Grounding in mixed-signal systems demystified, Part 2

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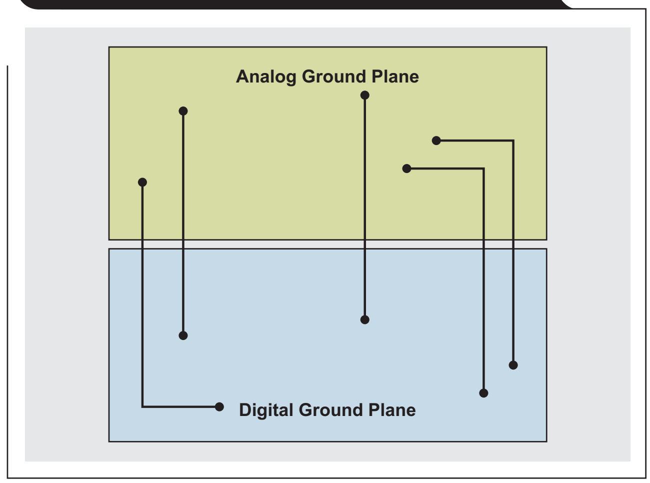
This article is the second of a two-part series. Part 1 (see Reference 1) explained typical terminologies and ground planes and introduced partitioning methods. Part 2 discusses the pros and cons involved in splitting the ground planes. It also explains grounding in systems with multiple converters and multiple boards.

If the ground planes are split and the traces are run across the split as shown in Figure 1, what will be the current return path? Assuming that the two planes are connected somewhere, usually at a single point, the return current has to flow in that large loop. High-frequency currents flowing in large loops produce radiation and high ground inductance. Low-level analog currents flowing in large loops are susceptible to interference.

If the two planes are connected only at the power supply (Figure 2), the return current is forced to flow all the way back to the power-supply ground, which is a really big loop! Also, the analog and digital ground planes, which are at different RF potentials and connected with long wires, unfortunately form a very effective dipole antenna.

It is preferred to have a continuous ground plane to avoid such long ground loops, but if it is absolutely necessary to have a split ground plane and traces are run across the split, the planes should first be connected at one location to form a bridge for the return current (Figure 3). Routing all the traces so they cross at this bridge provides a return path directly underneath each of the traces, producing a very small loop area. A typical application of this method is a weighing scale where high-resolution (≥20-bit) delta-sigma analog-to-digital converters (ADCs) are used.

Figure 1. Signal traces crossing a split on ground plane



Other options for passing the signal over a split plane are to use optoisolators (through light), transformers (through a magnetic field), or a true differential signal (where the signal flows down one trace and returns on the other trace with no ground needed for the return current).

A better approach is *partitioning*. It is always preferable to use only one ground plane, partitioning the PCB

