Chapter 8

The Power Supply

8

One of the most failure-prone components in any computer system is the power supply. You should understand both the function and limitations of a power supply, as well as its potential problems and their solutions.

Power Supply Function and Operation

The basic function of the power supply is to convert the type of electrical power available at the wall socket to that which is usable by the computer circuitry. The power supply in a conventional desktop system is designed to convert the 120-volt, 60 Hz, AC current into something the computer can use—specifically, both +5- and +12-volt DC current. Usually, the digital electronic components and circuits in the system (motherboard, adapter cards, and disk drive logic boards) use the +5-volt power, and the motors (disk drive motors and any fans) use the +12-volt power. You must ensure a good, steady supply of both types of current so that the system can operate properly.

If you look at a specification sheet for a typical PC power supply, you see that the supply generates not only +5v and +12v, but –5v and –12v as well. Because it would seem that the +5v and +12v signals power everything in the system (logic and motors), what are the negative voltages used for? The answer is not much! In fact, these additional negative voltages are not really used at all in modern systems.

Although –5v and –12v are indeed supplied to the motherboard via the power supply connectors, the motherboard itself uses only the +5v. The –5v signal is simply routed to the ISA Bus on pin B5 and is not used in any way by the motherboard. It was originally used by the analog data separator circuits found in older floppy controllers, which is why it was supplied to the bus. Because modern controllers do not need the –5v, it is no longer used, but still is required simply because it is part of the ISA Bus standard. Note that power supplies in systems with a Micro Channel Architecture (MCA) Bus do not have –5v. This power signal was not ever needed in these systems because they always used a more modern floppy controller design.

Both the +12v and –12v signals also are not used by the motherboard logic and instead are simply routed to pins B9 and B7 of the ISA Bus (respectively). These voltages can be used by any adapter card on the bus, but most notably they are used by serial port driver/receiver circuits. If the motherboard has serial ports built-in, then the +12v and –12v signals can be used for those ports. Note that the load placed on these voltages by a serial port would be very small; for example, the PS/2 Dual Async adapter uses only 35mA of +12v and 35mA of –12v (0.035 amps each) to operate two ports.

Most newer serial port circuits no longer use 12v driver/receiver circuits, but instead use circuits that run on 5v or even 3.3v only. If you have one of these modern design ports in your system, then the –12v signal from your power supply is likely to be totally unused by anything in the system.

The main function of the +12v power is to run disk drive motors. Usually a large amount of current is available, especially in systems that have a large number of drive bays such as in a Tower configuration. Besides disk drive motors, the +12v supply also is used by any cooling fans in the system, which of course should always be running. A single cooling fan can draw between 100mA to 250mA (0.1 to 0.25 amps); however, most newer ones seem to use the lower 100mA figure. Note that although most fans do run on +12v, most portable systems use fans that run on +5v or even 3.3v instead.

In addition to simply supplying power to run the system, the power supply also ensures that the system does not run unless the power being 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 correct power levels are present. Each power supply completes internal checks and tests before allowing the system to start. The power supply sends to the motherboard a special signal, called Power_Good. If this signal is not present, the computer does not run. The effect of this setup is that when the AC voltage dips and the power supply becomes over-stressed or overheated, the Power_Good signal goes down and forces a system reset or complete shutdown. If your system has ever seemed dead when the power switch is on and the fan and hard disks are running, you know the effects of losing the Power_Good signal.

IBM originally used this conservative design with the view that if the power goes low or the supply is overheated or over-stressed, causing output power to falter, the computer shouldn't be allowed to operate. You even can use the Power_Good feature as a method of designing and implementing a reset switch for the PC. The Power_Good line is wired to the clock generator circuit (originally an 8284 or 82284 chip in the original PC/XT and AT systems), which controls the clock and reset lines to the microprocessor. When you ground the Power_Good line with a switch, the chip and related circuitry stop the processor by killing the clock signal and then reset the processor when the Power_Good signal appears after you release the switch. The result is a full hardware reset of the system. Instructions for installing such a switch in a system not already equipped can be found in Chapter 17, "System Upgrades and Improvements."

Power Supply Form Factors

The shape and general physical layout of a component is called the *form factor*, and items that share form factor are generally interchangeable. When a system is designed, the designers can choose to use one of the popular standard form factors, or they can "roll their own." Choosing the former means that a virtually inexhaustible supply of inexpensive replacements is available in a variety of quality and power output levels. Choosing to go the custom route means that the supply will be unique to the system and only available from the original manufacturer in only the model or models they produce. If you can't tell already, I am a fan of the industry-standard form factors!

The form factor of the power supply that a particular system uses is based on the case design. Four popular case and power supply types can be called "industry standard." The different types are as follows:

- PC/XT style
- AT/Tower style
- Baby AT style
- Slimline style

Each of these supplies are available in numerous different configurations and output levels.

When IBM introduced the XT, they used the same basic power supply shape as the original PC, except that the new XT supply had more than double the power output capability (see fig. 8.1). Because they were identical in external appearance as well as the type of connectors used, you easily could install the better XT supply as an upgrade for a PC system. Because of the tremendous popularity of the original PC and XT design, a number of manufacturers began building systems that mimicked the shape and layout of these IBM systems. These clones (as they have been called) could interchange virtually all components with the IBM systems, including the power supply. Numerous manufacturers have since begun producing these components, and nearly all follow the form factor of one or more IBM systems.

When IBM later introduced the AT, they created a larger power supply that had a form factor different from the original PC/XT. This system was rapidly cloned as well and to this day still represents the basis for most IBM-compatible designs. Hundreds of manufacturers now make motherboards, power supplies, cases, and so on that are physically interchangeable with the original IBM AT. If you are buying a compatible system, I recommend those that are form factor compatible with the IBM AT because you will have numerous motherboards and power supplies to choose from.

The compatible market has come up with a couple of variations on the AT theme that are popular today. One is the Tower configuration, which is basically a full-sized AT-style system running on its side. The power supply and motherboard form factors are the same in the Tower system as in the AT. The Tower configuration is 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 a tower configuration. The type of power supply used in an AT system is identical to that used in a Tower system. This type of power supply is called an AT/Tower form-factor supply (see fig. 8.2).

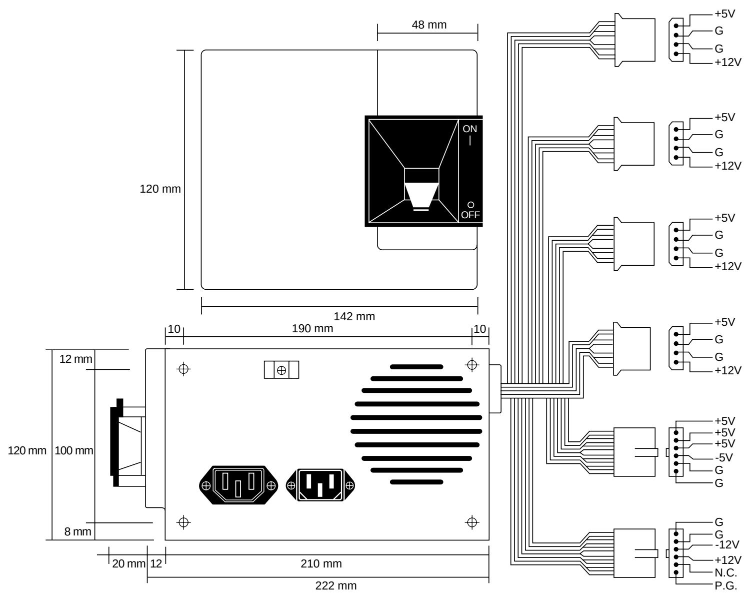

Fig. 8.1
PC/XT-style power supply.

Another type that has been developed is the so-called Baby AT, which is simply a shortened version of the AT system. The power supply in these systems is shortened on one dimension, however it matches the AT design in all other respects. These Baby AT-style power supplies can be used in both Baby AT chassis as well as the larger AT-style chassis, however the full size AT/Tower power supply does not fit in the Baby AT chassis (see fig. 8.3).

