to meet this minimum load, the supply shuts down.

Because of this characteristic, when IBM used to ship the original AT systems without a hard disk, they plugged the hard disk drive power cable into a large 5-ohm, 50-watt sandbar resistor, which was mounted in a little metal cage assembly where the drive would have been. The AT case had screw holes on top of where the hard disk would go, specifically designed to mount this resistor cage.

Note

Several computer stores I knew of in the mid-1980s would order the diskless AT and install their own 20MB or 30MB drives, which they could get more cheaply from other sources than from IBM. They were throwing away the load resistors by the hundreds! I managed to grab a couple at the time, which is how I know the type of resistor they used.

This resistor would be connected between pin 1 (+12V) and pin 2 (Ground) on the hard disk power connector. This would place a 2.4-amp load on the supply's +12V output, drawing 28.8 watts of power (it would get hot!) and thus enabling the supply to operate normally. Note that the cooling fan in most power supplies draws approximately 0.1–0.25 amps, bringing the total load to 2.5 amps or more. If the load resistor were missing, the system would intermittently fail to start up or operate properly. The motherboard would draw +5V at all times, but +12V would normally be used only by motors, and the floppy drive motors would be off most of the time.

Most of the power supplies in use today do not require as much of a load as the original IBM AT power supply. In most cases, a minimum load of 0–0.3 amps at +3.3V, 2.0–4.0 amps at +5V, and 0.5–1.0 amps at +12V is considered acceptable. Most motherboards easily draw the minimum +5V current by themselves. The standard power supply cooling fan draws only 0.1–0.25 amps, so the +12V minimum load might still be a problem for a diskless workstation. Generally, the higher the rating on the supply, the more minimum load required; however, exceptions do exist, so this is a specification you want to check when evaluating power supplies.

Some high-quality switching power supplies have built-in load resistors and can run under a no-load situation because the supply loads. Other high-quality power supplies, such as those from PC Power and Cooling, have no internal load resistors. They require only a small load on the +5V line to operate properly. Many of the cheaper clone supplies, which often do not have built-in load resistors, might require +3.3V, +5V, and +12V loads to work.

If you want to bench test a power supply, make sure you place loads on at least one but preferably all of the positive voltage outputs. This is one reason you should test the supply while it is installed in the system, instead of testing it separately on the bench. For impromptu bench testing, you can use a spare motherboard and hard disk drive to load the outputs.

Power Supply Ratings

A system manufacturer should be able to provide you the technical specifications of the power supplies it uses in its systems. This type of information can be found in the system's technical-reference manual, as well as on stickers attached directly to the power supply. Power supply manufacturers can also supply this data, which is preferable if you can identify the manufacturer and contact them directly or via the Web.

The input specifications are listed as voltages, and the output specifications are listed as amps at several voltage levels. IBM reports output wattage level as "specified output wattage." If your manufacturer does not list the total wattage, you can convert amperage to wattage by using the following simple formula:

$$\text{watts} = \text{volts} \times \text{amps}$$

For example, if a motherboard is listed as drawing 6 amps of +5V current, that would be 30 watts of power, according to the formula.

By multiplying the voltage by the amperage available at each output and then adding the results, you can calculate the total capable output wattage of the supply.

Table 21.14 shows the standard power supply output levels available in industry-standard form factors. Most manufacturers offer supplies with ratings from 100 watts to 450 watts or more. Table 21.15 shows the rated outputs at each of the voltage levels for supplies with different manufacturer-specified output ratings. To compile the table, I referred to the specification sheets for supplies from Astec Standard Power and PC Power and Cooling. Although most of the ratings are accurate, they are somewhat misleading for the higher wattage units.

Table 21.14 Typical Non-ATX Power Supply Output Ratings

Rated Output (Watts)	100W	150W	200W	250W	300W	375W	450W
Output current (amps):							
+5V	10.0	15.0	20.0	25.0	32.0	35.0	45.0
+12V	3.5	5.5	8.0	10.0	10.0	13.0	15.0
–5V	0.3	0.3	0.3	0.5	1.0	0.5	0.5
–12V	0.3	0.3	0.3	0.5	1.0	0.5	1.0
Calc. output (watts)	97.1	146.1	201.1	253.5	297.0	339.5	419.5

Adding a +3.3V output to the power supply modifies the equation significantly. Table 21.15 contains data for various ATX power supplies from PC Power and Cooling that include a +3.3V output.

Table 21.15 PC Power and Cooling ATX Power Supply Output Ratings

Rated Output	235W	275W	300W	350W	400W	425W
Output current (amps):						
+5V	22.0	30.0	30.0	32.0	30.0	50.0
+3.3V	14.0	14.0	14.0	28.0	28.0	40.0
Max watts +5V and +3.3V:	125W	150W	150W	215W	215W	300W
+12V	8.0	10.0	12.0	10.0	14.0	15.0
–5V	0.5	0.5	0.5	0.3	1.0	0.3
–12V	1.0	1.0	1.0	0.8	1.0	1.0

If you compute the total output using the formula described earlier, these power supplies seem to produce an output that is much higher than their ratings. The 300W model, for example, comes out at 354.7 watts. However, notice that the supply also has a maximum combined output for the +3.3V and +5V of 150 watts. This means you cannot draw the maximum rating on both the 5V and 3.3V lines simultaneously, but must keep the total combined draw between them at 150W. This brings the total output to a more logical 308.5 watts.

Most PC power supplies have ratings between 150 and 300 watts. Although lesser ratings are not usually desirable, you can purchase heavy-duty power supplies for most systems that have outputs as high as 600 watts or more.

The 300-watt and larger units are recommended for fully optioned desktops or tower systems. These supplies run any combination of motherboard and expansion card, as well as a large number of disk drives and other peripherals. In most cases, you cannot exceed the ratings on these power supplies—the system will be out of room for additional items first!

Most power supplies are considered to be universal, or worldwide. That is, they also can run on the 220V, 50-cycle current used in Europe and many other parts of the world. Many power supplies that can switch from 110V to 220V input do so automatically, but a few require you to set a switch on the back of the power supply to indicate which type of power you will access.

Caution

If your supply does not switch input voltages automatically, make sure the voltage setting is correct. If you plug the power supply into a 110V outlet while it's set in the 220V setting, no damage will result, but the supply won't operate properly until you correct the setting. On the other hand, if you are in a foreign country with a 220V outlet and have the switch set for 110V, you might cause damage.

Power Supply Specifications

In addition to power output, many other specifications and features go into making a high-quality power supply. I have had many systems over the years. My experience has been that if a brownout occurs in a room with several systems running, the systems with higher-quality power supplies and higher output ratings are far more likely to make it through the power disturbances unscathed, whereas others choke.

High-quality power supplies also help protect your systems. A power supply from a vendor such as Astec or PC Power and Cooling will not be damaged if any of the following conditions occur:

- A 100% power outage of any duration
- A brownout of any kind
- A spike of up to 2,500V applied directly to the AC input (for example, a lightning strike or a lightning simulation test)

Decent power supplies have an extremely low current leakage to ground of less than 500 microamps. This safety feature is important if your outlet has a missing or an improperly wired ground line.

As you can see, these specifications are fairly tough and are certainly representative of a high-quality power supply. Make sure that your supply can meet these specifications.

You can also use many other criteria to evaluate a power supply. The power supply is a component many users ignore when shopping for a PC, and it is therefore one that some system vendors might choose to skimp on. After all, a dealer is far more likely to be able to increase the price of a computer by spending money on additional memory or a larger hard drive than by installing a better power supply.

When buying a computer (or a replacement power supply), you always should learn as much as possible about the power supply. However, many consumers are intimidated by the vocabulary and statistics found in a typical power supply specification. Here are some of the most common parameters found on power supply specification sheets, along with their meanings:

- *Mean Time Between Failures (MTBF) or Mean Time To Failure (MTTF).* The (calculated) average interval, in hours, that the power supply is expected to operate before failing. Power supplies typically have MTBF ratings (such as 100,000 hours or more) that are clearly not the result of real-time empirical testing. In fact, manufacturers use published standards to calculate the results, based on the failure rates of the power supply's individual components. MTBF figures for power supplies often include the load to which the power supply was subjected (in the form of a percentage) and the temperature of the environment in which the tests were performed.

