

# Notes on the Troubleshooting and Repair of Small Switchmode Power Supplies

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[Document Version: **2.48**] [Last Updated: **05/25/1998**]

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## Chapter 1) About the Author & Copyright

### Notes on the Troubleshooting and Repair of Small Switchmode Power Supplies

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# Chapter 2) Introduction

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## 2.1) The switchmode power supply (SMPS)

Until the 1970s or so, most consumer electronic equipment used a basic power transformer/rectifier/filter capacitor type of power supply for converting the AC line into the various voltages needed by internal circuitry. Even regulation was present only where absolutely needed - the high voltage supplies of color TV sets, for example. Remember those old TVs with boat anchor type power transformers? (Of course, if you recall those, you also recall the fond days of vacuum tube sets and the corner drugstore with a public tube tester!)

Switchmode supplies had been commonplace in military and avionic equipment long before they found their way into consumer electronics. I have some DC-DC and DC-AC convertor modules from a Minuteman I missile from around 1962 as one example. I suppose that the cost of the switching transistors wasn't as big a deal with a \$100 million missile as a \$300 TV (even in 1960s dollars).

Nowadays, all TVs, monitors, PCs; most laptop and camcorder power packs; many printers, fax machines, and VCRs; and even certain audio equipment like portable CD players use this technology to reduce cost, weight, and size.

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## 2.2) Switchmode power supply repair

Unlike PC system boards where any disasters are likely to only affect your pocketbook, power supplies, especially line connected switchmode power supplies (SMPSs) can be dangerous. Read, understand, and follow the set of safety guidelines provided later in this document whenever working on line connected power supplies as well as TVs, monitors, or other similar high voltage equipment.

Having said that, repairing a power supply yourself may in fact be the only economical option. It is very common for service centers to simply replace the entire power supply board or module even if the problem is a 25 cent capacitor. It may simply not pay for them to take the bench time to diagnose down to the component level. Many problems with switchmode power supplies are easy to find and easy and inexpensive to fix. Not all, but surprisingly many.

This document will provide you with the knowledge to deal with a large percentage of the problems you are likely to encounter with the common small switchmode power supplies found in many types of consumer electronic equipment including PCs, printers, TVs, computer monitors, and laptop or camcorder power packs. It will enable you to diagnose problems and in many cases, correct them as well. With minor exceptions, specific manufacturers and models will not be covered as there are so many variations that such a treatment would require a huge and very detailed

text. Rather, the most common problems will be addressed and enough basic principles of operation will be provided to enable you to narrow the problem down and likely determine a course of action for repair. In many cases, you will be able to do what is required for a fraction of the cost that would be charged by a repair center - assuming they would even bother.

Should you still not be able to find a solution, you will have learned a great deal and be able to ask appropriate questions and supply relevant information if you decide to post to [sci.electronics.repair](mailto:sci.electronics.repair). It will also be easier to do further research using a repair text such as the ones listed at the end of this document. In any case, you will have the satisfaction of knowing you did as much as you could before taking it in for professional repair. With your new-found knowledge, you will have the upper hand and will not easily be snowed by a dishonest or incompetent technician.

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## 2.3) Most Common Problems

The following probably account for 95% or more of the common SMPS ailments:

- \* Supply dead, fuse blown - shorted switchmode power transistor and other semiconductors, open fusible resistors, other bad parts. Note: actual cause of failure may be power surge/brownout/lightning strikes, random failure, or primary side electrolytic capacitor(s) with greatly reduced capacity or entirely open - test them before powering up the repaired unit.
- \* Supply dead, fuse not blown - bad startup circuit (open startup resistors), open fusible resistors (due to shorted semiconductors), bad controller components.
- \* One or more outputs out of tolerance or with excessive ripple at the line frequency (50/60 Hz) or twice the line frequency (100/120 Hz) - dried up main filter capacitor(s) on rectified AC input.
- \* One or more outputs out of tolerance or with excessive ripple at the switching frequency (10s of KHz typical) - dried up or leaky filter capacitors on affected outputs.
- \* Audible whine with low voltage on one or more outputs - shorted semiconductors, faulty regulator circuitry resulting in overvoltage crowbar kicking in, faulty overvoltage sensing circuit or SCR, faulty controller.
- \* Periodic power cycling, tweet-tweet, flub-flub, blinking power light - shorted semiconductors, faulty over voltage or over current sensing components, bad controller.

In all cases, bad solder connections are a possibility as well since there are usually large components in these supplies and soldering to their pins may not always be perfect. An excessive load can also result in most of these symptoms or may be the original cause of the failure.

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## 2.4) Repair or replace

Some manufacturers have inexpensive flat rate service policies for power supplies. If you are not inclined or not interested in doing the diagnosis and repair yourself, it may be worthwhile to look into these. In some cases, \$25 will get you a replacement supply regardless of original condition. However, this is probably the exception and replacements could run more than the total original cost of the equipment - especially as in the case of most TVs and many computer monitors, where the power supply is built onto the main circuit board.

Nothing really degrades in a switchmode power supply except possibly the electrolytic capacitors (unless a catastrophic failure resulted in a total meltdown) and these can usually be replaced for a total cost of a few dollars. Therefore, it usually makes sense to repair a faulty supply assuming it can be done reasonably quickly (depending on how much you value your time and the down time of the equipment) and, of course, assuming that the equipment it powers is worth the effort. Most replacement parts are readily available and kits containing common service components are also available for many popular power supplies (such as those found in some terminals, MacIntosh and other Apple computers, various brands of video monitors, and some TVs and VCRs).

Where an exact replacement power supply is no longer available or excessively expensive, it may be possible to simply replace the guts if space allows and the mounting arrangement is compatible. For example, for an older full size PC tower, the original power supply may be in a non-standard box but the circuit board itself may use a standard hole configuration such that an inexpensive replacement may be installed in its place.

Alternatively, many surplus electronics distributors have a wide selection of power supplies of all shapes, sizes, output voltages, and current capacities. One of these may make a suitable replacement for your custom supply with a lot less hassle than attempting to repair your undocumented original. It will likely be much newer as well with no end-of-life issues like dried up electrolytic capacitors to deal worry about. Of course, you must know the voltage and current maximum current requirements of each of the outputs in order to make a selection.

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## 2.5) Related Information

See the manuals on "Failure Diagnosis and Repair of TVs" and "Failure Diagnosis and Repair of Computer and Video Monitors" for problems specific to that type of equipment. For computer power supplies and other general info, also see: "PC Switchmode Power Supplies". These are all available at this site under the Repair Menu.

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# Chapter 3) Switchmode Power Supplies

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## 3.1) Power Supply Fundamentals

A typical line connected power supply must perform the following functions:

- \* Voltage conversion - changing the 115/230 VAC line voltage into one or more other voltages as determined by application.
  - \* Rectification - turning the AC into DC.
  - \* Filtering - smoothing the ripple of the rectified voltage(s).
  - \* Regulation - making the output voltage(s) independent of line and load variations.
  - \* Isolation - separating the supply outputs from any direct connection to the AC line.
- 

## 3.2) Linear power supplies (LPSs)

A typical linear power supply of the type found in most audio equipment includes a line power transformer which converts the 115/230 VAC 50/60 Hz to other (usually lower) voltages (now that most equipment has done away with vacuum tubes except for CRTs, more on that later). The power transformer also provides the isolation between the load and the line. The outputs are rectified by a diode bridge or other solid state configuration. Filtering is accomplished with electrolytic capacitors and sometimes inductors or resistors arranged as a low pass filter C-L-C (pi) or C-R-C or other configuration.

Where regulation is important - that is, it is desirable for the output voltage to be relatively independent of line or load variations, a regulator stage is added. This may take the form of a Zener diode if the current requirements are modest, discrete transistor circuit, or an integrated 3 terminal regulator like an LM317 (variable), 7805 (+5), or 7912 (-12). There are many more as well as linear regulators for higher voltages such as +115 VDC or +125 VDC for TV power supplies and multiple output (e.g., +5.1 VDC, +12 VDC) hybrid regulators for VCRs.

The regulator circuit essentially compares the output (possibly only one if there are multiple outputs in the same package) with a reference and adjusts the current flow to make the output(s) as nearly equal to the desired voltage as possible. However, a significant amount of power may be lost in the regulator especially under high line voltage/high load conditions. Therefore, the efficiency of linear power supplies is usually quite low - under 50% overall is typical.

Notable characteristics of LPSs are excellent regulation and low output ripple and noise.

What is a switch mode power supply?  
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Also called switching power supplies and sometimes chopper controlled power supplies, SMPSs use high frequency (relative to 50/60 Hz) switching devices such as Bipolar Junction Transistors (BJTs), MOSFETs, Insulated Gate Bipolar Transistors (IGBTs), or Thyristors (SCRs or triacs) to take

directly rectified line voltage and convert it to a pulsed waveform.

Most small SMPSs use BJTs or MOSFETs. IGBTs may be found in large systems and SCRs or triacs are used where their advantages (latching in the on state and high power capability) outweigh the increased complexity of the circuitry to assure that they turn off properly (since except for special Gate Turn Off (GTO) thyristors, the gate input is pretty much ignored once the device is triggered and the current must go to zero to reset it to the off state.)

The input to the switches is usually either 150-160 VDC after rectification of 115 VAC, or 300-320 VDC after doubling of 115 VAC or rectification of 220-240 VAC. Up to this point, there is no line isolation as there is no line connected (large, bulky, heavy) power transformer.

A relatively small high frequency transformer converts the pulsed waveform into one or more output voltages which are then rectified and filtered using electrolytic capacitors and small inductors in a 'pi' configuration C-L-C, or for outputs that are less critical, just a capacitor.

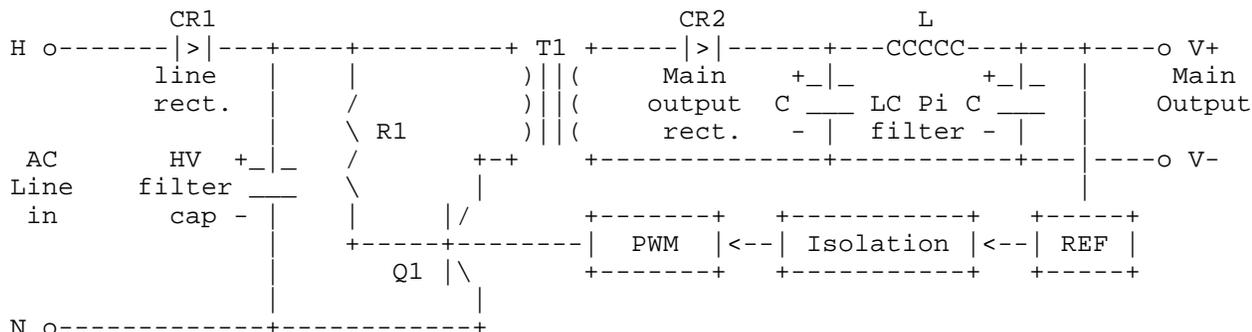
This high frequency transformer provides the isolation barrier and the conversion to generate the multiple voltages often provided by a SMPS.

Feedback is accomplished across the isolation barrier by either a small pulse transformer or opto-isolator. The feedback controls the pulse width or pulse frequency of the switching devices to maintain the output constant. Since the feedback is usually only from the "primary" output, regulation of the other outputs, if any, is usually worse than for the primary output. Also, because of the nature of the switching designs, the regulation even of the primary output is usually not nearly as good both statically and dynamically as a decent linear supply.

DC-DC convertors are switchmode power supplies without the line input rectification and filtering. They are commonly found in battery operated equipment like CD players and laptop computers. They have similar advantages to SMPSs in being compact, light weight, and highly efficient.

### 3.3) Description of typical flyback type SMPS

Probably the most common topology for small switchers is the flyback circuit shown below:



The input to the supply is the AC line which may have RFI and surge protection (not shown). There may be several inductors, coupled inductors, and capacitors

to filter line noise and spikes as well as to minimize the transmission of switching generated radio frequency interference back into the power line. There may be MOV type of surge suppressors across the three input leads (H, N, G). A line fuse is usually present as well to prevent a meltdown in case of a catastrophic failure. It rarely can prevent damage to the supply in the event of an overload, however.

Line rectification is usually via a voltage doubler or diode bridge. One common circuit uses a bridge rectifier as a doubler or normal bridge by changing one jumper. The voltage across the switching transistor is usually around 160-320 V. Some universal supplies are designed to accept a wide range of input voltages - 90-240 VAC (possibly up to 400 Hz or more) or DC - and will automatically work just about anywhere in the world as long as a suitable plug adapter can be found.

When Q1 turns on, current increases linearly in T1 based on the voltage applied and the leakage inductance of T1's primary winding. Little power is transferred to the secondary during this phase of the cycle. When Q1 turns off, the field collapses and this transfers power to the output. The longer Q1 is on, the more energy is stored (until saturation at which point it blows up). Thus, controlling the pulse width of the Q1 on-time determines the amount of power available from the output.

The output rectifier, CR2, must be a high efficiency, high frequency unit - a 1N400X will not work. The pie filter on the output smooths the pulses provided by CR2. Sometimes, a full wave configuration is used with a center tapped transformer secondary.

