The LTC®4213 is an Electronic Circuit Breaker. An overcurrent circuit breaker senses the voltage across the drain and source terminals of an external N-channel MOSFET with no need for a sense resistor. The advantages are a lower cost and reduced voltage and power loss in the switch path. An internal high-side driver controls the external MOSFET gate.

Two integrated comparators provide dual level overcurrent protection over the bias supply to ground common mode range. The slow comparator has 16µs response while the fast comparator trips in 1µs. The circuit breaker has three selectable trip thresholds: 25mV, 50mV and 100mV. An ON pin controls the ON/OFF and resets circuit breaker faults. READY signals the MOSFET is conducting and the circuit breaker is armed. The LTC4213 operates from VCC = 2.3V to 6V.

FEATURES
- Fast 1µs Response Circuit Breaker
- 3 Selectable Circuit Breaker Thresholds
- No Sense Resistor Required
- Dual Level Overcurrent Fault Protection
- Controls Load Voltages from 0V to 6V
- High Side Drive for External N-Channel FET
- Undervoltage Lockout
- READY Pin Signals When Circuit Breaker Armed
- Small Plastic (3mm x 2mm) DFN Package

APPLICATIONS
- Electronic Circuit Breaker
- High-Side Switch
- Hot Board Insertion

DESCRIPTION

TYPICAL APPLICATION

1.25V Electronic Circuit Breaker

Severe Overload Response

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No RSENSE is a trademark of Linear Technology Corporation. All other trademarks are the property of their respective owners.
LTC4213

ABSOLUTE MAXIMUM RATINGS
(Note 1)
Bias Supply Voltage (\(V_{CC}\)) ....................... \(-0.3\) V to 9V
Input Voltages
\(ON, SENSEP, SENSEN\) .......................... \(-0.3\) V to 9V
\(I_{SEL}\) ........................................ \(-0.3\) V to \((V_{CC} + 0.3\) V)
Output Voltages
\(GATE\) ..................................................... \(-0.3\) V to 15V
\(READY\) ..................................................... \(-0.3\) V to 9V
Operating Temperature Range
LTC4213C ............................................... \(0^\circ\) C to 70\(^\circ\) C
LTC4213I............................................. \(-40^\circ\) C to 85\(^\circ\) C
Storage Temperature Range ................. \(-65^\circ\) C to 150\(^\circ\) C
Lead Temperature (Soldering, 10sec)............... 300\(^\circ\) C

ELECTRICAL CHARACTERISTICS
The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at \(T_A = 25^\circ\) C. \(V_{CC} = 5\) V, \(I_{SEL} = 0\) unless otherwise noted. (Note 2)

