Common Mode Susceptibility of Computers

White Paper 9

Revision 2

by Neil Rasmussen

> Executive summary

This white paper examines and challenges the claims made in literature regarding the alleged high susceptibility of computers to common mode noise.

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Introduction

It has been claimed that common mode noise of levels of less than one volt on the AC power supplied to computer equipment can result in damage or malfunction. These claims are used to promote the sale of isolation transformers or "power conditioners". Closer analysis indicates that these claims are unfounded and not based on scientific fact.

The claims regarding the adverse affects of common mode noise on computer equipment are best enumerated by direct quotation of literature from a power conditioner manufacturer. The argument goes as follows:

"Normal mode noise is simply a voltage differential that appears briefly between the power line and its accompanying neutral line. As the name implies, these two lines represent the normal path of power through electric circuits, which gives any normal mode transient a direct route into sensitive components and therefore the opportunity to destroy or degrade those components. At today's levels of semiconductor density and sensitivity, normal mode transient voltages can start causing degradation at around 10 volts, and can cause destruction at 40 volts. "Common mode noise is a brief voltage differential that appears between the ground and either of the two normal mode lines. Common mode transients are most often the cause of disruption, because digital logic is either directly or capacitively tied to the safety ground as a zero-voltage data reference point for semiconductors. As a result, transient common mode voltage differences as small as 0.5V can cause that reference point to shift, momentarily "confusing" the semiconductors."

"Operating at high frequencies means that the switched mode power supply (SMPS) by design must be transparent to high frequencies, which in turn means that transient voltages above the normal 60Hz are allowed to pass through the SMPS and into the microelectronics."[1]

The above argument can be simplified into four key points to make it more understandable:

1. Computer circuits can be damaged or malfunction if subjected to small transients
2. The power line has small transients
3. The computer power supply passes the power line transients to the computer circuits
4. Small power line transients therefore damage computer circuits

There is no question that statements "1" and "2" are correct. Therefore, the conclusion "4" depends on the validity of statement "3". Analysis and experiment show that statement "3" is false and consequently the claims in the above quotation are false.

Conduction of power line noise into computer circuits

To understand how noise or transients might be passed to the computer circuits, we must inspect the diagram of a typical computer power supply in the accompanying **Figure 1**. The first thing we notice is that there are three wires entering this circuit and only two wires connecting the computer circuits. Common mode noise or transients by definition require three wires. Therefore we can immediately see that only normal mode noise can exist at the output of the power supply. To fully characterize the power supply with regard to its potential for passing through transients, we must only examine the amount of normal mode output transients which result from either common or normal mode input transients. Note that common mode input transients are only important to the extent that they can create normal mode output transients.

[1] Kevin Goulet, ONEAC Corp, *Automation Equipment of the '90s - Power Conditioning Equipment of the '60's*, PCIM '90 Conference Proceedings

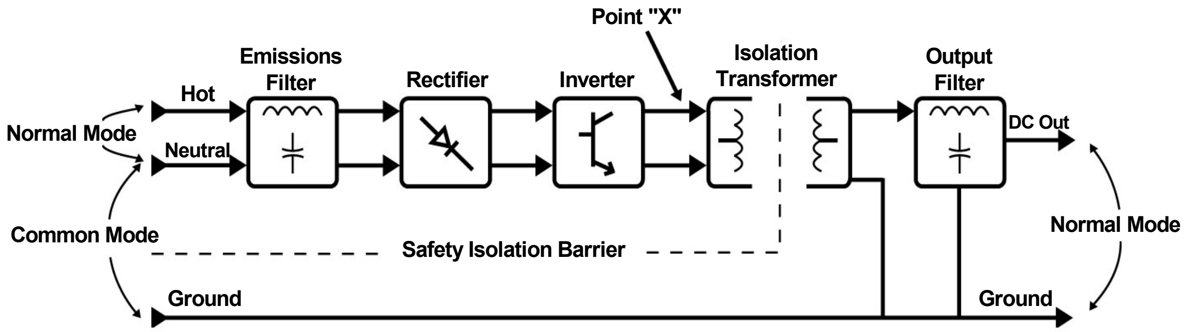

Figure 1

Wiring diagram of a computer power supply

One interesting feature to note in the diagram is that there is actually no physical wire connection between the noisy power lines and the power supply output. In fact, international safety agency requirements stipulate that there must be a minimum of 1/2 cm of physical spacing between input and output. Power is transferred using the magnetic field coupling of an isolation transformer.