- *Input Range (or Operating Range).* The range of voltages that the power supply is prepared to accept from the AC power source. For 110V AC current, an input range of 90V–135V is common; for 220V current, a 180V–270V range is typical.
- *Peak Inrush Current.* The greatest amount of current drawn by the power supply at a given moment immediately after it is turned on, expressed in terms of amps at a particular voltage. The lower the current, the less thermal shock the system experiences.
- *Hold-Up Time.* The amount of time (in milliseconds) that a power supply can maintain output within the specified voltage ranges after a loss of input power. This enables your PC to continue running without resetting or rebooting if a brief interruption in AC power occurs. Values of 15–30 milliseconds are common for today's power supplies, and the higher (longer), the better. The ATX12V specification calls for a minimum of 17ms hold-up time.
- *Transient Response.* The amount of time (in microseconds) a power supply takes to bring its output back to the specified voltage ranges after a steep change in the output current. In other words, the amount of time it takes for the output power levels to stabilize after a device in the system starts or stops drawing power. Power supplies sample the current being used by the computer at regular intervals. When a device stops drawing power during one of these intervals (such as when a floppy drive stops spinning), the power supply might supply too high a voltage to the output for a brief time. This excess voltage is called *overshoot*, and the transient response is the time that it takes for the voltage to return to the specified level. This is seen as a spike in voltage by the system and can cause glitches and lockups. Once a major problem that came with switching power supplies, overshoot has been greatly reduced in recent years. Transient response values are sometimes expressed in time intervals, and at other times they are expressed in terms of a particular output change, such as "power output levels stay within regulation during output changes of up to 20%."
- *Overvoltage Protection.* Defines the trip points for each output at which the power supply shuts down or squelches that output. Values can be expressed as a percentage (for example, 120% for +3.3 and +5V) or as raw voltages (for example, +4.6V for the +3.3V output and +7.0V for the +5V output).
- *Maximum Load Current.* The largest amount of current (in amps) that safely can be delivered through a particular output. Values are expressed as individual amperages for each output voltage. With these figures, you can calculate not only the total amount of power the power supply can supply, but also how many devices using those various voltages it can support.
- *Minimum Load Current.* The smallest amount of current (in amps) that must be drawn from a particular output for that output to function. If the current drawn from an output falls below the minimum, the power supply could be damaged or automatically shut down.
- *Load Regulation (or Voltage Load Regulation).* When the current drawn from a particular output increases or decreases, the voltage changes slightly as well, usually increasing as the current rises. Load regulation is the change in the voltage for a particular output as it transitions from its minimum load to its maximum load (or vice versa). Values, expressed in terms of a +/– percentage, typically range from +/–1% to +/–5% for the +3.3, +5, and +12V outputs.
- *Line Regulation.* The change in output voltage as the AC input voltage transitions from the lowest to the highest value of the input range. A power supply should be capable of handling any AC voltage in its input range with a change in its output of 1% or less.
- *Efficiency.* The ratio of power input to power output, expressed in terms of a percentage. Values of 65%–85% are common for power supplies today. The remaining 15%–35% of the power input is converted to heat during the AC/DC conversion process. Although greater efficiency means less heat inside the computer (always a good thing) and lower electric bills, it should not be emphasized at the expense of precision, stability, and durability, as evidenced in the supply's load regulation and other parameters.

- *Ripple (or Ripple and Noise, or AC Ripple, or PARD [Periodic and Random Deviation]).* The average voltage of all AC effects on the power supply outputs, normally measured in millivolts peak-to-peak or as a percentage of the nominal output voltage. The lower this figure, the better. Higher-quality units normally are rated at 1% ripple (or less), which if expressed in volts would be 1% of the output. Consequently, for +5V that would be 0.05V or 50mV (millivolts). Ripple can be caused by internal switching transients, feed through of the rectified line frequency, and other random noise.

Power Supply Certifications

Many agencies around the world list electric and electronic components for safety and quality. The most commonly known agency in the United States is Underwriters Laboratories, Inc. (UL). UL standard #1950—the *Standard for Safety of Information Technology Equipment, Including Electrical Business Equipment, Third Edition*—covers power supplies and other PC components. You always should purchase power supplies and other devices that are UL-listed. It has often been said that, although not every good product is UL-listed, no bad products are.

In Canada, electric and electronic products are listed by the Canadian Standards Agency (CSA). The German equivalents are TÜV Rheinland and VDE, and NEMKO operates in Norway. These agencies are responsible for certification of products throughout Europe. Power supply manufacturers that sell to an international market should have products that are listed at least by UL, the CSA, and TÜV—if not by all the agencies listed, and more.

Apart from UL-type certifications, many power supply manufacturers, even the most reputable ones, claim that their products have a Class B certification from the Federal Communications Commission, meaning that they meet FCC standards for electromagnetic and radio frequency interference (EMI/RFI). This is a contentious point, however, because the FCC does not list power supplies as individual components. Title 47 of the Code of Federal Regulations, Part 15, Section 15.101(c) states as follows:

> "The FCC does NOT currently authorize motherboards, cases, and internal power supplies. Vendor claims that they are selling 'FCC-certified cases,' 'FCC-certified motherboards,' or 'FCC-certified internal power supplies' are false."

In fact, an FCC certification can be issued collectively only to a base unit consisting of a computer case, motherboard, and power supply. Thus, a power supply purported to be FCC-listed was actually listed along with a particular case and motherboard—not necessarily the same case and motherboard you are using in your system. This does not mean, however, that the manufacturer is being deceitful or that the power supply is inferior. If anything, this means that when evaluating power supplies, you should place less weight on the FCC certification than on other factors, such as UL certification.

Power-Use Calculations

When expanding or upgrading your PC, you should ensure that your power supply is capable of providing sufficient current to power all the system's internal devices. One way to see whether your system is capable of expansion is to calculate the levels of power drain in the various system components and deduct the total from the maximum power supplied by the power supply. This calculation can help you decide whether you must upgrade the power supply to a more capable unit. Unfortunately, these calculations can be difficult to make because many manufacturers do not publish power consumption data for their products.

In addition, getting power-consumption data for many +5V devices, including motherboards and adapter cards, can be difficult. Motherboards can consume different power levels, depending on numerous factors. Most motherboards consume about 5 amps or so, but try to get information on the one you are using. For adapter cards, if you can find the actual specifications for the card, use those figures. To be on the conservative side, however, I usually go by the maximum available power levels set forth in the respective bus standards.

For example, consider the power-consumption figures for components in a modern PC, such as a desktop or Slimline system with a 200-watt power supply rated for 20 amps at +5V and 8 amps at +12V. The ISA specification calls for a maximum of 2.0 amps of +5V power and 0.175 amps of +12V power for each slot in the system. Most systems have eight slots, and you can assume that four are filled for the purposes of calculating power draw. The calculation shown in Table 21.16 shows what happens when you subtract the amount of power necessary to run the various system components.

Table 21.16 Power Consumption Calculation

	Available 5V Power (Amps):	20.0A		Available 12V Power (Amps):	8.0A
Less:	Motherboard	–5.0A	Less:	4 slots filled at 0.175 each	–0.7A
	4 slots filled at 2.0 each	–8.0A		3 1/2-inch hard disk drive motor	–1.0A
	3 1/2-inch floppy drive logic	–0.5A		3 1/2-inch floppy drive motor	–1.0A
	3 1/2-inch hard disk drive logic	–0.5A		Cooling fan motor	–0.1A
	CD-ROM/DVD drive logic	–1.0A		CD-ROM/DVD drive motor	–1.0A
	Remaining Power (amps):	5.0A		Remaining Power (amps):	4.2A

In the preceding example, everything seems all right for the present. With half the slots filled, a floppy drive, and one hard disk, the system still has room for more. Problems with the power supply could come up, however, if this system were expanded to the extreme. With every slot filled and two or more hard disks, problems with the +5V current definitely would occur. However, the +12V does seem to have room to spare. You could add a CD-ROM drive or a second hard disk without worrying too much about the +12V power, but the +5V power would be strained.

If you anticipate loading up a system to the extreme—as in a high-end multimedia system, for example—you might want to invest in the insurance of a higher-output power supply. For example, a 250-watt supply usually has 25 amps of +5V current and 10 amps of +12V current, whereas a 300-watt unit usually has 32 amps of +5V current available. These supplies enable you to fully load the system and are likely to be found in full-sized desktop or tower case configurations in which this type of expansion is expected.

Motherboards can draw anywhere from 4 to 15 amps or more of +5V power to run. In fact, a single Pentium 66MHz CPU draws up to 3.2 amps of +5V power all by itself. A 200MHz Pentium Pro CPU or 400MHz Pentium II consumes up to 15 amps. Considering that systems with two or more processors are now becoming common, you could have 30 amps or more drawn by the processors alone. A motherboard such as this—with two CPUs and 128MB or more of RAM for each CPU—might draw more than 40 amps all by itself. Very few “no-name” power supplies can supply this kind of current. For these applications, you should consider only high-quality, high-capacity power supplies from a reputable manufacturer, such as PC Power and Cooling.

In these calculations, bus slots are allotted maximum power in amps, as shown in Table 21.17.

Table 21.17 Maximum Power Consumption in Amps per Bus Slot

Bus Type	+5V Power	+12V Power	+3.3V Power
ISA	2.0	0.175	n/a
EISA	4.5	1.5	n/a
VL-bus	2.0	n/a	n/a
16-bit MCA	1.6	0.175	n/a
32-bit MCA	2.0	0.175	n/a
PCI	5	0.5	7.6

As you can see from the table, ISA slots are allotted 2.0 amps of +5V and 0.175 amps of +12V power. Note that these are maximum figures; not all cards draw this much power. If the slot has a VL-bus extension connector, an additional 2.0 amps of +5V power are allowed for the VL-bus.

Floppy drives can vary in power consumption, but most of the newer 3 1/2-inch drives have motors that run on +5V current in addition to the logic circuits. These drives usually draw 1.0 amps of +5V power and use no +12V at all. 5 1/4-inch drives use standard +12V motors that draw about 1.0 amps. These drives also require about 0.5 amps of +5V for the logic circuits. Most cooling fans draw about 0.1 amps of +12V power, which is negligible.

Typical 3 1/2-inch hard disks today draw about 1 amp of +12V power to run the motors and only about 0.5 amps of +5V power for the logic. 5 1/4-inch hard disks, especially those that are full-height, draw much more power. A typical full-height hard drive draws 2.0 amps of +12V power and 1.0 amp of +5V power.

Another problem with hard disks is that they require much more power during the spinup phase of operation than during normal operation. In most cases, the drive draws double the +12V power during spinup, which can be 4.0 amps or more for the full-height drives. This tapers off to a normal level after the drive is spinning.

