

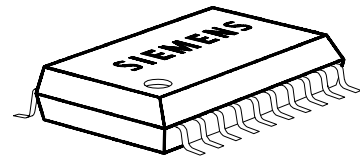
# Smart Two Channel Highside Power Switch

## Features

- Overload protection
- Current limitation
- Short-circuit protection
- Thermal shutdown
- Overvoltage protection
- Fast demagnetization of inductive loads
- Reverse battery protection<sup>1)</sup>
- Open drain diagnostic output
- Open load detection in OFF-state
- CMOS compatible input
- Loss of ground and loss of  $V_{bb}$  protection
- Electrostatic discharge (ESD) protection

## Product Summary

|                        |              |            |              |
|------------------------|--------------|------------|--------------|
| Overvoltage Protection | $V_{bb(AZ)}$ | 65         | V            |
| Operating voltage      | $V_{bb(on)}$ | 5.8 ... 58 | V            |
| active channels:       |              | one        | two parallel |
| On-state resistance    | $R_{ON}$     | 250        | 125          |
| Nominal load current   | $I_{L(NOM)}$ | 1.9        | 2.8          |
|                        |              |            | mΩ           |
|                        |              |            | A            |



## Application

- $\mu$ C compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- Most suitable for inductive loads
- Replaces electromechanical relays, fuses and discrete circuits

## General Description

N channel vertical power FET with charge pump, ground referenced CMOS compatible input and diagnostic feedback, monolithically integrated in Smart SIPMOS® technology.

Providing embedded protective functions.

### Pin Definitions and Functions

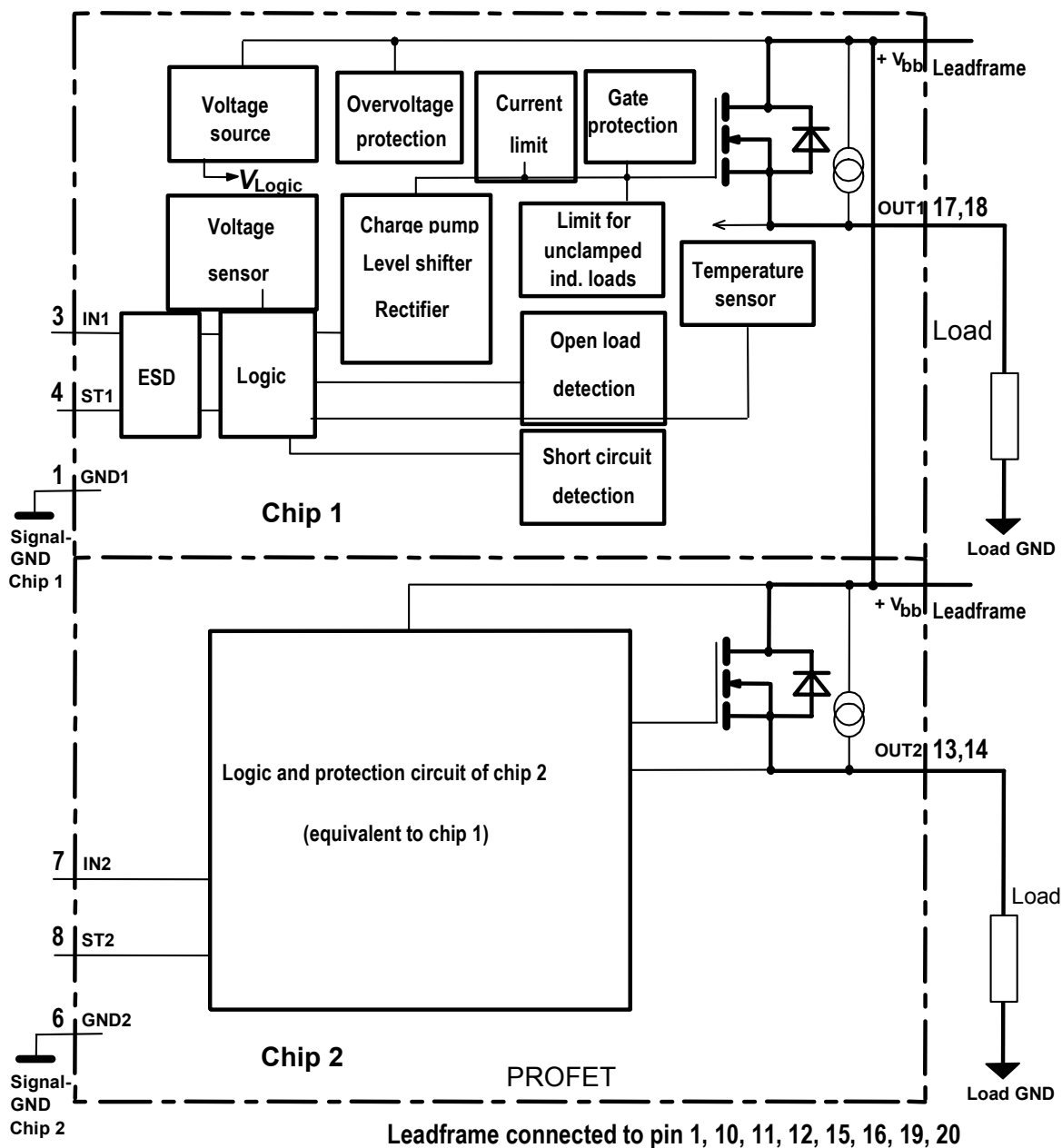
| Pin                                | Symbol   | Function                                                                                                                                                         |
|------------------------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1,10,<br>11,12,<br>15,16,<br>19,20 | $V_{bb}$ | <b>Positive power supply voltage.</b> Design the wiring for the simultaneous max. short circuit currents from channel 1 to 2 and also for low thermal resistance |
| 3                                  | IN1      | <b>Input 1,2</b> , activates channel 1,2 in case of                                                                                                              |
| 7                                  | IN2      | logic high signal                                                                                                                                                |
| 17,18                              | OUT1     | <b>Output 1,2</b> , protected high-side power output of channel 1,2. Design the wiring for the max. short circuit current                                        |
| 13,14                              | OUT2     |                                                                                                                                                                  |
| 4                                  | ST1      | <b>Diagnostic feedback 1,2</b> of channel 1,2,                                                                                                                   |
| 8                                  | ST2      | open drain, low in on state on failure or high in off state on failure                                                                                           |
| 2                                  | GND1     | <b>Ground 1</b> of chip 1 (channel 1)                                                                                                                            |
| 6                                  | GND2     | <b>Ground 2</b> of chip 2 (channel 2)                                                                                                                            |
| 5,9                                | N.C.     | <b>Not Connected</b>                                                                                                                                             |

