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Troubleshooting Computer Power Supplies

Rule #1: Be careful.

With the increasing availability of computer power supplies, hams are the recipients of both good and bad supplies. Because of their curiosity level and association with electronics, hams are prone to remove the cover from a power supply to see what makes it tick. Although troubleshooting a computer power supply isn't very difficult, it does present a potential danger.

Warning: Unless you have previous experience or are familiar with how to work with high-voltage/high-current circuits, do not remove the cover from a computer power supply. The internal voltages of a computer power supply reach 320 VDC with a current capacity up to one ampere. The energy generated within the circuit can be lethal — beware!

There is a tamperproof sticker on most computer power supplies warning of the danger of working inside of the box. Assuming that you understand the danger involved and have the background to work with high voltage circuits, I'll proceed to tell you what I know about switching power supplies and how to perform some troubleshooting techniques.

Theory of operation

Let me point out that there are about as many different circuit designs for computer power supplies as there are designers. Each is unique in its design, but the basic operation of each follows a single pattern, the single pattern being a high power switching circuit driving an output transformer. The technique is reminiscent of early car radios that used a vibrator to switch the DC applied to the primary of a power transformer.

The switching circuit may use one or two power transistors, depending upon the design. Because power switchers operate pretty much like a high-powered oscillator, the output voltage requires some form of voltage regulation/control. Some designs utilize an optical coupler to provide feedback from the output circuits back to the switchers. Other designs utilize a pulse-width-modulator (PWM) IC to sense the output circuits and control the switchers. Regardless of the method used, the output voltage is controlled to maintain a voltage level at some percentage value — typically +/-5% of nominal.

The more you know about how a computer power supply is designed/constructed, the easier it is to troubleshoot when there is a failure. To gain familiarity with a supply, look over

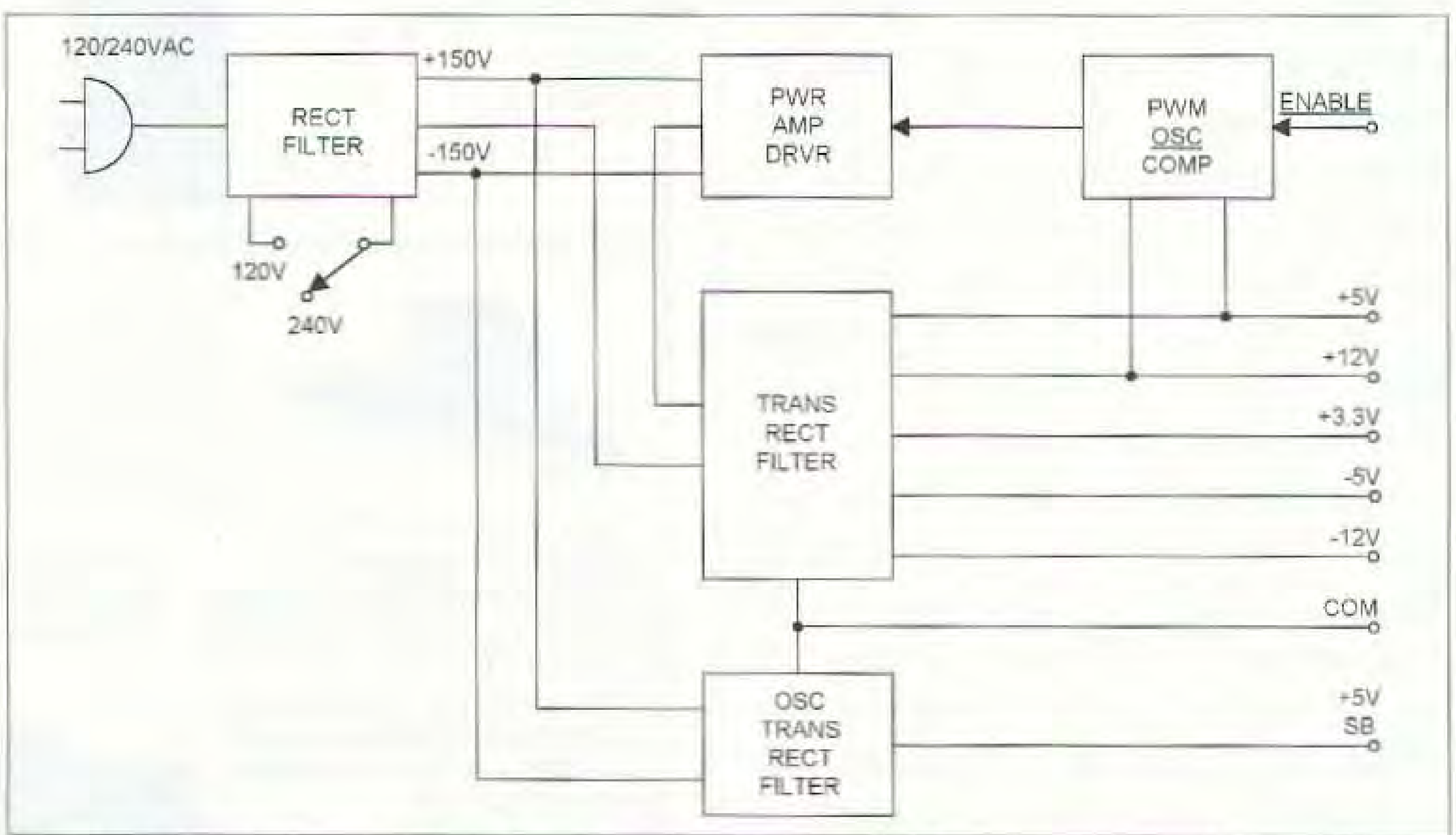

Fig. 1. Block diagram of an ATX-version computer switching power supply.

Fig. 1, which is a block diagram of a typical ATX-version switching power supply.

You'll notice that the input voltage may be either 120 VAC or 23O VAC. A switch is placed on the side of the power supply box allowing the user to select the input voltage that will be supplied. The switch changes the rectifier from a bridge (23O VAC) to a half-wave voltage doubler (120 VAC). In either case, the total voltage that is applied to the filter capacitors ends up being close to 320 VDC. The total of 320 VDC is divided equally across each filter capacitor and switching transistor. The outer +/- voltage lines are called "voltage rails."

Also connected across the 320V rails is an oscillator/driver/rectifier circuit used for developing +5 VDC at about 0.5 A. This is called standby power (SB) and is used to keep the computer "alive" even though it is intended to be asleep during periods of nonuse.

To the right of the power switching transistors is a block called the PWM. This is an IC that typically contains everything that is required to control and regulate the output voltages from the power supply during normal operation. In the case of an ATX power supply, an ENABLE line is provided to turn the PWM circuit ON or OFF as desired. Grounding the enable line will allow the PWM to come alive and drive the power switching transistors. A typical ATX power supply schematic is shown in **Fig. 2**.

