

## Pesky Ground Loop Problems?

A look at solving them – the right way

By Bill Whitlock

When a system contains two or more pieces of equipment that are grounded, whether via power cords or other ground connections, a “ground loop” will likely be formed. Regular readers of this column will recognize the ground loop shown in the simple system shown in **Figure 1**.

Previously we’ve discussed that although ground loops often involve power line safety ground connections, disabling them is both highly dangerous and illegal. However, devices called “ground isolators” can be inserted in the signal path to break the loop safely.

This approach attacks the problem

at its fundamental roots, while tampering with safety ground does not. In simple language, a ground isolator is a device that transfers a signal across an electrically insulated barrier. This is how it stops the flow of power-line currents that would otherwise generate noise as they flow through signal cables.

Because an isolator is not a filter that recognizes and removes noise, it must be inserted in the signal path at the point where the noise coupling actually occurs. (See *Clear Path*, January 2005 issue for more on logical troubleshooting to easily locate this point.)

On the other hand, a transformer can serve as an extremely effective ground isolator. As shown in **Figure 2** (next page), it transfers signal voltage from one winding to the other without an electrical connection between them. This electrical isolation blocks the flow of ground noise current in the signal cable. While the isolation would be total for an ideal transformer, physics imposes limitations on real-world transformers.

### TWO BASIC TYPES

In practice, noise reduction depends critically on the design of the transformer. Audio transformers fall into two basic types. The first, known as an output transformer, is by far the cheapest and easiest to build. Because its primary and secondary windings

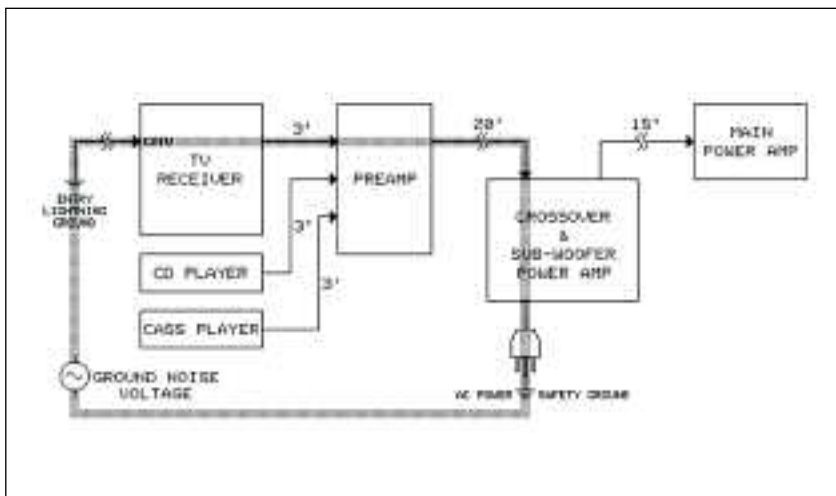


Figure 1: See the ground loop in this system?

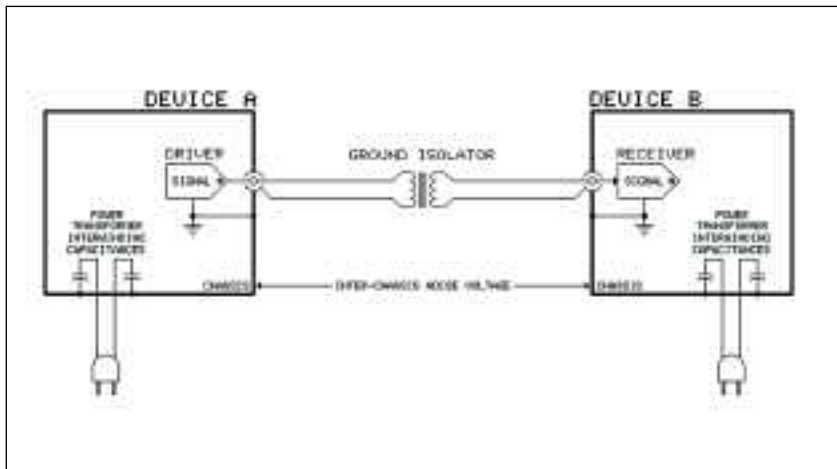


Figure 2: A transformer can serve as an extremely effective ground isolator, transferring signal voltage from one winding to the other without an electrical connection between.

