PC Power Supply Repair

by TJ Byers

Repairing a broken PC power supply is a lot simpler than you might think. Nine times out of ten you can do it yourself for under $10.00.

It's 8:00 a.m., the neighbor's dog barked all night, your coffee tastes like weak tea, and the phone message light blinks frantically. Full of resolve, you flip on your PC's power switch, and ... presto — nothing! No lights, no beep, no fan, nada. Suddenly you realize, it's gonna be a really bad hair day.

While there's nothing I can do about the early hour or the coffee, I can probably help you get your PC back on its feet. The most common case of "Sudden PC Death Syndrome" is a defective power supply. The problem can come from many sources, like heat, power surges, and old age. While it's easy enough to replace a power supply by swapping the old for new, it's not always practical.

A case in point: I have an AST 486SX that died when a truck plowed into the corner power pole and caused a two-hour black out. When the power came back on, my PC didn't. A quick check showed the cause was a fried power supply. Unfortunately, a call to AST revealed, to my horror, that a replacement power supply costs $150.00. Moreover, because of its unique case design, there's no generic substitute.

Fortunately, it's not difficult to fix PC power supplies. While they may look different on the outside, most PC power supplies use the same electronics on the inside. In this article, I'll show you how easy it is to fix a dead power supply.

The Basics

The power supply is a large metal box, mounted inside the PC that provides power to the motherboard and various peripherals. It's easily identified by a warning sticker on the case that reads "CAUTION! Hazardous Area" (or a similar high-voltage warning).

On the back of the power supply is an AC connector that plugs the PC into the wall. Often there's another AC connector that's used by some monitors. Most power supplies also have a voltage selector switch that lets it work with 110V or 220V power sources.

A typical PC power supply provides four DC output voltages: +5, +12, -5, and -12 volts. These voltages are available through four different types of connectors (Figure 1; 1-4). The color of the wire identifies the voltage and its use (Table 1).

Getting Started

A lot of power supply failures are actually simple problems that are easy to fix. Obviously, the place to start is at the beginning – in other words, are you getting power from the wall to the PC? As stupid as it sounds, the first thing to do is look under your desk and see if the PC is plugged into the wall. If it is, move the plug to a different socket (they go bad, too, you know).

That done, pull the power cord from the back of your PC and see if the power is getting that far. You can do this using a VOM or a simple neon lamp circuit tester, like part number 22-102 from Radio Shack.

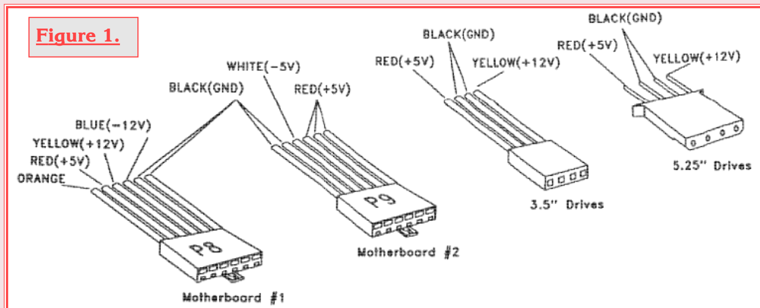
If there's no power, and you're plugged into a power strip or surge protector, the strip is probably the culprit. To test it, simply remove the PC's plug from the strip and plug it into a wall socket. If the PC starts working, the problem is in the strip. Generally, the problem is a blown fuse or a tripped circuit breaker. You'll find both at the cord end of the strip. The last item you should test before popping the hood is the power cord itself; replacing it with another cord is the fastest and safest method.

Under The Hood

Still nothing? Now it's time to remove the cover. Most covers are attached by five or six screws on the back. Before going any further, carefully read the instructions in the section called "Safety First."

The next logical place to look is at the power switch. Unfortunately, this may not be possible at this stage of the game. Many power supplies have a built-in power switch which isn't accessible until you dis-

Figure 1.



