

# Compact Hot Swap Solution Simplifies Advanced Mezzanine Card Design

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## Introduction

Advanced Mezzanine Cards (AdvancedMC) are 80W add-on modules that are central to the extensibility of MicroTCA and AdvancedTCA high availability systems. AdvancedTCA targets high capacity, high performance applications whereas MicroTCA serves smaller, cost-sensitive applications with less demanding requirements. Unlike other mezzanine modules, which are bolted on, AdvancedMC modules can be inserted into a live backplane improving serviceability and flexibility.

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The LTC4223 offers a compact and comprehensive Hot Swap solution for Advanced Mezzanine Cards, providing inrush control, overcurrent protection and supply monitoring. It detects board insertion and extraction, allowing the 12V and 3.3V auxiliary power supply to be delivered in a controlled manner without damaging the connector. The LTC4223 provides a current monitor output for the 12V supply, allowing real-time current monitoring. Short-circuit faults on the 12V and 3.3V output are rapidly isolated with

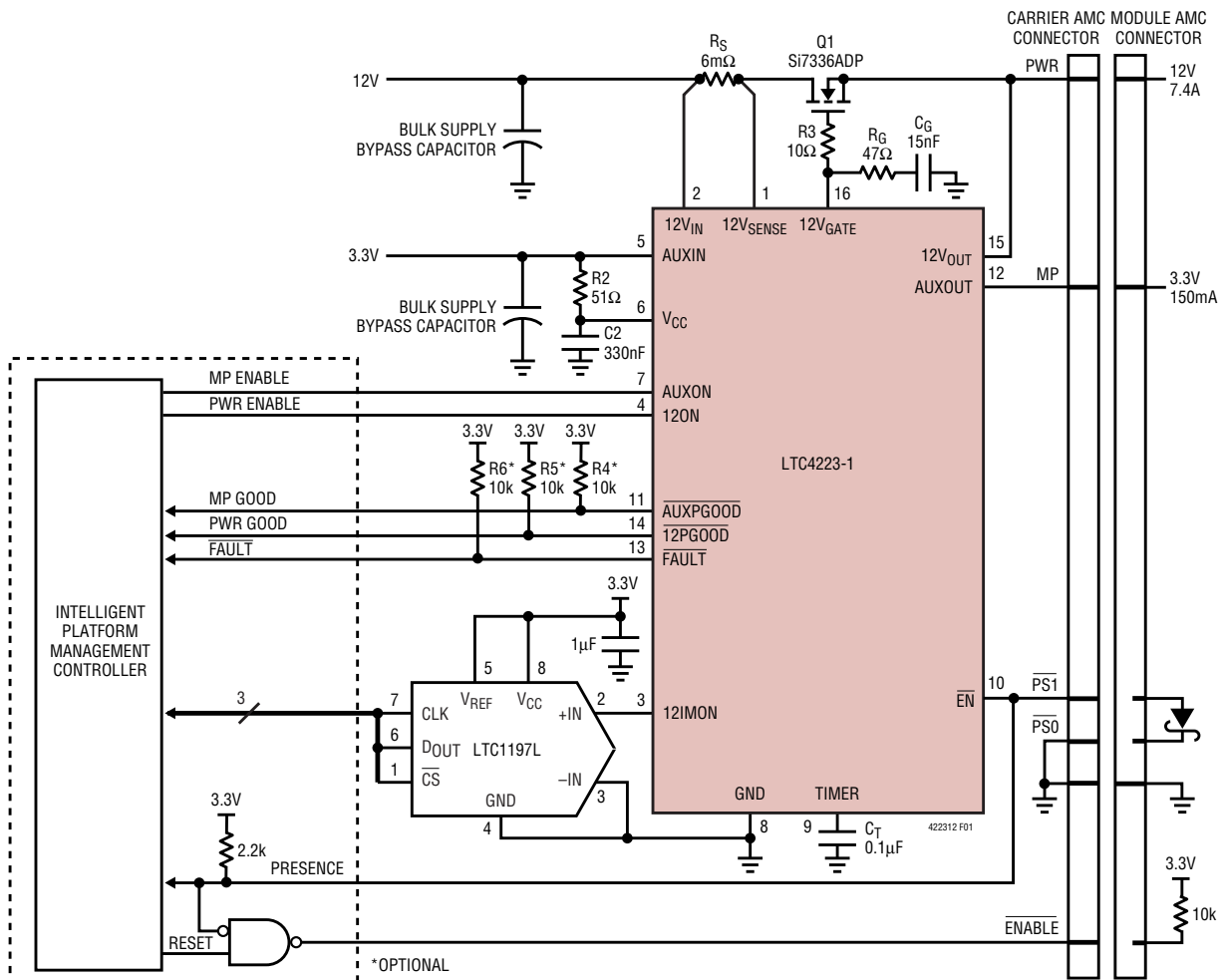
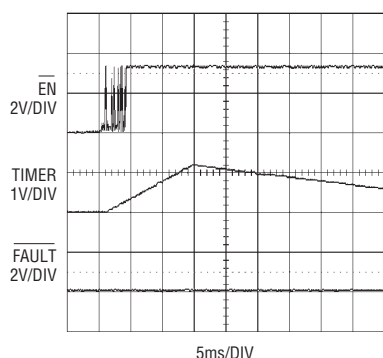


