Using Current Sensing Resistors with Hot Swap Controllers and Current Mode Voltage Regulators

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Introduction

Current mode switching regulators and Hot Swap controllers—such as the LTC1622 regulator and the LTC4210 Hot Swap controller—use a sub-50mV voltage across a sense resistor in a high-current (Amps to tens of Amps) path to control the current. Failure to properly Kelvin sense the current across the sense resistor is the most common cause of circuit malfunction in current mode power supplies and Hot Swap circuits.

Problems usually arise when the layout of the circuit does not take into account the high currents and small resistances involved. For instance, a low value precision sense resistor in the mΩ range is typically used to measure current in Hot Swap controllers and current mode switching regulators. A typical 0.003Ω, 1W sense resistor in a 2512 surface mount package is only 0.125 inches wide and 0.250 inches long. Consider the same length copper trace with a typical thickness of 0.0014 inches (1oz copper laminate). The resistance across a quarter inch of copper trace is 0.0009Ω at room temperature. Adding a quarter inch of copper to the measurement path induces a sense measurement error of 0.0009Ω/0.003Ω, or 30%! The circuit simply wouldn't work, because it would prematurely trip the current limit.

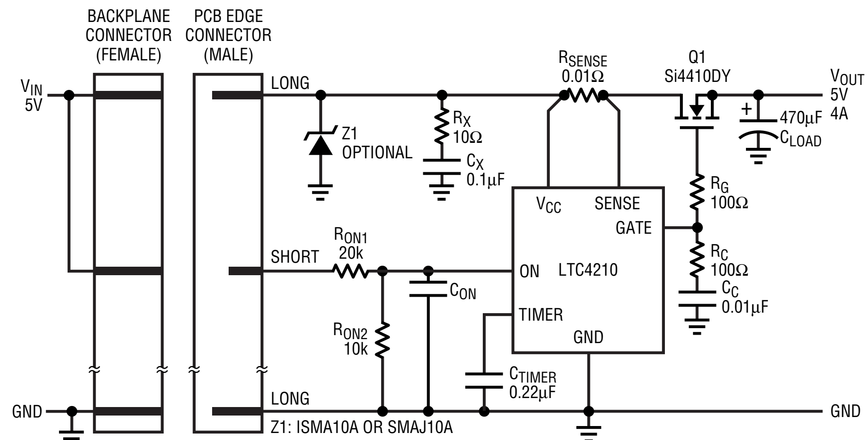

Figure 1. This Hot Swap circuit controls current by sensing the voltage across a small value resistor, R_{SENSE}—a method called Kelvin sensing. The layout of this circuit is important for accurate current sensing.

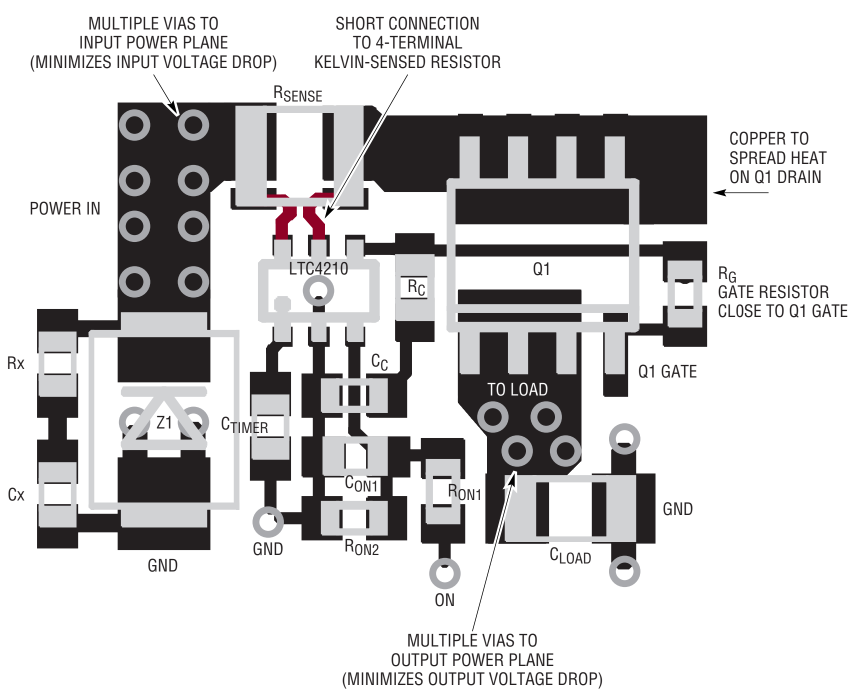

Figure 2. Example of proper Kelvin sense connections. The important features shown here are: short connections to terminals of Kelvin sense resistor, expanded copper to heat sink Q1, and multiple vias connecting power in and the load to pass FET Q1 for minimal voltage drop.

Pitfalls Lie in the Layout

The printed circuit board layout process is full of pitfalls, especially when an auto-router is part of the process. When one terminal of the sense resistor is the power plane, the sense pin on the IC and the terminal of the current sense resistor can end up connected across a significant span of copper, with uncontrolled current flow from other circuits on the board flowing between the resistor and IC connections. Excess voltage drop and noise coupling are a prescription for circuit malfunction. With many designs outsourced to PCB design houses, the circuit designer faces a formidable task of controlling the layout.

