AETECHRON

The Issues and Dangers of Improper System Grounding

1. Scope

This technical note will discuss the common issues found in the operation of amplifiers and the way that grounding affects the amplifier operation. For specific details pertaining to amplifier operation, see the manual relevant to the specific model.

2. Grounding

Grounding serves several purposes

- Provide a common voltage reference for devices and components
- Help control noise and signal quality
- Provide an alternative current path in the event of a fault, and trigger safety devices

Under normal operating conditions, the ground does not carry current. Ideally, a ground is a zero impedance conductor which does not interact with equipment or signals. This ideal, however is a laboratory abstraction which does not exist in the real world. Care must be taken to ensure that the ground is able to meet the three requirements listed above.

Ground Loop

A ground loop is formed when there is more than one path to ground, and the reference points (the “grounds”) are not at the same potential.

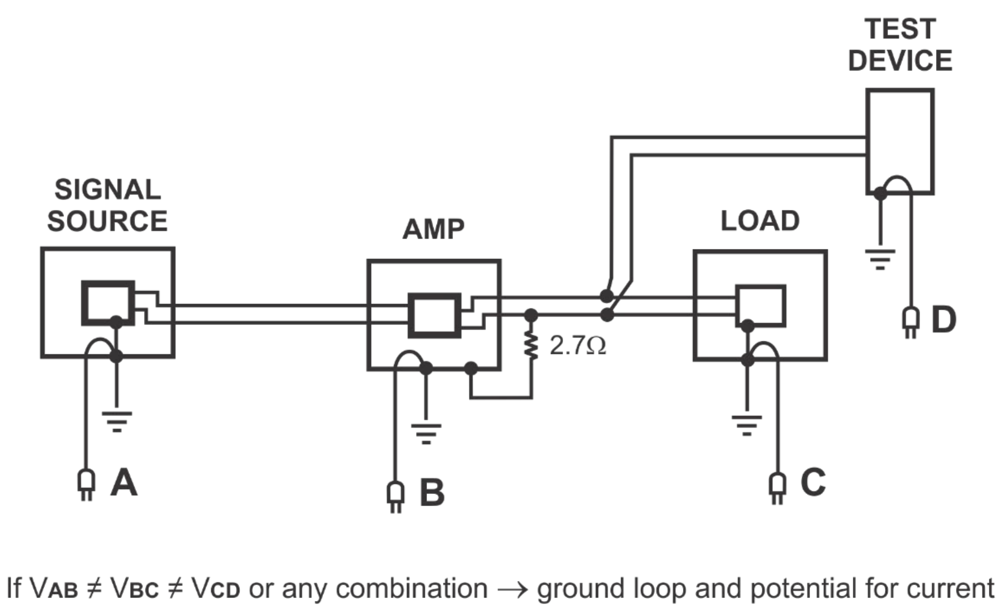

Figure 1: A Configuration for a Possible Ground Loop

The difference in voltage at any point in the reference causes a current to circulate through ground system, potentially affecting the low, or common, side of devices as well. The resistance in the ground wires turns the interference currents into voltage fluctuations in the ground system.

In the event that a ground loop current is present, the 2.7 Ω resistor shown in Figure 1 (or similar protections, discussed below) provide a weak link that either fail intentionally, or act to limit damage from these currents.

The Amplifier

The amplifier, including its output, is separated from the equipment ground on the amplifier case. The primary AC supply power has an equipment ground, as required. The case is also connected to this same AC ground. This ground is connected to the amplifier only through the 2.7 Ω resistor (or similar voltage/current limiting device) on the rear. This is shown schematically in Figure 2.