All power supplies operating off of an AC power line require rectifiers for changing AC voltages to DC. In the case of a switching power supply, the process is done twice, with the first step rectifying the power line to produce approximately 320 VDC to power the power switching transistors which create AC power at a frequency in the range of 2 to 50 kHz. In the second step, the high-frequency AC power is rectified to DC at the operating voltage levels required by the using circuit, i.e., the computer.

Before getting started with problems and troubleshooting, I recommend that you spend some time comparing the block diagram to the schematic of the ATX supply. Gaining an understanding of the circuits and what they represent will allow the troubleshooting process to proceed at a more rapid pace.

Typical problems

Although I've worked with switching power supplies for many years, I've only encountered a few repeating problems (although I suspect that many more exist). Here is a listing of the problems that I've found:

- Fan
- Dried out capacitors
- Power transistors
- PWM chip
- Fuse

Fan

Of this listing, perhaps the fan has been the most prevalent failure area. Switching transistors are directly dependent upon a flow of air across a heat sink to keep them cool (typically 75–80°F). When the fan either slows down or stops and the air flow ceases to be adequate, then the power transistors tend to burn up, creating a failure.

The typical fan used in computer power supplies is of the DC brushless type with either sleeve or ball bearings. Sleeve bearings are the most common, and have the highest failure rate. After many hours of use, the oil in the bearing dissipates and the bearing begins to wear and will develop a rattle. It's possible for the fan blade to actually hit the case, causing it to slow down. Another failure mode is for the dust accumulation to mix with the bearing oil, and create a hard muck that can stall the fan rotation.

Some fans are serviceable, but disassembling them is a little tricky because the plastic frequently cracks under tool pressure. Replacing the fan with a new one is recommended.

Capacitors

After a power supply has been in service for a long time and is typically full of dust, the air flow is somewhat restricted, causing the filter capacitors to warm up along with the power transistors. Warm to hot temperatures surrounding filter capacitors cause them to begin drying out, resulting in a loss of capacitance.

The one indicator of dried out capacitors is an intermittent start-up of the power supply. This is particularly

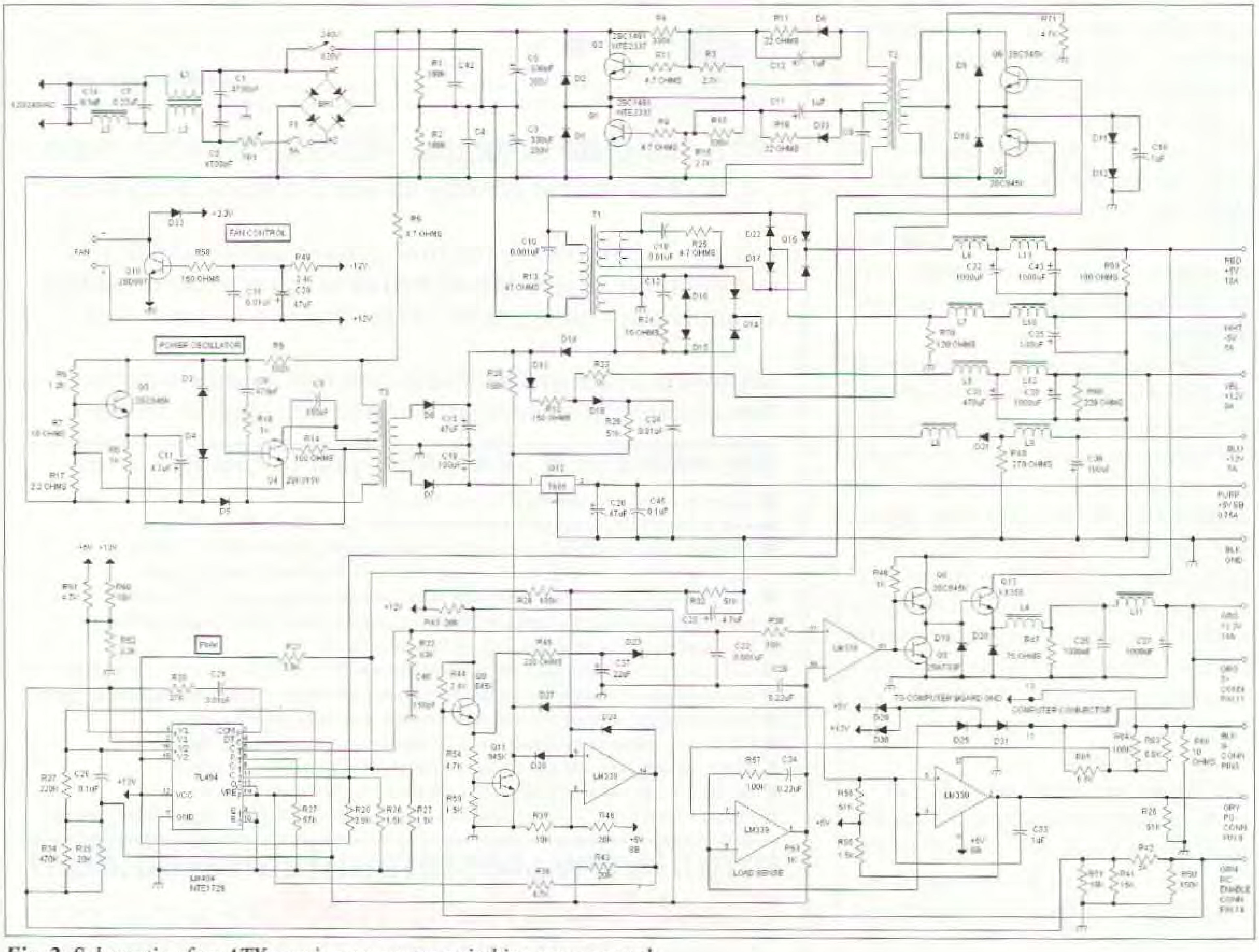

Fig. 2. Schematic of an ATX-version computer switching power supply.

true for the model series of supplies that use a voltage boost circuit to power the PWM IC. The voltage is boosted from about 12V to 21V to power the PWM IC and the small output driver transistors. If the boost filter capacitor is dried out, the voltage is never boosted and the power supply is very reluctant to "come up" when enabled.

Normal troubleshooting techniques will fail to identify a specific problem with the circuit, yet it fails to operate. When I've encountered such a problem, I go immediately to the boost filter capacitor and change it, which usually results in a more normal operation. As a rule, if one capacitor is dried out, others are most likely dried out as well. Changing all of the capacitors may be a good idea, but probably not a very practical solution.

