

## Smart Two Channel Highside Power Switch

### Features

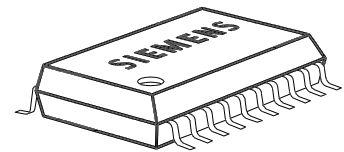
- Overload protection
- Current limitation
- Short-circuit protection
- Thermal shutdown
- Overvoltage protection (including load dump)
- Reverse battery protection<sup>1)</sup>
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis
- Open drain diagnostic output
- Open load detection in ON-state
- CMOS compatible input
- Loss of ground and loss of  $V_{bb}$  protection
- Electrostatic discharge (ESD) protection

### Product Summary

Overvoltage Protection	$V_{bb(AZ)}$	43	V
Operating voltage	$V_{bb(on)}$	5.0 ... 24	V
active channels:		one	two parallel
On-state resistance	$R_{ON}$	40	20
Nominal load current	$I_{L(NOM)}$	4.8	7.3
Current limitation	$I_{L(SCr)}$	21	21

### Application

- $\mu$ C compatible power switch with diagnostic feedback for 12 V DC grounded loads
- Most suitable for resistive and lamp 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. Fully protected by embedded protection functions.

#### Pin Definitions and Functions

Pin	Symbol	Function
1,10, 11,12, 15,16, 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 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>

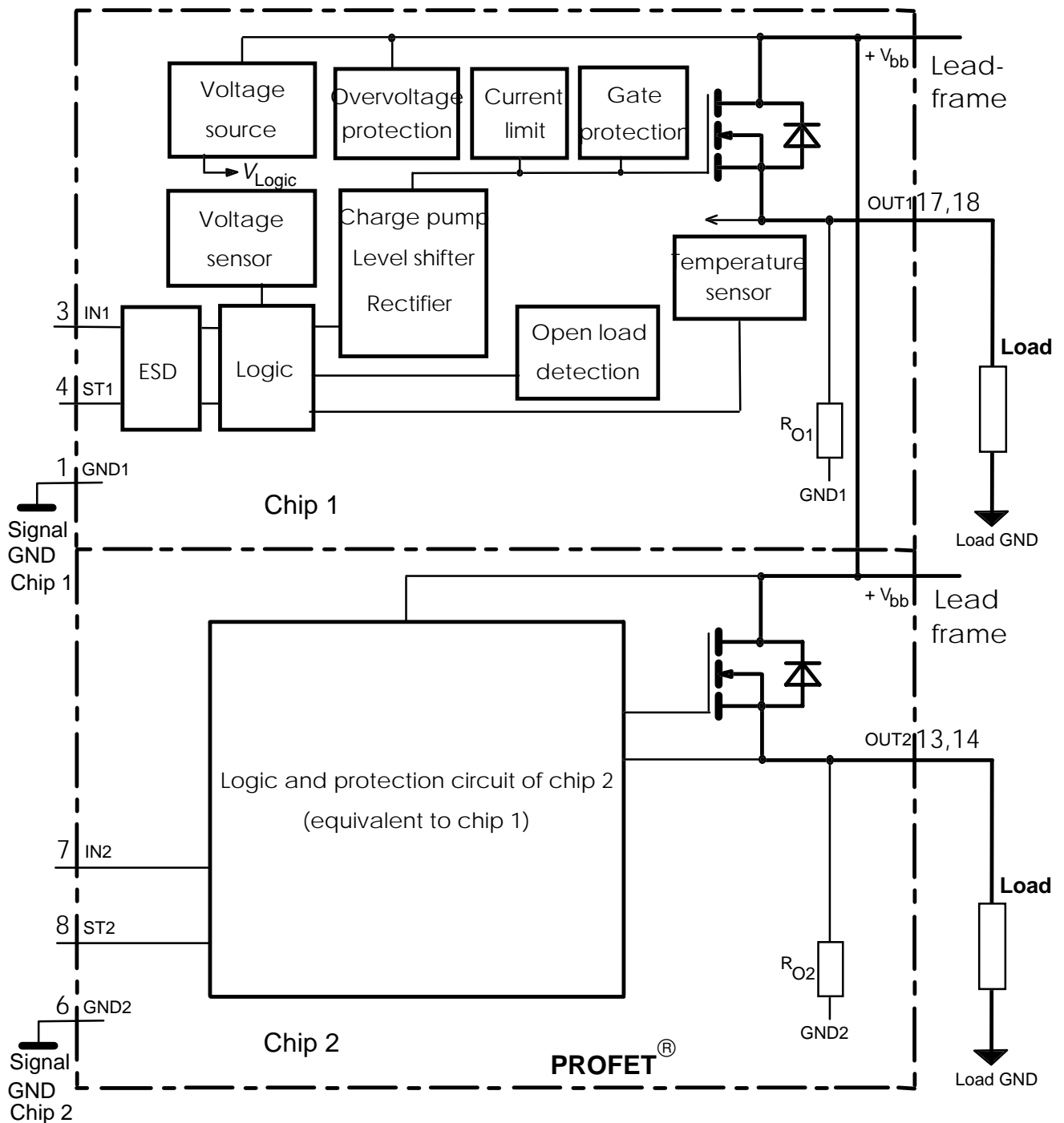
#### Pin configuration (top view)

$V_{bb}$	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

Two Channels; Open Load detection in on state;



Leadframe connected to pin 1, 10, 11, 12, 15, 16, 19, 20

**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

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

Parameter	Symbol	Values	Unit
Load current (Short-circuit current, see page 5)	$I_L$	self-limited	A
Load dump protection <sup>2)</sup> $V_{\text{LoadDump}} = U_A + V_s$ , $U_A = 13.5\text{ V}$ $R_l^3) = 2\ \Omega$ , $t_d = 200\text{ ms}$ ; IN = low or high, each channel loaded with $R_L = 2.8\ \Omega$ ,	$V_{\text{LoadDump}}^4)$	60	V
Operating temperature range	$T_j$	-40 ... +150	$^\circ\text{C}$
Storage temperature range	$T_{\text{stg}}$	-55 ... +150	
Power dissipation (DC) <sup>5)</sup> (all channels active)	$T_a = 25^\circ\text{C}$ : $T_a = 85^\circ\text{C}$ : $P_{\text{tot}}$	3.8 2.0	W
Electrostatic discharge capability (ESD) (Human Body Model)	$V_{\text{ESD}}$	1.0	kV
Input voltage (DC)	$V_{\text{IN}}$	-10 ... +16	V
Current through input pin (DC)	$I_{\text{IN}}$	$\pm 2.0$	mA
Current through status pin (DC) see internal circuit diagram page 8	$I_{\text{ST}}$	$\pm 5.0$	

