

# Smart High-Side Power Switch

## One Channel: 60mΩ

## Status Feedback

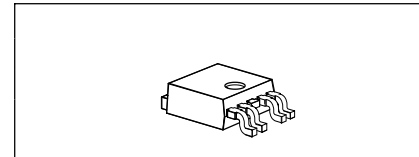


### Product Summary

On-state Resistance	$R_{ON}$	60mΩ
Operating Voltage	$V_{bb(on)}$	4.75...41V
Nominal load current	$I_{L(NOM)}$	7.0A
Current limitation	$I_{L(SCr)}$	17A

- AEC qualified
- Green product (RoHS compliant)

### Package



PG-TO-252

### General Description

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

### Applications

- μC 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

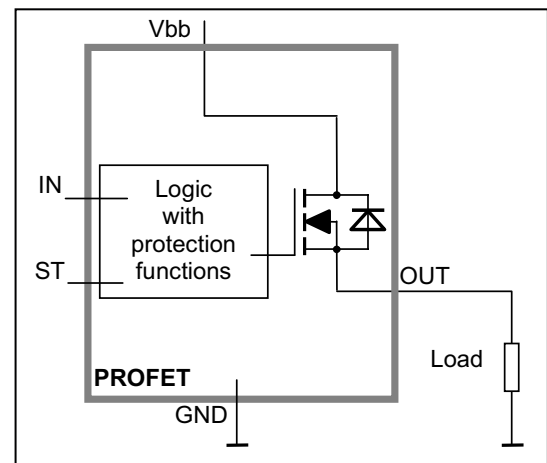
### Protection Functions

- 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)

