Smart Highside Power Switch

Reversave™
- Reverse battery protection by self turn on of power MOSFET

Features
- Short circuit protection
- Current limitation
- Overload protection
- Thermal shutdown
- Overvoltage protection (including load dump)
- Loss of ground protection
- Loss of Vbb protection (with external diode for charged inductive loads)
- Very low standby current
- Fast demagnetisation of inductive loads
- Electrostatic discharge (ESD) protection
- Optimized static electromagnetic compatibility (EMC)
- Green product (RoHS compliant)
- AEC qualified

Diagnostic Function
- Proportional load current sense (with defined fault signal during thermal shutdown)

Application
- Power switch with current sense diagnostic feedback for 12V and 24 V DC grounded loads
- All types of resistive, capacitive and inductive loads (no PWM with 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.

Product Summary

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating voltage</td>
<td>V_{bb(on)}</td>
</tr>
<tr>
<td>On-state resistance</td>
<td>R_{ON}</td>
</tr>
<tr>
<td>Load current (ISO)</td>
<td>I_{L(ISO)}</td>
</tr>
<tr>
<td>Current limitation</td>
<td>I_{L(SCR)}</td>
</tr>
</tbody>
</table>

| Package                        | PG-TO252-5-11       |

Data Sheet  Page 1 of 15  Rev. 1.0, 2007-02
**Pin Symbol** | **Function** |
--- | --- |
1 | OUT O | Output to the load. The pin 1 and 5 must be shorted with each other especially in high current applications!*) |
2 | IN I | Input, activates the power switch in case of short to ground |
Tab/(3) | Vbb + | Positive power supply voltage, the tab is shorted to this pin. |
4 | IS S | Diagnostic feedback providing a sense current proportional to the load current; high current on failure (see Truth Table on page 6) |
5 | OUT O | Output to the load. The pin 1 and 5 must be shorted with each other especially in high current applications!*) |

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

**Maximum Ratings** at $T_j = 25 \, ^\circ C$ 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 (overvoltage protection see page 4)</td>
<td>$V_{bb}$</td>
<td>36</td>
<td>V</td>
</tr>
<tr>
<td>Supply voltage for full short circuit protection (see also diagram on page 9)</td>
<td>$V_{bb}$</td>
<td>$24^{1)}$</td>
<td>V</td>
</tr>
<tr>
<td>Load dump protection $V_{\text{Load Dump}} = U_A + V_S$, $U_A = 13.5 , V$, $R_1 = 2 , \Omega$, $R_L = 2.7 , \Omega$, $t_d = 200 , ms$, $I_N$ low or high</td>
<td>$V_{\text{Load dump}}^{2)}$</td>
<td>60</td>
<td>V</td>
</tr>
<tr>
<td>Load current (Short-circuit current, see page 4)</td>
<td>$I_L$</td>
<td>self-limited</td>
<td>A</td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>$T_j$</td>
<td>-40 ... +150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature range</td>
<td>$T_{stg}$</td>
<td>-55 ... +150</td>
<td>°C</td>
</tr>
<tr>
<td>Power dissipation (DC) $T_C \leq 25 , ^\circ C$</td>
<td>$P_{tot}$</td>
<td>42</td>
<td>W</td>
</tr>
<tr>
<td>Inductive load switch-off energy dissipation, single pulse $U=12 , V$, $I=10 , A$, $L=3 , mH$</td>
<td>$E_{AS}$</td>
<td>0.15</td>
<td>J</td>
</tr>
<tr>
<td>Electrostatic discharge capability (ESD) (Human Body Model) acc. ESD assn. std. S5.1-1993; $R=1.5k\Omega$; $C=100pF$</td>
<td>$V_{ESD}$</td>
<td>4.0</td>
<td>kV</td>
</tr>
<tr>
<td>Current through input pin (DC)</td>
<td>$I_{IN}$</td>
<td>+15, -100</td>
<td>mA</td>
</tr>
<tr>
<td>Current through current sense pin (DC)</td>
<td>$I_{IS}$</td>
<td>+15, -100</td>
<td>mA</td>
</tr>
</tbody>
</table>