The fourth type of form factor that has developed is the Slimline (see fig. 8.4). These systems use a different motherboard configuration that mounts the slots on a "riser" card that plugs into the motherboard. The expansion cards then plug into this riser and are mounted sideways in the system. These types of systems are very low in height, hence the name "Slimline." A new power supply was specifically developed for these systems and allows interchangeability between different manufacturers' systems. Some problems with motherboard interchanges occur due to the riser cards, but the Slimline power supply has become a standard in its own right.

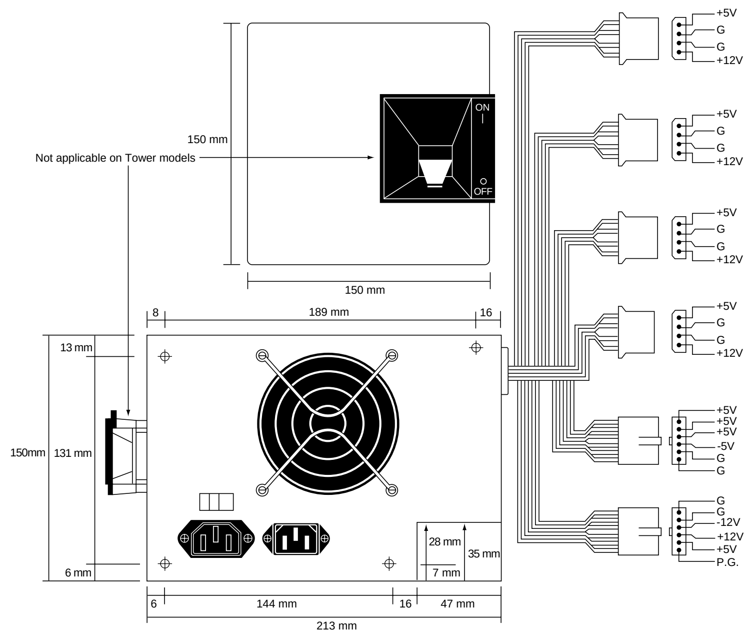

Fig. 8.2
AT/Tower-style power supply.

You will find it very easy to locate supplies that fit these industry-standard form factors. Several vendors who manufacture PC power supplies in all these form factors are listed later in this chapter. For proprietary units, you will likely have to go back to the manufacturer.

Power Supply Connectors

Table 8.1 shows the pinouts for most standard AT or PC/XT-compatible systems. Some systems may have more or fewer drive connectors, for example, IBM's AT system power supplies only have three disk drive power connectors, although most of the currently available AT/Tower type power supplies have four drive connectors. If you are adding drives and need additional disk drive power connectors, "Y" splitter cables are available from many electronics supply houses (including Radio Shack) that can adapt a single power connector to serve two drives. Make sure that your total power supply output is capable of supplying the additional power as a precaution.

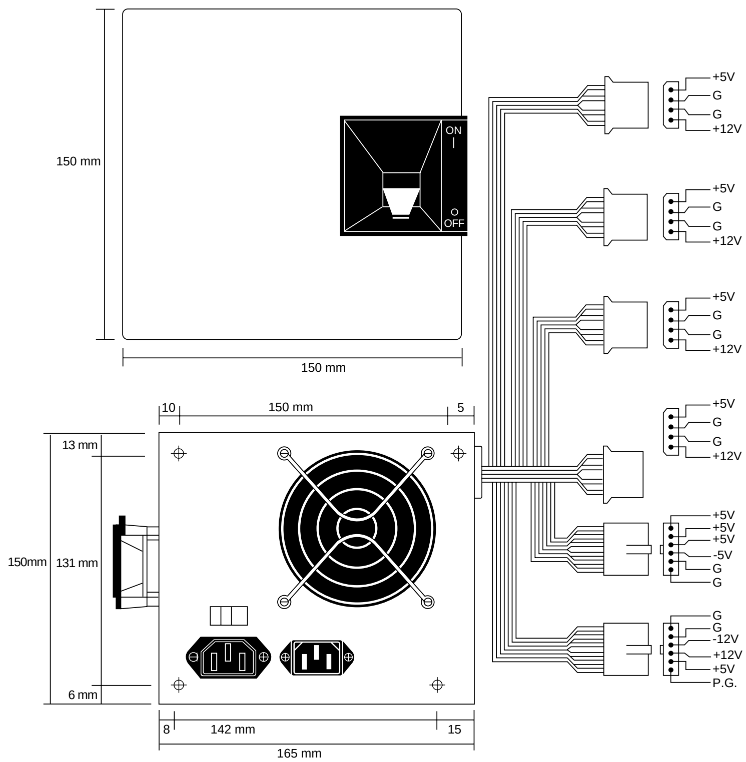

Fig. 8.3
Baby AT-style power supply.

Table 8.1 Typical PC-Compatible Power Supply Connections

Connector	AT/Tower Type	PC/XT Type
P8-1	Power_Good (+5v)	Power_Good (+5v)
P8-2	+5v	Key (No connect)
P8-3	+12v	+12v
P8-4	–12v	–12v
P8-5	Ground (0)	Ground (0)
P8-6	Ground (0)	Ground (0)
P9-1	Ground (0)	Ground (0)
P9-2	Ground (0)	Ground (0)
P9-3	–5v	–5v
P9-4	+5v	+5v
P9-5	+5v	+5v
P9-6	+5v	+5v
P10-1	+12v	+12v
P10-2	Ground (0)	Ground (0)

Connector	AT/Tower Type	PC/XT Type
P10-3	Ground (0)	Ground (0)
P10-4	+5v	+5v
P11-1	+12v	+12v
P11-2	Ground (0)	Ground (0)
P11-3	Ground (0)	Ground (0)
P11-4	+5v	+5v
P12-1	+12v	—
P12-2	Ground (0)	—
P12-3	Ground (0)	—
P12-4	+5v	—
P13-1	+12v	—
P13-2	Ground (0)	—
P13-3	Ground (0)	—
P13-4	+5v	—

Note that the Baby AT and Slimline power supplies also use the AT/Tower pin configuration.

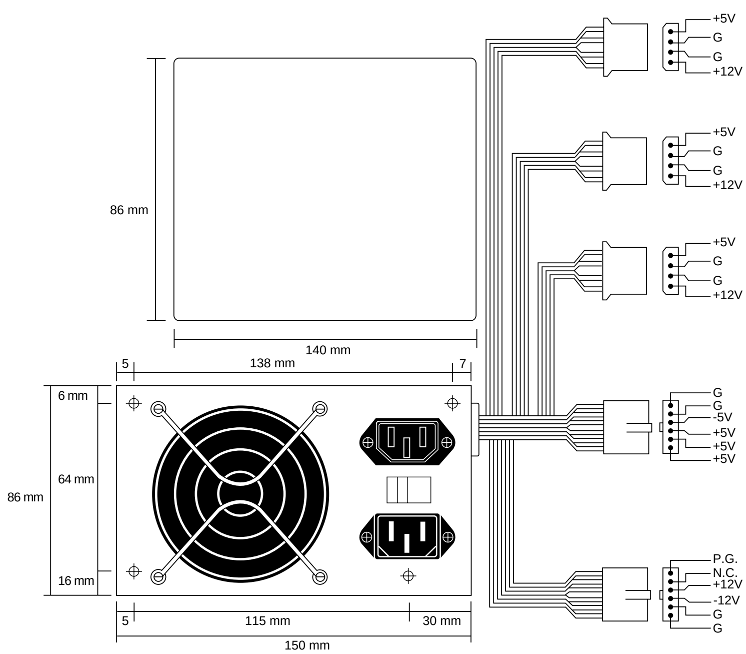

Fig. 8.4
Slimline-style power supply.

Although the PC/XT power supplies do not have any signal on pin P8-2, you can still use them on AT-type motherboards or vice versa. The presence or absence of the +5v signal on that pin has little or no effect on system operation. If you are measuring voltages for testing purposes, anything within ten percent is considered acceptable by many, although most manufacturers of high-quality power supplies specify a tighter 5-percent tolerance (see table 8.2). I prefer to go by the 5-percent tolerance, which is a tougher test to pass.

