Small DFN Electronic Circuit Breaker Eliminates Sense Resistor

by SH Lim

Introduction

Traditionally, an Electronic Circuit Breaker (ECB) comprises a MOSFET, a MOSFET controller and a current sense resistor. The LTC4213 is a new electronic circuit breaker that does away with the sense resistor by instead using the $R_{DS(ON)}$ of the external MOSFET. The result is a simple, small solution that offers significant low insertion loss advantage at low operating load voltage. The LTC4213 features two circuit breaking responses to varying over load conditions with three selectable trip thresholds and a high side drive for an external N-channel MOSFET switch.

Overcurrent Protection

The SENSEP and SENSEN pins monitor the load current via the $R_{DS(ON)}$ of the external MOSFET, and serve as inputs to two internal comparators—SLOWCOMP and FASTCOMP—with trip points at V_{CB} and $V_{CB(FAST)}$, respectively. The circuit breaker trips when an over-current fault causes a substantial voltage drop across the MOSFET. An overload current exceeding $V_{CB}/R_{DS(ON)}$ causes SLOWCOMP to trip the circuit breaker after a 16µs delay. In the event of a severe overload or short circuit current exceeding $V_{CB(FAST)}/R_{DS(ON)}$, the FASTCOMP trips the circuit breaker within 1µs, protecting both the MOSFET and the load.

When the circuit breaker trips, the GATE pin is pulled down immediately to disconnect the load from the supply. In order to reset the circuit breaker fault, either the ON pin must be taken below 0.4V for at least 80µs or the bias V_{CC} must be taken below 1.97V for at least 80µs. Both of the comparators have a common mode input voltage range from ground to V_{CC} + 0.2V. This allows the circuit breaker to operate even under severe output short circuit conditions where the load supply voltage collapses.

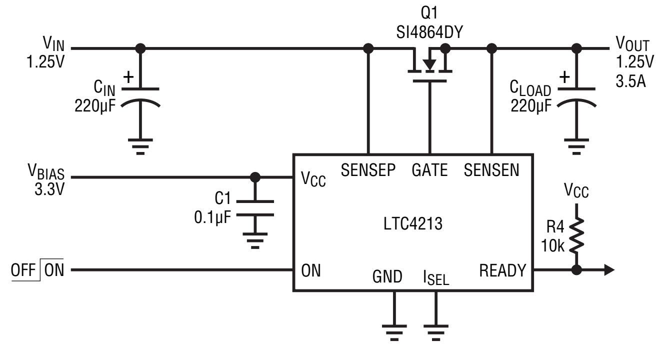

Figure 1. The LTC4213 in an electronic circuit breaker application

Flexible Overcurrent Setting

The LTC4213 has an I_{SEL} pin to select one of these three over-current settings:

- ❑ I_{SEL} at GND, V_{CB} = 25mV and $V_{CB(FAST)}$ = 100mV
- ❑ I_{SEL} left open, V_{CB} = 50mV and $V_{CB(FAST)}$ = 175mV
- ❑ I_{SEL} at V_{CC}, V_{CB} = 100mV and $V_{CB(FAST)}$ = 325mV

I_{SEL} can be stepped dynamically. For example, a higher over-current threshold can be set at startup and a lower threshold can be selected after the supply current has stabilized.

Overvoltage Protection

The LTC4213 can provide load overvoltage protection (OVP) above the bias supply. When $V_{SENSEP} > V_{CC}$ + 0.7V for 65µs, an internal OVP circuit activates with the GATE pin pulling low and the external MOSFET turning off. The OVP circuit protects the system from an incorrect plug-in event where the V_{IN} load supply is much higher than the V_{CC} bias voltage. The OVP circuit also cuts off the load from the supply during any prolonged over voltage conditions. The 65µs delay prevents the OVP circuit from triggering due fast transient noise. Nevertheless, if fast over voltage spikes are threats to the system, an external input bypass capacitor and/or transient suppressor should be installed.

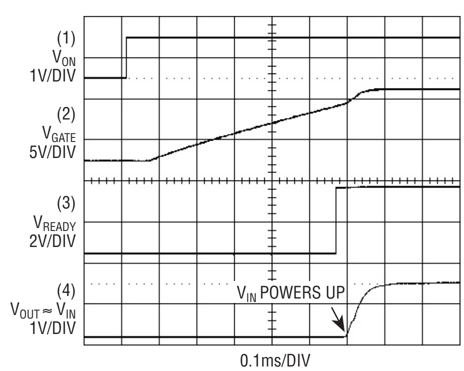

Figure 2. Normal power-up sequence

Typical Electronic Circuit Breaker (ECB) Application

Figure 1 shows the LTC4213 in a dual supply ECB application. An input bypass capacitor is recommended to prevent transient spikes when the V_{IN} supply powers-up or the ECB responds to overcurrent conditions. Figure 2 shows a normal power-up sequence. The LTC4213 exits reset mode once the V_{CC} pin is above the internal under voltage lockout threshold and the ON pin rises above 0.8V (see trace 1 in Figure 2). After an internal 60µs de-bounce cycle, the GATE pin capacitance is charged up from ground by an internal 100µA current source (see trace 2). As the GATE pin and the gate of MOSFET charges up, the external MOSFET turns on when V_{GATE} exceeds the MOSFET's threshold. The circuit breaker is armed when V_{GATE} exceeds ΔV_{GSARM}, a voltage at which the external MOSFET is deemed fully enhanced, and $R_{DS(ON)}$ minimized.