## Thermal Characteristics

Parameter and Conditions	Symbol	Values			Unit
		min	typ	max	
Thermal resistance junction - soldering point <sup>5),6)</sup> each channel:	$R_{\text{thjs}}$	--	--	11	K/W
junction - ambient <sup>5)</sup> one channel active:	$R_{\text{thja}}$	--	40	--	
all channels active:		--	33	--	

## Electrical Characteristics

Parameter and Conditions, each of the two channels 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) $I_L = 2\text{ A}$ each channel, $T_j = 25^\circ\text{C}$ : $T_j = 150^\circ\text{C}$ : two parallel channels, $T_j = 25^\circ\text{C}$ :	$R_{\text{ON}}$	--	36 67 18	40 75 20	m $\Omega$
--	-----------------	----	----------------	----------------	------------



2) Supply voltages higher than  $V_{\text{bb(AZ)}}$  require an external current limit for the GND and status pins, e.g. with a  $150\ \Omega$  resistor in the GND connection and a  $15\text{ k}\Omega$  resistor in series with the status pin. A resistor for input protection is integrated.

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

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

5) 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  $V_{\text{bb}}$  connection. PCB is vertical without blown air. See page 14

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

Parameter and Conditions, each of the two channels at $T_j = 25^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Nominal load current one channel active: two parallel channels active: Device on PCB <sup>5)</sup> , $T_a = 85^\circ\text{C}$ , $T_j \leq 150^\circ\text{C}$	$I_{L(\text{NOM})}$	4.4 6.7	4.8 7.3	--	A
Output current while GND disconnected or pulled up; $V_{bb} = 30\text{ V}$ , $V_{\text{IN}} = 0$ , see diagram page 9	$I_{L(\text{GNDhigh})}$	--	--	10	mA
Turn-on time <sup>7)</sup> IN  to 90% $V_{\text{OUT}}$ :	$t_{\text{on}}$	80	180	350	$\mu\text{s}$
Turn-off time IN  to 10% $V_{\text{OUT}}$ : $R_L = 12\ \Omega$ , $T_j = -40\dots+150^\circ\text{C}$	$t_{\text{off}}$	80	250	450	$\mu\text{s}$
Slew rate on <sup>7)</sup> 10 to 30% $V_{\text{OUT}}$ , $R_L = 12\ \Omega$ , $T_j = -40\dots+150^\circ\text{C}$ :	$dV/dt_{\text{on}}$	0.1	--	1	$\text{V}/\mu\text{s}$
Slew rate off <sup>7)</sup> 70 to 40% $V_{\text{OUT}}$ , $R_L = 12\ \Omega$ , $T_j = -40\dots+150^\circ\text{C}$ :	$-dV/dt_{\text{off}}$	0.1	--	1	$\text{V}/\mu\text{s}$

### Operating Parameters

Operating voltage <sup>8)</sup> $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(\text{on})}$	5.0	--	24	V
Undervoltage shutdown $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(\text{under})}$	3.5	--	5.0	V
Undervoltage restart $T_j = -40\dots+25^\circ\text{C}$ : $T_j = +150^\circ\text{C}$ :	$V_{bb(\text{u rst})}$	--	--	5.0 7.0	V
Undervoltage restart of charge pump see diagram page 13 $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(\text{ucp})}$	--	5.6	7.0	V
Undervoltage hysteresis $\Delta V_{bb(\text{under})} = V_{bb(\text{u rst})} - V_{bb(\text{under})}$	$\Delta V_{bb(\text{under})}$	--	0.2	--	V
Overvoltage shutdown $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(\text{over})}$	24	--	34	V
Overvoltage restart $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(\text{o rst})}$	23	--	--	V
Overvoltage hysteresis $T_j = -40\dots+150^\circ\text{C}$ :	$\Delta V_{bb(\text{over})}$	--	0.5	--	V
Overvoltage protection <sup>9)</sup> $T_j = -40\dots+150^\circ\text{C}$ : $I_{bb} = 40\text{ mA}$	$V_{bb(\text{AZ})}$	42	47	--	V
Standby current, all channels off $T_j = 25^\circ\text{C}$ : $V_{\text{IN}} = 0$ $T_j = 150^\circ\text{C}$ :	$I_{bb(\text{off})}$	--	16 24	40 50	$\mu\text{A}$
Leakage output current (included in $I_{bb(\text{off})}$ ) $V_{\text{IN}} = 0$	$I_{L(\text{off})}$	--	--	20	$\mu\text{A}$
Operating current <sup>10)</sup> , $V_{\text{IN}} = 5\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$ $I_{\text{GND}} = I_{\text{GND1}} + I_{\text{GND2}}$ , one channel on: two channels on:	$I_{\text{GND}}$	--	1.8 3.6	4 8	mA

7) See timing diagram on page 11.

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

9) see also  $V_{\text{ON(CL)}}$  in circuit diagram on page 8.

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

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

### Protection Functions

Initial peak short circuit current limit, (see timing diagrams, page 11) each channel, $T_j = -40^\circ\text{C}$ : $T_j = 25^\circ\text{C}$ : $T_j = +150^\circ\text{C}$ : two parallel channels	$I_{L(SCp)}$	52 42 23	65 53 31	75 63 43	A
		twice the current of one channel			
Repetitive short circuit current limit, $T_j = T_{jt}$ each channel two parallel channels (see timing diagrams, page 11)	$I_{L(SCr)}$	-- --	21 21	-- --	A
Initial short circuit shutdown time $T_{j,start} = -40^\circ\text{C}$ : $T_{j,start} = 25^\circ\text{C}$ : (see page 10 and timing diagrams on page 11)	$t_{off(SC)}$	-- --	3 2.5	-- --	ms
Thermal overload trip temperature	$T_{jt}$	150	--	--	$^\circ\text{C}$
Thermal hysteresis	$\Delta T_{jt}$	--	10	--	K

### Reverse Battery



Reverse battery voltage <sup>11)</sup>	$-V_{bb}$	--	--	32	V
Drain-source diode voltage ( $V_{out} > V_{bb}$ ) $I_L = -4.8\text{ A}$ , $T_j = +150^\circ\text{C}$	$-V_{ON}$	--	600	--	mV

### Diagnostic Characteristics

Open load detection current, (on-condition) each channel, $T_j = -40^\circ\text{C}$ : $T_j = 25^\circ\text{C}$ : $T_j = +150^\circ\text{C}$ : two parallel channels	$I_{L(OL)}$	100 100 100	-- -- --	1200 1000 1000	mA
		twice the current of one channel			
Open load detection voltage <sup>12)</sup> $T_j = -40..+150^\circ\text{C}$ :	$V_{OUT(OL)}$	2	3	4	V
Internal output pull down (OUT to GND), $V_{OUT} = 5\text{ V}$ $T_j = -40..+150^\circ\text{C}$ :	$R_O$	4	10	30	k $\Omega$

<sup>11)</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).