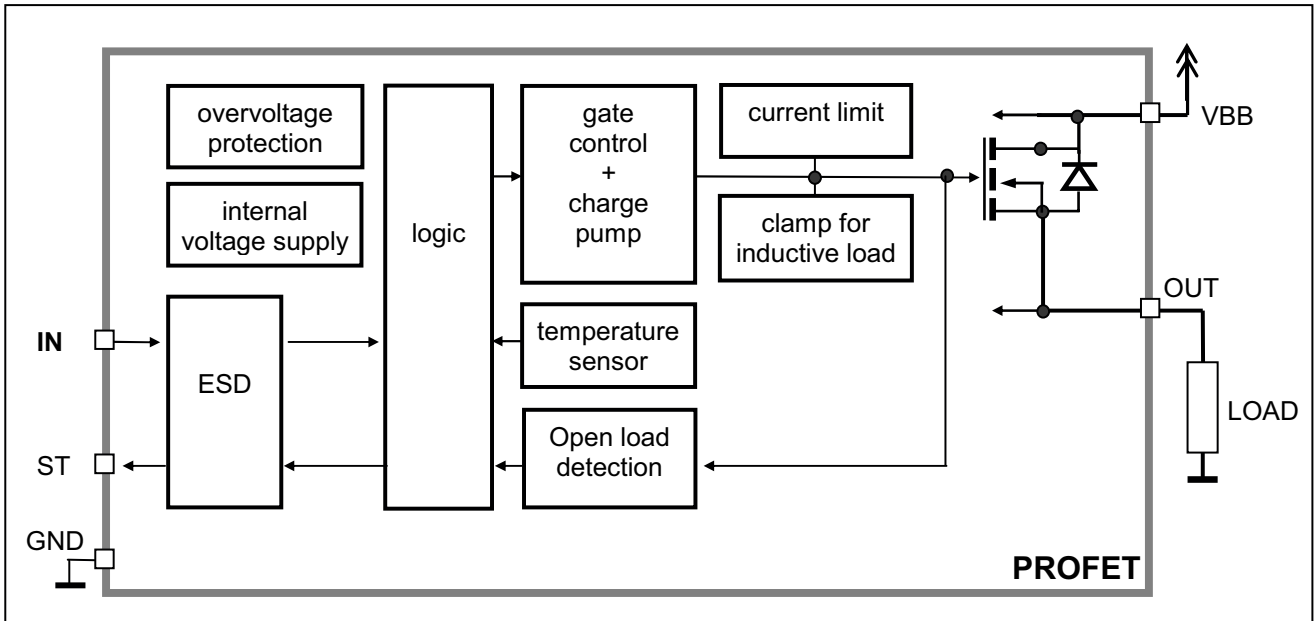
### Diagnostic Function

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

### Block Diagram



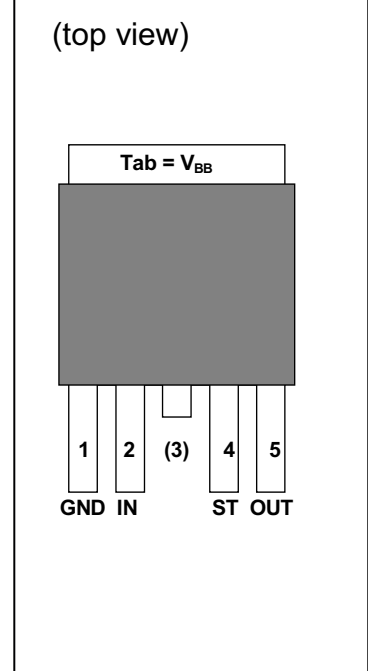
Functional diagram



Pin Definitions and Functions

Pin	Symbol	Function
1	GND	<b>Logic ground</b>
2	IN	<b>Input</b> , activates the power switch in case of logical high signal
3	V <sub>bb</sub>	<b>Positive power supply voltage</b> The tab is shorted to pin 3
4	ST	<b>Diagnostic feedback</b> , low on failure
5	OUT	<b>Output to the load</b>
Tab	V <sub>bb</sub>	<b>Positive power supply voltage</b> The tab is shorted to pin 3

Pin configuration



**Maximum Ratings** at  $T_j = 25\text{ °C}$  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 $T_{j\text{Start}} = -40 \dots +150\text{ °C}$	$V_{bb}$	24	V
Load dump protection <sup>1)</sup> $V_{\text{LoadDump}} = V_A + V_S$ , $V_A = 13.5\text{ V}$ $R_1^2 = 2\ \Omega$ , $R_L = 4.0\ \Omega$ , $t_d = 200\text{ ms}$ , IN= low or high	$V_{\text{Load dump}}^3)$	60	V
Load current (Current limit, see page 5)	$I_L$	self-limited	A
Operating temperature range	$T_j$	-40 ... +150	°C
Storage temperature range	$T_{\text{stg}}$	-55 ... +150	
Power dissipation (DC), $T_C \leq 25\text{ °C}$	$P_{\text{tot}}$	75	W
Maximal switchable inductance, single pulse $V_{bb} = 12\text{V}$ , $T_{j,\text{start}} = 150\text{ °C}$ , $T_C = 150\text{ °C}$ const. (See diagram on page 9) $I_L(\text{ISO}) = 7\text{ A}$ , $R_L = 0\ \Omega$ ; $E_{\text{AS}}^4 = 0.19\text{ J}$ :	$Z_L$	5.6	mH
Electrostatic discharge capability (ESD) IN: (Human Body Model) ST: out to all other pins shorted: acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993; $R = 1.5\text{ k}\Omega$ ; $C = 100\text{ pF}$	$V_{\text{ESD}}$	1.0 4.0 8.0	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 diagrams page 8	$I_{\text{ST}}$	$\pm 5.0$	

**Thermal Characteristics**

Parameter and Conditions	Symbol	Values			Unit
		min	typ	max	
Thermal resistance chip - case:	$R_{\text{thJC}}$	--	--	1.67	K/W
junction - ambient (free air):	$R_{\text{thJA}}$	--	--	75	
device on pcb <sup>5)</sup> :		--	42	--	

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

<sup>2)</sup>  $R_1$  = internal resistance of the load dump test pulse generator

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



<sup>4)</sup>  $E_{\text{AS}}$  is the maximum inductive switch-off energy

<sup>5)</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  $V_{bb}$  connection. PCB is vertical without blown air.