Figure 1. Typical Advanced Mezzanine Card application for MicroTCA systems



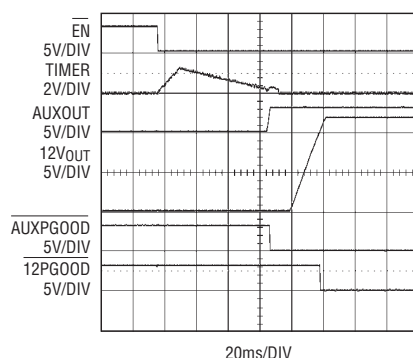
**Figure 2. TIMER blanking time prevents false fault reset from  $\overline{\text{EN}}$  pin contact bounces.**

a fast acting current limit to prevent the input supply from collapsing when the output is shorted or overloaded. The LTC4223-1 features a latch-off circuit breaker, while the LTC4223-2 provides automatic retry after a fault. Both options are available in 16-pin SSOP and space-saving 5mm × 4mm DFN packages.

## Typical AdvancedMC Hot Swap Application

In a typical AdvancedMC application, the LTC4223 resides on the carrier board, delivering 12V and 3.3V auxiliary power to the modules, as shown in Figure 1. It controls the 12V main supply with an external N-channel MOSFET and the 3.3V auxiliary supply with an integrated  $0.3\Omega$  switch. The current for the 12V supply is monitored via sense resistor  $R_S$ . The monitored current is reproduced as a relative voltage signal at the 12IMON pin. This signal can be fed to a control system using an LTC1197L ADC.

Resistor R3 prevents high frequency MOSFET self-oscillation in Q1, and  $R_G/C_G$  compensates the active current limit loop. R2/C2 filters the input power supply,  $V_{CC}$ , from supply transients. Several timers are configured by the capacitor,  $C_T$ , including the debounce cycle delay ( $C_T \cdot 741[\text{ms}/\mu\text{F}]$ ), aux current limit time-out during start-up ( $C_T \cdot 123[\text{ms}/\mu\text{F}]$ ) and 12V supply overcurrent response ( $C_T \cdot 6[\text{ms}/\mu\text{F}]$ ). The two supplies can be independently controlled by their respective ON pins, and their power-good and fault status are indicated using open-drain outputs with internal pull-ups.



