

## Smart High-Side Power Switch

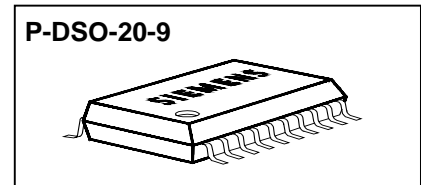
### Two Channels: 2 x 60mΩ

### Status Feedback

#### Product Summary

Operating Voltage	$V_{bb(on)}$	4.75...41V	
	Active channels	one	two parallel
On-state Resistance	$R_{ON}$	60mΩ	30mΩ
Nominal load current	$I_{L(NOM)}$	4.0A	6.0A
Current limitation	$I_{L(SCr)}$	17A	17A

#### Package



#### General Description

- N channel vertical power MOSFET with charge pump, ground referenced CMOS compatible input and diagnostic feedback, monolithically integrated in Smart SIPMOS® technology.
- Fully protected by embedded protection functions

#### Applications

- $\mu$ C compatible high-side power switch with diagnostic feedback for 5V, 12V and 24V grounded loads
- All types of resistive, inductive and capacitive loads
- Most suitable for loads with high inrush currents, so as lamps
- Replaces electromechanical relays, fuses and discrete circuits

#### Basic Functions

- Very low standby current
- CMOS compatible input
- Improved electromagnetic compatibility (EMC)
- Fast demagnetization of inductive loads
- Stable behaviour at undervoltage
- Wide operating voltage range
- Logic ground independent from load ground

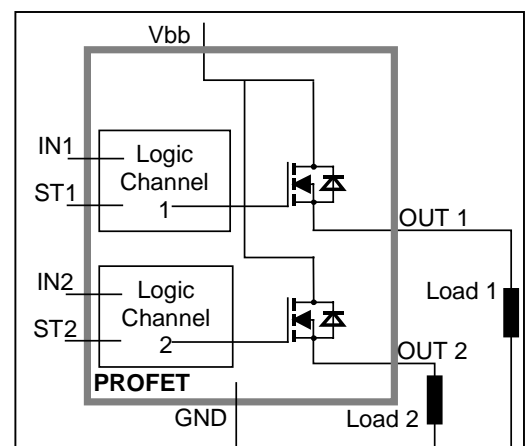
#### Protection Functions

- Short circuit protection
- Overload protection
- Current limitation
- Thermal shutdown
- Overvoltage protection (including load dump) with external resistor
- Reverse battery protection with external resistor
- Loss of ground and loss of  $V_{bb}$  protection
- Electrostatic discharge protection (ESD)

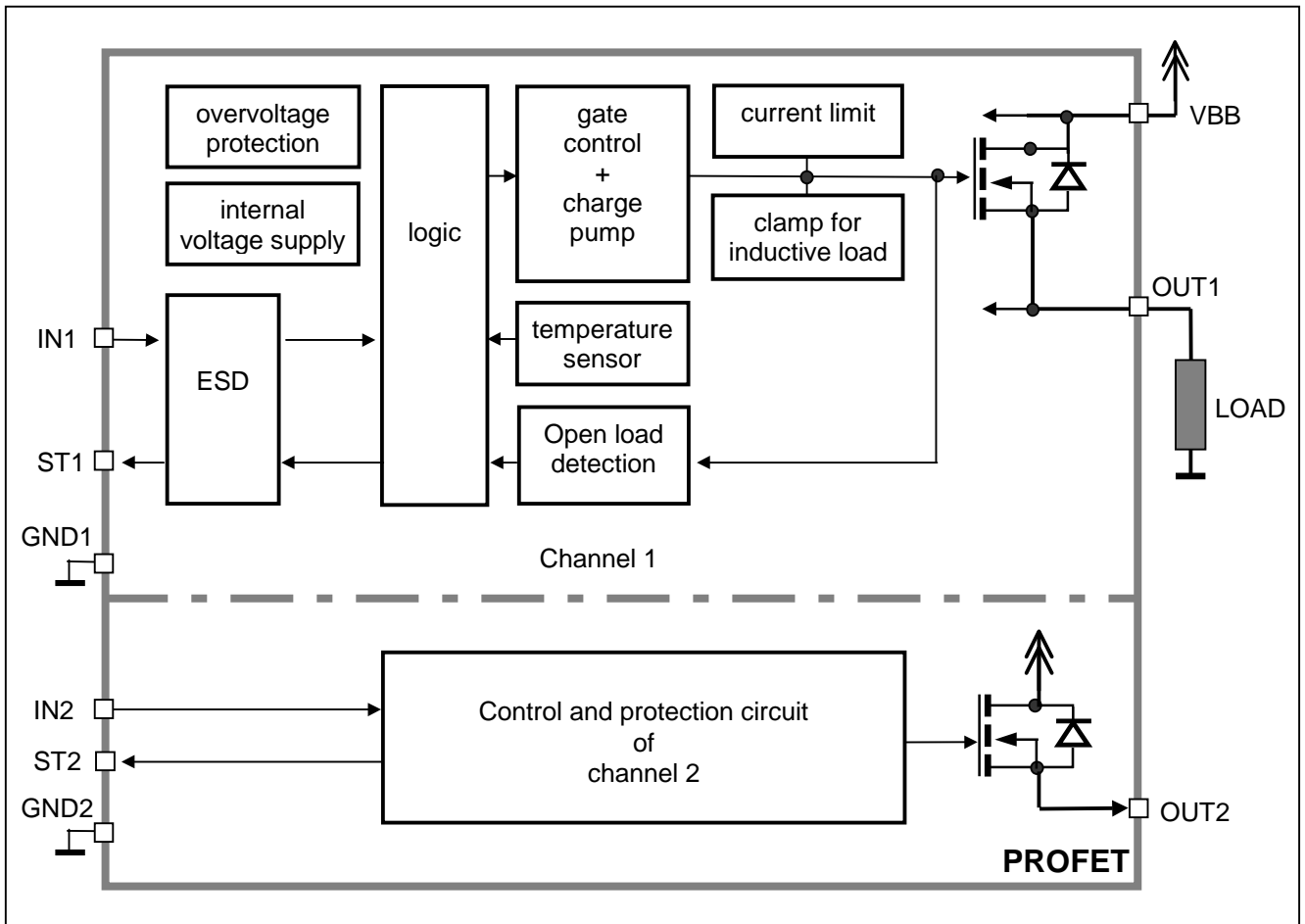
#### Diagnostic Function

- Diagnostic feedback with open drain output
- Open load detection in ON-state
- Feedback of thermal shutdown in ON-state

