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APPLICATION NOTE 5914

USING THE MAX15090/MAX15090B HOT-SWAP SOLUTION IN LOW-VOLTAGE APPLICATIONS FOR RESISTIVE LOADS

By: Don Corey, Principal Member of Technical Staff, Maxim Integrated

Abstract: The MAX15090/MAX1590B are hot-swap controllers designed for a 12V bus and have a unique current foldback feature that ensures the internal FET operates in the safe operating area (SOA) when driving large capacitive loads. This application note outlines a simple way to operate these parts at lower voltages when driving loads that are resistive in nature.

Introduction

Hot-swap controllers must contend with both steady-state and startup conditions. In steady-state operation, the MOSFET used as the controlled switch element must be designed to operate above the maximum current load of the internal FET and maintain junction temperature below the rated maximum junction temperature.

The steady-state power dissipation is basically the product of the square of the load current and the $R_{DS(ON)}$.

$$P_D = I_{LOAD}^2 \times R_{DS(ON)} \quad \text{(Eq. 1)}$$

Dynamic requirements such as startup must be considered when designing a hot-swap IC with integrated FETs. This is an important consideration when driving capacitive loads that serve as the energy reservoirs for downstream point-of-loads (POLs). The MAX15090/MAX15090B use a technique that monitors the V_{IN} - V_{OUT} difference and uses a current foldback technique to limit the current during startup, which will be discussed in greater detail.

MAX15090/MAX15090B

The MAX15090/MAX15090B ICs are integrated solutions for hot-swap applications requiring the safe insertion and removal of circuit line cards from a live backplane.

The devices integrate a hot-swap controller, 6mΩ power MOSFET and electronic circuit-breaker protection in a single package. These devices implement a foldback current limit during startup to control inrush current lowering di/dt and keep the MOSFET operating under safe operating area (SOA) conditions. This feature is very important at 12V when the load is highly capacitive. **Figure 1** outlines the foldback feature during device startup.

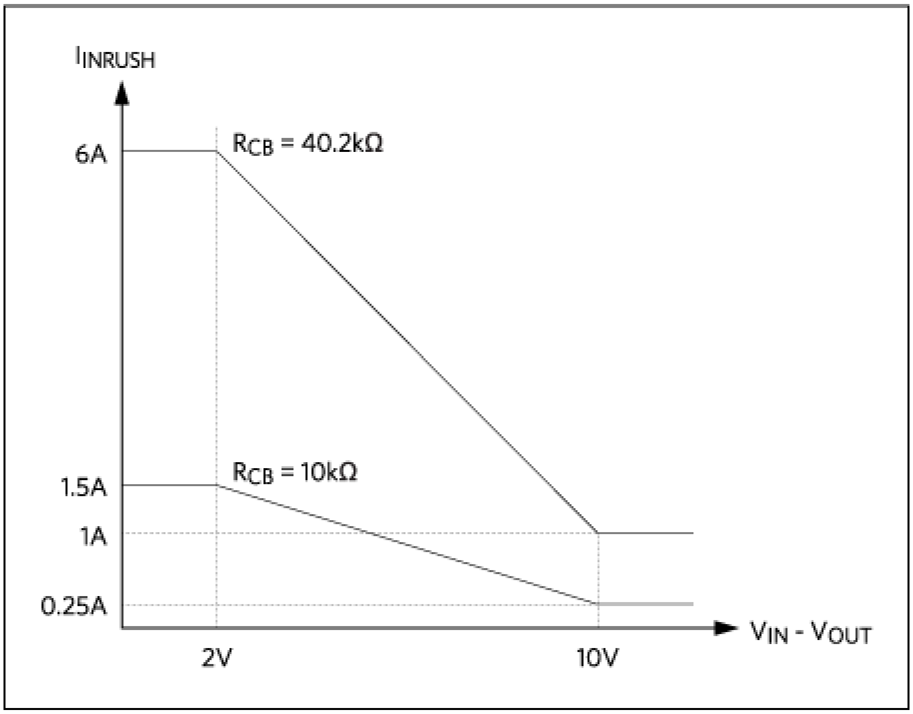

Figure 1. Variable speed/bi-level response. This should read startup inrush current foldback characterisics.

