Impedance Tolerant EMI/RFI Filtration

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Abstract

A well-designed EMI/RFI filter can prevent annoying equipment hang-ups, re-boots, unwanted clicks and buzzes in an audio chain, and disruptions in a video system. The purpose of this paper is to focus on AC power filtering and explain what causes powerline noise, how filtering works, and why it needs to be a critical part of any power conditioning solution. Through this discussion, the benefits of the SurgeX Impedance Tolerant filter become apparent.

Power Conditioning Introduction

We all know what power conditioning is, right? Well, ask ten people, and you'll probably get ten different answers, so maybe we could ask the question, what should a power conditioner do? Ideally, it would provide a perfect 120V/240V, 60Hz sine wave, and nothing else – no noise, surges, transients, interference – just the pure 60Hz sine wave.

One way to achieve this would be with the use of a full time Uninterruptable Power Supply (UPS). On-Line or Double Conversion UPS's actually turn AC power from the grid into DC, and then electronically regenerate the AC without the noise, transients, and interference that is introduced during the process of transmission and distribution of AC power. However, when physical space or budget is limited, the solution of choice is usually a "power conditioner".

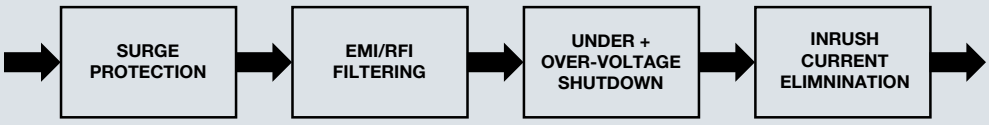
So, what is a power conditioner? Most power conditioners do not regenerate the AC power. The simplest units generally provide surge protection with some limited filtering, and the better models often include under- and over-voltage shutdown. Some also offer inrush current limiting/elimination. We will see further on in this paper that AC power filtering, often known as EMI/RFI filtering, is a very important part of any good quality power conditioner.

Powerline Disturbances

The purpose of a power conditioner, then, is to remove as much of the extraneous noise, transients and surges from the powerline as possible. Surges are extremely short over-voltage events that can be damaging to equipment. Transients are similar to surges, but are less likely to cause permanent damage. What is lumped together under the term "noise" is generally some form of higher-frequency interference that is in the radio band. This can be from a source of random interference, like noise from a dimmer pack or a motor switching off, and is known as Electro-Magnetic Interference (EMI); or can be from a continuous source, like a radio station or a walkie-talkie, and is known as Radio-Frequency Interference (RFI). Thus, the purpose of an EMI/RFI filter is to remove these higher frequency disturbances from the AC service.

There is no single technology that will remove surges, transients and noise from the AC powerline – this takes a tiered approach. Most power conditioners start with surge protection, which can be either shunt-mode (MOV) or Series Mode® (SurgeX). This targets the potentially-damaging lower-frequency events, and is then followed by filtering which targets higher-frequency transients and noise. It is worth mentioning that Series Mode technology is, in fact, a filter: a specially-designed filter which can handle up to and beyond 6000 Volts. As such, this high-voltage filter also provides noise filtering at the lower-end of the spectrum as well as eliminating catastrophic surges.

Example of A Full-Featured Power Conditioner



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EMI and RFI

EMI and RFI can get into A/V equipment in two ways: being conducted along the mains wiring, or radiated through the air. Lower frequency EMI/RFI is mostly conducted along wiring and higher frequency EMI/RFI is mostly radiated through the air. The upper frequency limit for conducted noise is generally considered to be 30MHz. Above that frequency, most of the RF energy is radiated, and powerline filters have limited effectiveness. An AC power EMI/RFI filter can only remove noise that is conducted along the mains wiring, and the best power conditioners cannot stop disturbances which are getting into an A/V system from radiated RF through the air, via signal cables, or because one or more pieces of equipment have a "Pin 1 problem". Furthermore, any power conditioner manufacturer claiming to attenuate noise above 50MHz is being totally unrealistic.

Normal Mode and Common Mode Noise

To complicate matters further, there are two types of EMI/RFI: normal mode and common-mode. It is important to understand the distinction because a separate filter is required to remove each type of noise. 120V AC power is distributed within buildings using three wires: Line, Neutral and Ground. Any type of electrical signal, whether it be the 120V, 60Hz power itself, a disturbance or extraneous noise, must be referenced to something. Think of how a voltage or signal is measured: always with two wires – the red and black leads of a multimeter or an oscilloscope probe and ground clip. A voltage cannot exist without a reference. Imagine a bird sitting on a 10,000 Volt powerline – the bird knows nothing and feels nothing of the voltage that could kill in an instant, because there is no reference. In the case of the multimeter, the black lead provides the reference and, in the case of the oscilloscope, the ground clip provides the reference.