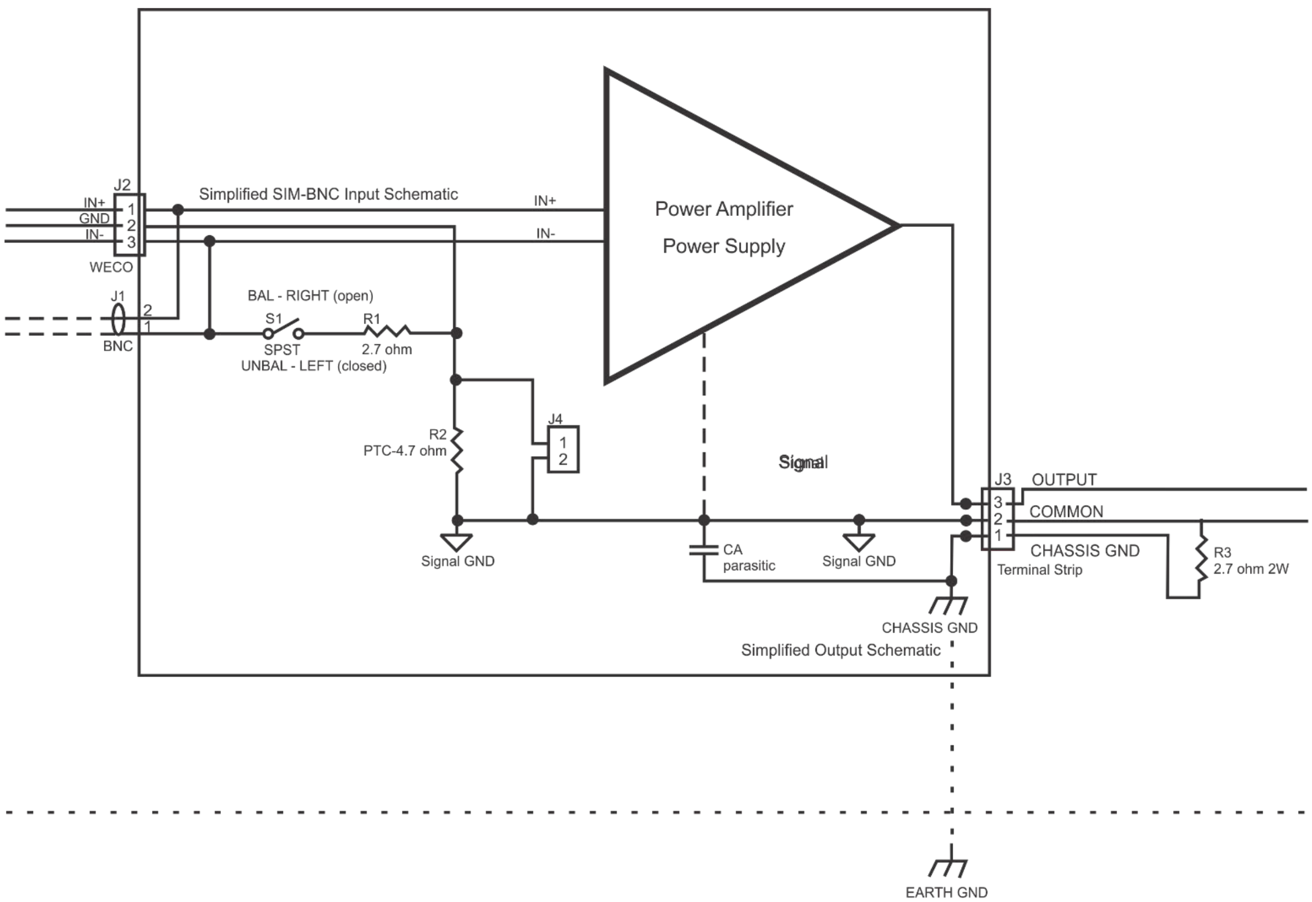

Figure 2. Simplified Amp Schematic

So, the amplifier is essentially floating with respect to the enclosure. The amplifier and enclosure are tied together only at the point where the 2.7 Ω resistor connects. This has two main advantages:

1. Provides the voltage reference needed for stable operation. The amplifier and its components all use the same reference. There are also amplifier internal signal grounds used for providing common references for components and to help provide stability
2. Protects the connected equipment. The 2.7 Ω resistor forms the weak link in the event that currents circulate in the ground system, failing before connected equipment.

