

GUIDELINES FOR THE MAX5977'S CRITICAL COMPONENT PLACEMENT AND ROUTING

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Abstract: This application note presents guidelines for the placement and routing of the most critical components and traces in a typical design for the MAX5977 high-performance, hot-swap, electronic fuse, high-side current-sense controller.

Introduction

The **MAX5977A** is a versatile, high-performance hot-swap controller with electronic fuse, and high-side current-sense output. Proper component placement and routing are critical in achieving the MAX5977's full performance. Here, we discuss the benefits and inadequacies of specific layout/placement techniques.

MAX5977 Application Diagram and Operation

Review the critical nodes in the application diagram to better understand the operation and layout requirements of the MAX5977. See **Figure 1**. Standard layout techniques can be used for the traces not shown.

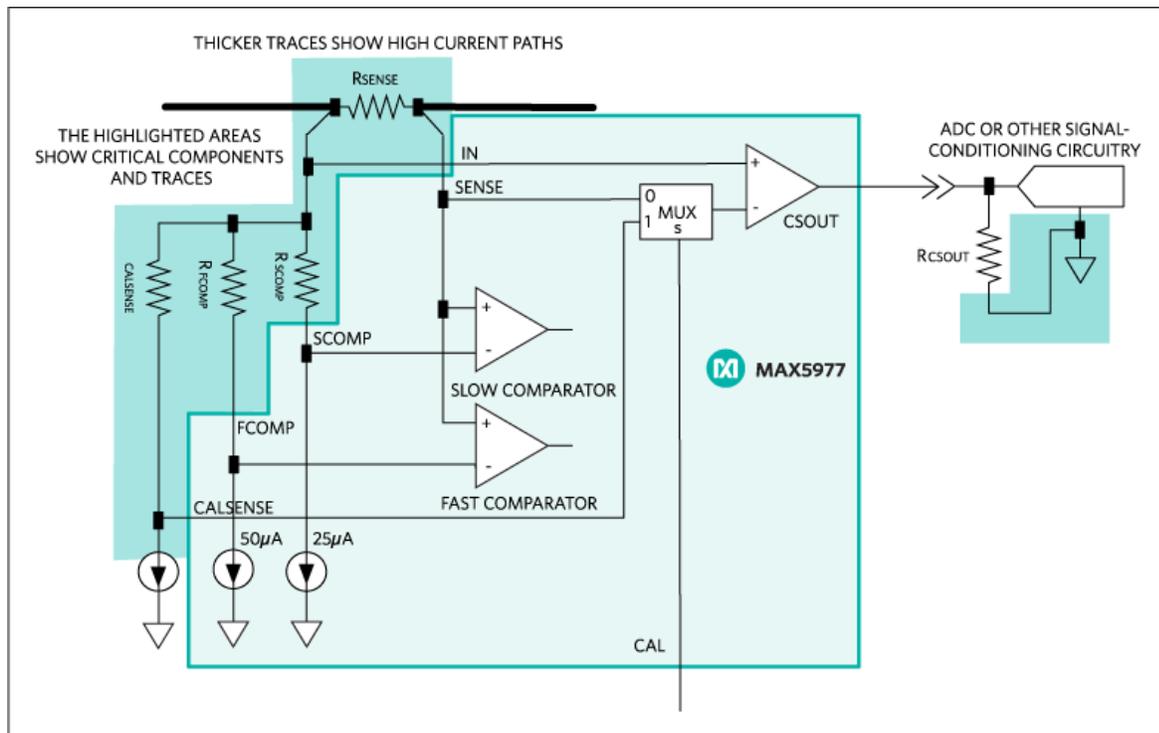


Figure 1. Applications diagram showing the critical components and traces for a MAX5977 circuit.

The circuit-breaker function compares the voltage across R_{SENSE} to the voltages across R_{SCOMP} and R_{FCOMP} . See **Figure 2**. When the voltage across R_{SENSE} exceeds the voltage across either R_{SCOMP} or R_{FCOMP} , the circuit breaker will trip. The voltages being compared will typically be in the 25mV to 100mV range. Improper component placement and layout can result in nuisance trips or failure to trip under some fault conditions.