Note that the transformer, T1, is a special type which includes an air gap in its core (among other things) to provide the inductive characteristics needed for operation in flyback mode.

Multiple output windings on T1 provide for up to a half dozen or more separate (and possibly isolated as well) positive or negative voltages but as noted, only one of these is usually used for regulation.

A reference circuit monitors the main output and controls the duty cycle of the switching pulses to maintain a constant output voltage. (Secondary outputs are not shown in the above schematic.)

R1 is the startup resistor (some startup circuits are more sophisticated) and provides the initial current to the switchmode transistor base. The PWM circuit guarantees that Q1 will not be turned on continuously.

Many small SMPSs use opto-isolators for the feedback. An opto-isolator is simply an LED and a photodiode in a single package. As its name implies, an opto-isolator provides the isolation barrier (between the low voltage secondary outputs and the line connected primary) for the feedback circuit. Typically, a reference circuit on the output side senses the primary output voltage and turns on the LED of the opto-isolator when the output voltage exceeds the desired value. The photodiode detects the light from the LED and causes the pulse width of the switching waveform to be reduced enough to provide just the right amount of output power to maintain the output voltage constant. This circuit may be as simple as putting the photodiode across the base drive to the BJT switch thus cutting it off when the output voltage exceeds the desired value. The reference is often a TL431 or similar shunt regulator chip monitoring a voltage divided version of the primary output. When the shunt regulator kicks in, the opto-isolator LED turns on reducing the switchmode transistor drive. There may be an adjustment for the output voltage.

Other designs use small pulse transformers to provide isolated feedback.

Where additional regulation is needed, small linear regulators may be

included following the output(s).

There are many other topologies for switching power supplies. However, the basic principles are similar but the detail differ depending on application. The flyback topology described above is one of the most common for small multi-output supplies. However, you may find other types of circuits in TVs and monitors. Some are downright strange (to be polite). I sometimes wonder if engineers are given bonuses based on the uniqueness and difficulty level of understanding their designs!

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## 3.4) Advantages of SMPSs compared to LPSs

The benefits provided by implementing switch mode operation are with respect to size, weight, and efficiency.

- \* Size and weight - since the transformer and final filter(s) run at a high frequency (we are talking about 10KHz to 1 MHz or more), they can be much smaller and lighter than the big bulky components needed for 50/60 Hz operation. Power density for SMPSs compared to LPSs may easily exceed 20:1.
- \* Efficiency - since the switching devices are (ideally) fully on or fully off, there is relatively little power lost so that the efficiency can be much higher for SMPSs than for LPSs, especially near full load. Efficiencies can exceed 85% (compared to 50-60% for typical LPSs) with improvements being made continuously in this technology.

Since the advent of the laptop computer, cellular phone, and other portable devices, the importance of optimizing power utilization has increased dramatically. There are now many ICs for controlling and implementing SMPSs with relatively few external components. Maxim, Linear Technology, and Unitrode are just a few of the major manufacturers of controller ICs.

Where are SMPSs used?

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Switch mode power supplies are commonly used in computer and other digital systems as well as consumer electronics - particularly TVs and newer VCRs though audio equipment will tend to use linear power supplies due to noise considerations. You will find SMPSs in:

- \* PCs, workstations, minicomputers, large computers.
- \* Laptop and notebook computers, PDAs - both internal DC-DC convertors and their AC power packs.
- \* Printers, fax machines, copiers.
- \* Peripheral and expansion boxes
- \* X-terminals and video terminals, point of sale registers.
- \* TVs, computer and video monitors.
- \* Many VCRs.
- \* Camcorder AC adapters.

In additional, you will find DC-DC converters which are SMPSs without the AC line connection, internally in an increasing number of consumer and industrial applications including things like portable CD players.

The up side is that they are usually quite reliable, efficient, and cool running.

The down side is that when a failure occurs, it may take out many parts in the supply, though not usually the equipment being powered unless the feedback circuitry screws up and there is no overvoltage protection.

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## Chapter 4) Switchmode Power Supply Troubleshooting

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### 4.1) SAFETY

The primary danger to you is from the input side of the supply which is directly connected to the AC line and will have large electrolytic capacitors with 320 V or greater DC when powered (often, even if the supply does not work correctly) and for some time after being unplugged (especially if the power supply is not working correctly but does not blow fuses).

Warning: the filter capacitors used in many switchmode power supplies can store an amount of energy that can kill - always discharge and confirm this before touching anything.

There is also risk of instantly destroying expensive parts of the supply (and any attached equipment as well) like the switchmode power transistor if your probe should slip and short something either directly or by killing the feedback circuit.

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### 4.2) Safety guidelines

These guidelines are to protect you from potentially deadly electrical shock hazards as well as the equipment from accidental damage.

Note that the danger to you is not only in your body providing a conducting path, particularly through your heart. Any involuntary muscle contractions caused by a shock, while perhaps harmless in themselves, may cause collateral damage - there are many sharp edges inside this type of equipment as well as other electrically live parts you may contact accidentally.

The purpose of this set of guidelines is not to frighten you but rather to

make you aware of the appropriate precautions. Repair of TVs, monitors, microwave ovens, and other consumer and industrial equipment can be both rewarding and economical. Just be sure that it is also safe!

- \* Don't work alone - in the event of an emergency another person's presence may be essential.
- \* Always keep one hand in your pocket when anywhere around a powered line-connected or high voltage system.
- \* Wear rubber bottom shoes or sneakers.
- \* Don't wear any jewelry or other articles that could accidentally contact circuitry and conduct current, or get caught in moving parts.
- \* Set up your work area away from possible grounds that you may accidentally contact.
- \* Know your equipment: TVs and monitors may use parts of the metal chassis as ground return yet the chassis may be electrically live with respect to the earth ground of the AC line. Microwave ovens use the chassis as ground return for the high voltage. In addition, do not assume that the chassis is a suitable ground for your test equipment!
- \* If circuit boards need to be removed from their mountings, put insulating material between the boards and anything they may short to. Hold them in place with string or electrical tape. Prop them up with insulation sticks - plastic or wood.
- \* If you need to probe, solder, or otherwise touch circuits with power off, discharge (across) large power supply filter capacitors with a 2 W or greater resistor of 5-50 ohms/V approximate value (e.g., for a 200 V capacitor, use a 1K-10K ohm resistor). Monitor while discharging and/or verify that there is no residual charge with a suitable voltmeter. In a TV or monitor, if you are removing the high voltage connection to the CRT (to replace the flyback transformer for example) first discharge the CRT contact (under the insulating cup at the end of the fat red wire). Use a 1M-10M ohm 1W or greater wattage resistor on the end of an insulating stick or the probe of a high voltage meter. Discharge to the metal frame which is connected to the outside of the CRT.
- \* For TVs and monitors in particular, there is the additional danger of CRT implosion - take care not to bang the CRT envelope with your tools. An implosion will scatter shards of glass at high velocity in every direction. There is several tons of force attempting to crush the typical CRT. Always wear eye protection.
- \* Connect/disconnect any test leads with the equipment unpowered and unplugged. Use clip leads or solder temporary wires to reach cramped locations or difficult to access locations.
- \* If you must probe live, put electrical tape over all but the last 1/16" of the test probes to avoid the possibility of an accidental short which could cause damage to various components. Clip the reference end of the meter or scope to the appropriate ground return so that you need to only probe with one hand.
- \* Perform as many tests as possible with power off and the equipment unplugged. For example, the semiconductors in the power supply section of a TV or monitor can be tested for short circuits with an ohmmeter.
- \* Use an isolation transformer if there is any chance of contacting line connected circuits. A Variac(tm) is not an isolation transformer! The use of a GFCI (Ground Fault Circuit Interrupter) protected outlet is a

good idea but will not protect you from shock from many points in a line connected TV or monitor, or the high voltage side of a microwave oven, for example. (Note however, that, a GFCI may nuisance trip at power-on or at other random times due to leakage paths (like your scope probe ground) or the highly capacitive or inductive input characteristics of line powered equipment.) A fuse or circuit breaker is too slow and insensitive to provide any protection for you or in many cases, your equipment. However, these devices may save your scope probe ground wire should you accidentally connect it to a live chassis.

- \* Don't attempt repair work when you are tired. Not only will you be more careless, but your primary diagnostic tool - deductive reasoning - will not be operating at full capacity.
- \* Finally, never assume anything without checking it out for yourself! Don't take shortcuts!

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## 4.3) SMPS troubleshooting

The diagnosis of problems in switchmode power supplies is sometimes made complicated due the interdependence of components that must function properly for any portion of the power supply to begin to work. Depending on design, SMPS may or may not be protected from overload conditions and may fail catastrophically under a heavy load even when supposedly short circuit proof. There is particular stress on the switching devices (they are often 800 V transistors) which can lead to early or unexpected failure. Also, SMPS may fail upon restoration of power after a blackout if there is any kind of power spike since turn-on is a very stressful period - some designs take this into account and limit turn on surge.

However, the cause of many problems are immediately obvious and have simple fixes - the blown chopper transistor or dried up main filter capacitor. Don't assume your problem is complex and convoluted. Most are not. You should not avoid attempting a repair just because there is a slight chance it will be more challenging!

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## 4.4) Test equipment

The most valuable piece of test equipment (in addition to your senses) will be a DMM or VOM. These alone will suffice for most diagnosis of faulty components (like shorted semiconductors or open fusible resistors).

In designs using controller ICs, an oscilloscope comes in handy when there are startup or overcurrent/voltage shutdown or cycling problems. Since everything runs at a relatively low frequency, almost any scope will do.

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## 4.5) Incredibly handy widgets

These are the little gadgets and homemade testers that are useful for many repair situations. Here are just a few of the most basic:

- \* Series light bulb for current limiting during the testing of TVs, monitors, switching power supplies, audio power amplifiers, etc. I built a dual outlet box with the outlets wired in series so that a lamp can be plugged into one outlet and the device under test into the other. For added versatility, add a regular outlet and 'kill' switch using a quad box instead. The use of a series load will prevent your expensive replacement part like a switchmode power transistor from blowing if there is still some fault in the circuit you have failed to locate. (Now, if I would only remember to do this more often!). See the section: "[The series light bulb trick](#)".
- \* A Variac. It doesn't need to be large - a 2 A Variac mounted with a switch, outlet and fuse will suffice for most tasks. However, a 5 amp or larger Variac won't hurt. If you will be troubleshooting 220 VAC equipment in the US, there are Variacs that will output 0-240 VAC from a 115 VAC line (just make sure you don't forget that this can easily fry your 115 VAC equipment.) By varying the line voltage, not only can you bring up a newly repaired monitor gradually to make sure there are no problems; you can also evaluate behavior at low and high line voltage. This can greatly aid in troubleshooting power supply problems. Warning: a Variac is an autotransformer - not an isolation transformer and does not help with respect to safety. You need an isolation transformer as well.
- \* Isolation transformer. This is very important for safely working on live chassis equipment like line connected switchmode power supplies (primary side). You can build one from a pair of similar power transformers back-to-back (with their highest rated secondaries connected together. I built mine from a couple of similar old tube type TV power transformers mounted on a board with an outlet box including a fuse. Their secondary high voltage windings were connected together to couple the two transformers together. The unused low voltage windings can be put in series with the primary or output windings to adjust voltage. Alternatively, commercial line isolation transformers suitable for TV troubleshooting are available for less than \$100 - well worth every penny.

There is absolutely no imaginable reason not to use an isolation transformer for troubleshooting SMPSs except possibly for the final test where confirmation is needed that the inrush from a direct line connection (which will have virtually unlimited instantaneous current capability) will not damage the newly repaired supply.

- \* Variable isolation transformer. You don't need to buy a fancy combination unit. A Variac can be followed by a normal isolation transformer. (The opposite order also works. There may be some subtle differences in load capacity.).

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## 4.6) Safe discharging of capacitors in switchmode power supplies

A working SMPS may discharge its capacitors fairly quickly when it is shut off but DO NOT count on this. The main filter capacitors may have bleeder resistors to drain their charge relatively quickly - but resistors can fail

and the term 'quickly' may be relative to the age of the universe. Don't depend on them.

The technique I recommend is to use a high wattage resistor of about 5 to 50 ohms/V of the working voltage of the capacitor. This will prevent the arc-welding associated with screwdriver discharge but will have a short enough time constant so that the capacitor will drop to a low voltage in at most a few seconds (dependent of course on the RC time constant and its original voltage).

Then check with a voltmeter to be double sure. Better yet, monitor while discharging.

Obviously, make sure that you are well insulated!

For the power supply filter capacitors which might be 400 uF at 200 V, a 2 K ohm 10 W resistor would be suitable.  $RC = .8$  second.  $5RC = 4$  seconds. A lower wattage resistor (compared to that calculated from  $V^2 / R$ ) can be used since the total energy stored in the capacitor is not that great (but still potentially lethal).

The discharge tool and circuit described in the next two sections can be used to provide a visual indication of polarity and charge for TV, monitor, SMPS, power supply filter capacitors and small electronic flash energy storage capacitors, and microwave oven high voltage capacitors.