### Pin configuration (top view)

|          |    |    |          |
|----------|----|----|----------|
| $V_{bb}$ | 1  | 20 | $V_{bb}$ |
| GND1     | 2  | 19 | $V_{bb}$ |
| IN1      | 3  | 18 | OUT1     |
| ST1      | 4  | 17 | OUT1     |
| N.C.     | 5  | 16 | $V_{bb}$ |
| GND2     | 6  | 15 | $V_{bb}$ |
| IN2      | 7  | 14 | OUT2     |
| ST2      | 8  | 13 | OUT2     |
| N.C.     | 9  | 12 | $V_{bb}$ |
| $V_{bb}$ | 10 | 11 | $V_{bb}$ |

<sup>1)</sup> With external current limit (e.g. resistor  $R_{GND}=150\ \Omega$ ) in GND connection, resistor in series with ST connection, reverse load current limited by connected load.

## Block diagram



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

| Parameter                                                                                        | Symbol    | Values           | Unit             |
|--------------------------------------------------------------------------------------------------|-----------|------------------|------------------|
| Supply voltage (overvoltage protection see page 4)                                               | $V_{bb}$  | 65               | V                |
| Supply voltage for full short circuit protection<br>$T_{j,start} = -40 \dots +150^\circ\text{C}$ | $V_{bb}$  | 40               | V                |
| Load current (Short-circuit current, see page 5)                                                 | $I_L$     | self-limited     | A                |
| Operating temperature range                                                                      | $T_j$     | $-40 \dots +150$ | $^\circ\text{C}$ |
| Storage temperature range                                                                        | $T_{stg}$ | $-55 \dots +150$ |                  |

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

| Parameter                                                              | Symbol           | Values                                                         | Unit |
|------------------------------------------------------------------------|------------------|----------------------------------------------------------------|------|
| Power dissipation (DC) <sup>2)</sup><br>(all channels active)          | $P_{\text{tot}}$ | $T_a = 25^\circ\text{C}$ : 3<br>$T_a = 85^\circ\text{C}$ : 1.6 | W    |
| Electrostatic discharge capability (ESD)<br>(Human Body Model)         | $V_{\text{ESD}}$ | IN, ST: 1.0<br>all other pins: 1.0                             | kV   |
| Input voltage (DC)                                                     | $V_{\text{IN}}$  | -0.5 ... +36                                                   | V    |
| Current through input pin (DC)                                         | $I_{\text{IN}}$  | $\pm 2.0$                                                      | mA   |
| Current through status pin (DC)<br>see internal circuit diagram page 7 | $I_{\text{ST}}$  | $\pm 5.0$                                                      |      |

## Thermal Characteristics

| Parameter and Conditions                                                        | Symbol            | Values |     |     | Unit |
|---------------------------------------------------------------------------------|-------------------|--------|-----|-----|------|
|                                                                                 |                   | min    | typ | max |      |
| Thermal resistance<br>junction - soldering point <sup>2),3)</sup> each channel: | $R_{\text{thjs}}$ | --     | --  | 18  | K/W  |
| junction - ambient <sup>2)</sup> one channel active:                            | $R_{\text{thja}}$ | --     | 45  | --  |      |
| all channels active:                                                            |                   | --     | 37  | --  |      |

## Electrical Characteristics

| Parameter and Conditions, each of the two channels<br>at $T_j = 25^\circ\text{C}$ , $V_{\text{bb}} = 12\text{ V}$ unless otherwise specified | Symbol | Values |     |     | Unit |
|----------------------------------------------------------------------------------------------------------------------------------------------|--------|--------|-----|-----|------|
|                                                                                                                                              |        | min    | typ | max |      |

## Load Switching Capabilities and Characteristics

|                                                                                                                                                                                                                                |                         |             |                   |                   |            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------|-------------------|-------------------|------------|
| On-state resistance ( $V_{\text{bb}}$ to OUT)<br>$I_L = 2\text{ A}$ each channel, $T_j = 25^\circ\text{C}$ :<br>$V_{\text{bb}} = 24\text{ V}$ $T_j = 150^\circ\text{C}$ :<br>two parallel channels, $T_j = 25^\circ\text{C}$ : | $R_{\text{ON}}$         | --          | 225<br>400<br>113 | 250<br>500<br>125 | m $\Omega$ |
| Nominal load current one channel active:<br>two parallel channels active:<br>Device on PCB <sup>2)</sup> , $T_a = 85^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$                                                             | $I_{\text{L(NOM)}}$     | 1.60<br>2.4 | 1.9<br>2.8        | --                | A          |
| Output current while GND disconnected or pulled up; $V_{\text{bb}} = 32\text{ V}$ , $V_{\text{IN}} = 0$ , see diagram page 8                                                                                                   | $I_{\text{L(GNDhigh)}}$ | --          | --                | 1.1               | mA         |

<sup>2)</sup> Device on 50mm\*50mm\*1.5mm epoxy PCB FR4 with 6cm<sup>2</sup> (one layer, 70 $\mu\text{m}$  thick) copper area for  $V_{\text{bb}}$  connection. PCB is vertical without blown air. See page 12

