Test Equipment Scene

By Leslie Solomon

GROUNDING

WHEN you use test equipment, you probably connect a signal across the input and an oscilloscope across the output of the circuit under test and watch the scope's CRT screen. What you may not realize is that in many cases what you see is not what the device under test is really capable of doing. In fact, what you might be looking at is what the test equipment and the device under test is *adding* to the input signal (exclusive of distortion products).

What accounts for this strange phenomenon? The name of the culprit is "ground." The way many of us handle this ground in performing tests is simple. We merely connect one ground point to another, using some convenient wire or test leads. It is the lack of understanding the meaning of "ground" that causes a lot of grief at the testbench.

What is Ground? Since all electrical measurements are relative, a voltage or signal must be compared to a reference—usually zero or ground. When we refer to ground, ground is literally what we mean, since the local potential of the planet Earth was chosen as our arbitrary zero reference.

There are many ways of connecting to this zero reference, each with its good and bad points. Many people swear by a metal rod driven into the soil. But the rod must be driven deep enough to contact a low-resistance layer, or the rod and surrounding soil must be kept moist to maintain a low earth resistance. Just driving a rod into the ground is not enough. As a general rule, the deeper the rod is driven into the earth, the better.

The second and perhaps best approach to achieving a good earth ground is to use a *cold*-water pipe as the ground connection. In almost all cases, this pipe makes intimate contact with the surrounding soil over a large area because it must lie below the local frost line. At such a depth, chances are good that the pipe will lie in a layer of low-resistance soil.

Contact with the cold-water pipe can be made with a brazed, soldered, or clamped-on connector. There may be a problem here. Although most cold-water pipes are metal, there may be plastic joints or even sections of plastic pipe. Plastic is not a conductor. If such is the case, you can bridge over the non-conductors—assuming you have access to them—with heavy-duty wire braid, making good electrical connections on both sides of the non-conductive break.

The idea of using the wall socket's junction box as a ground should be discarded. True, in some areas of the country, metal armored cable is prevalent. The armor is usually connected to the metal junction box and to earth ground at some point. Unfortunately, there are many places where plastic-insulated power lines are the norm; although in such a system the third (green) conductor is supposed to be at ground potential, there is always the possibility that it is not.

Do not use the so-called "grounded" side of the ac power line as a ground. Because it is not a perfect conductor, there will be an unwanted signal generated across the wire resistance. Besides, if you happen to use the wrong side of the line, it could prove disastrous.

If you occasionally use the metal finger stop on your telephone dial as a ground, that's not a good idea, either. The phone company frowns on this practice. But more importantly, circulating currents may exist in such a hookup.

Origins of Unwanted Signals. Now, let us take a look at the origins of those unwanted signals. Sketch A shows a typical three-conductor power feed. Because the wire used is not a perfect conductor, differences in potential can and often do exist between two points of a grounding system if any current flows in the system.

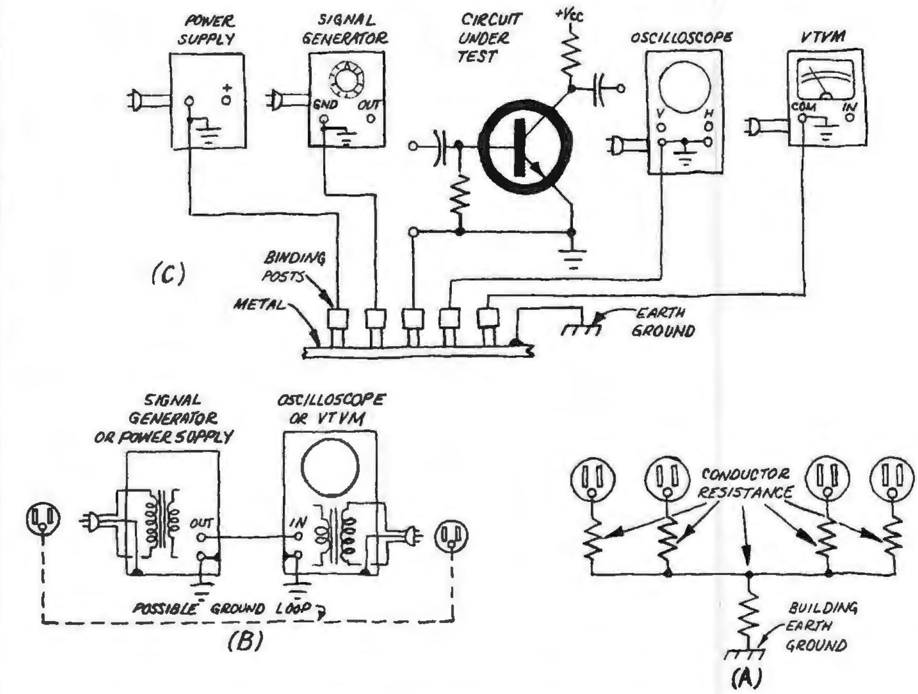
The sketch illustrates the phantom wire resistance that forms the common signal point. Note that any instrument plugged into the three-wire outlet is essentially coupled to all other outlets via an interlocking set of phantom resistors.

If you connect a couple of line-powered test instruments as shown in sketch B, a ground loop can occur. The metal chassis of both instruments are grounded via the third (green) wire of the receptacle. In some cases, there may be some real capacitors between the ac line and chassis. In all cases, there is the phantom capacitance across the power transformer. Hence, if any current is flowing within the building's power-line "ground," this signal will be "felt" by the measuring system, which will introduce a false signal into the measurement loop.

To break the ground loop and remove false signals, the third wire at one of the instrument power plugs must be broken. (Use a three-wire to two-wire adapter.) As a result, the system is grounded at only one point and, since the ground loop is now broken, false signals produced by ground currents are eliminated.

In using the ungrounded adapter, there is a potential danger if the "hot" power line within the instrument touches the metal chassis. So, before using this approach, make certain that all internal wiring is sound.

In multi-instrument setups, there may be more than one ground connection, creating more than one ground loop. Any one of these loops can introduce a problem. Since shielded cables are often used to interconnect a system, especially in audio, all shields should be connected together and then tied to ground at the same point used by the measurement system.



How grounding problems originate. (A) shows how differences in wire resistances create potential differences. (B) shows ground loop in building power line which introduces a false signal. At (C) is a typical test-bench setup with 2-wire plugs to eliminate loops.

A typical bench setup is shown in sketch C, where two-wire power plugs are used to eliminate the possibility of ground loops. In general, if more than one point in a system must be connected to ground, the ground connections must be made only at the same point where the input is grounded.

There are two excellent books that deal with the subject of grounding when working with test equipment. One is *Basic Electronic Instrument Handbook* by Clyde F. Coombs, Jr. (McGraw-Hill) and the other is *Guide to Electronic Measurements and Laboratory Practice* by Stanley Wolf (Prentice-Hall). ◈