Reasons to use a resistor and not a screwdriver to discharge capacitors:

- \* It will not destroy screwdrivers and capacitor terminals.
- \* It will not damage the capacitor (due to the current pulse).
- \* It will reduce your spouse's stress level in not having to hear those scary snaps and crackles.

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## 4.7) Capacitor discharge tool

A suitable discharge tool for each of these applications can be made as quite easily. The capacitor discharge indicator circuit described below can be built into this tool to provide a visual display of polarity and charge (not really needed for CRTs as the discharge time constant is virtually instantaneous even with a multi-M ohm resistor).

- \* Solder one end of the appropriate size resistor (for your application) along with the indicator circuit (if desired) to a well insulated clip lead about 2-3 feet long. For safety reasons, these connections must be properly soldered - not just wrapped.
- \* Solder the other end of the resistor (and discharge circuit) to a well insulated contact point such as a 2 inch length of bare #14 copper wire mounted on the end of a 2 foot piece of PVC or Plexiglas rod which will act as an extension handle.
- \* Secure everything to the insulating rod with some plastic electrical tape.

This discharge tool will keep you safely clear of the danger area.

Again, always double check with a reliable voltmeter or by shorting with

an insulated screwdriver!

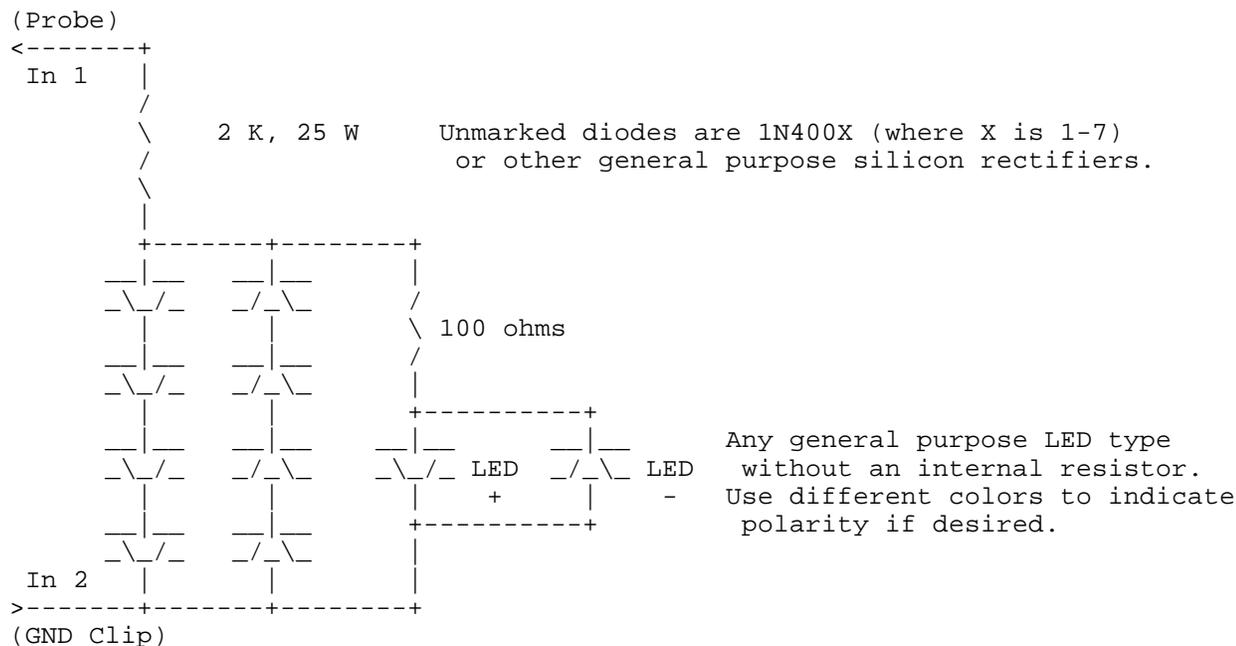
## 4.8) Capacitor discharge indicator circuit

Here is a suggested circuit which will discharge the main filter capacitors in switchmode power supplies, TVs, and monitors. This circuit can be built into the discharge tool described above.

A visual indication of charge and polarity is provided from maximum input down to a few volts.

The total discharge time is approximately 1 second per 100 uF of capacitance (5RC with R = 2 K ohms).

Safe capability of this circuit with values shown is about 500 V and 1000 uF maximum. Adjust the component values for your particular application.



The two sets of 4 diodes will maintain a nearly constant voltage drop of about 2.8-3 V across the LED+resistor as long as the input is greater than around 20 V. Note: this means that the brightness of the LED is NOT an indication of the value of the voltage on the capacitor until it drops below about 20 volts. The brightness will then decrease until it cuts off totally at around 3 volts.

Safety note: always confirm discharge with a voltmeter before touching any high voltage capacitors!

## 4.9) The series light bulb trick

When powering up a monitor (or any other modern electronic devices with expensive power semiconductors) that has had work done on any power circuits, it is desirable to minimize the chance of blowing your newly installed parts should there still be a fault. There are two ways of doing this: use of a Variac to bring up the AC line voltage gradually and the use of a series load to limit current to power semiconductors.

Actually using a series load - a light bulb is just a readily available cheap load - is better than a Variac (well both might be better still) since it will limit current to (hopefully) non-destructive levels.

What you want to do is limit current to the critical parts - usually the switchmode (chopper) power transistor of an SMPS or horizontal output transistor (HOT) of a TV or monitor. Most of the time you will get away with putting it in series with the AC line. However, sometimes, putting a light bulb directly in the B+ circuit will provide better protection as it will limit the current out of the main filter capacitors. Actually, an actual power resistor is probably better as its resistance is constant as opposed to a light bulb which will vary by 1:10 from cold to hot. The light bulb, however, provides a nice visual indication of the current drawn by the circuit under test. For example:

- \* Full brightness: short circuit or extremely heavy load - a major fault probably is still present.
- \* Initially bright but then settles at reduced brightness: filter capacitors charge, then lower current to rest of circuit. This is what is expected when the equipment is operating normally. There could still be a problem with the power circuits but it will probably not result in an immediate catastrophic failure.
- \* Pulsating: power supply is trying to come up but shutting down due to overcurrent or overvoltage condition. This could be due to a continuing fault or the light bulb may be too small for the equipment.

Note: for a TV or monitor, it may be necessary (and desirable) to unplug the degauss coil as this represents a heavy initial load which may prevent the unit from starting up with the light bulb in the circuit.

The following are suggested starting wattages:

- \* 40 W bulb for VCR or laptop computer switching power supplies.
- \* 100 W bulb for small (i.e., B/W or 13 inch color) monitors or TVs.
- \* 150-200 W bulb for large color monitors or projection TVs.

A 50/100/150 W (or similar) 3-way bulb in an appropriate socket comes in handy for this but mark the switch so that you know which setting is which!

Depending on the power rating of the equipment, these wattages may need to be increased. However, start low. If the bulb lights at full brightness, you know there is still a major fault. If it flickers or the TV (or other device) does not quite come fully up, then it should be safe to go to a larger bulb. Resist the temptation to immediately remove the bulb at this point - I have been screwed by doing this. Try a larger one first. The behavior should improve. If it does not, there is still a fault present.

Note that some TVs and monitors simply will not power up at all with any kind of series load - at least not with one small enough (in terms of wattage) to provide any real protection. The microcontroller apparently senses the drop in voltage and shuts the unit down or continuously cycles power. Fortunately, these seem to be the exceptions.

## 4.10) What about SMPSs in TVs and monitors?

TVs and monitors have at least one SMPS - the horizontal deflection flyback circuit and may have an additional SMPS to provide the low voltages or the DC for the horizontal output transistor. Most of the theory of operation and troubleshooting techniques apply to these as well. However, manufacturers of TVs and monitors tend to be really creative (can you say, obscure?) when it comes to these designs so a little more head scratching is often necessary to decipher the circuit and get into the mind of the designer. However, the basic failure modes are similar and the same test procedures may be used.

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## 4.11) SMPS failure modes

SMPS fail in many ways but the following are common:

- \* Shorted switchmode transistor - may take out additional parts such as fusible flameproof resistors in collector or emitter circuits (or source or drain circuits for MOSFETs). Main fuse will blow unless protected by fusible resistors.

Symptoms: totally dead supply, fuse blows instantly (vaporizes or explodes unless fusible resistor has opened). Measuring across C-E or D-S of switchmode transistor yields near zero ohms even when removed from circuit.

- \* Shorted rectifier diodes in secondary circuits - these are high frequency high efficiency diodes under a fair amount of stress.

Symptoms: In a very basic supply without overcurrent protection, the failure of one or more of these diodes may then overload the supply and cause a catastrophic failure of the switchmode power transistor (see above) and related components. Thus, these should be checked before reapplying power to a supply that had a shorted switchmode transistor.

On short circuit protected supplies, the symptom may be a periodic tweet-tweet-tweet or flub-flub-flub as the supply attempts to restart and then shuts down. Any power or indicator lights may be blinking at this rate as well.

Test with an ohmmeter - a low reading in both directions indicates a bad diode. Sometimes these will test ok but fail under load or at operating voltage. Easiest to replace with known good diodes to verify diagnosis. Rectifiers either look like 1N400X type on steroids - cylinders about 1/4" x 1/2" (example: HFR854) or TO220 packages (example: C92M) with dual diodes connected at the cathode for positive supplies or the anode for negative supplies (the package may include a little diagram as well). These may either be used with a center-tapped transformer, or simply parallel for high current capacity. If in doubt, remove from the circuit and test with the ohmmeter again. If not the output used for regulation feedback, try the supply with the rectifier removed. As noted, a test with an ohmmeter may be misleading as these rectifiers can fail at full voltage. When in doubt, substitute a known good rectifier (one half of a pair will be good enough for a test).

- \* Bad startup circuit - initial base (gate) drive is often provided by a high value, high power resistor or resistors from the rectified AC voltage. These can simply open for no good reason.

Symptoms: In this case the supply will appear totally dead but all the semiconductors will check out and no fuses will blow. Check the startup resistors with an ohmmeter - power resistors in the AC line input section. Warning: there will be full voltage on the main filter capacitor(s) - 1X or 2X peak or around 160 or 320 VDC depending on design. Discharge before probing.

- \* Dried up capacitors - either input or output side.

Symptoms: The main filter capacitor may dry up or open and cause the output to be pulsing at 60 (50) or 120 (100) Hz and all kinds of regulation problems. Measure voltage across main filter capacitor(s). If the reading is low and drops to a much lower value or 0 instantly upon pulling the plug, then one of these capacitors may be open or dried up. If you have an oscilloscope, monitor for ripple (use an isolation transformer!!). Excess ripple under moderate load is an indication of a dried up or open capacitor.

In extreme cases, a main filter capacitor with greatly reduce capacity or that is totally open may result in failure of the switchmode transistor and a dead supply that blows fuses or fusible resistors. Therefore, it is always a good idea to test the electrolytic capacitors whenever repairing a SMPS that has blown its switchmode transistor.

Capacitors in the low voltage section may fail causing regulation problems. Sometimes there are slew rate limiting capacitors which feed from the primary output to the regulator controller to limit initial in-rush and overshoot. A failure of one of these may mess up regulation at the very least. For example, excess leakage may reduce the output of the main output (and as a consequence, all the others as well).

Where a controller like a UC3842 is used, a failure of the capacitor on its Vcc pin may result in a aborted startup or cycling behavior as it is starved for juice each time it pulses the switchmode power transistor:

(From: John Hopkins (bugs71@ptdprolog.net)).

"I have encountered a bad cap (10uf 35v) on the Vcc input of a UC3842 IC in the power supply. Turn unit on, get very short burst of power supply output, then nothing. Every time the 3842 output a pulse, it ran out of VCC. Small part, big problem."

In almost all cases, when in doubt parallel a known good capacitor of similar capacitance and at least equal voltage rating (except for these slew rate limiting capacitors where substitution is the only sure test).

For Panasonic (and other) VCR power supplies, it has been suggested that one or more the output filter capacitors commonly fail and replacing all of them, while perhaps a brute force solution, will fix a whining supply or one having bad regulation or noise. However, check the semiconductors as well before applying power.

- \* Bad connection/cold solder joints - as with all other mass produced power systems (including TVs and monitors), cracked or defective solder connections are very common especially around the pins of high power components like transformers, power resistors and transistors, and connectors.

These are particularly common with portable equipment. Universal AC adapters for camcorders and laptop computers are often abused to the point of failure.

Large components like the line filter choke and high frequency transformer are prone to crack the solder bond at their pins or even break loose from the circuit board.

Symptoms: almost any kind of behavior is possible. The unit may be erratic, intermittent, or totally dead. Visually inspect the solder side of the circuit board with a bright light and magnifying glass if necessary. Gently prod or twist the circuit board with an insulating stick to see if the problem can be made to change. Note that a one-time intermittent can blow many components so inspecting for intermittents is a really good idea even you believe that all bad components have been replaced.

\* Regulation problems - outputs high or low.