<sup>12)</sup> External pull up resistor required for open load detection in off state.

Parameter and Conditions, each of the two channels at $T_j = 25^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
<b>Input and Status Feedback<sup>13)</sup></b>					
Input resistance (see circuit page 8)	$R_I$	2.5	3.5	6	$\text{k}\Omega$
Input turn-on threshold voltage  $T_j = -40..+150^\circ\text{C}$ :	$V_{IN(T+)}$	1.7	--	3.3	V
Input turn-off threshold voltage  $T_j = -40..+150^\circ\text{C}$ :	$V_{IN(T-)}$	1.5	--	--	V
Input threshold hysteresis	$\Delta V_{IN(T)}$	--	0.5	--	V
Off state input current $T_j = -40..+150^\circ\text{C}$ : $V_{IN} = 0.4\text{ V}$ :	$I_{IN(off)}$	1	--	50	$\mu\text{A}$
On state input current $T_j = -40..+150^\circ\text{C}$ : $V_{IN} = 5\text{ V}$ :	$I_{IN(on)}$	20	50	90	$\mu\text{A}$
Delay time for status with open load after switch off (see timing diagrams, page 12), $T_j = -40..+150^\circ\text{C}$ :	$t_{d(ST\ OL4)}$	100	520	1000	$\mu\text{s}$
Status invalid after positive input slope (open load) $T_j = -40..+150^\circ\text{C}$ :	$t_{d(ST)}$	--	250	600	$\mu\text{s}$
Status output (open drain)					
Zener limit voltage $T_j = -40...+150^\circ\text{C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage $T_j = -40...+25^\circ\text{C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(low)}$	--	--	0.4	
$T_j = +150^\circ\text{C}$ , $I_{ST} = +1.6\text{ mA}$ :		--	--	0.6	

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

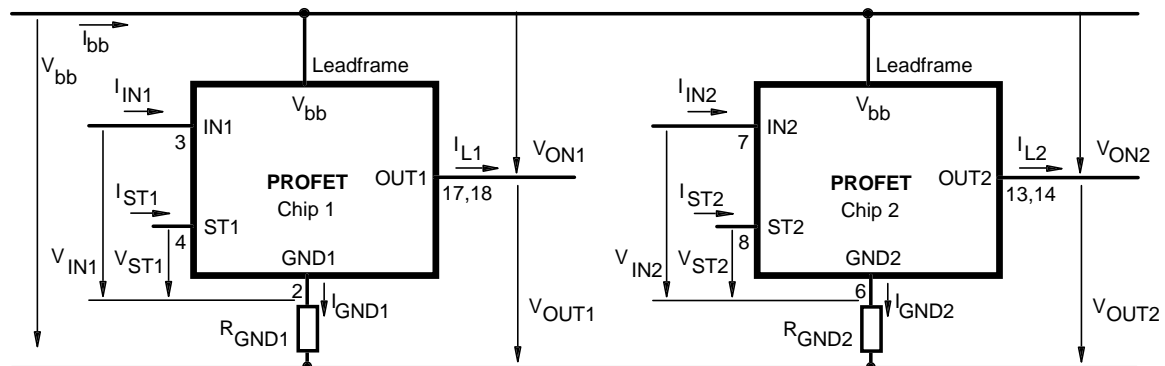
## Truth Table

Channel 1	Input 1	Output 1	Status 1
Channel 2	Input 2	Output 2	Status 2
	level	level	BTS 733L1
Normal operation	L	L	H
	H	H	H
Open load	L	Z	H (L <sup>14</sup> )
	H	H	L
Short circuit to V <sub>bb</sub>	L	H	L <sup>15</sup>
	H	H	H (L <sup>16</sup> )
Overtemperature	L	L	H
	H	L	L
Undervoltage	L	L	H
	H	L	H
Overvoltage	L	L	H
	H	L	H

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

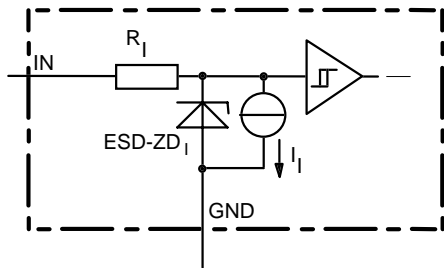


Leadframe ( $V_{bb}$ ) is connected to pin 1,10,11,12,15,16,19,20

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.

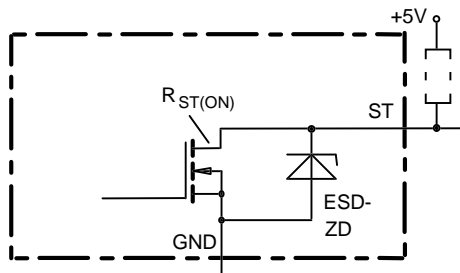
- 14) With external resistor between output and  $V_{bb}$
- 15) An external short of output to  $V_{bb}$  in the off state causes an internal current from output to ground. If  $R_{GND}$  is used, an offset voltage at the GND and ST pins will occur and the  $V_{ST\ low}$  signal may be erroneous.
- 16) Low resistance to  $V_{bb}$  may be detected by no-load-detection

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



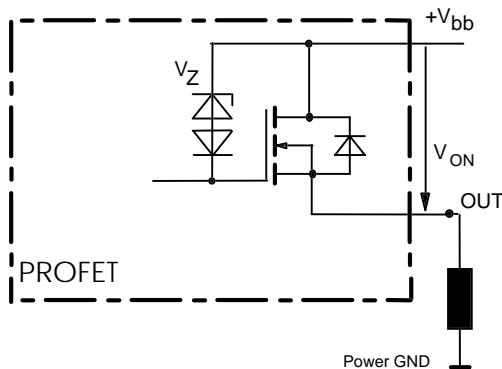
ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

## Status output, ST1 or ST2



ESD-Zener diode: 6.1 V typ., max 5.0 mA;  $R_{ST(ON)} < 375 \Omega$  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).

