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DIRTY AC POWER?

WHERE TO LAY THE BLAME FOR SYSTEM NOISE PROBLEMS

Chapter 3 of 4 in the Power & Conditioning Expert Series

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Replacing myth and misinformation with knowledge and clear understanding

By Bill Whitlock

The idea that "dirty" power causes audio system noise problems has a nearly irresistible intuitive appeal – and there are dozens of companies ready to cash in on this widespread but mistaken belief.

For example, here is a quote from a well-known manufacturer of power conditioning products: "Today's residential systems contractors face unprecedented challenges where high resolution, trouble-free operation is required. From inducing AC ground loops, video hum bars, static bursts, damage from AC line surges and variable audio and video performance, comprehensive control and conditioning of AC power is no longer an option."

In fact, the power line doesn't cause ground loops at all—and no amount of power "cleansing" or "purification" will prevent them!

Obviously, if every highway were smooth as glass, our cars wouldn't need suspension systems. But it's simply unrealistic to expect such highways – we pretty much have to accept them as they are.

The same is true for the AC power line. It's a utility used by all sorts of appliances and equipment – and it's certainly not pristine. Further, the power distribution systems in our buildings unavoidably create small voltages and currents that can potentially contaminate our signals.

Therefore, we need "suspension systems" to isolate our audio signal paths from the power line. Any pathway that allows coupling between the two is the fundamental problem causing noise in sound (and video and computer) systems.

Even though this is demonstrably true, and based on real science, it's often difficult to persuade folks that "bad" AC power isn't to blame. Audio systems routinely suffer from hum and buzz even when AC power is pristine.

In unbalanced interconnections, the noise is usually coupled in the audio cables. It isn't that the cables are poorly shielded; rather, it's due to the basic properties of wires.

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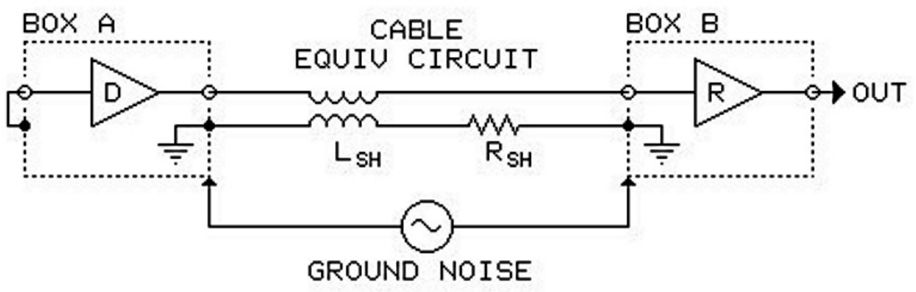

Figure 1: Cable couples, audio-frequency noise only.

A simplified equivalent circuit of an unbalanced audio cable (**Figure 1**) shows that the shield, like any wire, has both DC resistance and inductance and that this inductance is magnetically coupled to the inductance of the center conductor, creating a kind of transformer.

The impedance of an inductance increases in direct proportion to frequency. Therefore, when current flows in the shield at frequencies below about 10 kHz, most of the voltage drop occurs across the resistance and very little across the inductance. It is this voltage drop that adds noise to the audio signal and is responsible for 99 percent of noise problems in unbalanced interfaces.

But, at higher frequencies, most of the voltage drop occurs across the inductance and, through transformer action, induces an equal voltage in the center conductor, thus reducing the coupling as frequency increases.

We may conclude that noise coupling in unbalanced interfaces is a significant problem only at audio frequencies. Balanced interfaces are generally immune to this coupling mechanism, but can fall victim to others.

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Normal & Common

First, let’s briefly define some terms used to describe power-line noise. “Noise” in this context is generally defined as any voltage at a frequency other than 60 Hz (in the U.S.). Harmonics of 60 Hz, generally 3rd, 5th, 7th, etc. are usually the largest components of noise (heard as “buzz” when they enter the audio path). Differential or “normal-mode” noise is that between line and neutral, while “common-mode” noise is that between neutral and safety-ground.

Generally, normal-mode is larger because it's created not only by local loads on the branch circuit but can also be brought in through the main service panel from outside power lines. The combined normal-mode noise on each "phase" is conducted to all its branch circuits via the main service panel.