The 5.25-inch drive connector is the easiest to access for testing. The motherboard connectors P8 and P9 are identical, and can be reversed. They plug into the motherboard with the black leads together on the inside.

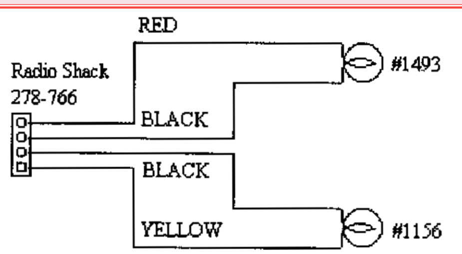


Figure 2. A dummy load can be made from a couple lamps that you can buy at any auto parts store and an extension cable from Radio Shack.

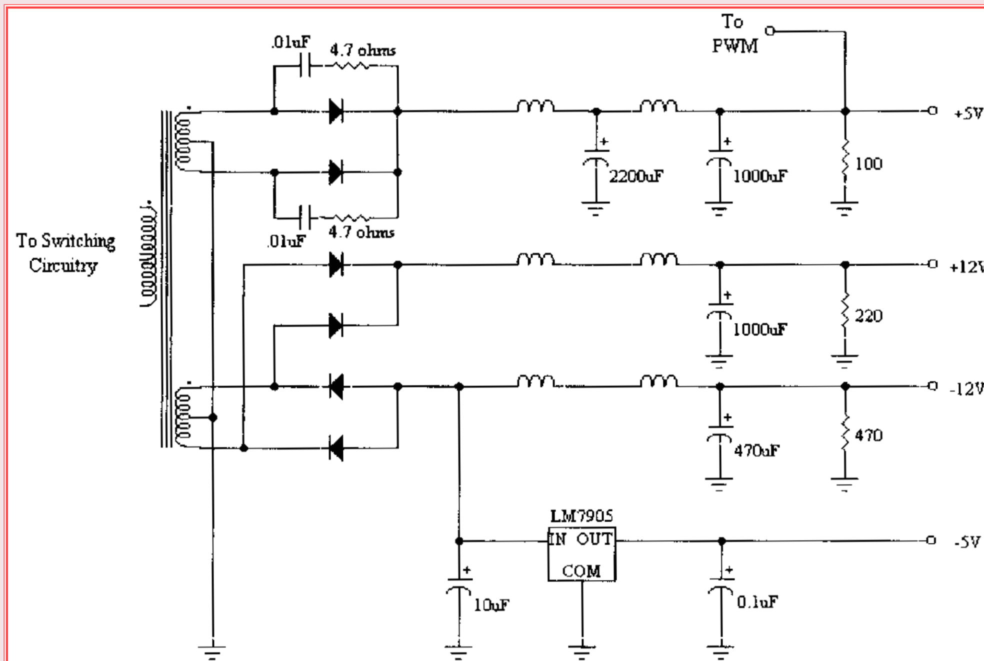


Figure 3. The low-voltage supply provides four output voltages.

Table 1. Power Supply Color Codes

Wire Color	Voltage	Use
Red	+5V	Motherboard, adapter cards, disk drives
White	-5V	Logic circuits (rarely used in modern PCs)
Yellow	+12V	Disk drive motors, RS-232 serial port, fans, adapter cards
Blue	-12V	RS-232 serial port, fans
Orange	n/a	Power OK signal
Black	0V	Ground (GND)

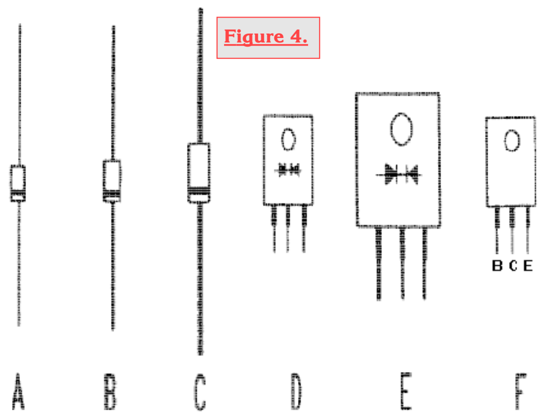


Figure 4.