1) Short circuit is tested with 100mΩ and 20µH

2) $V_{\text{Load dump}}$ is set-up 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>1.5  K/W</td>
</tr>
<tr>
<td></td>
<td>$R_{thJA}$</td>
<td>-- 80</td>
<td>--</td>
</tr>
</tbody>
</table>

3) Thermal resistance $R_{thCH}$ case to heatsink (about 0.5 ... 0.9 K/W with silicone paste) not included!

### Electrical Characteristics

<table>
<thead>
<tr>
<th>Parameter and Conditions</th>
<th>Symbol</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Switching Capabilities and Characteristics</td>
<td>$R_{ON}$</td>
<td>-- 13 16 mΩ</td>
<td></td>
</tr>
<tr>
<td>On-state resistance (pin 3 to pin 1,5)</td>
<td>$V_{ON}^{(NL)}$</td>
<td>-- 50 -- mV</td>
<td></td>
</tr>
<tr>
<td>Output voltage drop limitation at small load currents (Tab to pin 1,5)</td>
<td>$I_{L}^{(ISO)}$</td>
<td>21 25 -- A</td>
<td></td>
</tr>
<tr>
<td>ISO Proposal: $T_{C}=85^\circ C$, $V_{ON}^{=}0.5V$, $T_{J}^{=}150^\circ C$</td>
<td>$I_{L}^{(nom)}$</td>
<td>6.2 7.6 --</td>
<td></td>
</tr>
<tr>
<td>Nominal load current (Tab to pin 1,5)</td>
<td>$T_{J}^{=}=-40...150^\circ C$:</td>
<td>$t_{on}$</td>
<td>150 410 μs</td>
</tr>
<tr>
<td>$V_{IN}=0$, $I_{L}=5$ A</td>
<td>$I_{IN}$</td>
<td>90% $V_{OUT}$:</td>
<td>$t_{off}$</td>
</tr>
<tr>
<td>Turn-on time</td>
<td></td>
<td>$T_{J}^{=}=-40...150^\circ C$:</td>
<td>$RL=2.5\Omega$, $T_{J}^{=}=-40...150^\circ C$:</td>
</tr>
<tr>
<td>Turn-off time</td>
<td></td>
<td>$dV/dt_{on}$</td>
<td>0.1 1 V/μs</td>
</tr>
<tr>
<td>Slew rate on</td>
<td>$10$ to $30%$ $V_{OUT}$, $R_{L}=2.5\Omega$, $T_{J}^{=}=-40...150^\circ C$:</td>
<td>$-dV/dt_{off}$</td>
<td>0.1 1 V/μs</td>
</tr>
<tr>
<td>Slew rate off</td>
<td>$70$ to $40%$ $V_{OUT}$, $R_{L}=2.5\Omega$, $T_{J}^{=}=-40...150^\circ C$:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4) 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.
### Operating Parameters

**Operating voltage** (V\(_{IN}=0\)V)
- \(V_{bb(on)}\):
  - min: 5.0 V  
  - typ: -- V  
  - max: 36 V

**Undervoltage shutdown** \(^5\)
- \(V_{bIN(u)}\):
  - min: 1.5 V  
  - typ: 3.0 V  
  - max: 4.5 V

**Undervoltage restart of charge pump** (V\(_{IN}=0\)V)
- \(V_{bb(ucp)}\):
  - min: 3.0 V  
  - typ: 4.5 V  
  - max: 6.0 V