**Figure 3. Normal power-up sequence with  $C_{L1} = 2200\mu\text{F}$  and  $C_{L2} = 150\mu\text{F}$  after a debounce timing cycle**

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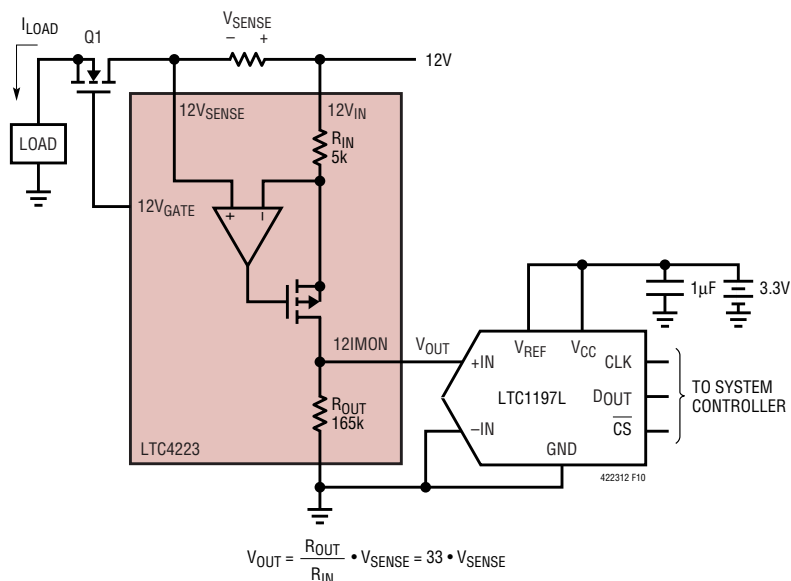
## Card Presence Detect Ignores Contact Bounces

Contact bounces as connector pins are mated can trigger unwanted system resets or can cause supplies to turn on unintentionally. To prevent this behavior, the LTC4223 ignores these contact bounces for one TIMER cycle before turning on the supplies.

When the connector pin  $\overline{\text{PSI}}$  is engaged low upon card insertion,  $\overline{\text{EN}}$  goes low and initiates a start-up debounce cycle if the ON pin is high. Any contact bounces on the  $\overline{\text{EN}}$  pin reset the **TIMER** and restart the ramp up until it reaches 1.235V, at which time the fault latches are cleared. If  $\overline{\text{EN}}$  remains low at the end of the debounce cycle, the switches are allowed to turn on. If  $\overline{\text{EN}}$  toggles high indicating card removal, all switches are turned off in 20 $\mu\text{s}$ , disconnecting the supplies to the modules. Latched faults are not cleared. However, because removing the card could cause the  $\overline{\text{EN}}$  pin voltage to bounce, the clearing of latched faults is blanked internally by a **TIMER** ramp-up time given by  $C_T \cdot 123[\text{ms}/\mu\text{F}]$ , as shown in Figure 2.

## Power-Up Sequence

Figure 3 shows the 3.3V auxiliary and 12V supplies powering up in sequence after  $\overline{\text{EN}}$  transitions low. The pre-conditions for start-up are:  $V_{\text{CC}}$  and the input supplies exceed



**Figure 4. High side current sense monitor with the LTC1197L ADC**

their undervoltage lockout thresholds,  $\overline{\text{TIMER}}$  is less than 0.2V and  $\overline{\text{EN}}$  is pulling low. If all of these conditions are met, a debounce timing cycle is initiated when the ON pin pulls high. By default, the internal Aux switch turns on first if both ON pins are high at the end of the debounce cycle. This satisfies the requirement to power up the controller first on the AdvancedMC module before turning on the 12V supply.

The charge current applied to the output capacitor  $C_{L2}$  is limited to 240mA by an internal ACL (Active Current Limit) amplifier, well below the maximum 500mA allowed for AdvancedMC modules. When the current limit is active, the  $\overline{\text{TIMER}}$  pin ramps up with a 10 $\mu$ A pull-up.  $\overline{\text{AUXPGOOD}}$  pulls low when  $\overline{\text{AUXOUT}}$  exceeds its power-good threshold of 2.901V unless the  $\overline{\text{TIMER}}$  pin reaches 1.235V and times out. When the  $\overline{\text{TIMER}}$  pin falls below 0.2V with a 2 $\mu$ A pull-down, the 12V supply external MOSFET turns on by charging the GATE with a 10 $\mu$ A current source. The GATE voltage rises with a slope equal to 10 $\mu$ A/ $C_G$  and the inrush current flowing into the load capacitor  $C_{L1}$  is limited to  $(C_{L1}/C_G) \cdot 10\mu\text{A}$ . If the sense resistor voltage drop becomes too large, the inrush current is limited at 60mV/ $R_S$  by the internal current limit circuitry.  $\overline{\text{12PGOOD}}$  pulls low when 12V<sub>OUT</sub> exceeds 10.36V.

