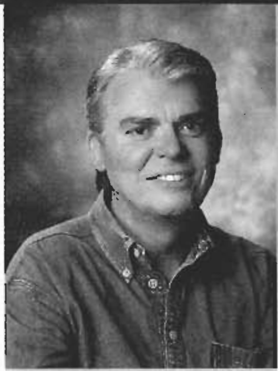

NEUTRAL GROUND

Finding Swaps in Power Wiring

Bill Whitlock

LAST YEAR, IN MY AUGUST COLUMN, I wrote about an electrical wiring error called a "neutral-ground swap." It's a problem that apparently occurs much more often than I imagined. A number of readers contacted me with horror stories about the difficulty and expense of diagnosing and locating this problem. In one case, it was the third in a series of power-system consultants who finally found it.

The point of the original column was: When trying to track down and correct audio-video system noise or interference problems, false assumptions can lead to lots of wasted time and frustration. One assumption that's all too easy to make is that power outlets are wired correctly. Low-cost outlet testers, which generally cost less than $10, will find *dangerous* problems such as hot-neutral or hot-ground reversals and open connections.

However, because these outlet testers check for correct voltages between the pins, and both neutral and ground are normally at zero volts, they cannot detect a neutral-ground reversal. This insidious wiring error, shown in **Figure 1**, can create nightmarish ground-loop problems in an audio or video system. The problem will also come and go as the load on the offending circuit varies or switches on and off.

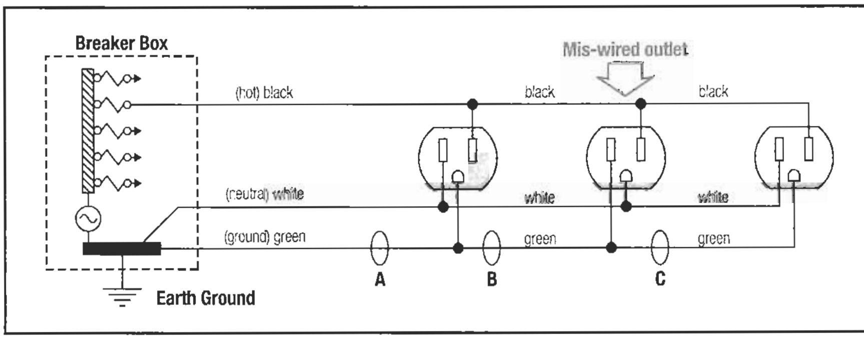

FIGURE 1: Current monitor points for troubleshooting.

WHERE THE HUM COMES FROM

In a properly wired power system, all load current flows in the hot (or "phase") and neutral (or "grounded") wires. The ground (or "grounding") conductor normally carries only small leakage currents from devices on the circuit having 3-prong, safety-grounded plugs. Of course, this conductor exists to divert otherwise dangerous fault currents back to the breaker-panel neutral in case of an equipment fault. But, unless there is such a fault, the leakage current is generally less than a few milliamperes (heavy industrial equipment will normally have higher leakage currents).

Because the safety ground conductors have small but significant resistance, the small current will cause voltage drops in them, creating small voltage differences between the grounds of any two outlets on the branch circuit. These voltage differences, even though they're usually only a few millivolts, are impressed across the length of signal cables that connect equipment plugged into different outlets. For systems with two or more pieces of equipment with grounding power plugs, and connected by unbalanced interfaces using coaxial video or RCA audio cables, even these tiny voltages can cause hum problems. Note, however, that balanced interfaces are generally much more immune to these small volt ages.

A sensitive current probe, the Hioki 3283.

But when an outlet is mis-wired as in Figure 1, the load current for any devic plugged into it flows in the ground con ductor. Depending on the device, thi current could be 15 amperes or more Again, because of normal resistance i the ground wiring, voltage difference will be created between outlet groun pins; but in this case they can be as hig as several volts. If the safety ground i tied to conduit (as with normal saddle grounded outlets) or to rack cabinets (vi outlet strips), these voltages will als appear in other part of the grounding sys tem.

The problem virtu ally guarantees seriou hum bars in vide monitors if they'r grounded to one o these outlets and th video source is groun ed to another. It wi also be devastating fo unbalanced audi interfaces and will ce tainly challenge eve proper balanced interfaces. This will happen despite following the generally recommended practice of powering all system equipment from a single branch circuit whenever possible.

DETECTING AND FIXING IT

As I stated last August, finding the error by visual inspection of outlets is one possibility, but this could get labor intensive if the number of outlets is large. For large systems, and even those that can't be powered down, a sensitive, non-contact, clamp-on current probe can help identify the current forks when you are troubleshooting. An example of such an instrument, the Hioki 3283 (available at www.mitchellinstrument.com as item #C53283) is shown. It has a 10mA full-scale range that can resolve 10 microamps.

Of course, with this troubleshooting method, it's essential that there be a load on the errant outlet or group of outlets. (One of the horror stories involved a mis-wired outlet strip in a rack cabinet.) For example, you can plug a 60-watt light bulb into each of the outlets (or any unused but suspect outlets). Then start checking for high current in the safety ground wires. For our light bulb dummy loads, checking ground current at points A, B and C would show 0.5 A (500 mA) at A and B but near zero at C. This would identify the center outlet, where safety-ground wire segments B and C join, as the culprit.

Low-cost outlet testers, which generally cost less than $10, will find dangerous problems.

If conduit is used as the safety ground conductor, or saddle-grounded outlets are used to bond the safety-ground wire to J-boxes and conduit, the strategy changes slightly. Instead of looking for load currents in the safety ground system, we compare currents in the hot and neutral wires. In a normal circuit, they are equal, except for the small leakage currents mentioned earlier. Using the previous example, checking current in the hot wire on line segments A, B and C would show 1.5 A, 1.0 A and 0.5 A, respectively. Checking the same segments of the neutral wire would show 1.0 A, 0.5 A and 0.5 A, respectively. Note that the hot and neutral current is the same for segment C, but unequal at A and B. This means 0.5 A of the current in the hot wire is *not* returning in the neutral wire beginning where segments B and C join. So, even though it's impractical to measure the current in the conduit itself, we can still locate the junction where load current escapes into the ground system — and causes the problem.

Preliminary tests to identify the faulty branch circuit can be done at the breaker box where hot and neutral wires are usually easy to access. Of course, you should always use extreme caution working around exposed, energized wiring. Better yet, engage the services of a qualified electrician. And remember, don't assume anything about electrical wiring — it can create some very elusive problems in audio and video systems. S&VC

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