Figure 2. Split planes connected at power supply

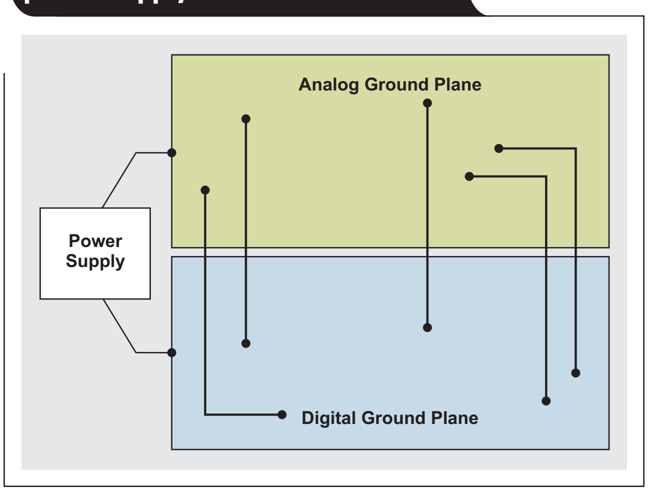


Figure 3. Ground-plane bridge for traces

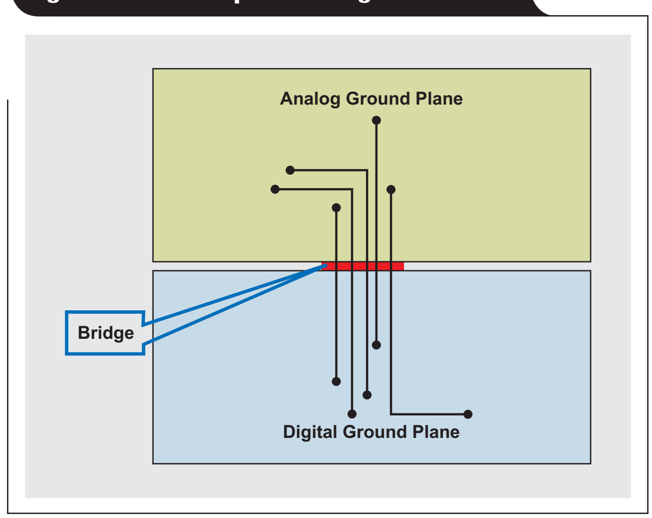
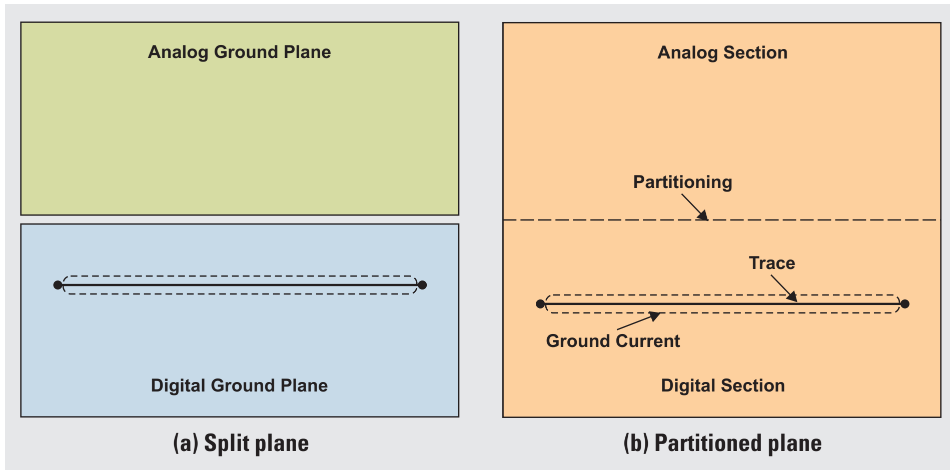


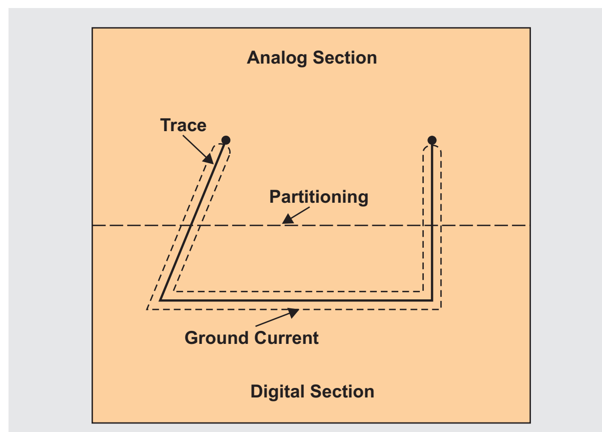
Figure 4. Ground-plane layouts



into analog and digital sections (see Figure 4b). Analog signals must be routed only in the board's analog section, and digital signals must be routed only in the board's digital section, with both on all layers. Under these conditions, the digital return currents do not flow in the analog section of the ground plane and remain under the digital signal trace. Figure 4 compares a split plane and a partitioned plane.

The only problem with partitioning is that it is difficult when analog signals are improperly routed into the board's digital section, or vice versa (Figure 5). So for any PCB layout, the important points are to use a single ground plane, partition it into analog and digital sections, and apply discipline in routing.

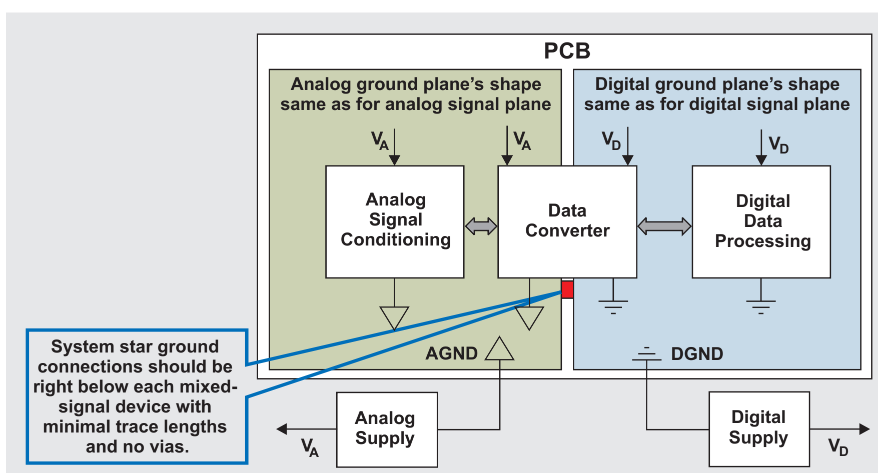
Figure 5. Improperly routed digital signal trace



Grounding when multiple data converters are used on a single board

Most datasheets for data converters discuss grounding relative to a single PCB, usually the manufacturer's own evaluation board. Usually the recommendation is to split the PCB ground plane into an analog plane and a digital plane. It is further recommended that the analog ground (AGND) and digital ground (DGND) pins of a converter be tied together and that the analog and digital ground planes be connected at that same point, as shown in Figure 6. This essentially creates the system's star ground point at the mixed-signal device. As explained in Part 1, all voltages in the circuit are measured with respect to this particular point, not just to an undefined ground wherever one can clip a probe.