#### Block Diagram



### Functional diagram

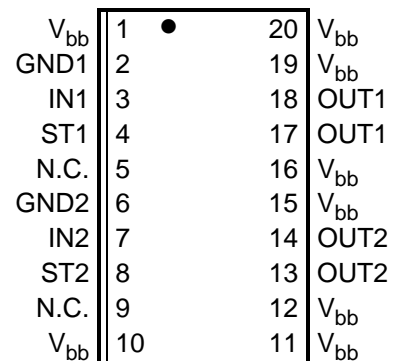


### Pin Definitions and Functions

Pin	Symbol	Function
1,10, 11,12, 15,16, 19,20	V <sub>bb</sub>	<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 logic high signal
7	IN2	
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, open drain, low on failure
8	ST2	
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)



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

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 4)	$V_{bb}$	43	V
Supply voltage for full short circuit protection $T_{j,start} = -40 \dots +150^\circ\text{C}$	$V_{bb}$	24	V
Load current (Short-circuit current, see page 5)	$I_L$	self-limited	A
Load dump protection <sup>1)</sup> $V_{LoadDump} = V_A + V_s$ , $V_A = 13.5 \text{ V}$ $R_l^{2)} = 2 \Omega$ , $t_d = 200 \text{ ms}$ ; IN = low or high, each channel loaded with $R_L = 8.0 \Omega$ ,	$V_{Loaddump}^{3)}$	60	V
Operating temperature range	$T_j$	-40 ... +150	$^\circ\text{C}$
Storage temperature range	$T_{stg}$	-55 ... +150	$^\circ\text{C}$
Power dissipation (DC) <sup>4)</sup> (all channels active)	$T_a = 25^\circ\text{C}$ : $T_a = 85^\circ\text{C}$ :	$P_{tot}$ 3.7 1.9	W
Maximal switchable inductance, single pulse $V_{bb} = 12\text{V}$ , $T_{j,start} = 150^\circ\text{C}^{4)}$ , $I_L = 4.0 \text{ A}$ , $E_{AS} = 220 \text{ mJ}$ , $0 \Omega$ one channel: $I_L = 6.0 \text{ A}$ , $E_{AS} = 540 \text{ mJ}$ , $0 \Omega$ two parallel channels: see diagrams on page 9	$Z_L$	19.9 22.3	mH
Electrostatic discharge capability (ESD) (Human Body Model) IN: ST: out to all other pins shorted: acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993 $R=1.5\text{k}\Omega$ ; $C=100\text{pF}$	$V_{ESD}$	1.0 4.0 8.0	kV
Input voltage (DC)	$V_{IN}$	-10 ... +16	V
Current through input pin (DC)	$I_{IN}$	$\pm 2.0$	mA
Current through status pin (DC) see internal circuit diagram page 8	$I_{ST}$	$\pm 5.0$	

### Thermal Characteristics

Parameter and Conditions	Symbol	Values			Unit
		min	typ	Max	
Thermal resistance junction - soldering point <sup>4),5)</sup> each channel: junction - ambient <sup>4)</sup> one channel active: all channels active:	$R_{thjs}$ $R_{thja}$	--	--	13.5	K/W
		--	41	--	
		--	34	--	

1) Supply voltages higher than  $V_{bb(AZ)}$  require an external current limit for the GND and status pins (a  $150\Omega$  resistor for the GND connection is recommended).

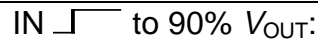
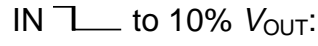
2)  $R_l$  = internal resistance of the load dump test pulse generator

3)  $V_{Load dump}$  is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839

4) Device on  $50\text{mm} \times 50\text{mm} \times 1.5\text{mm}$  epoxy PCB FR4 with  $6\text{cm}^2$  (one layer,  $70\mu\text{m}$  thick) copper area for  $V_{bb}$  connection. PCB is vertical without blown air. See page 14

5) Soldering point: upper side of solder edge of device pin 15. See page 14

## Electrical Characteristics

Parameter and Conditions, each of the two channels at $T_j = -40...+150^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	Max	
<b>Load Switching Capabilities and Characteristics</b>					
On-state resistance ( $V_{bb}$ to OUT); $I_L = 2\text{ A}$ , $V_{bb} \geq 7\text{ V}$ each channel, $T_j = 25^\circ\text{C}$ : $T_j = 150^\circ\text{C}$ : two parallel channels, $T_j = 25^\circ\text{C}$ : see diagram, page 10	$R_{ON}$	--	50 100	60 120	m $\Omega$
Nominal load current one channel active: two parallel channels active: Device on PCB <sup>6)</sup> , $T_a = 85^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$	$I_{L(NOM)}$	3.6 5.5	4.0 6.0	--	A
Output current while GND disconnected or pulled up; $V_{bb} = 30\text{ V}$ , $V_{IN} = 0$ , see diagram page 8; (not tested specified by design)	$I_{L(GNDhigh)}$	--	--	2	mA
Turn-on time <sup>7)</sup> IN  to 90% $V_{OUT}$ :	$t_{on}$	30	100	200	$\mu\text{s}$
Turn-off time IN  to 10% $V_{OUT}$ : $R_L = 12\ \Omega$	$t_{off}$	30	100	200	$\mu\text{s}$
Slew rate on <sup>7)</sup> 10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$ :	$dV/dt_{on}$	0.1	--	1	V/ $\mu\text{s}$
Slew rate off <sup>7)</sup> 70 to 40% $V_{OUT}$ , $R_L = 12\ \Omega$ :	$-dV/dt_{off}$	0.1	--	1	V/ $\mu\text{s}$