Transistors

Power switching transistors rarely fail in normal power supply operation. Therefore, when a transistor fails, it is usually caused by a lack of cooling air or a shorted DC output circuit.

Fuse

A fuse failure is somewhat obvious when the internal fuse link (element) has been vaporized. When that condition is observed, then you might conclude that something drastic created the actual failure and some extensive diagnosis may be required.

On the other hand, fuses also have their own failure mode, which isn't quite as obvious as a melted element. A fuse is typically made by attaching a fusable link between two metal end caps, and because the element is a resistor it will get warm during use. Heating and cooling of the element causes a mechanical stress on the element that will cause it to break. The break occurs more often than not near a cap rather than out in the middle, where the break might be observed through the glass tube.

Others

Rectifiers and filter capacitors can also fail, though rarely, but when they do fail, they place an excessive load on the switching transistors and cause them to fail. When a power transistor fails, look for additional problems that might have caused the failure.

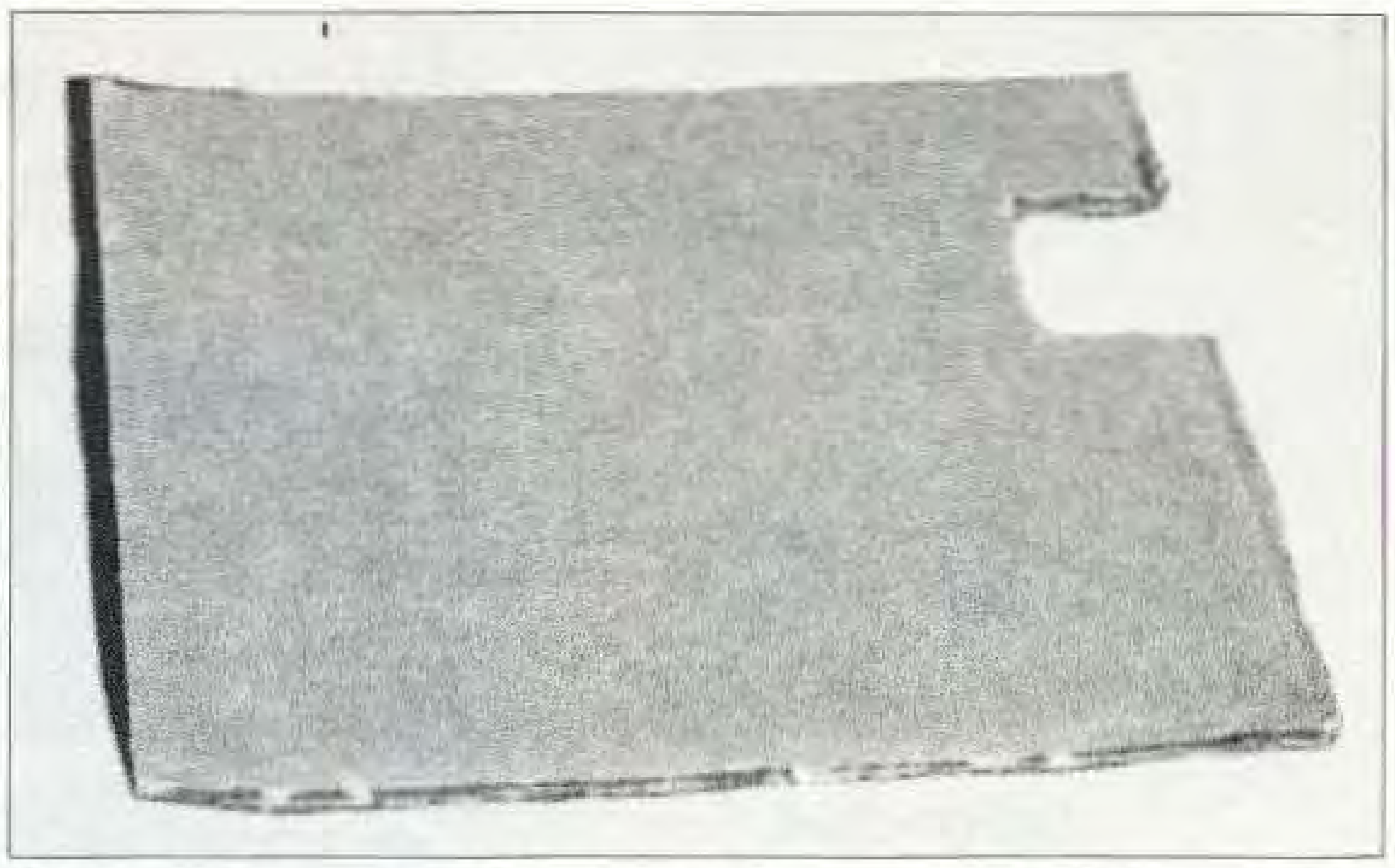

Photo A. Heavy cardboard used as a support during troubleshooting.

Up to this point, we've considered the safety issues involved and have gained some insight into the basic design of a computer switching power supply with a focus on effecting a repair. Some typical problems have been identified, along with a brief discussion of typical failure modes.

Safety tips

Personal safety is of the highest importance when working with any dangerous piece of equipment, and that includes computer power supplies. When working with an open computer power supply, it is imperative to work with only the low voltage side of the power supply when AC power is applied. There are times when some measurements must be made on the high voltage side of the supply, but when that's necessary, connections to the HV side must be done when the AC power is removed from the supply. A meter may be attached to the HV circuit and then read after the power is applied.

To work on the underside of the power supply board, the board must be lifted and turned upside down without having to remove the wires connected to the power connectors and switch. Either a cardboard or wooden sheet is placed between the board and the case to provide a fairly stable mount for the inverted board. **Photo A** shows a heavy cardboard sheet that I use as a support and insulator. **Photo B** shows the power supply board inverted on its case, exposing the circuitry for diagnosis.

While inverted, short solid jumper wires may be tack soldered to stand up on various pads where measurements are to be made. Meter leads can be clipped to the jumper wires so that hands may be kept away from the circuit when power is applied. Power is removed after making a measurement and before the meter leads are touched.

