Nonideality of Ground

Introduction

Ground is often considered an ideal zero-volt reference and a return path for current. In a real circuit, however, ground conductors have nonzero impedance, so current flowing through them can create voltage differences. Stray currents travel through non-superconducting material making voltages rise. Changes in ground potential can contribute to noise, instability, or other parasitic effects in a system. Every circuit is unique and grounding paths are different for every device on the system's board. This application note introduces ground-current paths and explains how they affect the assumption that ground remains at zero volts throughout a circuit.

Contents

1. Ground Current and Return Paths . . . 1
1.1 Ground is a Nonideal Reference . . . 1
1.2 Power Supply Bypassing and Ground Connections . . . 1
1.3 Ground-Plane Return Current Paths . . . 2
1.4 Reducing Crosstalk Between Return Paths . . . 3
2. Revision History . . . 3

1. Ground Current and Return Paths

Circuits are complete when current has a complete path to travel (that is why a switch can be placed anywhere along that path to interrupt flow and function). The power supply creates a potential difference, a push, for the current if a path exists for it to travel. In a single-supply system, the positive supply connection must be minimized and isolated. To filter the power supply voltage in every critical chip, add bypass capacitors with multiple values and types. Hook a ground pin on the IC to a grounded wire or ground plane.

1.1 Ground is a Nonideal Reference

A common method for tracking down a problem is to probe important nodes in the circuit with a digital multimeter. If that does not solve the problem, probe the ground in a different locations. The ground in a system is like the ground found in nature with a variety of materials from sand, clay, soil, and types of rock. The consistency and structure of the materials affects how things travel through the ground choosing the path of least resistance. They naturally avoid or travel around obstacles in their path.

In circuits, many factors can affect flow in the ground plane. For example, the purity of the metal composing the plane and the consistency applied to the printed circuit board (PCB). Also, the routes connecting to or through the ground plane can affect flow. There are currents from other ICs making their way through ground to the power supply.

1.2 Power Supply Bypassing and Ground Connections

Placing bypass capacitors as close to the IC as possible, provides a high-frequency path to short any high frequencies that can exist or are gathered on the power supply line. A copper wire is a fine dipole antenna picking strong frequencies depending on the length of the trace and/or wire. Probe with an oscilloscope when referring to the placement of bypass capacitors. This process identifies not only internal frequencies, but also signals from local radio stations or wireless transmissions. These are the signals that couple-in through longer traces and disrupt the system operations. Signals exist on power supply lines and circulate in the ground.

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Figure 1 shows an example of bypass capacitor placement. The SOT-23 package pads in the center holds an op amp. There is a bypass capacitor connected on each of the dual supply pins. The opposite sides of the capacitors are connected to ground. The ground connection is not a long wire and eventually connecting to the ground plane. Instead, a large rectangle of top layer metal allows high-frequency currents to easily coast through two nearby routes to the ground plane.

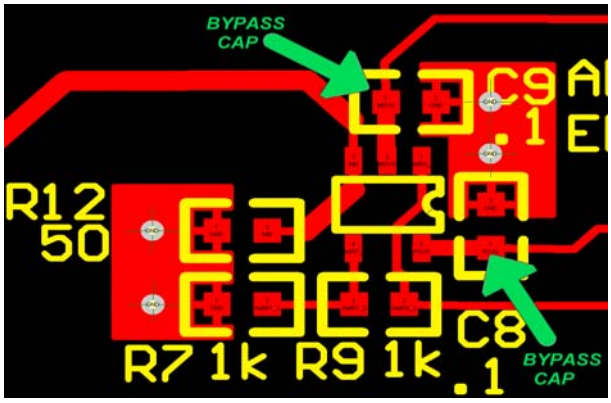


Figure 1. Location of Bypass Capacitors in a Layout of an Op Amp in a SOT-23 Package

1.3 Ground-Plane Return Current Paths

The unwanted signals do not disappear when reaching the ground plane, they continue to travel through the ground plane. Signals can couple into other signals in the system and affect more than just the IC with the long trace. To see how the current travels, refer to Figure 2. The op amp layout in Figure 1 is duplicated twice on the inputs of the circuit in Figure 2. Follow the current through the ground connection highlighted as a common connection between the bypass capacitors in Figure 1. Most of the current takes a direct path to the ground pins of the input connector. Observe how the density of the current spreads. It travels in a wider arc than expected. Superimpose the signal paths through every other ground route back to the connector grounds. This is how signals from one IC couple to another, and how interference signals can couple into every part of the system.