Important:
There are two types on ground loop protections on AET amplifiers, found on different models: The 2.7 Ω external resistor and internal PTC sensing circuits. *If the amplifier is designed to use the 2.7 Ω external resistor, it is strongly advised that the amplifier never be operated without this resistor being in place and in good working order.*

Some models (Model 7228, for example) do not have the external 2.7 Ω resistor, but rather use an internal PTC (positive temperature coefficient resistor), also located near the amplifier outputs, that increases resistance as ground current flows, limiting voltage/current due to ground loops. This PTC is in a sensing circuit internal to the amplifier. When a ground loop is detected, the PTC heats and its resistance increases, placing the amplifier in Standby Mode, rather than opening a resistor. When the fault clears the PTC cools and releases the Standby. The PTC is very robust and unlikely to fail. For these models, the chassis ground connection at on the rear panel is not connected to the amplifier via an external conductor or resistor.

3. Connections

Possible sources of ground loops:

- Connections, particularly with regard to measurement instruments
- Ground reference variations
- Transients

By far the most common source of ground loops, resulting in the opening of the 2.7 Ω resistor or triggering the PTC/Standby circuit, are problems with connections. Problems with ground references may be an issue if the grounds are poor or are spread out in the facility. Transients result from fluctuating EM fields in the environment. The conductors, including the ground plane, forms a large loop antenna that may pick up interference voltages/currents easily. The larger the loop, the larger the antenna area, the more interference. If a building's steel frame forms part of the ground, then the loop can be as large as the whole building. For a well-grounded table top installation, transients are rarely a cause of loop currents sufficient to trigger amplifier protections, but may result in noise (an issue not covered in the current brief).

The first two ground loop causes are more common. Taking the second cause first, extra care should be taken to ensure that all equipment grounds on all devices are at the same ground potential. From Figure 1, we can see that small differences may lead to undesirable currents, manifesting the failure of the 2.7 Ω resistor or heating the PTC. However, if all grounds are connected such that all are at the same reference, the voltage across the 2.7 Ω resistor is zero. This usually requires that all connections be made to a local master ground bus (sometimes called a "star" ground) that is in turn grounded. All ground connections should be very mechanically sound and clean (use of oxidation prevention grease provides improved long-term reliability), and of minimum length. From Figure 3, this requires that all connections to Earth Ground be at the same potential. Also, note that even though power receptacles may be close, they may be on different circuits, with their corresponding grounds also possibly separated, leading to small differences in ground voltage.