## Electrical Characteristics

Parameter and Conditions at $T_j = -40...+150^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

### Load Switching Capabilities and Characteristics

On-state resistance (pin 3 to 5) $I_L = 2\text{ A}$ ; $V_{BB} \geq 7\text{ V}$ $T_j = 25^\circ\text{C}$ : $T_j = 150^\circ\text{C}$ : see diagram, page 10	$R_{ON}$	--	50 100	60 120	m $\Omega$
Nominal load current, (pin 3 to 5) ISO 10483-1, 6.7: $V_{ON} = 0.5\text{ V}$ , $T_C = 85^\circ\text{C}$	$I_{L(ISO)}$	5.8	7.0	--	A
Output current (pin 5) while GND disconnected or GND pulled up <sup>6)</sup> , $V_{bb} = 30\text{ V}$ , $V_{IN} = 0$ , see diagram page 8	$I_{L(GNDhigh)}$	--	--	2	mA
Turn-on time IN  to 90% $V_{OUT}$ : $R_L = 12\ \Omega$ ,	$t_{on}$	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 10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$ ,	$dV/dt_{on}$	0.1	--	1	V/ $\mu\text{s}$
Slew rate off 70 to 40% $V_{OUT}$ , $R_L = 12\ \Omega$ ,	$-dV/dt_{off}$	0.1	--	1	V/ $\mu\text{s}$

### Operating Parameters

Operating voltage $T_j = -40^\circ\text{C}$ : $T_j = +25...+150^\circ\text{C}$ :	$V_{bb(on)}$	4.75	-- --	41 43	V
Overvoltage protection <sup>7)</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 (pin 3) <sup>8)</sup> $V_{IN} = 0$ ; see diagram on page 10 $T_j = -40...+25^\circ\text{C}$ : $T_j = 150^\circ\text{C}$ :	$I_{bb(off)}$	-- --	5 --	9 25	$\mu\text{A}$
Off-State output current (included in $I_{bb(off)}$ ) $V_{IN} = 0$	$I_{L(off)}$	--	1	10	$\mu\text{A}$
Operating current <sup>9)</sup> , $V_{IN} = 5\text{ V}$	$I_{GND}$	--	0.8	1.5	mA



<sup>6)</sup> not subject to production test, specified by design

<sup>7)</sup> 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 page 8.

<sup>8)</sup> Measured with load

<sup>9)</sup> Add  $I_{ST}$ , if  $I_{ST} > 0$ , add  $I_{IN}$ , if  $V_{IN} > 5.5\text{ V}$



Parameter and Conditions at $T_j = -40...+150^\circ\text{C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
<b>Input and Status Feedback<sup>14)</sup></b>					
Input resistance see circuit page 8	$R_I$	2.5	3.5	6	$\text{k}\Omega$
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 (pin 2), $V_{IN} = 0.4\text{ V}$	$I_{IN(off)}$	1	--	50	$\mu\text{A}$
On state input current (pin 2), $V_{IN} = 5\text{ V}$	$I_{IN(on)}$	20	50	90	$\mu\text{A}$
Delay time for status with open load after switch off (see timing diagrams on page 12)	$t_{d(ST\ OL4)}$	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>14)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor.

### Truth Table

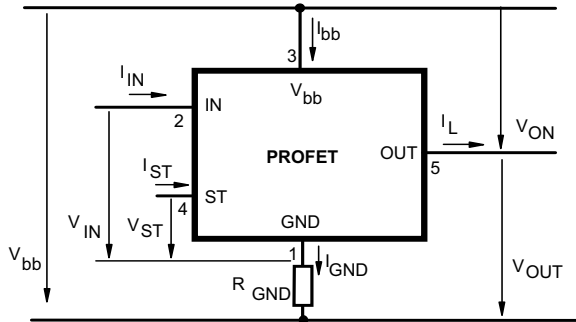
	Input level	Output level	Status BTS 428L2
Normal operation	L	L	H
	H	H	H
Open load	L	Z	H
	H	H	L
Overtemperature	L	L	H
	H	L	L

L = "Low" Level  
H = "High" Level

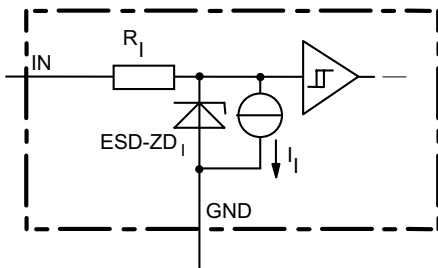
X = don't care

Z = high impedance, potential depends on external circuit  
Status signal after the time delay shown in the diagrams (see fig 5. page 12)