### Power Monitoring with High Side Current Sense

The LTC4223 features a high side current sense amplifier for the 12V supply that translates the sense resistor voltage drop from the positive rail to the negative rail. The voltage at the 12IMON pin is equal to  $33 \cdot V_{\text{SENSE}}$ . This can drive the input of an LTC1197L ADC, as shown in Figure 4 for data conversion, and allows the system controller to monitor the power consumed by the AdvancedMC module. Full scale input to the current sense amplifier is 82.5mV corresponding to an output of about 2.7V. If the input exceeds 100mV, the 12IMON output clamps at 3.2V.

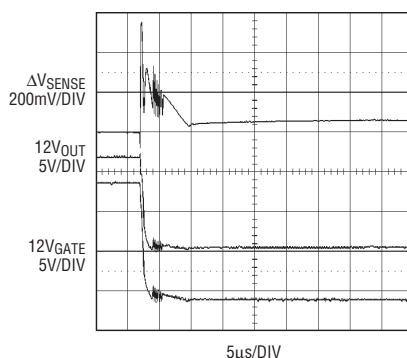


Figure 5. Fast acting current limit isolates severe short-circuit fault on 12V output

### Thermal Shutdown Protection

The internal 3.3V auxiliary supply switch is protected by a thermal shutdown circuit. If the switch's temperature reaches 150°C, the Aux switch shuts off immediately and  $\overline{\text{FAULT}}$  pulls low. The external 12V supply switch also turns off. The switches are allowed to turn on again only after both the ON pins are cycled low and then high after the internal switch's temperature falls below 120°C.

### Fast Acting Current Limit Isolates Fault

The LTC4223 features an adjustable current limit with circuit breaker function that protects the external MOSFET against excessive load current on the 12V supply. In the event of a severe short-circuit fault as shown in Figure 5, the LTC4223 brings the surge current under control within 1 $\mu$ s by pulling the MOSFET's GATE down to the SOURCE pin. Thereafter, the GATE recovers rapidly due to the  $R_G/C_G$  compensation network and

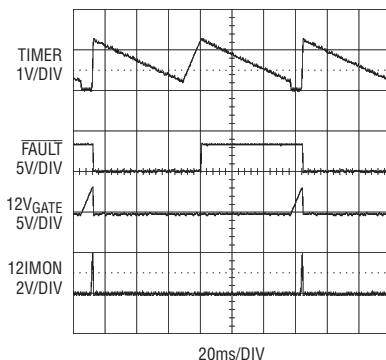


Figure 7. Auto-retry with 0.5% duty cycle during 12V output short

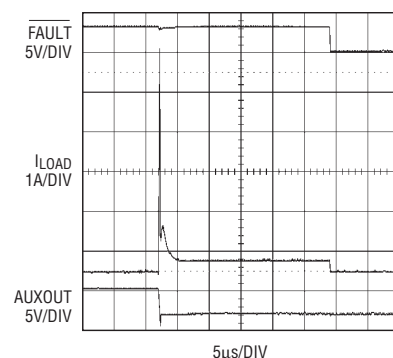


Figure 6. Fast acting current limit isolates short-circuit fault on 3.3V auxiliary output