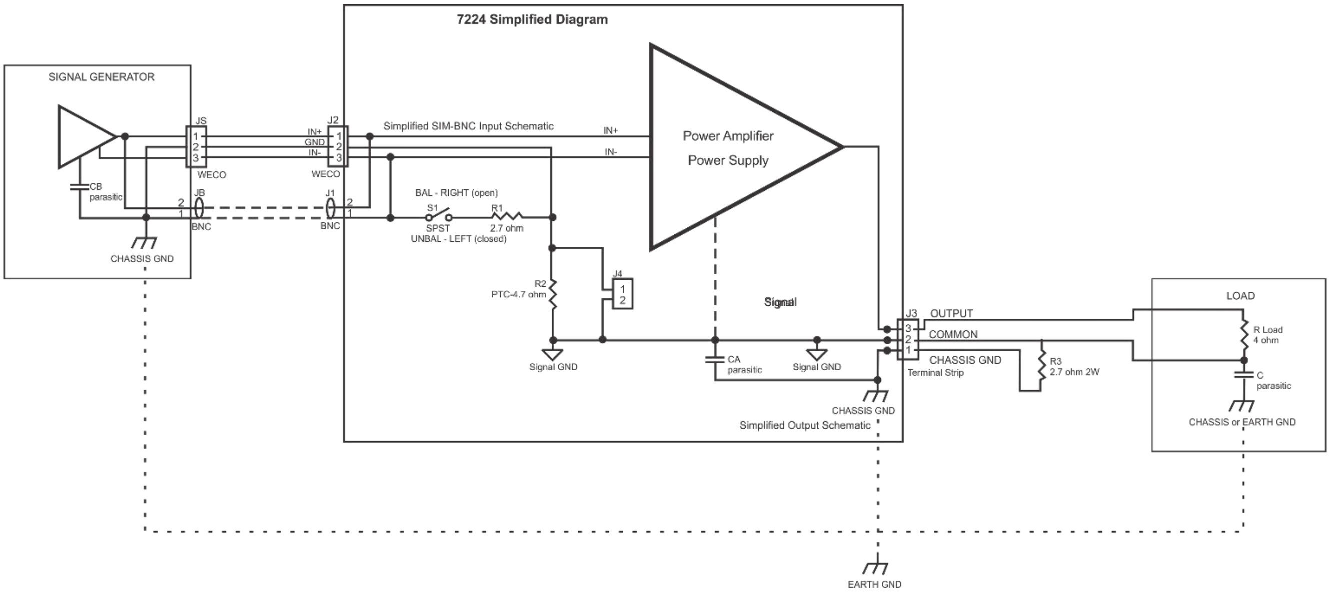

Figure 3: Connections with Earth Ground

Monitoring the Ground Status

It is possible to actively monitor the status of the ground connections through the amplifier. An auxiliary device, called a Ground Current Limiter, can be installed on the amplifier and this replaces the 2.7Ω resistor on the output (on those models that have the 2.7Ω resistor).

1. A comparator circuit monitors the voltage difference between the system's input ground and earth/safety ground. If the voltage differential between these two grounds exceeds ±4V, the GCL will automatically place the amplifier in Standby. In addition, the GCL has a second level of protection that monitors the current flow between signal ground and earth ground. When the current between these exceeds safe levels, the current is limited. This combination of current limit and voltage monitoring provides very robust protection against real-life measurement mistakes and DUT failures.
2. Visual indication is provided through an LED located on the GCL, which is illuminated when activated.
3. When the voltage difference returns to an acceptable range, the system releases the interlock and turns off the LED.
4. In place of the 2.7-ohm resistor, the GCL uses a 2.7-ohm PTC thermistor (resistance changes based on temperature) that will open if the voltage/current becomes too large. Once the PTC cools off, it will return to the 2.7-ohm value.

The GCL protection module suitable for environments where recirculating ground currents are likely or known to be a problem, or installations that may be used by inexperienced staff members.

Connections with Regard to Measuring Instruments

Most signal generators and measuring devices commonly have two-pole outputs/inputs, one of which is connected to the chassis ground, which is in turn connected to the earth ground (the outer shell of a BNC connector is most familiar). As discussed, it is essential that none of these low-side chassis poles ever be raised above the earth ground. There are several ways this can happen.

1. Use of more than one signal source on the input side of the amplifier. Some tests require combinations of signals (adding DC offsets or variations in periodic signals) and on occasion (if a single device is not available) this may be attempted with the use of more than one signal generator. Our recommendation is that this should be attempted with either devices designed to be “ganged” that have purpose designed interconnections with a single signal output, or with an arbitrary wave function generator.
2. Insertion of an auxiliary device or power supply, on the output side of the amplifier, without proper grounding or orientation of the poles.
3. The most common cause of ground loops related to measuring instruments is the inadvertent placement of probes on ungrounded portions of a device or circuit under test. This essentially inserts a powered portion of the circuit into the ground system, raising that part of the ground loop above zero, causing the stray ground current. The intent is that rather than damage the DUT or the measuring devices, the 2.7 Ω resistor will fail, or a ground limiting PTC circuit will engage.