<sup>3)</sup> Soldering point: upper side of solder edge of device pin 15. See page 12

| Parameter and Conditions, each of the two channels<br>at $T_j = 25^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified | Symbol         | Values |     |     | Unit                   |
|---------------------------------------------------------------------------------------------------------------------------------------|----------------|--------|-----|-----|------------------------|
|                                                                                                                                       |                | min    | typ | max |                        |
| Turn-on time to 90% $V_{OUT}$ :                                                                                                       | $t_{on}$       | 15     | --  | 80  | $\mu\text{s}$          |
| Turn-off time to 10% $V_{OUT}$ :                                                                                                      | $t_{off}$      | 20     | --  | 70  |                        |
| $R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$                                                      |                |        |     |     |                        |
| Slew rate on<br>10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ ,<br>$T_j = -40\dots+150^\circ\text{C}$ :           | $dV/dt_{on}$   | --     | --  | 6   | $\text{V}/\mu\text{s}$ |
| Slew rate off<br>70 to 40% $V_{OUT}$ , $R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ ,<br>$T_j = -40\dots+150^\circ\text{C}$ :          | $-dV/dt_{off}$ | --     | --  | 7   | $\text{V}/\mu\text{s}$ |

### Operating Parameters

|                                                                                                                                                                                                     |                                      |                               |     |            |     |               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-------------------------------|-----|------------|-----|---------------|
| Operating voltage <sup>4)</sup>                                                                                                                                                                     | $T_j = -40...+150^{\circ}\text{C}$ : | $V_{bb(\text{on})}$           | 5.8 | --         | 58  | V             |
| Undervoltage shutdown                                                                                                                                                                               | $T_j = -40...+150^{\circ}\text{C}$ : | $V_{bb(\text{under})}$        | 2.7 | --         | 4.7 | V             |
| Undervoltage restart                                                                                                                                                                                | $T_j = -40...+150^{\circ}\text{C}$ : | $V_{bb(\text{u rst})}$        | --  | --         | 4.9 | V             |
| Undervoltage restart of charge pump<br>see diagram page 10                                                                                                                                          | $T_j = -40...+150^{\circ}\text{C}$ : | $V_{bb(\text{ucp})}$          | --  | 5.6        | 7.5 | V             |
| Undervoltage hysteresis<br>$\Delta V_{bb(\text{under})} = V_{bb(\text{u rst})} - V_{bb(\text{under})}$                                                                                              |                                      | $\Delta V_{bb(\text{under})}$ | --  | 0.4        | --  | V             |
| Overvoltage protection <sup>5)</sup>                                                                                                                                                                | $T_j = -40...+150^{\circ}\text{C}$ : | $V_{bb(\text{AZ})}$           | 65  | 70         | --  | V             |
| $I_{bb} = 40 \text{ mA}$                                                                                                                                                                            |                                      |                               |     |            |     |               |
| Standby current, all channels off<br>$V_{\text{IN}} = 0$                                                                                                                                            | $T_j = 150^{\circ}\text{C}$ :        | $I_{bb(\text{off})}$          | --  | 20         | 70  | $\mu\text{A}$ |
| Operating current <sup>6)</sup> , $V_{\text{IN}} = 5\text{V}$ , $T_j = -40...+150^{\circ}\text{C}$<br>$I_{\text{GND}} = I_{\text{GND1}} + I_{\text{GND2}}$ ,<br>one channel on:<br>two channels on: |                                      | $I_{\text{GND}}$              | --  | 2.2<br>4.4 | --  | mA            |

### Protection Functions<sup>7)</sup>

|                                                                                              |                                  |     |    |    |                  |
|----------------------------------------------------------------------------------------------|----------------------------------|-----|----|----|------------------|
| Initial peak short circuit current limit, (see timing diagrams, page 9)                      |                                  |     |    |    |                  |
| each channel, $T_j = -40^\circ\text{C}$ :                                                    | $I_{L(SCp)}$                     | --  | -- | 19 | A                |
| $T_j = 25^\circ\text{C}$ :                                                                   |                                  | --  | 10 | -- |                  |
| $T_j = +150^\circ\text{C}$ :                                                                 |                                  | 4.0 | -- | -- |                  |
| two parallel channels                                                                        | twice the current of one channel |     |    |    |                  |
| Output clamp (inductive load switch off) <sup>8)</sup><br>at $V_{ON(CL)} = V_{bb} - V_{OUT}$ | $V_{ON(CL)}$                     | 59  | -- | 75 | V                |
| Thermal overload trip temperature                                                            | $T_{jt}$                         | 150 | -- | -- | $^\circ\text{C}$ |
| Thermal hysteresis                                                                           | $\Delta T_{jt}$                  | --  | 10 | -- | K                |

4) At supply voltage increase up to  $V_{bb} = 5.6\text{ V}$  typ without charge pump,  $V_{OUT} \approx V_{bb} - 2\text{ V}$

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

6) Add  $I_{ST}$ , if  $I_{ST} > 0$

7) 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.

8) If channels are connected in parallel, output clamp is usually accomplished by the channel with the lowest  $V_{ON(CL)}$

| Parameter and Conditions, each of the two channels<br>at $T_j = 25\text{ °C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified | Symbol | Values |     |     | Unit |
|-----------------------------------------------------------------------------------------------------------------------------------|--------|--------|-----|-----|------|
|                                                                                                                                   |        | min    | typ | max |      |

### Reverse Battery

|                                       |           |    |    |    |   |
|---------------------------------------|-----------|----|----|----|---|
| Reverse battery voltage <sup>9)</sup> | $-V_{bb}$ | -- | -- | 32 | V |
|---------------------------------------|-----------|----|----|----|---|

### Diagnostic Characteristics

|                                                                  |               |     |     |    |               |
|------------------------------------------------------------------|---------------|-----|-----|----|---------------|
| Open load detection current                                      | $I_{L(off)}$  | --  | 6   | -- | $\mu\text{A}$ |
| Open load detection voltage $T_j = -40\text{..}+150\text{ °C}$ : | $V_{OUT(OL)}$ | 2.4 | 3   | 4  | V             |
| Short circuit detection voltage<br>(pin 3 to 5)                  | $V_{ON(SC)}$  | --  | 2.5 | -- | V             |