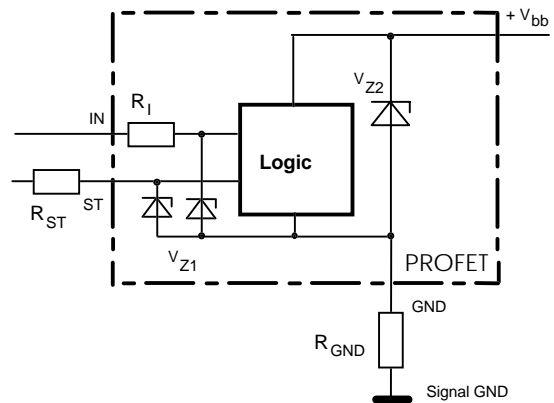
## overvoltage output clamp, OUT1 or OUT2



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

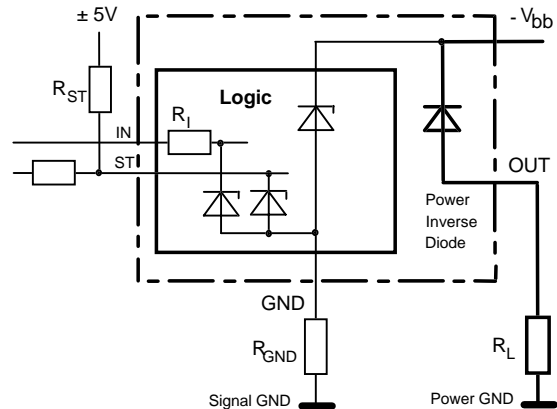
## Overvoltage protection of logic part

GND1 or GND2



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

## Reverse battery protection



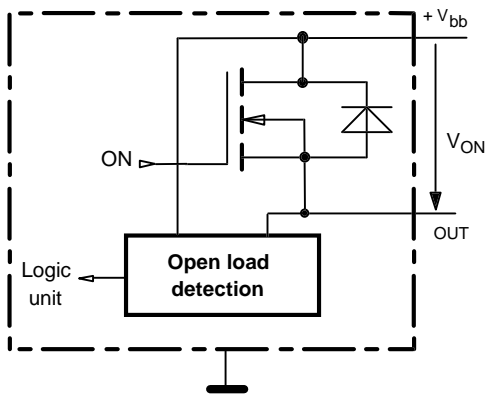
$R_{GND} = 150 \Omega$ ,  $R_I = 3.5 \text{ k}\Omega \text{ typ.}$

Temperature protection is not active during inverse current operation.

## Open-load detection, OUT1 or OUT2

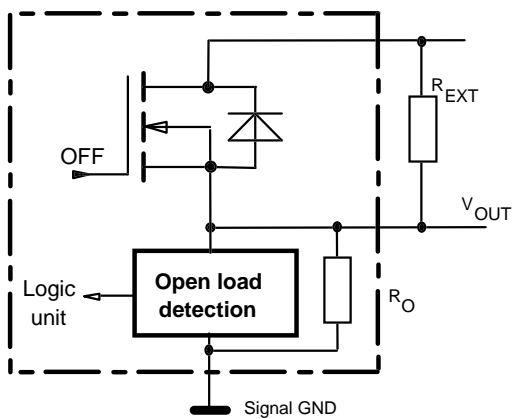
ON-state diagnostic condition:

$$V_{ON} < R_{ON} \cdot I_{L(OL)}; \text{IN high}$$

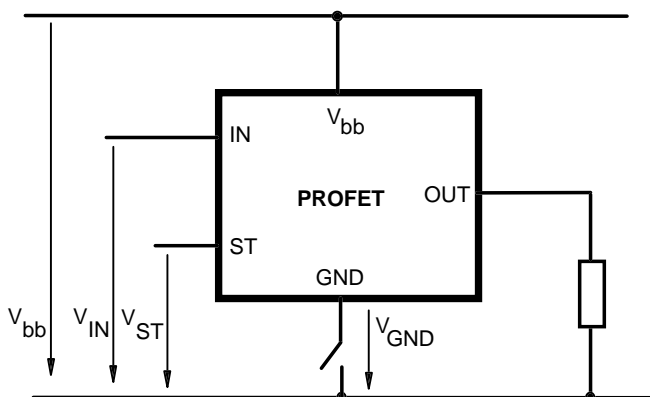


OFF-state diagnostic condition:

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

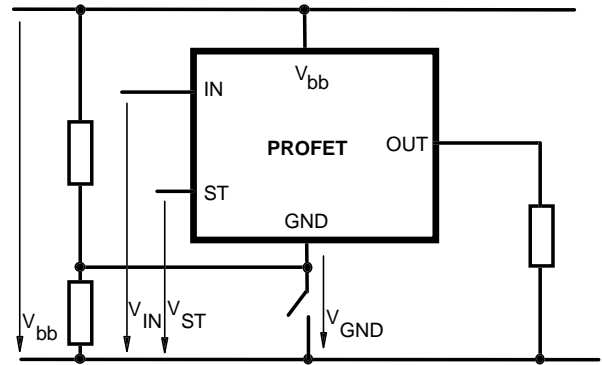


## GND disconnect



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.

