Smart Highside High Current Power Switch

Features
• Overload protection
• Current limitation
• Short circuit protection
• Over temperature protection
• Over voltage protection (including load dump)
• Clamp of negative voltage at output
• Fast deenergizing of inductive loads
• Low ohmic inverse current operation
• Reversave™ (Reverse battery protection)
• Diagnostic feedback with load current sense
• Open load detection via current sense
• Loss of $V_{bb}$ protection
• Electrostatic discharge (ESD) protection

Application
• Power switch with current sense diagnostic feedback for 12 V and 24 V DC grounded loads
• Most suitable for loads with high inrush current like lamps and motors; all types of resistive and inductive loads
• Replaces electromechanical relays, fuses and discrete circuits

General Description
N channel vertical power FET with charge pump, current controlled input and diagnostic feedback with load current sense, integrated in Smart SIPMOS® chip on chip technology. Providing embedded protective functions.

Reversave™

Product Summary
- Overvoltage protection $V_{bb(AZ)}$ 62 V
- Output clamp $V_{ON(CL)}$ 42 V
- Operating voltage $V_{bb(on)}$ 5.0 ... 34 V
- On-state resistance $R_{ON}$ 6.0 mΩ
- Load current (ISO) $I_L(ISO)$ 70 A
- Short circuit current limitation $I_L(SC)$ 130 A
- Current sense ratio $I_L : I_S$ 14 000

TO-220-7

Standard

SMD

1) With additional external diode.
2) Additional external diode required for energized inductive loads (see page 9).
### Pin Symbol Function

<table>
<thead>
<tr>
<th>Pin</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OUT O</td>
<td>Output: output to the load; pin 1, 2, 6 and 7 must be externally shorted with each other especially in high current applications.</td>
</tr>
<tr>
<td>2</td>
<td>OUT O</td>
<td>Output: output to the load; pin 1, 2, 6 and 7 must be externally shorted with each other especially in high current applications.</td>
</tr>
<tr>
<td>3</td>
<td>IN I</td>
<td>Input: has an internal pull up; activates the power switch in case of short to ground</td>
</tr>
<tr>
<td>4</td>
<td>Vbb +</td>
<td>Supply voltage: positive power supply voltage; tab and pin 4 are internally shorted; in high current applications use the tab.</td>
</tr>
<tr>
<td>5</td>
<td>IS S</td>
<td>Sense Output: Diagnostic feedback; provides a sense current proportional to the load current; zero current on failure (see Truth Table on page 7)</td>
</tr>
<tr>
<td>6</td>
<td>OUT O</td>
<td>Output: output to the load; pin 1, 2, 6 and 7 must be externally shorted with each other especially in high current applications.</td>
</tr>
<tr>
<td>7</td>
<td>OUT O</td>
<td>Output: output to the load; pin 1, 2, 6 and 7 must be externally shorted with each other especially in high current applications.</td>
</tr>
</tbody>
</table>

### Maximum Ratings at $T_j = 25 \, ^\circ \text{C}$ unless otherwise specified

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage (over voltage protection see page 4)</td>
<td>$V_{bb}$</td>
<td>42</td>
<td>V</td>
</tr>
<tr>
<td>Supply voltage for short circuit protection, $T_{j,\text{start}} = -40 \ldots +150 , ^\circ \text{C}$: (see diagram on page 10)</td>
<td>$V_{bb}$</td>
<td>34</td>
<td>V</td>
</tr>
<tr>
<td>Load current (short circuit current, see page 5)</td>
<td>$I_L$</td>
<td>self-limited</td>
<td>A</td>
</tr>
</tbody>
</table>
| Load dump protection $V_{\text{Load dump}} = V_A + V_S$, $V_A = 13.5 \, \text{V}$  
  $R_I = 2 \, \Omega$, $R_L = 0.54 \, \Omega$, $t_d = 200 \, \text{ms}$,  
  IN, IS = open or grounded | $V_{\text{Load dump}}$ | 75     | V    |
| Operating temperature range | $T_j$ | -40 ...+150 | °C |
| Storage temperature range | $T_{\text{stg}}$ | -55 ...+150 | °C |
| Power dissipation (DC), $T_C \leq 25 \, ^\circ \text{C}$ | $P_{\text{tot}}$ | 170    | W    |
| Inductive load switch-off energy dissipation, single pulse  
  $V_{bb} = 12 \, \text{V}$, $T_{j,\text{start}} = 150 \, ^\circ \text{C}$, $T_C = 150 \, ^\circ \text{C}$ const.,  
  $I_L = 20 \, \text{A}$, $Z_L = 7.5 \, \text{mH}$, $0 \, \Omega$, see diagrams on page 10 | $E_{\text{AS}}$ | 1.5    | J    |
| Electrostatic discharge capability (ESD)  
  Human Body Model acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993, C = 100 pF, R = 1.5 kΩ | $V_{\text{ESD}}$ | 4      | kV   |
| Current through input pin (DC) | $I_{\text{IN}}$ | +15, -250 | mA |
| Current through current sense status pin (DC) | $I_{\text{IS}}$ | +15, -250 | mA |