## Operating Parameters

Operating voltage	$T_j = -40$ $T_j = 25...150^\circ\text{C}$ :	$V_{bb(on)}$	4.75	-- --	41 43	V
Overvoltage protection <sup>8)</sup> $I_{bb} = 40\text{ mA}$	$T_j = -40^\circ\text{C}$ : $T_j = 25...150^\circ\text{C}$ :	$V_{bb(AZ)}$	41 43	-- 47	-- 52	V
Standby current <sup>9)</sup> $V_{IN} = 0$ ; see diagram page 10	$T_j = -40^\circ\text{C}...25^\circ\text{C}$ : $T_j = 150^\circ\text{C}$ :	$I_{bb(off)}$	-- --	10 --	18 50	$\mu\text{A}$
Leakage output current (included in $I_{bb(off)}$ ) $V_{IN} = 0$		$I_{L(off)}$	--	1	10	$\mu\text{A}$
Operating current <sup>10)</sup> , $V_{IN} = 5\text{ V}$ , $I_{GND} = I_{GND1} + I_{GND2}$ , one channel on: two channels on:		$I_{GND}$	-- --	0.8 1.6	1.5 3.0	mA

6) Device on 50mm\*50mm\*1.5mm epoxy PCB FR4 with 6cm<sup>2</sup> (one layer, 70 $\mu\text{m}$  thick) copper area for  $V_{bb}$  connection. PCB is vertical without blown air. See page 14

7) See timing diagram on page 11.

8) Supply voltages higher than  $V_{bb(AZ)}$  require an external current limit for the GND and status pins (a 150 $\Omega$  resistor for the GND connection is recommended). See also  $V_{ON(CL)}$  in table of protection functions and circuit diagram on page 8.

9) Measured with load; for the whole device; all channels off

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

Parameter and Conditions, each of the two channels at $T_j = -40\dots+150^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	Max	

### Protection Functions

Current limit, (see timing diagrams, page 12)	$I_{L(\text{lim})}$	$T_j = -40^\circ\text{C}$ :	21	28	36	A
		$T_j = 25^\circ\text{C}$ :	17	22	31	
		$T_j = +150^\circ\text{C}$ :	12	16	24	
Repetitive short circuit current limit, $T_j = T_{jt}$ each channel two parallel channels (see timing diagrams, page 12)	$I_{L(\text{SCR})}$		--	17	--	A
			--	17	--	
Initial short circuit shutdown time (see timing diagrams on page 12)	$T_{j,\text{start}} = 25^\circ\text{C}$ : $t_{\text{off}(\text{SC})}$		--	2.4	--	ms
Output clamp (inductive load switch off) <sup>11)</sup> at $V_{\text{ON}(\text{CL})} = V_{bb} - V_{\text{OUT}}$ , $I_L = 40\text{ mA}$	$V_{\text{ON}(\text{CL})}$	$T_j = -40^\circ\text{C}$ :	41	--	--	V
		$T_j = 25^\circ\text{C}\dots 150^\circ\text{C}$ :	43	47	52	
Thermal overload trip temperature	$T_{jt}$		150	--	--	$^\circ\text{C}$
Thermal hysteresis	$\Delta T_{jt}$		--	10	--	K

### Reverse Battery

Reverse battery voltage <sup>12)</sup>	$-V_{bb}$		--	--	32	V
Drain-source diode voltage ( $V_{\text{out}} > V_{bb}$ ) $I_L = -4.0\text{ A}$ , $T_j = +150^\circ\text{C}$	$-V_{\text{ON}}$		--	600	--	mV

<sup>11)</sup> If channels are connected in parallel, output clamp is usually accomplished by the channel with the lowest  $V_{\text{ON}(\text{CL})}$



<sup>12)</sup> Requires a  $150\ \Omega$  resistor in GND connection. The reverse load current through the intrinsic drain-source diode has to be limited by the connected load. Power dissipation is higher compared to normal operating conditions due to the voltage drop across the 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 8).

Parameter and Conditions, each of the two channels at $T_j = -40\dots+150^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	Max	

### Diagnostic Characteristics

Open load detection current, (on-condition) each channel	$I_{L(OL)}$	10	--	500	mA
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### Input and Status Feedback<sup>13)</sup>

Input resistance (see circuit page 8)	$R_I$	2.5	3.5	6	k $\Omega$
Input turn-on threshold voltage 	$V_{IN(T+)}$	1.7	--	3.2	V
Input turn-off threshold voltage 	$V_{IN(T-)}$	1.5	--	--	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	--	50	$\mu\text{A}$
On state input current $V_{IN} = 5\text{ V}$ :	$I_{IN(on)}$	20	50	90	$\mu\text{A}$
Delay time for status with open load after switch off; (see diagram on page 13)	$t_{d(ST\ OL4)}$	100	520	900	$\mu\text{s}$
Status output (open drain)					
Zener limit voltage $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(low)}$	--	--	0.4	

<sup>13)</sup> If ground resistors  $R_{GND}$  are used, add the voltage drop across these resistors.