## Terms

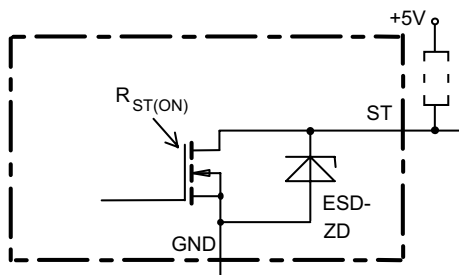


## Input circuit (ESD protection)



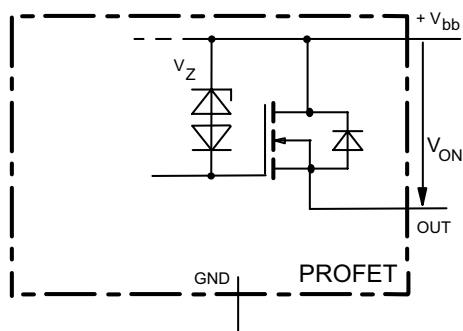
The use of ESD zener diodes as voltage clamp at DC conditions is not recommended

## Status output

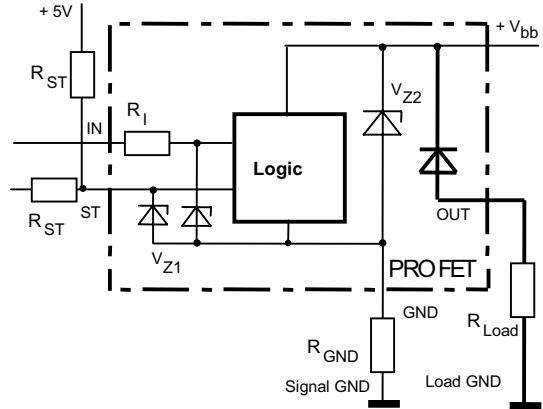


ESD-Zener diode: 6.1 V typ., max 5.0 mA;  $R_{ST(ON)} < 375 \Omega$  at 1.6 mA. The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

## Inductive and overvoltage output clamp



## Overvolt. and reverse batt. protection

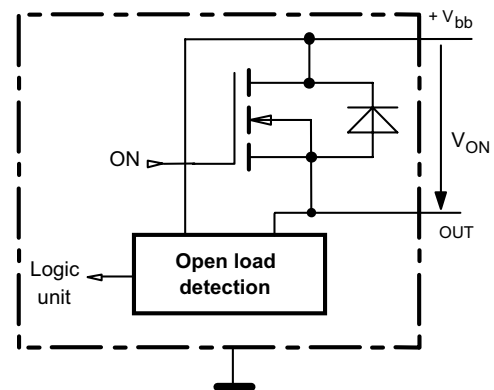


$V_{Z1} = 6.1 \text{ V typ.}$ ,  $V_{Z2} = 47 \text{ V typ.}$ ,  $R_{GND} = 150 \Omega$ ,  $R_{ST} = 15 \text{ k}\Omega$ ,  $R_I = 3.5 \text{ k}\Omega \text{ typ.}$

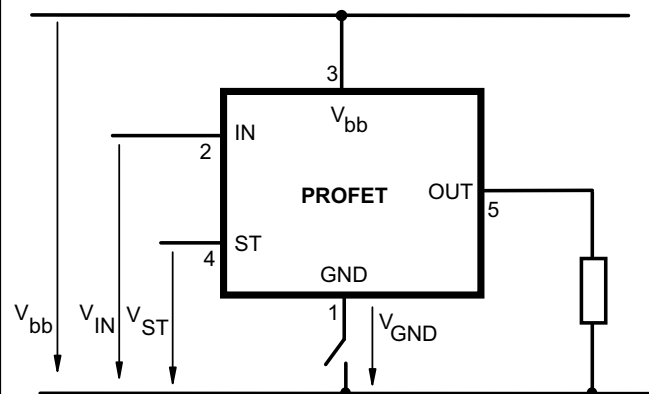
In case of reverse battery the load current has to be limited by the load. Temperature protection is not active