Recommendations

- By far the most critical recommendation we can make, for the prevention of this kind of ground loop current, is the use of active differential probes on oscilloscopes and other instruments that have an earth ground.

Other Techniques

- Connections can be made with isolation equipment (designed for the purpose, and which have proper safety and equipment grounds), such as monolithic isolation amplifiers or isolated input oscilloscopes.
- Battery-powered oscilloscopes. Note: These oscilloscopes MUST be used properly in order to meet safety requirements. There are typically voltage restrictions for use with grounding the oscilloscope chassis and other precautions.

Warnings

- Never attempt to defeat the factory ground system or terminal on any device
- Never use a measuring instrument as an isolated device that is not specifically designed for such use. This may result in dangerous voltages on probes, connections and other surfaces.
- When using grounded probes, always connect the ground first.
- We do not recommend the use of isolation transformers, as this may result in the presence of unsafe voltages on probes, connections and instrument surfaces.

Other issues with ground loops

Like fuses, resistors have a time-current property that determines the length of time required to open. As shown in Figure 4, (a close-up of a portion of Figure 1), the outer shell of the BNC input and the center pin of the three-wire WECO connector, both on the SIM (Specialized Input Module), are grounded. As such, they may also be subject to currents caused by ground loops. Note that the ground pathways are also protected by a PTC resistor which provides some protection from ground currents. However, if the ground current is high enough, and lasts long enough there may be some damage to the small resistors on the circuit boards of the SIM, or even less likely, to the fine traces on the board. These events are quite rare. If replacing the 2.7 Ω resistor does not restore stability and operation, this possibility is relatively easy to troubleshoot. Contact tech support at AE Techron for guidance; be sure to have the amplifier model and serial number so that the proper SIM card can be identified.

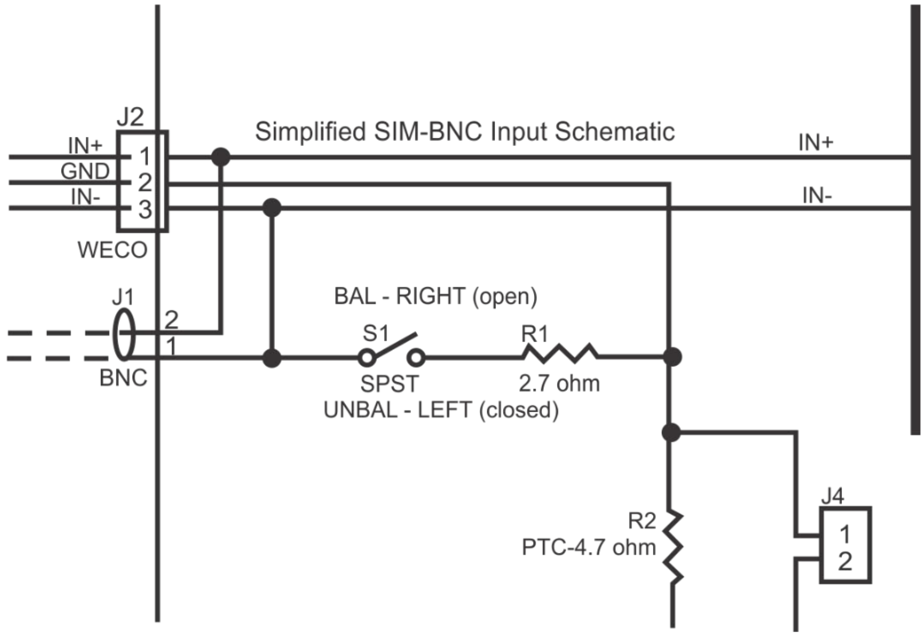

Figure 4: General Schematic of Input Card (SIM)

If you have any questions or comments, please contact AE Techron for help.