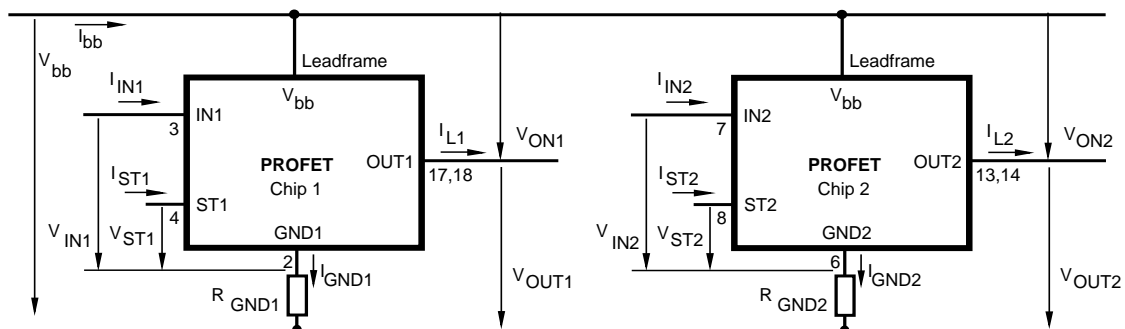
### Truth Table

Channel 1	Input 1	Output 1	Status 1
Channel 2	Input 2	Output 2	Status 2
	level	level	BTS 728L2
Normal operation	L	L	H
	H	H	H
Open load	L	Z	H
	H	H	L
Overtemperature	L	L	H
	H	L	L

L = "Low" Level      X = don't care      Z = high impedance, potential depends on external circuit  
H = "High" Level      Status signal valid after the time delay shown in the timing diagrams

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.

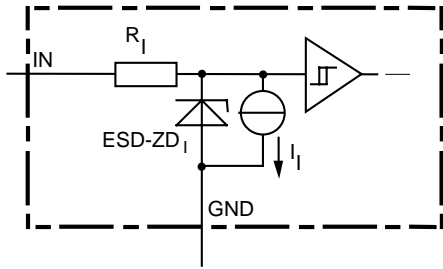
### Terms



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

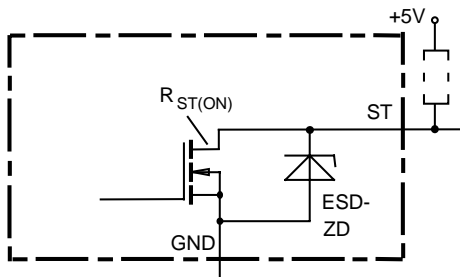
External  $R_{GND}$  optional; two resistors  $R_{GND1}$ ,  $R_{GND2} = 150 \Omega$  or a single resistor  $R_{GND} = 75 \Omega$  for reverse battery protection up to the max. operating voltage.

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



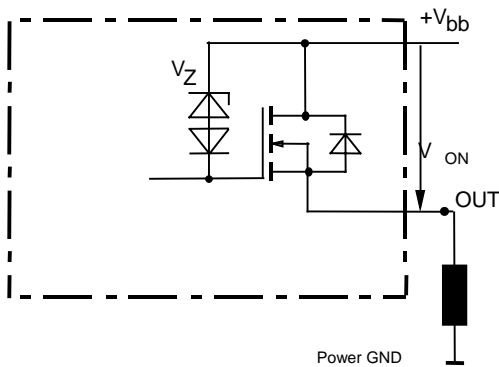
The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

### Status output, ST1 or ST2



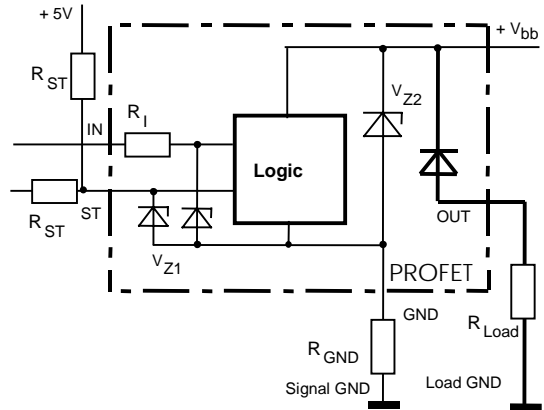
ESD-Zener diode: 6.1 V typ., max 5.0 mA;  $R_{ST(ON)} < 375 \Omega$  at 1.6 mA. The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

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



$V_{ON}$  clamped to  $V_{ON(CL)} = 47 \text{ V typ.}$

### Overvolt. and reverse batt. protection



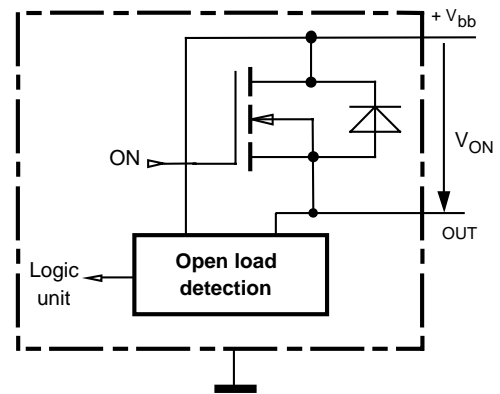
$V_{Z1} = 6.1 \text{ V typ.}$ ,  $V_{Z2} = 47 \text{ V typ.}$ ,  $R_{GND} = 150 \Omega$ ,  $R_{ST} = 15 \text{ k}\Omega$ ,  $R_I = 3.5 \text{ k}\Omega \text{ typ.}$

In case of reverse battery the load current has to be limited by the load. Temperature protection is not active

