**Ground Continuity Underneath a Connector**
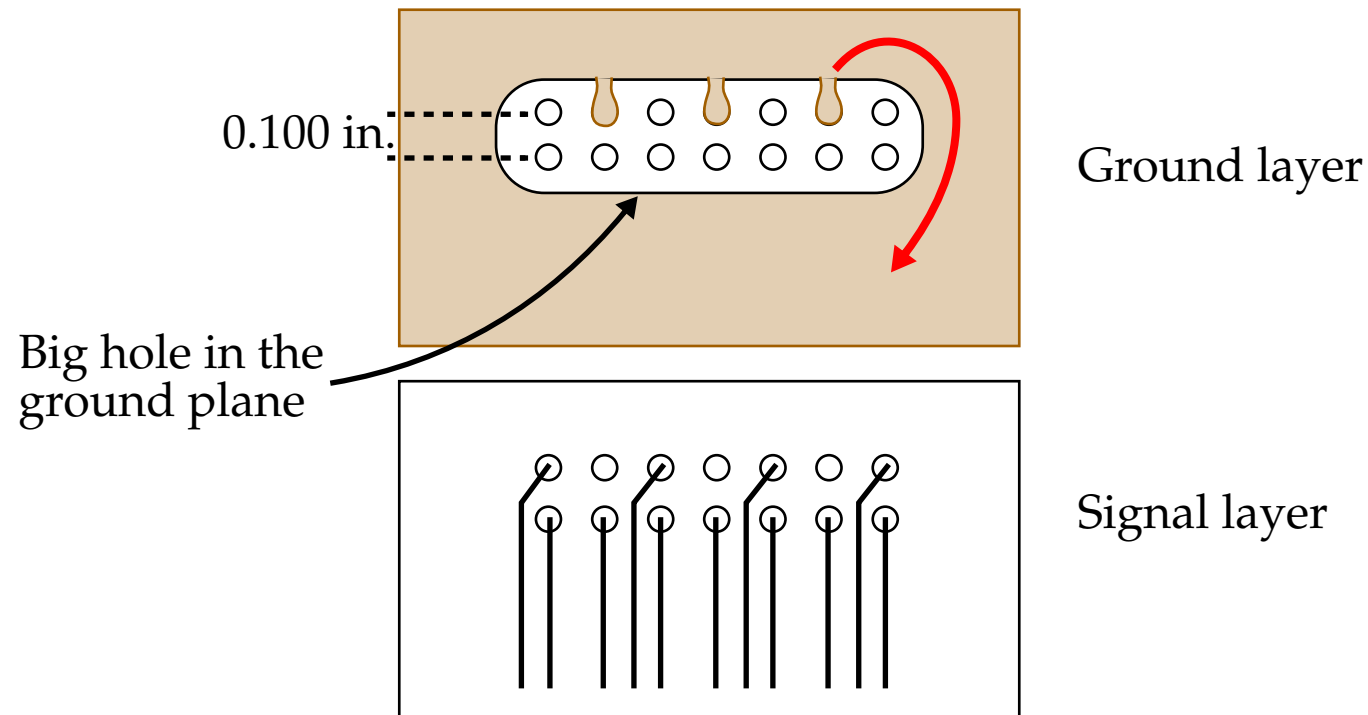
The following layout for a connector will not work properly at high speeds.

0.100 in.

Ground layer

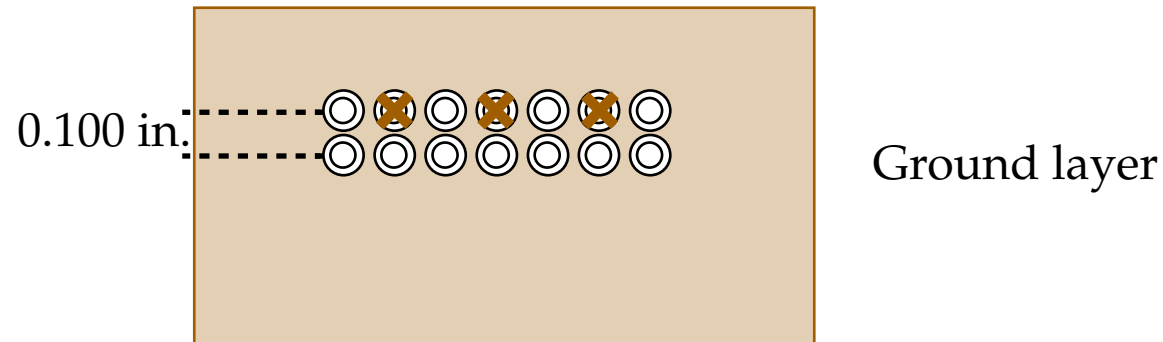Big hole in the
ground plane

Signal layer

All signal return current must flow around the top of the connector before
rejoining the signal path.