### Input and Status Feedback<sup>10)</sup>

|                                                                                                                    |                    |     |     |     |                  |
|--------------------------------------------------------------------------------------------------------------------|--------------------|-----|-----|-----|------------------|
| Input resistance<br>(see circuit page 7)                                                                           | $R_I$              | --  | 20  | --  | $\text{k}\Omega$ |
| Input turn-on threshold voltage   | $V_{IN(T+)}$       | 1   | --  | 2.5 | V                |
| Input turn-off threshold voltage  | $V_{IN(T-)}$       | 0.8 | --  | --  | V                |
| Input threshold hysteresis                                                                                         | $\Delta V_{IN(T)}$ | --  | 0.5 | --  | V                |
| Off state input current $V_{IN} = 0.4\text{ V}$ :                                                                  | $I_{IN(off)}$      | 1   | --  | 30  | $\mu\text{A}$    |
| On state input current $V_{IN} = 2.5\text{ V}$ :                                                                   | $I_{IN(on)}$       | 10  | 25  | 70  | $\mu\text{A}$    |
| Delay time for status with open load<br>(see timing diagrams, page 10)                                             | $t_{d(ST\ OL3)}$   | --  | 200 | --  | $\mu\text{s}$    |
| Status output (open drain)                                                                                         |                    |     |     |     |                  |
| Zener limit voltage $T_j = -40\text{...}+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :                              | $V_{ST(high)}$     | 5.4 | 6.1 | --  | V                |
| ST low voltage $T_j = -40\text{...}+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :                                   | $V_{ST(low)}$      | --  | --  | 0.4 |                  |

<sup>9)</sup> Requires a  $150\text{ }\Omega$  resistor in GND connection. The reverse load current through the intrinsic drain-source diode has to be limited by the connected load. Note that the power dissipation is higher compared to normal operating conditions due to the voltage drop across the intrinsic drain-source diode. The temperature protection is not active during reverse current operation! Input and Status currents have to be limited (see max. ratings page 3 and circuit page 7).

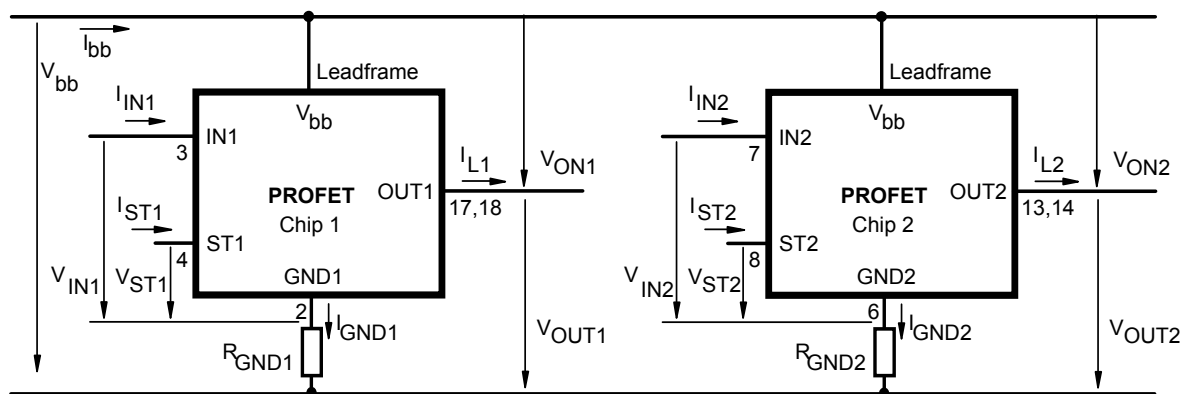
<sup>10)</sup> If ground resistors  $R_{GND}$  are used, add the voltage drop across these resistors.

## Truth Table

| Channel 1                 | Input 1                                       | Output 1 | Status 1 |
|---------------------------|-----------------------------------------------|----------|----------|
| Channel 2                 | Input 2                                       | Output 2 | Status 2 |
|                           | level                                         | level    | BTS 707  |
| Normal operation          | L                                             | L        | L        |
|                           | H                                             | H        | H        |
| Open load                 | L                                             | Z        | H        |
|                           | H                                             | H        | H        |
| Short circuit to GND      | L                                             | L        | L        |
|                           | H                                             | L        | L        |
| Short circuit to $V_{bb}$ | L                                             | H        | H        |
|                           | H                                             | H        | H        |
| Overtemperature           | L                                             | L        | L        |
|                           | H                                             | L        | L        |
| Under-voltage             | L                                             | L        | L        |
|                           | H                                             | L        | L        |
| Overvoltage               | no overvoltage shutdown, see normal operation |          |          |

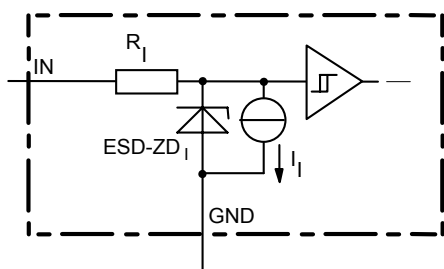
Parallel switching of channel 1 and 2 is easily possible by connecting the inputs and outputs in parallel. The status outputs ST1 and ST2 have to be configured as a 'Wired OR' function with a single pull-up resistor.

## Terms

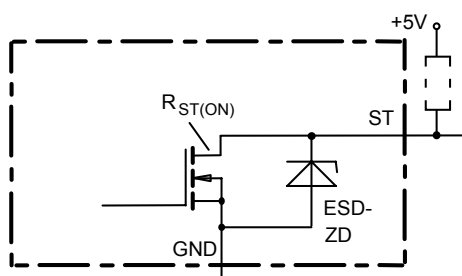


Leadframe ( $V_{bb}$ ) is connected to pin 1,10,11,12,15,16,19,20

External  $R_{GND}$  optional; two resistors  $R_{GND1}$ ,  $R_{GND2} = 150 \Omega$  or a single resistor  $R_{GND} = 75 \Omega$  for reverse battery protection up to the max. operating voltage.