3) Not shorting all outputs will considerably increase the on-state resistance, reduce the peak current capability and decrease the current sense accuracy

4) Otherwise add up to 0.7 mΩ (depending on used length of the pin) to the $R_{\text{ON}}$ if the pin is used instead of the tab.

5) $R_I =$ internal resistance of the load dump test pulse generator.

6) $V_{\text{Load dump}}$ is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839.
Thermal Characteristics

<table>
<thead>
<tr>
<th>Parameter and Conditions</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal resistance</td>
<td>$R_{thJC}$</td>
<td>--</td>
<td>-- 0.75</td>
</tr>
<tr>
<td></td>
<td>$R_{thJA}$</td>
<td>--</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--</td>
<td>33</td>
</tr>
</tbody>
</table>

Electrical Characteristics

<table>
<thead>
<tr>
<th>Parameter and Conditions</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>at $T_j = -40 \ldots +150 , ^\circ C$, $V_{bb} = 12 , V$ unless otherwise specified</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Load Switching Capabilities and Characteristics

<table>
<thead>
<tr>
<th>Parameter and Conditions</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-state resistance ($R_{ON}$)</td>
<td></td>
<td>4.4</td>
<td>6.0</td>
</tr>
<tr>
<td>$I_L = 20 , A$, $T_j = 25 , ^\circ C$; $V_{IN} = 0$, $I_L = 20 , A$, $T_j = 150 , ^\circ C$; $I_L = 90 , A$, $T_j = 150 , ^\circ C$; $V_{bb} = 6 , V$</td>
<td></td>
<td>7.9</td>
<td>10.5</td>
</tr>
<tr>
<td>$R_{ON(Static)}$</td>
<td></td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Nominal load current ($I_{L(ISO)}$)</td>
<td></td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td>ISO 10483-1/6.7: $V_{ON} = 0.5 , V$, $T_c = 85 , ^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal load current ($I_{L(NOM)}$)</td>
<td></td>
<td>13.6</td>
<td>17</td>
</tr>
<tr>
<td>$T_A = 85 , ^\circ C$, $T_j \leq 150 , ^\circ C$, $V_{ON} \leq 0.5 , V$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum load current in resistive range ($I_{L(Max)}$)</td>
<td></td>
<td>250</td>
<td>--</td>
</tr>
<tr>
<td>$V_{ON} = 1.8 , V$, $T_c = 25 , ^\circ C$</td>
<td></td>
<td>150</td>
<td>--</td>
</tr>
<tr>
<td>$V_{ON} = 1.8 , V$, $T_c = 150 , ^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn-on time ($t_{on}$)</td>
<td></td>
<td>100</td>
<td>--</td>
</tr>
<tr>
<td>Turn-off time ($t_{off}$)</td>
<td></td>
<td>30</td>
<td>--</td>
</tr>
<tr>
<td>$R_L = 1 , \Omega$, $T_j = -40 \ldots +150 , ^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slew rate on ($dV/dt_{on}$) ($10$ to $30%$ $V_{OUT}$)</td>
<td></td>
<td>--</td>
<td>0.7</td>
</tr>
<tr>
<td>$R_L = 1 , \Omega$, $T_j = 25 , ^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slew rate off ($dV/dt_{off}$) ($70$ to $40%$ $V_{OUT}$)</td>
<td></td>
<td>--</td>
<td>1.1</td>
</tr>
<tr>
<td>$R_L = 1 , \Omega$, $T_j = 25 , ^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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1) Thermal resistance $R_{thCH}$ case to heatsink (about 0.5 ... 0.9 K/W with silicone paste) not included!
2) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70μm thick) copper area for $V_{bb}$ connection. PCB is vertical without blown air.
3) Decrease of $V_{bb}$ below 10 V causes slowly a dynamic increase of $R_{ON}$ to a higher value of $R_{ON(Static)}$. As long as $V_{bin} > V_{bin(u)_{max}}$, $R_{ON}$ increase is less than 10 % per second for $T_J < 85 \, ^\circ C$.
4) Not subject to production test, specified by design
5) $T_J$ is about 105°C under these conditions.
6) See timing diagram on page 14.
### Inverse Load Current Operation