enters into active current limiting that maintains 60mV across the sense resistor. When the sense voltage exceeds the circuit breaker threshold (50mV with 5% accuracy), the  $\overline{\text{TIMER}}$  capacitor is pulled high with a 200 $\mu$ A current until the  $\overline{\text{TIMER}}$  reaches 1.235V, after which it pulls down with 2 $\mu$ A. When this occurs,  $\overline{\text{FAULT}}$  pulls low and the GATE is pulled down to ground with 1mA, turning off the MOSFET but not the internal Aux switch. Similarly, an internal ACL amplifier protects the 3.3V auxiliary supply from overcurrent by pulling down the gate of the internal pass transistor rapidly. Thereafter, the gate recovers and servos the output current to about 240mA for 25 $\mu$ s before pulling down to ground gently, turning the transistor off, as shown in Figure 6. At this time,  $\overline{\text{FAULT}}$  pulls low and the 12V supply switch also shuts off.

### Auto-Retry after a Fault

The LTC4223-1 latches off after an overcurrent fault while the LTC4223-2 automatically restarts. Following an

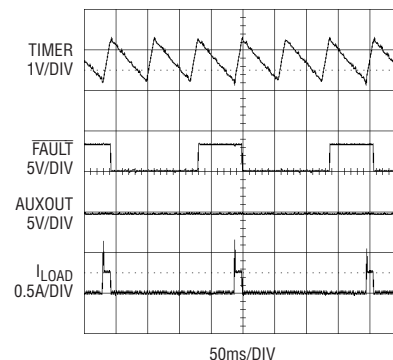
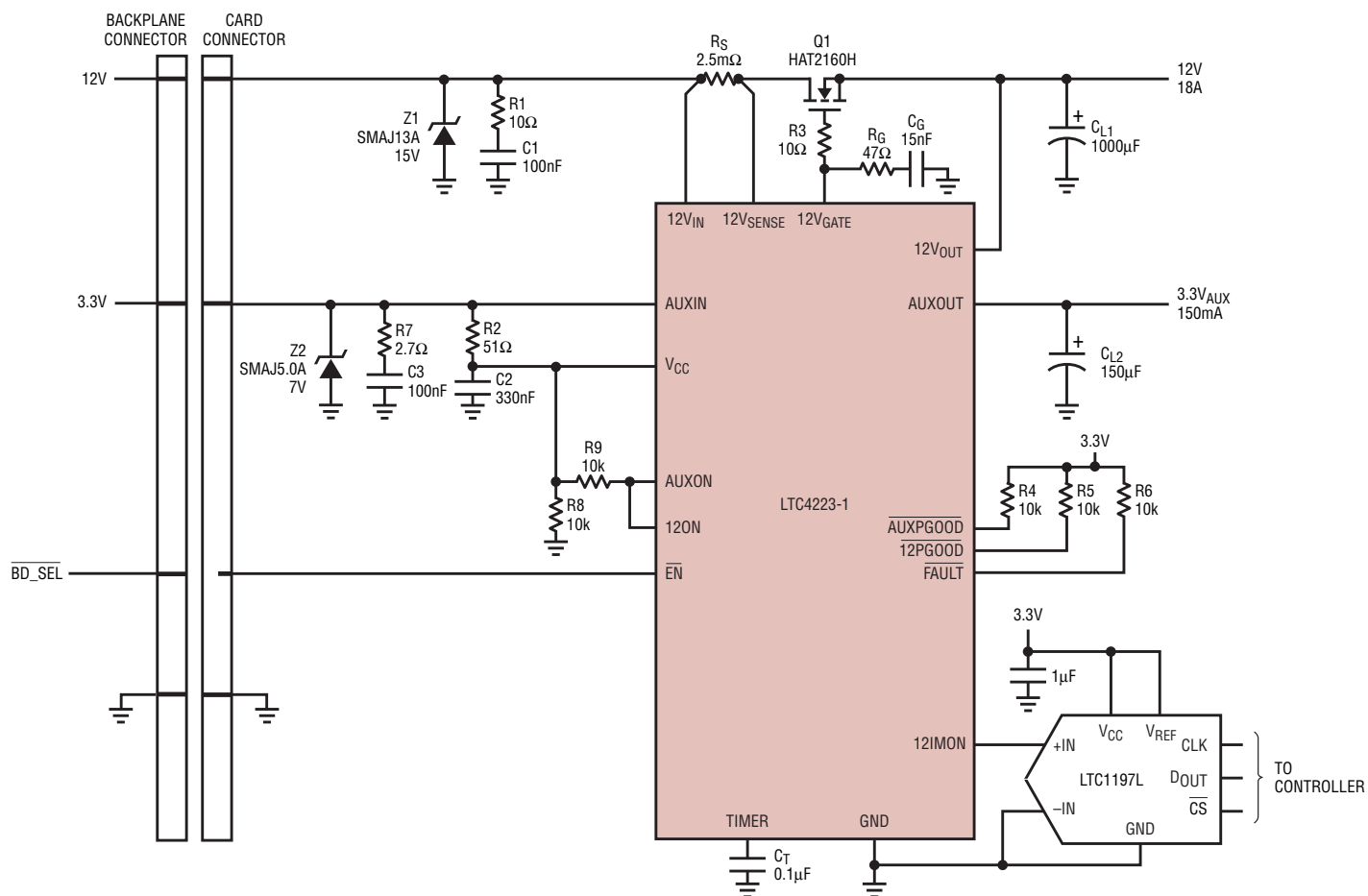


