

# ***Stopping Reverse Current Flow in Standard Hot Swap Applications***

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## **ABSTRACT**

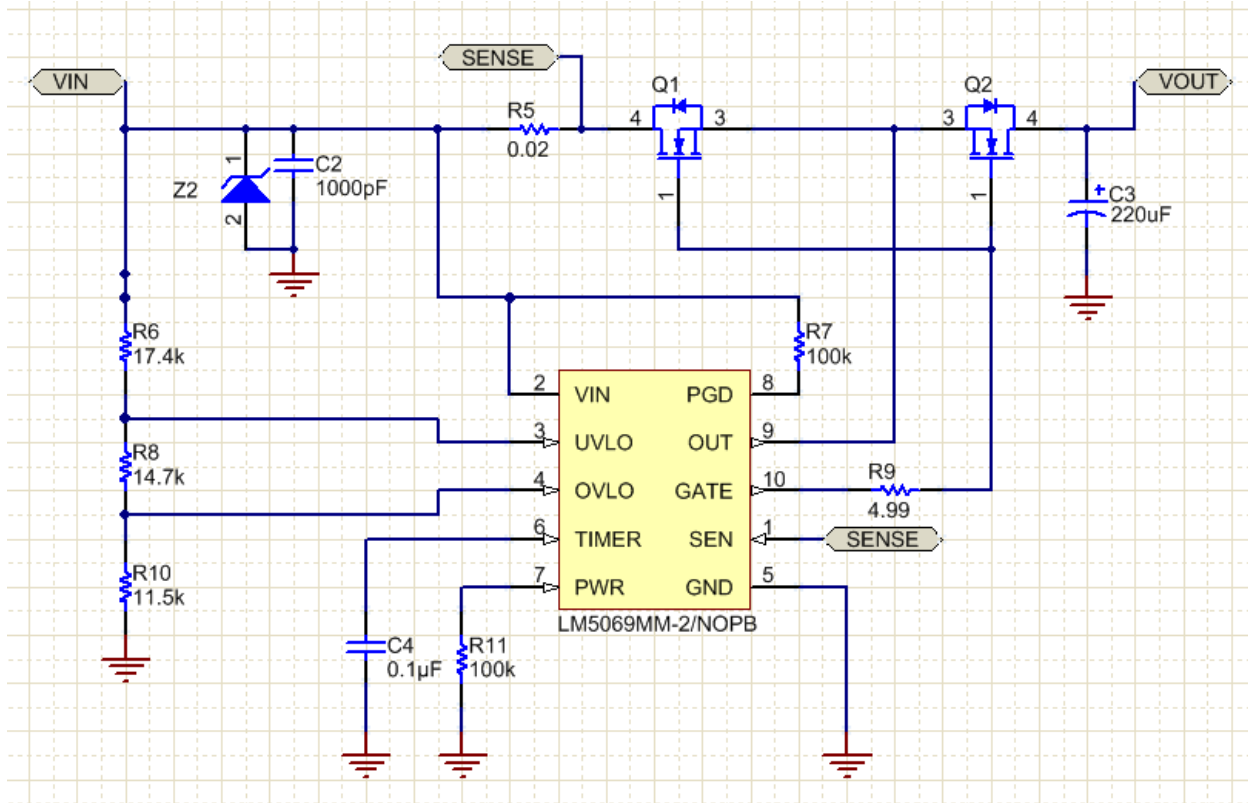
This report provides a solution to stop reverse current flow in hot swap controller applications. The proposed circuit uses an inexpensive operational amplifier to sense the condition of the output voltage exceeding the input voltage, and subsequently disable the hot swap controller, stopping the flow of reverse current (current flow from the output (load) into the input (supply)). The device used for testing this method is the LM5069, configured to provide hot swap control of input voltages from 11V to 22V to a load capacitor of 220  $\mu$ F. A schematic of the solution and results are provided.

## **INTRODUCTION**

Hot Swap controllers have become popular choice for system protection at the front end of many power supplies. They help increase reliability by providing inrush current protection, over- and under-voltage control, current limit, and circuit breaker functionality. However, most hot swap controllers do not provide any protection from reverse current flow (current flow from the load to the input supply). Maintaining the charge stored on the load capacitance in the event of an input supply collapse or removal is critical in many applications, such as Solid State Drives (SSD). In these applications, reverse current flow results in unnecessary energy loss from the load capacitance. A diode can easily provide this function but consumes power during forward current flow. This paper offers a solution for the reverse current flow problem with the addition of a FET and a low-cost operation amplifier to the standard hot swap configuration.