As shown in Figure 1, the device limits the amount of current to the load based on the V_{IN} - V_{OUT} difference. When the V_{IN} - V_{OUT} difference is 2V or less, the current is limited to R_{CB}/3333.3 × 0.5. If V_{OUT} rises above 0.9 × V_{IN} before the internal 50mS timer times out, the current limit reverts back to R_{CB}/3333.3. To use this part for lower voltage applications with loads that are resistive in nature, the foldback function may prevent the device from actually starting up. For example, for a 3.3V application with a 1.5Ω load, the load current should be 3.3V/1.5 or 2.2A. In this example, with R_{CB} = 10kΩ , the normal current limit is 3A while the foldback current is 1.5A. To exit the startup phase before the internal 50mS timer expires, the output voltage must be greater than 90% of the input to return to the normal current limit of R_{CB}/3333.3. Since 1.5A × 1.5 = 2.25V the part will not start up and will never increase the current limit to R_{CB}/3333.3 and will latch off (MAX15090) or retry (MAX15090B.

For low-voltage operation, the current foldback feature is not needed and can be disabled by forcing a voltage on the CB pin. This can be done using a resistive divider on the CB pin. In looking at **Figure 2** and examining the current-limit equation of R_{CB}/3333.3, the CB voltage setting should be 12µA × R_{CB}. For this example, to set the current limit to 3A, a 10kΩ resistor will be used. In normal current-limit mode, the voltage on the CB pin is 10kΩ ×12µA or 0.120V.

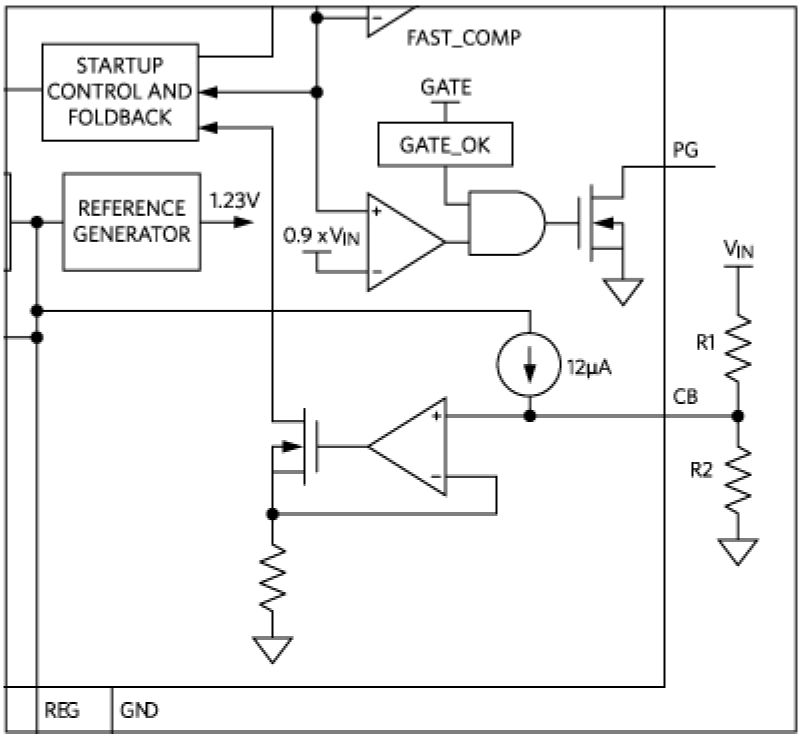

Figure 2. Setting a fixed current limit by disabling the current foldback feature.