Symptoms: voltage has changed and adjustment pot if one exists has no effect or is unable to set voltage to proper value. Check components in the feedback regulator, particularly the opto-isolator and its associated circuitry. A weak opto-isolator may allow for excessive output voltage. A shorted photodiode in the opto-isolator may prevent startup. An open photodiode may lead to a runaway condition. **WARNING:** probe these circuits with care both because of the safety issues but also since any slip of the probe may lead to a runaway condition and catastrophic failure of the switchmode transistor and its related parts as well as damage to any attached equipment.

Note that the high frequency transformer does not make the top 10 list - failure rates for these components are relatively low. You better hope so in any case - replacements re usually only available from the original manufacturer at outrageous cost.

All other parts are readily available from places like MCM Electronics, Dalbani, Premium Parts, and other national distributors.

Rebuild kits are available for many common supplies used in VCRs, monitors, terminals. See the section: "[Repair parts sources](#)".

Also, while it is tempting to suspect any ICs or hybrid controllers since it is thought that replacements are difficult and expensive to obtain, these parts are pretty robust unless a catastrophic failure elsewhere sent current where it should not have gone.

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## 4.12) General SMPS troubleshooting approach

The following sections provide a set of guidelines for attacking SMPS problems. Those in the next 5 paragraphs are common to SMPS using both discrete and integrated controllers:

1. First, determine that it is not something trivial like a blown fuse due to a legitimate overload (that has since been removed). I have a SCSI peripheral box that will blow its SMPS fuse if the SCSI cable is inserted live.
2. Categorize the problem into: startup problem, catastrophic failure, incorrect outputs, or excessive ripple or noise.
3. Determine what the proper output voltages should be. Identify the main (regulated) output.

4. Disconnect the supply from the equipment it is powering if possible. This will prevent the possibility of expensive damage should the output voltages soar to stratospheric levels for some reason. If this is not possible, you will need to be extra careful - always use a Variac to bring up the input slowly and monitor the main output at all times.
5. Determine an appropriate load for the outputs (if not connected to the equipment). A typical SMPS will want a minimum of 5% to 20% of full load current at least on the main output to regulate properly. Others may not need any load - it depends on the design or they may have an internal load. Here are some typical load currents:
  - \* VCR - .2 A on +5 V and +12 V outputs.
  - \* PC - 2 A on +5, 1 A on +12. A dual beam auto head light works well.
  - \* Monitor - .2 A on +60 to +120 V output.
  - \* Typical 40 W switcher = 1 A on +5 and +12.

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## 4.13) Troubleshooting SMPSs using discrete controllers

The following paragraphs apply mainly to SMPSs using discrete circuitry (no ICs) for pulse width control. For those using integrated controller chips, see the next section: "[Troubleshooting SMPSs using integrated controllers](#)".

- \* Startup problems - check the power on the switchmode transistor and work back from there if there is none. Check for open fusible resistors in the return as well. Determine if there is startup base/gate drive. Check for open startup resistors, bad connections, blown parts in the controller circuitry.
- \* Blows fuses - check switchmode transistor and all other semiconductors for shorted junctions. Then check for open fusible resistors and bad connections. Finally, check the electrolytic capacitors for reduced capacity and leakage.
- \* Power cycling - monitor current and voltage sensing signals to determine if they are actually signaling a fault. Open or out of tolerance resistors may result in incorrect sensing. With the series light bulb and/or Variac, disable each of these inputs by bypassing the appropriate components. If one of these experiments prevents the cycling behavior, either that circuit has a faulty component or the controller circuit is not functioning properly.
- \* Regulation or ripple/noise problems - check main HV filter capacitor and other filter capacitors for decreased value or opens. Check regulation components including shunt regulators and zener diodes.

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## 4.14) Troubleshooting SMPSs using integrated controllers

Since there are usually several fault conditions that can result in an aborted startup or cycling behavior, the basic troubleshooting procedure needs to be modified when dealing with SMPS using controller

ICs like the UC3840 or UC3842.

Also see the section: "[Typical controller ICs found in small switchmode power suppli](#)

The following paragraphs apply to SMPSSs using integrated controllers. For those using discrete components only (no ICs), see the previous section: "[Troubleshooting SMPSSs using discrete controllers](#)".

- \* Startup problems - check the power on the switchmode transistor and work back from there if there is none. Check for open fusible resistors in the return as well. Check for power to the controller. Determine that no fault condition inputs have abnormal voltages during startup. Check for drive out of the controller IC and see if it reaches the switchmode transistor. You will probably need to power cycle the line input - preferably with a Variac - and monitor each of the relevant signals as you do so. Determine if the supply is shutting down abnormally due to a legitimate or bogus over-current or over-voltage condition or is never actually starting up due to a lack of a voltage or a stuck-at fault on a sense line. Monitor its power to determine if it is stable during startup - a bad capacitor or diode could result in insufficient or decreasing voltage which causes the controller to give up.
- \* Blows fuses - check switchmode transistor and all other semiconductors for shorted junctions. Then check for open fusible resistors and bad connections. There is a chance that a blown transistor took out the controller chip as well. Under normal conditions, controllers like the UC3840 or UC3842 should current limit on a PWM cycle-by-cycle basis. Therefore, a blown fuse indicates a failure of either the switchmode transistor, controller or both.
- \* Power cycling - monitor current and voltage sensing and Vcc inputs to controller to determine which, if any, are at fault. Open or out of tolerance resistors may result in incorrect sensing. Check for faulty reference setting components like zener diodes. With the series light bulb and/or Variac, disable each of the sense inputs by bypassing the appropriate components. If one of these experiments prevents the cycling behavior, either that circuit has a faulty component or the controller IC's input characteristics have changed and it will need to be replaced. It should be possible to determine if these sensing reference levels are correct from the controller specifications and thus should be ignored by the controller as within normal limits.
- \* Regulation or ripple/noise problems - check main HV filter capacitor and other filter capacitors for decreased value or opens. Check regulation feedback components to controller including any reference voltage output and zener diodes. Determine if the controller is responding to error voltage. If possible, monitor both error and PWM drive signals on a dual trace scope.

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## 4.15) Initial post-repair testing

Once defective parts have been replaced, if possible remove the normal load from the supply if you have not already done so just in case it decides to put excessive voltage on its outputs and replace with a dummy load. For a multiple output supply, the most important output to have a load on is the one that is used for regulation but some modest load on all the outputs is preferred. You should be able to determine a suitable value by considering the application. For something like a VCR, a few hundred mA on the main

output is probably enough. This would require something like a 25 ohm 2 W resistor for a 5 or 6 volt output or 50 ohm 5 W resistor for a 12 volt output (depending on which is the primary output). For a PC power supply, a couple of amps may be needed - a 2 or 3 ohm 15 W resistor on the +5 output. The minimum load is sometimes indicated on the specification sticker. In the case of a TV or monitor, disconnecting the load may not be possible (or at least, easy).

If available, use a Variac to bring up the input voltage slowly while observing the main output. You should see something at about 50% of normal input voltage - 50 or 60 V for a normal 115 VAC supply. With a small load, the output should very quickly reach or even exceed its normal value. Regulation at very low line voltage may be far off - this is often normal. If you do not have a Variac, put a light bulb in series with the line (this is desirable in any case). Use a 100 W bulb for a TV or PC, 40 W for a VCR typical. The light bulb should limit the current to a non-destructive value long enough to determine whether everything is ok. It may not permit normal operation under full load, however. When power is first applied, the light bulb will flash briefly but may just barely be glowing once the output has stabilized. If it is fairly bright continuously, there is likely still a problem in the supply. See the section: "[The series light bulb trick](#)".

Once you are finished, save your schematic and notes for the future. For example, multiple models of VCRs even from different manufacturers use the same basic design, maybe even the same supply.

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## 4.16) Some general switchmode power supply repair comments

Any time the switchmode transistor requires replacement, check all semiconductors for shorts and fusible resistors for opens. even if you locate **\*\*the\*\*** problem early on. Multiple parts often fail and just replacing the transistor may cause it to fail as a result of something else still being bad. In particular, check primary side electrolytic capacitors for reduced capacity or opens. These conditions can result in a blown switchmode transistor as it attempt to supply adequate current during the troughs of the rectified high voltage DC. It only takes a few more minutes. For other problems like an open startup resistor this excessive caution is unnecessary as these are usually isolated failures. However, if any dried up electrolytics are found, it is good practice to test them all - or just replace them all since the cost and time will be minimal. As they say, 'peas in a pod fail at nearly the same time'.

It is often helpful to trace the circuit by hand if a service manual is not available. You will gain a better understanding of this supply and be able to put the knowledge to use when the next one shows up on your bench - there is a lot of similarity even between different manufacturers. A bright light behind the circuit board may help to make the foil runs and jumpers more visible. The only difficult part will be determining how the transformer windings are hooked up. An ohmmeter will help but even if you cannot entirely determine this, just make a note. For most purposes, the exact topology of the windings is not critical for diagnostic procedures.

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## 4.17) Periodic power cycling problems

These are of the form: tweet-tweet-tweet or flub-flub-flub or some other similar variation. Any LEDs may be flashing as well and in the case of something like a monitor or TV, there may be HV static or even a partial raster in synchrony with the sounds. These types of problems are more common with sophisticated implementations - the simple ones just blow up!

As noted elsewhere, shorted secondary components are a very likely cause of this behavior. These include diodes, capacitors, and overvoltage SCRs. The fact that there is some output suggests that the main switchmode (chopper) transistor is working. There would likely be no output at all if it were bad.

Other possibilities for periodic or pulsing outputs:

1. One of the diodes is failing at voltage - quite possible. As long as you do not remove both from the output that is used for feedback, it should be safe to take them out one at a time and then substitute for the one remaining in the feedback voltage. Use a Variac and series light bulb when testing in this manner and constantly monitor the main output.
2. Some other cause of excessive current - shorted capacitor, transformer (though not likely), etc.
3. Faulty current sense circuit - open or increased value resistor.
4. Faulty voltage sense circuit - detecting overvoltage or regulation defective and it is shutting down (correctly).
5. Faulty component in the startup circuit. This could be a bad diode, resistor, or even an electrolytic capacitor that has changed value or is open at low voltage (when the controller is just waking up).
5. Faulty controller IC (if applicable).

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# Chapter 5) Components Found in Switchmode Power Supplies

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## 5.1) Common, unusual, and strange

Most of the components used in switchmode power supplies are common and easily identified. However, some may be unfamiliar and unrecognizable. Others could be totally custom parts - ASICs or hybrid circuits - developed specifically for a particular model or product line. However, these rarely fail despite your temptation to blame them specifically \*because\* locating a replacement is difficult and most likely expensive.

Common components like transistors, diodes, capacitors, and resistors, can usually be tested with a multimeter at least for total failure. Also see the documents: "Testing of Bipolar Transistors with a VOM or DMM" and "[Testing Capacitors with a Multimeter and Safe Discharging](#)".

Of course, with catastrophic failures, no equipment beyond your eyeballs and nose may be needed.

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## 5.2) Switchmode (chopper) transistors and other semiconductors

- \* Bipolar power transistors (often BU or 2SC/2SD numbers) - high voltage power types are used for the main switchmode (chopper) transistor.

Test for shorted and open junctions. These are the most common failures for the power transistors. Partial failure where there is some leakage or various parameters change value are unlikely.

Substitution of a transistor with at least equal voltage and current ratings should be fine for testing as long as you use a series light bulb to limit the current should something still be wrong elsewhere in the circuit. A not-exact match may run hotter than normal. Always use a heatsink.

- \* Power MOSFETs (2SK numbers) - many newer supplies are using these rather than the bipolar type. In some ways they are more robust but testing is more difficult.

Testing for shorts is still possible but anything more requires additional equipment beyond a multimeter. However, the original problem did not blow a fuse or fusible resistor, if the MOSFET is not shorted, there is a good chance that it is still fine and you should look elsewhere for the problem. It may be a problem with the startup circuit or controller.

Note: if your supply produces any output (say, more than 10% of rated voltage), it is unlikely that the chopper transistor is bad as it must be working to some extent and, as noted, these usually blow totally.

- \* Small bipolar transistors - these may be found in feedback and control functions.

Test for shorted and open junctions with a multimeter. Substitute with similar known good transistor is best, however. I have seen little silicon transistors that had developed enough leakage to prevent a 400 W supply from coming up!

- \* Diodes and rectifiers - a bridge or set of 2 or 4 discrete diodes is usually used for the AC line rectification and/or doubling. High efficiency and/or fast recovery types are used in the secondary side for rectification of the various output voltages. These may look like normal axial lead diodes or may be combined in pairs inside TO220 type packages.

Test for shorted and open junctions. However, sometimes, diodes will only fail with full voltage in-circuit but test good with a multimeter.

Replacements for the primary side rectifiers are very inexpensive and readily available. If the unit blows fuses with the switchmode transistor and main filter capacitors pulled, the rectifiers may indeed be bad.

It is usually safe to remove secondary rectifiers one at a time to see if the supply will come up. As long as you do not remove all diodes for the output that provides the feedback for the regulation, this should be relatively low risk. (However, do this with a dummy load - not your expensive laptop computer just in case.) Even removing those diodes is usually safe if you can power the supply using a Variac since you will be able to limit the input (while monitoring the main output) should the outputs go overvoltage.