**Overvoltage protection** \(^6\)
- \(I_{bb}=15\) mA
- \(V_{Z,IN}\):
  - min: 61 V  
  - typ: 68 V  
  - max: -- V

**Standby current**
- \(I_{bb(off)}\):
  - \(T_j=-40\ldots+25^\circ\)C: 2 µA  
  - \(T_j=150^\circ\)C: 5 µA

### Protection Functions \(^7\)

**Short circuit current limit** (Tab to pin 1,5)
- \(V_{ON}=8\)V, time until limitation max. 300µs
  - \(T_j=-40^\circ\)C: 35 A  
  - \(T_j=25^\circ\)C: 75 A  
  - \(T_j=+150^\circ\)C: 110 A

**Output clamp (inductive load switch off)**
- at \(V_{OUT} = V_{bb} - V_{ON(CL)}\) (e.g. overvoltage)
  - \(V_{ON(CL)}\):
    - min: 35 V  
    - typ: 65 V  
    - max: 125 V

**Thermal overload trip temperature**
- \(T_{jt}\):
  - min: 150 °C

**Thermal hysteresis**
- \(\Delta T_{jt}\):
  - min: 10 °C

### Reverse Battery

**Reverse battery voltage**
- \(-V_{bb}\):
  - min: -- V  
  - typ: -- V  
  - max: 20 V

**On-state resistance** (pin 1,5 to pin 3)
- \(V_{bb}= -8\)V, \(V_{IN}= 0\), \(I_L = -5\) A, \(R_{IS} = 1\) kΩ,
  - \(T_j=25^\circ\)C:
    - \(R_{ON(rev)}\):
      - min: -- mΩ  
      - typ: -- mΩ  
      - max: 22 mΩ

- \(V_{bb}= -12\)V, \(V_{IN}= 0\), \(I_L = -5\) A, \(R_{IS} = 1\) kΩ,
  - \(T_j=25^\circ\)C:
    - \(R_{ON(rev)}\):
      - min: 16 mΩ  
      - typ: 19 mΩ  
      - max: 25 mΩ

  - \(T_j=150^\circ\)C:
    - \(R_{ON(rev)}\):
      - min: --- mΩ  
      - typ: 19 mΩ  
      - max: 32 mΩ

**Integrated resistor in \(V_{bb}\) line**
- \(R_{bb}\):
  - min: 200 Ω  
  - typ: -- Ω  
  - max: -- Ω

---

5) \(V_{bIN}=V_{bb}-V_{IN}\) see diagram on page 11.

6) see also \(V_{ON(CL)}\) in circuit diagram on page 7.

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

8) see also page 12.
### Diagnostic Characteristics

**Current sense ratio, static on-condition**
\[ k_{\text{ILIS}} = \frac{I_L}{I_S} \]

- \( V_{\text{ON}} < 1.5 \text{ V}, V_{\text{IS}} < V_{\text{OUT}} - 5 \text{ V}, V_{\text{biN}} > 4.5 \text{ V} \)

<table>
<thead>
<tr>
<th>( k_{\text{ILIS}} )</th>
<th>8200</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_L = 20 \text{ A}, T_j = -40^\circ \text{C} : )</td>
<td>7400</td>
<td>8300</td>
</tr>
<tr>
<td>( T_j = +25^\circ \text{C} : )</td>
<td>7500</td>
<td>8300</td>
</tr>
<tr>
<td>( T_j = +150^\circ \text{C} : )</td>
<td>7500</td>
<td>8200</td>
</tr>
<tr>
<td>( I_L = 10 \text{ A}, T_j = -40^\circ \text{C} : )</td>
<td>6800</td>
<td>8300</td>
</tr>
<tr>
<td>( T_j = +25^\circ \text{C} : )</td>
<td>7200</td>
<td>8300</td>
</tr>
<tr>
<td>( T_j = +150^\circ \text{C} : )</td>
<td>7200</td>
<td>8200</td>
</tr>
<tr>
<td>( I_L = 2.5 \text{ A}, T_j = -40^\circ \text{C} : )</td>
<td>6800</td>
<td>8500</td>
</tr>
<tr>
<td>( T_j = +25^\circ \text{C} : )</td>
<td>6800</td>
<td>8500</td>
</tr>
<tr>
<td>( T_j = +150^\circ \text{C} : )</td>
<td>6800</td>
<td>8100</td>
</tr>
<tr>
<td>( I_L = 1 \text{ A}, T_j = -40^\circ \text{C} : )</td>
<td>6800</td>
<td>8600</td>
</tr>
<tr>
<td>( T_j = +25^\circ \text{C} : )</td>
<td>6800</td>
<td>8600</td>
</tr>
<tr>
<td>( T_j = +150^\circ \text{C} : )</td>
<td>6800</td>
<td>8600</td>
</tr>
</tbody>
</table>