Common-mode noise can be created only by equipment on each branch circuit because neutral and safety ground for each branch circuit are bonded at the main service panel (this assumes there are no "shared neutrals"). See **Figure 2**, which shows a simplified schematic of a power-line filter. Such filters typically reduce normal-mode and common-mode noise only above about 50 kHz.

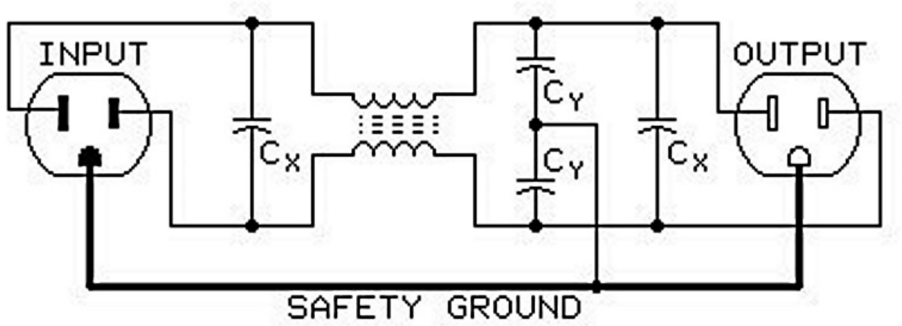

Figure 2: Typical AC power filter.

This is not very useful at reducing audio noise – audio cables themselves have significant rejection starting at high audio frequencies. Note that the normal "leakage" currents that flow in capacitors "Cy" couple noise from both line and neutral to safety ground.

Remember, safety ground is normally the reference "ground" for each piece of equipment. When additional noise currents flow into the safety ground wiring, more noise voltage is created between outlets. It's these voltage drops that can couple into our audio at some vulnerable point!

When any line filter, conditioner, or isolation transformer is used, electrical code requires that both it and the equipment it feeds remain connected to safety ground, as shown for the isolation transformer (**Figure 3**). Because capacitances in both transformers and filters divert additional 60 Hz and high-frequency noise currents into the safety ground system, they frequently aggravate the problem they claim to solve.

WHEN ADDITIONAL NOISE CURRENTS FLOW INTO THE SAFETY GROUND WIRING, MORE NOISE VOLTAGE IS CREATED BETWEEN OUTLETS. IT'S THESE VOLTAGE DROPS THAT CAN COUPLE INTO OUR AUDIO AT SOME VULNERABLE POINT!

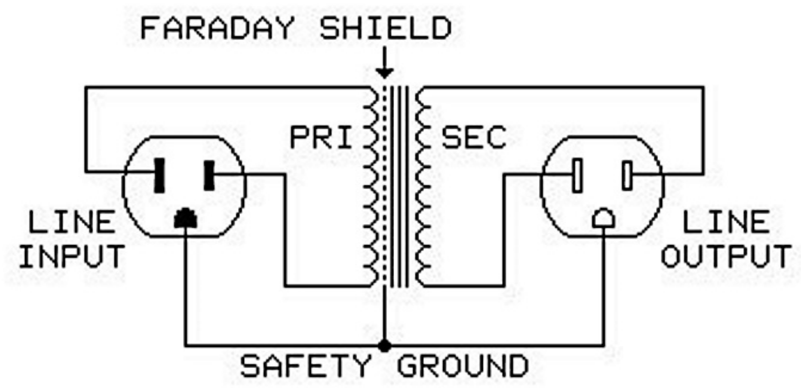

Figure 3: AC power isolation transformer.

Second, the touted noise attenuation figures for virtually all these power line devices are unrealistic. Laboratory measurement setups connect the device and test equipment to a large metal ground plane.

The resulting specifications can be impressive, but in my opinion they don't represent performance in a real-world system where the ground connection is to safety ground wiring or conduit.

However, these devices can be very effective if installed at the power service entrance, where all system safety grounds are bonded to each other.

Seductive Idea

So-called "balanced power" – or more properly, "symmetrical AC power" – is another seductively appealing idea.