Table 8.2 Power Supply Acceptable Voltage Ranges

Desired	Loose Tolerance		Tight Tolerance	
Voltage	Min. (–10%)	Max. (+8%)	Min. (–5%)	Max. (+5%)
+/–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 different tolerances than the other signals, although it is nominally a +5v signal in most systems. The trigger point for Power_Good is about +2.5v, but most systems require the signal voltage to be within the tolerances listed in table 8.3.

Table 8.3 Power_Good Signal Acceptable Range

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

A power supply should be replaced if the voltages are out of these ranges. A later section in this chapter details how to measure the power supply voltage and where to get replacement supplies as well.

Disk Drive Power Connectors. The disk drive connectors are fairly universal with regard to pin configuration and even wire color. Table 8.4 shows the standard disk drive power connector pinout and wire colors.

Table 8.4 Disk Drive Power Connector Pinout

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

This information applies whether the drive connector is the larger Molex version or the smaller mini-version used on most 3.5-inch floppy drives. In each case, the pinouts and wire colors are the same. To determine the location of pin 1, look at the connector carefully, and you will usually see it embossed in the plastic connector body; however, it often is very tiny and difficult to read.

Note that some drive connectors may only supply two wires—usually the +5v and a single ground (Pins 3 and 4)—because the floppy drives in most newer systems only run on +5v and do not use the +12v at all.

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), as well as specific connectors for the disk drives. The motherboard connectors used in all the industry-standard power supplies have not changed since 1981 when the IBM PC appeared; but with the advent of 3.5-inch floppy drives in 1986, a new smaller type of drive power connector appeared on the scene for these drives. Table 8.5 lists the standard connectors used for motherboard and disk drive power.

Table 8.5 Physical Power Connectors

Connector Description	Female (on Power Cable)	Male (on Component)
Motherboard P8/P9	Burndy GTC6P-1	Burndy GTC 6RI
Disk Drive (large style)	AMP 1-480424-0	AMP 1-480426-0
Disk Drive (small style)	AMP 171822-4	AMP 171826-4

You can get these raw connectors through the electronics supply houses (Allied, Newark, Digi-Key, and so on) listed in Appendix B, the "Vendor List." You also can get complete cable assemblies including drive adapters from the large to small connectors, disk drive "Y" splitter cables, and motherboard power extension cables from a number of the Cable and miscellaneous supply houses such as Cables To Go, the Cable Connection, Ci Design, and Key Power (see the vendor list).

The Power_Good Signal

The Power_Good signal is a +5v signal (+3.0 through +6.0 is generally considered acceptable) generated in the power supply when it has passed its internal self tests and the outputs have stabilized. This normally takes anywhere from 0.1 to 0.5 seconds after you turn on the power supply switch. This signal is then sent to the motherboard, where it is received by the processor timer chip, which controls the reset line to the processor.

In the absence of Power_Good, the timer chip continuously resets the processor, which prevents the system from running under bad or unstable power conditions. When the timer chip sees Power_Good, it stops resetting the processor, 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 proper output is restored, the Power_Good signal is regenerated, and the system again begins operation (as if you just powered on). By withdrawing Power_Good, the system never "sees" the bad power because it is "stopped" quickly (reset) rather than allowed to operate on unstable or improper power levels (which can cause parity errors and other problems).

In most systems, the Power_Good connection is made via connector P8-1 (P8 Pin 1) from the power supply to the motherboard.

A well-designed power supply delays the arrival of the Power_Good signal until all voltages stabilize after you turn the system on. Badly designed power supplies (found in *many* low-cost compatibles!) often do not delay the Power_Good signal properly and allow the processor to start too soon. The normal Power_Good delay is from 0.1 to 0.5 seconds. Improper Power_Good timing also causes CMOS memory corruption in some systems. If you find that a system does not boot up properly the first time you turn on the switch, but subsequently boots up if you press the reset or Ctrl-Alt-Del warm boot command, then you likely have a problem with Power_Good. This happens because the Power_Good signal is tied to the timer chip that generates the reset signal to the processor. What you need to do in these cases is to find a new high-quality power supply and see if it solves the problem.

Many cheaper power supplies do not have proper Power_Good circuitry and often 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 caused by improper Power_Good signal timing. A common example occurs when somebody replaces a motherboard in a system, and then finds that the system intermittently fails to start properly when the power is turned on. This ends up being very difficult to diagnose, especially for the inexperienced technician, because the problem appears to be caused by the new motherboard. Although it seems as if the new motherboard may be defective, it usually turns out to be that the original power supply is poorly designed and either cannot produce stable enough power to properly operate the new board, or more likely has an improperly wired or timed Power_Good signal. In these situations, replacing the supply with a high-quality unit is the proper solution.

Power Supply Loading

PC power supplies are of a switching rather than linear design. This type of design is very efficient and does not need a large internal transformer. One characteristic of all switching type power supplies is that they do not run without a load, which means that you must have the supply plugged into something drawing +5v and +12v, or the supply does not work. If you simply have the supply on a bench with nothing plugged into it, the supply either burns up, or protection circuitry shuts it down. Most power supplies are protected from no-load operation and will shut down; however, some of the cheap clone supplies lack the protection circuit and relay and are destroyed after a few seconds of no-load operation. A few power supplies even have their own built-in load resistors so that 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 load 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.

When IBM used to ship AT systems without a hard disk, they had the hard disk drive power cable plugged into a large 5-Ohm 50-watt sandbar resistor mounted in a little metal cage assembly where the drive would have been. The AT case even had screw holes (on top of where the hard disk would go) specifically designed to mount this resistor cage. Several computer stores I knew in the mid 80s would order the diskless AT and then install their own 20M or 30M drives, which they could get cheaper from other sources than 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 placed a 2.4-amp load on the supply's 12-volt output drawing 28.8 watts of power (it would get HOT!), thus enabling the supply to operate normally. Note that the cooling fan in most power supplies draws approximately 0.1 to 0.25 amps, bringing the total load to 2.5 amps or more. If the load resistor was missing, the system would intermittently fail to start up or operate properly. The motherboard draws +5v at all times, but +12v is normally used only by motors, and the floppy drive motors are off most of the time.

Most of the 200-watt 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 2.0 to 4.0 amps at +5v and a minimum of 0.5 to 1.0 amps at +12v are considered acceptable. Most motherboards will easily draw the minimum +5v current by themselves. The standard power supply cooling fan only draws 0.1 to 0.25 amps, so the +12v minimum load may still be a problem for a diskless workstation.

Some high-quality switching power supplies, like the Astec units used by IBM in all the PS/2 systems, have built-in load resistors and can run under a no-load situation because the supply loads itself. Most of the cheaper clone supplies do not have built-in load resistors, so they must have both +5v and +12v loads to work.

Tip

If you are setting up a "diskless" workstation, it is a good idea to install a load resistor, or the power supply may cause intermittent system problems. You can construct the same type of load resistor originally used by IBM by connecting a 5-Ohm, 50-watt sandbar resistor between pins 1 and 2 on a disk drive power connector. You only need to worry about loading the +12v power because the motherboard places a load on the +5v outputs.

If you want to bench test a power supply, make sure that loads are placed on both the +5v and +12v outputs. This is one reason that it is best to test the supply while it is installed in the system rather than separately on the bench. For impromptu bench testing, you can use a spare motherboard and hard disk drive to load the +5v and +12v outputs respectively. Information on building your own load resistor network for bench testing power supplies is covered later in this chapter.

Power-Supply Ratings

Most system manufacturers will provide you with the technical specifications of each of their system-unit power supplies. This type of information is usually found in the system's technical-reference manual and also is normally found on stickers attached directly to the power supply. Power supply manufacturers also can supply this data, which is preferred if you can identify the manufacturer and contact them directly.