The figures that most manufacturers report for maximum power supply output are full duty-cycle figures. The power supply can supply these levels of power continuously. You usually can expect a unit that continuously supplies a given level of power to be capable of exceeding this level for some noncontinuous amount of time. A supply usually can offer 50% greater output than the continuous figure indicates for as long as one minute. Systems often use this cushion to supply the necessary power to spin up a hard disk drive. After the drive has spun to full speed, the power draw drops to a value within the system's continuous supply capabilities. Drawing anything over the rated continuous figure for any extended length of time causes the power supply to run hot and fail early, and it can also create nasty symptoms in the system.

Tip

If you are using internal SCSI hard drives, you can ease the startup load on your power supply. The key is to enable the SCSI drive's Remote Start option, which causes the drive to start spinning only when it receives a startup command over the SCSI bus. The effect is that the drive remains stationary (drawing very little power) until the very end of the POST and spins up right when the SCSI portion of the POST is begun.

If you have multiple SCSI drives, they all spin up sequentially based on their SCSI ID settings. This is designed so that only one drive is spinning up at any one time and so that no drives start spinning until the rest of the system has had time to start. This greatly eases the load on the power supply when you first power the system on.

In most cases, you enable Remote Start through your SCSI host adapter's setup program. This program might be supplied with the adapter on separate media, or it might be integrated into the adapter's BIOS and activated with a specific key combination at boot time.

The biggest cause of power supply overload problems has historically been filling up the expansion slots and adding more drives. Multiple hard drives, CD-ROM drives, and floppy drives can create quite a drain on the system power supply. Make sure that you have enough +12V power to run all the drives you plan to install. Tower systems can be especially problematic because they have so many drive bays. Just because the case has room for the devices doesn't mean the power supply can support them. Be sure you have enough +5V power to run all your expansion cards, especially PCI cards. It pays to be conservative, but remember that most cards draw less than the maximum allowed. Today's newest processors can have very high current requirements for the +5- or +3.3-volt supplies. When selecting a power supply for your system, be sure to take into account any future processor upgrades.

Many people wait until an existing component fails to replace it with an upgraded version. If you are on a tight budget, this "if it ain't broke, don't fix it" attitude might be necessary. Power supplies, however, often do not fail completely all at once; they can fail in an intermittent fashion or allow fluctuating power levels to reach the system, which results in unstable operation. You might be blaming system lockups on software bugs when the culprit is an overloaded power supply. If you have been running your original power supply for a long time and have upgraded your system in other ways, you should expect some problems.

Although there is certainly an appropriate place for the exacting power-consumption calculations you've read about in this section, a great many experienced PC users prefer the "don't worry about it" power calculation method. This technique consists of buying or building a system with a good-quality 300-watt or higher power supply (or upgrading to such a supply in an existing system) and then upgrading the system freely, without concern for power consumption.

Tip

My preference is the 425W supply from PC Power and Cooling, which is probably overkill for most people, but for those who keep a system for a long time and put it through a number of upgrades, it is an excellent choice.

Unless you plan to build a system with arrays of SCSI drives and a dozen other peripherals, you will probably not exceed the capabilities of the power supply, and this method certainly requires far less effort.

Power Off When Not in Use

Should you turn off a system when it is not in use? To answer this frequent question, you should understand some facts about electrical components and what makes them fail. Combine this knowledge with information on power consumption, cost, and safety to come to your own conclusion. Because circumstances can vary, the best answer for your own situation might be different from the answer for others, depending on your particular needs and applications.

Frequently, powering a system on and off does cause deterioration and damage to the components. This seems logical, but the simple reason is not obvious to most people. Many believe that flipping system power on and off frequently is harmful because it electrically "shocks" the system. The real problem, however, is temperature or thermal shock. As the system warms up, the components expand; as it cools off, the components contract. In addition, various materials in the system have different thermal expansion coefficients, which means that they expand and contract at different rates. Over time, thermal shock causes deterioration in many areas of a system.

From a pure system-reliability viewpoint, you should insulate the system from thermal shock as much as possible. When a system is turned on, the components go from ambient (room) temperature to as high as 185° F (85° C) within 30 minutes or less. When you turn off the system, the same thing happens in reverse, and the components cool back to ambient temperature in a short period of time.

Thermal expansion and contraction remains the single largest cause of component failure. Chip cases can split, allowing moisture to enter and contaminate them. Delicate internal wires and contacts can break, and circuit boards can develop stress cracks. Surface-mounted components expand and contract at rates different from the circuit board they are mounted on, which causes enormous stress at the solder joints. Solder joints can fail due to the metal hardening from the repeated stress, resulting in cracks in the joint. Components that use heatsinks, such as processors, transistors, or voltage regulators, can overheat and fail because the thermal cycling causes heatsink adhesives to deteriorate and break the thermally conductive bond between the device and the heatsink. Thermal cycling also causes socketed devices and connections to loosen or *creep*, which can cause a variety of intermittent contact failures.

◀◀ See "SIMMs, DIMMs, and RIMMs," p. 421.

Thermal expansion and contraction affect not only chips and circuit boards, but also things such as hard disk drives. Most hard drives today have sophisticated thermal compensation routines that make adjustments in head position relative to the expanding and contracting platters. Most drives perform this thermal compensation routine once every 5 minutes for the first 30 minutes the drive is running, and then every 30 minutes thereafter. In many drives, this procedure can be heard as a rapid "tick-tick-tick-tick" sound. In essence, anything you can do to keep the system at a constant temperature prolongs the life of the system, and the best way to accomplish this is to leave the system either permanently on or permanently off. Of course, if the system is never turned on in the first place, it should last a long time indeed!

Now, I am not saying that you should leave all systems on 24 hours a day. A system powered on and left unattended can be a fire hazard (I have had monitors spontaneously catch fire—luckily, I was there at the time), is a data security risk (from cleaning crews and other nocturnal visitors), can be easily damaged if moved while running, and wastes electrical energy.

I currently pay 11 cents for a kilowatt-hour of electricity. A typical desktop-style PC with display consumes at least 300 watts (0.3 kilowatt) of electricity (and that is a conservative estimate). This means it would cost 3.3 cents to run my typical PC for an hour. Multiplying by 168 hours in a week means that it would cost $5.54 per week to run this PC continuously. If the PC were turned on at 9 a.m. and off at 5 p.m., it would be on only 40 hours per week and would cost only $1.32—a savings of $4.22 per week! Multiply this savings by 100 systems, and you are saving $422 per week. Multiply this by 1,000 systems, and you are saving $4,220 per week! Using systems listed under the EPA Energy Star program (so-called green PCs) would account for an additional savings of around $1 per system per week—or $1,000 per week for 1,000 systems. The great thing about Energy Star systems is that the savings are even greater if the systems are left on for long periods of time because the power management routines are automatic.

Based on these facts, my recommendations are that you power on the systems at the beginning of the workday and off at the end of the workday. Do not power the systems off for lunch, breaks, or any other short periods of time. If you are a home user, leave your computer on if you are going to be using it later in the day or if instant access is important. I'd normally recommend home users turn off the system when leaving the house or when sleeping. Servers, of course, should be left on continuously. This seems to be the best compromise of system longevity with pure economics. No matter what, these are just guidelines; if it works better for you to leave your system on 24 hours a day, seven days a week, make it so.

Power Management

As the standard PC configuration has grown to include capabilities formerly considered options, the power requirements of the system have increased steadily. Larger displays, CD-ROM drives, and audio adapters all need more power to run, and the cost of operating a PC rises steadily. To address these concerns, several programs and standards are now being developed that are intended to reduce the power needed to run a PC as much as possible.

For standard desktop systems, power management is a matter of economy and convenience. By turning off specific components of the PC when they are not in use, you can reduce the electric bill and avoid having to power the computer up and down manually.

For portable systems, power management is far more important. Adding CD-ROMs, speakers, and other components to a laptop or notebook computer reduces even further what is in many cases a short battery life. By adding new power management technology, a portable system can supply power only to the components it actually needs to run, thus extending the life of the battery charge.

Energy Star Systems

The EPA has started a certification program for energy-efficient PCs and peripherals. To be a member of this program, the PC or display must drop to a power draw at the outlet of 30 watts or less during periods of inactivity. Systems that conform to this specification get to wear the Energy Star logo. This is a voluntary program; however, many PC manufacturers are finding that it helps them sell their systems if they can advertise these systems as energy efficient.

One problem with this type of system is that the motherboard and disk drives can go to sleep, which means they can enter a standby mode in which they draw very little power. This causes havoc with some of the older power supplies because the low power draw does not provide enough of a load for them to function properly. Most of the newer supplies on the market, which are designed to work with these systems, have a very low minimum-load specification. I suggest you ensure that the minimum load will be provided by the equipment in your system if you buy a power supply upgrade. Otherwise, when the PC goes to sleep, it might take a power switch cycle to wake it up again. This problem would be most noticeable if you invested in a very high-output supply and used it in a system that draws very little power to begin with.

Advanced Power Management

Advanced Power Management (APM) is a specification jointly developed by Intel and Microsoft that defines a series of interfaces between power management–capable hardware and a computer's operating system. When it is fully activated, APM can automatically switch a computer between five states, depending on the system's current activity. Each state represents a further reduction in power use, accomplished by placing unused components into a low-power mode. The five system states are as follows:

- *Full On*. The system is completely operational, with no power management occurring.
- *APM Enabled*. The system is operational, with some devices being power managed. Unused devices can be powered down and the CPU clock slowed or stopped.
- *APM Standby*. The system is not operational, with most devices in a low-power state. The CPU clock can be slowed or stopped, but operational parameters are retained in memory. When triggered by a specific user or system activities, the system can return to the APM Enabled state almost instantaneously.
- *APM Suspend*. The system is not operational, with most devices unpowered. The CPU clock is stopped and operational parameters are saved to disk for later restoration. When triggered by a wakeup event, the system returns to the APM Enabled state relatively slowly.
- *Off*. The system is not operational. The power supply is off.