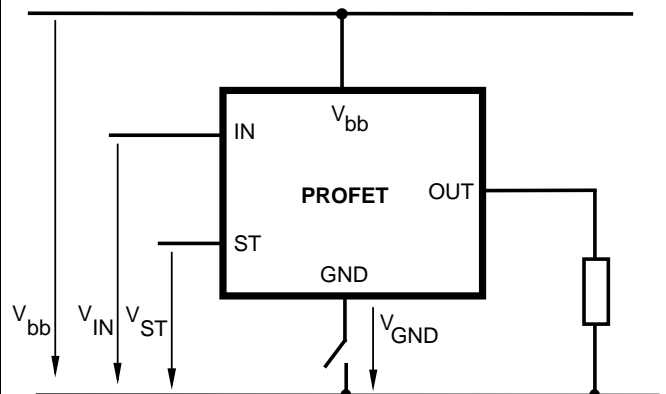
### Open-load detection OUT1 or OUT2

ON-state diagnostic

Open load, if  $V_{ON} < R_{ON} \cdot I_{L(OL)}$ ; IN high



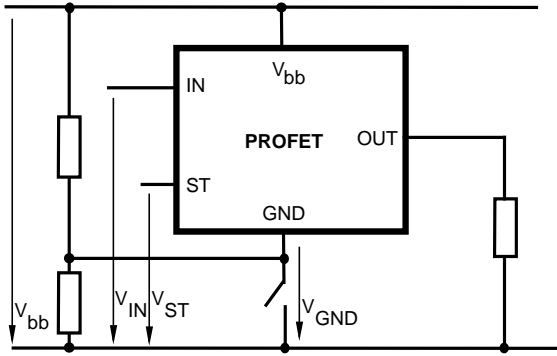
### GND disconnect



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

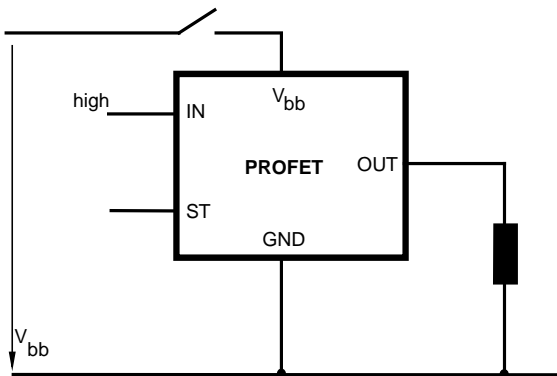


## GND disconnect with GND pull up



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

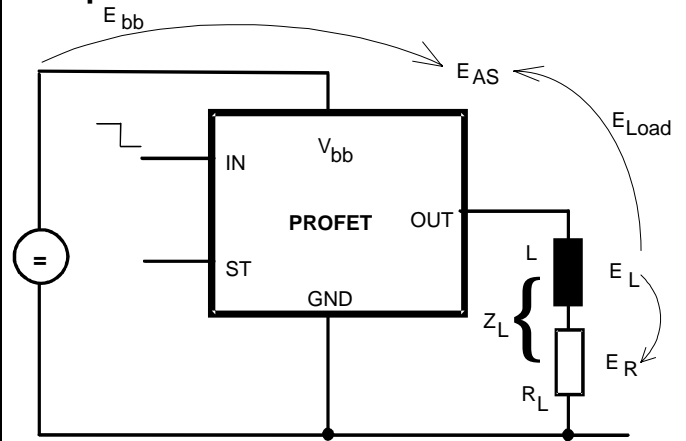
## V<sub>bb</sub> disconnect with energized inductive load



For inductive load currents up to the limits defined by  $Z_L$  (max. ratings and diagram on page 9) 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 all the 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

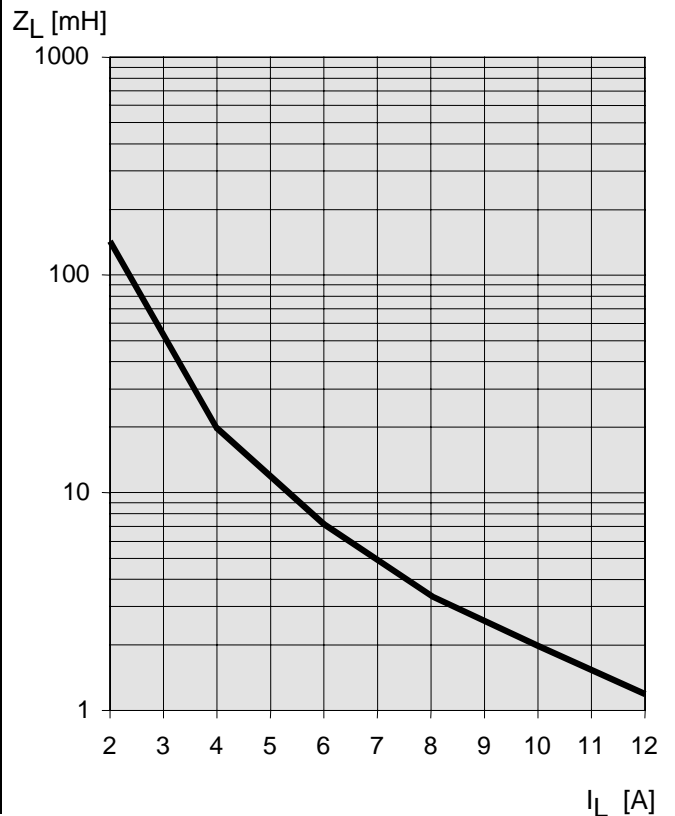
$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t) dt,$$

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

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

## Maximum allowable load inductance for a single switch off (one channel)<sup>4)</sup>

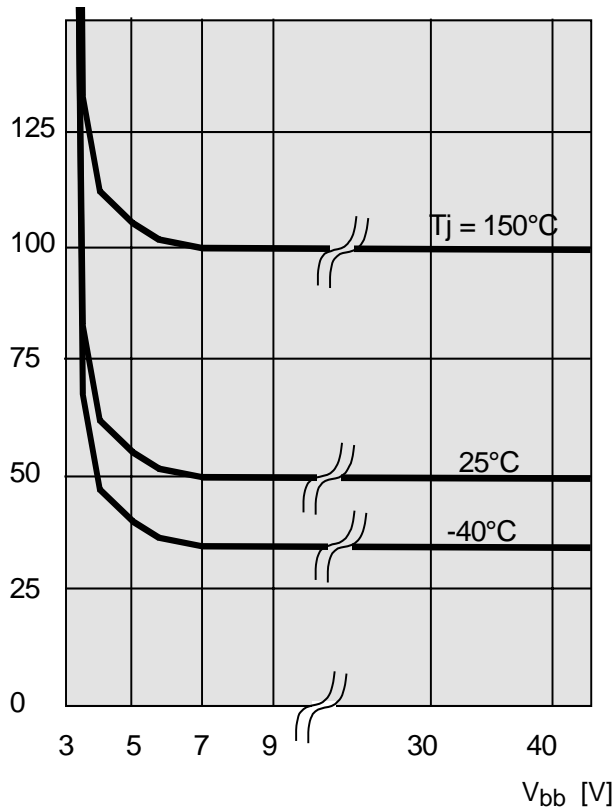
$$L = f(I_L); T_{j,start} = 150^\circ C, V_{bb} = 12 V, R_L = 0 \Omega$$