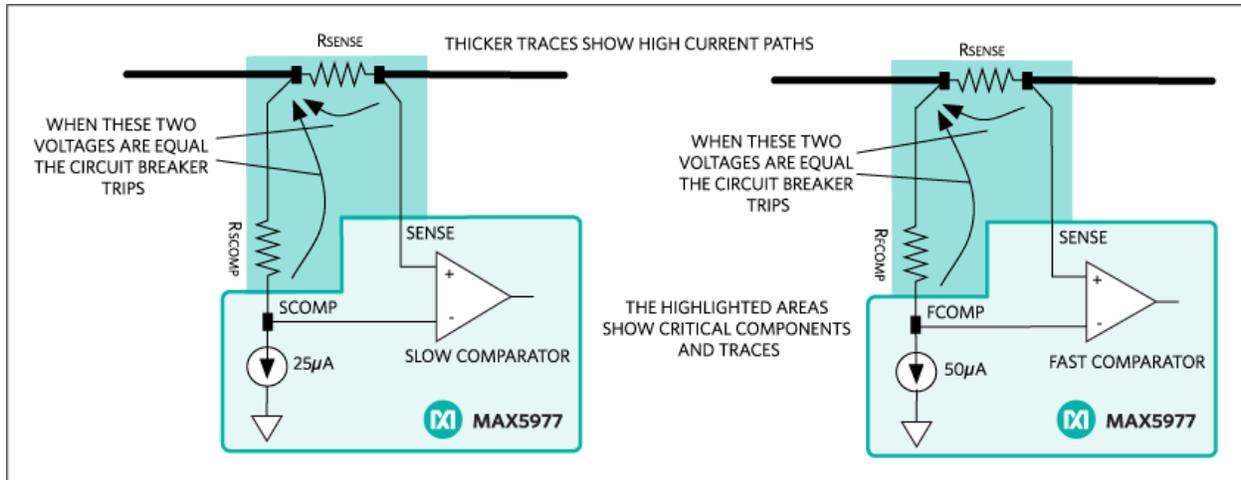


Figure 2. Simplified applications diagram of the MAX5977 fast and slow circuit-breaker functions.

The MAX5977's current reporting senses the voltage across R_{SENSE} through the IN and SENSE pins. See Figure 3. Internally, a transimpedance amplifier with a gain of $2500\mu S$ outputs a current on the CSOUT pin. An external resistor, R_{CSOUT} , converts this current into a voltage and, along with R_{SENSE} , sets the overall gain of the circuit. Similar to the circuit-breaker function, the voltage measured across R_{SENSE} is quite small, typically ranging from a couple of millivolts to 50mV. Improper placement or routing of the components shown in Figure 3 results in reduced accuracy across R_{CSOUT} .

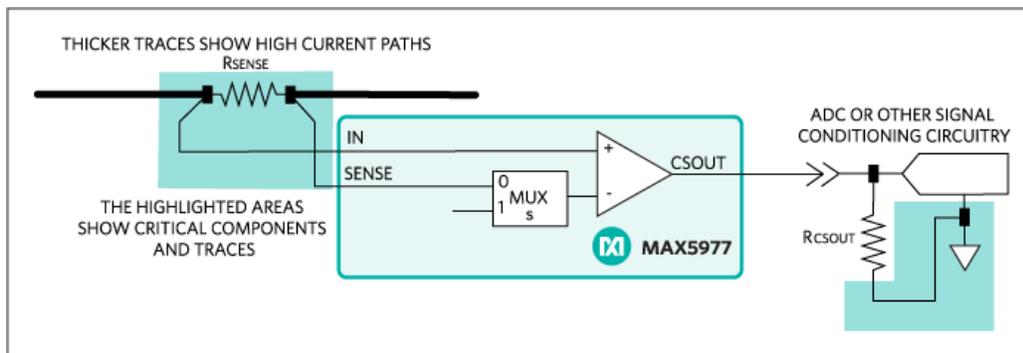


Figure 3. Simplified applications diagram for the MAX5977 current-reporting function.

