BY HOWARD JOHNSON, PhD

Ground loops

I design audio circuits. My mentor taught me to avoid ground loops at all costs, yet in digital products I see a solid ground plane holding hundreds of circuits. Between boards, I see a web of ground-referenced connections shooting off in all directions. How can this possibly work?

—Silence Dogood,
Analog rules

Imagine two parts of an electronic system. When device **A** sends to **B**, a signal current flows between them. At the same time, an equal and opposite current, called the returning signal current, flows back to **A** through the power or ground system. Current always makes a loop in that way. A ground loop is a situation where there exists more than one path for the flow of returning signal current.

Audio designers like single-point ground networks. Such a network of ground connections has the topology of a tree, with one main trunk and many branches and sub-branches. None of the branches touch, so it contains no loops. In this type of network there exists only one ground path between any two devices. When **A** sends to **B**, the returning signal current disturbs the ground along that path, affecting everything that touches that path or branches from it, but does not affect devices connected to other parts of the tree structure (**Figure 1**). That property provides a measure of isolation between devices.

In **Figure 1**, what happens if **A** sends to **C**? In that case, returning signal current must traverse a big section of the main trunk, polluting almost everything in the structure. Single-point ground networks provide isolation only when communications remain localized to isolated sections of the network.

Suppose the main trunk of the ground system comprises 12 in. of #18 gauge wire having a dc resistance of 6.5 mΩ. Assume that an audio-frequency current of 1A (that's 8W into an 8Ω speaker) traverses the main trunk. The ground noise observed from one end of the ground wire to the other equals 1A×6.5 mΩ, or 6.5 mV. Compared with an audio reference level of perhaps 4V, the headroom in the circuit, defined as the difference between the standard reference level and the ground noise, equals a mere 56 dB—enough possibly for cheap consumer-grade audio, but not within a factor of a thousand of acceptable performance for high-end audio. Good audio equipment uses a single-point ground system *and* keeps disparate circuits confined to isolated sections of the tree.

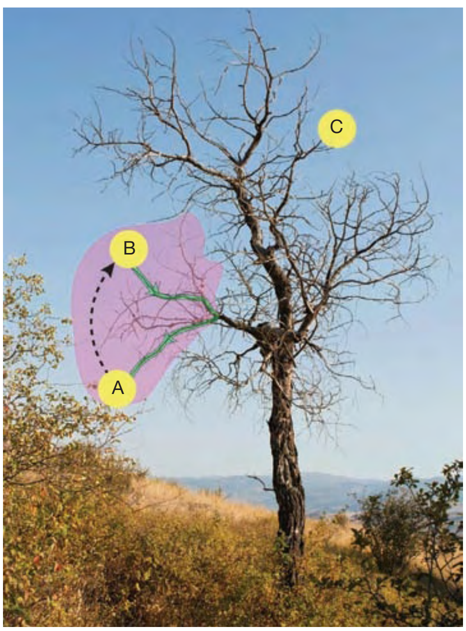

Figure 1 Communication from **A** to **B** pollutes all circuits that lie along the green path or branch from it; circuit **C** remains unaffected.

Single-point grounding provides isolation between localized regions.

In the digital world, the resistance measured from side to side across a solid-copper ground plane is on the order of 1 mΩ. A current of 25A induces ground-voltage differences on the order of only 25 mV or less. Digital circuitry easily tolerates that level of noise, so in most cases we simply do not need the complication of single-point grounding for ordinary digital logic.

In addition, all electronic systems suffer mutual-inductive coupling whose severity grows in proportion to the bandwidth of the signals involved. Because digital systems operate millions of times faster than audio systems, they suffer a correspondingly increased degree of inductive coupling, which, if not checked by the low-inductance properties of a solid plane, would incapacitate most modern digital electronics.

We must have solid planes to control inductive crosstalk in digital products; that is the planes' main function. **EDN**

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