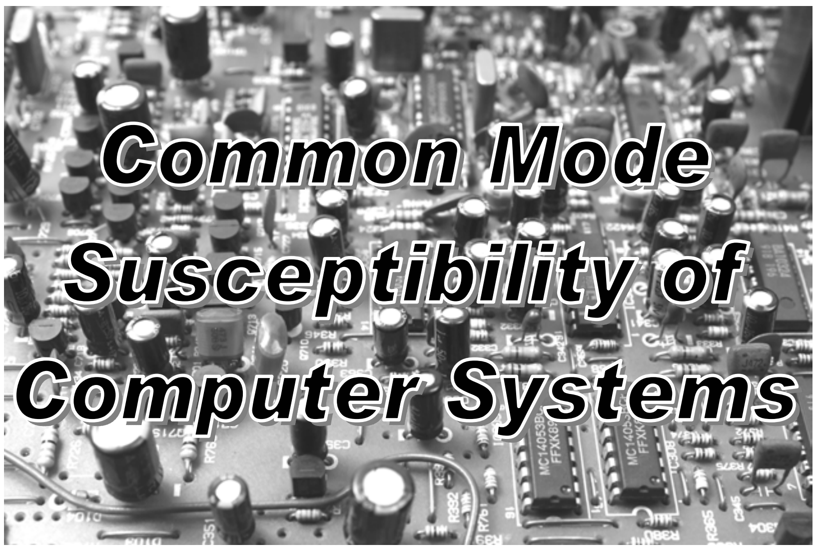
White Paper # 213



POWERVAR
Solutions for Power Quality®

Introduction

This POWERVAR Whitepaper has been researched and prepared to address recurring questions that are raised as a result of a paper written by American Power Conversion (originally in the late 1980s) and revised and re-released in 2003. The APC publication is titled *"Common Mode Susceptibility of Computers."* In the publication, APC refutes a claim from a manufacturer of isolation transformer based power conditioners (not POWERVAR) that computer equipment may be adversely affected by common mode noise voltage.

The APC whitepaper is over two decades old, but nevertheless continues to resurface as "evidence" that power conditioners are unnecessary since computer equipment is immune to power line noise disturbances.

While it's POWERVAR's position that real world experience speaks for itself, we do understand that, from time to time, our customers would like to have impartial information on which to base their power conditioning decisions, and it's for that reason, that we've prepared this whitepaper of our own.

The basic argument

In their publication, APC simplifies the argument into three basic premises that lead to a conclusion. They are:

Premise 1 – Computer circuits can be damaged or malfunction if subjected to small transients

Premise 2 – The power line has small transients

Premise 3 – The computer power supply passes the power line transients to the computer circuits

Conclusion – Small power line transients therefore damage computer circuits

It is the position of the APC whitepaper that both Premise 1 and Premise 2 are correct and that the authenticity of the conclusion rests solely on the validity of Premise 3. Their analysis purports to show that Premise 3 is false and that, therefore, the Conclusion is false, too.

There are several areas where the analysis is incomplete, inaccurate, or just plain misleading.

The Switched Mode Power Supply

The analysis provides a block diagram of a computer power supply and uses it to illustrate how numerous noise filters in the supply prevent noise from reaching the system electronics.

The power supply shown is a basic illustration of the switched mode supply (SMPS). Switched mode power supplies are the most commonly used power conversion devices for today's computer systems. They offer numerous advantages including size, efficiency, high power in a small package, and low cost.

The illustration provided in the APC whitepaper, however, is a generalization and not representative for the purposes of sustaining a good argument. Among the SMPS designs used most widely today, there are five non-isolating and nine isolating SMPS topologies used most frequently. Which design is chosen for a particular system is largely a function of the application and the power needs of the system. And as might be expected, each design has its own unique susceptibilities and immunities. Using a highly simplified block diagram to is poor evidence in support of the argument.

Isolating topologies utilize a high frequency power transformer. This power transformer is used for two primary purposes: 1) to change the amplitude of the high frequency pulses from the input switching transistors, which are then filtered into low-ripple DC and 2) to effectively provide DC isolation, since the transformer is not capable of passing DC current. Shown in Fig. 1 is a more specific schematic of a commonly employed isolating topology.