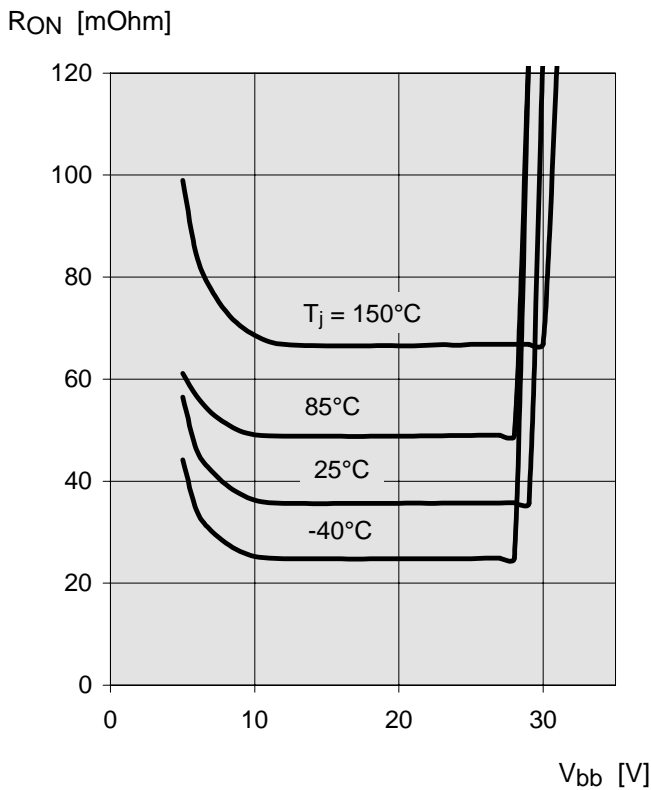
## GND disconnect with GND pull up



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

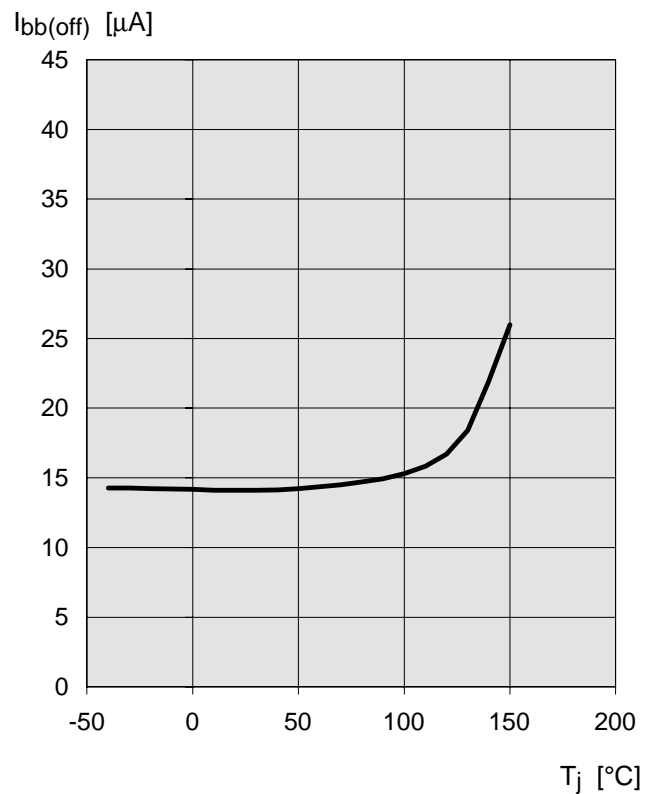
### Typ. on-state resistance

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



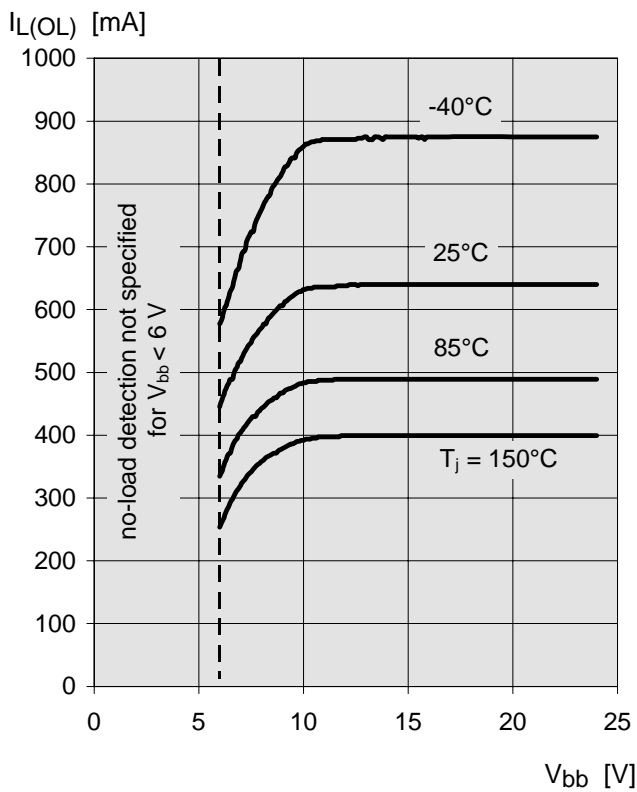
### Typ. standby current

$I_{bb(off)} = f(T_j)$ ;  $V_{bb} = 9\text{...}24\text{ V}$ ,  $I_{N1,2} = \text{low}$