APM requires support from both hardware and software to function. In this chapter, you've already seen how ATX-style power supplies can be controlled by software commands using the Power_On signal and the six-pin optional power connector. Manufacturers are also integrating the same sort of control features into other system components, such as motherboards, monitors, and disk drives.

Operating systems that support APM, such as Windows 9x, trigger power management events by monitoring the activities performed by the computer user and the applications running on the system. However, the OS does not directly address the power management capabilities of the hardware.

A system can have many hardware devices and many software functions participating in APM functions, which makes communication difficult. To address this problem, both the operating system and the hardware have an abstraction layer that facilitates communication between the various elements of the APM architecture.

The operating system runs an APM driver that communicates with the various applications and software functions that trigger power management activities, while the system's APM-capable hardware devices all communicate with the system BIOS. The APM driver and the BIOS communicate directly, completing the link between the OS and the hardware.

Thus, for APM to function, support for the standard must be built into the system's individual hardware devices, the system BIOS, and the operating system (which includes the APM driver). Without all these components, APM activities cannot occur.

Advanced Configuration and Power Interface

Advanced Configuration and Power Interface (ACPI) is a newer power management and system configuration standard supported by newer system BIOS software running Windows 98 and later operating systems. If your BIOS and operating system support ACPI, full power management control is now done by the operating system, rather than by the BIOS. ACPI is intended to offer a single place for power management and system configuration control; in the past, with APM you would often be able to make power management settings in the BIOS setup as well as the operating system that often overlapped or could have conflicting settings. ACPI is supported in newer systems in lieu of APM.

Tip

If, for any reason, you find that power management activities cause problems on your system, such as operating system freeze-ups or hardware malfunctions, the easiest way to disable APM is through the system BIOS. Most BIOSes that support APM include an option to disable it. This breaks the chain of communication between the operating system and the hardware, causing all power management activities to cease. Although you also can achieve the same end by removing the APM driver from the operating system, Windows 9x's Plug-and-Play (PnP) feature detects the system's APM capabilities whenever you restart the computer and attempts to reinstall the APM driver.

If you have a newer system with ACPI, you can disable the power management settings via the Power Management icon in the Windows control panel.

Power Supply Troubleshooting

Troubleshooting the power supply basically means isolating the supply as the cause of problems within a system and, if necessary, replacing it.

Caution

It is rarely recommended that an inexperienced user open a power supply to make repairs because of the dangerous high voltages present. Even when unplugged, power supplies can retain dangerous voltage and must be discharged (like a monitor) before service. Such internal repairs are beyond the scope of this book and are specifically not recommended unless the technician knows what he or she is doing.

Many symptoms lead me to suspect that the power supply in a system is failing. This can sometimes be difficult for an inexperienced technician to see because, at times little connection seems to exist between the symptom and the cause—the power supply.

For example, in many cases a parity check error message can indicate a problem with the power supply. This might seem strange because the parity check message specifically refers to memory that has failed. The connection is that the power supply powers the memory, and memory with inadequate power fails.

It takes some experience to know when this type of failure is power related and not caused by the memory. One clue is the repeatability of the problem. If the parity check message (or other problem) appears frequently and identifies the same memory location each time, I would suspect that defective memory is the problem. However, if the problem seems random, or if the memory location the error message cites as having failed seems random, I would suspect improper power as the culprit. The following is a list of PC problems that often are related to the power supply:

- Any power-on or system startup failures or lockups.
- Spontaneous rebooting or intermittent lockups during normal operation.
- Intermittent parity check or other memory-type errors.
- Hard disk and fan simultaneously failing to spin (no +12V).
- Overheating due to fan failure.
- Small brownouts cause the system to reset.
- Electric shocks felt on the system case or connectors.
- Slight static discharges disrupt system operation.

In fact, just about any intermittent system problem can be caused by the power supply. I always suspect the supply when flaky system operation is a symptom. Of course, the following fairly obvious symptoms point right to the power supply as a possible cause:

- System is completely dead (no fan, no cursor)
- Smoke
- Blown circuit breakers

If you suspect a power supply problem, some of the simple measurements and the more sophisticated tests outlined in this section can help you determine whether the power supply is at fault. Because these measurements might not detect some intermittent failures, you might have to use a spare power supply for a long-term evaluation. If the symptoms and problems disappear when a known good spare unit is installed, you have found the source of your problem.

Following is a simple flowchart to help you zero in on common power supply–related problems:

1. Check AC power input. Make sure the cord is firmly seated in the wall socket and in the power supply socket. Try a different cord.
2. Check DC power connections. Make sure the motherboard and disk drive power connectors are firmly seated and making good contact. Check for loose screws.
3. Check DC power output. Use a digital multimeter to check for proper voltages. If it's below spec, replace the power supply.

4. Check installed peripherals. Remove all boards and drives and retest the system. If it works, add back in items one at a time until the system fails again. The last item added before the failure returns is likely defective.

Many types of symptoms can indicate problems with the power supply. Because the power supply literally powers everything else in the system, everything from disk drive problems to memory problems to motherboard problems can often be traced back to the power supply as the root cause.

Overloaded Power Supplies

A weak or inadequate power supply can put a damper on your ideas for system expansion. Some systems are designed with beefy power supplies, as if to anticipate a great deal of system add-ons and expansion components. Most desktop or tower systems are built in this manner. Some systems have inadequate power supplies from the start, however, and cannot adequately service the power-hungry options you might want to add.

The wattage rating can sometimes be very misleading. Not all 300-watt supplies are created the same. People familiar with high-end audio systems know that some watts are better than others. This goes for power supplies, too. Cheap power supplies might in fact put out the rated power, but what about noise and distortion? Some of the supplies are under-engineered to just barely meet their specifications, whereas others might greatly exceed their specifications. Many of the cheaper supplies provide noisy or unstable power, which can cause numerous problems with the system. Another problem with under-engineered power supplies is that they can run hot and force the system to do so as well. The repeated heating and cooling of solid-state components eventually causes a computer system to fail, and engineering principles dictate that the hotter a PC's temperature, the shorter its life. Many people recommend replacing the original supply in a system with a heavier-duty model, which solves the problem. Because power supplies come in common form factors, finding a heavy-duty replacement for most systems is easy, as is the installation process.

Inadequate Cooling

Some of the available replacement power supplies have higher-capacity cooling fans than the originals, which can greatly prolong system life and minimize overheating problems—especially for the newer, hotter-running processors. If system noise is a problem, models with special fans can run more quietly than the standard models. These power supplies often use larger-diameter fans that spin more slowly, so they run more quietly but move the same amount of air as the smaller fans. PC Power and Cooling specializes in heavy-duty and quiet supplies; Astec has several heavy-duty models as well.

Ventilation in a system is also important. You must ensure adequate airflow to cool the hotter items in the system. Many processors today use passive heatsinks that require a steady stream of air to cool the chip. If the processor heatsink has its own fan, this is not much of a concern. If you have free expansion slots, you should space out the boards in your system to permit airflow between them. Place the hottest running boards nearest the fan or the ventilation holes in the system. Make sure that adequate airflow exists around the hard disk drive, especially for those that spin at high rates of speed. Some hard disks can generate quite a bit of heat during operation. If the hard disks overheat, data can be lost.

Always make sure you run your computer with the case cover on, especially if you have a loaded system. Removing the cover can actually cause a system to overheat. With the cover off, the power supply fan no longer draws air through the system. Instead, the fan ends up cooling the supply only, and the rest of the system must be cooled by simple convection. Although most systems do not immediately overheat for this reason, several of my own systems, especially those that are fully expanded, have overheated within 15–30 minutes when run with the case cover off.

In addition, be sure that any empty slot positions have the filler brackets installed. If you leave these brackets off after removing a card, the resultant hole in the case disrupts the internal airflow and can cause higher internal temperatures.

If you experience intermittent problems that you suspect are related to overheating, a higher-capacity replacement power supply is usually the best cure. Specially designed supplies with additional cooling fan capacity also can help. At least one company sells a device called a fan card, but I am not convinced these are a good idea. Unless the fan is positioned to draw air to or from outside the case, all it does is blow hot air around inside the system and provide a spot cooling effect for anything it is blowing on. In fact, adding fans in this manner contributes to the overall heat inside the system because the fan consumes power and generates heat.

CPU-mounted fans are an exception because they are designed only for spot cooling of the CPU. Many newer processors run so much hotter than the other components in the system that a conventional, finned aluminum heatsink cannot do the job. In this case, a small fan placed directly over the processor provides a spot cooling effect that keeps the processor temperatures down. One drawback to these active processor cooling fans is that the processor overheats instantly and can be damaged if they fail. Whenever possible, try to use the biggest passive (finned aluminum) heatsink you can find and purchase a CPU fan from a reputable vendor.

Using Digital Multimeters

One simple test you can perform on a power supply is to check the output voltages. This shows whether a power supply is operating correctly and whether the output voltages are within the correct tolerance range. Note that you must measure all voltages with the power supply connected to a proper load, which usually means testing while the power supply is still installed in the system and connected to the motherboard and peripheral devices.