- \* SCRs - small SCRs may be found in the overvoltage protection circuitry of some supplies. Note that SCR type of crowbars are used across the output as a way to guarantee that an overvoltage condition will kill the output regardless of the reason for the overvoltage condition. Hopefully, the supply's overcurrent protection will kick in rather than having the supply blow up. This is not always the case, unfortunately.

Test for shorts if output on which SCR is connected is not coming up. Remove the SCR. Now, using a Variac to bring up the voltage slowly, see if the relevant output is going over voltage, is still clamped at a low level, or is the correct voltage (under load). A momentary overvoltage spike at turn-on could also trip the crowbar. This could be due to a faulty inrush/slew rate limiting circuit.

- \* TL431 or similar shunt regulator IC - either a T092 or 8 pin DIP. Has 3 active terminals - A, C, and R. Current will flow from C to A if R-A is greater than 2.5 V.

Test for shorts but substitution is best. However, with care (using a Variac AND series light bulb to limit the input current, it is possible to determine if the circuit in which these are connected is working. Short across TL431 - supply should either turn off or run at greatly reduced output. Remove the TL431 - there should be no regulation - outputs should continue to climb as Variac is increased. By monitoring input to TL431 it should be possible to determine if it is doing its job.

- \* Optoisolator - either a 4 or 6 pin DIP or a 4 pin cylindrical object. This provides the regulator feedback across the isolation barrier. Replacements are readily available.

Test by putting 10-20 mA through LED and measuring decrease in resistance of reverse biased photodiode. However, this will not identify a weak optoisolator. Swapping is best.

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## 5.3) Capacitors (filter and bypass)

- \* Filter capacitors - electrolytic type are used for filtering of the rectified (possibly doubled) AC line input and for filtering of the various outputs of the power supply.

If no capacitor checker is available, test for opens, shorts, and leakage with a multimeter. For electrolytics, this is straightforward. Inspect the capacitor for any discoloration, a bulging case, or other evidence of trauma.

An ESR meter is a convenient device for rapidly checking the health of electrolytic capacitors. The ESR (Effective Series Resistance) of a capacitor increases as the capacitor deteriorates ('dries up'). Even a capacitor that tests good on a capacitor checker may not work properly due to excessive ESR.

When in doubt, the best approach is to substitute a known good capacitor of at least equal working voltage and similar uF rating.

Also see the document: "[Testing Capacitors with a Multimeter and Safe Discharging](#)"

- \* Bypass Capacitors - high quality plastic dipped or rectangular molded capacitors as part of RFI filter. These rarely fail.

Test for shorts - your multimeter will probably not be able to detect the small capacitance. Substitute if in doubt.

Note that many of these are special high quality low loss types with regulatory approval for use across the power line in the line filter. Exact replacements are required for safety.

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## 5.4) Resistors (normal and flameproof), NTC thermistors, MOVs

- \* Resistors - test for correct value with a multimeter. If measured in-circuit, value may read low if shunted by other components. If a higher than normal reading is obtained in-circuit, the resistor is bad. Metal film types like to go open circuit - especially very high value resistors.

Startup resistors in particular tend to go open-circuit resulting in a dead supply but no blown fuses or fusible resistors. These are usually high value (100K typical) medium wattage and run hot since they are across the full rectified line voltage.

- \* Flameproof or fusible resistors (They are the same) - these are often designated 'FR'. They will look like power resistors but will be colored blue or gray, or may be rectangular ceramic blocks. They should only be replaced with flameproof resistors with identical ratings. They serve a very important safety function: they cannot catch fire when overheated and will open rather than changing value which implements an overload protection function.

These usually serve as fuses in addition to any other fuses that may be present (and in addition to their function as a resistor, though this isn't always needed). If an FR type resistor has blown, you probably have shorted semiconductors that will need to be replaced as well. Check all the transistors and diodes in the power supply with an ohmmeter. You may find that the main switch mode transistor has decided to turn into a blob of solder - dead short. Check everything out even if you find one bad part - many components can fail or cause other components to fail if you don't locate them all. Check resistors as well, even if they look ok.

The most common location for these in a small SMPS is in the return circuit of a the switchmode transistor. However, they may be in the power feed as well. The value may be a fraction of an ohm but can be larger.

In TVs and monitors, these are often found in the hot power feed to the main low voltage power supply and in various secondary supply feeds as well. For the main supply, they will be 5-25 W rectangular ceramic power resistors. For the secondary supplies, they may be the 1/2-2 W blue or brown tubular variety.

Test for opens. Those in the return circuits are usually very low value - a fraction of an ohm to a few ohms - if in the return of the switchmode (chopper) transistor. The type in the power feeds may be anywhere from a fraction of an ohm to several K ohms depending on the circuit load.

For testing ONLY, a normal resistor may be substituted but the proper replacement MUST be installed before returning the supply to service.

Since they function as fuses, flameproof resistors should not be replaced with higher wattage types unless specifically allowed by the manufacturer. These would not blow at the same level of overload possibly resulting in damage to other parts of the circuitry and increasing the risk of fire.

- \* MOVs - Metal Oxide Varistors - look like brightly colored plastic coated disk capacitors but not marked with capacitance. These are surge suppressors. A severe surge or lightning strike may obliterate one or more of these. There will usually be either 1 between the Hot and Neutral or 3 across H, N, and safety ground.

If they are visibly damaged in any way, just remove (for now) or replace. Test with an ohmmeter - resistance should be nearly infinite.

- \* NTC resistors (thermistors) - Negative Temperature Coefficient resistors act as inrush surge limiters. There may be one or two of these in series with the AC input. These are a high value when cold but drop to a low value once they heat up due to current flow into the supply. These often look like fat black disk capacitors.

Test when cold and hot (use a hot air gun or hair dryer if not in-circuit). Resistance should drop from 10s of ohms to a very low value.

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## 5.5) Transformers and inductors

- \* High frequency transformers - these include the switchmode power transformer and any feedback (toroidal or E-I core type) transformers.

The main transformer which provides line isolation and generates the multiple output voltages from the 150-320 VDC input rail. These are usually custom wound for each model power supply and replacements are only available from the manufacturer. However, some distributors will stock replacements for a few TVs and computer monitors.

Testing for opens is usually easy since connections to the input (chopper) and output rectifiers are fairly obvious. However, feedback windings may be involved and these are not readily determined without a schematic or tracing the circuit (and, possibly not even then.) The good news is that failures of these transformers is less common than one might fear.

Some supplies use small transformers for feedback rather than optoisolators. These can be tested for opens but rarely cause problems.

Identifying shorted turns requires a 'ring test' or measurement of the Q. See the document: "[Testing of Flyback \(LOPT\) Transformers](#)".

- \* Inductors - test for opens. Identifying shorted turns requires a 'ring test' or measurement of the Q. See the document: "[Testing of Flyback \(LOPT\) Trans](#)

AC line input inductors can just be bypassed if they test open.

Output 'pi' filter inductors rarely fail but if you suspect one, just remove it and jumper across the pads for testing - ripple just won't be quite as good.

- \* Coupled Inductors - used as part of the Pi type RFI filter in the AC input circuit. These look like small transformers but the windings are in series with the AC line. There are usually 1 or 2 of these on better supplies and they are very reliable.

Test for opens. Identifying shorted turns requires a 'ring test' or measurement of the Q. See the document: "[Testing of Flyback \(LOPT\) Transformers](#)". testing if they are open since they only affect input line noise filtering.

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## Chapter 6) Items of Interest

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### 6.1) Typical controller ICs found in small switchmode power supplies

Here is some information on the Unitrode UC3840 programmable off-line PWM controller and its simplified cousin, the UC3842. These are typical of the types of sophisticated inexpensive integrated SMPS controller ICs that are now readily available.

<http://www.unitrode.com/powsup.htm> gets you the webpage for .pdf datasheets of Unitrode's power conversion controllers (more than 40 different devices!). The information below is just a summary.

These devices generate the PWM pulse control to the switchmode (chopper) transistor as well as various fault sensing and other control functions.

Parts such as these are now found in many small switchmode power supplies and provide much more precise control during startup and normal operation, and better handling of fault conditions compared to most implementations using discrete circuitry.

However, they also result in additional head scratching when troubleshooting since many faults or incorrectly detected faults can shut down the unit or cause a power cycling type of behavior. Therefore, a datasheet for the controller chip will prove essential. In many cases a scope will be needed to monitor the various sense, control, and drive signals. A systematic troubleshooting approach must be used to eliminate power, startup, sensing, and control components one at a time once obvious shorted or open parts or bad connections have been eliminated from consideration.

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## 6.2) Unitrode UC3840 programmable off-line PWM controller

Features of the Unitrode UC3840 include:

1. Fixed frequency operation set by user selected components.
2. A variable slope ramp generator for constant volt-second operation. providing open-loop line regulation and minimizing or in some cases, even eliminating the need for feedback control.
3. A drive switch for low current start-up off of the high voltage line.
4. A precision reference generator with internal over-voltage protection.
5. Complete over-voltage, under-voltage, and over-current protection including programmable shutdown and restart.
6. A high current single-ended PWM output optimized for fast turn-off of an external power switch.

The following pin descriptions for the Unitrode UC3840 were derived from a Unitrode application note. Errors in interpretation are quite possible.

Pin 1: Compensation	Error amplifier (op amp) compensation network.
Pin 2: Start/U.V. lockout	This comparator performs three functions. With an increasing voltage, it generates a turn-on signal at a start threshold. With a decreasing voltage, it generates an under-voltage fault signal at a lower level separated by a 200uA hysteresis current. At the under-voltage threshold, it also resets the Error Latch if the Reset Latch has been set.
Pin 3: OV sense	Over-voltage input from power supply output(s).
Pin 4: Stop (Ext stop)	External logic signal to inhibit power.
Pin 5: Reset	External logic signal to reset error condition caused by (1) over-voltage, (2) over-current, (3) input under-voltage detect, (4) external stop.
Pin 6: Current threshold	This voltage input sets the over-current trigger levels for the internal comparators.
Pin 7: Current sense	This is the pulse-by-pulse PWM current control. The input is a voltage taken across a series resistor in the switchmode transistor's return.

There are two internal comparators with a difference in threshold of 400 mV. The one with the lower threshold limits the current for each PWM cycle. The one with the higher threshold sets the error flop-flop and shuts down the supply if its threshold is ever

	exceeded.
Pin 8: Slow start	This input limits the maximum PWM duty cycle. During power-on, an RC delay can therefore control the rate at which the output ramps up. The final value limits the maximum PWM duty cycle during normal operation.
Pin 9: Rt/Ct	R and C determine the constant PWM oscillator frequency.
Pin 10: Ramp	Ramp generator output.
Pin 11: Vi sense	This voltage is normally derived from the DC input and controls the slope of the ramp.
Pin 12: PWM output	This is the drive signal to the switchmode transistor. This is an open collector output and will normally be used in conjunction with the Driver bias (Pin 14) signal to provide total drive to the switchmode transistor.
Pin 13: Ground	Signal and drive common.
Pin 14: Driver bias	Supplies drive current to external power switch to provide turn-on bias and pullup during normal operation. Disabled for shutdown if the Error Latch is set.
Pin 15: Vcc	UC3840 chip supply derived from the DC input rail during startup and secondary winding on high frequency transformer during normal operation.
Pin 16: 5 V reference	Stable voltage reference (output) for regulation control.
Pin 17: Inv input	Error amplifier inverting input.
Pin 18: Non inv input	Error amplifier non-inverting input.
	The difference between the inputs on Pins 17 and 18 control PWM duty cycle. These will generally be derived by comparing the main output with the desired voltage reference.

## 6.3) Unitrode UC3842 off-line PWM controller

The UC3842 provides the necessary functions to implement an off-line fixed frequency current mode control schemes with a minimal external parts count. Note how most of the pin functions are subsets of those found in the more sophisticated UC3840. The UC3842 retains most of the features of the UC3840 but requires fewer external components and comes in a much smaller package (8 vs. 18 pins).

The following pin descriptions for the Unitrode UC3842 were derived from a Unitrode application note. Errors in interpretation are quite possible.

Pin 1: Compensation	Error amplifier (op amp) compensation network.
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Pin 2: Vfb	Error amplifier (non-inverting) input for regulation feedback.  This input is used to control PWM duty cycle and is normally derived from the main regulated output voltage. It is similar in function to The non-inverting input, Pin 18, of the UC3840.
Pin 3: Current sense	This is the pulse-by-pulse PWM current control. The input is a voltage taken across a series resistor in the switchmode transistor's return.
Pin 4: Rt/Ct	R and C determine the constant PWM oscillator frequency.
Pin 5: Ground	Signal and drive common.
Pin 6: PWM output	This is the drive signal to the switchmode transistor. It uses a totem pole output which has a high current drive capability both high and low.
Pin 7: Vcc	UC3842 chip supply derived from the DC input rail during startup and secondary winding on high frequency transformer during normal operation.
Pin 8: 5 V reference	Stable voltage reference (output) for regulation control.