An examination of a typical power supply circuit shows that it contains numerous filters which act to reduce the normal mode output noise on the power supply. Analysis of these circuits shows that they provide extremely high levels of reduction to unwanted common or normal mode input transients. However, there is a more convincing, general argument which clearly shows that the amount of noise passed through from the power supply must be inconsequential.

The photograph of **Figure 2** is an actual recording of a waveform which exists inside every typical switching power supply. This waveform was recorded at the point “X" shown in **Figure 1** and is referenced to the common line at the output of the power supply. This is the necessary high frequency switching waveform which is used to transfer power, but it is unwanted high frequency "noise" as far as the computer circuits are concerned. The size of this unwanted transient is very high (500 V) yet a power supply typically specifies that it will let only less than .05 volts of this noise through to the output.

Therefore, if any common or normal mode input transient were to reach point "X" in the circuit, it would be reduced in amplitude by a factor of 10,000 by the time it reached the output of the power supply.

Definitions

Common Mode
For AC power systems, the term "common mode" may refer to either noise or surge voltage disturbances. Common mode disturbances are those that occur between the power neutral (white or blue wire) and the grounding conductor (green wire) Ideally, no common mode disturbances should exist since the neutral and grounding wires are connected at the AC service distribution or circuit breaker panel in most countries. However, unwanted common mode disturbances exist as a result of noise injection into the neutral or grounding wires, wiring faults, or overloaded power circuits. Modern computers are quite immune from common mode noise. Common mode noise is frequently mistakenly confused with **inter-system ground noise**, a distinct problem which frequently causes computer damage and data errors.

Normal Mode
For AC power systems, the term "normal mode" may refer to either noise or surge voltage disturbances. The terms "normal mode" and "differential mode" are interchangeable. Normal mode disturbances are those that occur between the power hot (black or brown wire) and the neutral conductor (white or blue wire). Most normal mode disturbances result from

load switching within a building, with motor type loads being a major contributor. Surge voltages that come from outside of the building, such as surges caused by lightning, enter the building on the hot (black or brown) wire and are therefore primarily normal mode in nature since the neutral (white or blue) wire is nominally at ground voltage. Surge suppressors sometimes divert normal mode noise and surges into the neutral wire, resulting in voltages on the neutral wire called "common mode" noise or surge voltages.

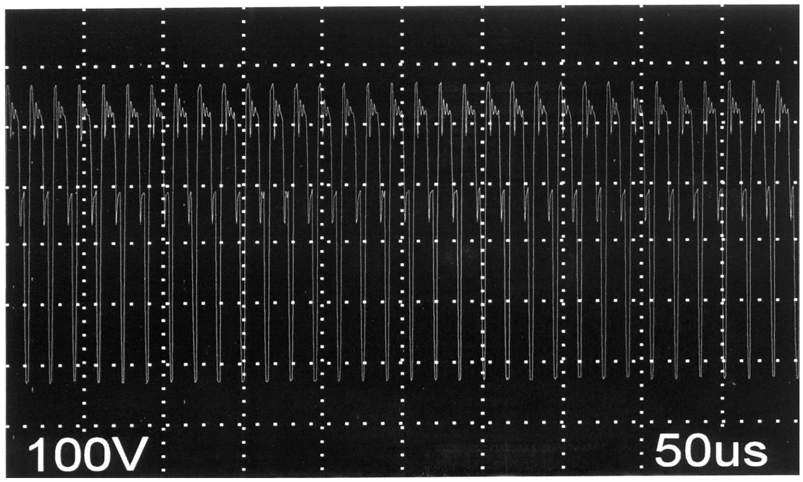

Figure 2

Waveform recorded at point "X"

If the power supply were transparent to high frequency noise, as has been suggested, then the noise signal recorded at point "X" would naturally pass back out of the power supply into the power line. Since noise of this high magnitude would interfere with the operation of communication equipment such as TV and radio, government regulations prohibit such emissions from computer equipment. To comply with regulations, computer manufacturers incorporate common and differential mode filters into all power supplies. Regulatory compliance requires that the noise injected by the power supply be less than approximately .0005 volts. The signal recorded at point "X" must be attenuated by a factor of nearly 1,000,000 to comply with this requirement. The filters, which accomplish this reduction, are approximately symmetrical meaning that they filter about as well from input to output as from output to input. Therefore, power line noise must be attenuated by approximately a factor of 1,000,000 from the power supply input to point "X".