Selecting a Meter

You need a simple Digital Multimeter (DMM) or Digital Volt-Ohm Meter (DVOM) to perform voltage and resistance checks on electronic circuits (see Figure 21.22). You should use only a DMM instead of the older needle-type multimeters because the older meters work by injecting 9V into the circuit when measuring resistance, which damages most computer circuits.

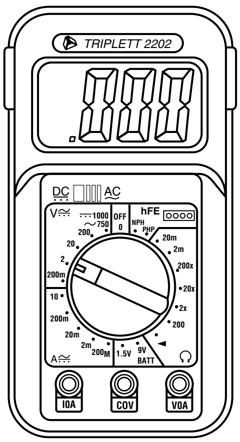

Figure 21.22 A typical DMM.

A DMM uses a much smaller voltage (usually 1.5V) when making resistance measurements, which is safe for electronic equipment. You can get a good DMM with many features from several sources. I prefer the small, pocket-size meters for computer work because they are easy to carry around.

Some features to look for in a good DMM are as follows:

- *Pocket size.* This is self-explanatory, but small meters are available that have many, if not all, of the features of larger ones. The elaborate features found on some of the larger meters are not really necessary for computer work.
- *Overload protection.* This means that if you plug the meter into a voltage or current beyond the meter's capability to measure, the meter protects itself from damage. Cheaper meters lack this protection and can be easily damaged by reading current or voltage values that are too high.
- *Autoranging.* This means that the meter automatically selects the proper voltage or resistance range when making measurements. This is preferable to the manual range selection; however, really good meters offer both autoranging capability and a manual range override.
- *Detachable probe leads.* The leads easily can be damaged, and sometimes a variety of differently shaped probes are required for different tests. Cheaper meters have the leads permanently attached, which means you cannot easily replace them. Look for a meter with detachable leads that plug into the meter.
- *Audible continuity test.* Although you can use the ohm scale for testing continuity (0 ohms indicates continuity), a continuity test function causes the meter to produce a beep noise when continuity exists between the meter test leads. By using the sound, you quickly can test cable assemblies and other items for continuity. After you use this feature, you will never want to use the ohms display for this purpose again.
- *Automatic power off.* These meters run on batteries, and the batteries can easily be worn down if the meter is accidentally left on. Good meters have an automatic shutoff that turns off the unit when it senses no readings for a predetermined period of time.
- *Automatic display hold.* This feature enables you to hold the last stable reading on the display even after the reading is taken. This is especially useful if you are trying to work in a difficult-to-reach area single-handedly.
- *Minimum and maximum trap.* This feature enables the meter to trap the lowest and highest readings in memory and hold them for later display, which is especially useful if you have readings that are fluctuating too quickly to see on the display.

Although you can get a basic pocket DMM for as little as $20, one with all these features is priced in the $100–$200 range. Radio Shack carries some nice inexpensive units, and you can purchase the high-end models from electronics supply houses, such as Newark or Digi-Key.

Measuring Voltage

To measure voltages on a system that is operating, you must use a technique called *back probing* on the connectors (see Figure 21.23). You cannot disconnect any of the connectors while the system is running, so you must measure with everything connected. Nearly all the connectors you need to probe have openings in the back where the wires enter the connector. The meter probes are narrow enough to fit into the connector alongside the wire and make contact with the metal terminal inside. The technique is called back probing because you are probing the connector from the back. You must use this back-probing technique to perform virtually all the following measurements.

To test a power supply for proper output, check the voltage at the Power_Good pin (P8-1 on AT, Baby-AT, and LPX supplies; pin 8 on the ATX-type connector) for +3V to +6V of power. If the measurement is not within this range, the system never sees the Power_Good signal and therefore does not start or run properly. In most cases, the power supply is bad and must be replaced.

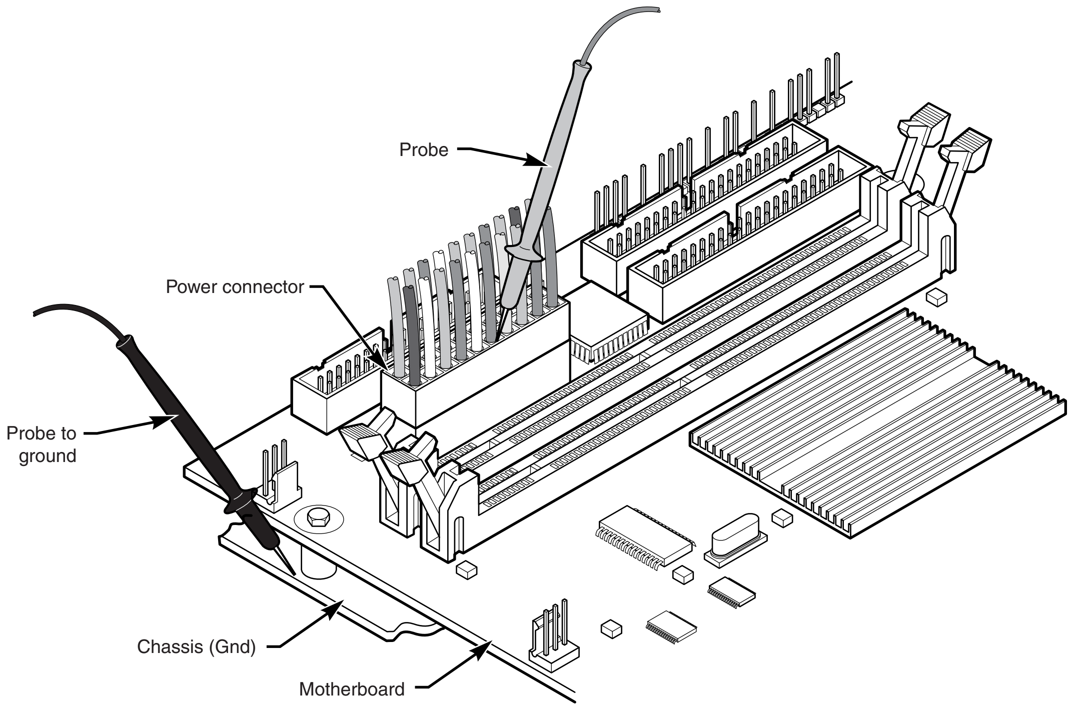

Figure 21.23 Back probing the power supply connectors.

Continue by measuring the voltage ranges of the pins on the motherboard and drive power connectors. If you are measuring voltages for testing purposes, any reading within 10% of the specified voltage is considered acceptable, although most manufacturers of high-quality power supplies specify a tighter 5% tolerance. For ATX power supplies, the specification requires that voltages must be within 5% of the rating, except for the 3.3V current, which must be within 4%. The following table shows the voltage ranges within these tolerances.

Desired Voltage	Min. (-10%)	Loose Tolerance Max. (+8%)	Min. (-5%)	Tight Tolerance Max. (+5%)
+3.3V	2.97V	3.63V	3.135	3.465
+/–5.0V	4.5V	5.4V	4.75	5.25
+/–12.0V	10.8V	12.9V	11.4	12.6

The Power_Good signal has tolerances that are different from the other voltages, although it is nominally +5V in most systems. The trigger point for Power_Good is about +2.4V, but most systems require the signal voltage to be within the tolerances listed here:

Signal	Minimum	Maximum
Power_Good (+5V)	3.0V	6.0V

Replace the power supply if the voltages you measure are out of these ranges. Again, it is worth noting that any and all power supply tests and measurements must be made with the power supply properly loaded, which usually means it must be installed in a system and the system must be running.

Specialized Test Equipment

You can use several types of specialized test gear to test power supplies more effectively. Because the power supply is one of the most failure-prone items in PCs today, you should have these specialized items if you service many PC systems.

Digital Infrared Thermometer

One of the greatest additions to my toolbox is a digital infrared thermometer. They also are called noncontact thermometers because they measure by sensing infrared energy without having to touch the item they are reading. This enables me to make instant spot checks of the temperature of a chip, a board, or the system chassis. They are available from companies such as Raytek (`http://www.raytek.com`) for under $100. To use these handheld items, you point at an object and then pull the trigger. Within seconds, the display shows a temperature readout. These devices are invaluable in checking to ensure your system is adequately cooled.

Variable Voltage Transformer

When testing power supplies, it is sometimes desirable to simulate different AC voltage conditions at the wall socket to observe how the supply reacts. A variable voltage transformer is a useful test device for checking power supplies because it enables you to exercise control over the AC line voltage used as input for the power supply (see Figure 21.24). This device consists of a large transformer mounted in a housing with a dial indicator that controls the output voltage. You plug the line cord from the transformer into the wall socket and plug the PC power cord into the socket provided on the transformer. The knob on the transformer can be used to adjust the AC line voltage received by the PC.

Most variable transformers can adjust their AC outputs from 0V to 140V, no matter what the AC input (wall socket) voltage is. Some can cover a range from 0V to 280V, as well. You can use the transformer to simulate brownout conditions, enabling you to observe the PC's response. Thus, you can check a power supply for proper Power_Good signal operation, among other things.

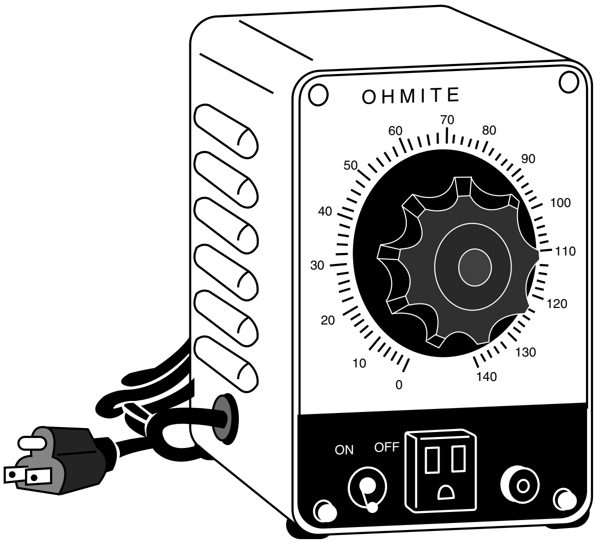

Figure 21.24 A variable voltage transformer.