Tables 8.6 and 8.7 list power-supply specifications for several of IBM's units, from which most of the compatibles are derived. The PC-system power supplies are the original units that most compatible power supplies have duplicated. The input specifications are listed as voltages; the output specifications 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:

Wattage = Voltage * Amperage

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

Table 8.6 Power Supply Output Ratings for IBM "Classic" Systems

	PC	PPC	XT	XT-286	AT
Minimum Input Voltage	104	90	90	90	90
Maximum Input Voltage	127	137	137	137	137
Worldwide Power (220v)?	No	Yes	No	Yes	Yes
110/220v Switch?	–	Switch	–	Auto	Switch
Output Current (amps): +5v	7.0	11.2	15.0	20.0	19.8
–5v	0.3	0.3	0.3	0.3	0.3
+12v	2.0	4.4	4.2	4.2	7.3
–12v	0.25	0.25	0.25	0.25	0.3
Calculated output wattage	63.5	113.3	129.9	154.9	191.7
Specified output wattage	63.5	114.0	130.0	157.0	192.0

Table 8.7 shows the standard power supply output levels available in industry-standard form factors. Most manufacturers that offer supplies have supplies with different ratings for each type of supply. Supplies are available with ratings from 100 watts to 450 watts or more. Table 8.7 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 both Astec Standard Power and PC Power and Cooling. Although most of the ratings are accurate, as you can see they are somewhat misleading for the higher wattage units.

Table 8.7 Typical Compatible Power Supply Output Ratings

Specified Output Wattage	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
–5v	0.3	0.3	0.3	0.5	1.0	0.5	0.5
+12v	3.5	5.5	8.0	10.0	10.0	13.0	15.0
–12v	0.3	0.3	0.3	0.5	1.0	0.5	1.0
Calculated output wattage	97.1	146.1	201.1	253.5	297.0	339.5	419.5

Most compatible power supplies have ratings between 150 to 250 watts output. Although lesser ratings are not usually desirable, it is possible to purchase heavy duty power supplies for most compatibles that have outputs as high as 500 watts.

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

Table 8.8 shows the rated output levels of IBM's PS/2 power supplies. IBM uses very high quality supplies in these systems. They are normally supplied to IBM by Astec, but other manufacturers have made IBM supplies as well.

Table 8.8 Power Supply Output Ratings for PS/2 Systems

Model	Part Number	Worldwide Power (220v)	110/220v Manual/Auto	Output Wattage
25	8525-xx1 8525-xx4	Yes Yes	Manual Manual	90 115
30	8530-0xx	Yes	Auto	70
25 286	8525-xxx	Yes	Manual	124.5
30 286	8530-Exx	Yes	Manual	90
35 SX	8535-xxx	Yes	Auto	118
40 SX	8540-0xx	Yes	Manual	197
50	8550-0xx	Yes	Auto	94
55 SX	8555-xxx	Yes	Manual	90
57 SX	8557-0xx	Yes	Manual	197

(continues)

Table 8.8 Continued

Model	Part Number	Worldwide Power (220v)	110/220v Manual/Auto	Output Wattage
60	8560-041	Yes	Auto	207
	8560-071	Yes	Auto	225
65 SX	8565-xxx	Yes	Auto	250
70 386	8570-xxx	Yes	Auto	132
70 486	8570-Bxx	Yes	Auto	132
P70 386	8573-xxx	Yes	Auto	85
P75 486	8573-xxx	Yes	Auto	120
80 386	8580-xxx	Yes	Auto	225
	8580-Axx	Yes	Auto	242
	8580-Axx	Yes	Auto	250
90 XP 486	8590-0xx	Yes	Auto	194
95 XP 486	8595-0xx	Yes	Auto	329

Most power supplies are considered to be *universal*, or *worldwide*: they run on the 220-volt, 50-cycle current used in Europe and many other parts of the world. Most power supplies that can switch to 220-volt input are automatic, 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. (The automatic units sense the current and then switch automatically.)

My PS/2 P75, for example, runs on both 110- and 220-volt power; all I have to do is plug it in, and the system automatically recognizes the incoming voltage and switches circuits accordingly. This is different from some other systems that run on both levels of power, but require you to flip a switch manually to select the proper circuits within the power supply.

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, and my experience has been if a brownout occurs in a room with several systems running, the systems with higher quality power supplies and higher output ratings always make it over power disturbances in which others choke. I would not give $5 for many of the cheap, junky power supplies that come in some of the low-end clone systems.

To get an idea of the expected performance from a power supply, you should know the specifications IBM dictates for all its PS/2 power supplies. This information comes from the *PS/2 Hardware Maintenance Manual* (#S52G-9971-01) and is an example of what a properly designed power supply should do. Keep in mind that Astec makes virtually all IBM PS/2 supplies, and it also makes supplies for a number of other high-end system vendors. IBM's specifications for its PS/2 power supplies follow:

> PS/2 power supplies operate continuously over two ranges: the first is from 90 to 137 VAC, and the second is from 180 to 265 VAC. The AC signal must be a sine

wave and have a maximum of 5-percent total harmonic distortion. Some units have an automatic voltage range selection feature whereas others require a switch be set to operate on either the 100v or 200v ranges.

PS/2 power supplies are protected from both input over and under voltages. If the input voltage goes over or under the acceptable range, the power supply shuts down until the power switch is recycled.

All PS/2 supplies have output over-current protection. This means that if more than a safe load is drawn from the supply, it shuts down until the power switch is recycled. This protection extends to short circuits as well. If any short is placed between an output and ground, or between any two outputs, the power supply shuts down until the power switch is recycled.

Most PS/2 power supplies have an automatic restart feature that causes the power supply to recycle automatically after an AC power outage. Beginning with products announced in October 1990, a three to six second delay was added to the restart time to allow any subsystems or peripherals enough time to reset before the system restarts.

IBM states that the PS/2 supplies sustain operation during the following power line disturbances:

- A 20-percent below nominal voltage (that is, 80 volts) brownout lasting up to two seconds repeated up to 10 times with a 10-percent duty cycle
- A 30-percent below nominal voltage (70 volts) brownout lasting up to .5 seconds repeated up to 10 times with a 10-percent duty cycle
- A 15-percent above nominal voltage (143 volts) surge lasting up to one second repeated up to 10 times with a 10-percent duty cycle
- A 400 Hz oscillatory (exponentially decaying) disturbance at the peak of the input line voltage that increases the line voltage by two times (200 volts) that occurs up to 100 times at three second intervals
- A transient pulse of 1.5 times the peak input voltage (150 volts) superimposed at the input voltage peak and repeated up to 100 times at three second intervals

IBM also states that their PS/2 supplies (or attached systems) are not damaged if any of the following conditions occur:

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

PS/2 power supplies have an extremely low current leakage to ground of less than 500 microamps. This safety feature is very important if your outlet has a missing or 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. The vendors recommended in this chapter produce supplies that meet or exceed these specifications.

Power-Use Calculations

One way to see whether your system is capable of expansion is to calculate the levels of power drain in the different system components and then deduct the total from the maximum power supplied. This calculation might help you decide when to 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.

It is very difficult to get power consumption data for most +5v devices including motherboards and adapter cards. Motherboards can consume different power levels depending on numerous factors. Most 486DX2 motherboards consume about 5 amps or so, but if you can get data on the one you are using, so much the better. For adapter cards, if you can find the actual specifications for the card, then use those figures; however, to be on the conservative side, I usually go by the maximum available power levels as set forth in the respective bus standards.

For example, consider the typical power consumption figures for components in a modern PC system. Most standard desktop or Slimline PC systems today come 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 and 0.175 amps of +12v power for each slot in the system. Most systems have eight slots, and you can assume that four of them are filled for the purposes of calculating power draw. The following calculation shows what happens when you subtract the amount of power necessary to run the different system components.

5-Volt Power:			20.0 Amps
	Less:	Motherboard	–5.0
		4 slots filled at 2.0 each	–8.0
		3.5" and 5.25" floppy drives	–1.5
		3.5" hard disk drive	–0.5
Remaining power			5.0 amps
12-Volt Power:			8.0 Amps
	Less:	4 slots filled at 0.175 ea.	–0.7
		3.5" hard disk drive	–1.0
		3.5" and 5.25" floppy drives	–1.0
		Cooling fan	–0.1
Remaining power			5.2 amps

In the preceding example, everything seems okay for now. With half the slots filled, two floppy drives, and one hard disk, the system still has room for more. There might be trouble if this system was expanded to the extreme. With every slot filled and two or more hard disks, there definitely will be problems with the +5v, 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 will be strained. If you anticipate loading up a system to the extreme, for example as in a high-end multimedia system, then you may want to invest in the insurance of a higher output supply. For example, a 250-watt supply usually has 25 amps of +5v and 10 amps of +5v current, whereas a 300-watt unit has 32 amps of +5v power. These supplies would allow a fully expanded system and are likely to be found in full-sized desktop or tower case configurations in which this capability can be fully used.