For safety's sake, it is important to not touch any live circuit or the HV side of the circuit board. How do you tell the LV section from the HV section? It takes a little practice, but the bottom side of the circuit board is

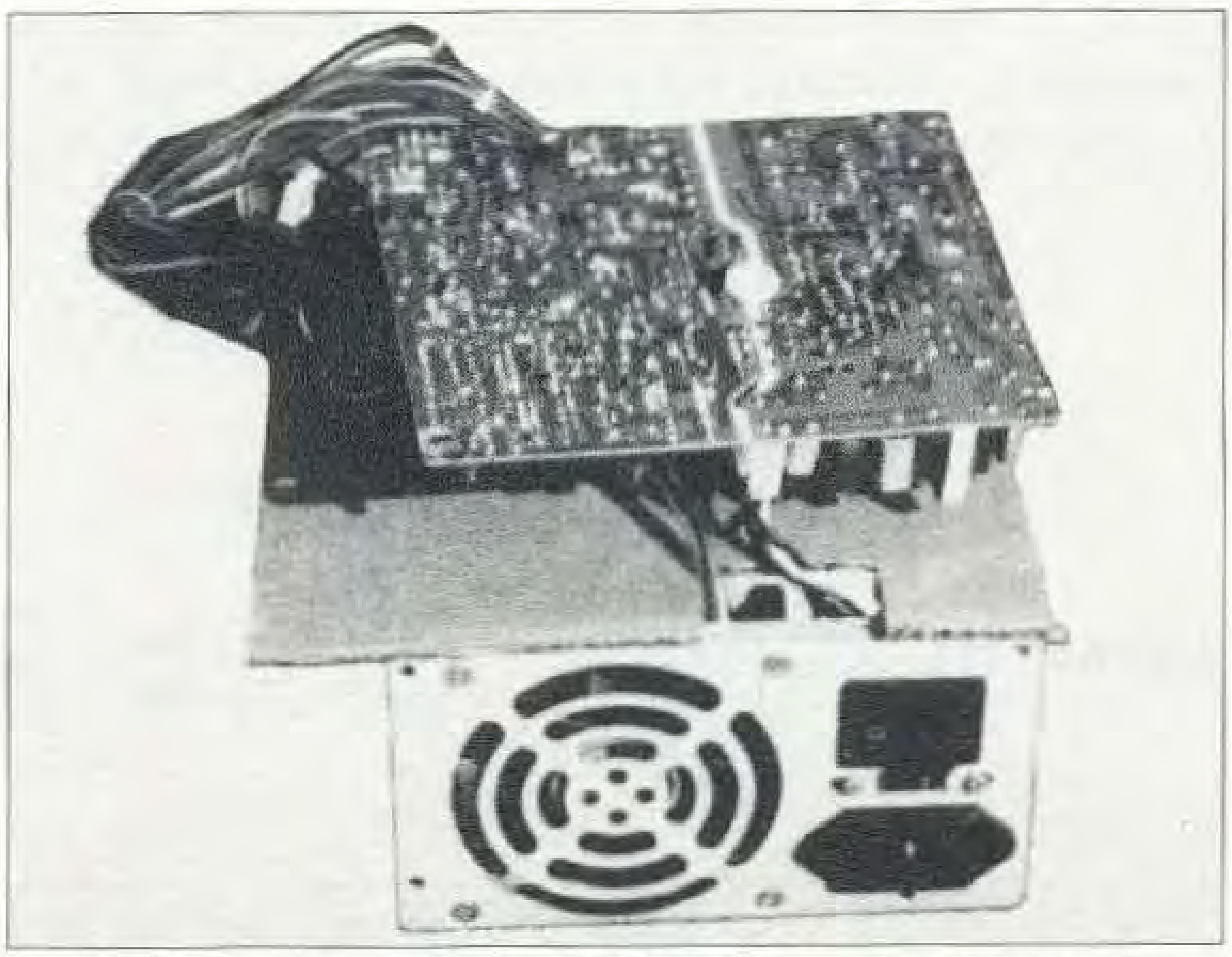

Photo B. Power supply board inverted on the cardboard and ready for diagnosis.

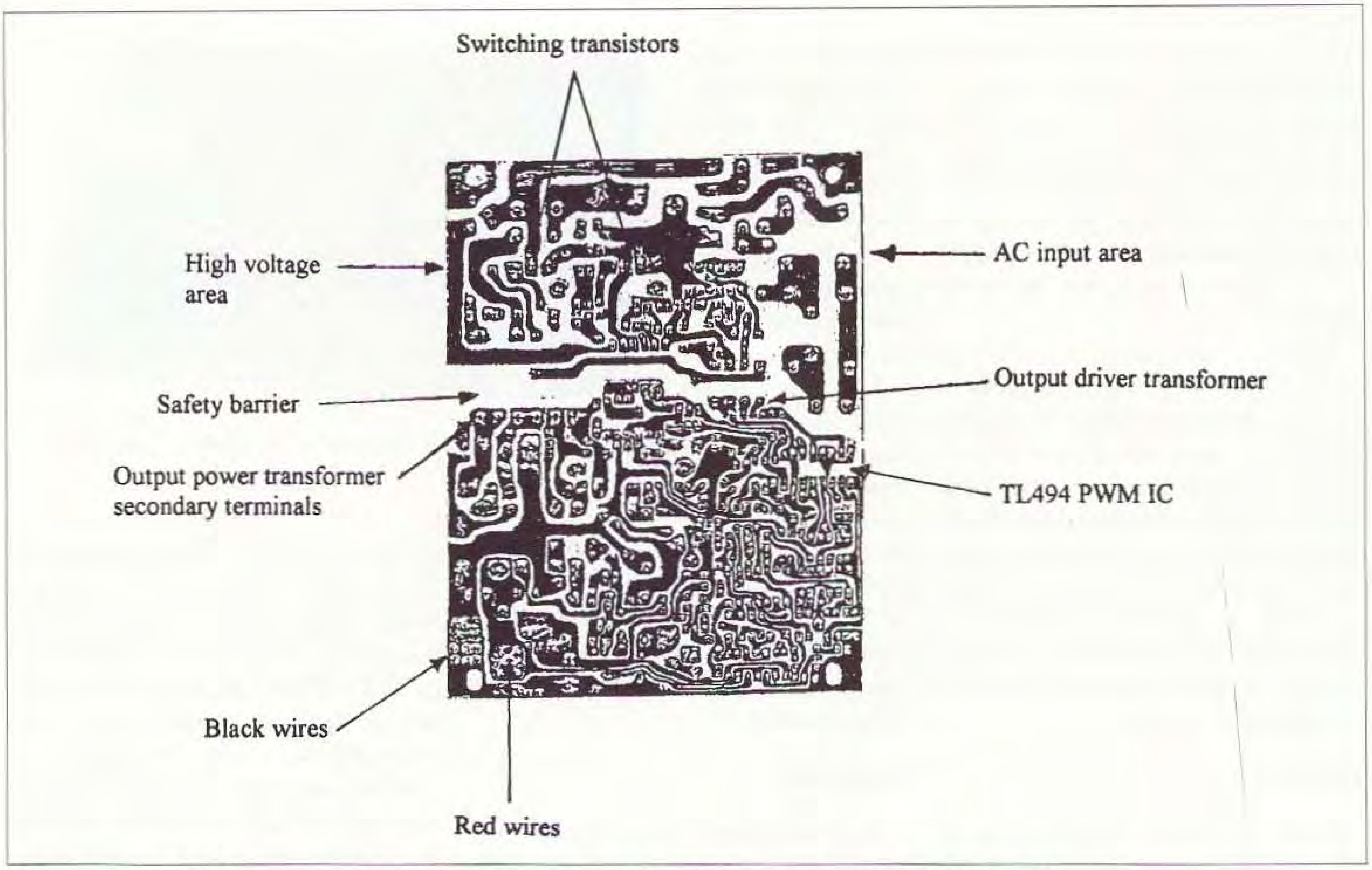

Fig. 3. Bottom side of a typical switching power supply board. Specific items are noted for identification.

divided to provide isolation between the HV and LV sections. It really pays to just study the bottom side of the board and identify as much as you can about it before ever applying power. **Fig. 3** shows the bottom side of a typical switching power supply. Specific identification points are shown that will both support safety as well as assist the troubleshooting process.