By running the PC and dropping the voltage until the PC shuts down, you can see how much reserve is in the power supply for handling a brownout or other voltage fluctuations. If your transformer can output voltages in the 200V range, you can test the capability of the power supply to run on foreign voltage levels. A properly functioning supply should operate between 90V and 135V but should shut down cleanly if the voltage is outside that range.

One indication of a problem is seeing parity check-type error messages when you drop the voltage to 80V. This indicates that the Power_Good signal is not being withdrawn before the power supply output to the PC fails. The PC should simply stop operating as the Power_Good signal is withdrawn, causing the system to enter a continuous reset loop.

Variable voltage transformers are sold by a number of electronic parts supply houses, such as Newark and Digi-Key. You should expect to pay anywhere from $100 to $300 for this device.

Repairing the Power Supply

Hardly anyone actually repairs power supplies anymore, primarily because simply replacing the supply with a new one is usually cheaper. Even high-quality power supplies are not that expensive when compared to the labor required to repair them.

A defective power supply usually is discarded unless it happens to be one of the higher-quality or more expensive units. In that case, it is usually wise to send the supply out to a company that specializes in repairing power supplies and other components. These companies usually provide what is called depot repair, which means you send the supply to them, and they repair it and return it to you. If time is of the essence, most of the depot repair companies immediately send you a functional equivalent to your defective supply and take yours in as a core charge. Depot repair is the recommended way to service many PC components, such as power supplies, monitors, and printers. If you take your PC in to a conventional service outlet, they often determine which component has the problem and send it out to be depot repaired. You can do that yourself and save the markup the repair shop normally charges in such cases.

For those with experience around high voltages, you might be able to repair a failing supply with two relatively simple operations; however, these require opening the supply. I do not recommend doing so, but I mention it only as an alternative to replacement in some cases.

Most manufacturers try to prevent you from entering the supply by sealing it with special tamperproof Torx screws. These screws use the familiar Torx star driver but also have a tamper-prevention pin in the center that prevents a standard driver from working. Most tool companies, such as Jensen or Specialized, sell sets of TT (tamperproof Torx) bits, which remove the tamper-resistant screws. Other manufacturers rivet the power supply case shut, which means you must drill out the rivets to gain access.

Caution

The manufacturers place these obstacles there for a reason—to prevent entry by those who are inexperienced with high voltage. Consider yourself warned!

Obtaining Replacement Units

Most of the time, it is simply easier, safer, or less expensive (considering the time and materials involved) to replace the power supply rather than to repair it. As mentioned earlier, replacement power supplies are available from many manufacturers. Before you can shop for a supplier, however, you should consider other purchasing factors.

Deciding on a Power Supply

When you are shopping for a new power supply, you should take several factors into account. First, consider the power supply's shape, or form factor. For example, the power supply used in an AT-style system differs in size from the one used in a Slimline computer. The larger AT form factor power supplies simply will not fit into a Slimline case designed for an LPX supply. ATX supplies are consistent in size, so any ATX supply should fit any ATX chassis.

Apart from electrical considerations, power supply form factors can differ physically in their sizes, shapes, screw-hole positions, connector types, number of connectors, fan locations, and switch positions. However, systems that use the same form factor can easily interchange power supplies. When ordering a replacement supply, you need to know which form factor your system requires.

Some systems use proprietary power supply designs, which makes replacement more difficult. If a system uses one of the common form factor power supplies, replacement units are available from hundreds of vendors. An unfortunate user of a system with a nonstandard form factor supply does not have this kind of choice and must get a replacement from the original manufacturer of the system—and usually pay through the nose for the unit. Although you can find standard form factor supplies for under $100, the proprietary units from some manufacturers run as high as $400 or more. PC buyers often overlook this and discover too late the consequences of having nonstandard components in a system.

▶▶ See "Power Supply Form Factors," p. 1107.

Cheaper retail-store systems are notorious for using proprietary form factor power supplies. Even Dell has been using proprietary supplies in many of their systems. Be sure you consider this if you intend to own these types of systems out of warranty. Personally, I always insist on systems that use industry-standard power supplies, such as the ATX form factor supply found in many systems today.

Sources for Replacement Power Supplies

Because one of the most failure-prone items in PC systems is the power supply, I am often asked to recommend a replacement. Literally hundreds of companies manufacture PC power supplies, and I certainly have not tested them all. I can, however, recommend some companies whose products I have come to know and trust.

Although other high-quality manufacturers are out there, at this time I recommend power supplies from either Astec Standard Power or PC Power and Cooling.

Astec makes the power supplies used in most of the high-end systems by IBM, Hewlett-Packard, Apple, and many other name-brand systems. They have power supplies available in a number of standard form factors (AT/Tower, Baby-AT, LPX, and ATX) and a variety of output levels. They have power supplies with ratings of up to 450 watts and power supplies especially designed for Green PCs, which meet the EPA Energy Star requirements for low-power consumption. Their Green power supplies are specifically designed to achieve high efficiency at low-load conditions. Be aware that high-output supplies from other manufacturers might have problems with very low loads. Astec also makes a number of power supplies for laptop and notebook PC systems and has numerous nonPC type supplies.

PC Power and Cooling has a complete line of power supplies for PC systems. They make supplies in all the standard PC form factors used today. Versions are available in a variety of quality and output levels, from inexpensive replacements to very high-quality, high-output models with ratings of up to 600–850 watts. They even have versions with built-in battery backup and redundant power systems, and a series of special models with high-volume, low-speed (quiet) fan assemblies. Their quiet models are especially welcome to people who work in quiet homes or offices and are annoyed by the fan noise that some power supplies emanate. My favorite is their 425W ATX supply, which has specs that put most others to shame.

PC Power and Cooling also has units available that fit some of Compaq's proprietary designs. This can be a real boon if you have to service or repair Compaq systems because the PC Power and Cooling units are available in higher output ratings than Compaq's. These units cost much less than Compaq's and bolt in as direct replacements.

Tip

PC Power and Cooling also have SFX style supplies that can be used to upgrade systems with Flex-ATX boards and chassis, including E-machines and other low-cost systems. If you have one of these systems and need a high-quality replacement supply to support your upgrades, PC Power and Cooling can help.

The support offered by PC Power and Cooling is excellent as well, and they have been in business a long time, which is rare in this industry. Besides power supplies, they also have an excellent line of cases.

A high-quality power supply from either of these vendors can be one of the best cures for intermittent system problems and can go a long way toward ensuring trouble-free operation in the future.

Custom Cases

Several companies make specialized cases for unique systems. These cases offer features such as multiple drive bays, unique appearance, and specialized cooling.

Perhaps the most unique cases on the market are those by Kryotech. They market a case with a built-in refrigeration unit in the base, connected directly to a thermal plate that mounts on the CPU. The plate runs at +80° F (+27° C) and can maintain a CPU temperature in the 90°–100° F range with processors generating up to 45W. These cases also feature an LCD temperature display on the front for monitoring the temperature. A safety system shutdown is designed to trip if the processor overheats. They have models available for Socket 7, Socket 370, Slot 1, or Slot A processors.

The only drawback to these cases is the expense; they cost about $400 each. They also do not include a power supply, which would cost another $100–$200 for something 300W or greater to go with it.

Note that Kryotech does make a specialized cooling system that cools the CPU down to –40° F (–40° C), but these are only sold complete with motherboards and processors because of their specialized natures.

Another company offering special cases is PC Power and Cooling. They have a line of heavy-duty, solid steel cases with multiple drive bays for serious expansion and server use. For those who want something that's different and sure to evoke stares from all that see it, they also offer a tower case with a chrome-plated front bezel and black cover.

Using Power-Protection Systems

Power-protection systems do just what the name implies: They protect your equipment from the effects of power surges and power failures. In particular, power surges and spikes can damage computer equipment, and a loss of power can result in lost data. In this section, you learn about the four primary types of power-protection devices available and when you should use them.

Before considering any further levels of power protection, you should know that a quality power supply already affords you a substantial amount of protection. High-end power supplies from the vendors I recommend are designed to provide protection from higher-than-normal voltages and currents, and they provide a limited amount of power-line noise filtering. Some of the inexpensive aftermarket power supplies probably do not have this sort of protection. If you have an inexpensive computer, further protecting your system might be wise.

Caution

All the power-protection features in this chapter and the protection features in the power supply inside your computer require that the computer's AC power cable be connected to a ground.

Many older homes do not have three-prong (grounded) outlets to accommodate grounded devices.

Do not use a three-pronged adapter (that bypasses the three-prong requirement and enables you to connect to a two-prong socket) to plug in a surge suppressor, computer, or UPS into a two-pronged outlet. They often don't provide a good ground and can inhibit the capabilities of your power-protection devices.

You also should test your power sockets to ensure they are grounded. Sometimes outlets, despite having three-prong sockets, are not connected to a ground wire; an inexpensive socket tester (available at most hardware stores) can detect this condition.