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{CC})</td>
<td>Bias Supply Voltage</td>
<td>●</td>
<td>2.3</td>
<td>6</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>(V_{SENSEP})</td>
<td>SENSEP Voltage</td>
<td>●</td>
<td>0</td>
<td>6</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>(I_{CC})</td>
<td>(V_{CC}) Supply Current</td>
<td>●</td>
<td>1.6</td>
<td>3</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>(V_{CC(UVLR)})</td>
<td>(V_{CC}) Undervoltage Lockout Release (V_{CC}) Rising</td>
<td>●</td>
<td>1.8</td>
<td>2.07</td>
<td>2.23</td>
<td>V</td>
</tr>
<tr>
<td>(\Delta V_{CC(UVHYST)})</td>
<td>(V_{CC}) Undervoltage Lockout Hysteresis</td>
<td>●</td>
<td>30</td>
<td>100</td>
<td>160</td>
<td>mV</td>
</tr>
<tr>
<td>(I_{SENSEP})</td>
<td>SENSEP Input Current (V_{SENSEP} = V_{SENSEN} = 5) V, Normal Mode</td>
<td>●</td>
<td>15</td>
<td>40</td>
<td>80</td>
<td>(\mu)A</td>
</tr>
<tr>
<td>(I_{SENSEN})</td>
<td>SENSEN Input Current (V_{SENSEP} = V_{SENSEN} = 5) V, Normal Mode</td>
<td>●</td>
<td>15</td>
<td>40</td>
<td>80</td>
<td>(\mu)A</td>
</tr>
<tr>
<td>(V_{CB})</td>
<td>Circuit Breaker Trip Voltage (V_{CB} = V_{SENSEP} – V_{SENSEN})</td>
<td>(I_{SEL} = 0, V_{SENSEP} = V_{CC})</td>
<td>●</td>
<td>22.5</td>
<td>25</td>
<td>27.5</td>
</tr>
<tr>
<td>(V_{CB(FAST)})</td>
<td>Fast Circuit Breaker Trip Voltage (V_{CB(FAST)} = V_{SENSEP} – V_{SENSEN})</td>
<td>(I_{SEL} = 0, V_{SENSEP} = V_{CC})</td>
<td>●</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>(V_{CB(FAST)})</td>
<td>Fast Circuit Breaker Trip Voltage (V_{CB(FAST)} = V_{SENSEP} – V_{SENSEN})</td>
<td>(I_{SEL} = 0, V_{SENSEP} = V_{CC})</td>
<td>●</td>
<td>90</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>(I_{GATE(UP)})</td>
<td>GATE Pin Pull Up Current (V_{GATE} = 0) V</td>
<td>●</td>
<td>–50</td>
<td>–100</td>
<td>–150</td>
<td>(\mu)A</td>
</tr>
<tr>
<td>(I_{GATE(DN)})</td>
<td>GATE Pin Pull Down Current (\Delta V_{SENSEP} – V_{SENSEN} = 200) mV, (V_{GATE} = 8) V</td>
<td>●</td>
<td>10</td>
<td>40</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>(\Delta V_{GSMAX})</td>
<td>External N-Channel Gate Drive (V_{SENSEP} = 0, V_{CC} \geq 2.97) V, (I_{GATE} = –1) (\mu)A</td>
<td>(V_{SENSEP} = 0, V_{CC} = 2.3) V, (I_{GATE} = –1) (\mu)A</td>
<td>●</td>
<td>4.8</td>
<td>6.5</td>
<td>8</td>
</tr>
<tr>
<td>(\Delta V_{SSARM})</td>
<td>(V_{DS}) Voltage to Arm Circuit Breaker (V_{SENSEP} = 0, V_{CC} \geq 2.97) V (V_{SENSEP} = 0, V_{CC} = 2.3) V</td>
<td>●</td>
<td>4.4</td>
<td>5.4</td>
<td>7.6</td>
<td>V</td>
</tr>
</tbody>
</table>

Consult LTC Marketing for parts specified with wider operating temperature ranges.
*The temperature grade is identified by a label on the shipping container.

ORDER PART
NUMBER
LTC4213CDDB
LTC4213DDB

DDB PART* MARKING
LBHV

TOP VIEW

DDB PACKAGE
8-LEAD (3mm × 2mm) PLASTIC DFN

TJMAX = 125° C, θJA = 250° C/W
EXPOSED PAD (PIN 9)
PCB CONNECTION OPTIONAL

Downloaded from Arrow.com.
# LTC4213

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at \( T_A = 25^\circ C \). \( V_CC = 5V \), \( I_SEL = 0 \) unless otherwise noted. (Note 2)