The first and most prominent indication of which section is which: Look for the switching transistors, as they are always on the HV side of the supply. In addition, the HV filter capacitors are also on the HV side. Another indicator of the LV section is the location where the heavy black, red, yellow, etc., wires are connected.

Remember, it is for your safety that you become as familiar as possible with the board layout and circuit voltages before beginning a troubleshooting process. Dangerous voltages are present on the power supply board, and care must be taken when the board is openly exposed while AC power is applied. Caution must be exercised at all times.

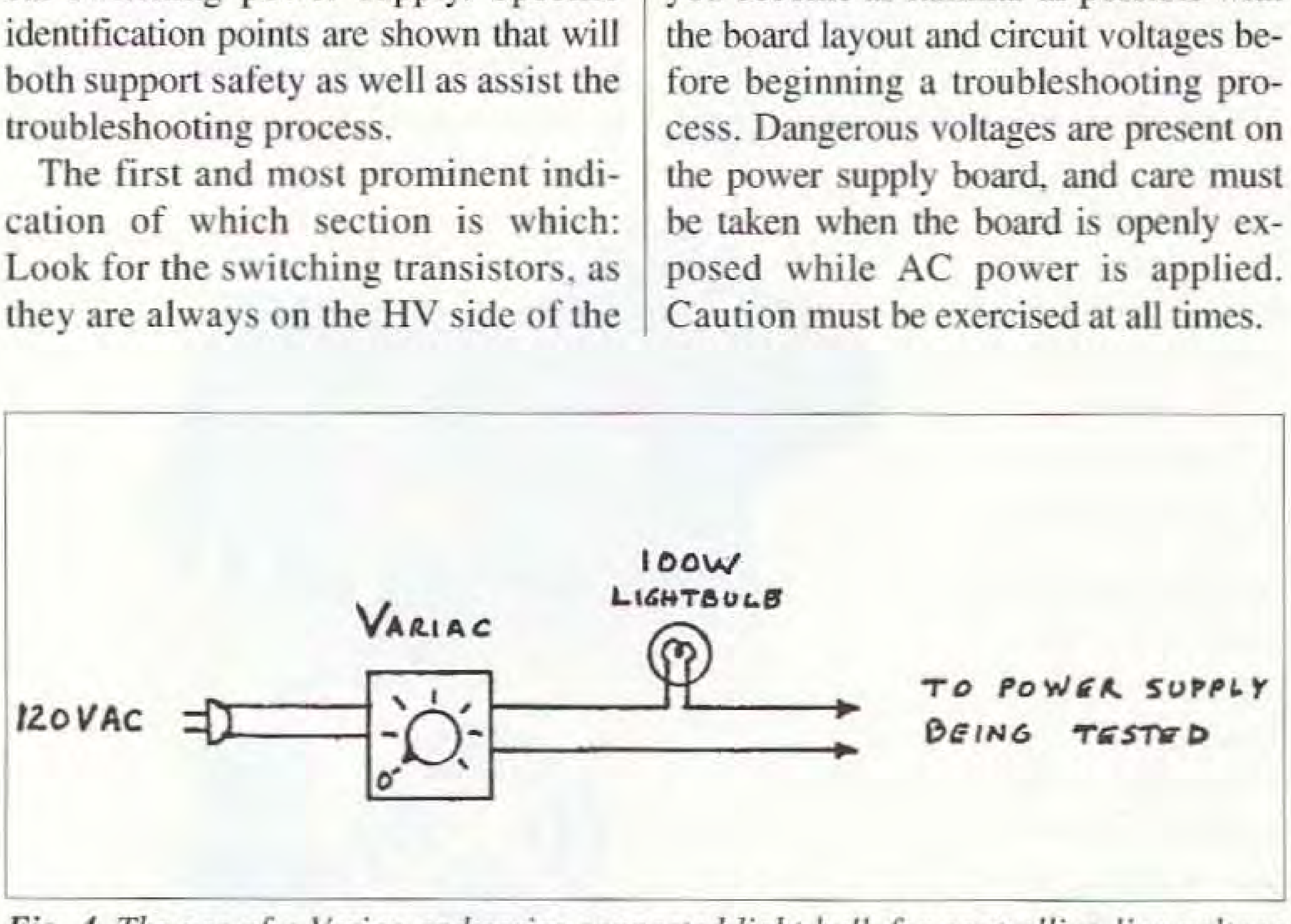

Fig. 4. The use of a Variac and series-connected light bulb for controlling line voltage and current while a power supply is undergoing diagnosis. The light bulb provides a visual indication of the amount of current being drawn.

Troubleshooting

Troubleshooting the circuit board starts by an attempt to identify and classify the problem symptoms that exist. In most cases, when a computer power supply fails, it is "dead" and fails to operate. That particular clue is generally not sufficient to lead you to a defective component. Because a switching power supply operates pretty much as a closed loop system, all pieces of the system must be operational before the power supply will come up and operate. Therefore, it's sometimes very frustrating to sort out what is really causing the failure. The most logical troubleshooting process is to check as much of the various parts of the circuit at possible and "clear" them of any fault. By a process of elimination, the fault will eventually surface.

