Ground Loops

(c) Kent English, Pass Labs

Introduction

Your brand new component is hooked up, fresh from the box, and the first time you power it up is a sonic disaster; it hums, it buzzes and in general sounds absolutely dreadful. Glaring at your equipment or dealer doesn't help and twisting knobs only makes the noise worse; what now?

From years of experience we find that the vast majority of excessive noise in audio electronics can be traced directly to poor grounding techniques. While we recommend balanced interconnects on your audio components whenever possible, it must be understood that balanced interconnects address only the problems of induced noise. Ground loops are a very different problem, and not at all related to the issues of induced noise.

A Little theory

In order to successfully battle ground loops you must first understand why they occur. Each component in your audio system has at its heart an internal ground. The key points to understand are that there is no such thing as a perfect ground and that no two ground points within any system are ever exactly equipotential to one another.

Wherever two grounds of different potential exist within a system, there is a likelihood of a ground loop related noise issue. When devices are tied together with interconnect cables, these of necessity tie the signal grounds of the interconnected devices to one another. This communication between the two signal grounds is a necessary and desirable circumstance, the problem of "ground looping" arises when this connection occurs in more than one instance. The typical culprit being the safety ground supplied by the power cordage or rails in a rack mount being in direct contact with the signal return grounds.

These situations create a closed loop, where current flows from one unit's ground to the other unit and back to the first unit through the additional ground connection, provided by the power distribution network. Typically the impedance's of these unwanted circuits are quite low, in the order of very small fractions of an ohm. Don't expect to measure this resistance with your handy multi-meter, it likely does not have the required resolution or sensitivity. Accurate measurement requires the use of a device known as an impedance bridge. Fortunately, the cure for ground related noise rarely requires this level of diagnostic sophistication.

In accordance with the revered teachings of *Georg Simon Ohm,* these voltages while quite low are capable of generating significant current flow. It is then these "looping" currents that create the unwanted noise by impressing their signature on low level signals, usually in the form of common mode noise.

In order to minimize ground loop issues Pass Labs never manufactures equipment with signal ground and chassis ground contiguous. By separating signal ground and safety grounds, connecting units together should never cause ground loop issues; however, not all manufacturers follow this line of thinking.

Now What

Once you have an understanding of what causes ground loops, they should with some persistence and effort become non-issues. To the greatest extent possible you will need to keep safety grounds, signal returns and shielding of low level cables separate.

Unbalanced cables have persisted as the consumer audio norm, in spite of their inherent frailties. In systems with very few components RCA type connections work reasonably well, but as systems (particularly A/V systems) become more complex their successful implementation becomes problematic. If you are running unbalanced cables, always use two conductor shielded wire. Using the more common single conductor inside a shield mandates that you combine signal return and shielding to the same wire; thus breaking the preferred protocol.

Shields are to keep stray noise out of component inputs; the common or signal return is part of the signal path, two opposed tasks. Because of these separate tasks your cables should be directional, and the shields should be

part of the input circuit only. Shield ground should not be connected on the source end of the wire, only at the input component end; label them and don't forget! This will of course mean that at the input component end of cable the shield and ground signal conductors will bond together.

This would be the preferred connection for all unbalanced connections where the manufacturer has taken the care to isolate chassis ground from signal ground, unfortunately this is as yet not a universal practice in consumer audio.

The same sort of logic should apply when fabricating XLR cables. Start with a cable that has three wires in addition to a separate shield; pin one on the connector is ground, pin two is positive input and pin three is inverted input. The case connection on the input component end XLR becomes your only shield connection; labeling here is unnecessary, as they are directionally polarized cables by virtue of construction.

If one component has a safety ground isolated from signal and another does not, chances are very good that ground loops will not become an issue. When ground loop problems arise it is most often a result of two interconnected components, each having safety grounds and signal grounds joined inside the component. In these circumstances one of the grounds will have to be abandoned, or you will have make them all more alike….. your choice.

Ok, lets say you have interconnect cables and components that you fancy, and re-engineering or otherwise damaging the product is out of the question, now what?

Logically one would think, you could eliminate ground loops by disconnecting the power-cord grounds on all your gear. Some people might try to break the ground connection by cutting the grounding pin on the power cord, using a cheater plug, cutting the ground wire inside the equipment, taping over the grounding connector etc. As logic predicts this may effect a cure for the noise.

Do not do this. Removing the ground connection isn't right! It is against electrical safety regulations and potentially very dangerous. Removing a safety ground connection can defeat the actions of the noise filter or spike protector inside the equipment. If the ground connection is cut then a fault in the insulation inside equipment may apply dangerous voltages to the equipment case instead of interrupting a fuse. Running without a power ground will not automatically electrocute you but will make this much more probable if something goes wrong in your system.

Many a noted authority has suggested repolarizing your equipment by inverting the power cord thus reverse the hot and neutral power connections. **Do not do this.** As a practical matter this may slightly reduce your power-supply related noise issues, but there is a potential down side as well. Inverting your power cord will put the internal fuse and power switch in the neutral power line (goodbye protection). In case of accident as a result, insurance companies will be laughing at your heirs!

If we cannot separate the signal grounds and safety grounds our only other option is to make them as alike as possible by careful configuration of mains supply and safety ground. There are a number of power distribution techniques intended to reduce or at least minimize ground loop issues. The most common technique is called a star distribution. In star distribution, a point is chosen as the arbitrary lowest voltage potential ground. From this point radiating in as many directions as necessary power will reach all interconnected components. Then all safety grounds will terminate back to the master safety ground at this common point. These star configured ground connections must be made of heavy gauge wire and all arms of the star must be the same length and gauge wire.

When all the ground conductors to a star connections central point are of equal length, then the ends of the star are very close to the same ground potential. Assuming faultless implementation of this grounding; signal wiring between any equipment grounded to the star will be at zero potential, thus avoiding ground loops.

The most cost effective way to do this by connecting all your low level components into a quality power strip rather than numerous wall outlets. The wall outlet chosen to plug the power strip into should be the one closest to the mains panel for that particular branch circuit. Anything you do to reduce the overall electrical resistance of the power supply circuit brings the benefit of having "ground" closer to earth potential. Lowering power source impedance's in this manner allows your components internal EMI / RFI filters to perform as intended.

Any noise producing devices on the same branch circuit, such as fans or portable fluorescent lights should be

located closer still too the mains panel. Many power strips have MOV's and neon lights; if you are seeking the ultimate in RFI free power, do not put these devices on your entertainment system. Both devices can input a small but measurable amount of noise on the power line. Is this small amount of noise significant, no but it is certainly cumulative.

MOV's have a place in your home electrical system, to be most beneficial they should be as close to the mains panel as possible. The best of the MOV devices hard wire directly onto the breaker panel buss bars. MOV's however wear out, and will occasionally need replacement. They tend to fail catastrophically rather than gradually and failed units are not too difficult to spot.

Many small gains in noise reduction can and do have a dynamic impact on what you ultimately hear in a high-resolution audio system. In many instances taking advantage of these incremental gains represents little additional expense or effort.