\( I_N = 0 \) (e.g. during de-energising of inductive loads):

<table>
<thead>
<tr>
<th>( I_{\text{IS(fault)}} )</th>
<th>2.5</th>
<th>4</th>
<th>--</th>
</tr>
</thead>
</table>

**Sense current under fault conditions;**
\( V_{DS} > 1.5 \text{ V}, \text{ typ.} \)

| \( t_{\text{delay(fault)}} \) | 0.8 | ms |

**Fault-Sense signal delay after negative input slope**

| \( I_{\text{IN(on)}} \) | 0.7 | 1.2 | mA |

**Current sense leakage current**

- \( I_{\text{IN}} = 0 \):
  - \( I_{\text{IS(L)}} \):
    - \( V_{\text{IN}} = 0, I_L = 0 \):
      - \( I_{\text{IS(LH)}} \): 0.5 µA
  - \( I_{\text{IS(L)}} \): 4 µA

**Current sense settling time to \( I_{\text{IS}} \) static ±10% after positive input slope,**
\( I_L = 0 \) \( \sqrt{20 \text{ A}} \) \( T_j = -40...+150^\circ \text{C} : \)

| \( t_{\text{son(IS)}} \) | 400 | µs |

**Overvoltage protection**

- \( I_{bb} = 15 \text{ mA} \)
  - \( T_j = -40...+150^\circ \text{C} : \)
    - \( V_{\text{biS(Z)}} \): 61 | 68 | -- | V |

---

9) If \( V_{\text{ON}} \) is higher, the sense current is no longer proportional to the load current due to sense current saturation.

10) Not subject to production test, specified by design.
### Truth Table

<table>
<thead>
<tr>
<th>Input Current level</th>
<th>Output level</th>
<th>Current Sense $I_{IS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal operation</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Overload</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Short circuit to GND</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Overtemperature</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>Short circuit to $V_{bb}$</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Open load</td>
<td>L</td>
<td>Z</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

$L = \text{"Low" Level}$  
$H = \text{"High" Level}$  
$Z = \text{high impedance, potential depends on external circuit}$

### Terms

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

$^{11)}$ Low ohmic short to $V_{bb}$ may reduce the output current $I_L$ and therefore also the sense current $I_{IS}$. 
Input circuit (ESD protection)

ESD-Zener diode: 68 V typ., max 15 mA;

Current sense output
Normal operation

\[ V_{Z,IS} = 68 \text{ V (typ.)}, \quad R_{IS} = 1 \text{k}\Omega \text{ nominal (or } 1 \text{k}\Omega /n, \text{ if } n \text{ devices are connected in parallel}) \]

\[ I_{IS} = I_{IL}/K_{IL} \text{ can be only driven by the internal circuit as long as } V_{out} - V_{IS} > 5 \text{ V}. \]

If you want to measure load currents up to \( I_{L(M)} \), \( R_{IS} \) should be less than \( V_{bb} - 5V \):

\[ V_{Z,IS} = 68 \text{ V (typ.)}, \quad R_{IS} = 1 \text{k}\Omega \text{ nominal. Note that when overvoltage exceeds 73 V typ., a voltage above 5V can occur between IS and GND, if } R_{V}, V_{Z,VIS} \text{ are not used.} \]