The total attenuation of the power supply from input to output must be the combination of the attenuation from input to point "X" combined with the reduction from point "X" to the output. It has been demonstrated that these two attenuations must be on the order of 10,000 and 1,000,000, respectively. Therefore, the total noise and transient attenuation from input to output must be on the order of 10,000,000,000. This means that a 10 volt power supply input transient would result in an output transient of .0000000001 volts, which is 100 million times smaller than the transients that computer circuits generate themselves and 2000 million times less than the amount which could cause any damage. This analysis is only meant to be approximate, and the attenuation factors are frequency dependent, but even if it is wrong by a factor of a million, the fact is that small levels of power line noise or transients are proved to have no possibility of damaging computer circuits.

Effect of the building wiring system on common mode noise

Another interesting fact which is overlooked with regard to common mode noise susceptibility of computers is that common mode noise is affected by the building wiring system. In an ideal 3-wire grounded office wiring system, there is no common mode noise because the neutral wire is supposed to be connected to the grounding wire. In a practical environment, noise will exist between the neutral wire and the grounding wire. This is the common mode noise which is alleged to cause computer malfunction even at low levels. There are, however, a significant number of possible wiring arrangements in which none of the power wires are grounded.

In North America, many computers such as the IBM AS/400 are wired for operation from 208 V single-phase wiring. In Norway, the neutral wire is not grounded in office wiring systems. In both of these cases, there is a large amount of common mode noise due to the lack of a grounded neutral wire. If computers were susceptible to small amounts of common mode noise, then 208 V computers and systems used in Norway should exhibit reduced reliability when compared with systems which are powered by wiring with a grounded neutral. The fact that this problem is not encountered in practice is another clear indication that low levels of common mode noise do not affect computer circuits.

Conclusion

This analysis is not meant to imply that computers cannot be affected by power line related noise or transients. There is no question that if any of these disturbances are sufficient in magnitude as to exceed the normal input operating voltage of the power supply (a few hundred volts) then the possibility for breakdown of insulating barriers becomes a genuine threat to computer hardware. Quality surge suppressors can be used to control this problem. Another real problem for systems made up of interconnected computer equipment is not common or normal mode noise, but is another type of noise called **inter-system ground noise**.

Inter-system ground noise is the noise that exists between the power grounding wires of different pieces of computer equipment. The causes and effects of this problem are addressed the references listed below. This problem is sometimes explained in terms of "ground loops" or "ground reference level shifting". It is important to understand that this is a different phenomenon than common or normal mode noise and susceptibility cannot be prevented by use of isolation transformers, line conditioners, or filters - even though the literature for these products implies that they do fix this problem.

About the author

Neil Rasmussen is a Senior VP of Innovation for Schneider Electric. He establishes the technology direction for the world's largest R&D budget devoted to power, cooling, and rack infrastructure for critical networks.

Neil holds 19 patents related to high-efficiency and high-density data center power and cooling infrastructure, and has published over 50 white papers related to power and cooling systems, many published in more than 10 languages, most recently with a focus on the improvement of energy efficiency. He is an internationally recognized keynote speaker on the subject of high-efficiency data centers. Neil is currently working to advance the science of high-efficiency, high-density, scalable data center infrastructure solutions and is a principal architect of the APC InfraStruXure system.

Prior to founding APC in 1981, Neil received his bachelors and masters degrees from MIT in electrical engineering, where he did his thesis on the analysis of a 200MW power supply for a tokamak fusion reactor. From 1979 to 1981 he worked at MIT Lincoln Laboratories on flywheel energy storage systems and solar electric power systems.

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