As illustrated here, the output of the SMPS transformer may or may not be bonded to AC ground. Contrary to other assertions that have been made, the EMI filters employed on the input of any of these designs are not primarily intended to prevent power line noise from reaching the SMPS. All noise filters are designed to address specific frequencies or bands of frequencies – in this case, the noise frequencies generated by the action of the switching transistors in the SMPS itself. The primary function of the noise

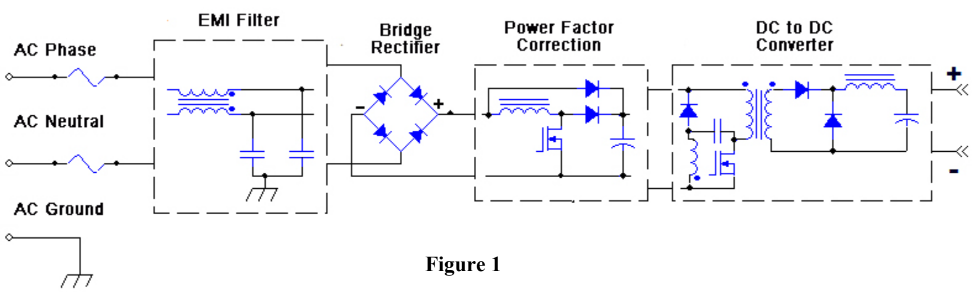


Figure 1

filter on the input to the power supply is to prevent high frequency noise from the SMPS from contaminating the AC mains. The filters provide a low impedance return path for the noise back to the source of the noise, which is the SMPS. To imply that these front end EMI filters also provide primary noise immunity for the SMPS is a red herring of the first order since the filter is not likely to be effective against both the noise frequencies generated by the SMPS itself as well as the broad range of noise frequencies impinging on it from the power line.

The validity of Premise 3

The basic argument about the noise immunity of computer systems depends solely on establishing the validity of the third premise. Do computer power supplies actually allow power line noise transients to pass through to system electronics?

To claim that they do 100% of the time would be as disingenuous as APC's claim that power supplies never pass power line transients at all. Where can the facts pertaining to this matter be found, and what may truthfully be said about computer systems and their susceptibility or immunity to power line noise disturbances? How may we establish the validity of the third premise if, in fact, it is true even occasionally?

The best source of accurate information is to reference the work done by experts in the field of power supply design, operation, and EMC issues - experts who neither design nor profit from the sale of uninterruptible power supplies, power conditioners, surge protectors, or power protection equipment.

The Hidden Schematic

In an article that appears in Compliance Engineering[1], professional EMC engineers William D. Kimmel and Daryl D. Gerke of Kimmel Gerke Associates Ltd. discuss what they call "the hidden schematic" that lurks inside each power supply. According to these engineers, power supplies play three roles – they are sources of interference, recipients of interference, and conduits of interference.

The “hidden schematic” to which Kimmel and Gerke allude is not shown on any actual drawing but is invisible and exists as a result of a variety of parasitic elements including grounding impedance, stray capacitance, individual component inductance, inductance of wires and traces, and inductance between components themselves. They document instances in which noise disturbances from either the power line or the load itself interfere with power supply regulation and feedback paths.

Another article in a September 1996 issue of EC&M magazine[2] notes that “a power supply’s reservoir capacitors don’t absorb transient energy because their impedance (negligible at 60 Hz) introduces significant isolating impedance at the megahertz frequencies of fast-rise transients. As a result, transient energy follows the line of least resistance, which is directly to the power supply’s output terminals.” Even the high frequency power transformer found in SMPS designs possesses stray capacitance, which increases the probability that high frequency noise will see the transformer as nothing more than a coupling capacitor allowing it to pass unobstructed to the power supply output.

Power line noise is unlikely to damage power supply components, but as the article explains, few power supply designs benefit from careful component shielding and placement. Quoting once again, “Line noise can be coupled by stray capacitance to the DC output, where it disrupts communications and computer circuits. Because the noise may be intermittent and usually beyond the frequency range of many measuring instruments, diagnosing the source of equipment malfunction is difficult and time consuming.”