<table>
<thead>
<tr>
<th>Parameter and Conditions</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-state resistance (Pins 1, 2, 6, 7 to pin 4)</td>
<td>$R_{ON(inv)}$</td>
<td>--</td>
<td>4.4</td>
</tr>
<tr>
<td>Nominal inverse load current (Pins 1, 2, 6, 7 to Tab)</td>
<td>$I_{(inv)}$</td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td>Drain-source diode voltage ($V_{out} &gt; V_{bb}$)</td>
<td>$-V_{ON}$</td>
<td>--</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### Operating Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating voltage ($V_{IN} = 0V$)</td>
<td>$V_{bb(on)}$</td>
<td>5.0</td>
<td>--</td>
</tr>
<tr>
<td>Under voltage shutdown</td>
<td>$V_{blN(u)}$</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Under voltage start of charge pump</td>
<td>$V_{blN(ucp)}$</td>
<td>3.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Over voltage protection</td>
<td>$V_{Z,IN}$</td>
<td>60</td>
<td>--</td>
</tr>
<tr>
<td>Standby current</td>
<td>$I_{bb(off)}$</td>
<td>--</td>
<td>15</td>
</tr>
</tbody>
</table>

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13) If the device is turned on before a $V_{bb}$-decrease, the operating voltage range is extended down to $V_{blN(u)}$. For all voltages 0 ... 34 V the device is fully protected against overtemperature and short circuit.

14) $V_{blN} = V_{bb} - V_{IN}$ see diagram on page 7. When $V_{blN}$ increases from less than $V_{blN(u)}$ up to $V_{blN(ucp)} = 5 V$ (typ.) the charge pump is not active and $V_{OUT} = V_{bb} - 3 V$.

15) See also $V_{ON(CL)}$ in circuit diagram on page 9.
### Parameter and Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>at $T_j = -40 \ldots +150^\circ C$, $V_{bb} = 12$ V unless otherwise specified</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protection Functions</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Short circuit current limit

- $V_{ON} = 12$ V, time until shutdown max. 350 $\mu$s
- $T_C = -40^\circ C$: $I_{L(SC)} = -- 110 -- A$
- $T_C = 25^\circ C$: $I_{L(SC)} = -- 130 180 A$
- $T_C = +150^\circ C$: $I_{L(SC)} = 65 115 -- A$

#### Short circuit shutdown delay after input current positive slope, $V_{ON} > V_{ON(SC)}$

- $T_C = -40^\circ C$: $t_d(SC) = 80 -- 350 \mu$s
- $T_C = 25^\circ C$: $t_d(SC) = -- 80 \mu$s
- $T_C = +150^\circ C$: $t_d(SC) = -- 350 \mu$s