**Input circuit (ESD protection), IN1 or IN2**


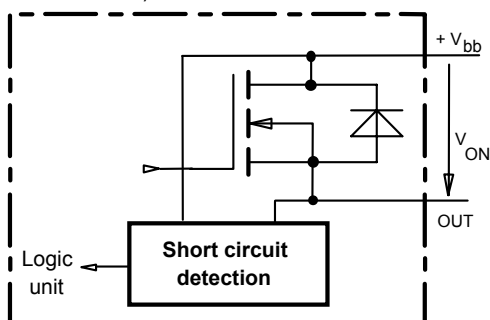
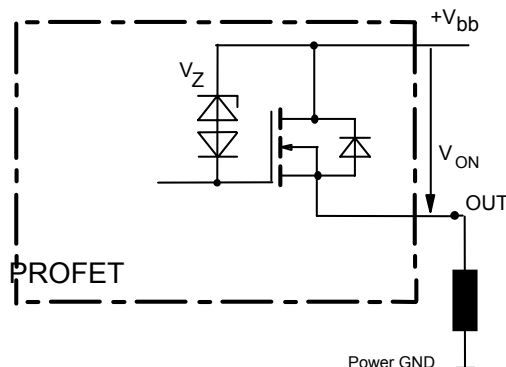
ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

**Status output, ST1 or ST2**


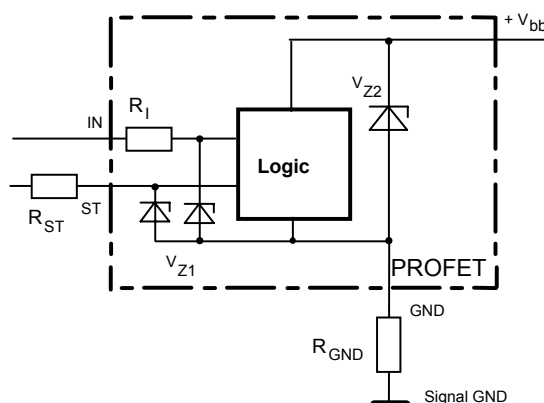
ESD-Zener diode: 6.1 V typ., max 5.0 mA;  $R_{ST(ON)} < 0 \Omega$  at 1.6 mA, ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

**Short Circuit detection**

Fault Signal at ST-Pin:  $V_{ON} > 2.5 \text{ V}$  typ., no switch off by the PROFET itself, external switch off recommended!


**Inductive and overvoltage output clamp, OUT1 or OUT2**


$V_{ON}$  clamped to  $V_{ON(CL)} = -V$  typ.

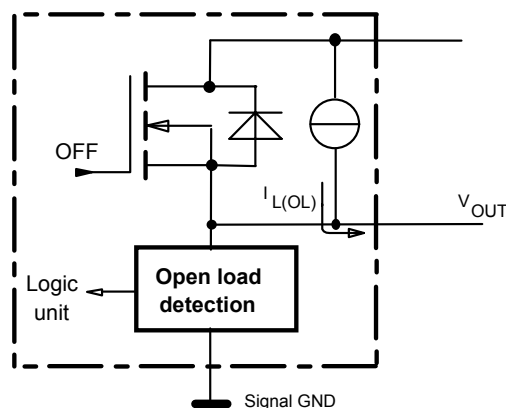
**Overvoltage protection of logic part GND1 or GND2**


$V_{Z1} = 6.1 \text{ V}$  typ.,  $V_{Z2} = 70 \text{ V}$  typ.,  $R_I = 20 \text{ k}\Omega$  typ.,  $R_{GND} = 150 \Omega$ ,  $R_{ST} = 15 \text{ k}\Omega$  nominal.

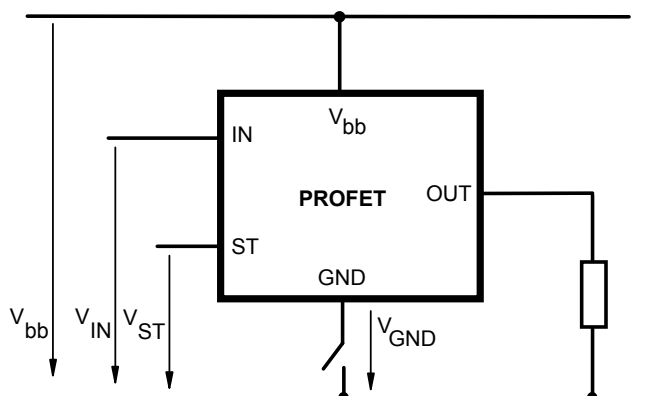
**Open-load detection, OUT1 or OUT2**

OFF-state diagnostic condition:

$V_{OUT} > 3 \text{ V}$  typ.; IN low

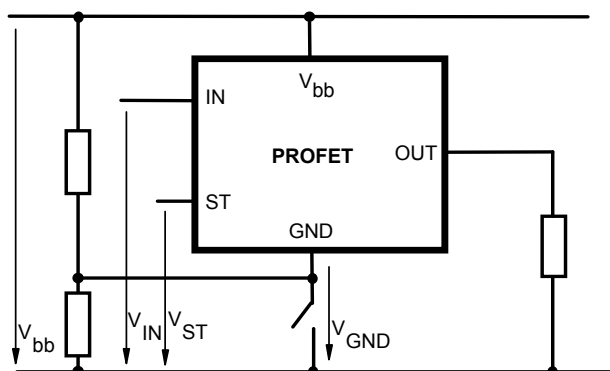


### GND disconnect



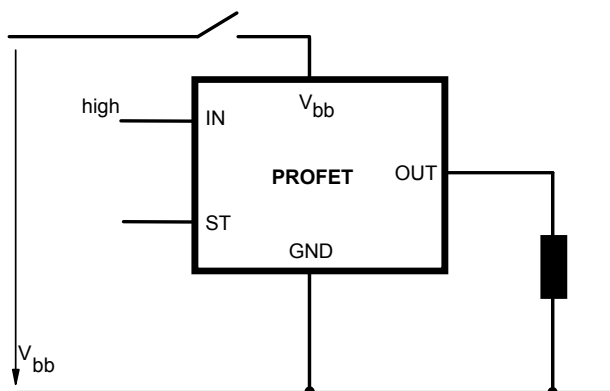
Any kind of load. In case of  $IN = \text{high}$  is  $V_{OUT} \approx V_{IN} - V_{IN(T+)}$ .  
Due to  $V_{GND} > 0$ , no  $V_{ST} = \text{low}$  signal available.