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</tr>
</thead>
<tbody>
<tr>
<td>( \Delta V_{GS_{MAX}} - \Delta V_{GS_{ARM}} )</td>
<td>Difference Between ( \Delta V_{GS_{MAX}} ) and ( \Delta V_{GS_{ARM}} )</td>
<td>( V_{SENSEN} = 0 ), ( V_CC \geq 2.97V )</td>
<td>●</td>
<td>0.3</td>
<td>1.1</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( V_{SENSEN} = 0 ), ( V_CC = 2.3V )</td>
<td>●</td>
<td>0.15</td>
<td>0.8</td>
<td>V</td>
</tr>
<tr>
<td>( V_{READY(OL)} )</td>
<td>READY Pin Output Low Voltage</td>
<td>( I_{READY} = 1.6mA ), Pull Down Device On</td>
<td>●</td>
<td>0.2</td>
<td>0.4</td>
<td>V</td>
</tr>
<tr>
<td>( I_{READY(LEAK)} )</td>
<td>READY Pin Leakage Current</td>
<td>( V_{READY} = 5V ), Pull Down Device Off</td>
<td>●</td>
<td>0</td>
<td>±1</td>
<td>( \mu A )</td>
</tr>
<tr>
<td>( V_{ON(TH)} )</td>
<td>ON Pin High Threshold</td>
<td>ON Rising, GATE Pulls Up</td>
<td>●</td>
<td>0.76</td>
<td>0.8</td>
<td>0.84</td>
</tr>
<tr>
<td>( \Delta V_{ON(HYST)} )</td>
<td>ON Pin Hysteresis</td>
<td>ON Falling, GATE Pulls Down</td>
<td></td>
<td>10</td>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>( V_{ON(RST)} )</td>
<td>ON Pin Reset Threshold</td>
<td>ON Falling, Fault Reset, GATE Pull Down</td>
<td>●</td>
<td>0.36</td>
<td>0.4</td>
<td>0.44</td>
</tr>
<tr>
<td>( I_{ON(IN)} )</td>
<td>ON Pin Input Current</td>
<td>( V_{ON} = 1.2V )</td>
<td>●</td>
<td>0</td>
<td>±1</td>
<td>( \mu A )</td>
</tr>
<tr>
<td>( \Delta V_{OV} )</td>
<td>Overvoltage Threshold ( \Delta V_{OV} = V_{SENSEP} - V_CC )</td>
<td></td>
<td>●</td>
<td>0.41</td>
<td>0.7</td>
<td>1.1</td>
</tr>
<tr>
<td>( t_{OV} )</td>
<td>Overvoltage Protection Trip Time</td>
<td>( V_{SENSEP} = V_{SENSEN} = ) Step 5V to 6.2V</td>
<td></td>
<td>25</td>
<td>65</td>
<td>160</td>
</tr>
<tr>
<td>( t_{FAULT(SLOW)} )</td>
<td>( V_{CB} ) Trips to GATE Discharging</td>
<td>( \Delta V_{SENSE} ) Step 0mV to 50mV, ( V_{SENSEN} = 0), ( V_CC = V_{SENSEP} = 5V )</td>
<td>●</td>
<td>7</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>( t_{FAULT(FAST)} )</td>
<td>( V_{CB(FAST)} ) Trips to GATE Discharging</td>
<td>( \Delta V_{SENSE} ) Step 0V to 0.3V, ( V_{SENSEP} ) Falling, ( V_{SENSEP} = 5V )</td>
<td>●</td>
<td>1</td>
<td>2.5</td>
<td>( \mu s )</td>
</tr>
<tr>
<td>( t_{DEBOUNCE} )</td>
<td>Startup De-Bounce Time</td>
<td>( V_{ON} = 0V ) to 2V Step to Gate Rising, ( (\text{Exiting Reset Mode}) )</td>
<td></td>
<td>27</td>
<td>60</td>
<td>130</td>
</tr>
<tr>
<td>( t_{READY} )</td>
<td>READY Delay Time</td>
<td>( V_{GATE} = 0V ) to 8V Step to READY Rising, ( V_{SENSEP} = V_{SENSEN} = 0 )</td>
<td></td>
<td>22</td>
<td>50</td>
<td>115</td>
</tr>
<tr>
<td>( t_{OFF} )</td>
<td>Turn-Off Time</td>
<td>( V_{ON} = 2V ) to 0.6V Step to GATE Discharging</td>
<td></td>
<td>1.5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>( t_{ON} )</td>
<td>Turn-On Time</td>
<td>( V_{ON} = 0.6V ) to 2V Step to GATE Rising, ( (\text{Normal Mode}) )</td>
<td></td>
<td>4</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>( t_{RESET} )</td>
<td>Reset Time</td>
<td>( V_{ON} ) Step 2V to 0V</td>
<td></td>
<td>20</td>
<td>80</td>
<td>150</td>
</tr>
</tbody>
</table>

**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** All currents into device pins are positive; all currents out of device pins are negative. All voltages are referenced to ground unless otherwise specified.
LTC4213

**TYPICAL PERFORMANCE CHARACTERISTICS** Specifications are at \( T_A = 25°C \). \( V_{CC} = 5V \) unless otherwise noted.