You can generally identify the semiconductors by their shapes. From left to right, the first three are diodes, +12V rectifier, +5V rectifier, and switching transistor.

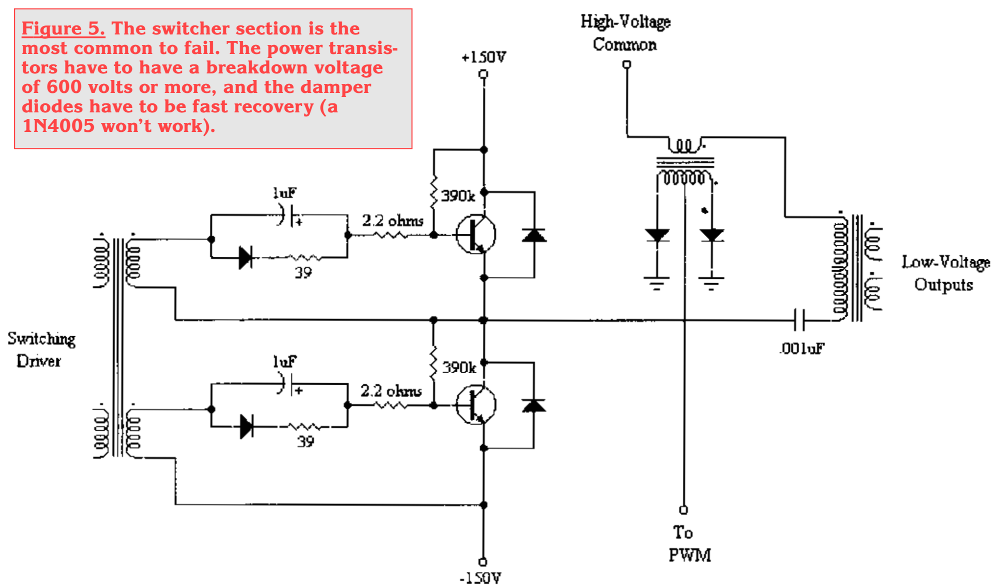


Figure 5. The switcher section is the most common to fail. The power transistors have to have a breakdown voltage of 600 volts or more, and the damper diodes have to be fast recovery (a 1N4005 won't work).

mantle the unit. If you have a tower computer case, though, the switch is located on the front panel, and connected to the power supply via four wires. All you have to do is unplug the wires from the switch – with the computer unplugged from the wall, of course – and test the switch with an ohmmeter. If you want to do a hot test of the switch (that is, bypass the switch), you can short the power wires together using two insulated jumper wires and plug the computer back into the wall. Just be careful that the jumpers don't touch anything.

Let's now look at the DC voltages. (If you removed the AC wires from the front-panel power switch, replace them first.) With the main switch off, locate a free power connector (the 5-1/4 inch version, Figure 1d, is preferred) or unplug a floppy drive to free up one. Don't unplug the hard disk; you'll need it for the entire duration of this test. Power up the PC, and measure the +5-volt (red) and +12-volt (yellow) lines using a VOM (black is ground). Make sure they fall within the voltage range specified in Table 2.

If they are out of range, power off the system and disconnect the mechanical drives one at a time, beginning with the floppies. Measure the +5- and +12-volt lines at each step. This will tell you whether or not the power problem is specific to a device. Don't forget to power off the system each time you disconnect a device. With the hard disk(s) still connected, remove plugs P8 and P9 (Figure 1) from the motherboard.

Finally, it's time to deal with the unlikely possibility of a shorted hard disk. If you have more than one hard disk, start shedding them one at a time. When you're down to your last hard disk, unplug it and connect its power plug to the dummy load shown in Figure 2. (I don't recommend running a PC power supply without a load.) If the power supply is still dead, it's off to the drawing board.