Figure 8. Auto-retry with 6.5% duty cycle during 3.3V auxiliary output short



**Figure 9. A 12V at 18A card-resident application**

overcurrent fault, the LTC4223-1 does not power up again until the fault is cleared by either pulling the ON or  $\overline{\text{EN}}$  pin from high to low or by  $V_{\text{CC}}$  falling below its UVLO threshold. The LTC4223-2 automatically clears faults after a cool-off cycle and powers up again, as shown in Figure 7 for a 12V fault and Figure 8 for a 3.3V fault.

The latched fault is cleared during the start-up cycle and  $\overline{\text{FAULT}}$  pulls high. If the output-short persists, the device powers up into an output-short with active current limiting until the TIMER times out and  $\overline{\text{FAULT}}$  pulls low again. The device restarts after a cool-off cycle and the process repeats until the output-short is removed. The cool-off cycle time is given by  $C_T \cdot 1358[\text{ms}/\mu\text{F}]$  after a 12V supply fault and  $C_T \cdot 1482[\text{ms}/\mu\text{F}]$  after an auxiliary supply fault. If the TIMER capacitor  $C_T = 0.1\mu\text{F}$ , the auto-retry duty cycle is 0.5% for the 12V supply and 6.5% for the 3.3V auxiliary.

## 12V at 18A Card-Resident Application

In addition to the AdvancedMC application where the LTC4223 is on the carrier board, it can also reside on the plug-in card side of the connector. Figure 9 shows a typical 12V at 18A application. The 3.3V auxiliary supply may be used to power up on-board logic drawing not more than 150mA. The 12V supply inrush current is limited to 0.7A by  $R_G/C_G$  compensation network when powering up into a large load capacitor of 1000μF. When no bulk capacitor is present on the card supply, transient voltage suppressors (Z1, Z2) are required to clamp supply transients and the snubber (R1/C1, R7/C3) eliminates ringing during an output-short. For the LTC4223 to work with a different load at 12V output, choosing the correct sense resistor and external MOSFET is crucial. This ensures that the circuit breaker threshold is not exceeded under the

maximum load condition, and that the power dissipated in the MOSFET is well within its safe operating area (SOA) while in active current limit during an output-short.

## Conclusion

The LTC4223 provides Hot Swap control for a 3.3V auxiliary and a 12V supply. It features board insertion and extraction detection, active current limit into large load capacitors and sequenced supply turn-on with power-good status, all critical in Advanced Mezzanine Card applications. Its tight 5% circuit breaker threshold accuracy and fast acting current limit protect the supplies against overcurrent faults. The current monitor output allows measurement of the 12V supply's power consumption. With these features, the LTC4223 offers a compact Hot Swap solution that simplifies the Advanced Mezzanine Card design.