Figure 6. Grounding mixed-signal devices on a single PCB



All noisy digital currents flow through the digital power supply to the digital ground plane and back to the digital supply, thus being isolated from the board's sensitive analog portion. The system's star ground point occurs where the analog and digital ground planes are joined together at the data converter. While this approach generally works in a simple system with a single PCB and a single data converter, it usually is not good for multicard and multiconverter systems. If there are several data converters located on different PCBs, the concept breaks down because the analog and digital ground systems are joined at each converter on the PCB, creating ground loops.

Suppose a designer is working on an eight-layer PCB that has three DACs and two ADCs. To minimize noise, the analog and digital ground planes should be connected together solidly under all the ADC and digital-to-analog converter (DAC) chips. The AGND and DGND pins should be connected to each other and to the analog ground plane, and the analog and digital ground planes should be connected individually back to the power supply. The power should enter the board in the digital partition and be fed directly to the digital circuitry, then filtered or regulated to feed the analog circuitry. Then only the digital ground plane should be connected back to the power supply. Figure 7 shows the partitioned analog and digital ground planes and the power-supply connection for a PCB with multiple data converters.

Multicard mixed-signal systems

Confusion about mixed-signal grounding has increased since designers started applying single-card grounding concepts to multicard systems. In systems having several data converters on different PCBs, the analog and digital ground planes are connected at several points, creating the possibility of ground loops and making a single-point star ground system impossible.

The best way to minimize ground impedance in a multicard system is to use a motherboard PCB as a backplane for interconnections between cards. This provides a continuous ground plane to the backplane. The PCB connector should have at least 30 to 40% of its pins devoted to ground. These pins should be connected to the ground plane on the backplane motherboard. To complete the overall system grounding scheme, there are two possibilities:

1. The backplane's ground plane can be connected to the chassis ground at numerous points, thereby diffusing the various ground-current return paths. This is commonly referred to as a multipoint grounding system (Figure 8).
2. The ground plane can be connected to a single star ground point (generally at the power supply).

The first approach is most often used in all-digital systems but can also be used in mixed-signal systems, provided that the ground currents from digital circuits are sufficiently low and diffused over a large area. The low

Figure 7. Power and ground for PCB with multiple ADCs

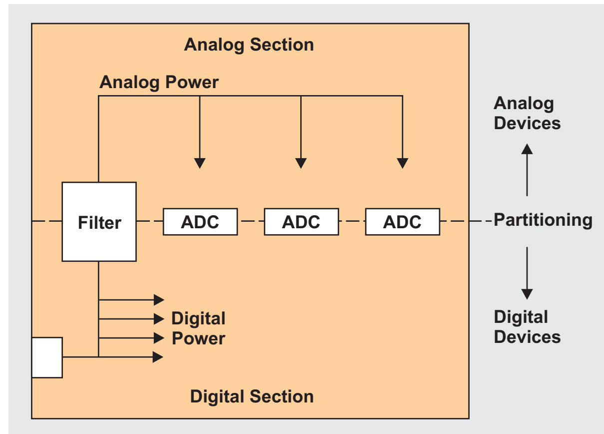
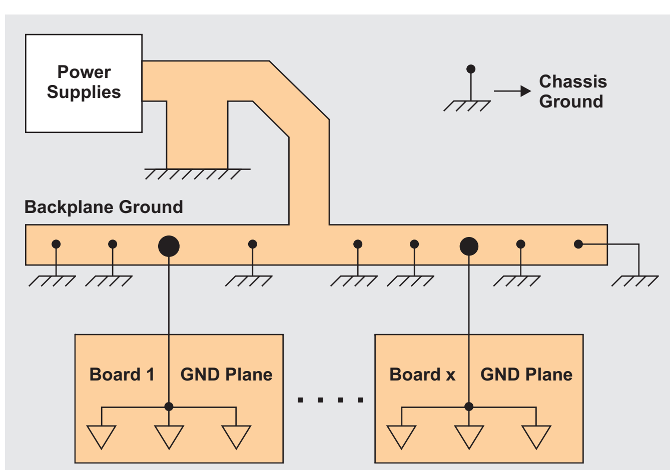


Figure 8. Grounding scheme for multicard system



ground impedance is maintained all the way through the PCBs, the backplane, and ultimately the chassis. However, it is critical that good electrical contacts be made where the grounds are connected to the sheet-metal chassis. This requires self-tapping sheet-metal screws or biting washers. Special care must be taken where anodized aluminum is used for the chassis material, since its surface acts as an insulator.

The second approach, a single-point star ground, is often used in high-speed mixed-signal systems having separate analog and digital ground systems.

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