

Unbalanced Invites Trouble

How to avoid noise problems

By Bill Whitlock

While hum and buzz are often blamed on “improper grounding,” actually, this is rarely the case. Properly installed, fully code-compliant AC power distribution systems will develop small, entirely safe voltage differences between the safety grounds of all outlets. These normally insignificant voltages cause problems only when they couple into the signal path at a vulnerable signal interface. (For more on this topic, see *Clear Path*, September 2004 issue.)

Let’s look at why **unbalanced** interfaces are extremely prone to this coupling and cause noise problems even when no safety ground connections exist. I find it ironic that virtually all consumer electronics, including the most expensive audiophile gear, still uses this trouble-prone interface. In my opinion, equipment with unbal-

anced input or output connections is unworthy of the term “professional.”

Every signal *interface* consists of a line driver at the output of device A, the *line* (or cable) itself, and a *receiver* at the input of device B. The line, like every electrical circuit, must have two conductors. Whether a given interface is *balanced* or *unbalanced* depends ONLY on the IMPEDANCES of these two conductors with respect to a ground reference. In AC circuits, impedance is the functional equivalent of resistance.

As shown in **Figure 1**, in an **unbalanced** interface, one conductor is grounded (i.e., zero-impedance) and the other has some higher impedance.

When an output is connected to an input, the output impedance (Z_o) of the driver (often unspecified by equipment makers) and the input impedance of the receiver (Z_i) form a *series circuit*. Since the same current flows in all parts of a series circuit, voltage drops are proportional to impedances, and the arrangement is sometimes called a *voltage divider*.

To deliver maximum signal voltage, Z_i must be much larger than Z_o . In typical equipment, Z_o is 1 kilo ohms or less and Z_i is 10 kilo ohms or more. This transfers at least 90 percent of the available signal voltage.

There is a common misconception that *audio* outputs and inputs must be *impedance matched*. This idea stems from a practice necessary only with extremely long cables, such as telephone line pairs. Energy travels in a cable at 70 percent to 90 percent of

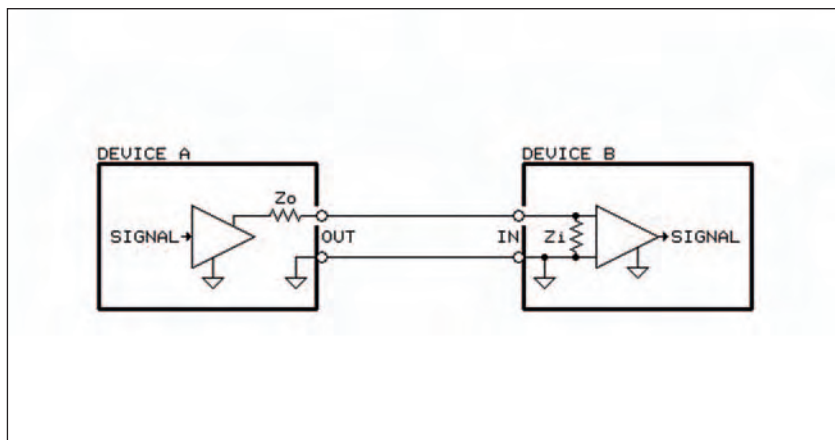


Figure 1: An unbalanced interface, where one conductor (in this case, Device B) is grounded, while Device A has higher impedance.

focus

(v. to concentrate energy)



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Clear Path

the speed of light and the distance traveled during one signal cycle is its **wavelength**.

Any cable will begin to exhibit "transmission line" effects when its physical length is 10 percent or more of a wavelength at the highest signal frequency. Transmission line effects occur in video cables over a few feet long and with CATV cables over a few inches long.

To avoid reflections and "standing waves," the driver output and receiver input impedances at the physical ends of the cable must equal the *characteristic impedance* of the cable itself. Such impedance matching or **termination** is required for virtually all video and RF cables because the signals have physically small wavelengths. However, termination of audio cables is NOT required until they are some 4,000 feet long!

NOISE COUPLING

Contrary to popular belief and information offered by cable manufacturers, noise coupling has very little to do with cable shielding. Nearly all noise problems are caused by a tiny but significant voltage between the grounded ends of the cable. This voltage can be created two ways.

In all real equipment, parasitic capacitances exist between the power line and the internal equipment ground. They are the unavoidable inter-winding capacitances of its power transformer (including external "wall-wart" power supplies) that are *never* shown in schematic diagrams. (Figure 2)

If the equipment contains anything digital, internal electro-magnetic interference (a.k.a. EMI) filters further add to the capacitance. Leakage current will flow through these capacitances from the power line to the signal/chassis ground inside each piece of equipment.

In UL-approved ungrounded (i.e., two-prong AC power plug) devices, this current is limited to 0.75 milliamps. Note that such equipment incorporates a number of protective mechanisms so that it remains safe in spite of internal component failures, overload, and rough handling.

Because it has no safety ground connection, the chassis and/or signal connections can assume alarmingly high voltages with respect to an external ground system. Although a voltmeter may indicate well over 50 volts, the current available is small and will be felt as a slight tingle when it flows through your body. What's important, however, is that any connection between two such devices or such a device and a grounded one will conduct this inter-chassis leakage current.

