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APPLICATION NOTE 4245

Three Approaches to Creating Negative Low-Voltage Hot-Swap Circuits

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Abstract: This application note details three methods of creating negative low-voltage hot-swap circuit because ICs to perform this function are not generally available. Two methods operate in conjunction with positive-voltage supplies, while the third method is suitable for use with only a negative supply.

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Introduction

In addition to the usual array of positive-voltage supplies, many systems that need to be hot-plugged into a live backplane utilize at least a single -5V or -5.2V supply. There are numerous positive low-voltage hot-swap controllers for use in these applications; however, negative low-voltage controllers are rare to nearly nonexistent. Since the need for a negative low-voltage hot-swap circuit typically arises when a positive low-voltage hot-swap circuit is also in use, it is useful to create the negative-voltage circuit with the aid of a positive supply voltage.

This application note presents two circuits for implementing hot-swap control on dual +5V/-5.2V supplies. One employs a two-chip design using separate controllers for each channel, while the other uses a single controller IC for both channels. A third single-chip design is also presented for performing hot-swap on a single -5.2V supply. All three circuits provide the functions of plug-in hot-swap with startup delay and controlled inrush current, but only one circuit includes an overload-detection and circuit-breaker function.

The two-chip solution shown in **Figure 1** allows independent circuit-breaker action on both negative- and positive-voltage channels. The two single-chip circuits shown in **Figures 2** and **3** provide startup inrush-current control, but neither provides current-limiting or circuit-breaker functions for the negative-voltage channel.

Two-Chip Solution

The Figure 1 circuit provides full hot-swap control, including current-limit and circuit-breaker functions for both a +5V channel and a -5.2V channel. The circuit uses a MAX4272 positive low-voltage controller for the +5V channel. No negative low-voltage hot-swap controllers are available, so the circuit uses a MAX5900 negative high-voltage controller for the -5.2V channel. With the MAX5900's normal ground connection referenced to the +5V supply, the resultant +10.2V differential supply allows the MAX5900 to operate within its -9V to -100V operating range. The MAX5900 was selected specifically because of its low -9V minimum operating supply voltage. The MAX4272 is but one of many positive low-voltage

controllers that could be used, but was selected because of its full feature set in an 8-pin package.

Each channel is set for overload fault shutdown at approximately 1A with autorestart action after a fault condition. The MAX5900 utilizes the M2 MOSFET's $R_{DS(ON)}$ as the current-sense resistor, and the V_{SENSE} trip point is 200mV. Selecting M2 for $R_{DS(ON)}$ = 0.2Ω thus allows an approximate 1A overload trip point. Please refer to the individual data sheets for delay and timing information.
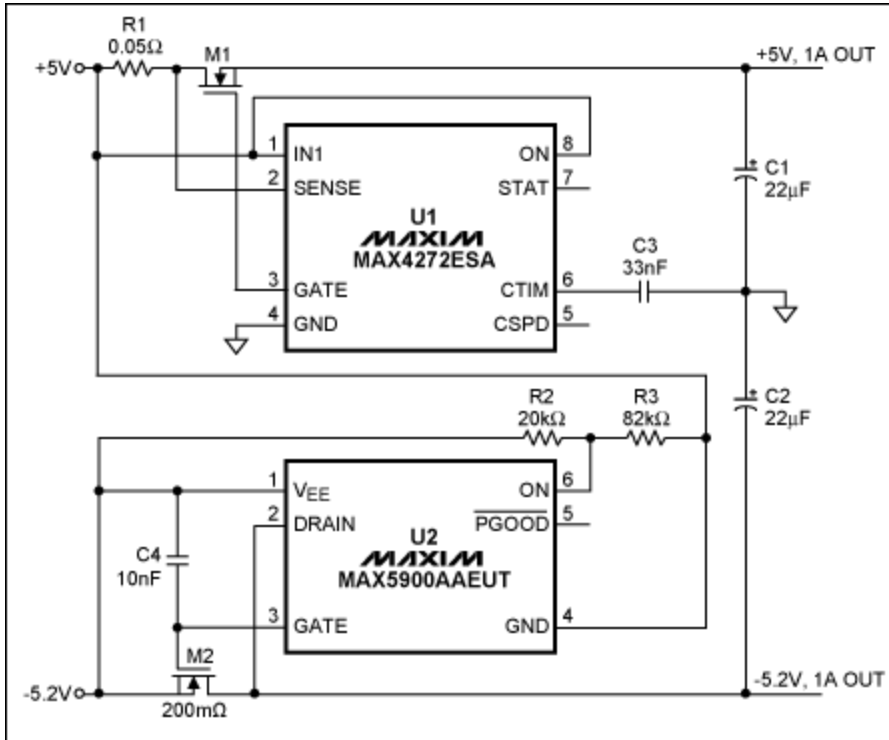

Figure 1. A two-chip approach to providing hot-swap control on positive and negative low-voltage supplies provides overload fault detection on both channels.