Before applying power to the supply, gather all of the test gear and resistive loads that are desired. I've found the following items to be needed:

- One or two voltmeters (analog or battery-powered instruments only)

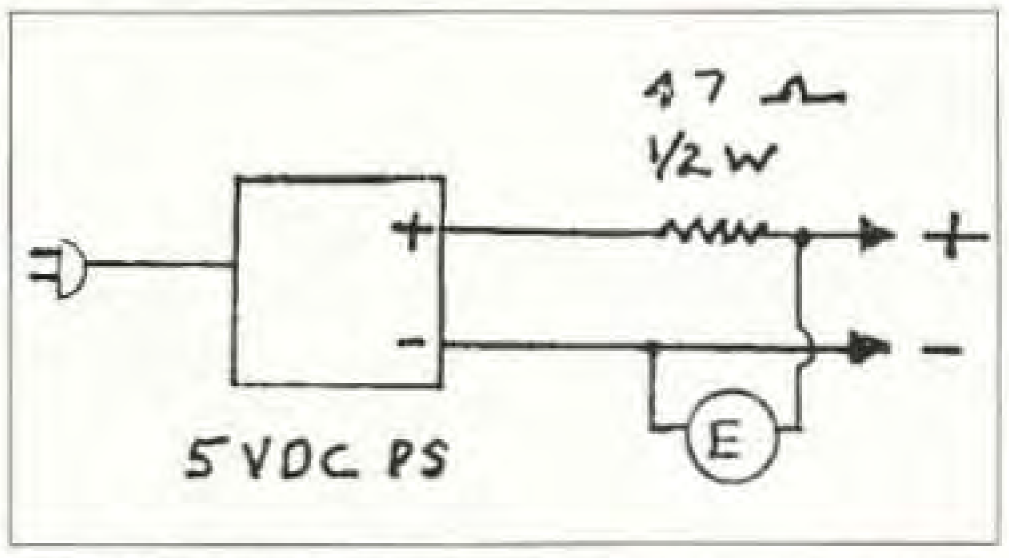

Fig. 5. A 5 VDC power supply, or a 3–6V battery, used for testing shorted components in the output circuits of a computer power supply.

- An oscilloscope
- 5 VDC power supply (or a 3-6V battery)
- 5 ohm 10 W resistor
- 10 ohm 20 W resistor
- 47 ohm 1/2 W resistor
- Selection of clip leads
- Variac
- 120V/100W light bulb in a socket with a line cord attached

Notes

1. As a caution, oscilloscope use must be restricted to only the LV side of the supply.

2. The 100 W light bulb is placed in series between the Variac and the computer power supply (see **Fig. 4**).

3. The 5V power supply is used to test all of the low voltage output circuits for shorts. A 47 ohm resistor is connected in series with the output of the 5V supply and acts as a current limiter (see **Fig. 4**).

4. In the case of an ATX-type supply, the enable line must be switched to ground for the supply to be "turned on."

5. Remember that if the board fault is found and fixed while the board is inverted, there will be no heat sink cooling from the fan. Excessive testing must be avoided to prevent overheating of the switching transistors and rectifiers.

Test steps

CAUTION: Be sure to observe voltage polarity for all components and measurements.

DO NOT RELY ONLY ON THE POWER SWITCH TO REMOVE AC POWER; PULL THE PLUG BEFORE ATTEMPTING TO TOUCH OR WORK ON THE CIRCUIT. ALLOW A FEW MINUTES FOR THE HV FILTER CAPACITORS TO DISCHARGE — CHECK THEM WITH A VOLTMETER.

A. Clear all DC output circuits of any shorts. This process involves connecting an external 5 VDC power source through a 47 ohm resistor to each of the 5V

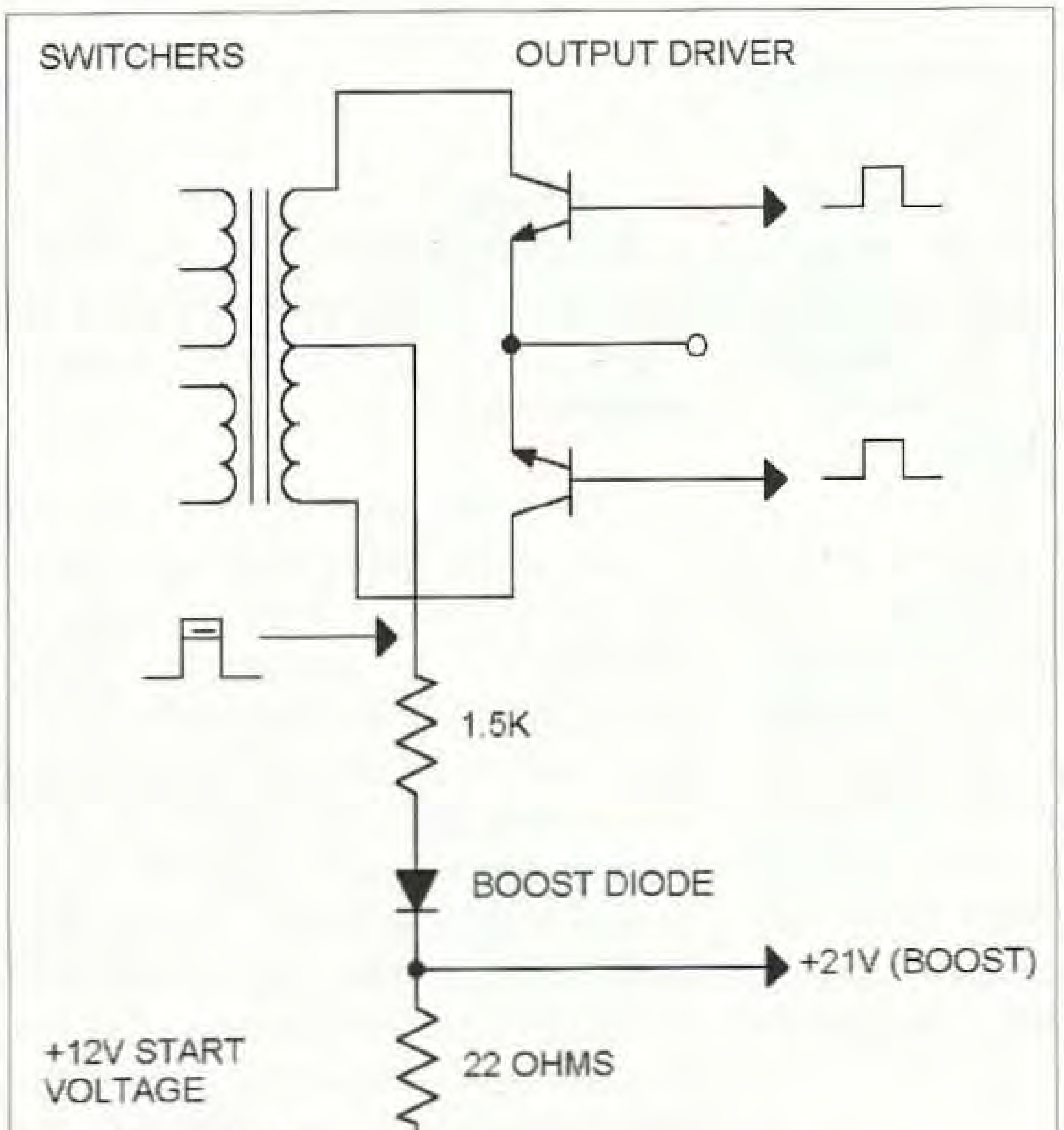

Fig. 6. Typical voltage boost circuit used in some computer power supplies. The transformer flyback pulse is rectified and filtered to create a voltage output higher than the 12V source (boost voltage).

