Repairing switchers

Contents:

[Document Version: **1.02**] [Last Updated: **Jan_11_1994**]

---

1. Introduction

1.1) About the Author

Author : Keith Lofstrom
E-mail : keithl@klic.rain.com
Version: 1.01
Date : Jan 11, 1994

1.2) Disclaimer

****
WARNING! DANGER! WARNING! DANGER! WARNING! DANGER!
****

Power supplies contain lethal voltages. That means they can kill YOU. Yes, YOU! Unless YOU are especially cautious, YOU won't wake up tomorrow. Pretend you are playing with a nuclear bomb. A bomb can't kill you any deader.

If you don't understand electronics, don't bother with power supplies. This is analog circuitry, not cookbook logic stuff. You need to have a feel for currents and voltages and waveforms, or you won't be able to figure out what's happening. Find some circuit nerd (like me) who needs some software written, and swap services. Don't risk your life unless you know what you are doing.

Power supply repair is a challenge, like mountain climbing. Probably about as dangerous. Allow adequate time (3-4 hours, plus trips to the parts store), don't attempt it while tired or distracted, and have the right tools available. Make sure somebody is around to haul you to the hospital if you zap yourself.

If you DO hurt yourself, in spite of my warnings, I am NOT responsible. I never posted this, my signature is forged, the important parts got deleted by your newsfeed, etc. If you can't take responsibility for your own life, don't repair power supplies.

****

WARNING! DANGER! WARNING! DANGER! WARNING! DANGER!

****

1.3) About

I've fixed about 40 of them. The broken ones were all broken by bad design or sloppy manufacturing - inadequate component choice, usually. If you want to fix one properly, you will need to be able to find heftier components that still meet the other design goals - made somewhat easier by the advances in components. A proper repair involves a little design.

You will need access to a semiconductor curve tracer, or else be ready to build a lot of ad hoc kludges for pulse characterization of components. Most of the power components that fail will have no easily available direct replacements. Looking at some components with DC sources can cook them.

You will also need an oscilloscope (5MHz bandwidth will do), a voltmeter, and access to a huge pile of power transistor and diode databooks. National Semiconductor, International Rectifier, Texas Instruments, Motorola books will probably do; you may need SGS Thompson, Siemens, and Signetics for some regulator chips.

Without a schematic, be prepared to spend some time tracing out circuits. If you live in East Armpit, Nebraska, you probably won't be able to find the components you need, so give up now.

An isolation transformer and a Variac are handy. Also a pile of power resistors from which you can build a test load. A bench supply to externally power the secondaries is useful, though I use the curve tracer for this.

1.4) Further Information

[Notes on the diagnosis and repair of small SwitchMode Power Supplies] (SMPS) V2.23 - written by Samuel M. Goldwasser. This is an excellent guide to just about anything you may want to know about switching power supplies. A **Fil's Must-Read**!

2. General Guidelines

1. Put at least two switches between you and line. Unplugging counts as one switch. You are human, and you will forget one switch from time to time. Forgetting shouldn't have to be lethal. Take off watches and metal jewelry. Hell, get someone else to do it. Life is too short anyway. If you are a professor, find a gullible grad student :-)

2. Check the fuse. Keep plenty on hand - you may end up blowing a dozen or so. About a third of the time fuses blow for no reason at all.

3. Is everything hooked up and switched properly? I've seen a PhD spend 4 hours debugging a simple little box that "should work but didn't". When I innocently asked "what does this little switch do?" he thought for about 10 seconds and turned the prettiest shade of red...

4. Good designs rarely fail. If it is broken, it is because of an idiot engineer, most likely. Don't assume anything is designed right; if a circuit you've traced out can't possibly work, check it again. If it simply LOOKS stupid, you have discovered a fundamental truth about some power supply designers. There are lots of good power supply designers out there - I've rarely had a chance to explore their work, because I've never had to fix their designs.

5. A toasted resistor means something else failed first. Figure out what could toast the resistor, or you will toast another one.

6. Buy extra replacement parts. You will blow a few things up during debugging.

7. Before firing the supply up, figure out the primary circuit. Typical switched 115/230V supplies have a full wave bridge and two filter caps, resulting in about 340 volts DC on the primary. Make sure there is a discharge path through a power resistor - if not, temporarily solder one on while you work on the supply. A 20K ohm, 10W resistor will discharge a 1000 uF primary in about 1 minute. You can switch in a smaller value resistor for faster discharge, but you will probably forget to turn it off, and end up blowing it up when you turn the supply back on. In any case, get rid of the primary side voltage somehow before you mess with things.

8. When building test loads, load all the supplies. Some switchers get unhappy if there isn't at least a trickle of current on each supply. A 20% load is often adequate.

9. When you think you have the supply fixed, run it up and down with the Variac; run it up to at least 1.2X normal line, if you can. Note: some switchers get very unhappy with 0.5X line - see note on stupid designers above. If you end up breaking it this way, at least you know what will happen during brownouts. If the result is overvoltage on the outputs (I've seen this once) then throw the supply away, and kludge on a different design if possible. Overvoltage eats expensive equipment.

10. Anything can be fixed. Sometimes it's too much work. Be willing to give up.

---

3. What usually fails

The things I have seen fail, in order, are:

1. Electrolytics. Switchers put a lot of AC current into electrolytics, many of which aren't designed for this treatment. The capacitors cook, and either short out or unweld themselves open. The nastiest failure is an "almost open" that opens and closes itself at line rates (I've encountered a couple of those - murder to diagnose).