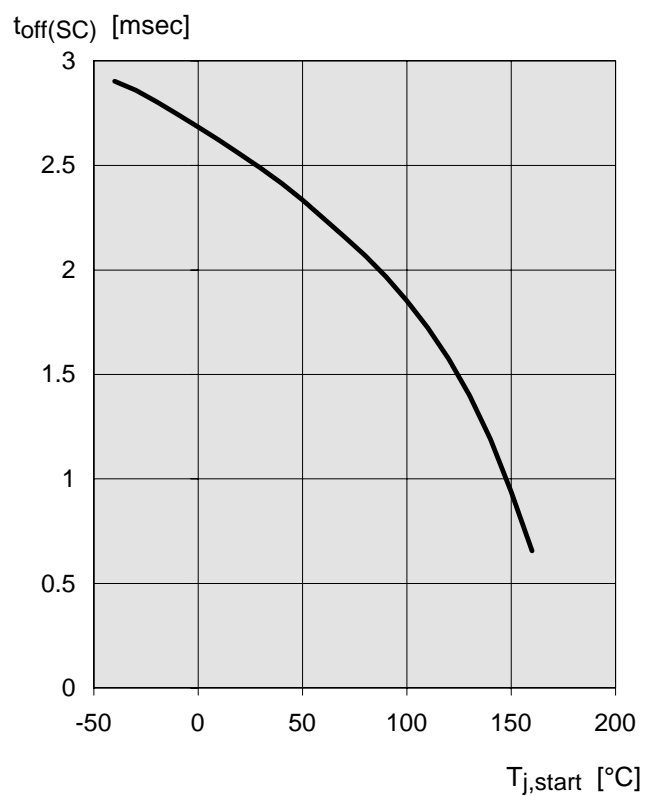
### Typ. open load detection current

$I_{L(OL)} = f(V_{bb}, T_j)$ ;  $I_N = \text{high}$



### Typ. initial short circuit shutdown time

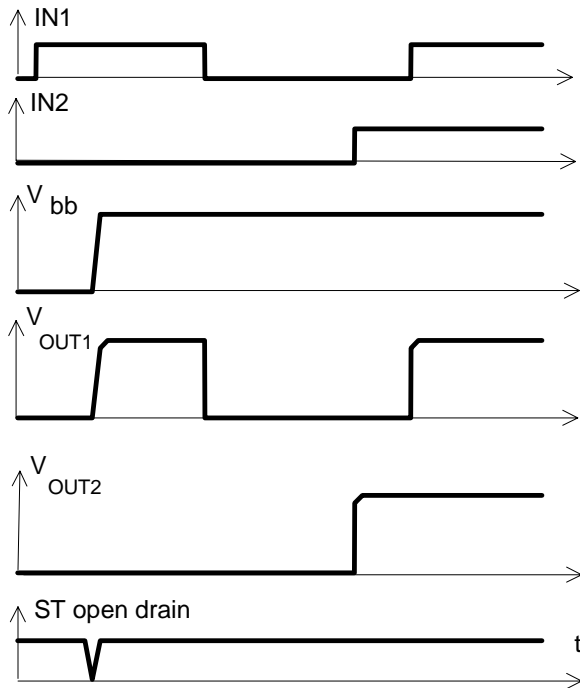
$t_{off(SC)} = f(T_{j,start})$ ;  $V_{bb} = 12\text{ V}$



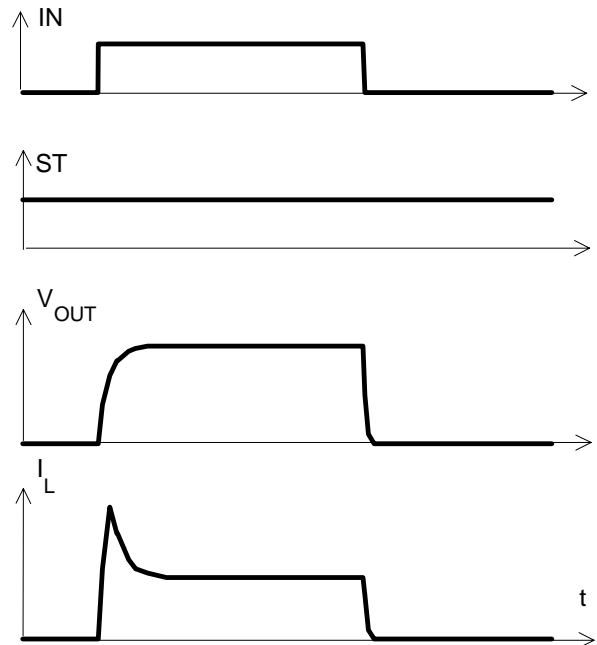
## Timing diagrams

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

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

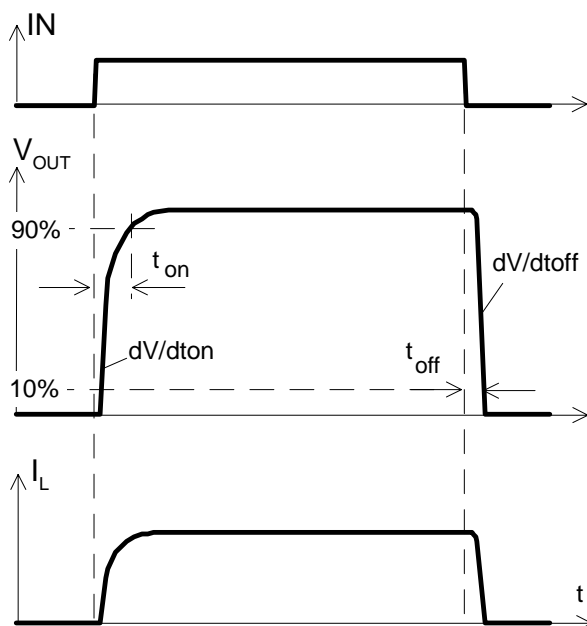


**Figure 2b:** Switching a lamp:

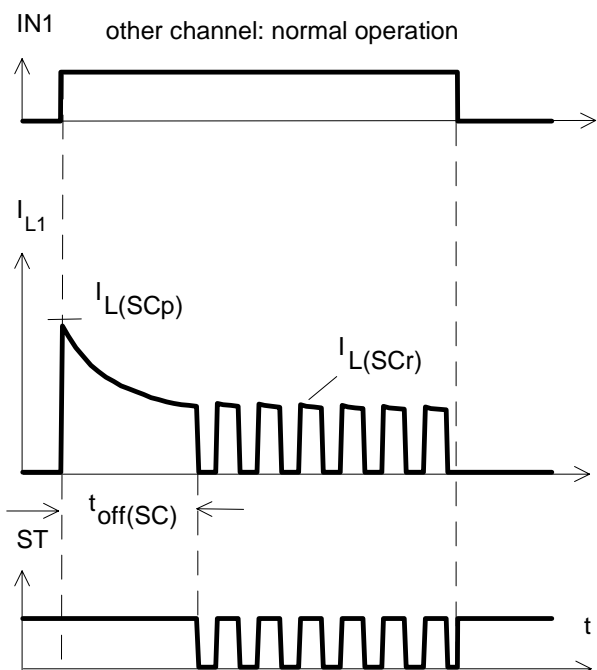


The initial peak current should be limited by the lamp and not by the initial short circuit current  $I_{L(SCp)} = 53 \text{ A typ.}$  of the device.