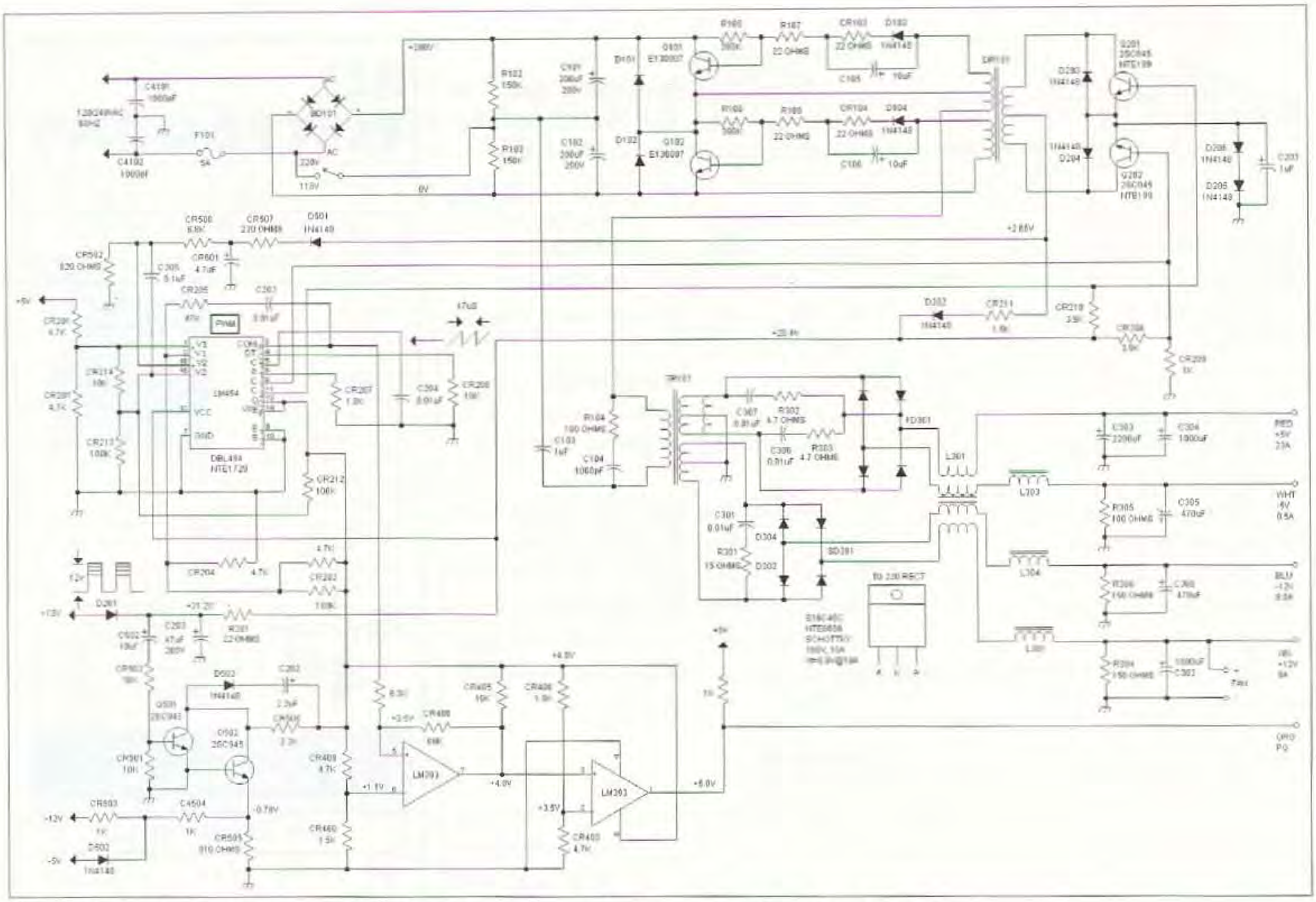

Fig. 7. Schematic of a typical non-ATX computer power supply that uses a voltage boost circuit.

and 12V output circuits individually — while observing polarity. With 5V applied, measure the voltage on the computer PS side of the resistor and it should be essentially the same as that on the 5V source side.

Note: Typically the +5V and +12V output circuits may have a 150–470 ohm resistor to ground that operates as a bleeder for the circuit. Therefore, the voltage measured, when using the 5V supply and a 47 ohm resistor, will be nominally 4V.

To check the 3.3V output: With 5V applied to the main 5V output, measure the voltage on the 3.3V output. The 3.3V output is sourced through a regulator or pass transistor from the 5V output. If necessary, remove the 47 ohm resistor from the 5V power supply in order for the 3.3V circuit to operate normally. Note: The 3.3V output is sourced from the main 5V output, but the 3.3V driver/controller may be sourced from the 12V output. Therefore, little or no 3.3V may be present during this portion of the test.

If deemed necessary, the 3.3V output circuit may be checked by momentarily applying 5V through the 47 ohm resistor. After clearing all of the plus voltage output circuits, reverse the polarity and check the negative 5V and 12V output circuits.

Problem: If one of the output circuits exhibits a voltage lower than expected (except perhaps for the 3.3V output), then examine that circuit for any leakage path that would be drawing sufficient current to lower the 5V value. Potential leakage paths exist with the diode rectifiers and filter capacitors. When in doubt, temporarily remove the item in question and repeat the 5V test.

B. Using an ohmmeter, check the resistors, diodes, and the coupling capacitor located in the base circuit of each switching power transistor.

Problem: Occasionally one of the small components will fail, shutting down the supply. It is usually necessary to lift one end of one or more of the components in order to obtain a proper measurement indication. Note: Seldom are the switching power transistors damaged when one of these components fails.

C. Once the DC output circuits are cleared of any potential shorts, power may be applied to the power supply from the AC line through the Variac and light bulb. The objective of the light bulb is to function as a current limiter, but more importantly it provides a direct visual indication of the current being drawn by the supply. The Variac and light bulb should remain in the AC line until the power supply has been deemed operational. If all of the above steps have been completed, then it is now time to apply AC power to the power supply.

Again, the dangers involved must be emphasized and that you must exercise caution when working around high voltage circuits. Test equipment such as voltmeters must be connected to the HV circuit prior to having power applied, and then removed after the AC power has been turned off. Any AC-powered test equipment such as an oscilloscope must not be connected to the HV circuit at any time, as there is insufficient voltage isolation to protect either the operator or the equipment. Use of the oscilloscope must be restricted to only the low-voltage side of the circuit.