To minimize the voltage-setting error at the CB pin, the 12µA can be taken into account. For a 3A current limit, ideally 0.120V must be at the CB pin. As such, the current through R2 must be 0.120V/R2. If R2 is equal to 1000Ω then I_{R2} is equal to 120µA. Therefore, the current from R1 must be 120µA - 12µa or 108µA. So R1 must be 3.3V - 0.120/108µA or 29444. From the standard 1% resistor chart, the closest value is 29400, which provides a nominal error of only 160µV. The bigger error will be derived from the tolerance of the input supply voltage. The tolerance of the resistor-dividers must be taken into account. Since the divider ratio is 29:1, any voltage ripple on the 3.3V power supply will be divided down and should not affect the current-limit threshold.

Limitations

Since the startup current foldback feature is being disabled, there are precautions the designer must consider when using this approach. This application note is intended for low-voltage applications where tradeoffs are made to ensure the MAX15090/MAX15090B stay within the SOA. In normal operation (as soon as the UVLO, UV, and OV thresholds are satisfied), the current foldback circuit becomes active and operates as shown in Figure 1. When the part is starting up and enhancing the internal FET, a 50mS timer is started. If the voltage output is greater than 90% of the voltage input and the gate voltage is at least V_{OUT} + 3V, the current limit shifts to the normal current limit defined by R_{CB}/3333.3. This sequence of events ensures that when the output is connected to high-capacitive loads, the internal FET of the MAX15090/MAX1509B operates in the SOA region. By disabling this feature, the current-limit settings are now defined by $V_{IN} \times I_{LIM}$ = 13.5W where I_{LIM} is the current limit set by the voltage applied to the CB pin. **Figure 3** is a graphical representation of the current-limit limitation when disabling the foldback feature of the MAX15090/MAX15090B.