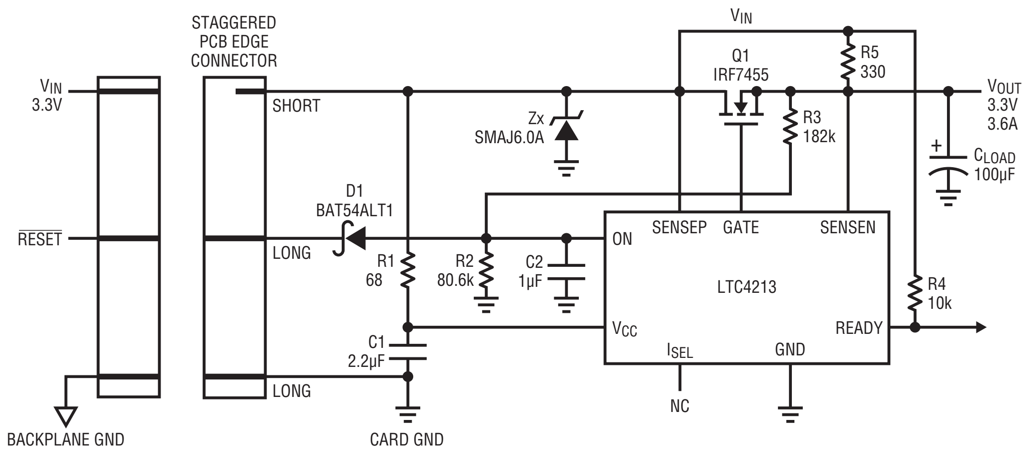

Figure 3. The LTC4213 in a Hot Swap application

Then, 50µs after the circuit breaker is armed and the READY pin goes high (see trace 3), the V_{IN} supply starts to power-up. To prevent power-up failures, the V_{IN} supply should rise with a ramp-rate that keeps the inrush current below the ECB trip level. Trace 4 shows the V_{OUT} waveform during the V_{IN} supply power-up. The gate voltage finally peaks at $\Delta V_{GSMAX} + V_{SENSEN}$. The MOSFET gate overdrive voltage is ΔV_{GSMAX} which is higher than the ΔV_{GSARM}. This ensures that the external MOSFET is fully enhanced and the R_{DSON} is further reduced. Choose the MOSFET with the required R_{DSON} at V_{GS} approximately equal to ΔV_{GSMAX}. The LTC4213 monitors the load current when the gate overdrive voltage exceeds ΔV_{GSARM}.

Typical Hot Swap Application

Figure 3 shows the LTC4213 in a single supply Hot Swap application where the load can be kept in shutdown mode until the Hot Swap action is completed. Large input bypass capacitors should be avoided in Hot Swap applications as they cause large inrush currents. Instead, a transient voltage suppressor should be employed to clip and protect against fast transient spikes.

In this application, the backplane starts with the $\overline{RESET}$ signal held low. When the PCB long trace makes contact the ON pin is held below 0.4V by the D1 schottky diode. This keeps the LTC4213 in reset mode. The V_{IN} supply is connected to the card when the short trace makes contact. The V_{CC} pin is biased via the R1-C1 filter and V_{OUT} is pre-charged by resistor R5. To power-up successfully, the R5 resistor should provide sufficient initial start up current for the shutdown load circuit and the 280µA sinking current source at SENSEN pin. On the other hand, the R5 resistor value should limit the load surge current during board insertions and fault conditions. When $\overline{RESET}$ signals a high at the backplane, capacitor C2 at the ON pin charges up via the R3/R2 resistive divider. When ON pin voltage exceeds 0.8V, the GATE pin ramps up. The GATE voltage finally peaks and the external MOSFET is fully turned on to reduce the voltage drop between V_{IN} and V_{OUT}. The LTC4213 monitors the load current when the gate overdrive voltage exceeds ΔV_{GSARM}.

Conclusion

The LTC4213 is a small package, No R_{SENSE} Electronic Circuit Breaker that is ideally suited for low voltage applications with low MOSFET insertion loss. It includes selectable dual current level and dual response time circuit breaker functions. The circuit breaker has wide operating input common-mode-range from ground to V_{CC}.

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low by an internal N-channel device and C_{AUTO} is discharged to ground. The GATE pin is pulled immediately to ground to disconnect the board. When the ON pin goes below 0.4V for more than 100µs, the ECB is reset. The internal N-channel device at the $\overline{FAULT}$ pin is switched off and R_{AUTO} starts to charge C_{AUTO} slowly towards the load supply.

When the ON pin rises above 0.8V, the LTC4216 attempts to reconnect the board and start the first timing cycle. With a dead short at the 5V output in Figure 6, the ECB trips when the FILTER pin voltage exceeds 1.253V after the first timing cycle. The entire cycle is repeated until the short is removed. The duration of each cycle is given by the time needed to charge C_{AUTO} to within 0.8V of the ON pin voltage, after the $\overline{FAULT}$ pin is pulled low and the first timing cycle delay. With $R_{AUTO} = 200k\Omega$, $C_{AUTO} = 1\mu F$ and C1 = 100nF, the cycle time is 85ms. The external MOSFET is on for about 2ms giving a duty cycle of 2.3%.

Conclusion

The LTC4216 Hot Swap controller is designed to handle very low supply voltages, down to 0V. Its adjustable soft-start function controls the inrush current slew rate at start-up, important with the large load capacitors used in low voltage systems. The analog current limit amplifier, the electronic circuit breaker with low trip threshold of 25mV and adjustable response time provides dual level overcurrent protection.