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## 6.4) Description of UC3842 startup operation and cycling problems

Depending on the particular circuit design, a variety of fault conditions can result in cycling or shutdown of an SMPS controlled by a chip like the UC3842.

In addition to the overload condition described below, a dried up electrolytic capacitor on the Vcc line can also result in this cycling behavior since it is unable to hold up the voltage between output pulses. In addition, the sense inputs can trigger shutdown. In all, an often complex difficult to understand and troubleshoot situation - sometimes too much so for its own good!

(Portions from: Yves Houbion (yves.houbion@fundp.ac.be)).

Pin 7 is the power supply (Vcc). The oscillator inside the 3842 begins to work above 16 V on Vcc and stops working when this voltage drops below 11 V. With a stopped oscillator, the current consumption is very low, around 1 mA; with a working oscillator, the current is much higher, about 12 mA. (The specific voltages and currents are typical values for one particular version of the 3842 and can vary from device to device and depending on model.)

Vcc is generally powered in two ways: a high value power (startup) resistor connected to the main bridge (e.g., +300V) and a from a winding off the transformer (via a rectifier/filter capacitor). The value of the startup resistor is selected such that there is more than 16 V with 1 mA but less than 11 V at 12 mA. So the oscillator can't continue to work with only the startup resistor supplying power.

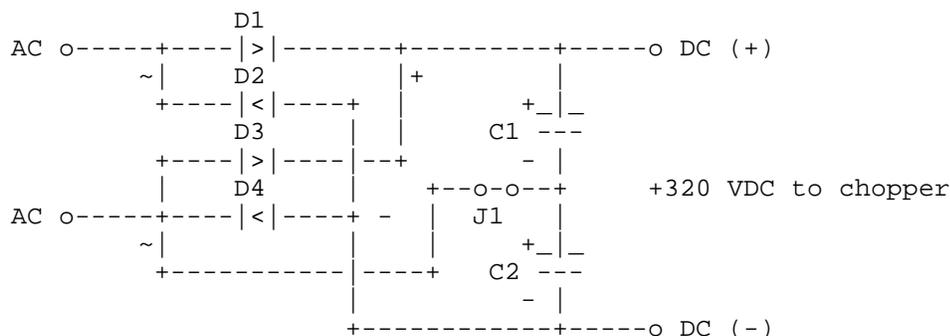
Suppose we apply AC power to the supply. The +300V comes on. First, the 3842 consumes only 1 mA, Vcc reaches 16 V, and the oscillator starts up. If all is well (no overloads), the transformer provides the necessary 12 mA current to maintain Vcc at more than 11 V.

However, if the transformer is overloaded, Vcc falls under 11 V and the oscillator stops working. The current decreases to 3 mA, the voltage increase (coming from the +300V) the oscillator start again, ad-infinitum.

Tweet-tweet-tweet....

## 6.5) Switching between 115 VAC and 230 VAC input

Assuming it is not a wide compliance 'universal type', a common way to do this is with a jumper (or switch) in the line input circuitry:



- \* With the jumper, J1, installed, the circuit is a voltage doubler for use on 115 VAC. (D3 and D4 never actually conduct because they are always reverse biased.)
- \* With the jumper, J1, removed, the circuit is a simple bridge rectifier for use on 230 VAC.

## 6.6) Changing the input voltage of a switchmode power supply

Would it be possible to modify a power supply designed for operation on 120 VAC for use overseas where the power is 240 VAC?

I don't advise it. There are many factors involved in changing a power supply unless it is designed for dual voltage or autoswitching. They saved a few cents if it is not easily switched, what can I say?

The problem is that it is probably a flyback convertor and these are pretty finicky about changes. In addition to the caps, and switching transistor, the transformer would probably saturate at the higher voltage unless the switching frequency were also doubled. Getting these things to work normally without blowing up is touchy enough. To change one without a thorough understanding of all the design parameters would be

really risky.

Going the other way may be more realistic if (and this is a big if) you will not be running at anywhere near full capacity. Many switchmode power supplies will run on much lower than their rated input voltage. However, regulation may be poor and the switchmode transistor will need to be passing much higher current to maintain the same power output. To maintain specifications could require extensive changes to the circuitry and replacement of the switchmode transistor and possibly transformer and other parts as well. Again, I do not recommend this.

Use a small stepup or stepdown transformer instead. The only exception is if there are clearly marked jumpers to select the input voltage or the supply is clearly marked as being autoswitching or having universal power input.

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## 6.7) Slightly modifying the output voltage of a PC power supply

Surplus PC power supplies are widely available and inexpensive. However, what do you do if 5 V isn't exactly what you need for a project?

(From: Winfield Hill (hill@rowland.org)).

Some of the PC power supplies I've dissected do have pots, but they have a limited voltage-adjustment range. One interesting thing, every design used a TL431 chip, which is a 3-pin TO-92 regulating IC, as the voltage reference and opto-feedback component. Find this chip and trace out the resistors connected to it to determine which part to change to make a higher voltage.

But, watch out for the SCR over-voltage circuit in some supplies. This is usually set to trip around 6 to 6.5 volts, and its trip point would need to be modified as well.

As far as the step-down transformer turns ratio, there's little trouble one will encounter here, because the power supply is no doubt designed to function properly with reduced AC line voltages. The penalty one will pay for turning up the output voltage is a higher minimum AC voltage.

In most designs, the +12 and -12V supplies merely track the 5V supply, and are not separately regulated. They may soar to higher voltages anyway if unloaded, but will be additionally increased in voltage by the ratio of 5V output increase. Even though the rating of the 5V electrolytic may not be exceeded, and still have a sufficient safety margin, this may not be the case for the 12V outputs. So that issue should be examined as well.

Finally, a reminder for any reader tempted to break open the box and start experimenting. Voltages of up to 320 V are present, so be careful. Know what you're doing. For safety, stay away from open supplies when plugged in, or always keep one hand behind your back when probing. Remember that the AC bridge and HV DC and flyback transformer portion of all these supplies is operating straight from the AC line, so don't connect the ground of your oscilloscope to any of that circuitry. A battery-operated multimeter is best.

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## 6.8) Use of surge suppressors and line filters

Should you always use a surge suppressor outlet strip or line circuit? Sure, it shouldn't hurt. Just don't depend on these to provide protection under all circumstances. Some are better than others and the marketing blurb is at best of little help in making an informed selection. Product literature - unless it is backed up by testing from a reputable lab - is usually pretty useless and often confusing.

Line filters can also be useful if power in you area is noisy or prone to spikes or dips.

However, keep in mind that most well designed electronic equipment already includes both surge suppressors like MOVs as well as L-C line filters. More is not necessarily better but may move the point of failure to a readily accessible outlet strip rather than the innards of your equipment if damage occurs.

Very effective protection is possible through the use of a UPS (Uninterruptible Power Supply) which always runs the equipment off its battery from the internal inverter (not all do). This provides very effective isolation power line problems as the battery acts as a huge capacitor. If something is damaged, it will likely be the UPS and not your expensive equipment. Another option is to use a constant voltage transformer (SOLA) which provides voltage regulation, line conditioning, and isolation from power spikes and surges. Manufacturers of these products may even provide equipment damage warranties which will reimburse for surge damage to the powered equipment while using their products. I am not sure how one proves that the UPS was being used at the time, however!

It is still best to unplug everything if the air raid sirens go off or you see an elephant wearing thick glasses running through the neighborhood (or an impending lightning storm).

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## 6.9) GFCI tripping with monitor (or other high tech equipment)

Ground Fault Circuit Interrupters (GFCIs) are very important for minimizing shock hazards in kitchens, bathrooms, outdoors and other potentially wet areas. They are now generally required by the NEC Code in these locations. However, what the GFCI detects to protect people - an imbalance in the currents in the Hot and Neutral wires caused possibly by someone touching a live conductor - may exist safely by design in 3 wire grounded electronic equipment and result in false tripping of the GFCI. The reason is that there are usually small capacitors between all three wire - Hot, Neutral, and Ground in the RFI line filters of computer monitors, PCs, and printers. At power-on and even while operating, there may be enough leakage current through the capacitors between Hot and Ground in particular to trip the GFCI. Even for ungrounded 2 wire devices, the power-on surge into inductive or capacitive loads like switching power supplies may falsely trip the GFCI. This is more likely to happen with multiple devices plugged into the same GFCI protected outlet especially if they are controlled by a common power switch.

Therefore, I do not recommend the use of a GFCI for computer equipment as

long as all 3 wire devices are connected to properly grounded circuits. The safety ground provides all the protection that is needed.

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## 6.10) Why do power supplies seem to fail after a power outage?

Startup is the most stressful time for a typical switchmode power supply. The output filter capacitors as well as the load must be driven while the input voltage is changing - possibly wildly. With careful design, these factors can be taken into consideration. Not all power supplies are designed carefully or thoroughly tested under all conditions. When power is restored, surges, dips, brownouts, and multiple on-off cycles are possible. This is why it is always recommended that electronic equipment be unplugged until power has been restored and is stable.

Supplies that are autoselecting with respect to input power are vulnerable to voltages at an intermediate value between their low and high ranges. At some values, they may autoselect the incorrect input range:

(From: Mike Diack (moby@kcbbs.gen.nz)).

A subject dear to my heart due to a recent unpleasant experience - Was using a PictureTel videoconference ISDN codec on a job when, because of a powerline fault, the line voltage dropped to 170 volts. The PicTel has a big Onan switchmode PSU which is autoswitching between 100-120 and 200-240 volts. It got confused, and (regrettably) chose the former.... with very smelly results.

Moral: turn off things with cunning PSUs when brownouts occur (oh yes the airconditioner units got very hot and tripped out, too)

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## 6.11) Buzzing or other sounds from SMPSs

(From: Ray Hackney (rhackney@unicomp.net)).

Simplistically speaking, the sound comes from something moving.

With non switch mode power supplies (SMPS), it may be ferrous material (like a metal cover) being drawn toward the power transformer. That's obvious since pushing on the cover will soften the hum. The frequency is usually 60Hz or 120Hz.

The only time you should hear a "noise" from a SMPS is during a period of "unstable" operation (i.e. their "loop" isn't stable and in regulation.) That's why you may hear them "chirp" or whistle when you first turn them on or off. It may also indicate a PC type power supply that's overloaded. In years gone by, I've seen a quiet PC become a whistler after having a new, big (30 meg, full height!) hard disk added. Sometimes the pitch of the whistle would change depending on what parts of the system were being accessed or what software was being executed. (Usually, when the old Intel AboveBoard was being accessed in this '286, the audible pitch was lower indicating greater current draw.)

For all power supplies, it may be the windings on the "magnetics" (inductor or transformer). If they're not wound tightly and secured they can vibrate. Many video monitors exhibit this problem when their flyback transformer emits a whistle. It may be the windings themselves moving or the winding assembly may be loose on the core.

Sometimes the capacitors in a SMPS will emit sound. Caps in SMPS' frequently have high AC current levels. If the supply is supposed to have what's known as "continuous current" and goes into "discontinuous current" mode, the capacitor plates get stressed pretty heavily and move in the capacitor body (but only with some types). Since the SMPS will go into and out of discontinuous mode at a rate  $< 10\text{kHz}$ , it's audible. I've run into this on breadboards I've built for 200W and 2.5kW SMPS'.

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## 6.12) Cool electrolytics - temperature rating versus ESR

(From: Jeroen H. Stessen (Jeroen.Stessen@ehv.ce.philips.com)).

Electrolytic capacitors like to be kept cool! If there's anything that these capacitors can't stand, it's heat. It causes them to dry out.

Electrolytic capacitors exist in (at least) two different temperature ratings: 85 C and 105 C. The latter are obviously more temperature resistant. Unfortunately they also tend to have a higher ESR than their 85 C counterparts. So in an application where the heat is due to  $I^2 * \text{ESR}$  dissipation, the 105 C type may actually be a *worse* choice! If the heat is due to a nearby hot heatsink then 105 C is indeed a better choice.

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## 6.13) When better may be worse

ESR is usually something to be minimized in a capacitor. However, where the original design depended (probably by accident) on a certain ESR, this may not always be the case:

(From: Lee Dunbar (dunbar@unitrode.com)).

Substitutions of low ESR caps into circuits which had lousy caps is not always the good idea that it appears to be.... Caution is advised, as low ESR caps will not limit surge currents.

The circuits' series impedance drops (compare substituted capacitors ESR when new with the original capacitor's ESR was when it was a new capacitor), which, in turn, lets the surge magnitude rise, the higher currents destroy can semiconductors and other components.

I guess what the industry needs is a good capacitor cross reference guide for aluminum electrolytics!

## 6.14) John's notes on SMPS repair

(From: John Croteau (croteau@erols.com)).

Switchmode power supply repairs can be difficult. The problem is manufacturers don't usually give you an easy test set up. They should tell you if it will run at no load or what dummy load to use. Secondly they should tell you what voltage or resistance to use to replace the opto-isolator (or transformer) for that load. The SMPS hot side is a high frequency oscillator whose 'on time' is varied by feedback supplied through the opto-isolator. The troubleshooting procedure should normally be in this order.