Additional corroboration

There are other authoritative sources as well. In their paper titled **Study of conducted susceptibility of power converters,** M.L. Sudheer and M.K. Gunasekaran[3] summarize as follows. “The most widely used switched mode power supplies (SMPS) are prone to conducted noise, despite line filters and other protection circuitry at their front-end. They are exposed to low voltage power line transients, which are one of the most dangerous types of conducted noise. These transients can be either differential mode (DM) type or common mode (CM) type. The CM line transients can cause malfunctioning of SMPS during its normal working and hence cause disturbance in its output voltage.”

In another study by Victor Anunciada and Hugo Ribeiro titled **Impact and characterization of voltage transients as a problem to sensitive loads,**[4] the authors have conducted a scholarly study of switched mode power supplies and their response to a range of power line disturbances. Their data supports that switched mode power supplies all pass power line transients to their connected computer circuitry. The results of their study are very nearly definitive. In Figure 2 to the left, they have documented four specific power line anomalies and the unique effect of each on the output of a switched mode power supply.

Event	Characteristic	Impact in the SMPS
Notch	phase to neutral > 120% V_1 10us < t < 10ms	damage the rectifier diodes, output voltage transients, blows of the input fuse
Spike	neutral to ground > 50V 10us < t < 10ms	output voltage transients
v_{nt} Transient	> 120V/us - neutral to ground	output voltage transients
v_{fn} Transient	> 1V/us - phase to neutral	output voltage transients, transformer saturation

Figure 2

During their investigations, the authors found that prevailing susceptibility analyses of switched mode power supplies to voltage transients and noise have been based on concepts developed for older linear power supplies and that these concepts are not valid to understanding the interaction of switched mode power supplies to power line disturbances .The author’s conclusions are quite unequivocal. “Voltage transients in phase to ground and neutral to ground can provoke effects in the output voltage of the switched mode power supply due to the leakage capacitances present in the isolation transformer.

The Validity of Premise 3

By now it should be obvious that impartial authorities agree with the premise that switched mode power supplies can pass power line transients to their output. As a result, Premise 3 is proven to be valid. Switch mode power supplies do pass power line transients to connected computer circuitry. If all three premises are valid, then the conclusion that small power line transients damage computer circuits must also be valid. It would be more accurate, however, to state the conclusion thusly: *Power line transients may damage computer circuits in addition to destroying them or interfering with their operation.* It's important to understand that computers are affected by power line disturbances in three ways – called the **3 Ds**. Depending on the amplitude and frequency of the disturbance, a power line disturbance may **destroy** computer circuits, **degrade** computer circuits, or **disrupt** computer performance. Of the three, disruption is the most frequently observed symptom of power quality issues.

Additional Considerations

There is a consensus that the susceptibility or immunity of any given SMPS design is greatly affected by several factors. These include shielding, component layout, physical size of the packaging, and the operating frequency of the SMPS switching transistors, which itself affects the values of other components in the design. All these factors contribute to the existence of stray or parasitic noise pathways through or around the switch mode power supply. It's clear from most scholarly research that if great care is taken in designing and laying out the power supply, it's possible to create a reasonable amount of immunity to power line noise disturbances. It's here, however, that we encounter a double conundrum.

Power supply designers are constantly moving toward ever faster edge rates because doing so improves efficiency and reduces both size and cost. Kimmel and Gerke have observed that even small advances in faster switching speeds can result in great sacrifices in both power supply emissions and in their susceptibility to power line noise. Secondly, power supply designers and manufacturers are always under pressure to provide more power in smaller packages at an ever lower cost. The pursuit of higher performance, smaller packaging, and lower cost is not conducive to achieving higher levels of immunity to power line disturbances.

References

[1] The Hidden Schematic: EMC Threats in Medical Power Supplies, William D. Kimmel and Daryl D. Gerke, Compliance Engineering, November/December 2001

[2] Why Poor Power Quality Causes Electronics Failures, EC&M Magazine, September 1996

[3] Study of Conducted Susceptibility of Power Converters, Sudheer, M.L.; Gunasekaran, M.K., IEEE Explore, Electromagnetic Interference and Compatibility apos;99. Proceedings of the International Conference on Volume , Issue , 6-8 Dec. 1999 Page(s): 231 – 236

[4] Impact and Characterization of Voltage Transients as a Problem to Sensitive Loads, Victor Anunciada and Ribeiro, International Conference on Power Systems Transients, 2007 Conference Paper