### Typ. on-state resistance

$R_{ON} = f(V_{bb}, T_j)$ ;  $I_L = 2\text{ A}$ ,  $I_N = \text{high}$

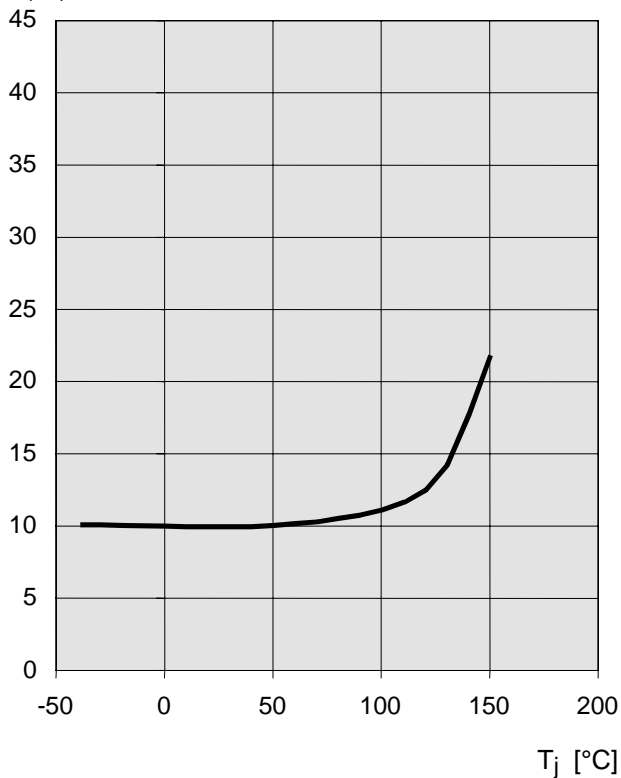
$R_{ON}$  [mOhm]



### Typ. standby current

$I_{bb(\text{off})} = f(T_j)$ ;  $V_{bb} = 9 \dots 34\text{ V}$ ,  $I_{N1,2} = \text{low}$

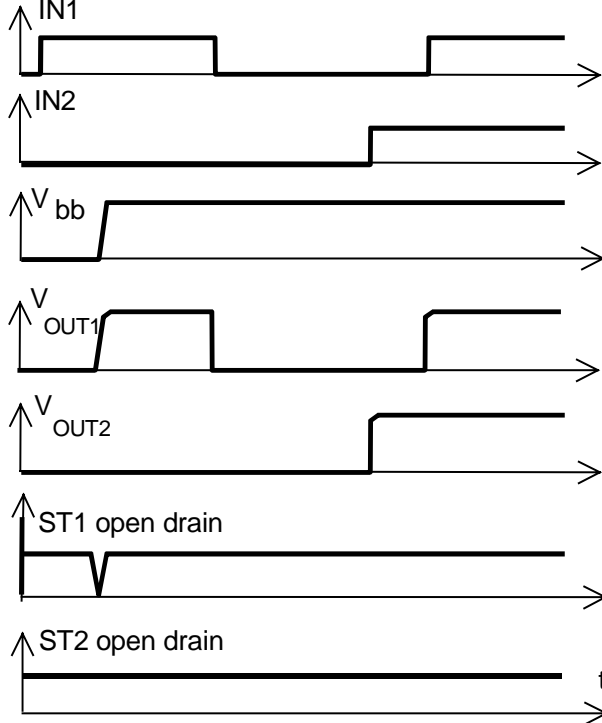
$I_{bb(\text{off})}$  [ $\mu\text{A}$ ]