This is no better than putting a single ground pin on one of the edges.
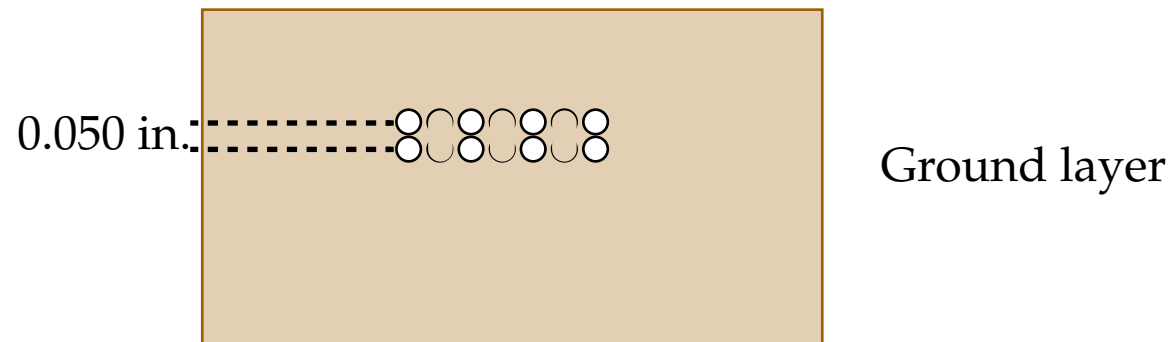
## Ground Continuity Underneath a Connector

One solution routes ground connections through the connector pin field.

0.100 in.

Ground layer

Miniature connectors using a 0.050 in. pitch can use the following.

0.050 in.

Ground layer

This approach is not as good as the previous but its better than the original method.

**Ground Continuity Underneath a Connector**

Some manufacturers can produce pads on the inner layers much smaller than pads on the outer layers.

Sometimes this allows traces to be routed between pins on the inner layers where there is room to do so.

Some connectors come with a staggered pin pattern which increases the space between pins.

**Fixing EMI Problems with External Connections**

Exposed wiring between boards carrying high speed signals always fails FCC (and VDE) radiated emission tests.

There are three ways to reduce radiated emissions.
- Filter the signals to remove high-frequency content.
- Shield the cable.

Shields provide a low inductance return path.
- Place a common mode choke on the cable.

This **increases** the inductance of *remote current paths*.

**Fixing EMI Problems with External Connections**

The problem with *filtering* is the degradation in rise time.

Typical filters involve a small impedance in series with each logic driver.
Series impedance usually feeds into a shunt cap to ground.

Be sure not to shunt to a digital ground, which carries enough noise to exceed
FCC emission regulations if carried outside the chassis.

Manufacturers now offer a "D"-size connector with built-in filtering.

*Shielding* is the most common approach taken by digital designers.
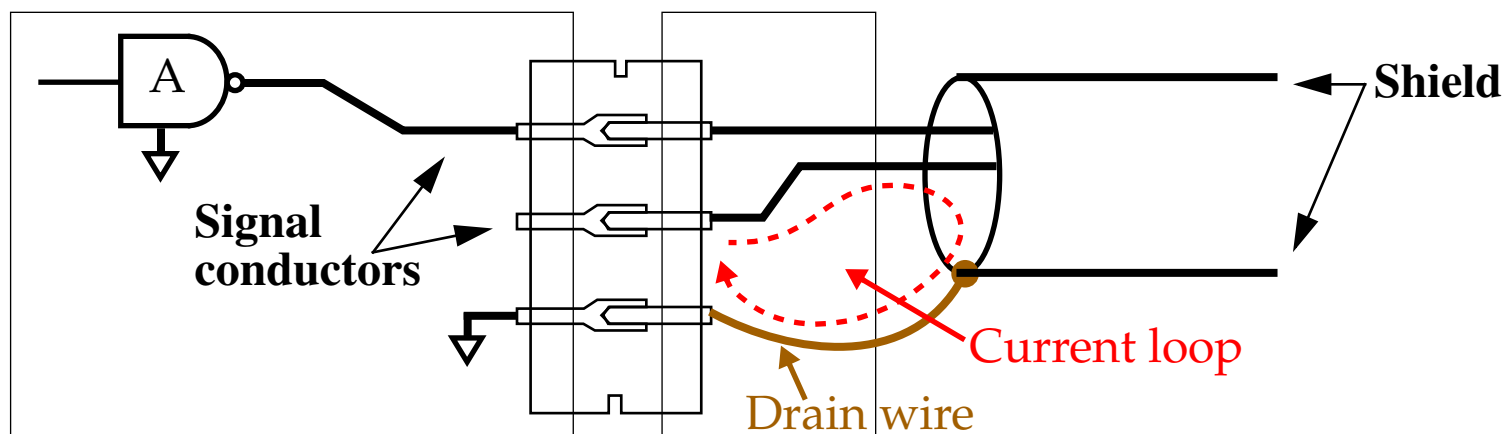
**Fixing EMI Problems with External Connections**

Return currents distribute evenly around the shield and tightly surround the inner conductor, virtually eliminating radiation.