The CALSENSE pin allows for a single-point calibration of the current reporting. See Figure 4. An external current source generates a known voltage across $R_{CALSENSE}$. This calibration voltage is multiplexed into an external ADC through the CAL pin. The calibration voltage will typically be in the 25mV to 50mV range. Improper placement and routing will cause errors during calibration and adversely affect all future current measurements.

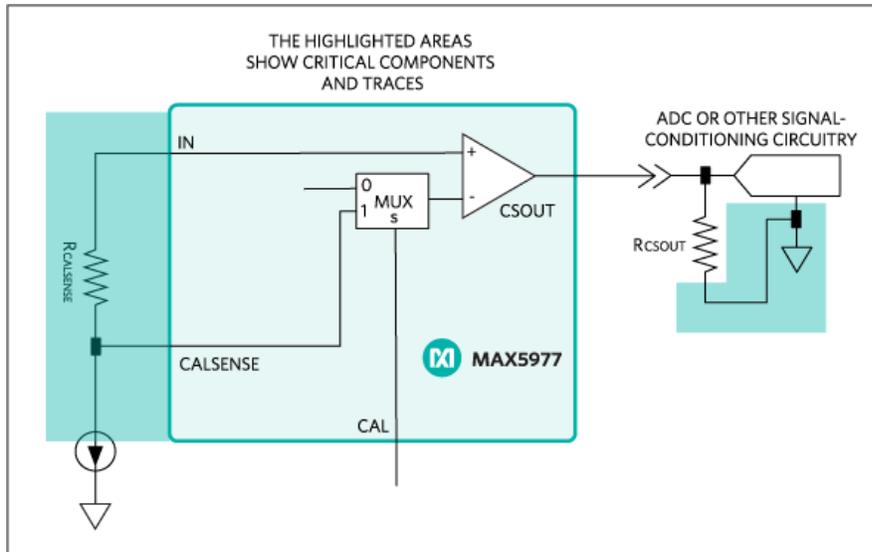


Figure 4. Simplified applications diagram showing the circuitry for single-point calibration of the current reporting.

Layout Guidelines

This section includes rough guidelines for proper placement and routing. These guidelines are not hard-and-fast rules, but provide a framework to help maximize the performance of the MAX5977. While proper placement and routing are always good ideas, circuits with higher R_{SENSE} values are less susceptible to errors. As such, circuits with high R_{SENSE} values can take some liberties without adversely affecting performance. Conversely, lower R_{SENSE} values need to adhere more strictly to the suggested guidelines.

R_{SENSE} Connections

- Load current carrying traces that connect to R_{SENSE} should be connected to the ends of R_{SENSE} and not the sides. The width of these traces should be roughly the width of the pads at the connection point. See Figure 5. Proper connections of these traces prevent uneven current densities, and therefore, voltage differences across the pads.

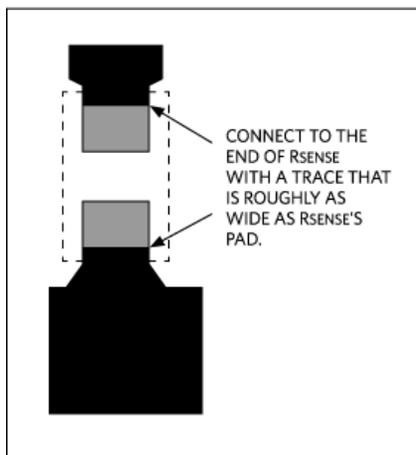


Figure 5. Connect the high-current traces to the ends of R_{SENSE} and not the sides. Keep the trace widths roughly equal to the pad widths at the points of connection.

- A four- (or six-) terminal sense resistor is recommended when using lower value resistances. If a two-terminal sense resistor is used, connect the voltage-sensing leads to R_{SENSE} with a kelvin connection. See Figure 6.

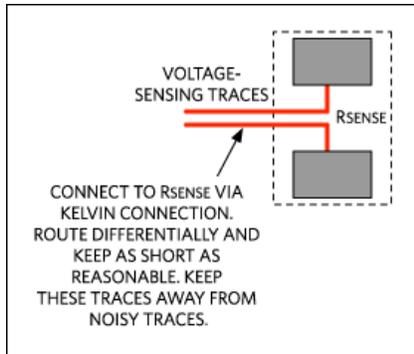


Figure 6. Diagram showing a kelvin connection on a two-terminal R_{SENSE} .