The Drawing Board

Now that we've done all that we can do with the power supply inside the cabinet, it's time to remove the unit and place it on the workbench. Since we've already disconnected all the power connectors, it's a simple matter of removing the mounting screws and sliding the power supply out of the cabinet, right? Well, hopefully.

Unless you have a tall tower, you'll probably run into obstacles, like adapter boards, disk drive signal cables, and support brackets. If you're lucky enough to have a detailed user's manual, it shows you the procedure. Otherwise you're on your own. In either case, make notes of where everything is, how they're connected, and keep the screws with the items they came from.

WARNING: MAKE SURE THE PC IS DISCONNECTED FROM THE WALL BEFORE STARTING DISASSEMBLY!

If the supply was powered from the AC line within the last few minutes, the large electrolytic capacitors in the high-voltage section will most likely still have a charge in them that could give you a shocking awakening. If so, let the power supply rest for a while before you crack the case.

Each case has its own method of construction, but generally two sides of the enclosure are what protect the inside electronics. Remove the cover screws, taking care to watch out for attached leads, switches, and sharp edges. If you have to disconnect any leads (typically fan wires) or mechanical parts, note carefully how they go back together.

Give the electronics a good looking over, paying attention to any scorched or burned parts that may point to a failure. If you have a built-in power switch, now is the time to check it. Next, check the fuse. Is it blown? If in doubt, use the VOM to test for continuity (use the X100 range). If the fuse is blown, replace it with one of the same type and rating before going any further. It's possible the trouble is the result of metal fatigue or mechanical failure of the fuse itself. To see if this solved the problem, connect the dummy load to one of the drive connectors and apply power.

If nothing happens, remove the dummy load and proceed to the resistance checks procedure. If the fuse blows with an explosion, go to the high-voltage repair section.

Resistance Checks

Referring to Table 2, perform a resistance measurement test. Keep the VOM's polarity correct, that is red to ground when testing a negative source, and wait for the filter capacitors to charge before taking a reading. The resistance values listed in Table 2 are only representative (the figures were gathered from actual measurements of several power supplies using a cheap VOM), so don't worry if your values are different from those listed.

However, if a resistance value is abnormally high or low, you have a problem. As a rule of thumb, a reading of 50 ohms or higher on the 5-volt and 12-volt lines means the output is probably okay. A resistance value of 40 ohms or less indicates a short, generally in the rectifier diodes. The five-volt line is the most prone to failure because it carries the heaviest load (typically 20 amps). An extraordinarily high resistance reading indicates an open, probably a zapped board trace or a burned resistor. Both conditions are often harbingers of problems in the high-voltage section, but not necessarily. It depends on how fast the shutdown circuit reacted. But before we face that possibility, we first need to find the extent of the low-voltage damage.

Low-Voltage Repair

The low-voltage section of the power supply is a very simple rectifier, L-section filter design (Figure 3). Key to the success of this design is a multiple secondary power transformer. There is a 5-volt winding and a 12-volt winding. In high-power supplies (250 watts and larger), there are usually two five-volt windings that are paralleled for higher output current — yet treated as a single winding.

Safety First!

Would you put a hairpin in an AC outlet socket? Not hardly! So why would you consider putting your finger in a power supply that is clearly labeled CAUTION!? Always unplug your PC before going under the hood. Once there, pay attention to my WARNING! signs. I've done my best to make the troubleshooting processing as shock free as possible, but power has to be provided at various stages of the game. Be alert, don't be stupid, and if you don't know what to do next, stop now!