- **I\textsubscript{CC} vs V\textsubscript{CC}**
- **I\textsubscript{CC} vs Temperature**
- **V\textsubscript{CC(UVR)} vs Temperature**
- **Normalized V\textsubscript{CB} vs V\textsubscript{CC}**
- **Normalized V\textsubscript{CB} vs Temperature**
- **Normalized V\textsubscript{CB(FAST)} vs V\textsubscript{CC}**
- **Normalized V\textsubscript{CB(FAST)} vs Temperature**
- **I\textsubscript{GATE(UP)} vs V\textsubscript{CC}**
- **I\textsubscript{GATE(UP)} vs Temperature**
**TYPICAL PERFORMANCE CHARACTERISTICS**

Specifications are at \( T_A = 25°C \). \( V_{CC} = 5V \) unless otherwise noted.
TYPICAL PERFORMANCE CHARACTERISTICS

Specifications are at $T_A = 25$°C. $V_{CC} = 5V$

unless otherwise noted.
**PIN FUNCTIONS**

**READY (Pin 1):** READY Status Output. Open drain output that goes high impedance when the external MOSFET is on and the circuit breaker is armed. Otherwise this pin pulls low.

**ON (Pin 2):** ON Control Input. The LTC4213 is in reset mode when the ON pin is below 0.4V. When the ON pin increases above 0.8V, the device starts up and the GATE pulls up with a 100µA current source. When the ON pin drops below 0.76V, the GATE pulls down. To reset a circuit breaker fault, the ON pin must go below 0.4V.

**ISEL (Pin 3):** Threshold Select Input. With the ISEL pin grounded, float or tied to VCC the VCB is set to 25mV, 50mV or 100mV, respectively. The corresponding VCB(FAST) values are 100mV, 175mV and 325mV.

**GND (Pin 4):** Device Ground.

**GATE (Pin 5):** GATE Drive Output. An internal charge pump supplies 100µA pull-up current to the gate of the external N-channel MOSFET. Internal circuitry limits the voltage between the GATE and SENSEN pins to a safe gate drive voltage of less than 8V. When the circuit breaker trips, the GATE pin abruptly pulls to GND.

**SENSE (Pin 6):** Circuit Breaker Negative Sense Input. Connect this pin to the source of the external MOSFET. During reset or fault mode, the SENSE pin discharges the output to ground with 280µA.

**SENSEP (Pin 7):** Circuit Breaker Positive Sense Input. Connect this pin to the drain of external N-channel MOSFET. The circuit breaker trips when the voltage across SENSEP and SENSEN exceeds VCB. The input common mode range of the circuit breaker is from ground to VCC + 0.2V when VCC < 2.5V. For VCC ≥ 2.5V, the input common mode range is from ground to VCC + 0.4V.

**VCC (Pin 8):** Bias Supply Voltage Input. Normal operation is between 2.3V and 6V. An internal under-voltage lockout circuit disables the device when VCC < 2.07V.

**Exposed Pad (Pin 9):** Exposed pad may be left open or connected to device ground.
OPERATION

Overview

The LTC4213 is an Electronic Circuit Breaker (ECB) that senses load current with the R_{DSON} of the external MOSFET instead of using an external sense resistor. This no RSENSE method is less precise than RSENSE method due to the variation of R_{DSON}. However, the advantages are less complex, lower cost and reduce voltage and power loss in the switch path owing to the absence of a sense resistor. Without the external sense resistor voltage drop, the V_{OUT} improvement can be quite significant especially in the low voltage applications. The LTC4213 is designed to operate over a bias supply range from 2.3V to 6V. When bias supply voltage and the ON pin are sufficiently high, the GATE pin starts charging after an internal debounce delay of 60\mu s. During the GATE ramp-up, the circuit breaker is not armed until the external MOSFET is fully turned on. Once the circuit breaker is armed, the LTC4213 monitors the load current through the R_{DSON} of the external MOSFET.

Circuit Breaker Function

The LTC4213 provides dual level and dual response time circuit breaker functions for overcurrent protection. The LTC4213 circuit breaker function block consists of two comparators, SLOWCOMP and FASTCOMP. The thresholds of SLOWCOMP and FASTCOMP are V_{CB} and V_{CB(FAST)}. The I_{SEL} pin selects one of the three settings:

1. V_{CB} = 25mV and V_{CB(FAST)} = 100mV with I_{SEL} at GND
2. V_{CB} = 50mV and V_{CB(FAST)} = 175mV with I_{SEL} floating
3. V_{CB} = 100mV and V_{CB(FAST)} = 325mV with I_{SEL} at VCC