Of course, the easiest form of protection is to turn off and unplug your computer equipment (including your modem) when a thunderstorm is imminent. When this is not possible, however, other alternatives are available.

Power supplies should stay within operating specifications and continue to run a system even if any of these power line disturbances occur:

- Voltage drop to 80V for up to 2 seconds
- Voltage drop to 70V for up to .5 seconds
- Voltage surge of up to 143V for up to 1 second

Neither most high-quality power supplies nor systems will be damaged by the following occurrences:

- Full power outage
- Any voltage drop (brownout)
- A spike of up to 2,500V

Because of their internal protection, many computer manufacturers that use high-quality power supplies state in their documentation that external surge suppressors are not needed with their systems.

To verify the levels of protection built into the existing power supply in a computer system, an independent laboratory subjected several unprotected PC systems to various spikes and surges of up to 6,000V—considered the maximum level of surge that can be transmitted to a system through an electrical outlet. Any higher voltage would cause the power to arc to the ground within the outlet. None of the systems sustained permanent damage in these tests. The worst thing that happened was that some of the systems rebooted or shut down when the surge was more than 2,000V. Each system restarted when the power switch was toggled after a shutdown.

I do not use any real form of power protection on my systems, and they have survived near-direct lightning strikes and powerful surges. The most recent incident, only 50 feet from my office, was a direct lightning strike to a brick chimney that blew the top of the chimney apart. None of my systems (which were running at the time) were damaged in any way from this incident; they just shut themselves down. I was able to restart each system by toggling the power switches. An alarm system located in the same office, however, was destroyed by this strike. I am not saying that lightning strikes or even much milder spikes and surges cannot damage computer systems—another nearby lightning strike did destroy a modem and serial adapter installed in one of my systems. I was just lucky that the destruction did not include the motherboard.

This discussion points out an important oversight in some power-protection strategies: Do not forget to provide protection from spikes and surges on the phone line.

The automatic shutdown of a computer during power disturbances is a built-in function of most high-quality power supplies. You can reset the power supply by flipping the power switch from on to off and back on again. Some power supplies even have an auto-restart function. This type of power supply acts the same as others in a massive surge or spike situation: It shuts down the system. The difference is that after normal power resumes, the power supply waits for a specified delay of 3–6 seconds and then resets itself and powers the system back up. Because no manual switch resetting is required, this feature might be desirable in systems functioning as network servers or in those found in other unattended locations.

The first time I witnessed a large surge cause an immediate shutdown of all my systems, I was extremely surprised. All the systems were silent, but the monitor and modem lights were still on. My first thought was that everything was blown, but a simple toggle of each system-unit power switch caused the power supplies to reset, and the units powered up with no problem. Since that first time, this type of shutdown has happened to me several times, always without further problems.

The following types of power-protection devices are explained in the sections that follow:

- Surge suppressors
- Phone-line surge protectors
- Line conditioners
- Standby power supplies (SPS)
- Uninterruptible power supplies (UPS)

Surge Suppressors (Protectors)

The simplest form of power protection is any one of the commercially available surge protectors—that is, devices inserted between the system and the power line. These devices, which cost between $20 and $200, can absorb the high-voltage transients produced by nearby lightning strikes and power equipment. Some surge protectors can be effective for certain types of power problems, but they offer only very limited protection.

Surge protectors use several devices, usually metal-oxide varistors (MOVs), that can clamp and shunt away all voltages above a certain level. MOVs are designed to accept voltages as high as 6,000V and divert any power above 200V to ground. MOVs can handle normal surges, but powerful surges such as a direct lightning strike can blow right through them. MOVs are not designed to handle a very high level of power and self-destruct while shunting a large surge. These devices therefore cease to function after either a single large surge or a series of smaller ones. The real problem is that you cannot easily tell when they no longer are functional. The only way to test them is to subject the MOVs to a surge, which destroys them. Therefore, you never really know whether your so-called surge protector is protecting your system.

Some surge protectors have status lights that let you know when a surge large enough to blow the MOVs has occurred. A surge suppressor without this status indicator light is useless because you never know when it has stopped protecting.

Underwriters Laboratories has produced an excellent standard that governs surge suppressors, called UL 1449. Any surge suppressor that meets this standard is a very good one and definitely offers a line of protection beyond what the power supply in your PC already offers. The only types of surge suppressors worth buying, therefore, should have two features:

- Conformance to the UL 1449 standard
- A status light indicating when the MOVs are blown

Units that meet the UL 1449 specification say so on the packaging or directly on the unit. If this standard is not mentioned, it does not conform. Therefore, you should avoid it.

Another good feature to have in a surge suppressor is a built-in circuit breaker that can be manually reset rather than a fuse. The breaker protects your system if it or a peripheral develops a short. These better surge suppressors usually cost about $40.

Phone Line Surge Protectors

In addition to protecting the power lines, it is critical to provide protection to your systems from any connected phone lines. If you are using a modem or fax board that is plugged into the phone system, any surges or spikes that travel through the phone line can damage your system. In many areas, the phone lines are especially susceptible to lightning strikes, which are the leading cause of fried modems and damage to the computer equipment attached to them.

Several companies manufacture or sell simple surge protectors that plug in between your modem and the phone line. These inexpensive devices can be purchased from most electronics supply houses. Most of the cable and communication products vendors listed in the Vendor List sell these phone line surge protectors. Some of the standard power line surge protectors include connectors for phone line protection as well.

Line Conditioners

In addition to high-voltage and current conditions, other problems can occur with incoming power. The voltage might dip below the level needed to run the system, resulting in a brownout. Forms of electrical noise other than simple voltage surges or spikes might travel through the power line, such as radio-frequency interference or electrical noise caused by motors or other inductive loads.

Remember two things when you wire together digital devices (such as computers and their peripherals):

- Any wire can act as an antenna and have voltage induced in it by nearby electromagnetic fields, which can come from other wires, telephones, CRTs, motors, fluorescent fixtures, static discharge, and, of course, radio transmitters.
- Digital circuitry responds with surprising efficiency to noise of even a volt or two, making those induced voltages particularly troublesome. The electrical wiring in your building can act as an antenna, picking up all kinds of noise and disturbances.

A line conditioner can handle many of these types of problems. A line conditioner is designed to remedy a variety of problems. It filters the power, bridges brownouts, suppresses high-voltage and current conditions, and generally acts as a buffer between the power line and the system. A line conditioner does the job of a surge suppressor, and much more. It is more of an active device, functioning continuously, rather than a passive device that activates only when a surge is present. A line conditioner provides true power conditioning and can handle myriad problems. It contains transformers, capacitors, and other circuitry that can temporarily bridge a brownout or low-voltage situation. These units usually cost $100–$300, depending on the power-handling capacity of the unit.

Backup Power

The next level of power protection includes backup power-protection devices. These units can provide power in case of a complete blackout, thereby providing the time necessary for an orderly system shutdown. Two types are available: the standby power supply (SPS) and the uninterruptible power supply (UPS). The UPS is a special device because it does much more than just provide backup power: It is also the best kind of line conditioner you can buy.

Standby Power Supplies

A standby power supply is known as an offline device: It functions only when normal power is disrupted. An SPS system uses a special circuit that can sense the AC line current. If the sensor detects a loss of power on the line, the system quickly switches over to a standby battery and power inverter. The power inverter converts the battery power to 110V AC power, which is then supplied to the system.

SPS systems do work, but sometimes a problem occurs during the switch to battery power. If the switch is not fast enough, the computer system shuts down or reboots anyway, which defeats the purpose of having the backup power supply. A truly outstanding SPS adds to the circuit a ferroresonant transformer, a large transformer with the capability to store a small amount of power and deliver it during the switch time. This device functions as a buffer on the power line, giving the SPS almost uninterruptible capability.

SPS units also might have internal line conditioning of their own. Under normal circumstances, most cheaper units place your system directly on the regular power line and offer no conditioning. The addition of a ferroresonant transformer to an SPS gives it additional regulation and protection capabilities because of the buffer effect of the transformer. SPS devices without the ferroresonant transformer still require the use of a line conditioner for full protection. SPS systems usually cost from a couple hundred to several thousand dollars, depending on the quality and power-output capacity.

Uninterruptible Power Supplies

Perhaps the best overall solution to any power problem is to provide a power source that is conditioned and that cannot be interrupted—which is the definition of an uninterruptible power supply. UPSes are known as online systems because they continuously function and supply power to your computer systems. Because some companies advertise ferroresonant SPS devices as though they were UPS devices, many now use the term *true UPS* to describe a truly online system. A true UPS system is constructed in much the same way as an SPS system; however, because the computer is always operating from the battery, there is no switching circuit.

In a true UPS, your system always operates from the battery. A voltage inverter converts from 12V DC to 110V AC. You essentially have your own private power system that generates power independently of the AC line. A battery charger connected to the line or wall current keeps the battery charged at a rate equal to or greater than the rate at which power is consumed.

When the AC current supplying the battery charger fails, a true UPS continues functioning undisturbed because the battery-charging function is all that is lost. Because the computer was already running off the battery, no switch takes place, and no power disruption is possible. The battery begins discharging at a rate dictated by the amount of load your system places on the unit, which (based on the size of the battery) gives you plenty of time to execute an orderly system shutdown. Based on an appropriately scaled storage battery, the UPS functions continuously, generating power and preventing unpleasant surprises. When the line power returns, the battery charger begins recharging the battery, again with no interruption.

Note

Occasionally, a UPS can accumulate too much storage and not enough discharge. When this occurs, the UPS emits a loud alarm, alerting you that it's full. Simply unplugging the unit from the AC power source for a while can discharge the excess storage (as it powers your computer) and drain the UPS of the excess.