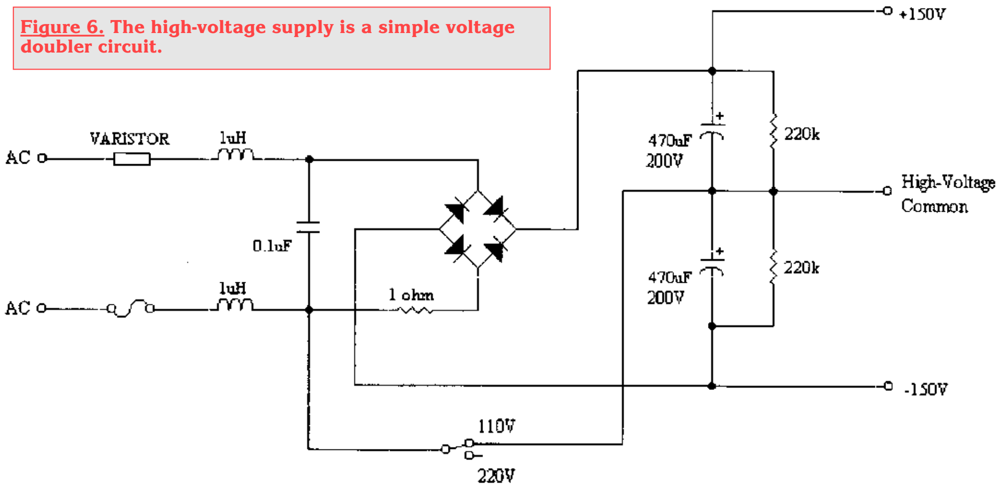


Figure 6. The high-voltage supply is a simple voltage doubler circuit.

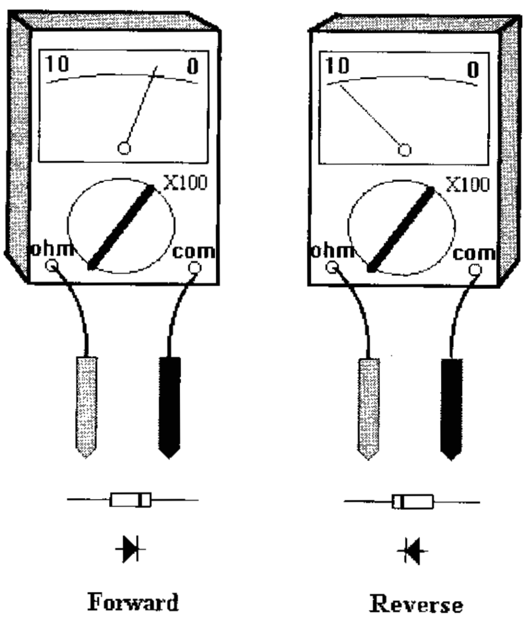
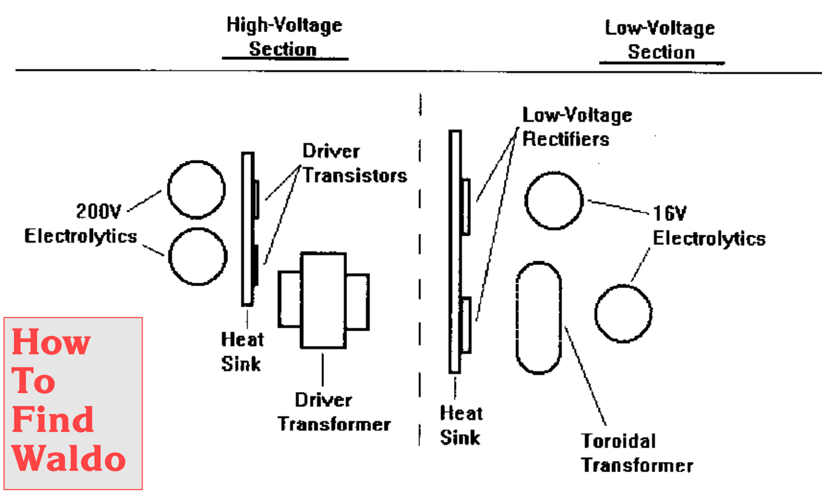


Figure 7. A cheap VOM is the best way to check transistors and diodes. Why? Because the test voltage has to be enough to breach the barrier voltage of a silicon diode, typically 0.7 volts, and a lot of DVMs have a probe voltage of 0.3 volts and less.