What can be done?

Several resistor manufacturers[1] now sell 4-terminal Kelvin current sense

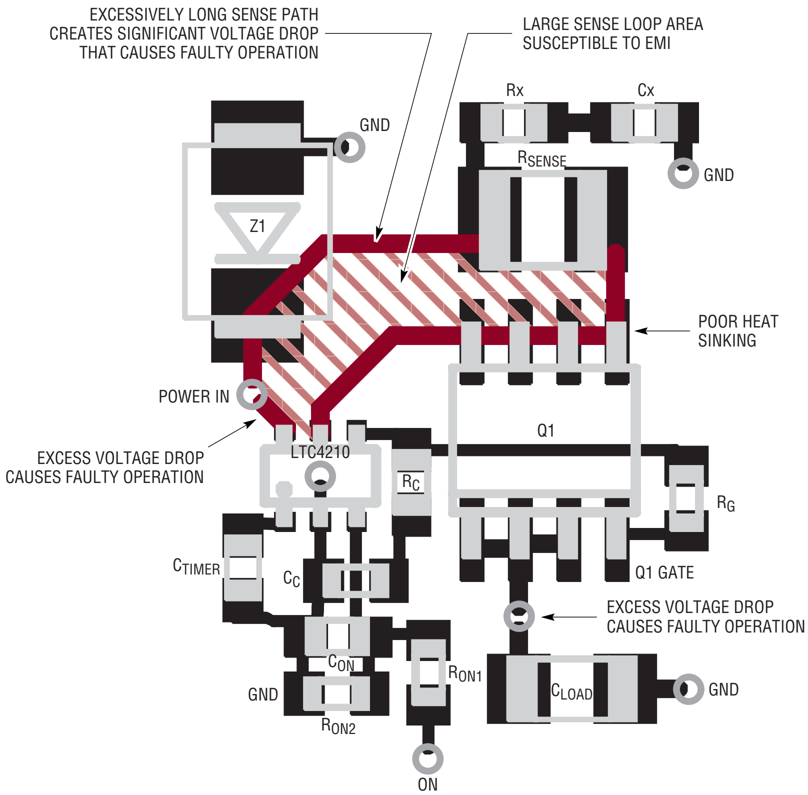

Figure 3. Example of layout that can reduce the accuracy of Kelvin sensing. The problems shown here include: excess length of thin high resistance track in series with sense resistor, inadequate heat sinking on Q1, and an insufficient number of vias for input power and output load connections.

resistors. The use of a 4-terminal resistor forces the auto router to make a correct Kelvin connection to the current sense resistor. But this alone is not enough. High speed switch mode power supplies have a high dI/dt path that can inductively couple with the sense loop and also cause malfunction. To minimize inductive coupling, the Kelvin sense circuit must exhibit minimal loop area.

Setting the Proper Constraints in an Auto-Router

Set the auto-router constraints to route the Kelvin sense connections as a differential pair to keep the connections side by side and close together. Use maximum length constraints to prevent the connections from wandering too far from the direct path. Constrain the connection to the component layer on a multi-layer PC board to prevent unwanted vias in this critical connection path. Although the proper choice of sense resistor and layout constraints can mitigate many of the PCB layout pitfalls, in the end it's up to the designer to carefully check the layout.

Notes

[1] Some sources of 4-terminal Kelvin sensed resistors include:
- www.Caddock.com
- www.IMS-Resistors.com
- www.IRCtt.com
- www.Vishay.com

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that power is delivered when diagonal switches are on. It differs in that during the free-wheeling portion of the switching cycle, either the top or bottom switches of the bridge remain on. This provides for recovery of parasitic energy and zero-voltage turn-on transitions for the primary switches. The LTC3722-1 can be configured to provide adaptive (with programmable time-out) or fixed delay control for zero voltage switching operation. In adaptive DirectSense™ mode, the turn-on timing adjusts automatically by sensing the transition voltages on the bridge legs, eliminating external trims. This provides accurate zero voltage transition timing with changes in input voltage, output load and circuit parasitics. Fixed (or manual) delay control is also available, which allows for fixed transition delays or even custom dynamic timing schemes. The LTC3722-1 also features adjustable synchronous rectifier timing.

Conclusion

The new LTC3722-1 current-mode controller provides a wealth of features targeted at high power isolated full bridge applications, including flexible timing control, synchronous rectifier outputs, under-voltage lockout, programmable slope compensation and current mode leading edge blanking.

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Summary

The LTC4302-1/LTC4302-2 addressable 2-wire bus buffers ease the practical issues associated with complex 2-wire bus systems. They allow I/O cards to be hot-plugged into live systems and break one large capacitive bus into several smaller ones, while still passing the SDA and SCL signals to every device in the system. They can also connect and disconnect different bus segments at different times, providing nested addressing capability and easing the debugging process during stuck low situations.