I_{SEL} can be stepped dynamically, such as to allow a higher circuit breaker threshold at startup and a lower threshold after supply current has settled. The inputs of the comparators are SENSEP and SENSEN pins. The voltage across the drain and source of the external MOSFET is sensed at SENSEP and SENSEN.

\[ \Delta V_{SENSE} = V_{SENSEP} - V_{SENSEN} \] (1)

When \( \Delta V_{SENSE} \) exceeds the \( V_{CB} \) threshold but is less than \( V_{CB(FAST)} \), the comparator SLOWCOMP trips the circuit breaker after a 16\mu s delay. If \( \Delta V_{SENSE} \) is greater than \( V_{CB(FAST)} \), the comparator FASTCOMP trips the circuit breaker in 1\mu s.

A severe short circuit condition can cause the load supply to dip substantially. This does not pose a problem for the LTC4213 as the input stages of the current limit comparators are common mode to ground.

APPLICATIONS INFORMATION

Figure 1 shows an electronic circuit breaker (ECB) application. An external auxiliary supply biases the VCC pin and the internal circuitry. A V_{IN} load supply powers the load via an external MOSFET. The SENSEP and SENSEN pins sense the load current at the drain and source of the external MOSFET. In ECB applications, large input bypass capacitors are usually recommended for good transient performance.

Undervoltage Lockout

An internal undervoltage lockout (UVLO) circuit resets the LTC4213 if the VCC supply is too low for normal operation. The UVLO comparator (UVCOMP) has a low-to-high threshold of 2.07V and 100mV of hysteresis. UVLO shares the glitch filters for both low-to-high transition (startup) and high-to-low transition (reset) with the ON pin comparators. Above 2.07V bias supply voltage, the LTC4213 starts if the ON pin conditions are met. Short, shallow bus bias

Figure 1. LTC4213 Electronic Circuit Breaker Application
supply transient dips below 1.97V of less than 80µs are ignored.

ON Function
When VON is below comparator COMP1’s threshold of 0.4V for 80µs, the device resets. The system leaves reset mode if the ON pin rises above comparator COMP2’s threshold of 0.8V and the UVLO condition is met. Leaving reset mode, the GATE pin starts up after a tDEBOUNCE delay of 60µs. When ON goes below 0.76V, the GATE shuts off after a 5µs glitch filter delay. The output is discharged by the external load when VON is in between 0.4V to 0.8V. At this state, the ON pin can re-enable the GATE if VON exceeds 0.8V for more than 8µs. Alternatively, the device resets if the ON pin is brought below 0.4V for 80µs. Once reset, the GATE pin restarts only after the tDEBOUNCE 60µs delay at VON rising above 0.8V. To protect the ON pin from overvoltage stress due to supply transients, a series resistor of greater than 10k is recommended when the ON pin is connected directly to the supply. An external resistive divider at the ON pin can be used with COMP2 to set a supply undervoltage lockout value higher than the internal UVLO circuit. An RC filter can be implemented at the ON pin to increase the powerup delay time beyond the internal 60µs delay.

Gate Function
The GATE pin is held low in reset mode. 60µs after leaving reset mode, the GATE pin is charged up by an internal 100µA current source. The circuit breaker arms when V\text{GATE} > V\text{SENSEN} + \Delta V\text{GSARM}. In normal mode operation, the GATE peak voltage is internally clamped to \Delta V\text{GSMAX} above the SENSEN pin. When the circuit breaker trips, an internal MOSFET shorts the GATE pin to GND, turning off the external MOSFET.

READY Status
The READY pin is held low during reset and at startup. It is pulled high by an external pullup resistor 50µs after the circuit breaker arms. The READY pin pulls low if the circuit breaker trips or the ON pin is pulled below 0.76V, or V\text{CC} drops below undervoltage lockout.

\Delta V\text{GSARM} and \Delta V\text{GSMAX}
Each MOSFET has a recommended VGS drive voltage where the channel is deemed fully enhanced and RDSON is minimized. Driving beyond this recommended VGS voltage yields a marginal decrease in RDSON. At startup, the gate voltage starts at ground potential. The GATE ramps past the MOSFET threshold and the load current begins to flow. When VGS exceeds \Delta V\text{GSARM}, the circuit breaker is armed and enabled. The chosen MOSFET should have a recommended minimum VGS drive level that is lower than \Delta V\text{GSARM}. Finally, VGS reaches a maximum at \Delta V\text{GSMAX}.