#### Output clamp

- $I_L = 40$ mA:
  - $V_{OUT(CL)} = 14 16.5 20 V$

#### Output clamp (inductive load switch off)

- $V_{ON(CL)} = 39 42 47 V$

#### Short circuit shutdown detection voltage

- $V_{ON(SC)} = -- 6 -- V$

#### Thermal overload trip temperature

- $T_{jt} = 150 -- -- ^\circ C$

#### Thermal hysteresis

- $\Delta T_{jt} = -- 10 -- K$

### Reverse Battery

<table>
<thead>
<tr>
<th>Reverse battery voltage</th>
<th>- $V_{bb}$</th>
<th>--</th>
<th>--</th>
<th>16</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-state resistance (Pins 1,2,6,7 to pin 4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{bb} = -12$ V, $V_{IN} = 0$, $I_L = -20$ A</td>
<td>$R_{ON(rev)} = 5.4$</td>
<td>5.4</td>
<td>7.0</td>
<td>m$\Omega$</td>
<td></td>
</tr>
<tr>
<td>$T_j = 25^\circ C$:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{bb} = 120$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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16) Integrated protection functions are designed to prevent IC destruction under fault conditions described in the data sheet. Fault conditions are considered as "outside" normal operating range. Protection functions are not designed for continuous repetitive operation.

17) This output clamp can be "switched off" by using an additional diode at the IS-Pin (see page 8). If the diode is used, $V_{OUT}$ is clamped to $V_{bb} - V_{ON(CL)}$ at inductive load switch off.

18) The reverse load current through the intrinsic drain-source diode has to be limited by the connected load (as it is done with all polarity symmetric loads). Note that under off-conditions ($I_{IN} = I_S = 0$) the power transistor is not activated. This results in raised power dissipation due to the higher voltage drop across the intrinsic drain-source diode. The temperature protection is not active during reverse current operation! Increasing reverse battery voltage capability is simply possible as described on page 9.
Diagnostic Characteristics

Current sense ratio, $I_L = 90\, \text{A}, T_j = -40\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = \frac{I_L}{I_{\text{IS}},_{\text{lim}}}$$

$T_j = 25\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 12\,500, 14\,200, 16\,000$$

$T_j = 150\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,500, 13\,000, 14\,500$$

$V_{\text{ON}} < 1.5\, \text{V}$

$V_L = 20\, \text{A}, T_j = -40\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 12\,500, 14\,500, 17\,500$$

$T_j = 25\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 12\,000, 14\,000, 16\,500$$

$T_j = 150\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,500, 13\,400, 15\,000$$

$V_{\text{IS}} < V_{\text{OUT}} - 5\, \text{V}$

$V_L = 10\, \text{A}, T_j = -40\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 12\,500, 15\,000, 19\,000$$

$T_j = 25\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,500, 14\,300, 17\,500$$

$T_j = 150\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,500, 13\,500, 15\,500$$

$V_{\text{IN}} > 4.0\, \text{V}$

$V_L = 4\, \text{A}, T_j = -40\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,000, 18\,000, 28\,500$$

$T_j = 25\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,000, 15\,400, 22\,000$$

$T_j = 150\, ^\circ\text{C}$:

$$k_{\text{ILIS}} = 11\,200, 14\,000, 19\,000$$

$I_{\text{IS}} = 0$ by $I_{\text{IN}} = 0$ (e.g. during deenergizing of inductive loads):

- **Sense current saturation**
  - $I_{\text{ILS},_{\text{lim}}} = 6.5\, \text{mA}$

- **Current sense leakage current**
  - $V_{\text{IN}} = 0, I_L \leq 0$:
    - $I_{\text{ILS(LH)}} = 2\, \mu\text{A}$
  - $I_{\text{IN}} = 0$:
    - $I_{\text{ILS(LL)}} = 0.5\, \mu\text{A}$

- **Current sense over voltage protection**
  - $T_j = -40\, ^\circ\text{C}$:
    - $I_{\text{IS}_{\text{Z}}} = 60\, \text{V}$
  - $T_j = 25\, \cdots +150\, ^\circ\text{C}$:
    - $I_{\text{IS}_{\text{Z}}} = 62\, \text{V}$

- **Current sense settling time**
  - $I_{\text{IS}} = 500\, \mu\text{s}$

Input

- **Input and operating current (see diagram page 13)**
  - $I_{\text{IN(on)}} = 0.8\, \text{mA}$
  - $I_{\text{IN(off)}} = 1.5\, \text{mA}$

- **Input current for turn-off**
  - $I_{\text{IN(off)}} = 80\, \mu\text{A}$

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19) If $V_{\text{ON}}$ is higher, the sense current is no longer proportional to the load current due to sense current saturation, see $I_{\text{ILS},_{\text{lim}}}$.

