Abstract: Use of a hot-swap controller IC provides inrush-current-limiting and circuit-breaker functions for medium to high-voltage circuit protection.

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Medium- and high-voltage systems that range from 9V to 72V often require one or more of the following circuit capabilities: hot-swap control, circuit-breaker fault protection, and inrush current limiting.

The circuit of Figure 1 provides inrush current limiting and a reliable circuit-breaker function for the load (C1 and R2), yet contains only a p-channel MOSFET, a hot-swap controller IC, and two optional resistors (R1 and R3). Adding a low-value resistor at the MOSFET drain provides an adjustable trip-point and improved accuracy over the operating temperature range (Figure 2).

Figure 1. Standard circuit-breaker application.
Figure 2. Adding a trip-point-adjust resistor (R4) to the circuit of Figure 1 improves its initial accuracy and accuracy over temperature.

For hot-swap applications, U1 limits the inrush current based on a typical gate-drive slew rate of 9V/mS. Inrush current is given by the equation \( I = \frac{C}{dV/dt} = CSR \), where \( C \) = load capacitance and \( SR \) is the slew rate, set by U1 at 9V/mS (typical). For a load capacitance of 100\( \mu \)F, the IC limits inrush current to approximately 0.9A.

U1’s circuit-breaker function uses an internal comparator and the MOSFET on-resistance \((R_{DS(on)})\) to sense a fault condition. \((R_{DS(on)})\) for Q1 is typically 52m\( \Omega \) and U1 has selectable circuit-breaker trip points (CB) of 300mV, 400mV, or 500mV. At the lowest trip point (300mV), the CB trip current at \( T_J = 25^\circ\text{C} \) is typically 5.77A.

The circuit breaker’s voltage-trip value is determined from the equation \( V_{CB} > (R_{DS(on)})I_{LOAD(MAX)} \), or \( V_{CB}/I_{LOAD(MAX)} > (R_{DS(on)}) \).

Suppose the desired limit is 2A. Using typical values,

\[
300\text{mV}/2\text{A} \approx 150\text{m}\Omega > (R_{DS(on)}).
\]

Instead of substituting another MOSFET with higher on-resistance, add a \( \approx 100\text{m}\Omega \) resistor in series with Q1 (i.e., R4 in Figure 2). Besides allowing adjustable circuit-breaker levels, R4 provides better circuit-breaker accuracy and improved stability over temperature. For example, \((R_{DS(on)})\) for Q1 is \( \approx 52\text{m}\Omega \) at \( T_J = 25^\circ\text{C} \) and \( \approx 130\text{m}\Omega \) at \( T_J = 125^\circ\text{C} \), a change of 150%. If you add a 100m\( \Omega \), 100ppm/\( ^\circ\text{C} \) resistor (which varies by 0.001\( \Omega \) from 25\( ^\circ\text{C} \) to 125\( ^\circ\text{C} \)), the combined variance from 25\( ^\circ\text{C} \) (152m\( \Omega \)) to 125\( ^\circ\text{C} \) (231m\( \Omega \)) is only 79\( \Omega \), which is 52%.

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