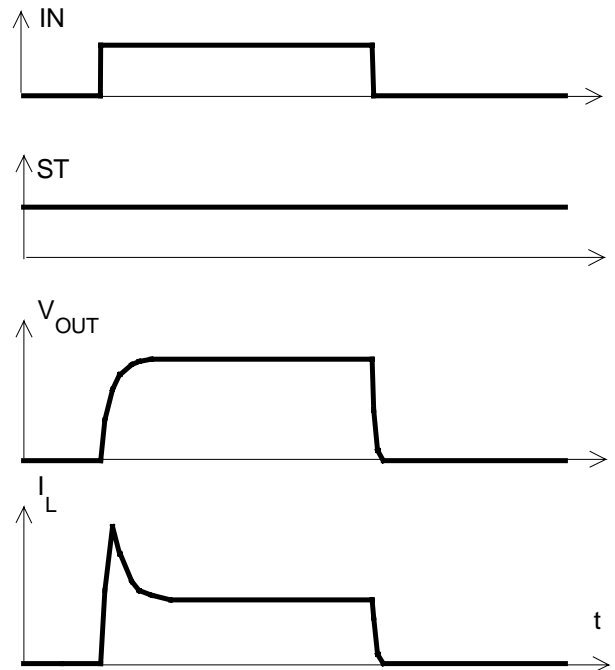
## Timing diagrams

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

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

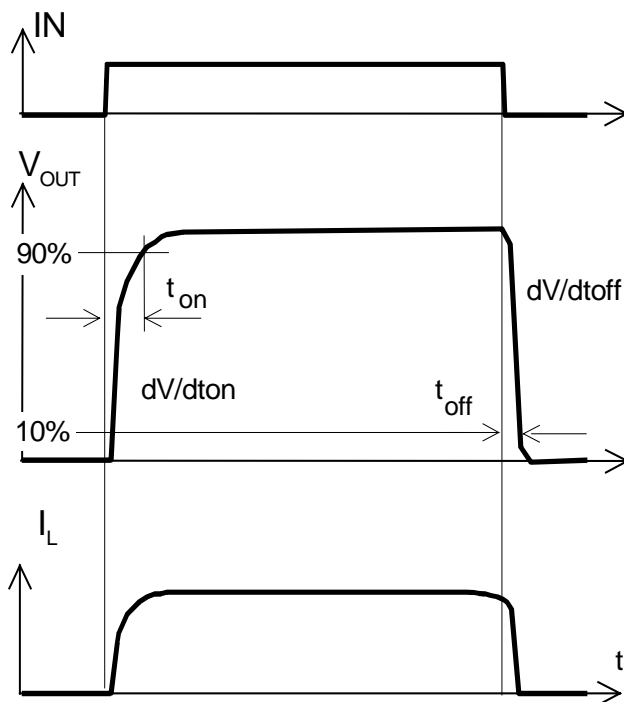


**Figure 2b:** Switching a lamp:

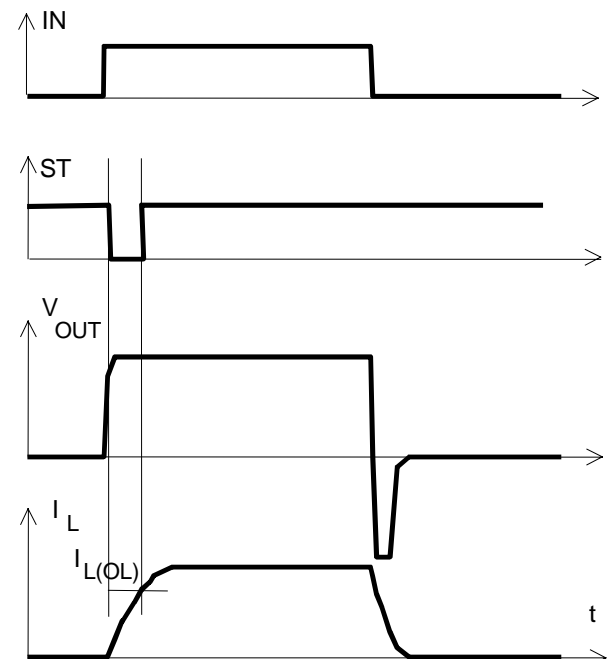


The initial peak current should be limited by the lamp and not by the current limit of the device.

**Figure 2a:** Switching a resistive load, turn-on/off time and slew rate definition:

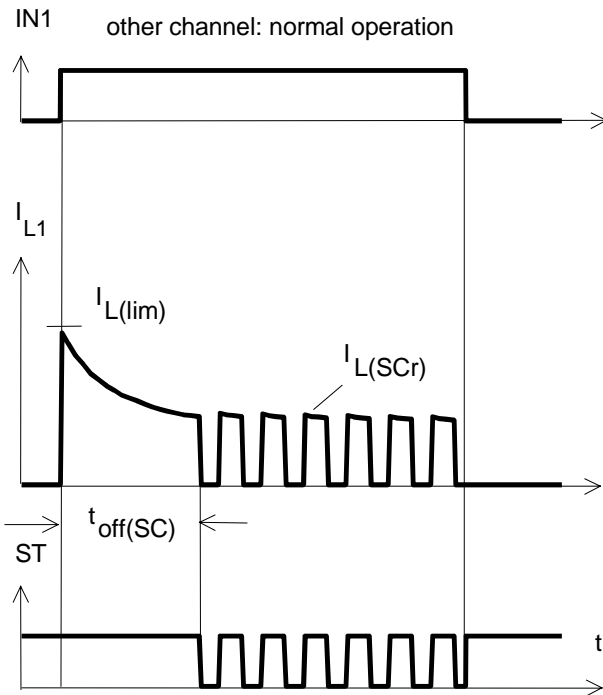


**Figure 2c:** Switching an inductive load



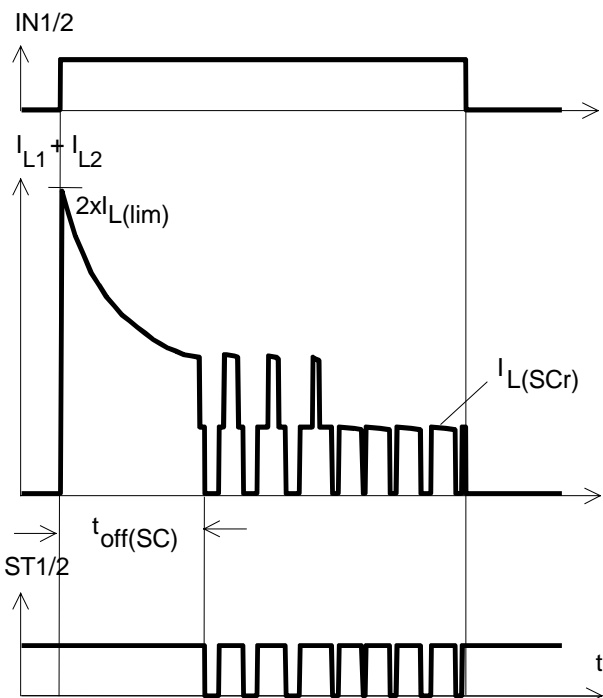
\*) if the time constant of load is too large, open-load-status may occur