Trip and Reset Circuit Breaker
Figure 2 shows the timing diagram of V\text{GATE} and V\text{READY} after a fault condition. A tripped circuit breaker can be reset either by cycling the V\text{CC} bias supply below UVLO threshold or pulling ON below 0.4V for >t\text{RESET}. Figure 3 shows the timing diagram for a tripped circuit breaker being reset by the ON pin.

Calculating Current Limit
The fault current limit is determined by the RDSON of the MOSFET and the circuit breaker voltage V\text{CB}.

\[
I_{\text{LIMIT}} = \frac{V_{\text{CB}}}{R_{\text{DSON}}} \tag{2}
\]

The RDSON value depends on the manufacturer’s distribution, VGS and junction temperature. Short Kelvin-sense connections between the MOSFET drain and source to the LTC4213 SENSEP and SENSEN pins are strongly recommended.

For a selected MOSFET, the nominal load limit current is given by:

\[
I_{\text{LIMIT(NOM)}} = \frac{V_{\text{CB(NOM)}}}{R_{\text{DSON(NOM)}}} \tag{3}
\]

The minimum load limit current is given by:

\[
I_{\text{LIMIT(MIN)}} = \frac{V_{\text{CB(MIN)}}}{R_{\text{DSON(MAX)}}} \tag{4}
\]
The maximum load limit current is given by:

\[ I_{\text{LIMIT(MAX)}} = \frac{V_{\text{CB(MAX)}}}{R_{\text{DSON(MIN)}}} \]  

(5)

Most MOSFET data sheets have an \( R_{\text{DSON}} \) specification with typical and maximum values but no minimum value. Assuming a normal distribution with typical as mean, the minimum value can be estimated as

\[ R_{\text{DSON(MIN)}} = 2 \cdot R_{\text{DSON(NOM)}} - R_{\text{DSON(MAX)}} \]  

(6)

The LTC4213 gives higher gate drive than the manufacturer specified gate drive for \( R_{\text{DSON}} \). This gives a slightly lower \( R_{\text{DSON}} \) than specified. Operating temperature also modulates the \( R_{\text{DSON}} \) value.

Example Current Limit Calculation

An Si4410DY is used for current detection in a 5V supply system with the LTC4213 \( V_{\text{CB}} \) at 25mV \( (I_{\text{SEL}} \text{ pin grounded}) \).

The \( R_{\text{DSON}} \) distribution for the Si4410DY is

- Typical \( R_{\text{DSON}} = 0.015\Omega = 100\% \)
- Maximum \( R_{\text{DSON}} = 0.02\Omega = 133.3\% \)
- Estimated MIN \( R_{\text{DSON}} = 2 \cdot 15 - 20 = 0.010\Omega = 66.7\% \)

The \( R_{\text{DSON}} \) variation due to gate drive is

- \( R_{\text{DSON}} @ 4.5V_{\text{GS}} = 0.015\Omega = 100\% \) (spec. TYP)
- \( R_{\text{DSON}} @ 4.8V_{\text{GS}} = 0.014\Omega = 93\% \) (MIN \( \Delta V_{\text{GSMAX}} \))
- \( R_{\text{DSON}} @ 7V_{\text{GS}} = 0.0123\Omega = 82\% \) (NOM \( \Delta V_{\text{GSMAX}} \))
- \( R_{\text{DSON}} @ 8V_{\text{GS}} = 0.012\Omega = 80\% \) (MAX \( \Delta V_{\text{GSMAX}} \))

![Figure 2. Short Circuit Fault Timing Diagram](image-url)
Figure 3. Resetting Fault Timing Diagram
Operating temperature of 0° to 70°C.