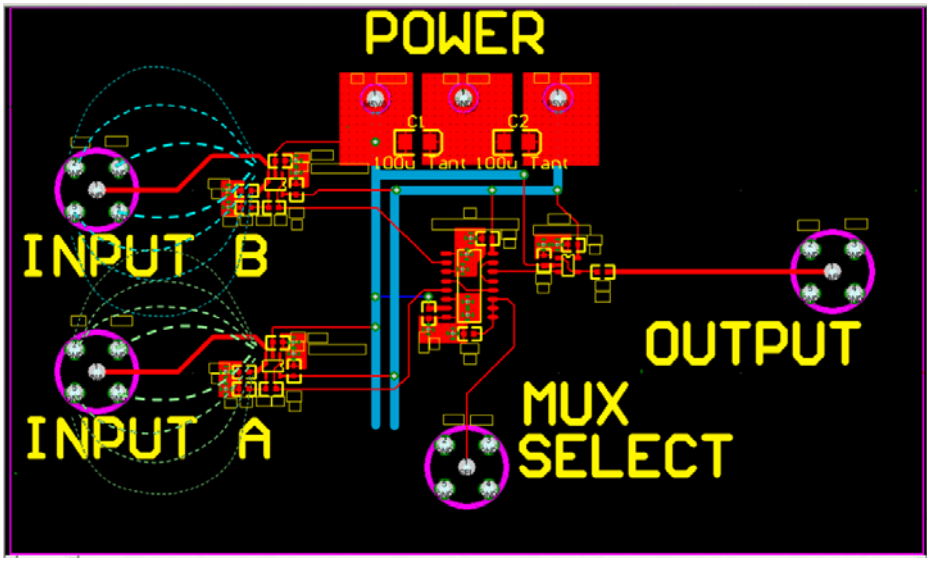


Figure 2. PCB Layout with Two Inputs to Two Separate Op Amps Feeding a Multiplexer

The green dashed lines show an example path that signals take through the ground plane back to the ground pins of the input connector. The longer the green dashes, the higher the concentration of ground current.

1.4 Reducing Crosstalk Between Return Paths

Two characteristics affect the spreading of the current and the shape of the return path. The first is distance. Making smaller consumer products helps with this aspect. However, as the PCBs become smaller, the devices get closer together. Distance is reduced, but now the multiple ground return paths are closer together. When the fringes of current overlap, the signals intertwine.

Keep high-frequency circuitry space-optimized. Isolate these devices with metal traces or cuts in ground planes. Figure 3 shows an example. The return current of input A does not overlap with the return current of input B. Knowing the nonideal nature of ground allows to improve the operation of the system. A plane with cuts to guide the return current works better than a full ground plane. This improvement is not possible assuming ground is ideal.

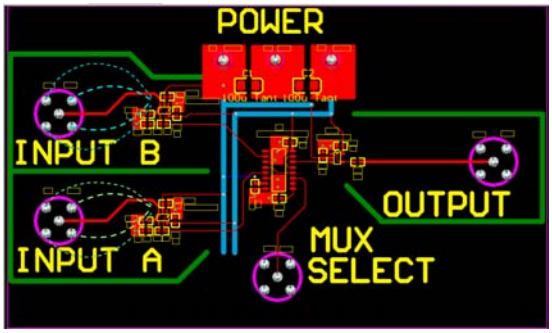


Figure 3. Space-Optimized Circuitry

Cutouts in the ground plane eliminate any crosstalk between the return ground paths of input A and input B.

2. Revision History

Revision	Date	Description
1.00	Nov 11, 2026	▪ Applied the latest template ▪ Added Revision History section
0.00	Mar 5, 2005	Initial release

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Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

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