20) not subject to production test, specified by design

21) We recommend the resistance between IN and GND to be less than 0.5 $\Omega$ for turn-on and more than 500 $\Omega$ for turn-off. Consider that when the device is switched off ($I_{\text{IN}} = 0$) the voltage between IN and GND reaches almost $V_{\text{bb}}$. 

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2003-Oct-01

Infineon Technologies AG
Truth Table

<table>
<thead>
<tr>
<th>Input current level</th>
<th>Output level</th>
<th>Current Sense $I_{IS}$</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal operation</td>
<td>$L$</td>
<td>$L$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$H$</td>
<td>$H$</td>
<td>$I_{IS}$, up to $I_{IS} = I_{IS,lim}$</td>
</tr>
<tr>
<td>Very high load current</td>
<td>$H$</td>
<td>$H$</td>
<td>$I_{IS,lim}$ up to $V_{ON} = V_{ON(Fold back)}$</td>
</tr>
<tr>
<td></td>
<td>$L$</td>
<td>$L$</td>
<td>$I_{IS}$ no longer proportional to $I_L$</td>
</tr>
<tr>
<td>Current-limitation</td>
<td>$H$</td>
<td>$H$</td>
<td>0</td>
</tr>
<tr>
<td>Short circuit to GND</td>
<td>$L$</td>
<td>$L$</td>
<td>0</td>
</tr>
<tr>
<td>Over temperature</td>
<td>$L$</td>
<td>$L$</td>
<td>0</td>
</tr>
<tr>
<td>Short circuit to $V_{bb}$</td>
<td>$L$</td>
<td>$H$</td>
<td>0</td>
</tr>
<tr>
<td>Open load</td>
<td>$L$</td>
<td>$Z^{22}$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$H$</td>
<td>$H$</td>
<td>0</td>
</tr>
<tr>
<td>Negative output voltage clamp</td>
<td>$L$</td>
<td>$L$</td>
<td>0</td>
</tr>
<tr>
<td>Inverse load current</td>
<td>$L$</td>
<td>$H$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>$H$</td>
<td>$H$</td>
<td>0</td>
</tr>
</tbody>
</table>

$L$ = "Low" Level; $H$ = "High" Level

Over temperature reset by cooling: $T_j < T_{jt}$ (see diagram on page 15)

Short circuit to GND: Shutdown remains latched until next reset via input (see diagram on page 14)

Terms

Two or more devices can easily be connected in parallel to increase load current capability.

$V_{bb}$ force

Out Force contacts (both out pins parallel)

Sense contacts

Typical $R_{ON}$ for SMD version is about 0.2 mΩ less than straight leads due to $l = 2$ mm

$22)$ Low ohmic short to $V_{bb}$ may reduce the output current $I_L$ and can thus be detected via the sense current $I_{IS}$.

$23)$ Power Transistor "OFF", potential defined by external impedance.
Input circuit (ESD protection)

When the device is switched off ($I_{IN} = 0$) the voltage between IN and GND reaches almost $V_{bb}$. Use a mechanical switch, a bipolar or MOS transistor with appropriate breakdown voltage as driver. $V_{Z,IN} = 66$ V (typ).

Short circuit detection

Fault Condition: $V_{ON} > V_{ON(SC)}$ (6 V typ.) and $t > t_{d(SC)}$ (80 ... 350 µs).

Current sense status output

$V_{Z,IS} = 66$ V (typ.), $R_{IS} = 1 \, \text{k}\Omega$ nominal (or $1 \, \text{k}\Omega / n$, if $n$ devices are connected in parallel). $I_{S} = I_{L}/K_{ilis}$ can be driven only by the internal circuit as long as $V_{out} - V_{IS} > 5$ V. If you want to measure load currents up to $I_{L(M)}$, $R_{IS}$ should be less than $V_{bb} - 5$ V / $K_{ilis}$.

Note: For large values of $R_{IS}$ the voltage $V_{IS}$ can reach almost $V_{bb}$. See also over voltage protection.

If you don’t use the current sense output in your application, you can leave it open.