- Differentially route the voltage-sensing leads connected to R_{SENSE} as long as possible and keep them as short as possible.
- Keep the voltage-sensing leads away from any noisy traces.

$R_{CALSENSE}$, R_{SCOMP} , and R_{FCOMP}

- $R_{CALSENSE}$ (if used), R_{SCOMP} , and R_{FCOMP} should be placed as close as possible to the MAX5977. Keep the traces from these resistors to the MAX5977 as short as possible.
- The connection from $R_{CALSENSE}$, R_{SCOMP} , and R_{FCOMP} to R_{SENSE} should be made directly to the differentially routed kelvin-sensed traces. See Figure 7.

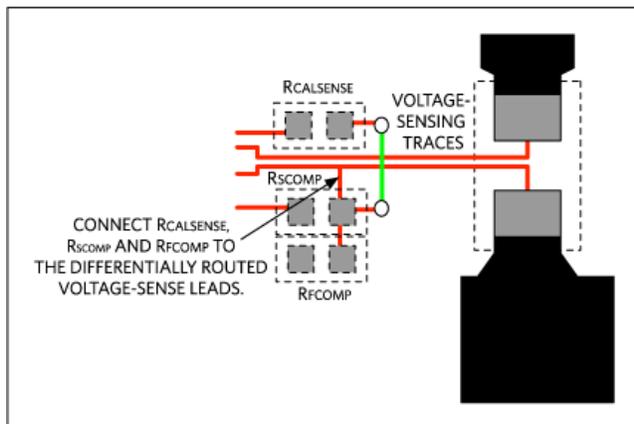


Figure 7. Connect $R_{CALSENSE}$, R_{SCOMP} , and R_{FCOMP} to the differentially routed voltage-sense leads.

- Keep $R_{CALSENSE}$, R_{SCOMP} , and R_{FCOMP} , and their associated traces away from noisy traces.

R_{CSOUT}

- Less critical, but also important, is the placement and grounding of R_{CSOUT} . R_{CSOUT} is usually connected to an ADC or other signal-conditioning circuitry (we will use an ADC in this case). This ADC can be located a significant distance from the MAX5977 or, in some cases, can be located on a different board. Ground differences between the MAX5977 and the ADC can reduce measurement accuracy. Therefore, it is important to place and ground R_{CSOUT} next to the ADC. See Figure 8.

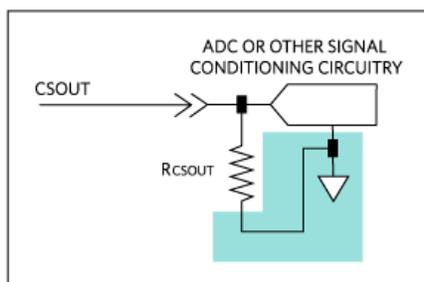


Figure 8. Ground R_{CSOUT} directly at the ADC or signal-conditioning circuitry. This is especially important if the ADC or signal-conditioning circuitry is on a different board than the MAX5977.

- Keep the CSOUT trace away from any noisy traces.

Grounding

- The MAX5977 has two different grounds: AGND and GND. AGND (pin 3 and the exposed pad) is connected to the precision signals inside the MAX5977. The current sources connected to FCOMP and SCOMP are both grounded to AGND, along with other precision signals as shown in **Figure 9**. GND (pin 13) is used for the digital signals and the gate pulldown driver also shown in **Figure 9**.