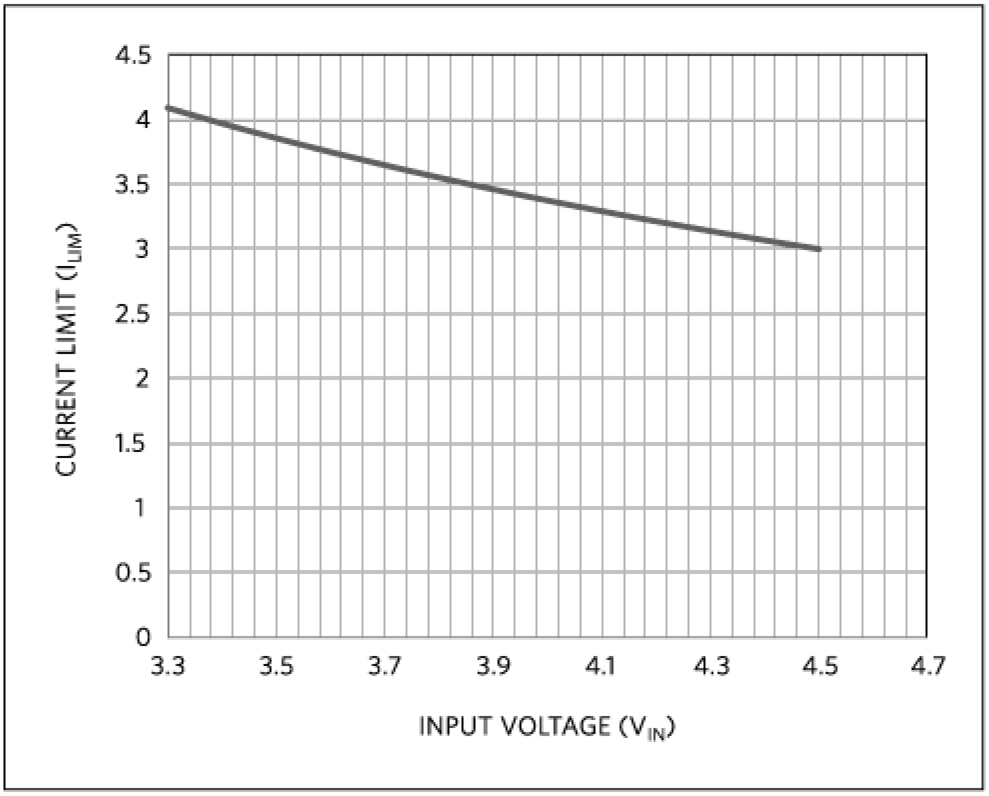

Figure 3. Safe operating area when disabling the foldback feature.

Two-Level Current-Limit Scheme

Another approach to driving resistive loads is to use the PG signal to switch between two RCB current-limit resistors. As shown in **Figure 4**, the addition of R_{CB2} and a small-signal FET 2N7002 (Q1) provides a simple way to increase the foldback current limit on startup but does not eliminate the SOA protection. During the startup phase, the PG signal (see **Figure 5**) is active-low, which in turn keeps Q1 off and R_{CB1} sets the current limit during the startup phase. When the voltage output is greater than 90% of the voltage input, the PG signal is pulled up to 3.3V and Q1 turns on, which places R_{CB2} in parallel with R_{CB1}. As such, during the startup phase, R_{CB1} sets the foldback current limit and after successful startup, the normal current limit is set by the parallel combination of R_{CB1} and R_{CB2}.

Referring back to Figure 1, since the maximum foldback current is R_{CB}/3333.3 × 0.5, R_{CB1} can be set to 2 × R_{CB}/3333.3 to increase the current limit to enable to startup in resistive loads. For example, if the normal current limit is 3A then setting R_{CB1} and R_{CB2} to 20k½ allows for a maximum foldback current limit of 20k/3333.3 = 6A during startup and 20k||20k/3333.3 = 3A for the desired current limit after a successful startup. This technique has also been used for other Maxim Integrated hot-swap ICs with internal FETs. Application note 4872[1] outlines this technique when using the MAX5976.