Many SPS systems are advertised as though they are true UPS systems. The giveaway is the unit's switch time. If a specification for switch time exists, the unit cannot be a true UPS because UPS units never switch. However, a good SPS with a ferroresonant transformer can virtually equal the performance of a true UPS at a lower cost.

Note

Many UPSes today come equipped with a cable and software that enables the protected computer to shut down in an orderly manner on receipt of a signal from the UPS. This way, the system can shut down properly even if the computer is unattended. Some operating systems, such as Windows NT/2000, contain their own UPS software components.

UPS cost is a direct function of both the length of time it can continue to provide power after a line current failure and how much power it can provide. You therefore should purchase a UPS that provides enough power to run your system and peripherals and enough time to close files and provide an orderly shutdown. Remember, however, to manually perform a system shutdown procedure during a power outage. You will probably need your monitor plugged into the UPS and the computer. Be sure the UPS you purchase can provide sufficient power for all the devices you must connect to it.

Because of a true UPS's almost total isolation from the line current, it is unmatched as a line conditioner and surge suppressor. The best UPS systems add a ferroresonant transformer for even greater power conditioning and protection capability. This type of UPS is the best form of power protection available. The price, however, can be high. To find out just how much power your computer system requires, look at the UL sticker on the back of the unit. This sticker lists the maximum power draw in watts, or sometimes in just volts and amperes. If only voltage and amperage are listed, multiply the two figures to calculate the wattage.

As an example, if the documentation for a system indicates that the computer can require as much as 110V at a maximum current draw of 5 amps, the maximum power the system can draw is about 550 watts. This wattage is for a system with every slot full, two hard disks, and one floppy—in other words, a system at the maximum possible level of expansion. The system should never draw any more power than that; if it does, a 5-amp fuse in the power supply will blow. This type of system normally draws an average of 300 watts; to be safe when you make calculations for UPS capacity, however, be conservative. Use the 550-watt figure. Adding a monitor that draws 100 watts brings the total to 650 watts or more. Therefore, to run two fully loaded systems, you'll need a 1,100-watt UPS. Don't forget two monitors, each drawing 100 watts. Therefore, the total is 1,300 watts. A UPS of that capacity or greater will cost approximately $500–$700. Unfortunately, that is what the best level of protection costs. Most companies can justify this type of expense only for critical-use PCs, such as network servers.

Note

The highest-capacity UPS sold for use with a conventional 15-amp outlet is about 1,400 watts. If it's any higher, you risk tripping a 15-amp circuit when the battery is charging heavily and the inverter is drawing maximum current.

In addition to the total available output power (wattage), several other factors can distinguish one UPS from another. The addition of a ferroresonant transformer improves a unit's power conditioning and buffering capabilities. Good units also have an inverter that produces a true sine wave output; the cheaper ones might generate a square wave. A square wave is an approximation of a sine wave with abrupt up-and-down voltage transitions. The abrupt transitions of a square wave are not compatible with some computer equipment power supplies. Be sure that the UPS you purchase produces power that is compatible with your computer equipment. Every unit has a specification for how long it can sustain output at the rated level. If your systems draw less than the rated level, you have some additional time.

Caution

Be careful! Most UPS systems are not designed for you to sit and compute for hours through an electrical blackout. They are designed to provide power only to essential components and to remain operating long enough to allow for an orderly shutdown. You pay a large amount for units that provide power for more than 15 minutes or so. At some point, it becomes more cost effective to buy a generator than to keep investing in extended life for a UPS.

Some of the many sources of power protection equipment include American Power Conversion (APC), Tripp Lite, and Best Power. These companies sell a variety of UPS, SPS, line, and surge protector products.

Caution

Don't connect a laser printer to a backed-up socket in any SPS or UPS unit. Such printers are electrically noisy and have widely varying current draws. This can be hard on the inverter in an SPS or a UPS, frequently causing the inverter to fail or detect an overload and shut down. Either case means that your system will lose power, too.

Printers are normally noncritical because whatever is being printed can be reprinted. Don't connect them to a UPS unless there's a good business need to do so.

Some UPSes and SPSes have sockets that are conditioned but not backed up—that is, they do not draw power from the battery. In cases such as this, you can safely plug printers and other peripherals into these sockets.

RTC/NVRAM Batteries (CMOS Chips)

All 16-bit and higher systems have a special type of chip in them that combines a real-time clock (RTC) with at least 64 bytes (including the clock data) of Non-Volatile RAM (NVRAM) memory. This chip is officially called the RTC/NVRAM chip but is often referred to as the CMOS chip or CMOS RAM because the type of chip used is produced using a CMOS (Complementary Metal-Oxide Semiconductor) process. CMOS design chips are known for very low power consumption. This special RTC/NVRAM chip is designed to run off a battery for several years.

The original chip of this type used in the IBM AT was the Motorola 146818 chip. Although the chips used today have different manufacturers and part numbers, they all are designed to be compatible with this original Motorola part.

These chips include a real-time clock. Its function should be obvious: The clock enables software to read the date and time and preserves the date and time data even when the system is powered off or unplugged.

The NVRAM portion of the chip has another function. It is designed to store basic system configuration, including the amount of memory installed, types of floppy and hard disk drives, and other information. Some of the more modern motherboards use extended NVRAM chips with as much as 2KB or more of space to hold this configuration information. This is especially true for Plug-and-Play systems, which store not only the motherboard configuration but also the configuration of adapter cards. This system can then read this information every time you power on the system.

These chips normally are powered by some type of battery while the system is off. This battery preserves the information in the NVRAM and powers the clock. Most systems use a lithium-type battery because they have a very long life, especially at the low power draw from the typical RTC/NVRAM chip.

Some systems have a chip that has the battery embedded within it. These are made by several companies—including Dallas Semiconductor and Benchmarq. These chips are notable for their long lives. Under normal conditions, the battery will last for 10 years—which is, of course, longer than the useful life of the system. If your system uses one of the Dallas or Benchmarq modules, the battery and chip must be replaced as a unit because they are integrated. Most of the time, these chip/battery combinations are installed in a socket on the motherboard just in case a problem requires an early replacement. You can get new modules direct from the manufacturers for $18 or less, which is often less than the cost of the older separate battery alone.

Some systems do not use a battery at all. Hewlett-Packard, for example, includes a special capacitor in some of their systems that is automatically recharged anytime the system is plugged in. Note that the system does not have to be running for the capacitor to charge; it only has to be plugged in. If the system is unplugged, the capacitor will power the RTC/NVRAM chip for up to a week or more. If the system remains unplugged for a duration longer than that, the NVRAM information is lost. In that case, these systems can reload the NVRAM from a backup kept in a special flash ROM chip contained on the motherboard. The only pieces of information that will actually be missing when you repower the system will be the date and time, which will have to be reentered. By using the capacitor combined with an NVRAM backup in flash ROM, these systems have a very reliable solution that will last indefinitely.

Many systems use only a conventional battery, which can be either directly soldered into the motherboard or plugged in via a battery connector. For those systems with the battery soldered in, normally a spare battery connector exists on the motherboard where you can insert a conventional plug-in battery, should the original ever fail. In most cases, you would never have to replace the motherboard battery, even if it were completely dead.

Conventional batteries come in many forms. The best are of a lithium design because they will last from two to five years or more. I have seen systems with conventional alkaline batteries mounted in a holder; these are much less desirable because they fail more frequently and do not last as long. Also, they can be prone to leak, and if a battery leaks on the motherboard, the motherboard can be severely damaged. By far, the most commonly used battery for motherboards today is the 2032 lithium coin battery, which is about the size of a quarter and is readily available.

Besides the various battery types, the chip can require any one of several voltages. The batteries in PCs are normally 3.0V, 3.6V, 4.5V, or 6V. If you are replacing the battery, be sure your replacement is the same voltage as the one you removed from the system. Some motherboards can use batteries of several voltages. Use a jumper or switch to select the various settings. If you suspect your motherboard has this capability, consult the documentation for instructions on changing the settings. Of course, the easiest thing to do is to replace the existing battery with another of the same type.

Symptoms that indicate that the battery is about to fail include having to reset the clock on your PC every time you shut down the system (especially after moving it) and problems during the system's POST, such as drive-detection difficulties. If you experience problems such as these, you should make note of your system's CMOS settings and replace the battery as soon as possible.

Caution

When you replace a PC battery, be sure you get the polarity correct; otherwise, you will damage the RTC/NVRAM (CMOS) chip. Because the chip is soldered onto most motherboards, this can be an expensive mistake! The battery connector on the motherboard and the battery normally are keyed to prevent a backward connection. The pinout of this connector is on the CD, but it should also be listed in your system documentation.

When you replace a battery, in most cases the existing data stored in the NVRAM is lost. Sometimes, however, the data remains intact for several minutes (I have observed NVRAM retain information with no power for an hour or more), so if you make the battery swap quickly, the information in the NVRAM might be retained. Just to be sure, I recommend that you record all the system configuration settings stored in the NVRAM by your system Setup program. In most cases, you would want to run the BIOS Setup program and copy or print out all the screens showing the various settings. Some Setup programs offer the capability to save the NVRAM data to a file for later restoration if necessary.

Tip

If your system BIOS is password protected and you forget the password, one possible way to bypass the block is to remove the battery for a few minutes and then replace it. This will reset the BIOS to its default settings, removing the password protection.

After replacing a battery, power up the system and use the Setup program to check the date and time setting and any other data that was stored in the NVRAM.