### GND disconnect with GND pull up



Any kind of load. If  $V_{GND} > V_{IN} - V_{IN(T+)}$  device stays off  
Due to  $V_{GND} > 0$ , no  $V_{ST} = \text{low}$  signal available.

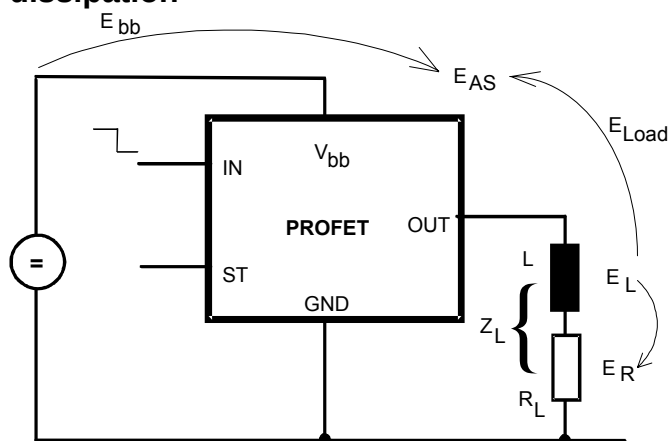
### V<sub>bb</sub> disconnect with energized inductive load



For an inductive load current up to the limit defined by  $E_{AS}$  (max. ratings) each switch is protected against loss of  $V_{bb}$ .

Consider at your PCB layout that in the case of  $V_{bb}$  disconnection with energized inductive load the whole load current flows through the GND connection.

### 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

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

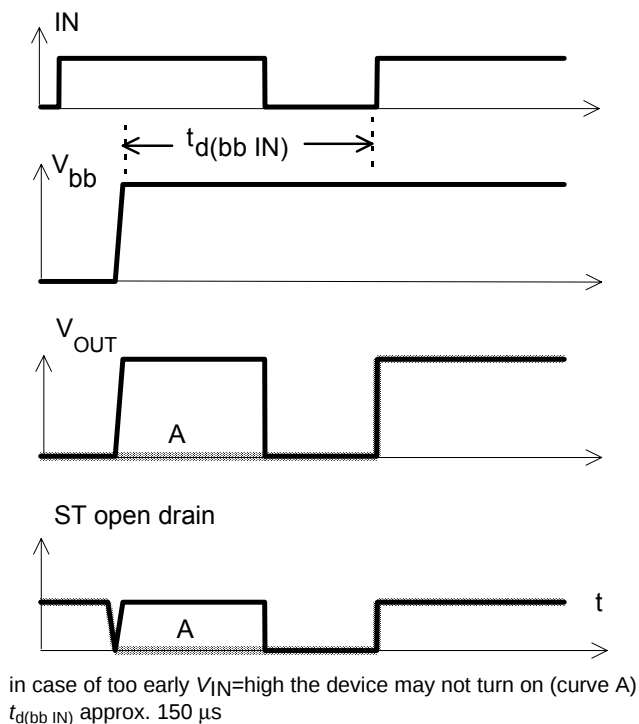
with an approximate solution for  $R_L > 0 \Omega$ :

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

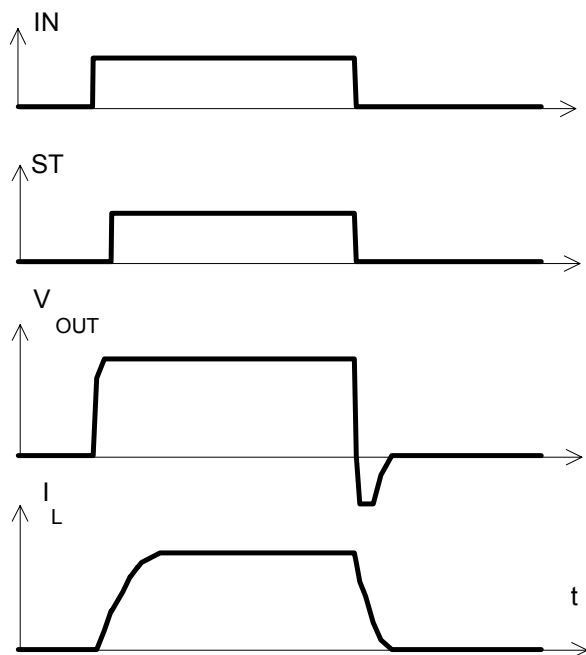
## Timing diagrams

Both channels are symmetric and consequently the diagrams are valid for channel 1 and channel 2

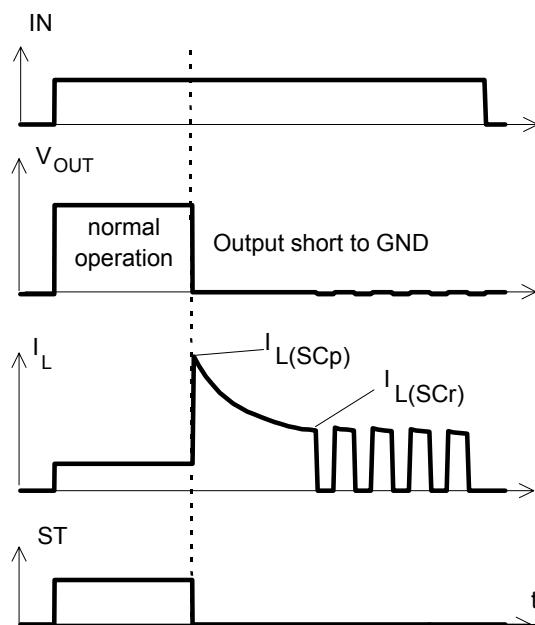
**Figure 1a:**  $V_{bb}$  turn on, :



