LINEAR TECHNOLOGY

DESIGN NOTES

Electronic Circuit Breaker in Small DFN Package Eliminates Sense Resistor – Design Note 402

SH Lim

Introduction

Traditionally, an Electronic Circuit Breaker (ECB) comprises a MOSFET, a MOSFET controller and a current sense resistor. The LTC®4213 does away with the sense resistor by using the $R_{DS(ON)}$ of the external MOSFET. The result is a simple, small solution that offers a significant low insertion loss advantage at low operating load voltage. The LTC4213 features two circuit breaking responses to varying overload 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 overcurrent 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.

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 as the load supply turns on from 0V.

Flexible Overcurrent Setting

The LTC4213 has an I_{SEL} pin to select one of these three overcurrent 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

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.

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 debounce 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 $R_{DS(ON)}$

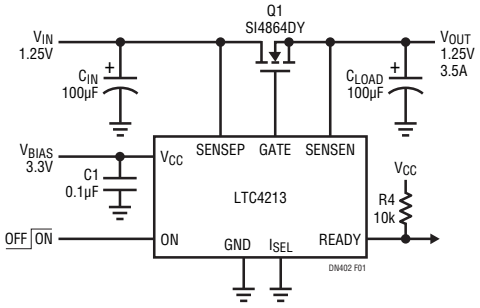

Figure 1. The LTC4213 in an Electronic Circuit Breaker Application

minimized. Then, 50µs after the circuit breaker is armed, the READY pin goes high (see trace 3) and signals the system to power up V_{IN}. Trace 4 shows the related V_{OUT} waveform when V_{IN} powers up. In order to not trip the circuit breaker during startup, the load current must be lower than V_{CB}/R_{SENSE}. If needed, the I_{SEL} pin can be stepped dynamically for a higher overcurrent threshold at startup and a lower threshold when the load current has stabilized.

Accurate ECB with Sense Resistor

The $R_{DS(ON)}$ voltage drop sensing method trades the circuit breaker accuracy for system simplicity. The majority of sensing inaccuracy is due to the external MOSFET's $R_{DS(ON)}$ varied by operating temperature and under different V_{GS} bias condition. The MOSFET vendors also do not specify the $R_{DS(ON)}$ distribution tightly due to manufacturing variation. If an external tight tolerance resistor is employed for current sensing instead, the LTC4213 reveals its ±10% circuit breaker accuracy. Figure 3 shows a tolerable R_{SENSE} resistor voltage drop and the LTC4213 is used for accurate ECB applications.

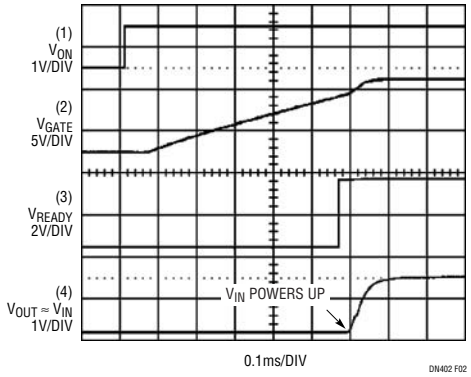

Figure 2. Normal Power-Up Sequence

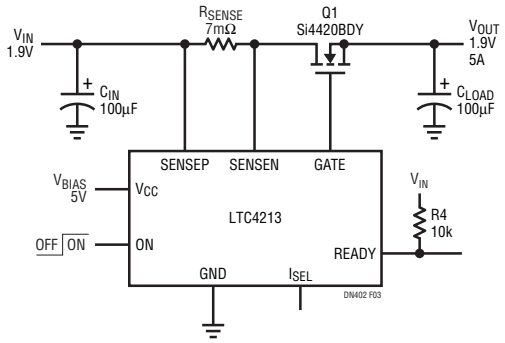

Figure 3. Accurate ECB with High Side Sense Resistor

High Side Switch for N-Channel Logic Level MOSFET

Logic level N-Channel MOSFET applications usually requires a minimum gate drive voltage of 4.5V. Figure 4 shows the LTC4213 in a High Side Switch application. The LTC4213's internal charge pump boosts the GATE above the logic level gate drive requirement and ensures the MOSFET is fully enhanced for $V_{CC} \geq 3V$. The typical gate drive versus bias supply voltage curve is shown in Figure 5.

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}.

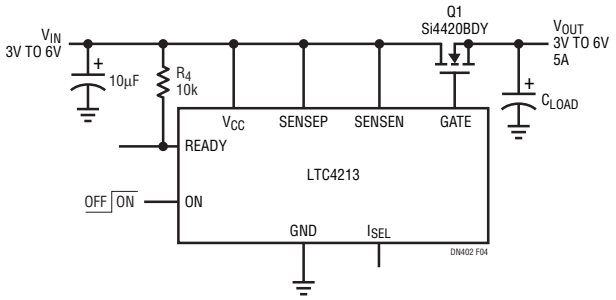

Figure 4. High Side Switch for Logic Level N-Channel MOSFET, V_{CC} > 3V

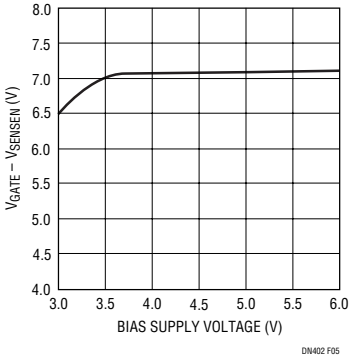

Figure 5. Gate Drive Voltage vs Bias Supply Voltage

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