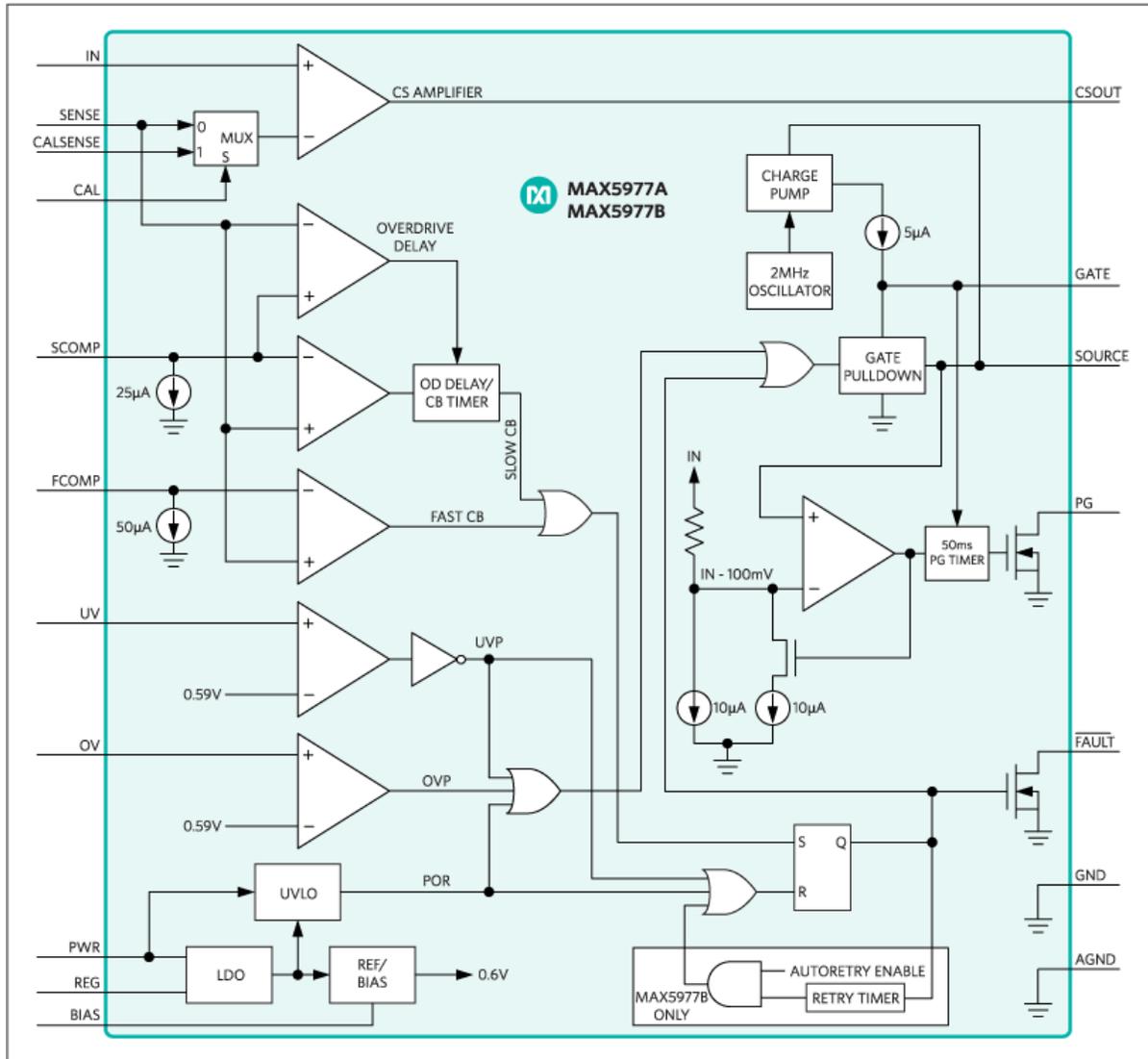


Figure 9. Block Diagram of the MAX5977. AGND (pin 3 and the exposed pad) is used for the precision or low-noise circuitry. GND (pin 13) is used for the digital circuitry and the gate pulldown.

- Connect pin 3 and the exposed pad, both AGND, together through a short trace as shown in **Figure 10**. Connect the exposed pad to the ground plane with one or more vias. Note that the MAX5977's power dissipation will be significantly less than 100mW. It is not necessary to have a large number of vias connected to the exposed pad for thermal reasons.
- Connect GND (pin 13) directly to the ground plane with its own via as show in **Figure 10**.

