Maxim > Design Support > Technical Documents > Application Notes > Amplifier and Comparator Circuits > APP 3328
Maxim > Design Support > Technical Documents > Application Notes > Circuit Protection > APP 3328
Maxim > Design Support > Technical Documents > Application Notes > Hot-Swap and Power Switching Circuits > APP 3328

Keywords: hot-swap controllers, inrush current, circuit protection, short-circuit current

APPLICATION NOTE 3328

Minimize Short-Circuit Current Pulse in Hot-Swap Controller

Sep 20, 2004

Abstract: Because of internal circuit-breaker delay and limited MOS-gate pulldown current, many hot-swap controllers do not limit current during the first 10µs to 50µs following a shorted output. The result can be a brief flow of several hundred amperes. A simple external circuit counters this problem by minimizing the initial current spike and terminating the short circuit within 200ns to 500ns.

A typical +12V, 6A, hot-swap controller circuit (**Figure 1**) contains (like many others) slow and fast comparators with trip thresholds of 50mV and 200mV. The 6mΩ Sense resistor (RS) allows a nominal slow-comparator trip at 8.3A for overload conditions, and a fast-comparator trip at 33.3A for short circuits.

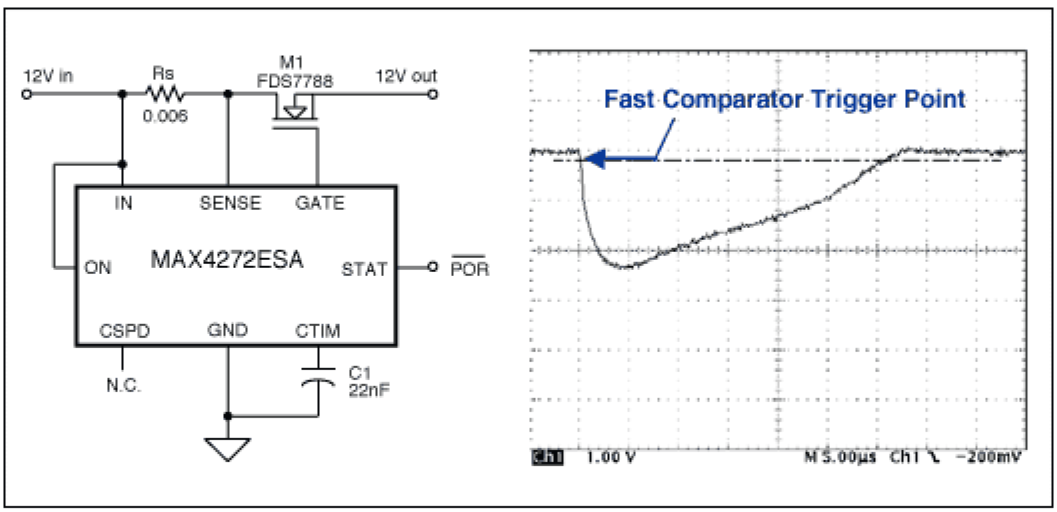

Figure 1. Typical hot-swap controller circuit exhibits a 30ms short-circuit current pulse of 400A peak.

The initial short-circuit current spike is limited only by circuit resistances¹ during a period that includes the fast-comparator delay and the 30µs it takes to complete interruption of the short circuit by discharging M1's gate capacitance. The waveform recorded during a short circuit indicates a peak current of 400A (due to 2.4Vpk across Rs), decreasing to 100A in 28µs.

The short-circuit current duration can be limited to ≤ 0.5ms by adding a Darlington pnp transistor (Q1) to speed the gate discharge (**Figure 2**). D1 allows the gate to charge normally at turn-on, but at turn-off the controller's 3mA gate-discharge current is directed to the base of Q1. Q1 then acts quickly to discharge the gate, in ≤ 100ns. Thus, the high-current portion of the short circuit is limited to slightly more than the fast-comparator's delay time of 350ns.

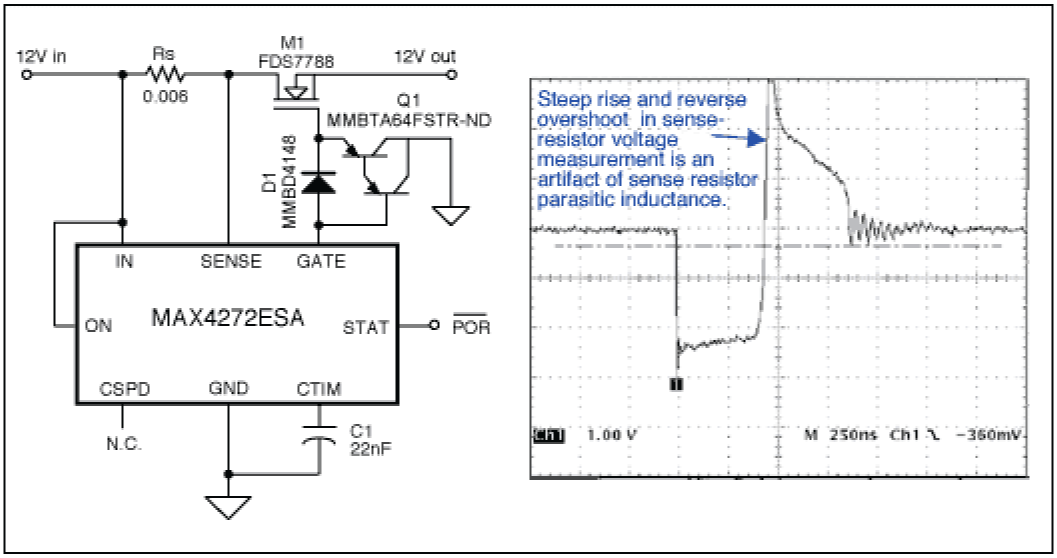

Figure 2. The addition of Q1 increases the gate-pulldown current, limiting the short-circuit current duration to less than 0.5ms.