Overvoltage protection of logic part

Inductive and overvoltage output clamp

\( V_{ON} \) is clamped to \( V_{ON(CL)} = 42 \text{ V typ.} \)
Reversave™ (Reverse battery protection)

$R_V \geq 1\, \text{k} \Omega$; $R_{IS} = 1\, \text{k} \Omega$ nominal. Add $R_{IN}$ for reverse battery protection in applications with $V_{bb}$ above 16V; recommended value: $\frac{1}{R_{IN}} + \frac{1}{R_{IS}} + \frac{1}{R_V} = \frac{0.05 \text{A}}{|V_{bb}| - 12\text{V}}$

To minimise power dissipation at reverse battery operation, the summarised current into the IN and IS pin should be about 50mA. 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 $R_V$. Since the current through $R_{bb}$ generates additional heat in the device, this has to be taken into account in the overall thermal considerations.

$V_{bb}$ disconnect with energised inductive load

Provide a current path with load current capability by using a diode, a Z-diode, or a varistor. ($V_{ZL} < 73\, \text{V}$ 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:
Inductive load switch-off energy dissipation

Energy stored in load inductance:

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

While demagnetising load inductance, the energy dissipated in PROFET is

\[ E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t) \, dt, \]

with an approximate solution for \( R_L > 0 \Omega \):

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

The device is not suitable for permanent PWM with inductive loads if active clamping occurs every cycle.

Maximum allowable load inductance for a single switch off

\[ L = f(I_L); \quad T_j,\text{start} = 150^\circ C, \quad V_{bb} = 12 V, \quad R_L = 0 \Omega \]
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 1b: typical behaviour of sense output:

Figure 2a: Switching motors and lamps:

Sense current above \( I_{\text{IS,fault}} \) can occur at very high inrush currents.

Figure 2b: Switching an inductive load:
**Figure 3a:** Short circuit:

- $I_{IN}$
- $I_L$
- $I_{L(SCr)}$
- $I_{L(SCp)}$
- $I_{IS}$
- $I_{IS(fault)}$
- $t$

**Figure 4a:** Overtemperature
Reset if $T_j < T_R$

- $I_{IN}$
- $I_{IS}$
- $I_{IS(fault)}$
- $V_{OUT}$
- $T_j$

**Figure 5a:** Undervoltage restart of charge pump, overvoltage clamp

- $V_{IN} = 0$
- $V_{ON(CL)}$
- Undervoltage not below $V_{blN(u)}$
- Overvoltage clamp $V_{blN(ucp)}$
- $V_{bb}$

Dynamic, short
Figure 6a: Current sense versus load current:

Figure 6b: Current sense ratio\(^{12}\):

\[ k_{ILIS} \]

\(8200\)

\(0\) \(2.5\) \(5\) \(10\) \(15\) \(20\)

\( [A] I_L \)

\( [mA] I_{IS} \)

\( [A] I_L \)

\( [V] V_{ON} \)

\( [V] V_{ON(NL)} \)

\( R_{ON} \)

Figure 7a: Output voltage drop versus load current:

\(^{12}\) This range for the current sense ratio refers to all devices. The accuracy of the \(k_{ILIS}\) can be raised by means of calibration the value of \(k_{ILIS}\) for every single device.
Package Outlines
All dimensions in mm

D-Pak-5 Pin: PG-TO252-5-11

Sales Code  BTS 443P

Green Product
To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).
## Revision History

<table>
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<tr>
<th>Version</th>
<th>Date</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rev. 1.0</td>
<td>2007-02-21</td>
<td>RoHS-compliant version of BTS443P</td>
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<tr>
<td></td>
<td></td>
<td>Page 1, page 13: RoHS compliance statement and Green product feature added</td>
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<tr>
<td></td>
<td></td>
<td>Page 1, page 13: Change to RoHS compliant package PG-TO252-5-11</td>
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</table>
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