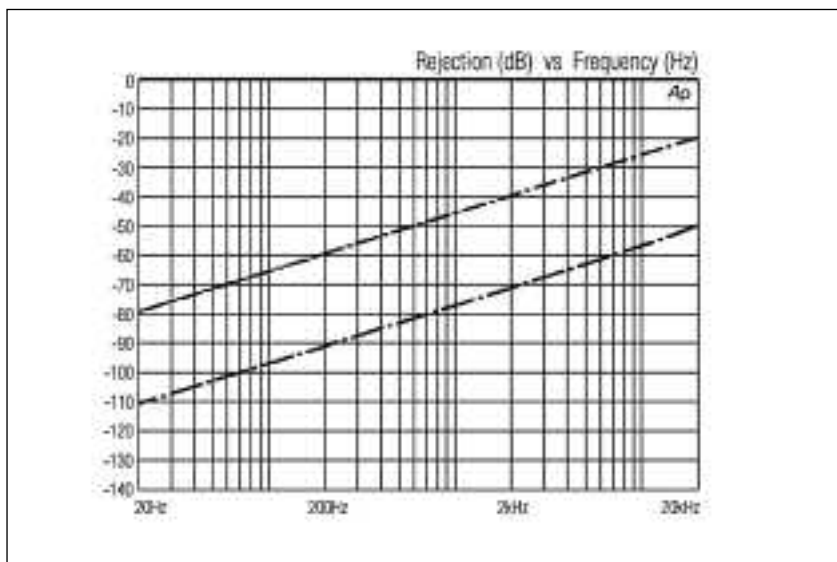


Figure 3: Noise rejection versus frequency for a typical unbalanced interface.



Figure 4: A Jensen ISO-MAX transformer, up close and personal.

are physically interleaved, considerable capacitance is created which allows noise currents, especially at higher audio frequencies, to flow between windings. This limits its ability to stop ground noise.

The second type, known as an input transformer, is built with internal metal foil shielding between its windings. This “Faraday shield” effectively eliminates capacitive coupling and vastly improves noise rejection. A magnetic shield serves a completely different purpose and, if used, is on the outside of a transformer surrounding both the core and the windings (Reference 1).

Figure 3 shows noise rejection versus frequency for a typical unbalanced interface. With no isolator, by definition, there is 0 dB of rejection in the interface, as shown in the upper plot.

The middle plot shows results for a typical isolator using an output transformer. Hum at 60 Hz is cut by 70 dB, but buzz artifacts around 3 kHz are reduced by only 35 dB.

The lower plot shows results for a typical isolator using an input transformer. Hum is cut by over 100 dB and buzz by over 65 dB.

The overwhelming majority of “black boxes” intended to solve ground loop problems use output transformers. One advantage of these boxes is that they can be installed anywhere along the length of a cable or can be used at patch-bays. Although boxes made with input transformers have some 30 dB better noise rejection, they must be installed thoughtfully.

In Figure 4, we see a commercial black box. Because high-frequency response can be degraded by excessive cable capacitance at their outputs, these types of boxes must be installed near the equipment input they drive, generally through no more than 3 feet of cable.

Some commercial interface devices are “active” (i.e., powered) devices. Although these often have useful features, they invariably use differential amplifier circuits to “isolate” their unbalanced inputs. In a future discussion of balanced interfaces, we’ll find that ordinary diff-amps do this job very poorly. Typical products in this vein often deliver only 15 dB to 30 dB

# Clear Path

of noise rejection under typical real-world conditions.

Incidentally, to eliminate noise in an unbalanced cable run, it's not necessary to "balance" the line (using a converter at the driving end) and then "unbalance" it (using another converter at the receiving end). The noise rejection of such a scheme is no better, and often worse, than that of a single high-performance isolator (i.e., input transformer) installed at the receiving end.

Check performance data for isolators carefully. Many have scanty, vague or conspicuously non-existent specifications, and many use cheap, telephone-grade transformers. These can cause loss of deep bass, bass distortion, and poor transient response. Data for high-quality isolators is complete, unambiguous, and verifiable. Input-transformer-based isolators have other benefits, too, including:

Their inputs are truly universal, accepting signals from either unbalanced or balanced sources, while main-

taining extremely high noise rejection.

They provide inherent suppression of RF and ultrasonic interference. The subsequent reduction of "spectral contamination" is often described as a marvelous new sonic clarity (*Reference 2*)

They are passive, requiring no power. And, they are inherently robust, reliable, and virtually immune to transient over-voltages.