How To Find Waldo

Each winding has a grounded center tap to permit fullwave rectification using just two diodes (fullwave bridge rectifiers need four diodes). The direction of the rectifiers determines the polarity of the output voltage. Common cathodes are positive, and common anodes are negative. Because of its high-current requirements, the +5-volt rectifier is usually an array of parallel Schottky diodes in a single package (Figure 4) that mounts on a heat sink. The -5-volt output is often derived from the -12-volt rectifier via an IC regulator (typically an LM7905 equivalent) rather than from the five-volt transformer winding. However, I've seen it done both ways.

SOURCES

Allied Electronics
800-433-5700
Digi-Key
800-344-4539
Marshall Electronics
800-877-9839
Newark Electronics
800-344-4539
Radio Shack
800-843-7422
Wyle Laboratories Electronic Marketing Group
800-672-3475

The output of the rectifiers is filtered first by an inductor, called a choke, then by a heavy-duty electrolytic capacitor. In some designs, the five-volt line is double-filtered to reduce ripple by cascading two L-section filters on the output. Invariably, a bleeder resistor is placed across the output to discharge the capacitors after power off.

The most common cause of low-voltage failure is a shorted rectifier. If one blows, so does its companion, which forces you to replace them as a package deal. Second on the hit list is a shorted capacitor, which usually does less overall damage. Most of the time, the failure is limited to just one output line, but there's no guarantee.

The first step is to locate the shorted components. For this operation you need access to the bottom side of the printed circuit board. This is the hard part, because no two supplies are alike. Use your imagination, and be careful not to damage other components in the process. For example, twisting and turning the board too many times can cause attached wires to break loose.

Now comes the tricky part, because you have to first locate the affected parts on the circuit board. Use the road map, "How To Find Waldo," to help you in your quest. An ohmmeter is a good way to probe suspected areas for shorted devices. Once the area is located, the real work begins because it's virtually impossible to tell the difference between a shorted diode and a shorted capacitor without removing one or the other. Since the rectifier is the most likely culprit and the easier to remove (the electrolytics are glued in place), I'd start there.

The +5-volt and +12-volt diodes are most likely nestled inside a transistor case mounted on a heat sink. The bigger one (Figure 4e) is the +5-volt rectifier, and the smaller one (Figure 4d) is the +12-volt rectifier. The negative-voltage rectifiers are individual diodes typically in a DO-41 case.

With the suspect rectifier or diodes in hand, do a resistance check of the defective voltage output line again. If the reading is within the normal range, trash the old part or parts and replace with new. (Helpful Hint: If the new diodes come in an axial-lead package, typically DO-41, solder them on the trace side of the circuit board instead of the component side. It's a lot easier.) If the output still shows a short, yank the electrolytic and check again. If the output is still shorted, make sure you're pulling the right teeth.

Exact replacement parts always cost more than generics, so go with the generic. You can get "universal" replacements from GE, RCA, and Philips ECG. Unfortunately, they're almost as expensive as the original. For the +5-volt rectifier, I recommend the MBR series from General Instruments and Motorola (available from Digi-Key and Allied Electronics, respectively). The +12-volt rectifier is a dual Schottky device that's available from several vendors, and generally sells for a buck or two. The negative voltage rectifiers must be fast recovery diodes, like a 1N4933. Replacement electrolytic capacitors are as close as your local Radio Shack.

When the voltage line has a three-terminal IC voltage regulator, check the resistance between both the input and the output (Figure 4) to ground. If only the output pin is shorted, the output capacitor is bad.