Motherboards can draw anywhere from 4 to 15 amps or more of +5v power to run. In fact, a single Pentium 66 MHz CPU draws up to 3.2 amps of +5v power all by itself. Considering that dual 100 MHz Pentium processor systems are now becoming available, you could have 6.4 amps or more drawn by the processors alone. A motherboard like this with 64M of RAM might draw 15 amps or more all by itself. Most 486DX2 motherboards draw approximately 5 to 7 amps of +5v. Bus slots are allotted maximum power in amps as shown in table 8.9.

Table 8.9 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 and not all cards draw this much power. If the slot has a VL-Bus extension connector, then an additional 2.0 amps of +5v power is allowed for the VL-Bus.

Floppy drives can vary in power consumption, but most of the newer 3.5-inch drives have motors that run off +5v in addition to the logic circuits. These drives usually draw 1.0 amps of +5v power and use no +12v at all. Most 5.25-inch drives do 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 almost negligible.

Typical 3.5-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. The 5.25-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 amps 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 then tapers off to normal after the drive is spinning.

The figures most manufacturers report for maximum power supply output are full duty-cycle figures, which means that these levels of power can be supplied continuously. You usually can expect a unit that continuously supplies some level of power to supply more power for some noncontinuous amount of time. A supply usually can offer 50 percent greater output than the continuous figure indicates for as long as one minute. This cushion often is used to supply the necessary power to start spinning a hard disk. After the drive has spun to full speed, the power draw drops to some value within the system's continuous supply capabilities. Drawing anything over the rated continuous figure for any long length of time causes the power supply to run hot and fail early, and can prompt several nasty symptoms in the system.

Tip

If you are using internal SCSI hard drives, then a very useful tip can ease the startup load on your power supply. The key is to enable the Remote Start option on the SCSI drive, which causes the drive to start spinning only when it receives a startup command over the SCSI bus. The effect is such that the drive remains stationary (drawing very little power) until the very end of the POST, and spins upright 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 setting. This is designed so that only one drive is spinning up at any one time and 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. This tip is essential when dealing with portable type systems in which power is at a premium. I burned up a supply in one of my portable systems before resetting the internal drive to Remote Start.

The biggest causes of overload problems are filling up the slots and adding more drives. Multiple hard drives, CD-ROM drives, floppy drives, and so on can exact quite a drain on the system power supply. Make sure that you have enough +12v power to run all the drives you are going to install. Tower systems can be a problem here because they have so many drive bays. Also make sure that you have enough +5v power to run all your expansion cards, especially if you are using VL-Bus or EISA cards. It pays to be conservative, but remember that most cards draw less than the maximum allowed.

Many people wait until an existing unit fails before they replace it with an upgraded version. If you're on a tight budget, this "if it ain't broke, don't fix it" attitude works. Power supplies, however, often do not just fail; 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've been running with your original power supply for a long time, you should expect some problems.

Leave It On or Turn It Off?

A frequent question that relates to the discussion of power supplies concerns whether you should turn off a system when not in use. You should understand some facts about electrical components and what makes them fail. Combine this knowledge with information on power consumption and cost, not to mention safety, and perhaps you can come to your own conclusion. Because circumstances can vary, the best answer for your own situation might be different depending on your particular needs and application.

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

From a pure system reliability point, it is desirable to 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 degrees F (85 degrees C) within 30 minutes or less. When you turn the system off, the same thing happens in reverse, and the components cool back to ambient temperature in a short period of time. Each component expands and contracts at slightly different rates, which causes the system an enormous amount of stress.

Thermal expansion and contraction remains the single largest cause of component failure. Chip cases can split, allowing moisture to enter and contaminate the chip. Delicate internal wires and contacts can break, and circuit boards can develop stress cracks. Surface-mounted components expand and contract at different rates 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 causing cracks in the joint. Components that use heat sinks such as processors, transistors, or voltage regulators can overheat and fail because the thermal cycling causes heat sink adhesives to deteriorate, breaking the thermally conductive bond between the device and the heat sink. Thermal cycling also causes socketed devices and connections to "creep," which can cause a variety of intermittent contact failures.

Thermal expansion and contraction not only affect chips and circuit boards, but things like hard disk drives as well. 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 five 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 on or off permanently. Of course, if the system is never turned on in the first place, it should last a long time indeed!

Now, although it seems like I am saying that you should leave all systems on 24 hours a day, that is not necessarily true. 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 (cleaning crews, other nocturnal visitors, and so on), can be easily damaged if moved while running, and simply wastes electrical energy.

I currently pay $0.11 for a kilowatt-hour of electricity. A typical desktop-style PC with display consumes at least 300 watts (0.3 kilowatts) of electricity (and that is a conservative estimate). This means that it would cost 3.3 cents to run this 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 9:00 a.m. and off at 5:00 p.m., it would only be on 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; multiplied by 1,000 systems, you are saving $4,220 per week! Using systems certified under the new EPA Energy Star program (that is, "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 the systems on at the beginning of the work day, and off at the end of the work day. Do not power the systems off for lunch, breaks, or any other short duration of time. Servers and the like of course should be left on continuously. This seems to be the best compromise of system longevity with pure economics.

Power Supply Problems

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-on or expansion components. Most desktop or tower systems are built in this manner. Some systems have inadequate power supplies from the start, however, and cannot accept the number and types of power-hungry options you might want to add.

In particular, portable systems often have power supply problems because they are designed to fit into a small space. Also, many older systems had inadequate power supply capacity for system expansion. For example, the original PC's 63.5-watt supply was inadequate for all but the most basic system. Add a graphics board, hard disk, math coprocessor (8087) chip, and 640K of memory, and you would kill the supply in no time. The total power draw of all the items in the system determines the adequacy of the power supply.

The wattage rating can sometimes be very misleading. Not all 200-watt supplies are created the same. Those who are into high-end audio systems know that some watts are better than others. Cheap power supplies may 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 may greatly exceed their specifications. Many of the cheaper supplies output noisy or unstable power, which can cause numerous problems with the system. Another problem with under-engineered power supplies is that they 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.

Some of the available replacement supplies have higher capacity cooling fans than the originals, which can greatly prolong system life and minimize overheating problems, especially with some of the newer high-powered processors. If noise is a problem, models with special fans can run quieter than the standard models. These types often use larger diameter fans that spin slower so that they run quietly while moving the same amount of air as the smaller fans. A company called PC Power and Cooling (see Appendix B, the "Vendor List") specializes in heavy-duty as well as quiet supplies; another company called Astec (see Appendix B) has several heavy-duty models as well. Astec supplies are found as original equipment in many high-end systems such as those from IBM, Hewlett Packard, and so on.

Ventilation in a system can be important. You must ensure adequate air flow to cool the hotter items in the system. Most processors have heat sinks today that require a steady stream of air to cool the processor. If the processor heat sink has its own fan, then this is not much of a concern. If you have free slots, space the boards out in your system to allow air flow between them. Place the hottest running boards nearest the fan or ventilation holes in the system. Make sure that adequate air flow is around the hard disk drive, especially those that spin at higher rates of speed. Some hard disks can generate quite a bit of heat during operation, and if the hard disks overheat, data is lost.

Always make sure that you run with the lid on, especially if you have a loaded system. Removing the lid can actually cause a system to overheat because with the lid 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 because of this, several of my own systems, especially those that are fully expanded, have overheated within 15 to 30 minutes when run with the case lid off.

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 especially convinced these are a good idea. Unless the fan is positioned to draw air to or from outside the case, all the fan 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 each fan consumes power and generates heat.

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

Tip

If you seal the ventilation holes on the bottom of the PC chassis, starting from where the disk drive bays begin and all the way to the right side of the PC, you drop the interior temperature some 10 to 20 degrees Fahrenheit—not bad for two cents' worth of electrical tape. IBM "factory-applied" this tape on every XT and XT-286 it sold. The result is greatly improved interior aerodynamics and airflow over the heat-generating components.