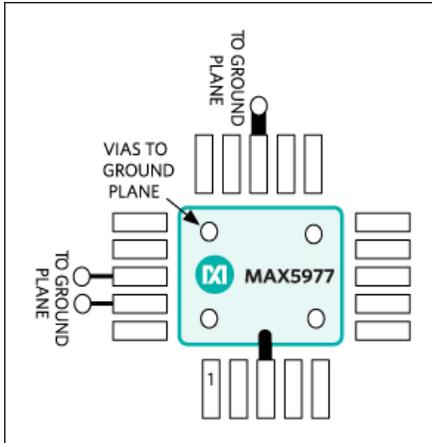


Figure 10. Connect pin 3 (AGND) directly to the exposed pad. Connect the exposed pad to the ground plane with a via or vias. Connect the GND pin (pin 13) to the ground plane with a via.

GATE and SOURCE

- When an overcurrent event occurs, the MAX5977 turns off the external MOSFET by shorting the FET's gate and source. In the case of a hard short, it is important to turn the external FET off as quickly as possible. Quickly turning off the FET prevents hard shorts from propagating to the bus. The MAX5977 has a very fast 200ns typical response time and a 500mA shorting current. The high shorting current is required to quickly discharge the external FET's gate-to-source capacitance (CGS). Properly route the GATE and SOURCE to keep the FET turn-off time as short as possible.
- The traces connecting the GATE and SOURCE pins to the external FET should be as short as reasonable to minimize parasitic inductance. Thicker traces should be used to also minimize inductance and to support the 500mA discharge current. See **Figure 11**.

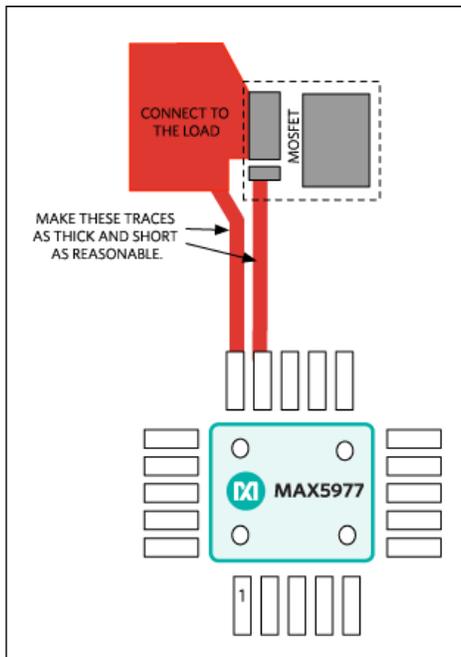


Figure 11. Connect the GATE and SOURCE pins to the external FET with short and wide traces. This keeps the turn-off time short by minimizing trace inductance.

Putting it All Together

Figure 12 shows one possible layout with all of the above suggestions along with other guidelines.