Table 2. Output Voltage and Resistance

Nominal Voltage	*Voltage Range*	*Resistance*	*Wire Color*
+5V	+4.75V to +5.25V	>100 ohms	Red
-5V	-4.75V to -5.25V	>100 ohms	White
+12V	+9V to +15V	>250 ohms	Yellow
-12V	-9V to -15V	>250 ohms	Blue
n/a	0V or +5V	˜1000 ohms	Orange
0V	0V	0 ohms	Black

Still Don't Work, Huh?

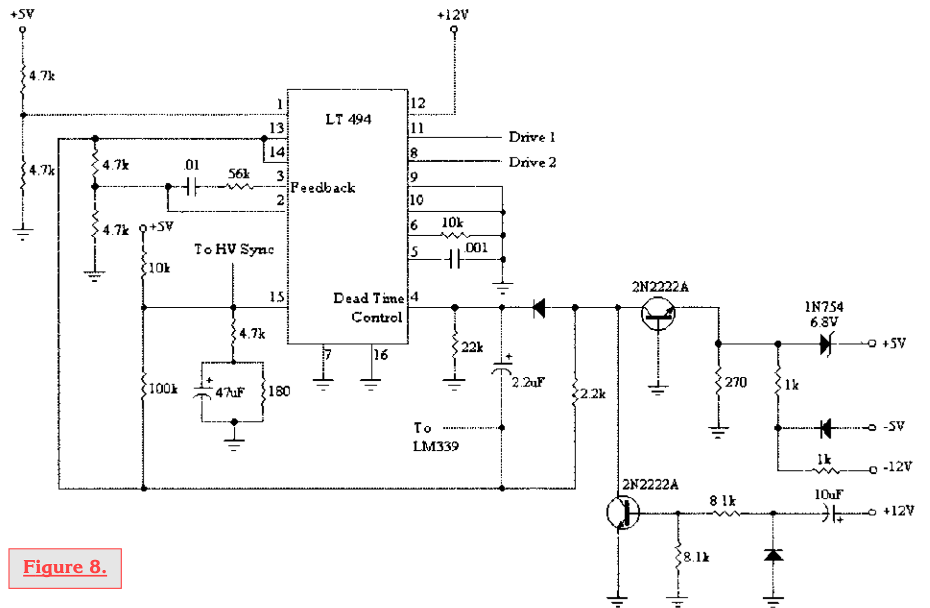


Figure 8.

Nine times out of ten, the troubleshooting techniques presented in this article will solve your PC power supply problems. But what if the power supply still doesn't work? There can be lots of reasons, ranging from a faulty transformer (good luck finding a replacement) to a bad solder connection. In most situations, I'd cut my losses and find a substitute power supply or try to salvage the motherboard for use in another system. But if you're really dead set on reviving the system, there is one more stage we haven't discussed — the PWM (pulse-width modulator). But put your seat belt on, 'cause this is gonna be short and fast. It's not for everybody.

The PWM (Figure 8) is what drives the switching transistors, and when it doesn't work, nothing works. Consider it the brains of the power supply. The PWM is generally a single IC chip, most likely a Motorola TL 494. But before you replace the chip, let's see if it's working or not. For this you'll need an oscilloscope and a power supply.

The simplest way to test the PWM chip is to grab a disk drive connector and pump +12 volts into its yellow wire from an independent power supply. This can be done using another PC power supply or any other DC source (batteries work, too). Once power is applied to the PWM chip, observe the output waveforms on pins 8 and 11. Both outputs should be active squarewaves. If at first you don't succeed, ground pin 4 and try again. If the scope still shows nothing, replace the LT 494 chip. If the scope shows waveforms, the most likely culprit is the LM339 comparator. The LM339 is cheap, about a buck, and readily available, so it's worth a shot.

My method of replacing an IC is to clip the leads as close as possible to the body of the IC, leaving 14 or so metal pegs standing upright from the main board. Paying attention to direction, slip the replacement IC alongside the pegs and solder the new component in place.

If by now the power supply still doesn't work — chuck it.

If only the input pin is shorted, the rectifiers are bad. If both are shorted, the chance is both the diodes and the IC are shorted. To verify this theory, remove the IC and check the resistance again. If it reads okay, replace the semiconductors. The re-placement for the -5-volt IC voltage regulator is an LM7905.