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

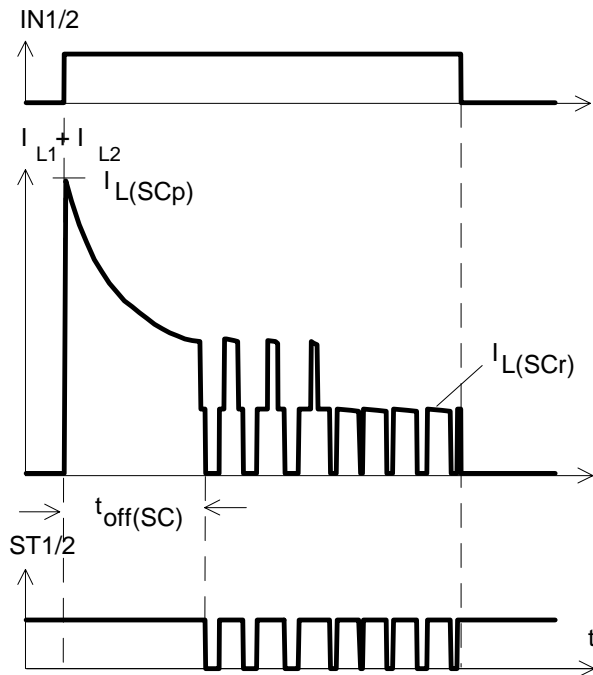


**Figure 3a:** Turn on into short circuit: shut down by overtemperature, restart by cooling



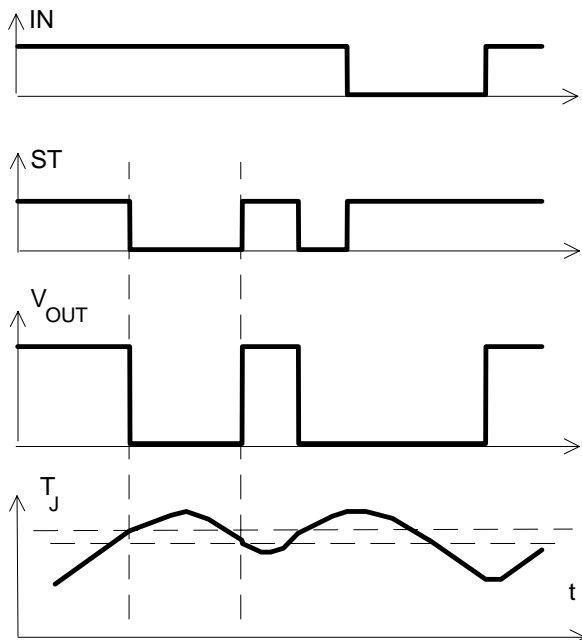
Heating up of the chip may require several milliseconds, depending on external conditions ( $t_{off(SC)}$  vs.  $T_{j,start}$  see page 10)

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

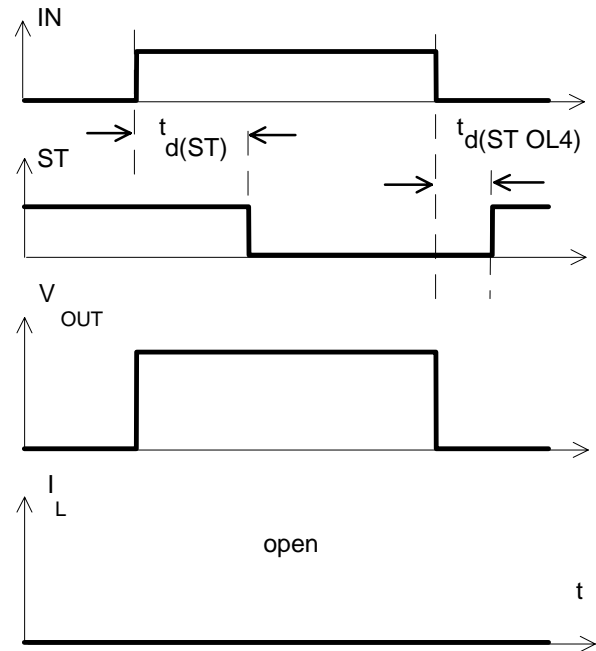


ST1 and ST2 have to be configured as a 'Wired OR' function ST1/2 with a single pull-up resistor.

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

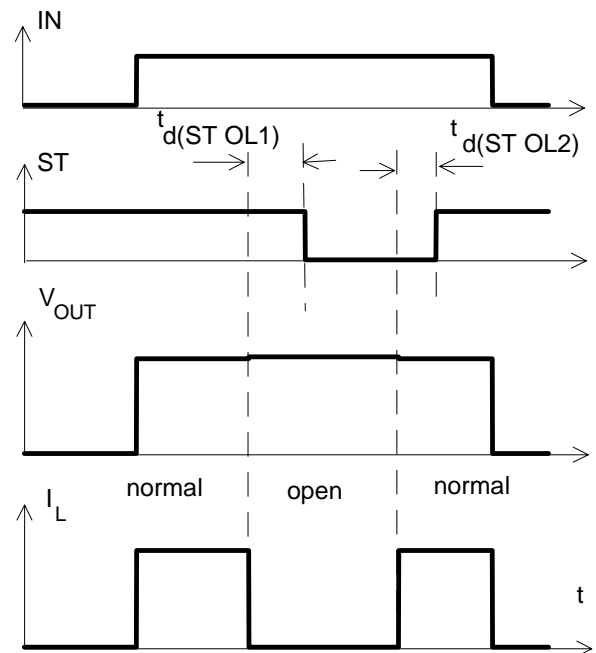


**Figure 5a:** Open load: detection in ON-state, turn on/off to open load



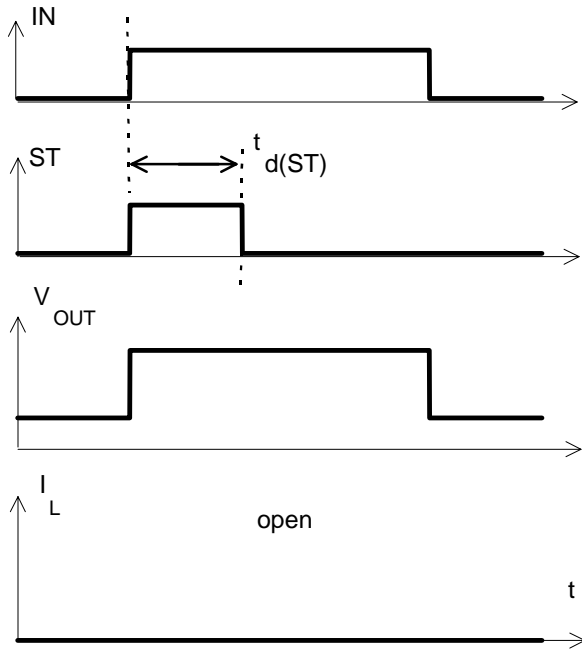
The status delay t<sub>d(ST OL4)</sub> is for differentiation between the failure modes "open load in ON-state" and "overtemperature"; t<sub>d(ST OL4)</sub> only appears after turn off to open load.