When connecting a signal cable between them, power-line leakage current flows in the grounded signal conductor. Since this conductor does not have zero resistance, a small noise voltage is generated over its length – a simple application of Ohm's Law.

Because the interface is a series circuit, this noise voltage is **directly added** to the signal arriving at the receiver. We *must* accept this fact of life. Because the impedance of the

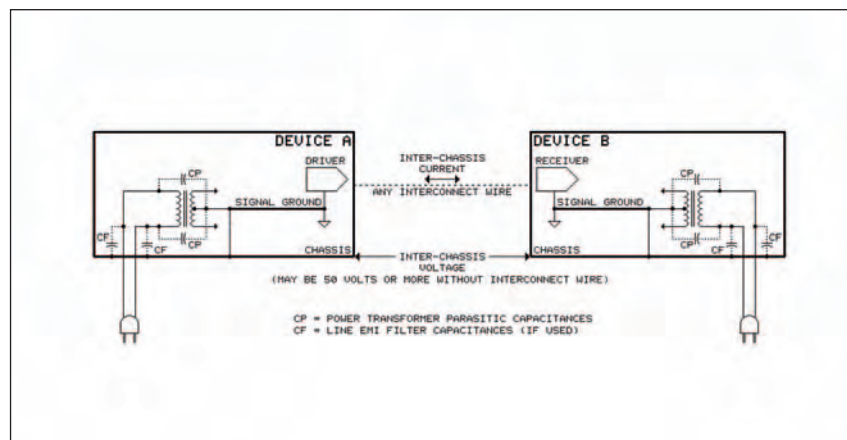


Figure 2: Parasitic capacitances exist between the power line and the internal equipment ground.

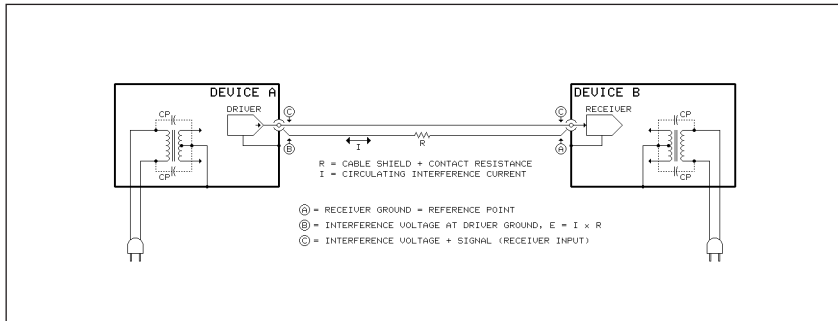


Figure 3: The connection between these two devices could conduct inter-chassis leakage current.

grounded conductor is part of or “common” to both the signal and leakage current (noise) paths, this mechanism is called **common impedance coupling**. (Figure 3)

Consider a 25-foot interconnect cable with foil shield and a #26 AWG drain wire. The resistance of the shield (which usually, but not always, serves as grounded conductor) is found to be 1.0 Ohms. *The resistance of the inner conductor is insignificant and not discussed here.* If the 60 Hz leakage current is 316 microamps (less than half the UL limit), the noise voltage will be 316 microvolts.

Because the -10 dBV reference level for consumer audio is 316 mV, the noise will be only 20 x log (316 microvolts/316 millivolts) equals -60 dB relative to the signal. For most systems, this is a *very poor* signal-to-noise ratio. Since the noise voltage developed is directly proportional to shield resistance, replacing the cable with Belden #8241F, for example, reduces shield resistance to 0.065 Ohms and reduces noise by about 24 dB! This is much better but still may be inadequate for high-performance systems.

If an unbalanced signal cable connects two pieces of equipment that are safety grounded (either directly or via other signal cables), noise coupling can become very severe. Any ground voltage difference developed in the building wiring, which can range from a few millivolts to over a volt, is effectively connected across the ends of the cable shield.

Ground voltage differences may be even higher between the power grounding system and some other ground connection, such as a CATV (cable television) feed. The resulting

hum can often be louder than a reference-level signal!

THE REAL CULPRIT

Based on this discussion, it should now be obvious that in most cases, the problem is not “dirty power” or “poor shielding” of cables. The most direct and effective solution is to find and eliminate the noise coupling where it actually happens.

As I’ve noted in previous columns, many technicians routinely and casually disconnect safety grounds to solve this kind of noise problem. But doing so can result in grave danger and devastating legal liability!

Next time, we’ll explain a test method that pinpoints the exact entry point of noise by temporarily placing “dummies” (consisting of two connectors and two resistors) at strategic locations in the interface. The test, although simple, reveals precise information about the nature of the problem. It can specifically identify:

- Common-impedance coupling in unbalanced cables;
- Induction of noise into the cable by nearby magnetic or electric fields;
- Common-impedance coupling *inside* poorly designed equipment (sometimes called the “Pin 1 Problem”).



Then, of course, we’ll move along to the pros and cons of various solutions to the problem. ■

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force

(n. energy exerted or brought to bear)

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