Inductive and over voltage output clamp

$V_{ON}$ is clamped to $V_{ON(CL)} = 42$ V typ. At inductive load switch-off without $D_{S}$, $V_{OUT}$ is clamped to $V_{OUT(CL)} = -19$ V typ. via $V_{ZG}$. With $D_{S}$, $V_{OUT}$ is clamped to $V_{bb} - V_{ON(CL)}$ via $V_{Z1}$. Using $D_{S}$ gives faster deenergizing of the inductive load, but higher peak power dissipation in the PROFET. In case of a floating ground with a potential higher than 19V referring to the OUT – potential the device will switch on, if diode $D_{S}$ is not used.
Over voltage protection of logic part

$R_{bb} = 120 \Omega \text{ typ.}, \quad V_{Z,IN} = V_{Z,IS} = 66 \text{V typ.}, \quad R_{IS} = 1 \text{k}\Omega \text{ nominal. Note that when over voltage exceeds } 71 \text{V typ. a voltage above 5V can occur between IS and GND, if } R_V, V_{Z,VIS} \text{ are not used.}$

Reverse battery protection

$R_V \geq 1 \text{k}\Omega, \quad R_{IS} = 1 \text{k}\Omega \text{ nominal. Add } R_{IN} \text{ for reverse battery protection in applications with } V_{bb} \text{ above } 16 \text{V}\text{[18]}; \text{ recommended value:}$

\[ \frac{1}{R_{IN}} + \frac{1}{R_{IS}} + \frac{1}{R_V} = \frac{0.1A}{|V_{bb}| - 12V} \text{ if } D_S \text{ is not used (or } \frac{1}{R_{IN}} = \frac{0.1A}{|V_{bb}| - 12V} \text{ if } D_S \text{ is used).}$

To minimize power dissipation at reverse battery operation, the summarized current into the IN and IS pin should be about 120mA. The current can be provided by using a small signal diode D in parallel to the input switch, by using a MOSFET input switch or by proper adjusting the current through $R_{IS}$ and $R_V$. 

$V_{bb}$ disconnect with energized inductive load

Provide a current path with load current capability by using a diode, a Z-diode, or a varistor. ($V_{ZL} < 72 \text{V} \text{ or } V_{Zb} < 30 \text{V if } R_{IN}=0$). For higher clamp voltages currents at IN and IS have to be limited to 250 mA.

Version a:

Version b:

Version c:

Note that there is no reverse battery protection when using a diode without additional Z-diode $V_{ZL}, V_{Zb}$.

Version c: Sometimes a necessary voltage clamp is given by non inductive loads $R_L$ connected to the same switch and eliminates the need of clamping circuit:
Inverse load current operation

The device is specified for inverse load current operation ($V_{OUT} > V_{bb} > 0V$). The current sense feature is not available during this kind of operation ($I_{IS} = 0$). With $I_{IN} = 0$ (e.g. input open) only the intrinsic drain source diode is conducting resulting in considerably increased power dissipation. If the device is switched on ($V_{IN} = 0$), this power dissipation is decreased to the much lower value $R_{ON(INV)} * I^2$ (specifications see page 4).

Note: Temperature protection during inverse load current operation is not possible!

Inductive load switch-off energy dissipation

Energy stored in load inductance:

$$E_L = \frac{1}{2} \cdot L \cdot I_L^2$$

While demagnetizing load inductance, the energy dissipated in PROFET is

$$E_{AS} = E_{bb} + E_L = V_{ON(CL)} \cdot I_L(t) \, dt,$$

with an approximate solution for $R_L > 0\Omega$:

$$E_{AS} = \frac{1}{2} \cdot I_L \cdot L \cdot (V_{bb} + |V_{OUT(CL)}|) \ln \left(1 + \frac{I_L \cdot R_L}{V_{OUT(CL)}} \right)$$

Maximum allowable load inductance for a single switch off

$$L = f(I_L); \; T_{j,\text{start}} = 150^\circ \text{C}, \; V_{bb} = 12 \, \text{V}, \; R_L = 0 \, \Omega$$

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Externally adjustable current limit