- $R_{DSON} @ 25°C = 100%$
- $R_{DSON} @ 0°C = 90%$
- $R_{DSON} @ 70°C = 120%$

MOSFET resistance variation:

- $R_{DSON(NOM)} = 15m \times 0.82 = 12.3m\Omega$
- $R_{DSON(MAX)} = 15m \times 1.333 \times 0.93 \times 1.2 = 15m \times 1.488 = 22.3m\Omega$
- $R_{DSON(MIN)} = 15m \times 0.667 \times 0.80 \times 0.90 = 15m \times 0.480 = 7.2m\Omega$

$V_{CB}$ variation:

- NOM $V_{CB} = 25mV = 100%$
- MIN $V_{CB} = 22.5mV = 90%$
- MAX $V_{CB} = 27.5mV = 110%$

The current limits are:

- $I_{LIMIT(NOM)} = 25mV/12.3m\Omega = 2.03A$
- $I_{LIMIT(MIN)} = 22.5mV/22.3m\Omega = 1.01A$
- $I_{LIMIT(MAX)} = 27.5mV/7.2m\Omega = 3.82A$

For proper operation, the minimum current limit must exceed the circuit maximum operating load current with margin. So this system is suitable for operating load current up to 1A. From this calculation, we can start with the general rule for MOSFET $R_{DSON}$ by assuming maximum operating load current is roughly half of the $I_{LIMIT(NOM)}$. Equation 7 shows the rule of thumb.

$$I_{OPMAX} = \frac{V_{CB(NOM)}}{2 \times R_{DSON(NOM)}} \quad (7)$$

Note that the $R_{DSON(NOM)}$ is at the LTC4213 nominal operating $\Delta V_{GSMAX}$ rather than at typical vendor spec. Table 1 gives the nominal operating $\Delta V_{GSMAX}$ at the various operating $V_{CC}$. From this table users can refer to the MOSFET’s data sheet to obtain the $R_{DSON(NOM)}$ value.

**Load Supply Power-Up after Circuit Breaker Armed**

Figure 4 shows a normal power-up sequence for the circuit in Figure 1 where the $V_{IN}$ load supply power-up after circuit breaker is armed. $V_{CC}$ is first powered up by an auxiliary bias supply. $V_{CC}$ rises above 2.07V at time point 1. $V_{ON}$ exceeds 0.8V at time point 2. After a 60µs debounce delay, the GATE pin starts ramping up at time point 3. The external MOSFET starts conducting at time point 4. At time point 5, $V_{GATE}$ exceed $\Delta V_{GSARM}$ and the circuit breaker is armed. After 50µs ($t_{READY}$ delay), READY pulls high by an external resistor at time point 6. READY signals the $V_{IN}$ load supply module to start its ramp. The load supply begins soft-start ramp at time point 7. The load supply ramp rate must be slow to prevent circuit breaker tripping as in equation (8).

$$\frac{\Delta V_{IN}}{\Delta t} < \frac{I_{OPMAX} - I_{LOAD}}{C_{LOAD}} \quad (8)$$

Where $I_{OPMAX}$ is the maximum operating current defined by equation 7.

For illustration, $V_{CB} = 25mV$ and $R_{DSON} = 3.5m\Omega$ at the nominal operating $\Delta V_{GSMAX}$. The maximum operating current is 3.5A (refer to equation 7). Assuming the load can draw a current of 2A at power-up, there is a margin of 1.5A available for $C_{LOAD}$ of 100µF and $V_{IN}$ ramp rate should be <15V/ms. At time point 8, the current through the MOSFET reduces after $C_{LOAD}$ is fully charged.
Figure 4. Load Supply Power-Up After Circuit Breaker Armed
Load Supply Power-Up Before \( V_{CC} \)

Referring back to Figure 1, the \( V_{IN} \) load supply can also be powered up before \( V_{CC} \). Figure 5 shows the timing diagram with the \( V_{IN} \) load supply active initially. An internal circuit ensures that the GATE pin is held low. At time point 1, \( V_{CC} \) clears UVLO and at time point 2, ON clears 0.8V. 60\( \mu \)s later at time point 3, the GATE is ramped up with 100\( \mu \)A. At time point 4, GATE reaches the external MOSFET threshold \( V_{TH} \) and \( V_{OUT} \) starts to ramp up. At time point 5, \( V_{SENSE} \) is near its peak. At time point 6, the circuit breaker is armed and the circuit breaker can trip if \( \Delta V_{SENSE} > V_{CB} \).

At time point 7, the GATE voltage peaks. 50\( \mu \)s after time point 6, READY goes HIGH.