   One capacitor failed on the input side of a pi filter on a secondary:

   ```
   --|&gt;|------+----- Inductor ------+--------- 5V out
                |                      |
              -----   This one       -----
              -----   &lt;---           -----
                |                      |
   ```

   This was on the 5 volt supply of a 5V/12V switcher, the regulator worked off the filtered 5V. When the indicated capacitor opened, the inductor swallowed most of the switching voltage from the transformer and diodes, resulting in the regulator kicking in much harder to try to make 5V on the other side. This put 35 volts on the allegedly 12V supply - as a result, all the 16V tantalums on the 12V supply got blown out, as well as much of the stuff hooked up to the 12V supply.

   The reason for the pi filter in the first place was too much ripple on the supply - the reason for too much ripple was the high ESR of the capacitors used. I replaced with better capacitors.

   Replacement: Don't just go for the same voltage and capacitance. You need low ESR, and if the first one failed, the second one will too. One sorta brain-damaged way to get low ESR is to use more capacitors - and possibly more capacitance - wired in parallel. You can get some idea of ESR with the curve tracer - with a small voltage (approx 200mV) AC drive, a low ESR cap looks like a circle, while a high ESR cap looks like an ellipse from the resistive component. Look for high temperature ratings, too - at least 105C

   If there are any power resistors sitting right next to an electrolytic, move them enough to get airflow between. Electrolytics are too damned temperature sensitive - most are rated to only 85C.

2. The main switch transistor(s). Usually a TO3 power transistor. These usually fail because something shorted things out (there should be a current sense shutdown, but this involves buying another 5 cent resistor; too expensive :-( ). These also often fail from inadequate voltage rating.

These are usually the easiest component to check, assuming a curve tracer is available, even if they are less likely to fail than one of the 10 or so electrolytics. I pull the transistor and check it before trying anything else. If the transistor works, write down some of the curve tracer measurements. You may accidentally fry it during repair.

You will want a transistor that can stand off at least 1.5X the peak primary DC voltage, preferably 2X. You will need to find what the current rating of the transistor you pulled out is, and meet that with the replacement. When you are looking for a replacement, find a new transistor with:

- Same type - usually NPN, non-darlington
- Same case
- Better voltage rating
- Better current rating
- Similar Beta/Hfe/Current Gain
- Same or Higher Ft
- Same or lower capacitance

Advances in components make finding an adequate replacement possible. Curve trace the replacement.

3. Secondary diodes: I've lost a few of these. The result of a diode failure is usually an imbalance in secondary voltages.

   Replace with:

   - Same type - usually Shottkey diode
   - Similar case (you may have some lattitude here)
   - Better voltage rating
   - Better current rating (make sure with curve tracer)
   - Lower capacitance

4. Regulator ICs - these rarely fail, but a manufacturer can get a bad batch. The result is a whole bunch of the same supply type failing. There are so many different ways a regulator can fail that you will just have to figure it out; though a supply that goes tick ... tick ... tick may have a broken regulator chip, if you can't find anything else wrong. The ticking noise means the regulation loop is broken somewhere.

   You may have a heck of a time finding a replacement. An exact replacement is required. Socket the replacement. Use a good socket that grips the chip tightly - thermal excursions can walk an IC out of its socket.

---

4. Techniques for repair

1. Check the fuse.

2. Dust the damn thing, with kleenex and Qtips. Of course you've never changed filters on the fan. Dust kills power supplies. After this, you'll change them.
3. Look at a working version of the supply, if any are available. Get a schematic if you can. Apple and Sun are lousy for schematics, HP is good. Clones are impossible.
4. Look for all the usual visual stuff, open traces, shorts, burned components.
5. Disconnect the supply, writing down somewhere where all the connectors go and which direction (if I need to be telling you this stuff, you aren't qualified). Don't use the regular circuit as a dummy load, though you may want to find out how much current it draws, to help you build test loads. Use a bench supply for testing the regular circuit.
6. Power up the secondaries - one at a time, with an external voltage source - first. Look for shorts. Drive capacitors with curve tracer AC. Look for ESR or opens.
7. Load the outputs at about 20% of full load. Power up the primary with curve tracer in AC mode, slowly, to about 40VAC. You should be able to watch the primary capacitors charge up. This finds primary shorts and capacitor opens.
8. If you bring the supply up to full input and nothing happens, check for primary voltage - usually 340 volts. If the supply is 115 volt only, and there is only one capacitor, there is probably only 170 volts across it.
9. If there is voltage, AND the primary is separately isolated with an isolation transformer, locate the primary common, usually the lowest voltage on primary side (You traced the circuit, remember?). Hook the scope signal input to this point (at 50V / div, line sweep and sync), there will probably be a significant AC signal here. Try connecting this point to oscilloscope ground with a 100 Kohm resistor - if the signal doesn't diminish, you aren't properly isolated. If it does diminish, power down, disconnect, and discharge, ground the scope here, and power back up.
10. Check for oscillations around the regulator chip. If none, check for voltage. Switcher regulators are sometimes powered with their own separate little supply, or off a big power resistor from primary voltage. Sometimes they are powered with a little kickstart circuit from the primary, then a separate winding off the transformer. These are good for the tick...tick...tick type of failures. You may have to power the regulator separately, with a bench supply, to get things started.
11. From here on out, it's measurement, and debugging, and tinkering, and such. Let us know what you find wrong. Perhaps we can embarrass some manufacturers into doing a better job on their supplies.

NOTICE: Again - **and I repeat** - don't repair power supplies unless you are a pretty good analog circuit tinkerer, can act safely around high voltage, and have the right tools. Take the thing to a TV repair shop, instead. It would spoil my day to find out somebody with more ambition than sense took the above notes and hurt themselves trying to do something they weren't ready for yet.