As a reminder, should the switching transistors be made operational during the power test phase, insufficient cooling air will be present to protect the transistors. Power-on test periods must be kept short.

Now, continuing with the test steps:

D. Setup steps in preparation for applying AC power.

Assuming that the fuse checks "good," then steps may be taken to apply AC power following these suggested steps:

1. Connect the 5 ohm resistor to the main 5V output (red) and ground.

2. Connect the 10 ohm resistor to the main 12V output (yellow) and ground.

3. Connect a voltmeter (set on the 500-600V range) to the 320V rails.

4, Using the Variac, raise the AC line voltage and observe the voltage developed across the rails. The value measured, with the switch set for 120V, should be approximately 2.8 times the AC RMS applied voltage.

5. If the light bulb glows dimly as the Variac supplied voltage is raised, then slowly increase the line voltage to 120V. Take note of the "320V" reading.

Problem: If the voltage fails to track at approximately 2.8 times the RMS source voltage, then remove power and troubleshoot the HV rectifiers and filter capacitors. It may be necessary to temporarily remove the switching transistors should they be suspected of being shorted.

Note: To remove the switching transistors, remove the whole assembly by unsoldering the transistor leads, and then remove the heatsink retainer screws. Carefully lift the assembly, making sure that the transistor leads lift out of the board.

6. If the 320 volts fails to measure reasonably close to the 320V, then connect the voltmeter across each of the HV filter capacitors as the AC input voltage is raised.

Problem: If the two measured capacitor voltages are drastically different, consider that one of the power transistors or one of the capacitors may be shorted. Temporarily remove the power transistors and repeat step 6 to verify an equal voltage across each capacitor. If the voltages still fail to be close (equal) in value, check the capacitors with an ohmmeter. If the capacitors are OK, then consider the HV rectifier or the 120/230V switch as a possible problem.

E. The voltage boost circuit is always a potential problem when it is used in the power supply. Refer to the partial schematic of the boost circuit as shown in **Fig. 6**.

Note: Not all switching power supplies use a boost circuit.

One technique that has worked for me is to tack solder a 47 μF/50V capacitor between pin 12 and ground of the TL494 PWM IC.

Problem: If the power supply comes up into operation reliably with an external capacitor in place, trace the TL494 pin 12 circuit back to a filter capacitor. The boost filter capacitor should be of a value similar to 47 μF. After changing the boost filter capacitor, be sure to remove the tacked-in 47 μF test capacitor.

F. Output filter capacitors do fail by drying out over time. The failure mode is typically a loss of capacitance, causing the output ripple to increase.

Test method: A capacitor of 100 μF or greater having a voltage in excess of the circuit being tested may be tack-soldered across the suspected capacitor. If the power supply operates, then replace the suspected capacitor.

Another test method is to connect the scope across the circuit in question and observe the ripple value. Note: There must be a resistive load on the output of the circuit being tested.

Observe any significant change in the ripple when a like capacitance value is added to the circuit. Note: Be

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sure to remove power before adding or removing a filter capacitor.

G. Having cleared all output circuits, the voltage boost circuit, and the power supply still fails to operate; it may be time to use an oscilloscope to check the PWM waveforms. A complete schematic of a voltage boosted power supply circuit is shown in **Fig. 7**.

Attach the oscilloscope probes only to the low-voltage side of the supply. The scope is sometimes useful for looking at the signal output from the TL494 IC. Pins 8 and 11 are the oscillator output pins and they provide a pulsed waveform that is used to drive the bases of the output driver transistors. The scope ground is attached to the black DC (ground) output lead and the probe tip is connected first to pin 8 and then to pin 11 of the TL494.

Problem: The waveform obtained from both pins 8 and 11 should be very similar in shape and amplitude. The peak amplitude of the pulse will be limited to a value approaching 2.1V. If the waveform is missing, verify that DC voltage is applied to the PWM IC. If the DC voltage is there, consider substituting another TL494 before repeating the tests. It's also possible that the RC timing circuit connected to pins 5 and 6 of the TL4494 is defective.

H. Measure the DC voltage from the driver transistor emitters to ground. Typically, two diodes are connected in series conducting from the transistor emitters to ground. The DC voltage drop across those two diodes must be in the range 1.2–1.8V when the transistors are being properly driven by the PWM.

Problem: If the voltage across the diodes is low, the driver transistors are not being turned on. Use the scope to observe the driving pulse found on the base of the driver transistors. Check twice before connecting the scope probe.

I. Assuming that TL494 pins 8 and 11 are exhibiting equal pulses, then place the scope probe onto the center tap at the driver transformer (collector/primary side). If the power supply utilizes a DC boost voltage, a series of vertical rising pulses should be observed at the center tap with an amplitude approaching 15-20V.

Problem: If the center tap voltage pulse is present, then the boost voltage should be available at approximately 20V. When the boost voltage fails to rise from 12V to 20V at startup, check the following components: boost diode, boost filter capacitor, and resistors.

Another place to check is the input to one PWM voltage comparator. One voltage comparitor is used to monitor the boost voltage. Check all of the components associated with the boost sensor circuit.

Replacement parts

At this point almost all of the obvious failure mechanisms have been checked within the power supply and hopefully the problem has been detected and perhaps corrected. Repairing a power supply requires, in most cases, a part to replace the bad one, and there is always a quandary as to where replacement parts can be located.

One of the biggest dilemmas facing a ham these days is in locating suitable parts for projects. Because much of our electronic equipment is now built offshore, replacement parts are not readily available. One of the techniques that I use to get around the shortage is to salvage TV and VCR boards as they are scrapped.

Parts such as capacitors and resistors can always be used in ham projects so they are of great importance to me. Semiconductors from TV and VCR boards are of a lower priority unless I know the part and have a place to store it.

When it comes to parts for computer power supplies, a source for available parts is certainly lacking. NTE replacement semiconductors are perhaps the most readily available, but many types are not covered by the service. To counter the problem, I've started collecting used computer power supplies and "rob" parts from one or two as the need arises in order to repair another.

Occasionally power supply HV filter capacitors appear in the new and surplus parts catalogs so you need to keep a sharp eye peeled for the items needed.

Conclusion

Repairing a computer power supply is quite a satisfying experience for a ham. It's also a new exposure to HV techniques and safety practices beyond what you might experience in typical solid-state circuits. Personal safety is an important issue when working with computer power supplies and caution is not to be avoided for expediency.

Hams get involved in a lot of electronic projects, and it is expected that an attempt at repairing a computer power supply will occur. The suggestions provided here on troubleshooting computer power supplies should allow a ham to be successful in the process.

Although the troubleshooting process and finding a "bad" part is fairly easy, safety is the word. Please be careful! 73