The apparent reverse overshoot current and the steep rise seen in the waveforms of Figures 2 and 3 is created by parasitic series inductance in the sense resistor chip, and the leading-edge oscillation seen in **Figure 3** is an artifact introduced by the oscilloscope ground lead.

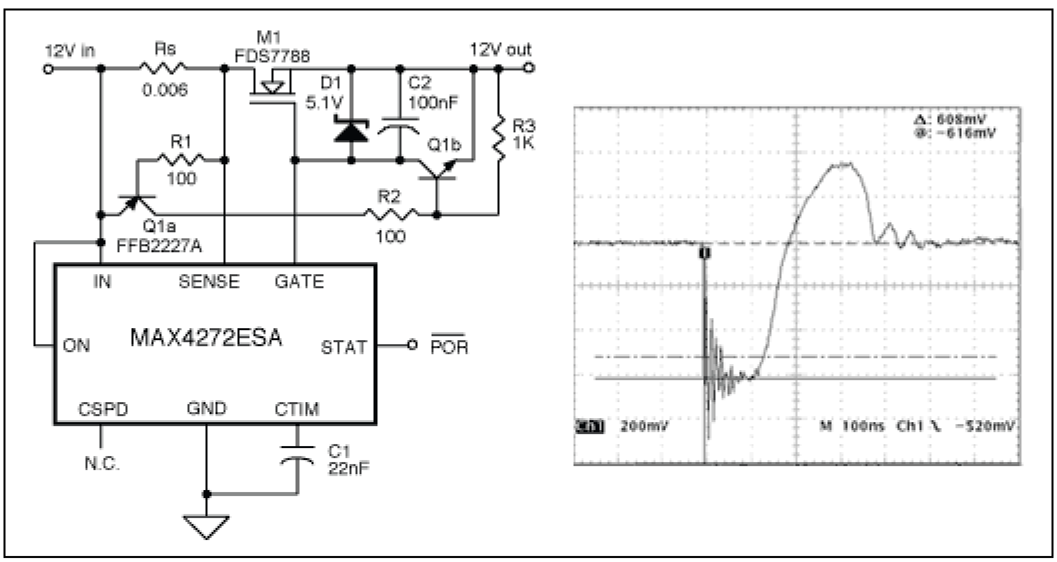

Figure 3. Hot-swap controller with fast limiting of short-circuit current peaks, and short-circuit waveform.

The circuit of Figure 3 can limit short-circuit current to ≈100A for < 200ns. The pnp transistor Q1a, which is triggered when the voltage across RS reaches ≈600mV, drives the npn transistor Q1b to quickly discharge M1's gate capacitance. Quick triggering of the pnp transistor is aided by the steep voltage waveform, which in turn is a result of parasitic inductance in the sense-resistor.

C2 is connected between the gate and source of M1 to reduce the positive transient step voltage applied to the gate during a short circuit. Zener diode D1 reduces $I_{D(ON)}$ by limiting V_{GS} to something less than the 7V available from the MAX4272. Although D1 is rated 5.1V when biased at 5mA, it limits V_{GS} to ≈3.4V in this circuit because only 100mA of gate-charging current (zener bias current) is available from the IC. The limited V_{GS} lowers $I_{D(ON)}$—at some expense to $R_{D(ON)}$—and allows a quicker turn off of M1. D1 and C2 can also be employed to some advantage in Figure 1 and Figure 2, to reduce $I_{D(ON)}$ during short circuits.

Either of the two circuits above can protect a backplane power source by minimizing the energy dissipated when a hot-swap-controlled circuit is shorted. The simpler circuit (Figure 2) dramatically shortens the short-circuit-current interval to somewhat less than 500ns, and the slightly more complex circuit (Figure 3) reduces the peak short-circuit current to 100A, as well as truncating the pulse width to less than 200ns. Either technique can be applied to most hot-swap controller circuits. Individual results vary[2] according to the impedance of the power source, the impedance of the short circuit, and (especially) the quality and attack time of the short circuit itself.

[1]Source resistance, short-circuit quality, value of RS, MOSFET's $R_{DS(ON)}$, and MOSFET's $I_{D(ON)}$.
[2]Note that it is inordinately difficult to achieve a repeatable low-resistance short circuit by manual manipulation of a shorting bar. Careful layout and low-ESR capacitors are required to create a power source with very low ESR.

This design idea appeared in the May 27, 2004 issue of *EDN*.

Related Parts		
MAX4272	3V to 12V, Current-Limiting, Hot Swap Controllers with Autoretry, DualSpeed/BiLevel Fault Protection	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 3328: http://www.maximintegrated.com/an3328
APPLICATION NOTE 3328, AN3328, AN 3328, APP3328, Appnote3328, Appnote 3328