High-Voltage Repair

If the new fuse blows when you apply power, there's a problem in the high-voltage section. We know this because the low-voltage section has an automatic shutdown circuit that reacts a lot faster than the fuse; that is, a low-voltage problem disables the power supply long before the fuse has time to blow. That doesn't necessarily mean the low-voltage outputs are okay, because failure of the -12-volt line can cause cascading damage that goes all the way back to the high-voltage section.

The high-voltage section is divided into two parts: the high-voltage power supply and the switching circuit. Most high-voltage failures occur in the switching circuit.

WARNING: COMPLETELY DISCHARGE THE INPUT CAPACITORS BEFORE WORKING IN THE HIGH-VOLTAGE SECTION!

If the fuse has a "mirrored" look to it, you can bet the farm that at least one of the two switching transistors is shorted (Figure 5). Typically they perish as a couple. These transistors are mounted on the heat sink(s) closest to the two largest electrolytic capacitors (see "How To Find Waldo"). With the red probe of a VOM on the collector of the first transistor, check the collector-to-emitter resistance, then the collector-to-base resistance (Figure 4). If a short is found, replace both the transistor and the damper diode that's across its emitter-collector. I normally use a Motorola MJE13009 for the power transistor and a 1N4937 for the damper diode.

You should also replace the low-value resistor that's in series with the transistor's base. This resistor is often used as a fusible link that goes puff when the switcher fails. Its purpose is to protect other components in the chain from harm. If the resistor is burned beyond recognition, you can replace it with any 1/4-watt resistor with a value of 1 to 10 ohms (the exact value isn't important). Sometimes, though, even the fusible isn't fast enough to prevent damage. So before installing the new parts, it's wise to check out the pulse shaper network (typically a resistor-diode-capacitor combination) associated with the base circuit, too. A quick way to test all three components at once is to treat the network like a single diode, checking it as a whole for shorts and opens (Figure 7). Now repeat the procedure for the second switching transistor.

The high-voltage supply is a simple voltage doubler with an output of about 300 volts (Figure 6). While this section rarely fails on its own, a shorted switching transistor can wipe out the bridge rectifier in an instant. Check the AC input for shorts, and replace the entire bridge if a short is found. Bridges can be either discrete diodes or a large, rectangular module, and you can find suitable replacements from Radio Shack. There's probably a one-ohm resister in line with the AC input that needs to be checked, too. On the outside chance that one of the doubler capacitors is shorted, do a resistance check of each.

When powered from a 220-volt AC power source, the capacitors serve as voltage dividers to provide an artificial ground. Consequently, the capacitance and ESR (equivalent series resistance) values of the capacitors are critical when operating from a 220-volt line and have to be evenly matched, otherwise the switching voltages will be uneven. As electrolytics age, both the capacitance and ESR changes. If the mismatch is too great, one voltage could exceed the limits of the switching transistor, which can start parts a-poppin'. You can check the voltage balance with a VOM. Always replace both capacitors, not just one, and use a good grade capacitor, like the Panasonic TSU series.

It's Showtime

If you've made it this far, you probably have a working power supply. But before you apply power, let's make sure we've covered everything.

– You did a final resistance check on the output voltage lines, and all are within the specifications of Table 2, right?

– You checked the resistance across the AC input (with the power switch on) and it measures 1 megohm or better, check?

– You checked the fuse.

– Any broken wires or burned parts?

Good! Then it's showtime. Re-assemble the power supply. Plug the dummy load into one of the disk drive connectors. Apply power.

If both lights light, congratulations! You've got yourself a working power supply, because the power supply itself needs the -5- and -12-volt lines to operate. Consequently, you don't have to test them, unless you're as curious as I would be. Now all you have to do is put everything back together and enjoy a more peaceful day — except for the coffee. Here I suggest ... **NV**