Power Supply Troubleshooting

Troubleshooting the power supply basically means isolating the supply as the cause of problems within a system. Rarely is it recommended to go inside the power supply to make repairs because of the dangerous high voltages present. 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 would 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 appears between the symptom and the cause (the power supply).

For example, in many cases a "parity check" type of error message or problem indicates a problem with the supply. This may seem strange because the parity check message itself specifically refers to memory that has failed. The connection is that the power supply is what powers the memory, and memory with inadequate power fails. It takes some experience to know when these failures are not caused by the memory and are in fact power related. 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, then I would indeed suspect defective memory as the problem. However, if the problem seems random, or the memory location given as failed seems random or wandering, then I would suspect improper power as the culprit. The following is a list of PC problems that often are power supply related:

- Any power on 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 fail 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 simple measurements as well as more sophisticated tests outlined in this section can help you determine whether the power supply is at fault. Because these measurements may 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, then you have found the source of your problem.

Digital Multi-Meters

A simple test that can be done to a power supply is to check the output voltage. This shows if a power supply is operating correctly and whether the output voltages are within the correct tolerance range. Note that all voltage measurements must be made with the power supply connected to a proper load, which usually means testing while the power supply is still installed in the system.

Selecting a Meter. You need a simple Digital Multi-Meter (DMM) or Digital Volt-Ohm Meter (DVOM) to make voltage and resistance checks in electronic circuits (see fig. 8.5). You should only use a DMM rather than the older needle-type multi-meters because the older meters work by injecting a 9v signal into the circuit when measuring resistance. This will damage most computer circuits! 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 from many sources and with many different features. I prefer the small pocket-sized meters for computer work because they are easy to carry around. The following lists some features to look for in a good DMM:

- *Pocket Size.* This is self-explanatory, but small meters are available that have many if not all the features of larger ones. The elaborate features found on some of the larger meters are not really needed for computer work.
- *Overload Protection.* This means that if you plug the meter into a voltage or current beyond the capability of the meter to measure, the meter protects itself from damage. Cheaper meters lack this protection and can easily be 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 preferred to the manual range selection; however, really good meters offer both autoranging capability and a manual range override.
- *Detachable Probe Leads.* The leads can be easily damaged and sometimes a variety of differently shaped probes are required for different tests. Cheaper meters have the leads permanently attached, which means that they cannot easily be replaced. 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 a beep noise to be heard when continuity exists between the meter test leads. Using the sound, you can more quickly 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 meter if no readings are sensed for a predetermined period of time.
- *Automatic Display Hold.* This feature allows the last stable reading to be held 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 allows the lowest and highest readings to be trapped in memory and held for later display. This 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 about $30, one with all these features costs about $200. Radio Shack carries some nice inexpensive units, whereas the high-end models can be purchased from electronics supply houses like Allied, Newark, or Digi-Key (see Appendix B, the “Vendor List”).

Measuring Voltage. When making measurements on a system that is operating, you must use a technique called *back probing* the connectors. This is because you cannot disconnect any of the connectors while the system is running and instead 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. This technique is called back probing because you are probing the connector from the back. Virtually all the following measurements must be made using this back probing technique.

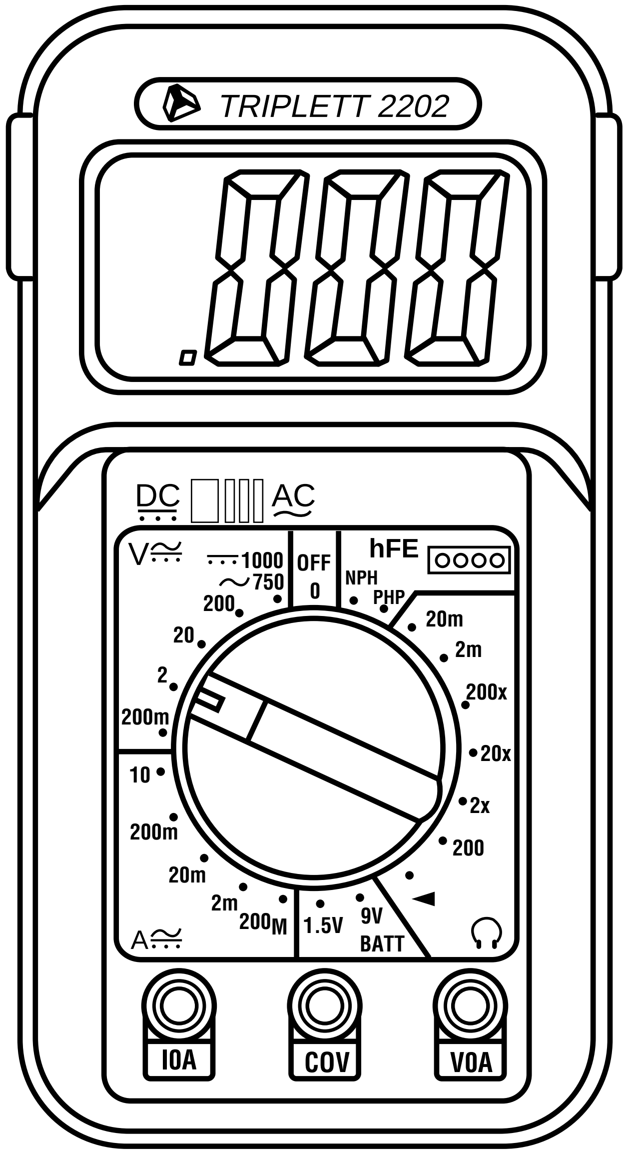

Fig. 8.5
A typical Digital Multi-Meter (DMM).

To test a power supply for proper output, first check the voltage at the Power_Good pin (P8-1 on most IBM-compatible supplies) for +3v to +6v. If the measurement is not within this range, then the system never sees the Power_Good signal and therefore does not start or run properly. In most cases, the supply is bad and must be replaced.

Continue by measuring the voltage ranges of the pins on the motherboard and drive power connectors (see table 8.10). Note that the exact pin specifications and acceptable voltage ranges may vary for different manufacturer's systems, however these figures are representative of most IBM-compatibles. Many follow the looser tolerance guidelines of accepting anything approximately 10 percent too low or 8 percent too high, especially for the –5v and –12v (negative) signals. I prefer to use tighter tolerances myself, and would only pass a supply that is within 5 percent or less of the correct voltages. Some manufacturers have even tighter tolerances on their systems, and in that case you should go by what the manufacturer specifies. Consult your system's technical reference manual for this information to make sure.

Table 8.10 Power Supply Acceptable Voltage Ranges

Desired	Loose Tolerance		Tight Tolerance	
Voltage	Min. (–10%)	Max. (+8%)	Min. (–5%)	Max. (+5%)
+/–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 different from the other signals, although it is nominally a +5v signal in most systems. The trigger point for Power_Good is about +2.5v, but most systems require the signal voltage to be within the tolerances listed in table 8.11.

Table 8.11 Power_Good Signal Acceptable Range

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 more effectively test power supplies. Because the power supply is perhaps the most failure-prone item in PCs today, if you service many PC systems, it is wise to have many of these specialized items.

Load Resistors. If you want to bench test a power supply, you must make sure that loads are placed on both the +5v and +12v outputs. This is one reason that it is best to test the supply while it is installed in the system rather than separately on the bench.

For impromptu bench testing, you can use a spare motherboard and hard disk drive to load the +5v and +12v outputs respectively while you make voltage measurements or check overall system operation.

If you are frequently testing power supplies, then you may want to construct your own load resistors to make testing easier. In my shop, I often use one of the +12v load resistors originally installed in AT systems sold without hard disks. Although these are nice, they do not load the +5v signal, and often I want more than a 2.4-amp load on the +12v as well.