**Figure 2a:** Switching an inductive load

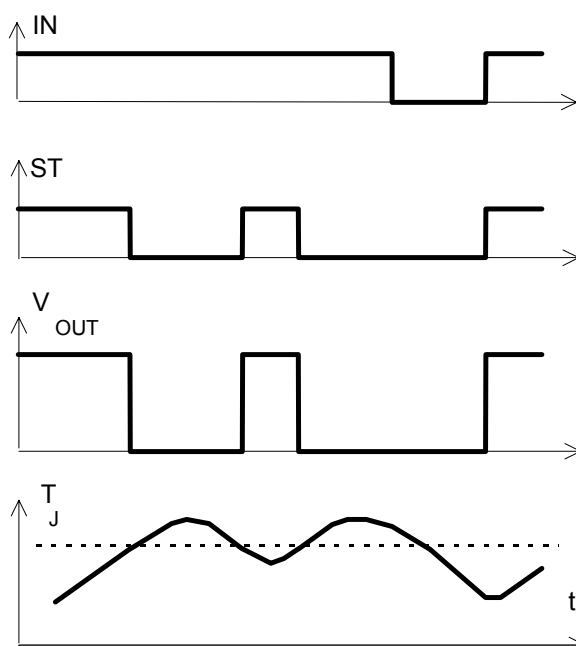


**Figure 3a:** Short circuit:  
shut down by overtemperature, reset by cooling

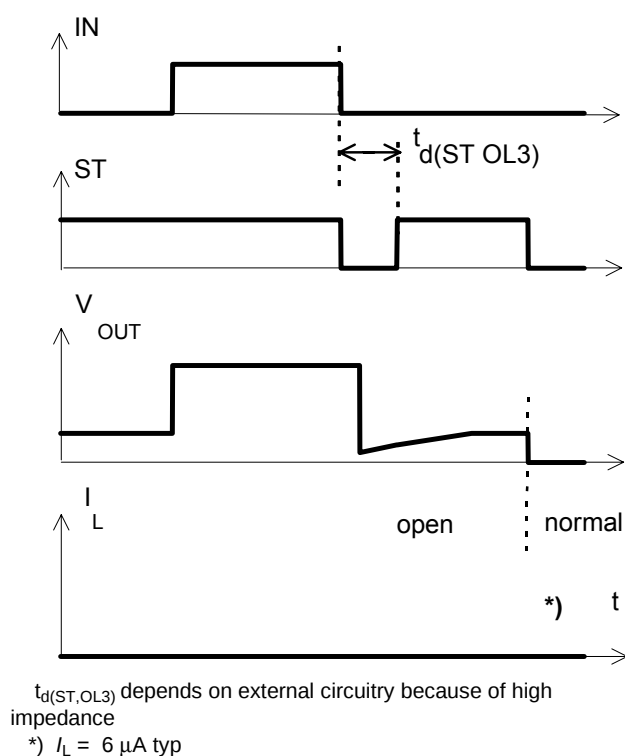


Heating up requires several milliseconds, depending on external conditions. External shutdown in response to status fault signal recommended.

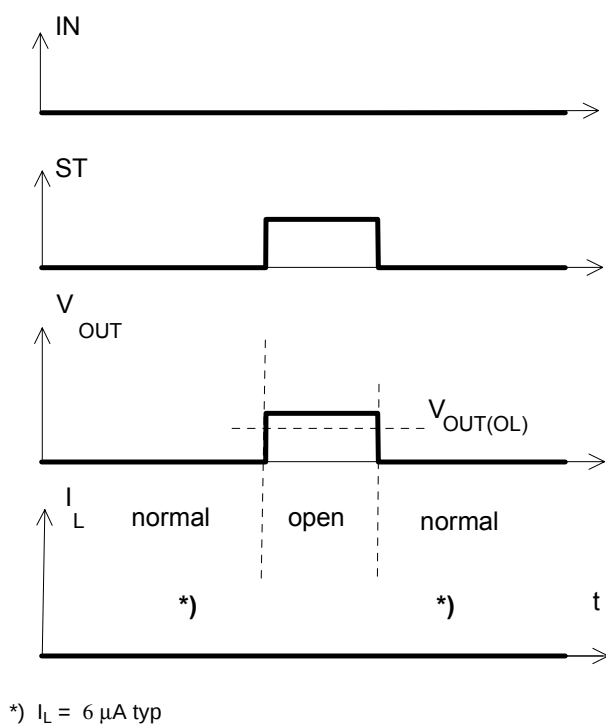
**Figure 4a:** Overtemperature:  
Reset if  $T_j < T_{jt}$



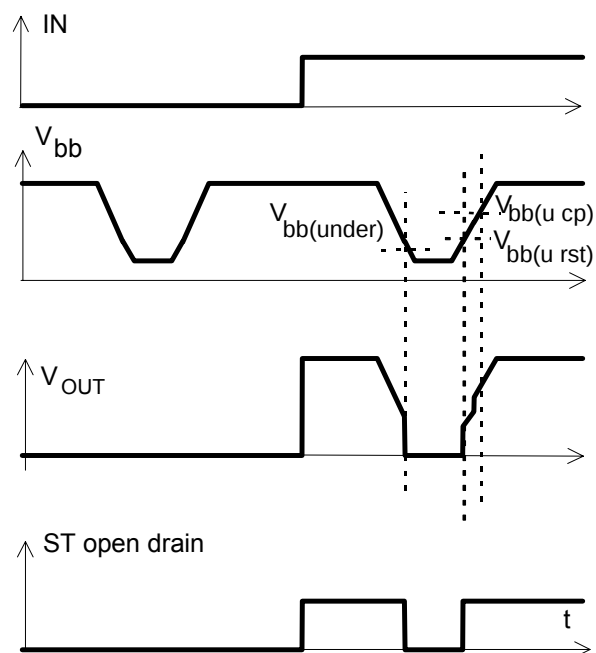
**Figure 5a:** Open load, : detection in OFF-state, turn on/off to open load