## **BLOCKING REVERSE CURRENT WHEN THE HOT SWAP IS DISABLED**

Adding a single FET in series to the standard pass FET blocks reverse current flow when the gate of the pass FET is off. Figure 1 shows a standard hot swap circuit using the LM5069, with the addition of a reverse blocking FET (Q2) that is oriented with the source connected to the pass FET (Q1) source. The gates are tied together such that when the GATE pin is low, the pass FET stops current flow from the input to output and the blocking FET stops current flow from output to input.



**Figure 1. Reverse Current Blocking with the LM5069 When Device is Disabled**

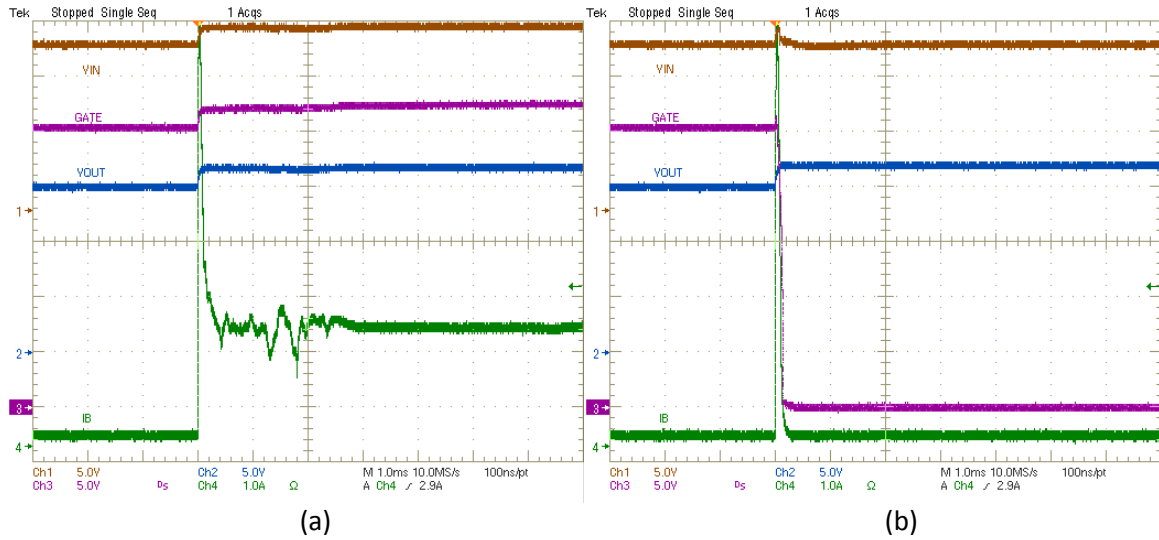
This addition can provide reverse current blocking in situations where the load can encounter positive voltages while the hot swap controller is in its insertion delay period, or if it has been shut off during a fault condition. The problem with this solution, though, is that once the gate is enabled, the hot swap controller does not react to a negative sense voltage. Therefore, if the input supply is lowered or removed, there is no mechanism to stop the flow of current from VOUT to VIN, and VOUT will track VIN until the hot swap controller's under-voltage threshold (UVLO) is crossed. Additionally, any external voltage impressed on the load can result in large current flow from the load to the input, limited only by the on-resistance of the pass FET, the sense resistance, and the internal impedance of the input supply.

## BLOCKING REVERSE CURRENT WHEN THE HOT SWAP IS ENABLED

Active reverse current protection can easily be incorporated into the standard hot swap configuration with the use of a low-cost operational amplifier, the additional FET, and a handful of passive components. The premise is simple: detect a negative voltage from the input to the output, and disable the hot swap such that the gate of both the pass FET and the blocking FET are low. This condition can be maintained until the output falls back down to the input voltage or the system is disabled. The circuit in Figure 2 provides this function: when VOUT goes 3.5 mV above VIN, the operational amplifier U1 will swing its output from the negative rail created by Z1 to the positive rail, or VIN. When this happens, the transistor connected to the UVLO and OVLO resistor network will shut off. This causes the UVLO voltage to fall to ground, and the LM5069 in turn shuts off the gates of the pass and blocking FETs. This shut down state is reversed when the output voltage decreases to equal the input voltage, at which point the output of U1 will go to the negative rail and enable the hot swap.







**Figure 4. Hot swap Gate Response with the Reverse Blocking Circuitry Disabled (a) and Enabled (b)**

## CONCLUSION

A simple, inexpensive circuit addition to the standard hot swap controller configuration has been proposed to add active reverse current blocking capability. This functionality can be useful in applications that already use a hot swap and cannot tolerate current flow from the output to the input. While the response to reverse current conditions is not as fast as what is possible with a stand-alone diode, it offers improved efficiency due to minimal voltage drop during forward current flow.

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