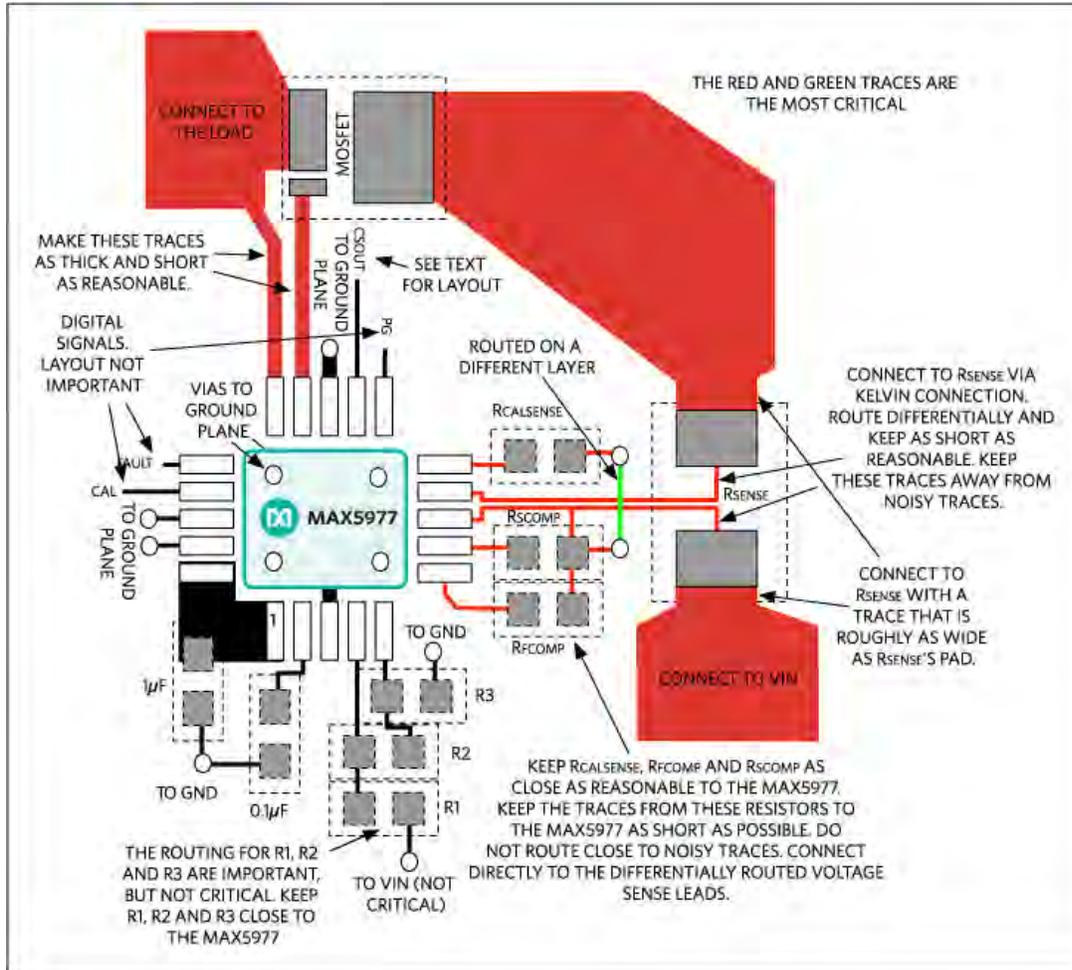


Figure 12. Summary of placement and routing guidelines for the MAX5977.

Effect of Poor Routing

Assume in Figure 13 that R_{SENSE} is a 2010-sized 2.5mΩ resistor with 0.12in wide pad. Let's also assume that the sensing points are incorrectly connected 0.12in away from the pads of the sense resistor.

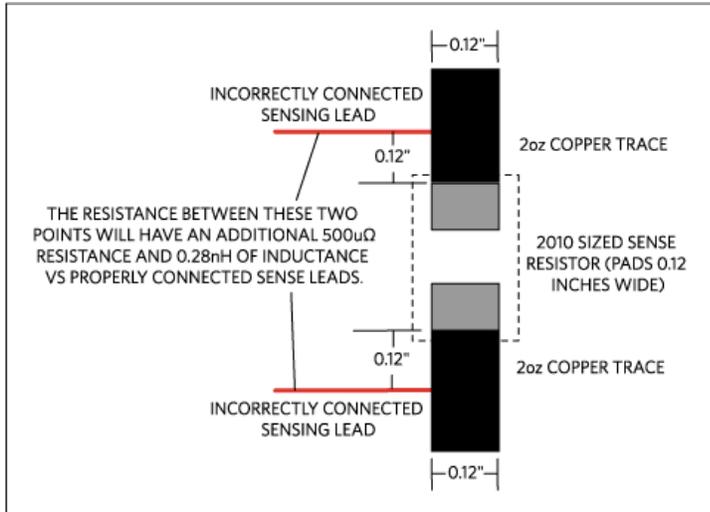


Figure 13. Improperly connecting to the sense resistor can lead to significant errors.

Each 0.12in × 0.12in trace between the sensing point and R_{SENSE} will add roughly $250\mu\Omega$ of resistance and 0.14nH of inductance (Note 1). **Figure 14** shows the equivalent circuit.

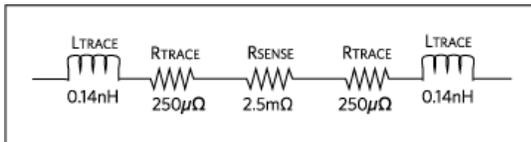


Figure 14. Equivalent circuit of the improperly connected R_{SENSE} shown in Figure 13.