Explanations of the concept often mistakenly assume that the internal capacitances from power line to chassis that exist in all equipment (C1 and C2 or C3 and C4 in the figure as shown in **Figure 4**) are equal.

Of course, if this were true, the normal "leakage" currents in these capacitors would completely cancel because the voltages across them are equal but of opposing polarity.

But this assumption is not valid for typical real-world equipment, where one capacitance is often several times larger than the other. Therefore, real-world noise reduction is usually less than 10 dB and rarely exceeds 15 dB, a fact even promoters admit.

BECAUSE CAPACITANCES IN BOTH TRANSFORMERS AND FILTERS DIVERT ADDITIONAL 60 HZ AND HIGH-FREQUENCY NOISE CURRENTS INTO THE SAFETY GROUND SYSTEM, THEY FREQUENTLY AGGRAVATE THE PROBLEM THEY CLAIM TO SOLVE.

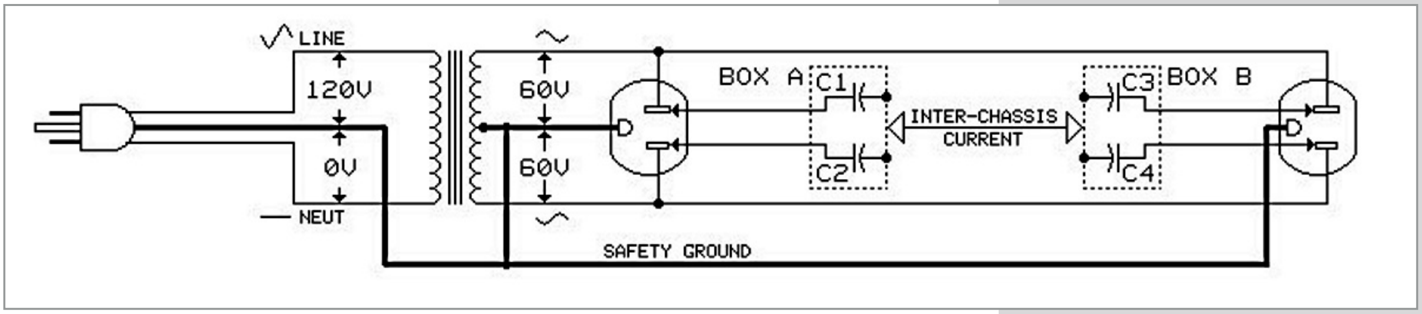

Figure 4: Balanced power attempts to cancel ground noise current.

In audio systems, 10 dB improvements rarely "solve" noise problems. But 10 dB might be cost-effective if it makes a "hum bar" disappear from a video display. Increased cancellation of noise would require manufacturers to better match power line to chassis capacitances in their equipment, which is unlikely.

In systems where all equipment uses two-prong (ungrounded) power connections, filters and isolation transformers will have little effect on noise, but balanced power may offer some improvement. However, in systems where some or all equipment uses three-prong power connections, the effects of leakage currents pale in comparison to magnetic effects in premises wiring.

By transformer action, current flow in line and neutral wires create a magnetic field that can induce significant voltages over the length of the safety ground wire. Although this is a major source of ground voltage differences between outlets (contributing to system noise), power conditioning has no effect on it whatsoever.

Explaining Benefits

When power conditioning is installed, usual practice is to power most, if not all, system equipment with its output. The fact that all system equipment is powered from very closely spaced outlets may drastically reduce ground voltage differences between pieces of equipment.

This may explain most of the benefit usually attributed to the conditioner. But this can be done with an ordinary outlet strip or, at the very least, by powering all system equipment from the same branch circuit.

Although ground loops often involve safety ground connections, it cannot be emphasized enough that disabling them with “lifters” or ripping out the third pin is both highly dangerous and illegal. I’ve seen pricey audiophile power “accessories” whose most notable features were an internal disconnection of safety ground and, of course, lack of a UL label.

Generally, the most dramatic and cost-effective solution to system noise is to locate and eliminate the ground loops or other problems that allow noise to couple into signal paths in the first place. This approach solves the fundamental problem, which tampering with safety grounds does not.

Bill Whitlock has served as president of Jensen Transformers for more than 20 years and is recognized as one of the foremost technical writers in professional audio.

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