**Figure 3a:** Turn on into short circuit:  
shut down by overtemperature, restart by cooling



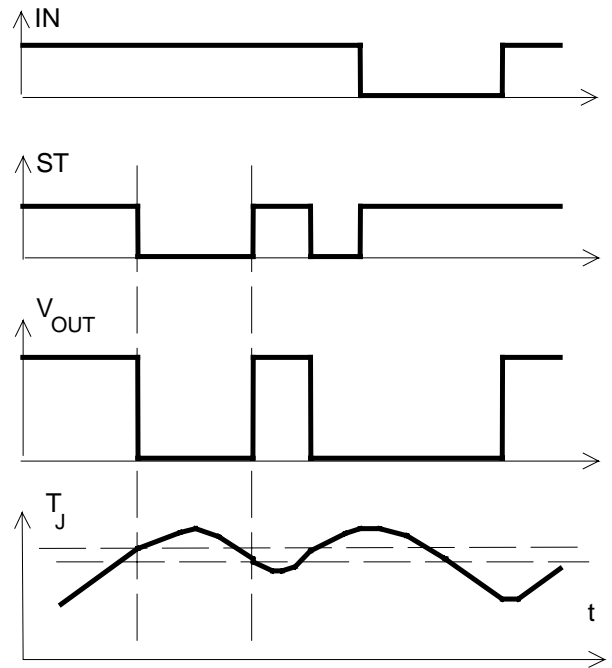
Heating up of the chip may require several milliseconds, depending on external conditions

**Figure 3b:** Turn on into short circuit:  
shut down by overtemperature, restart by cooling  
(two parallel switched channels 1 and 2)

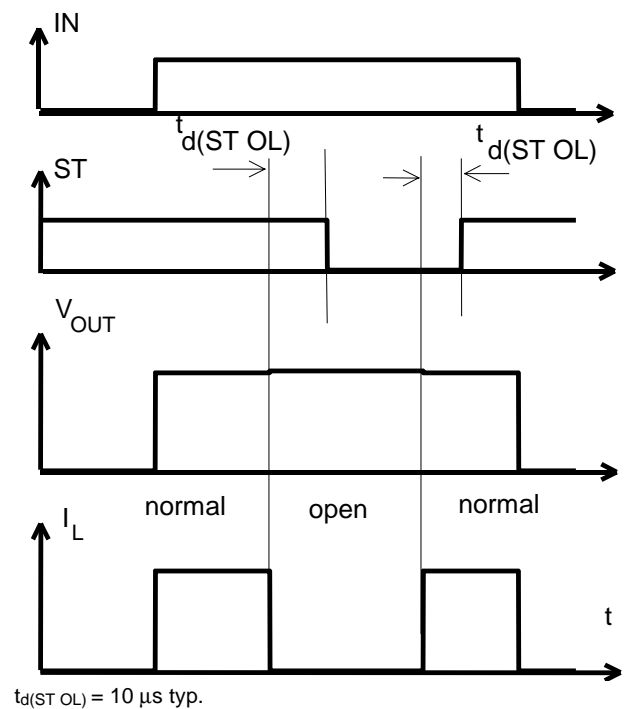


ST1 and ST2 have to be configured as a 'Wired OR' function ST1/2 with a single pull-up resistor.

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

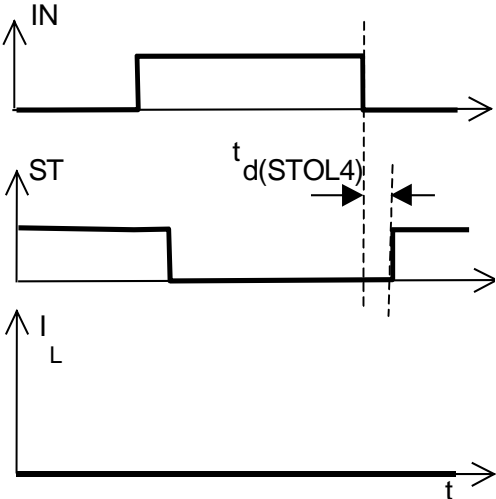


**Figure 5a:** Open load: detection in ON-state, open load occurs in on-state



$t_{d(ST OL)} = 10 \mu s$  typ.

Figure 5b: Open load: turn on/off to open load

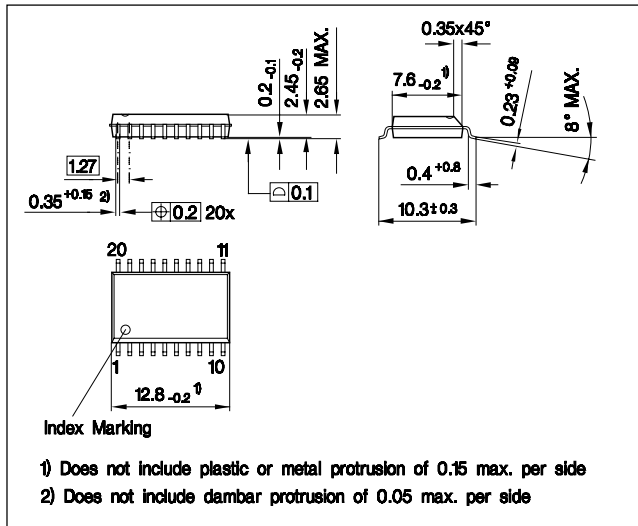


## Package and Ordering Code

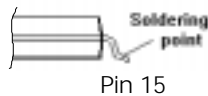
Standard: P-DSO-20-9

Sales Code	BTS 728 L2
Ordering Code	Q67060-S7014-A2

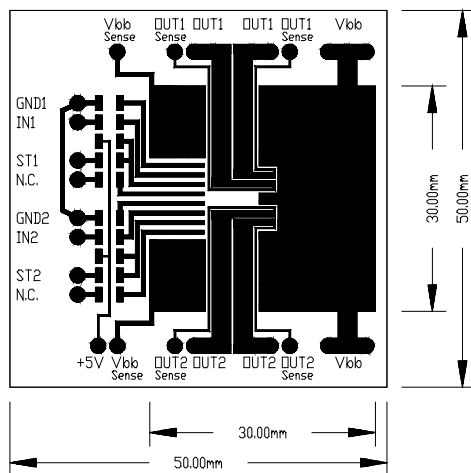
All dimensions in millimetres



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  
 $70\mu\text{m}$ ,  $6\text{cm}^2$  active heatsink area) as a reference for  
max. power dissipation  $P_{\text{tot}}$ , nominal load current  
 $I_{L(\text{NOM})}$  and thermal resistance  $R_{\text{thja}}$



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