You can construct your own power supply load resistor network out of light bulbs. By wiring a set of light sockets in parallel, you can vary the load by adding or removing bulbs from their sockets. The type of bulb to use for a +12v load is the standard #1156 bulb used in many automobile exterior light assemblies. These bulbs are designed to run on +12v and draw approximately 2.1 amps of current or about 25 watts. Each bulb effectively acts as if it were a 5.7-ohm resistor. I recommend that you wire up at least four bulb sockets in parallel, mounted on a non-conductive breadboard. For testing high output supplies, you could wire up as many as eight sockets in parallel. It would be wise to have four disk drive connectors also wired in parallel in the same circuit to balance the draw from the supply. A single drive connector cannot handle more than a two-bulb (4-amp) load reliably. To use this load tester, plug the bulb loading network into the disk drive power connectors, and by adding or removing bulbs from their sockets you can control the load. With four bulbs installed, you have approximately an 8-amp load, which is good for maximum load testing of a standard 200-watt PC power supply rated for 8 amps of +12v output.

You will still need a +5v load as well. Unfortunately, a #1156 type bulb does not work well for a +5v load because each bulb only draws 0.875 amps at +5v (4.4 watts). Even eight of these bulbs would only draw 7 amps or 35 watts of +5v power. You could substitute a #1493 bulb instead, which draws about 2.75 amps at +5v or about 14 watts. You would still need eight of these bulbs, which would draw 22 amps at +5v, to perform a maximum load test on a standard 200-watt-rated PC power supply.

Perhaps a better solution than using bulbs is to use heavy duty wirewound resistors to construct a load network. For a +12v load, you could mount a series of 6-ohm 50-watt resistors in a parallel network with a toggle switch to bring each one into the circuit. Using a 6-ohm resistor would draw 2 amps or 24 watts exactly, so make sure that each switch is rated for 3 amps or more to be safe. As you switch each additional resistor into the circuit, the load increases by 2 amps or 24 watts. Note that the resistors are rated to handle up to 50 watts, which means we are simply being conservative. I might start this network off with a single #1156 bulb because the visual information from the light is useful. The fact that the light is lit means of course that power is available, and sometimes you can see voltage variations as changes in the brightness of the lamp as you switch in additional loads. This can give you a visual impression of how well the supply is performing.

This same type of setup can be used to create a +5v load network. In this case, I recommend you use 1-ohm 50-watt wirewound resistors in the same type of parallel network, with a switch for each resistor. You could start the network off with a single #1493 bulb for a visual indicator of power supply output, which would draw 2.75 amps or about 14 watts of power. Each 1-ohm 50-watt resistor draws 5 amps of +5v current or exactly 25 watts. Again, I would specify resistors with a 50-watt rating and a switch with a rating higher than 5 amps to be on the conservative side. A network of four of these resistors alone draws exactly 20 amps of power, which is exactly what the typical 200-watt PC power supply has to offer in +5v. By switching four of these resistors into the load, you could perform a full stress test on the supply. Add more, and you could test higher output supplies as well. Again it would be prudent to draw this through four disk drive connectors simultaneously so as to balance the load between the connectors. You also could get some motherboard (P8 and P9 type) connectors and draw the load through all the +5v pins on those connectors.

You can purchase all these components including wirewound resistors, bulbs, sockets, connectors, breadboard, and so on through electronics parts supply houses such as Allied, Newark, and Digi-Key (see the vendor list).

Variable Voltage Transformer. In testing power supplies, it is desirable to simulate different voltage conditions at the wall socket to observe how the supply reacts. A *variable voltage transformer* can be a very useful test device for checking power supplies because it enables you to have control over the AC line voltage used as input for the power supply (see fig. 8.6). This device consists of a large transformer mounted in a housing with a dial indicator to control the output voltage. You plug the line cord from the transformer into the wall socket, and then plug the PC power cord into the socket provided on the transformer. The knob on the transformer can then be used to adjust the AC line voltage seen by the PC.

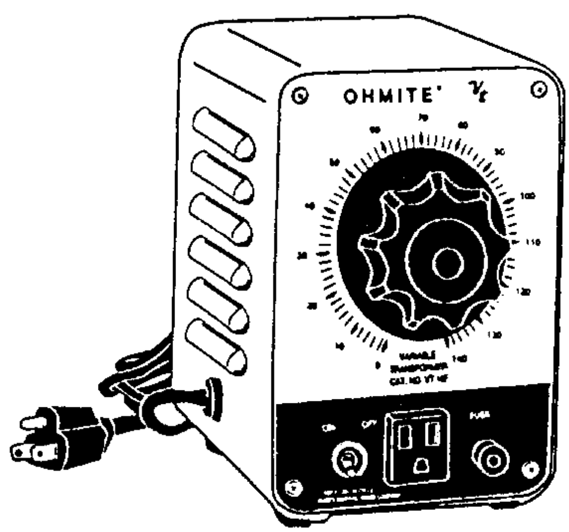

Fig. 8.6
A variable voltage transformer.

Most variable transformers can adjust their AC output from 0v to 140v no matter what the AC input (wall socket) voltage is. Some can even 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. This enables you to check for proper Power_Good signal operation among other things.

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, then you also can test the capability of the power supply to run on foreign voltage levels as well. A properly functioning supply should operate between 90v to 137v, but shut down cleanly if the voltage is outside that range.

An 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. What should happen is that the PC simply stops 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 Allied, Newark, and Digi-Key (see the vendor list). You should expect to pay anywhere from $100 to $300 for these devices.

PC PowerCheck. The PC PowerCheck card by Data Depot (see the vendor list) is an ISA bus plug-in card that can be used to easily test power supplies while in the system or on a bench. It has a series of LEDs that indicate over or under voltage conditions, noise, and transient spike occurrences. These indicators can be set up to run in real time, or to trap any anomalies and stay lit.

The PC PowerCheck card can connect to the system in two ways. The easiest way to use it is to plug it directly into a slot like any other adapter card. One caution is to make sure that you plug the card in the correct orientation; if you plug it in backwards, serious damage to the card and motherboard can result. No metal bracket is on the card, so it is possible to plug it in either way. You will make that mistake only once!

A second way to use the card is in a bench test mode. In this case, you remove the power supply from the system and plug it directly into the power connectors found on the card. The power connectors on the PC PowerCheck card are not keyed, so if your power supply has keyed connectors, they can be difficult to plug in. Also, you must make sure that the power supply connectors are plugged in the proper orientation. If you plug the connectors in backwards, you may destroy the card.

In the bench test mode, the card is substituting for the motherboard. The PC PowerCheck card has built-in load resistors, however they are very small, drawing only 0.5 amps of +5v and 0.1 amps of +12v current. These loads are certainly not enough to stress the supply and may not be enough in many cases for the supply to operate at all. In this case, additional load can be placed on the supply by plugging in a hard disk, or using custom-made load resistors.

The PC PowerCheck also has an LED to monitor the Power_Good signal, but to monitor that signal the power supply must be plugged in directly in the bench test mode. When plugged into a slot, the same LED then monitors the bus Reset line, which is controlled by the Power_Good signal giving you a secondary indication of Power_Good status.

The PC PowerCheck can be a useful tool in testing PC power supplies as installed in a system, especially for those unwilling to use a digital voltmeter. It is extremely useful for quick pass/fail testing such as on a PC assembly line. Supplies that fail the test can be quickly identified and replaced, and the defective units can be subjected to further testing without holding up the assembly process. The bench test mode is not as useful because additional loads must be placed on the supply for proper stress testing. In any mode, the LED indicators for noise, transients, and Power_Good/Reset are very informative, useful, and unique for this product.

PC Power System Analyzer. The most sophisticated power supply test device I have used is the PC Power System Analyzer from TCE (see Appendix B, the "Vendor List"). This is a portable toaster-sized piece of gear that comes in a padded case for transport that contains the Analyzer and all its accessories. This device sells for around $750 and performs three main functions, all of which are conducted with the supply still installed in the system unit.

The primary function is to load test the system. The PC Power System Analyzer comes with a bus adapter (for both ISA/EISA and MCA) that probes the power output and adds a couple of amps additional load to the +5v and +12v lines. Using this additional load in conjunction with the load of the system, it analyzes the capability of the supply to deliver the proper current.

