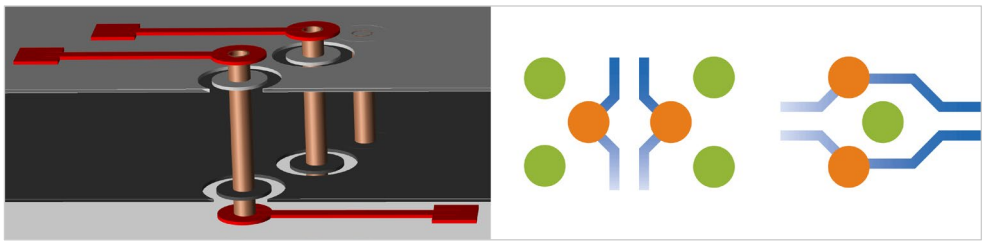
Quality of Signal Return Path

In electronics we always had an electricity circle, where signals travel from the transmitter to the receiver and to make it work, we have to close the circle by the ground connection. Return path is the way the current uses to close the circle. In the past, ground system was often close to ideal and could be ignored. But these effects have an impact on the quality of the return path:

- Miniaturization adds many wholes in the ground plance from vias going through the planes
- High-speed signals use a different return path then DC signals
- Higher frequencies and faster rise / fall times
- Lower operating voltages have smaller tolerances (noise margin)

High-speed signals don't follow the path of least resistance; they follow the path of least impedance. Are High-speed signals different? Of course, the answer is no, but with DC or low speed signals the effect could be ignored and the assumption, that the current uses the least resistance was good enogh for PCB design. But with fast rise and fall times of a signal, the frequencies required for such a fast switching are in the GHz area and here the impact can no longer be ignored. All signals use the path of least impedance, on the traces and on the reference planes.



Ground vias close to signal vias

Switching signals (currents) have an electromagnetic field around them and the energy in these fields are responsible, where the return current will flow. Inductive and capacitive coupling instantly create a return circuit for the current. It is where the electromagnetic fields build the least impedance in the copper geometries build of ground planes with splits, wholes and stiching vias. These complex 3D geometries can be solved with a 3D field solver to calculate the impedance.

If there is no dedicated return path near the high-speed signal traces and signal vias, the current will find its unwanted way in nearby conductors. These wider current loops might build an antenna. A 3D electromagnetic field solver and simulator allows to visualize the circuit's behaviors at various frequencies.

Best Practices

- Provide an uninterrupted ground return path close to the signal on the same layer or an adjacent layer to minimize radiated EMI noise
- Use ground vias next to signal vias, when the reference plane changes
- Route fast switching signals between two ground planes and surround them with shielding vias

The effect of impedance becomes increasingly important as frequencies increase and as rise / fall times decrease.