1. First eliminate external causes such as shorts or no load as the cause of the shutdown.
2. Eliminate the secondary side shorted diodes, capacitors, etc.
3. After eliminating overloads on the outputs check the DC supply to the power device.
4. Check the bias coming from the feedback. Trace the bias supplied by the feedback and try to determine what is the correct bias for that situation (usually no power same as start-up).
  - \* If the bias is as on the schematic then troubleshoot the hot (primary) side as any oscillator.
  - \* If the bias is wrong and there is no short on the output then concentrate on why the feedback doesn't supply the expected voltage to bias the oscillator on.
5. If you work on many of the same type SMPS:
  - \* Determine the normal load and make a dummy load.
  - \* Determine the value of resistance that is created at the output of the opto-isolator (hint: use Ohm's law). Then remove one leg of the output of the opto-isolator and replace it with a resistor as calculated.

By using a fixed load and cutting out the feedback it is very easy to troubleshoot. Don't forget to check the voltages and waveforms in your test set-up and record them for future reference.

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## 6.15) Russell's comments on SMPS repair

(From: Russell Houlton (71101.2454@CompuServe.com))

I wanted to pass on some comments on repair of switchmode power supplies. I've fixed a few myself.

1. I see quite a few where the filter capacitors have failed. Not all electrolytic capacitors are the same. You should get capacitors that are rated for high frequency service. Use of "normal" caps that one finds in the local electronics stores are likely to go bad in about a year. Not something a professional who values his reputation wants to see happen. In fact, I suspect that some manufacturer fail to understand

this and use the wrong caps causing common failures in their units. Especially units that may be subjected to use in warmer areas. I see this mostly with specialized devices rather than mass consumer items.

I highly recommend the Panasonic HFS series cap that can be bought from DigiKey (and other places I'm sure). These unit are specially designed for good size as well as use in switching supplies. They are also rated for 105 degrees C as opposed to the more common 85 degrees C temperature rating. I have never had to replace a HFS cap I installed, where I've had to replace "common" caps in repair situations. (No I don't sell the HFS or have stock in DigiKey, I'm just passing some info that has worked well for me.)

2. SMPS usually try to regulate one of the output voltages by using the switcher, usually it's the output with the most power, but might be the one that's most voltage critical. If the filter caps go bad in the main output voltage, the auxiliary output voltages will go high. The SMPS may also start to make high-pitched sounds as the ripple messes with the feedback system. The aux output voltages may go so high that the secondary regulator may go into foldback to protect itself. I found this out the hard way. It's really something that can kick you in the pants because normally one would not check the 5V supply if the problem seems to be a bad 23.5V regulator.
3. Noisy (whining or buzzing) SMPSSs that still work tend to be either bad main output voltage capacitors or bad electrolytics in the power oscillator circuit. See the section: "[Buzzing or other sounds from SMPSSs](#)".
4. Most SMPSSs have also have a \*minimum\* power draw requirement from their loads. This is especially true of the main output voltage. If not enough power is drawn from the supply, the supply may not be stable and can not supply full power on the auxiliary voltages. An example of this is using a 250W PC power supply just to drive a disk drive. Without the heavy 5V power draw of a motherboard, the supply may not start up reliable or provide the needed 12V power for the hard drives.
5. I've also seen cases where one of the voltage doubler caps will open up causing failure in one of the switching transistor(s). It will short out a single transistor unit, but in a dual switching unit, the transistor associated with the good cap will over-work itself and open. An easy way to test is to remove the other switching transistor (in a dual unit) and apply power for 2 seconds. (Take all prudent precautions for working around a live and open unit!) Disconnect power and use your voltmeter to check the voltage across each of the caps. They should discharge at a roughly equal rate. A bad cap will lose all it's voltage in less then 2 seconds. A good cap will hold it's charge much longer.
6. Lastly, some unit that have the switch mode power supply in the same enclosure as the CRT will have a sync signal that comes from the horizontal flyback transformer. This keeps the SMPS in sync with the display so that the small magnetic fields that are created by the SMPS don't create a wavy pattern on the screen. Something to remember if a newly re-assembled unit shows a window screen like interference pattern on the display.

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## 6.16) Bob's description of how a typical PC power supply works

(From: Bob Wilson (rfwilson@intergate.bc.ca)).

I really suggest you refer to a handbook on basic switchmode power supply design for the nitty-gritty.

I have a schematic of a 200 Watt PC power supply, and I assure you that there are enough cost-saving clever shortcuts in the design, that unless you know a fair amount about the design of switchers, it will just totally and completely baffle you.

Nearly all 200 W PC power supplies are \*identical\* knock offs of one-another (except for the power-good comparator section). The transformer has a +5 V output which is what is regulated. It also has a +12 V output and a -12 V output. The -5 V output is derived from the -12 V output using a 7905 regulator. All transformer outputs are related in voltage by the transformer turns ratio. The power supply topology is a Half Bridge, which normally requires a "buck section" in each output (namely an inductor, catch diode and capacitor). To vastly improve the cross regulation between windings, a common core is used to wind all the 3 output inductors on.

Basically, however, a 200 W PC power supply is a half-bridge design, with a bridge-type voltage doubler in front which simply rectifies 220 V, or doubles 110 V to 220 V. So the thing is basically a 220 Volt design.

The controller is typically a TI TL494 that operates off the output of the supply. This means that in order to start, there must already be an output voltage present! How they do this is really really clever, and also extremely confusing. The power transformer is itself, self oscillating. This generates a rudimentary output voltage that allows the thing to bootstrap up to normal operation, and the controller chip to take over.

The +12 Volt output is what is used to power the PWM chip. Thus, the supply runs off its own output. This is done to eliminate the need for troublesome opto-coupler feedback. To boot itself up (after all, there is no initial +12 V to allow itself to start), the driver transformer is modified (very cleverly) to form part of a blocking oscillator. Thus the unit initially self oscillates in a crude fashion until there is enough voltage on the +12 V output to allow the PWM to start, which then swamps out the self oscillation and normal operation commences.

Since the controller resides on the output side of the transformer, the drive to the 2 half-bridge FETs is by a driver transformer (direct connection cannot be made because the FETs are on the primary side).

Frequency of operation is 50 KHz, which is low by today's standards, but this means lower cost transformer winding (Litz wire is not needed, for example).

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## 6.17) PC power supply information (pinouts, testing and non-standard uses)

When testing or operating a common PC (computer) power supply without being connected to its mainboard and peripherals, a substitute load must be provided. This would be the case if you wanted to determine whether a supply was good or wanted to use the supply for other purposes.

To test the supply, you want to:

- \* Remove all of the (expensive) stuff - mainboard, drives, etc. Unplug all of the power supply connectors.
- \* Provide a dummy load to +5 and +12 outputs.
- \* Typical (but not always) color codes for PC power supplies:  
 Red: +5, Yellow: +12, Black: Gnd (Probably case as well).  
 White: -5, Blue: -12, Orange: Power\_good (output).  
 (Some newer supplies may have a +3.3 output as well which may be green).
- \* PC power supplies (as well as most other switchers) need a minimum load on +5 and possibly on +12 as well. An amp (e.g., 5 ohms on +5) should be enough.

I use an old dual beam auto headlight. It adds a touch of class as well to an otherwise totally boring setup. :-) You can also use auto tail light bulbs or suitable power resistors or old disk drives you don't really care about (you know, those boat anchors).

- \* There are no sense lines. There is a 'Power\_Good' line which is an output from the power supply to the mainboard and can be ignored unless you want to connect it to an indicator to let you know all the outputs are within specs (it may need a pullup and I don't know its drive capability).
- \* Pinout for the standard PC and clone connector (some companies like Compaq do NOT use this type of connector, however.). Black (Gnd) wires together for the P8 and P9 connectors when installed to mainboard.

J8: Pin 1 = Power_Good	J9: Pin 1 = Gnd
Pin 2 = +5	Pin 2 = Gnd
Pin 3 = +12	Pin 3 = -5
Pin 4 = -12	Pin 4 = +5
Pin 5 = Gnd	Pin 5 = +5
Pin 6 = Gnd	Pin 6 = +5

Note: for an XT only, J8-Pin 1 is Gnd, J8-Pin 2 is no connect.

- \* The peripheral connectors are: Pin 1: +12, Pin 2 and 3: Gnd, Pin 4 = +5.

## 6.18) War stories - the Boschert 2-stage SMPSU

(From: Tony Duell (ard@p850ug1.demon.co.ku)).

In case you have been lucky enough not to have come across the beast, the basic idea is:

1. Rectify/smooth mains, giving 340V DC.
2. Put that into a non-isolated step-down switching converter using a fat power transistor, a freewheel diode and an inductor. The control IC for this is a 723 (!) with feedback applied via an optocoupler from the secondary side. Oh, and there's a current-limit shutdown from a 0R15 resistor in series with the 'load' (section 3, etc). The output of this stage is about 150V
3. The output of that feeds a pair of transistors that run as a free-running

push/pull oscillator. That drives the primary of the main chopper transformer (which provides isolation from the mains).

4. The secondaries of that transformer are rectified to provide output voltages. There's a feedback to (2) as described, and also a crowbar.

Now for the failure mode (seen it happen):

1. The first chopper goes short-circuit because it feels like it. The 150V line jumps to 340V (remember, no isolation, and the inductor/transistor are in series from the 340V line to the 150V line).
2. The crowbar fires, shorting the output. The primary-side current goes up as well.
3. The overcurrent trip operates, and the 723 tries to shut down. It removes the drive from the `_first_` chopper. But that's shorted, so removing the drive doesn't do a darn thing.
4. The 2 transistors in the push/pull circuit short as well.
5. Rectified mains is now connected across : 3 shorted transistors, a few small windings (oscillator feedback transformer, inductor, etc), and the 0R15 resistor. The latter explodes.
6. 340V is now applied across the connections of the ex-0R15 resistor. A few small transistors and the 723 expire, along with some PCB tracks.
7. The fuse (10A, FF blow) fails.

Repairing that was an entertainment. I still have my photocopy of the schematic with all the dud components circled!

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## Chapter 7) Repair Information and Parts Sources

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### 7.1) Advanced troubleshooting

If the solutions to your problems have not been covered in this document, you still have some options other than replacement.

(Also see the related document: "Sources of Repair Information and General Comments" as well as "Repair Briefs: an Introduction".)

Manufacturer's service literature: Service manuals may be available for for your equipment. Once you have exhausted other obvious possibilities, the cost may be well worth it. Depending on the type of equipment, these can range in price from \$5-100 or more. Sometimes, these may even be free (yes, even in this day and age where you have to pay for free air at your local gas station!) Some are more useful than others. However, not all

include the schematics so if you are hoping to repair an electronic problem try to check before buying.

Inside cover of the equipment: TVs often have some kind of circuit diagram pasted inside the back cover. In the old days, this was a complete schematic. Now, if one exists at all for a monitor, it just shows part numbers and location for key components - still very useful.

Sams Photofacts: These have been published for over 45 years mostly for TVs and radios. There are some for VCRs and a few for some early PC monitors and other pre-Jurassic computers. However, for the power supplies in TVs, there will nearly always be a Sams with complete schematics.

Whatever the ultimate outcome, you will have learned a great deal. Have fun - don't think of this as a chore. Electronic troubleshooting represents a detective's challenge of the type that Sherlock Holmes could not have resisted. You at least have the advantage that the electronics do not lie or attempt to deceive you (though you may beg to differ at times). So, what are you waiting for?

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## 7.2) SMPS controller datasheets on-line

Many companies now have very extensive information available via the World Wide Web. Here are a few sites:

- \* Lambda Semiconductors: <http://www.lambda.com/to/main.html>
- \* Maxim Integrated Products: <http://www.maxim-ic.com>
- \* SGS-Thomson: <http://www.st.com>
- \* Unitrode Corporation: <http://www.uicc.com>

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## 7.3) References on SMPS technology and troubleshooting

Here are some suggested books with information relating to SMPS and DC-DC convertor design, testing, troubleshooting, repair, etc.:

1. Power Supplies, Switching Regulators, Inverters & Converters, 2nd Edition.  
Irving Gottlieb  
TAB Books, 1994  
ISBN 0-8306-4404-0
2. Modern DC-to-DC Switchmode Power Converter Circuit  
Rudolf P. Severns and Gordon E. Bloom  
Van Nostrand Reinhold  
ISBN 0-442-21396-4
3. Principles of Solid State Power Conversion  
Ralph E. Tarter  
Howard W. Sams & Co., Inc.  
ISBN 0-672-22018-0

4. Advances in Switched-Mode Power Conversion  
R.D. Middlebrook & Slobodan Cuk  
Contact: TeslaCo, Pasadena, CA 91107 (last known address)
5. Simplified Design of Switching Power Supplies  
John D. Lenk  
ISBN 0-7506-9821-7.
6. Power Electronics, 2nd ed.  
B.W. Williams  
McGraw-Hill, 1992  
ISBN 0-07-070439-2
7. Switching Power Supply Design  
Abraham Pressman, Second Edition  
McGraw-Hill, 1998  
ISBN 0-07-052236-7.  
ISBN 0-07-050806-2 (First Edition, 1991).
8. Switch Mode Power Conversion  
K. Kit Sum
9. Switchmode Power Supply Handbook  
Keith Billings  
McGraw-Hill, 1989  
ISBN 0-07-005330-8
10. Transformer and Inductor Design Handbook  
Colonel Wm. T. McLyman (yes, his 1st name is "Colonel" - not military)  
Marcel Dekker, Inc.  
ISBN 0-8247-6801-9
11. Magnetic Core Selection for Transformers & Inductors  
Colonel Wm. T. McLyman  
Marcel Dekker, Inc.  
ISBN 0-8247-1873-9
12. Magnetic Components, Design and Applications  
Steve Smith  
ISBN 0-442-20397-7.
13. Soft Ferrites, 2nd ed.  
E.C. Snelling  
Butterworth, 1988  
ISBN 0-408-02760-6

In addition, many semiconductor manufacturers publish extensive information on switchmode technology. Mostly, this is in connection with their product lines but will also contain a lot of general information. Much of this is available on Internet via the World Wide Web. Companies include: Maxim, Linear Technology, and Unitrode.