The current reporting and slow-trip circuit breaker have filtering and should not be affected by the added inductance. However, the added resistance of $500\mu\Omega$ will create a +20% error with respect to the $2.5m\Omega$ sense resistor. For reference, the data-sheet current reporting error is $\pm 4.1\%$ worst case (Note 2). This small routing mistake has increased the overall error from roughly $\pm 4\%$ to +16%/+24%. A full 4x to 6x increase in error!

Both the added resistance and inductance impact the fast-trip comparator since it lacks filtering. A $10A/\mu s$ current transient through R_{SENSE} will create an additional 2.8mV error on top of the 20% resistance error. Faster slew rates will create proportionally larger errors.

The errors introduced into the slow and fast circuit breaker thresholds can result in the MAX5977 turning off the downstream circuitry unnecessarily. Depending on the severity of these nuisance trips, the design could be rendered unusable.

Examples of Bad Placement and Routing

Figure 15 shows an example of bad placement and routing.

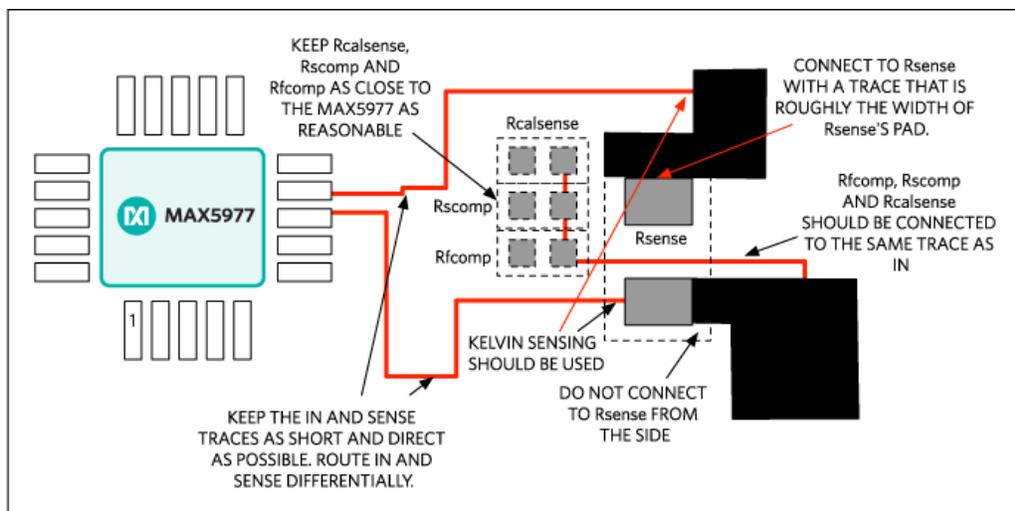


Figure 15. Example of incorrect placement and routing on a MAX5977 circuit.

Notes

Note 1

- Assume 5 mil spacing between the trace and ground plane.
- For simplicity, the errors introduced by the pads themselves have been ignored.

Note 2

- $2\text{mV} < (V_{\text{IN}} - V_{\text{SENSE}}) < 25\text{mV}$ (-40°C to $+85^{\circ}\text{C}$),
- $\% \text{ error} = (I_{\text{CSOUT}} - (V_{\text{IN}} - V_{\text{SENSE}}) \times 0.0025) / (25\text{mV} \times 0.0025)$

Related Parts

MAX5977A	1V to 16V, Single-Channel, Hot-Swap Controllers with Precision Current-Sensing Output	Free Samples
MAX5977B	1V to 16V, Single-Channel, Hot-Swap Controllers with Precision Current-Sensing Output	Free Samples

More Information

For Technical Support: <http://www.maximintegrated.com/en/support>

For Samples: <http://www.maximintegrated.com/en/samples>

Other Questions and Comments: <http://www.maximintegrated.com/en/contact>

Application Note 5882: <http://www.maximintegrated.com/en/an5882>

APPLICATION NOTE 5882, AN5882, AN 5882, APP5882, Appnote5882, Appnote 5882

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