Startup Problems

There is no current limit monitoring during output charging for the figure 5 power-up sequence where the load supply is powered up before \( V_{CC} \). This is because the GATE voltage is below \( \Delta V_{GSARM} \) and the MOSFET may not reach the specified \( R_{DSON} \). The \( V_{IN} \) load supply should have sufficient capability to handle the inrush as the output charges up. For proper startup, the final load at time...
The selected MOSFET VGS absolute maximum rating should meet the LTC4213 maximum ∆VGSMAX of 8V.

Other MOSFET criteria such as VBDSS, IDMAX, and RDSON should be reviewed. Spikes and ringing above maximum operating voltage should be considered when choosing VBDSS. IDMAX should be greater than the current limit. The maximum operating load current is determined by the RDSON value. See the section on “Calculating Current Limit” for details.

Supply Requirements

The LTC4213 can be powered from a single supply or dual supply system. The load supply is connected to the SENSEP pin and the drain of the external MOSFET. In the single supply case, the VCC pin is connected to the load supply, preferably with an RC filter. With dual supplies, VCC is connected to an auxiliary bias supply VAUX where VAUX voltage should be greater or equal to the load supply voltage. The load supply voltage must be capable of sourcing more current than the circuit breaker limit. If the load supply current limit is below the circuit breaker trip current, the LTC4213 may not react when the output overloads. Furthermore, output overloads may trigger UVLO if the load supply has foldback current limit in a single supply system.

VIN Transient and Overvoltage Protection

Input transient spikes are commonly observed whenever the LTC4213 responds to overload. These spikes can be large in amplitude, especially given that large decoupling capacitors are absent in hot swap environments. These short spikes can be clipped with a transient suppressor of adequate voltage and power rating. In addition, the LTC4213 can detect a prolonged overvoltage condition. When
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SENSEP exceeds $V_{CC} + 0.7V$ for more than 65µs, the LTC4213’s internal overvoltage protection circuit activates and the GATE pin pulls down and turns off the external MOSFET.

Typical Electronic Fuse Application for a Single Supply System

Figure 6 shows a single supply electronic fuse application. An RC filter at $V_{CC}$ pin filters out transient spikes. An optional Schottky diode can be added if severe $V_{CC}$ dips during a fault start-up condition is a concern. The use of the Schottky and RC filter combination is allowed if the load supply is above 2.9V and the total voltage drop towards the $V_{CC}$ pin is less than 0.4V. The LTC4213’s internal UVLO filter further rejects bias supply’s transients of less than $t_{RESET}$. During power-up, it is good engineering practice to ensure that $V_{CC}$ is fully established before the ON pin enables the system at $V_{ON} = 0.8V$. In this application, the $V_{CC}$ voltage reached final value approximately after a $5.3 \cdot R_1 \cdot C_1$ delay. This is followed by the ON pin exceeding 0.8V after a $0.17 \cdot R_2 \cdot C_2$ delay. The GATE pin starts up after an internal $t_{DEBOUNCE}$ delay.

Typical Single Supply Hot Swap™ Application

A typical single supply Hot Swap application is shown in Figure 7. The RESET signal at the backplane is held low initially. When the PCB long edge makes contact the ON pin is held low (<0.4V) and the LTC4213 is kept in reset mode. When the short edge makes contact the $V_{IN}$ load supply is connected to the card. The $V_{CC}$ is biased via the RC filter. The $V_{OUT}$ is pre-charged via $R_5$. To power-up successfully, the $R_5$ resistor value should be small enough to provide the load requirement and to overcome the 280µA current source sinking into the SENSE pin. On the other hand, the $R_5$ resistor value should be big enough avoiding big inrush current and preventing big short circuit current. When RESET signals high at backplane, $C_2$ capacitor at the ON pin charges up via the $R_3/R_2$ resistive divider. When ON pin voltage exceeds $0.8V$, the GATE pin begins to ramp up. When the GATE voltage peaks, the external MOSFET is fully turned on and the $V_{IN}$-to-$V_{OUT}$ voltage drop reduces. In normal mode operation, the LTC4213 monitors the load current through the $R_{DSON}$ of the external MOSFET.

Hot Swap is a trademark of Linear Technology Corporation.
Information furnished by Linear Technology Corporation is believed to be accurate and reliable. However, no responsibility is assumed for its use. Linear Technology Corporation makes no representation that the interconnection of its circuits as described herein will not infringe on existing patent rights.
## RELATED PARTS

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<td>LTC1642</td>
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Figure 7. Single Supply Hot Board Insertion