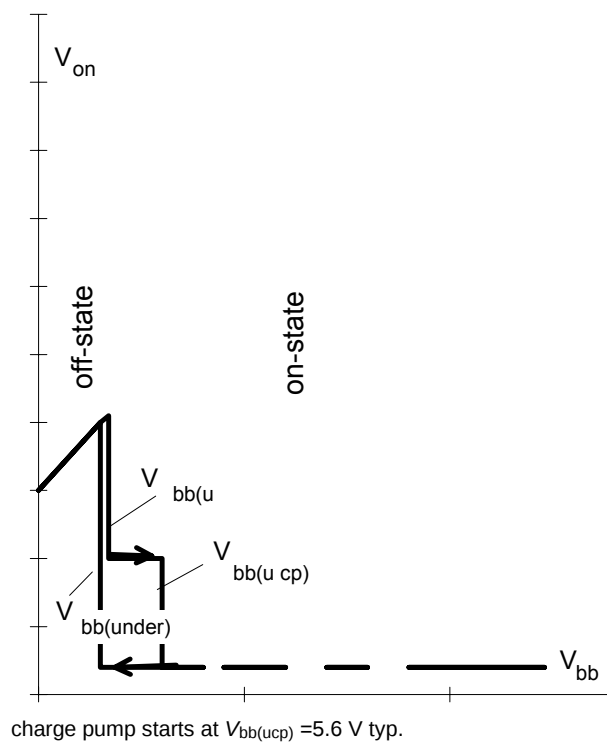
**Figure 5b:** Open load, : detection in OFF-state, open load occurs in off-state



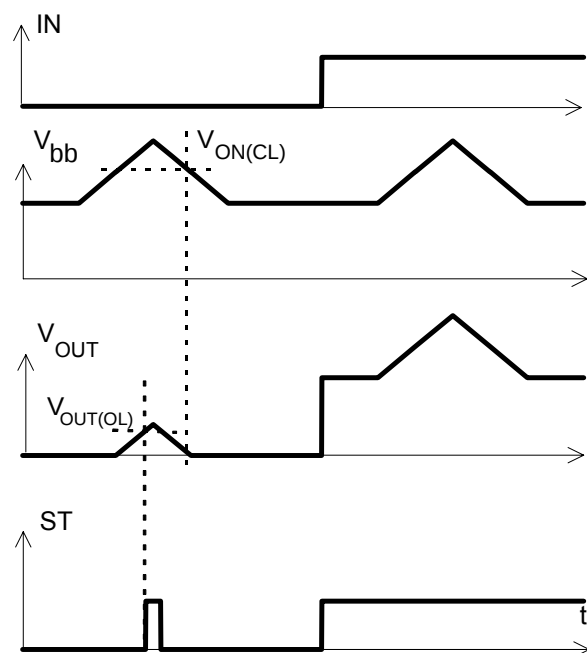
**Figure 6a:** Undervoltage:



**Figure 6b:** Undervoltage restart of charge pump



**Figure 7a:** Overvoltage, no shutdown:

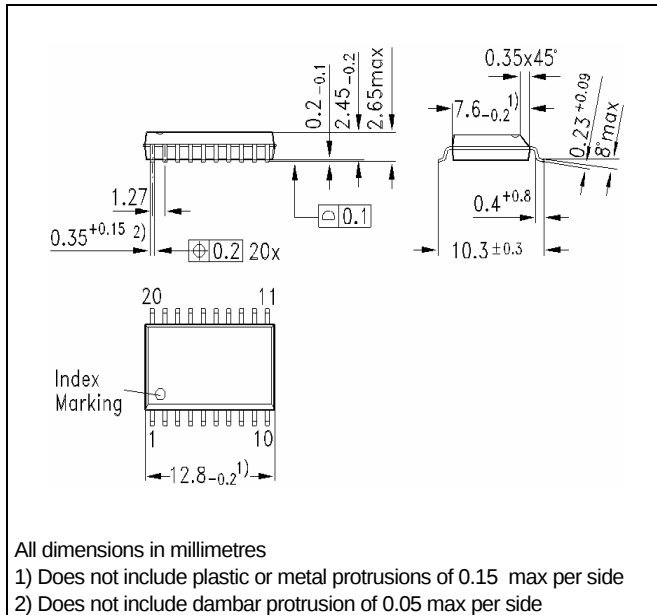


## Package and Ordering Code

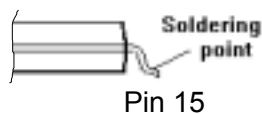
Standard P-DSO-20-9

Ordering Code

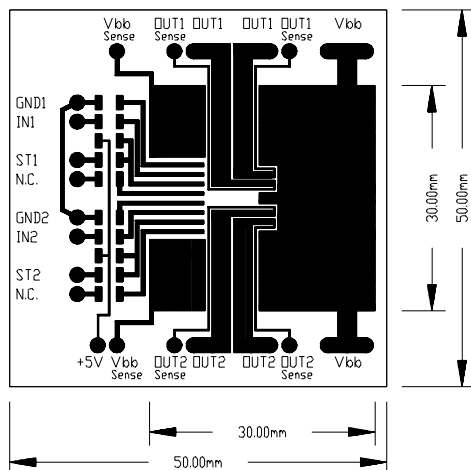
|         |                 |
|---------|-----------------|
| BTS 707 | Q67060-S7010-A2 |
|---------|-----------------|



Definition of soldering point with temperature  $T_S$ :  
upper side of solder edge of device pin 15.



Printed circuit board (FR4, 1.5mm thick, one layer  
70µm, 6cm<sup>2</sup> active heatsink area) as a reference for  
max. power dissipation  $P_{tot}$ , nominal load current  
 $I_{L(NOM)}$  and thermal resistance  $R_{thja}$



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