If follows that *crosstalk* between two shielded cables is virtually zero.

In contrast, crosstalk is large for multiple signal wires *within the same shield* because they share the same ground path.

At the end of the cable, a low-inductance path is needed for current from the shield onto the chassis ground.

Some manufacturers provide a *drain wire*, that is the same gauge as the conductors in the cable.

However, it provides a **poor ground** for high-speed digital circuits because of the current loop that is created (see figure).

Insist on a connector with a **metal shell** that mates with a wide, flat contact to connect to the chassis.

**Fixing EMI Problems with External Connections**

A *common mode choke* is usually applied as a patch to badly designed systems that fail FCC regulations.

To install one, wind the I/O cable several turns through a large magnetic core (near the connector).

Since normal signal currents go out and back through the cable conductors, the *net current* through the core is near zero and are unaffected.

For currents returning through another path, they pass in only one direction through the core and encounter the **full inductance** of the winding.

If the core inductance is *larger* than the natural inductance of other paths, the core reduces their magnitude.

**Special Connectors for High-speed Apps.**

AMP and Augat provide high-speed point-to-point connectors which incorporate *ground structures* internal to the connector.

The ground structures serve two functions.
- They provide low impedance signal return paths for low crosstalk.
- They **increase** the parasitic cap to ground of each pin, balancing it with the pin's *series inductance* (this minimizes signal distortion).

Text describes AMP Z-Pack and Augat point-to-point connectors and Teradyne's multidrop bus connector.

**Differential Signaling through a connector**

Differential signal deals with the signal return current problem by eliminating it (in contrast to providing a low impedance path).

Differential signaling sends two signals, instead of one, where the second signal is the inverse of the first.

**Differential Signaling through a Connector**

　　At the receiver, the two signals are compared by inspecting their *difference*.
　　　　This eliminates variations in the local reference voltages on both sides.

　　The **return current** for the first signal is *positive* while it is *negative* for the second, thereby eliminating it.
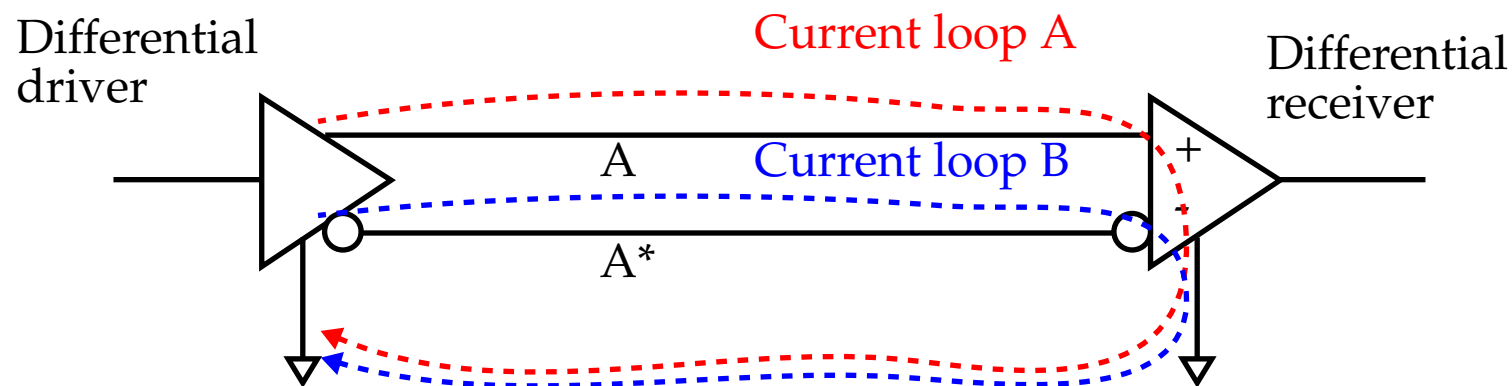


**Return paths are identical, if exactly opposite, they cancel.**

　　However, imbalances in the two transmitted signals will cause a return signal current called a **common mode current**.

　　In well designed systems, the common mode current is a factor of 100 less than the primary current.

**Differential Signaling through a Connector**

Keep differential signals on adjacent pins in the connector and close together on the board.

Formula for estimating the amount of *current imbalance,* as a fraction of the signal current, when one trace is slightly longer than the other:

$$\text{Imbalance fraction} = \frac{T_p X}{T_{10\text{-}90}}$$

where $T_p$ = propagation delay of the media (ps/in.)

$X$ = length difference between traces (in.)

$T_{10\text{-}90}$ is the rise time of the signals (ps)

For example, assume FR-4 board and 500 ps signals.

Assume one signal diverts by 0.3 in. to miss a via.

$$\text{Imbalance fraction} = \frac{(180)(0.3)}{500} = 0.108$$

An increase from approximately 1% to 10%.

**Differential Signaling through a Connector**

> You don't need to worry about crosstalk in a differential pair because the crosstalk correlates and produces only small interference.

> Therefore, the traces can be routed closer together than normal traces.