(From: OneStone (OneStone@bigpond.com)).

"Try Linear technologies website at:

\* <http://www/linear-tech.com/>

Look for their App notes:

AN25 Switching regulators for Poets.  
AN19 LT1070 Design manual  
AN29 Some thoughts on DC-DC converters  
AN30 Switching regulator circuit collection.

AN31 Linear Circuits for digital systems.

Then try one of their new data sheets, such as the LT1370, for some modern circuit configurations, such as SEPIC converters. The above APP notes are all contained in their Linear Applications handbook, Volume 1, 1990. If you are a designer they also have a CD-ROM available, which includes some switcher and filter design software. It's a bit limited, but a great starting point if you don't need to stretch the boundaries."

For diagnosing power problems in TVs and Computer or Video monitors, here is one book that includes many illustrations and case histories.

#### 14. Troubleshooting and Repairing Solid State TVs

Homer L. Davidson  
2nd Edition, 1992  
TAB Books, Inc.  
Blue Ridge Summit, PA 17214

(From: Ernst C. Land, Jr. (a6mech@ionet.net)  
and Mark Zenier (mzenier@eskimo.com or mzenier@netcom.com)).

The September 1996 (VOL. 17 NO. 9) issue of Nuts & Volts Magazine has a great article on theory, troubleshooting, and repair of PC power supplies. Their web site is: <http://www.nutsvolts.com>.

When you get there, click on [more], then [back issues]

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## 7.4) Parts information

I have found one of the most useful single sources for general information on semiconductors to be the ECG Semiconductors Master Replacement Guide, about \$6 from your local Philips distributor. STK, NTE, and others have similar manuals. The ECG manual will enable you to look up U.S., foreign, and manufacturer 'house' numbers and identify device type, pinout, and other information. Note that I am not necessarily recommending using ECG (or other generic) replacements if the original replacements are (1) readily available and (2) reasonably priced. However, the cross reference can save countless hours searching through databooks or contacting the manufacturers. Even if you have a wall of databooks, this source is invaluable. A couple of caveats: (1) ECG crosses have been known to be incorrect - the specifications of the ECG replacement part were inferior to the original. (2) Don't assume that the specifications provided for the ECG part are identical to the original - they may be better in some ways. Thus, using the ECG to determine the specifications of the parts in your junk bin can be risky.

Other cross reference guides are available from the parts source listed below.

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## 7.5) Information sources on the Internet

Many manufacturers are now providing extensive information via the World Wide Web. The answer to your question may be a mouse click

away. Perform a net search or just try to guess the manufacturer's home page address. The most obvious is often correct. It will usually be of the form "http://www.xxx.com" where xxx is the manufacturers' name, abbreviation, or acronym. For example, Hewlett Packard is hp, Sun Microsystems is sun, Western Digital Corp. is wdc. NEC is, you guessed it, nec. It is amazing what is appearing freely accessible via the WWW. For example, monitor manufacturers often have complete information including detailed specifications for all current and older products. Electronic parts manufacturers often have detailed datasheets and application notes for their product offerings.

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## 7.6) Interchangeability of components

The question often arises: If I cannot obtain an exact replacement or if I have a monitor, TV, or other equipment carcass gathering dust, can I substitute a part that is not a precise match? Sometimes, this is simply desired to confirm a diagnosis and avoid the risk of ordering an expensive replacement and/or having to wait until it arrives.

For safety related items, the answer is generally NO - an exact replacement part is needed to maintain the specifications within acceptable limits with respect to line isolation, X-ray protection and to minimize fire hazards. Typical parts of this type include flameproof resistors, some types of capacitors, and specific parts dealing with CRT high voltage regulation. However, during testing, it is usually acceptable to substitute electrically equivalent parts on a temporary basis. For example, an ordinary 1 ohm resistor can be substituted for an open 1 ohm flameproof resistor to determine if there are other problems in the the SMPS chopper before placing an order as long as you don't get lazy and neglect to install the proper type before considering the repair complete.

For other components, whether a not quite identical substitute will work reliably or at all depends on many factors. Some deflection circuits are so carefully matched to a specific horizontal output transistor that no substitute will be reliable.

Here are some guidelines:

1. Fuses - same type (usually normal or fast blow), exact same current rating and at least equal voltage rating. I have often soldered a normal 3AG size fuse onto a smaller blown 20 mm long fuse as a substitute.
2. Resistors, capacitors, inductors, diodes, switches, potentiometers, LEDs, and other common parts - except for those specifically marked as safety-critical - substitution as long as the replacement part fits and specifications should be fine. It is best to use the same type - metal film resistor, for example. But for testing, even this is not a hard and fast rule and a carbon resistor should work just fine.
3. Rectifiers - many of these are high efficiency and/or fast recovery types. Replacements should have equal or better PRV, I<sub>max</sub>, and Tr specifications. However, the AC input bridge can usually be replaced with anything with at least equal voltage and current ratings.
4. Main filter capacitor(s) - use replacements with at least equal working voltage and similar uF rating. For testing, even something with half the capacity will be fine. For the final replacement bigger is not always better and even using a smaller one (uF) will be fine as long

as you are not running the supply near full load capacity. Use of a higher temperature rated capacitor than the original may be desirable as its life may have been shorted by a hot environment. This practice will never hurt.

5. Transistors and thyristors (except SMPS choppers or HOTs) - substitutes will generally work as long as their specifications meet or exceed those of the original. For testing, it is usually ok to use types that do not quite meet all of these as long as the breakdown voltage and maximum current specifications are not exceeded. However, performance (like regulation specifications) may not be quite as good. For power types, make sure to use a heatsink.
6. SMPS chopper (or horizontal output) transistors - exact replacement is generally best but except for very high performance monitors, generic HOTs that have specifications that are at least as good will work in many cases. Make sure the replacement transistor has an internal damper diode if the original had one. For testing with a series light bulb, even a transistor that doesn't quite meet specifications should work well enough (and not blow up) to enable you to determine what else may be faulty. The most critical parameters are  $V_{ce0}/V_{cbo}$ ,  $I_c$ , and  $H_{fe}$  which should all be at least equal to the original transistor. I have often used by favorite BU208D as a temporary substitute for other HOTs and SMPS (chopper) transistors. Make sure you use a heatsink (with insulating washer if applicable) and thermal grease in any case - even if you have to hang the assembly with a cable-tie to make it fit.

Also see the section: "[Replacement power transistors while testing](#)".

The following are usually custom parts and substitution of something from your junk box is unlikely to be successful even for testing: flyback (LOPT) and SMPS transformers, interstage coils or transformers, microcontrollers, and other custom programmed chips.

Substituting entire circuit boards and other modules from identical models is, of course, possible and an excellent troubleshooting aid even if it is only used to confirm or identify a bad part. However, if the original failure was catastrophic, you do run some risk of damaging components on the substitute circuit board as well.

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## 7.7) Replacement power transistors while testing

During testing of horizontal deflection circuits or switchmode power supplies, particularly where the original failure resulted in the death of the HOT or chopper, overstress on replacement transistors is always a possibility if all defective components have not been identified.

Therefore, using a part with better specifications may save you in the long run by reducing the number of expensive blown parts. Once all other problems have been located and repaired, the proper part can be installed.

However, this is not always going to work. In a TV and especially a high performance monitor, the HOT may be closely matched to the drive and output components of the deflection circuits. Putting in one with higher  $V_{ce}$ ,  $I_c$ , or  $P$  specifications may result in overheating and failure due to lower  $H_{fe}$ .

Where possible, a series load like a light bulb can be used to limit the maximum current to the device and will allow you to power the equipment while checking

for other faults. Some designs, unfortunately, will not start up under these conditions. In such cases, substituting a 'better' device may be the best choice for testing.

(From: Glenn Allen (glenn@manawatu.gen.nz)).

I been repairing SMPS of all types but when I started on those using MOSFETs I was blowing a few of them when replaced because something else was faulty.

Ever since I have been using a BUZ355 on a heat sink I haven't blown it. It is rated at 800 V, 6 A, and 220 W. it is a TO218 case bigger than a T0220. It seems the higher ratings allows you to do repair where as a something like a 2SK1117 or MTP6N60 will just blow.

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## 7.8) Testing of replacement chopper transistors

The following is useful both to confirm that a substitute replacement chopper transistor is suitable and that no other circuit problems are still present. However, this will not catch single shot events that may blow the transistor instantly without any increase in temperature.

It was written with TV and monitor horizontal output transistors in mind but applies to the switchmode/chopper transistors found in line powered SMPSs as well.

(From: Raymond Carlsen (rccc@u.washington.edu)).

After installing a replacement HOT in a TV set or monitor, I like to check the temperature for awhile to make sure the substitute is a good match and that there are no other problems such as a weak H drive signal. The input current is just not a good enough indicator. I have been using a WCF (well calibrated finger) for years. For me, the rule of thumb, quite literally, is: if you can not hold your finger on it, it's running too hot, and will probably fail prematurely. Touching the case of the transistor or heat sink is tricky....

Metal case transistors will be connected to the collector and have a healthy pulse (>1,200 V peak!) and even with plastic case tab transistors, the tab will be at this potential. It is best to do this only after the power is off and the B+ has discharged. In addition, the HOT may be hot enough to burn you.

A better method is the use of an indoor/outdoor thermometer. I bought one recently from Radio Shack for about \$15 (63-1009). It has a plastic 'probe' on the end of a 10' cable as the outdoor sensor. With a large alligator clip, I just clamp the sensor to the heat sink near the transistor and set up the digital display near the TV set to monitor the temperature. The last TV I used it on was a 27" Sanyo that had a shorted H. output and an open B+ resistor. Replacement parts brought the set back to life and the flyback pulse looked OK, but the transistor was getting hot within 5 minutes... up to 130 degrees before I shut it down and started looking for the cause. I found a 1 uF 160 volt cap in the driver circuit that was open. After replacing the cap, I fired up the set again and monitored the heat sink as before. This time, the temperature slowly rose to about 115 degrees and stayed there. I ran the set all day and noticed little variation in the measurement. Test equipment doesn't have to cost a fortune.

## 7.9) Repair parts sources

For general electronic components like resistors and capacitors, most electronics distributors will have a sufficient variety at reasonable cost. Even Radio Shack can be considered in a pinch.

However, for modern electronics equipment repairs, places like Digikey, Allied, and Newark do not have the a variety of Japanese semiconductors like ICs and transistors or any components like flyback transformers or degauss Posistors.

The following are good sources for consumer electronics replacement parts, especially for VCRs, TVs, and other audio and video equipment:

- \* MCM Electronics (VCR parts, Japanese semiconductors, tools, test equipment, audio, consumer electronics including microwave oven parts and electric range elements, etc.)  
U.S. Voice: 1-800-543-4330.  
U.S. Fax: 1-513-434-6959.  
Web: <http://www.mcmelectronics.com/>
  
- \* Dalbani (Excellent Japanese semiconductor source, VCR parts, other consumer electronics, xenon flash tubes, car stereo, CATV).  
U.S. Voice: 1-800-325-2264.  
U.S. Fax: 1-305-594-6588.  
Int. Voice: 1-305-716-0947.  
Int. Fax: 1-305-716-9719.  
Web: <http://www.dalbani.com/>
  
- \* Premium Parts (Very complete VCR parts, some tools, adapter cables, other replacement parts.)  
U.S. Voice: 1-800-558-9572.  
U.S. Fax: 1-800-887-2727.  
Web: <http://www.premiumparts.com/>
  
- \* Computer Component Source (Mostly computer monitor replacement parts, also, some electronic components including semiconductors.)  
U.S. Voice: 1-800-356-1227.  
U.S. Fax: 1-800-926-2062.  
Int. Voice: 1-516-496-8780.  
Int. Fax: 1-516-496-8784.
  
- \* Studio Sound Service (Rebuild kits for many popular VCR switchmode power supplies, VCR parts, some components. They will be happy to identify specific VCR part numbers as well based on model and description as well.)  
U.S. Fax: 1-812-949-7743  
Email: [studio.sound@datcom.iglou.com](mailto:studio.sound@datcom.iglou.com)

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