The unit also performs a Power_Good timing test, which checks to see that the Power_Good signal arrives within the proper time span of 100 to 500 ms. Personally, I have seen many supplies that have problems with the Power_Good signal, and some motherboards are more sensitive to this than others. This unit quickly identifies these failing or improperly designed supplies.

The other tests are voltage tests. Both the power supply output as well as line (wall current) voltage are continuously tested, and minimums and maximums are recorded over time. Information from all the tests can be output to a printer via a parallel port on the unit. During voltage measurements, any anomalies are recorded along with the time of the occurrence, actual voltage values, duration of the failure, and additional information. The unit also has several LEDs to indicate failures or proper operation under the different tests.

The printout is excellent especially when you are servicing systems for others. When you have to explain to a customer how their power supply is failing, it gives you documentation to back you up.

The TCE Power System Analyzer is one of the most sophisticated and specialized pieces of test gear for power supplies. It can be used in PC service shops or assembly operations to quickly test and validate power supply function. Because it is portable, it also can easily be carried into the field for testing remote systems. It is more of a professional tool and is probably too pricey for the average end user.

Repairing the Power Supply

Actually repairing a power supply is rarely done anymore primarily because it is usually cheaper simply to replace the supply with a new one. Even high-quality power supplies are not that expensive relative to the labor required to repair them.

Defective power supplies are usually discarded unless they happen 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 provide what is called *depot repair*, which means you send the supply to them; 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 then take yours in as a core charge. Depot repair is the recommended way to service many PC components such as power supplies, monitors, printers, and so on. If you take your PC in to a conventional service outlet, they often diagnose the problem to the major component, and then 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, it may be possible to repair a failing supply with two relatively simple operations; however, these require opening the supply. I do not recommend this; I am only mentioning it as an alternative to replacement in some cases. Most manufacturers try to prevent you from entering the supply by sealing it with special tamper-proof 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 (see Appendix B) sell sets of TT (tamper-proof 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. Again, the manufacturers place these obstacles there for a reason—to prevent entry by those who are inexperienced around high voltage. Consider yourself warned!

Most power supplies have an internal fuse that is part of the overload protection. If this fuse is blown, then the supply does not operate. It is possible to replace this fuse if you open up the supply. Be aware that in most cases in which an internal power supply problem causes the fuse to blow, replacing it does nothing but cause it to blow again until the root cause of the problem is repaired. In this case, you are better off sending the unit to a professional depot repair company. Appendix B lists several companies that do depot repair on power supplies and other components.

PC power supplies have a voltage adjustment internal to the supply that is calibrated and set when the supply is manufactured. Over time, the values of some of the components in the supply can change, thus altering the output voltages. If this is the case, you often can access the adjustment control and tweak it to bring the voltages back to where they should be. Several adjustable items are in the supply—usually small variable resistors that can be turned with a screwdriver. You should use a nonconductive tool such as a fiber-glass or plastic screwdriver designed for this purpose. If you were to drop a metal tool into an operating supply, dangerous sparks and possibly fire could result, not to mention danger of electrocution and damage to the supply. You also have to figure out which of the adjustments are for voltage, and which are for which voltage signal. This requires some trial-and-error testing. You can mark the current positions of all the resistors, begin measuring a single voltage signal, and then try moving each adjuster slightly until you see the voltage change. If you move an adjuster and nothing changes, then put it back to the original position you marked. Through this process, you can locate and adjust each of the voltages to the standard 5v and 12v levels.

Obtaining Replacement Units

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

Deciding on a Power Supply

When looking at getting a new power supply, there are several things you should take into account. First, consider the power supply's shape, or *form factor*. For example, the power supply used in the IBM AT differs physically from the one used in the PC or XT. Therefore, AT and PC/XT supplies are not interchangeable.

Differences exist in the size, shape, screw-hole positions, connector type, number of connectors, and switch position in these and other power supplies. Systems that use the same form-factor supply can easily interchange. The compatible manufacturers realized this and most began designing systems that mimicked the shape of IBM's AT with regard to motherboard and power supply configuration and mounting. As the clone market evolved, four standard form factors for power supplies became popular—the AT/Tower, Baby AT, Slimline, and PC/XT form factors. You can easily interchange any supply with another one of the same form factor. Earlier this chapter gave complete descriptions of these form factors. When ordering a replacement supply, you need to know which form factor your system requires.

Many systems use proprietary designed power supplies, which makes replacement difficult. IBM uses a number of designs for the PS/2 systems, and little interchangeability exists between different systems. Some of the supplies do interchange, especially between any that have the same or similar cases, such as the Model 60, 65, and 80. Several different output level power supplies are available for these systems, including 207-, 225-, 242-, and 250-watt versions. The most powerful 250-watt unit was supplied originally for the Model 65 SX and later version Model 80 systems, although it fits perfectly in any Model 60, 65, or 80 system. I have not found any company manufacturing aftermarket supplies for the PS/2 systems, probably because the IBM factory-supplied units are more than adequate for their intended application. Although these supplies are mostly made by Astec, they do not sell them directly because of contractual agreements with IBM. Traditionally, it is too expensive to purchase parts from IBM, so a great number of third-party companies are repairing and even reselling brand new IBM PS/2 power supplies (and other IBM parts) at prices greatly below what IBM charges for the same thing. Scan the "Vendor List" in Appendix B for some recommended vendors of these parts.

One risk with some of the compatibles is that they might not use one of the industry-standard form-factor supplies. If a system uses one of the common form-factor power supplies, then replacement units are available from hundreds of vendors. An unfortunate user of a system with a nonstandard form-factor supply doesn't 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 AT form-factor units for as little as $50, the proprietary units from some manufacturers run as high as $400. When *Popular Mechanics* magazine reviews an automobile, it always lists the replacement costs of the most failure-prone and replacement-prone components, from front bumpers to alternators to taillights. PC buyers often overlook this type of information and discover too late the consequences of having nonstandard components in a system.

An example of IBM-compatible systems with proprietary power supply designs are those from Compaq. None of its systems use the same form-factor supply as the IBM systems, which means that Compaq usually is the only place you can get a replacement. If the power supply in your Compaq Deskpro system "goes south," you can expect to pay $395 for a replacement, and the replacement unit will be no better or quieter than the one you're replacing. You have little choice in the matter because almost no one offers Compaq form-factor power supplies except Compaq. An exception is that PC Power and Cooling offers excellent replacement power supplies for the earlier Compaq Portable systems and for the Deskpro series. These replacement power supplies have higher output power levels than the original supplies from Compaq and cost much less.

Sources for Replacement Power Supplies

Because one of the most-failure prone items in PC systems is the power supply, I am often called on to recommend a replacement. Literally hundreds of companies manufacture PC power supplies, and I certainly have not tested them all; however, I have come up with a couple of companies whose product I have come to know and trust.

Although other high-quality manufacturers are out there as well, at this time I recommend power supplies from either Astec Standard Power or PC Power and Cooling (see Appendix B).

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, and Slimline) and a variety of output levels. They have power supplies with ratings of up to 300 watts, and also now have power supplies especially designed for "Green" PCs that 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 may have problems with very low loads. Astec also makes a number of power supplies for laptop and notebook PC systems and has numerous non-PC type supplies as well.

PC Power and Cooling has the most complete line of power supplies for PC systems. They make supplies in all the standard PC form factors used today (AT/Tower, Baby AT, PC/XT, and Slimline). Versions are available in a variety of different quality and output levels, from inexpensive replacements to very high-quality high-output models with ratings up to 450 watts. They even have versions with built-in battery backup systems and a series of special models with high-volume low-speed (quiet) fan assemblies. Their quiet models are especially welcome to people who can't take the fan noise that some power supplies emanate.

PC Power and Cooling also has units available to 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 own; they cost much less than Compaq; and they bolt in as a direct replacement.

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

Summary

This chapter examined the power supply in great detail. You should now have an understanding of how the supply functions in the system and the characteristics of power supply operation. You should understand the function of the Power_Good signal and its role in the system. Also covered was troubleshooting power supply problems and using test equipment to check out power supply operation. I have always found that the power supply is the single most failure-prone component in a PC system, and the information presented here should help greatly whether you are building systems from scratch, upgrading existing systems, or repairing a system with a failing power supply.