## EXPLORE THE OPTIONS

In many systems, including the one seen in **Figure 1** (page 32), there is more than one way to break the ground loop. Observe that the noise voltage between the CATV ground and the ac power safety ground at the subwoofer causes noise current flow in the shield of all the signal cables between the CATV ground and the sub-woofer.

Common-impedance coupling will induce noise in both audio cables in the path, generally in proportion to their lengths. CATV feeds are notorious

for having "ground" at their shield several volts different from utility AC power ground, therefore this system might exhibit a very loud hum regardless of preamp control settings because of coupling in the 20-foot cable.

Of course, the loop could be broken by defeating the subwoofer safety ground – but don't do it! Remember, audio cables that connect equipment together will also carry lethal voltages throughout the system or could start a fire if the sub-woofer develops a defect.

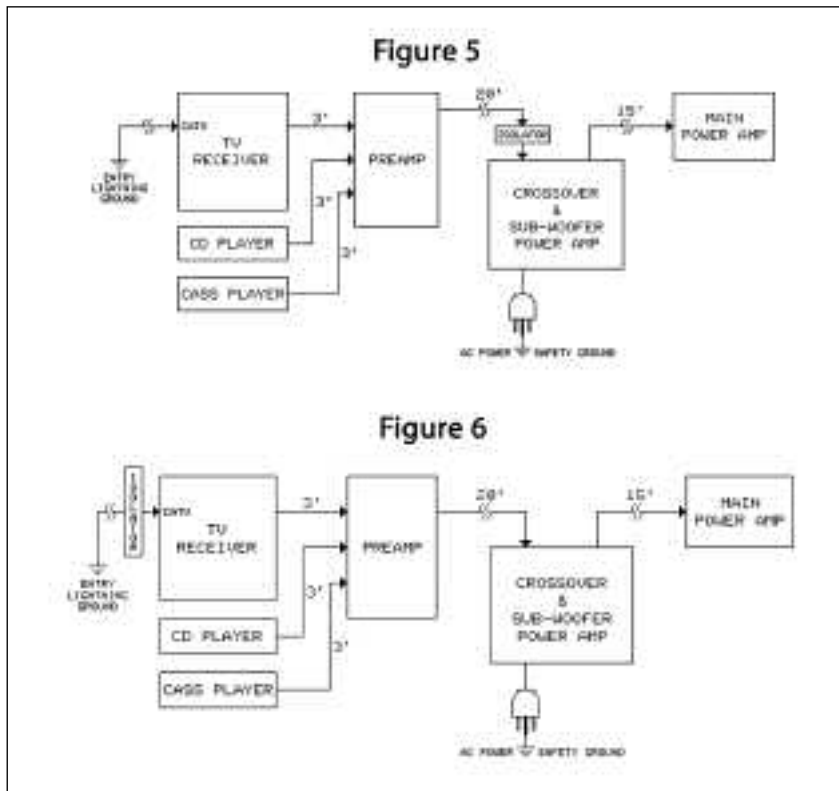
A safe way to break the ground loop is to install a ground isolator somewhere in the audio signal path from TV to subwoofer. Because longer cables are more likely to couple more noise, the preferred location in this system would be at the receive end of the 20-foot cable (**Figure 5**).

Another safe, and potentially less expensive, solution is to break the loop by installing a ground isolator in the CATV feed as shown in **Figure 6**. CATV isolators must be installed downstream of the lightning ground and should generally be installed where the cable first connects to the audio or video system, such as at a VCR or TV input.

Next time, we'll look more at CATV and satellite dish connections, isolators for digital interfaces like RS-232, and talk about the marketing hype and mysticism associated with audio cables. ■



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Two safe ways of breaking ground loops. Figure 5 shows a ground isolator inserted in the audio signal path between TV and subwoofer, while Figure 6 depicts a potentially less expensive method of inserting the isolator in the CATV feed.

## REFERENCE

- 1) Bill Whitlock, *Handbook for Sound Engineers*, 3rd Edition, Focal Press, 2001, Glen Ballou, editor, Chapter 11, Audio Transformers.
- 2) Deane Jensen and Gary Sokolich, *Spectral Contamination Measurement*, Audio Engineering Society 85th Convention, 1988, Preprint #2725.