Normal mode noise, therefore, is between the Line and Neutral wires, and common-mode noise is between both the Line + Neutral wires and the Ground wire (the noise is common to both AC lines with respect to Ground). Surges and lower-frequency noise tend to be normal-mode because of the way these disturbances are generally produced. Lightning surges, for example, entering a building on the AC service will encounter the Neutral wire bonded to the ground wire and ground stake at the service entrance. The energy will, therefore, flow along the live wire with respect to the Neutral wire. Transients and noise from an electrical motor being switched on and off, will also be between Line and Neutral, because that is where the current is flowing.

These lower-frequency disturbances tend to be normal-mode, and higher-frequetncy disturbances tend to be common-mode. Part of the reason for this is, regardless of how noise is generated, higher-frequency noise will tend to couple electrically and magnetically between the Line and Neutral wires as it travels along the building wiring. So, in order to stop EMI/RFI on the AC powerline, two physically distinct filters are required – a normal-mode filter and a common-mode filter. A glance at the specifications for any given power conditioner will quickly reveal whether the product includes both or only one. There needs to be both common-mode and normal-mode (sometimes called differential-mode) attenuation specs listed. If both these two terms are not mentioned in the specs, there can be little doubt that the product in question includes only normal-mode filtering. Common-mode filtering requires a special type of inductor known as a common-mode choke (or mutual inductor) and is more expensive to implement.

The Real World

Having covered the basics of EMI/RFI filtering, it is now time to look at real-world applications. EMI/RFI filters fall into the category of "passive low-pass filters", which have been part of the electronic toolkit since the early days of radio. The design of any passive filter, however, relies on the source and load impedances being a known fixed value. What do we mean by that? Here are some examples: video inputs and outputs are always 50 Ohms; preamplifier inputs tend to be high impedance, and preamplifier outputs tend to be low impedance. In the case of powerline filters, the source impedance means the impedance of the electrical service or branch circuit. The load impedance is the impedance of whatever is plugged into the filter. Yes, you're right –we have no way of knowing what those impedances are in any given situation. So how do we design a low-pass filter if we don't know what the source and load impedances are? Well, we can make some assumptions. We know the impedance of the electrical service is going to be very low, and we can make some assumptions on what is likely to be plugged into a power conditioner.

Why do we care about the source and load impedances presented to an EMI/RFI filter? The reason is because the characteristics of the filter will change if the source and load impedances are not 50 Ohms. That is, the filter will not perform as designed and certain frequency bands may be poorly attenuated. Worse than that, when there is an impedance mismatch, certain noise frequencies may actually be increased! This is why the SurgeX design team modeled its EMI/RFI filter over a range of source and load impedances, and designed it to be "tolerant" to a range of "impedances".

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The SurgeX Impedance Tolerant® Filter

As explained above, the SurgeX Impedance Tolerant filter was designed to be more forgiving of real-world source and load impedances and thus provide EMI/RFI filtering that meets its specifications over the full frequency spectrum all the way up to 30MHz and beyond. The market-leader that SurgeX has always been, our IT filter has included both normal-mode and common-mode filtering from the beginning. We could never understand why many competitors only provide normal-mode filtering. What is the point of only filtering out part of the EMI/RFI? Some manufacturers are now trying to catch up by adding common-mode filtering, but their technology provides only a minimum level of coverage. A quick check of the product specs will reveal the internal filtering capability. Another thing to be on the lookout for are EMI/RFI filter specs that claim to attenuate above 50MHz. Such claims should be treated with considerable suspicion.

Benefits

A/V gear is more sensitive and complex than it has ever been, and signal-to-noise ratios are at levels once not thought possible. However, electrical disturbances and interference on the powerline continue to be a part of life. Preventing even the smallest clicks, pops and buzzes from getting into an audio chain is, therefore, more critical than at any time in the past.
Video systems are not immune to noise on the powerline. An unexpected, brief disruption in the video is likely to be due to a powerline transient. Once inside a piece of equipment, EMI/RFI can sneak its way onto any wiring or into any circuitry. It is vital to stop electrical noise from getting inside equipment enclosures.
Almost all A/V equipment now has a microprocessor or a DSP embedded inside it. Anywhere there is a memory chip or a digital device running code there is a risk of memory loss, a crash, a hang-up or a re-boot. Many of these unexpected occurrences are caused by powerline disturbances: transients or noise.

Only the very best power conditioner with an EMI/RFI filter designed to perform under real-world conditions can prevent these kinds of problems from occurring. SurgeX products include our proprietary Series Mode Surge Elimination technology and Impedance Tolerant EMI/RFI filter – a combination that was designed to work seamlessly together to provide you with the cleanest AC power you can get, short of generating it yourself!

All this adds up to benefits for you, the installer. There is no better advertising than a happy customer, and when your installation continues to work to the complete satisfaction of your customer, then your customer will be happy. When you have service contracts, a reduction in support calls will save you the cost of including SurgeX in your installations many times over, enhancing both the profitability and reputation of your company.

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