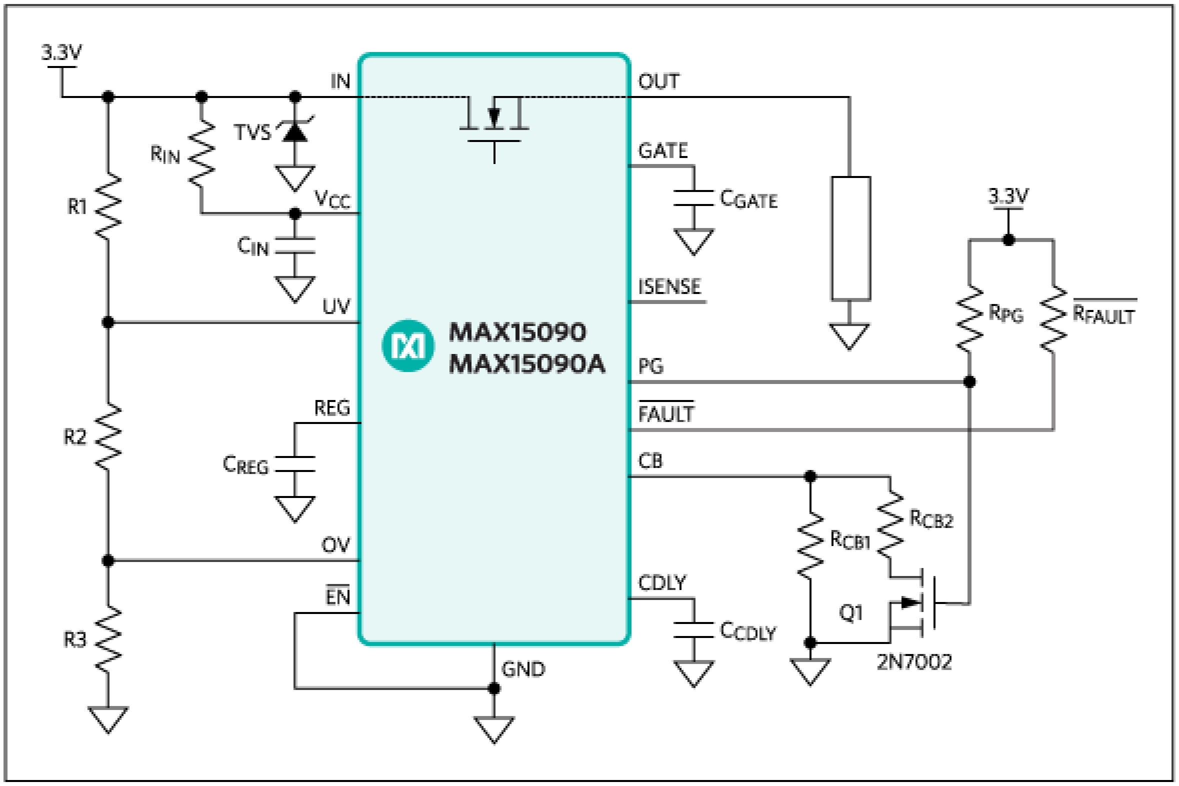

Figure 4. Dual-level current-limit control.

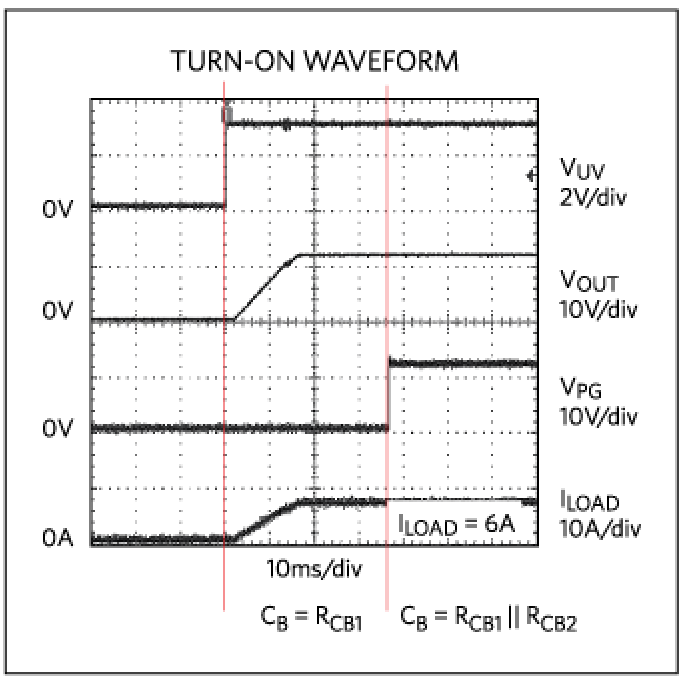

Figure 5. Current-limit zones with dual -level control.

Conclusion

This application note outlines two techniques that can be used when driving resistive type loads with the MAX15090/MAX1509B. Another technique not discussed is to simply use the PG to sequence downstream POLs and other loads that have enable pins. This allows for safely charging output capacitors and ramping up the output voltage while minimizing the inrush current.

References

1. Maxim Integrated's application note 4872, "Protect Your Integrated-FET Power Switches with Automatic Current-Limit Adjustment"
2. Dwight Larson. "Selecting n-channel MOSFETs for High-Side Hot-Swap Control." Power Electronics, Nov. 1, 2010. http://powerelectronics.com/discrete-power-semis/selecting-n-channel-mosfets-high-side-hot-swap-control

Related Parts		
MAX15090	2.7V to 18V, 12A, Hot-Swap Solution with Current Report Output	Free Samples
MAX15090B	2.7V to 18V, 12A, Hot-Swap Solution with Current Report Output	Free Samples