If the device is conducting, the sense current can be used to reduce the short circuit current and allow higher lead inductance (see diagram above). The device will be turned off, if the threshold voltage of T2 is reached by $I_{IS} \cdot R_{IS}$. After a delay time defined by $R_{V} \cdot C_{V}$, T1 will be reset. The device is turned on again, the short circuit current is defined by $I_{L(SC)}$ and the device is shut down after $t_{d(SC)}$ with latch function.
## Options Overview

<table>
<thead>
<tr>
<th>Type</th>
<th>BTS</th>
<th>6510</th>
<th>550P</th>
<th>555</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over temperature protection with hysteresis</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>$T_j &gt; 150 , ^\circ \text{C}$, latch function(^{24})</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>$T_j &gt; 150 , ^\circ \text{C}$, with auto-restart on cooling</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Short circuit to GND protection</td>
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<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with over temperature shutdown</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>switches off when $V_{ON} &gt; 6$ V typ.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(when first turned on after approx. 180 $\mu$s)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Over voltage shutdown</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Output negative voltage transient limit to $V_{bb} - V_{ON(CL)}$</td>
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<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>to $V_{OUT} = -19$ V typ</td>
<td></td>
<td>X(^{25})</td>
<td>X(^{25})</td>
<td>X(^{25})</td>
</tr>
</tbody>
</table>

\(^{24})\text{ Latch except when } V_{bb} - V_{OUT} < V_{ON(SC)} \text{ after shutdown. In most cases } V_{OUT} = 0 \text{ V after shutdown } (V_{OUT} \neq 0 \text{ V only if forced externally). So the device remains latched unless } V_{bb} < V_{ON(SC)} \text{ (see page 5). No latch between turn on and } t_{d(SC)} .

\(^{25})\text{ Can be "switched off" by using a diode } D_S \text{ (see page 8) or leaving open the current sense output.}
Characteristics

Current sense versus load current:
\[ I_{IS} = f(I_L), \quad T_J = -40 \ldots +150 \, ^\circ C \]

Current sense ratio:
\[ K_{ILS} = f(I_L), \quad T_J = 25 \, ^\circ C \]
\[ K_{ILS} = f(I_L), \quad T_J = 150 \, ^\circ C \]
Typ. current limitation characteristic

\[ I_L = f(V_{ON}, T_j) \]

In case of \( V_{ON} > V_{ON(SC)} \) (typ. 6 V) the device will be switched off by internal short circuit detection.

Typ. on-state resistance

\[ R_{ON} = f(V_{bb}, T_j) \; \text{;} \; I_L = 20\; \text{A}; \; V_{IN} = 0 \]

Typ. input current

\[ I_{IN} = f(V_{BIN}), \; V_{BIN} = V_{bb} - V_{IN} \]

\[ I_{IN} \; \text{[mA]} \]

\[ V_{bb} \; \text{[V]} \]

\[ V_{ON} \; \text{[V]} \]

\[ V_{ON} > V_{ON(SC)} \; \text{only for } t < t_{d(SC)} \; \text{(otherwise immediate shutdown)} \]

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\[ I_{IN} = f(V_{BIN}), \; V_{BIN} = V_{bb} - V_{IN} \]

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\[ V_{ON} \; \text{[V]} \]

\[ V_{ON} > V_{ON(SC)} \; \text{only for } t < t_{d(SC)} \; \text{(otherwise immediate shutdown)} \]
Timing diagrams

Figure 1a: Switching a resistive load, change of load current in on-condition:

The sense signal is not valid during a settling time after turn-on/off and after change of load current.

Figure 2b: Switching motors and lamps:

Sense current saturation can occur at very high inrush currents (see $I_{S, lim}$ on page 6).

Figure 2c: Switching an inductive load:

Figure 3d: Short circuit: shut down by short circuit detection, reset by $I_{IN} = 0$.

Shut down remains latched until next reset via input.
Figure 4e: Over temperature
Reset if $T_j < T_{jt}$

Figure 6f: Under voltage restart of charge pump, over voltage clamp
Package and Ordering Code

All dimensions in mm

Standard: TO-220-7-3  Ordering code

| BTS650P     | Q67060-S6308-A002 |

SMD: TO220-7-180  Ordering code

| BTS650P E3180A | T&R: Q67060-S6308-A004 |

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