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

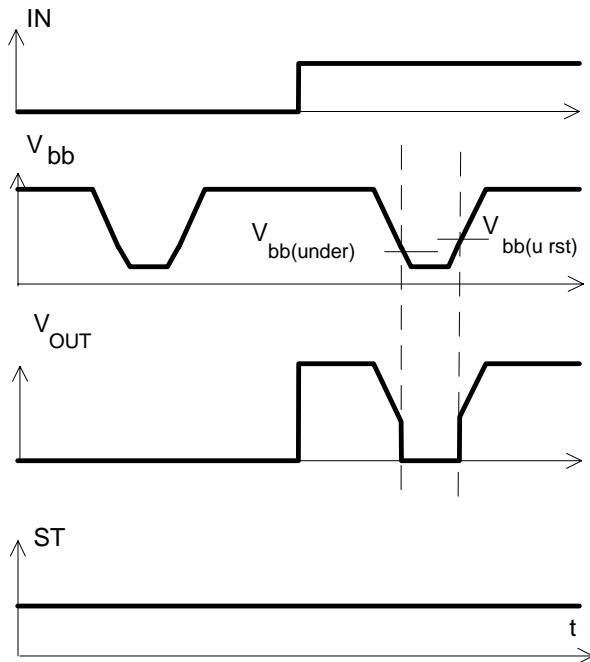


t<sub>d(ST OL1)</sub> = 20 μs typ., t<sub>d(ST OL2)</sub> = 10 μs typ

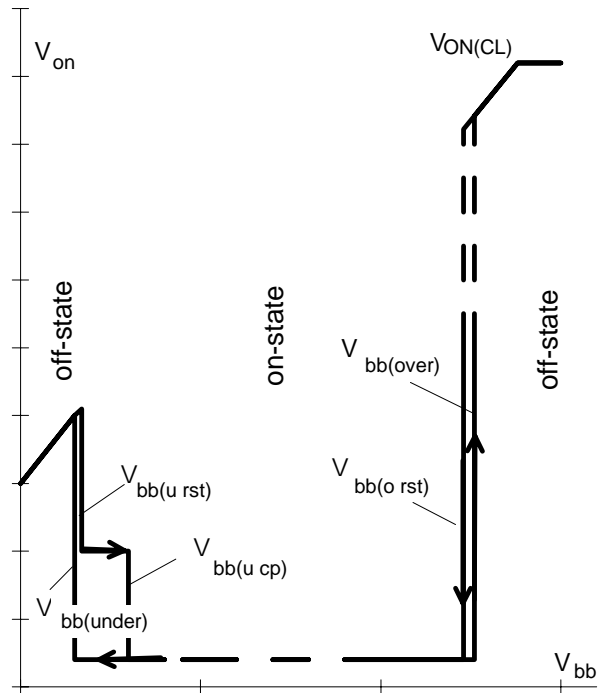
**Figure 5c:** Open load: detection in ON- and OFF-state (with  $R_{EXT}$ ), turn on/off to open load



**Figure 6a:** Undervoltage:

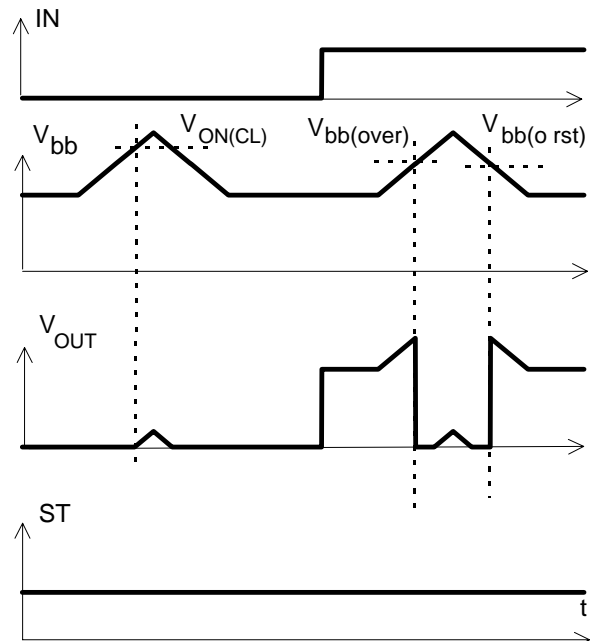


**Figure 6b:** Undervoltage restart of charge pump



IN = high, normal load conditions.  
Charge pump starts at  $V_{bb(ucp)} = 5.6V$  typ.

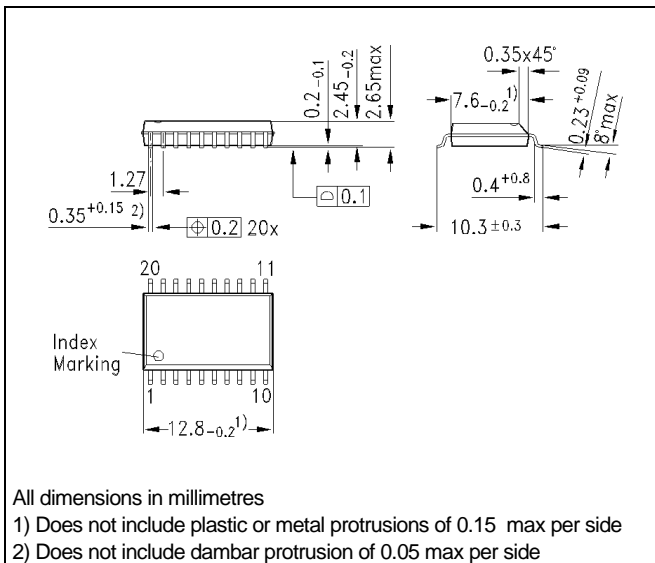
**Figure 7a:** Overvoltage:



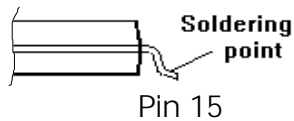
## Package and Ordering Code

Standard P-DSO-20-9      Ordering Code

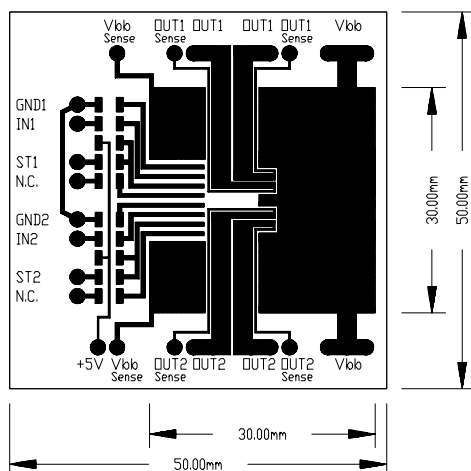
BTS733L1	Q67060-S7008-A2
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Definition of soldering point with temperature  $T_s$ :  
upper side of solder edge of device pin 15.



Printed circuit board (FR4, 1.5mm thick, one layer 70 $\mu$ m, 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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