One-Chip Solution

The Figure 2 circuit provides current-limited, hot-swap startup control on both channels, but includes current-limit and circuit-breaker functions for only the +5V channel. This one-chip solution employs a single two-channel MAX5904 controller to control both the +5V and the -5.2V channels. The MAX5904 normally controls two positive-voltage channels; however, it is possible to control one positive- and one negative-voltage channel with the circuit as shown. The MAX5904 was selected because of its dual-channel capability and because of the few external components required.

With the following configuration, the MAX5904 treats the +5V channel as a +10.2V circuit with full circuit-breaker function, and it treats the -5.2V channel as if it were a +5.2V circuit.
- Connect the MAX5904's GND pin to -5.2V
- Connect the IN1 and SENSE1 pins to ground
- Connect the IN2 pin to +5V

When the MAX5904 is in off mode, both gates are pulled down to -5.2V. In on mode, the GATE2 drive is 5.4V above V_{IN2}, and the GATE1 drive is 5.4V above V_{IN1}. Thus, normal inrush-current-limited turn-on functionality is provided for both the +5V and the -5.2V channels. No circuit-breaker action is

available for the negative-voltage channel when used in this way; therefore, a fuse is provided to protect the negative supply circuit.

A fault on the negative channel will not be recognized by the MAX5904, but a fault on the +5V channel will shut down both channels. Both channels will restart after an autoretry delay time. The ON pin may be brought out for logic control of the on/off function, but a simple level shifter is required because the MAX5904 is referenced to -5.2V instead of GND.

Figure 2. A single-chip solution provides inrush-current-limited turn-on functionality to positive and negative supplies, but without a circuit-breaker function on the -5.2V channel.

Single-Channel Solution

The -5.2V, single-channel hot-swap circuit of Figure 3 provides full startup control using a MAX4272 positive low-voltage hot-swap controller. The MAX4272's GND pin is connected to the -5.2V supply, while the IN and SENSE pins are connected to circuit ground. The MAX4272 then operates as if it were in a +5.2V circuit, except that no sense resistor is in the circuit, thus no overload circuit-breaker action is provided. The MAX4272 is but one of several suitable controllers that may have been selected, but was chosen because relatively few external components are required.

Figure 3. A single-chip design provides hot-swap control without circuit-breaker function on a single negative supply, while also allowing for adjustment of the turn-on voltage.

The MAX4272's ON pin may be connected directly to circuit ground, and the circuit will start 150ms after the -5.2V supply reaches -2.4V. Alternatively, resistors R1 and R2 may be included in the circuit to set the turn-on voltage closer to +5V. Adjust the R1/(R1 + R2) voltage-divider ratio so that the ON pin rises 0.6V above the negative-voltage supply at the desired supply turn-on voltage.

There is no internal current limiting at startup, so CG has been included to slow the gate voltage rate of rise at turn on. As the internal gate drive is set to approximately 100µA, the load capacitor will charge at a rate described by the following equation:

$$I_{CLOAD} = 0.1 \frac{C_{LOAD}}{C_{GATE}} \ (mA)$$

where $C_{GATE} = C_G + C_{GS}$ (of M1).

As no current-limiting shutdown function is supplied, it may be desirable to include a fuse in series with the -5.2V supply input terminal as is shown in Figure 2.

Related Parts		
MAX4272	3V to 12V, Current-Limiting, Hot Swap Controllers with Autoretry, DualSpeed/BiLevel Fault Protection	Free Samples
MAX5900	-100V, SOT23/TDFN, Simple Swapper Hot-Swap Controllers	Free Samples
MAX5904	Low-Voltage, Dual Hot-Swap Controllers/Power Sequencers	Free Samples

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