## Open-load detection in on-state

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



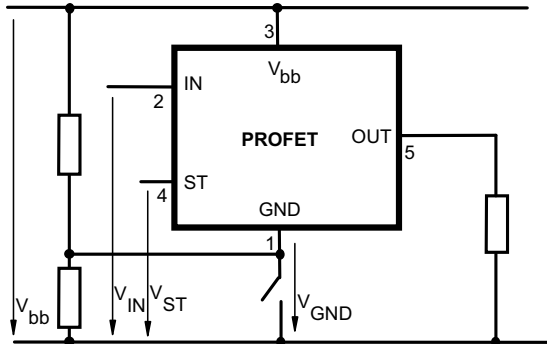
## GND disconnect



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

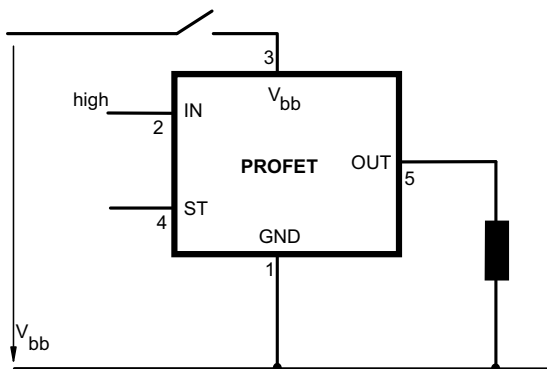


### GND disconnect with GND pull up



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.

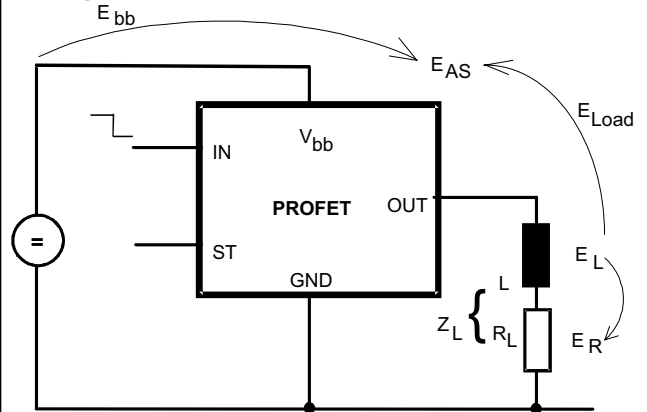
### V<sub>bb</sub> disconnect with energized inductive load



For 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

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

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

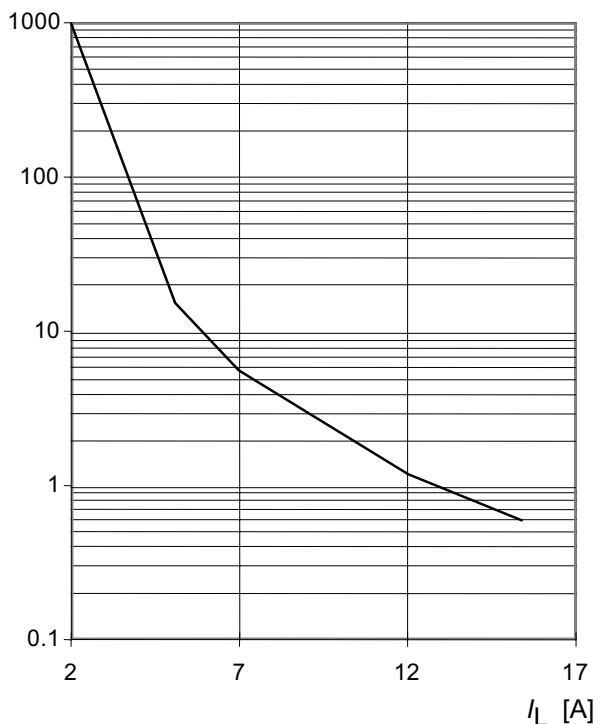
$$E_{AS} = \frac{I_L \cdot L}{2 \cdot R_L} \cdot (V_{bb} + |V_{OUT(CL)}|) \cdot \ln \left( 1 + \frac{I_L \cdot R_L}{|V_{OUT(CL)}|} \right)$$

### Maximum allowable load inductance for a single switch off

$L = f(I_L)$ ;  $T_{j,start} = 150^\circ\text{C}$ ,  $T_C = 150^\circ\text{C}$  const.,

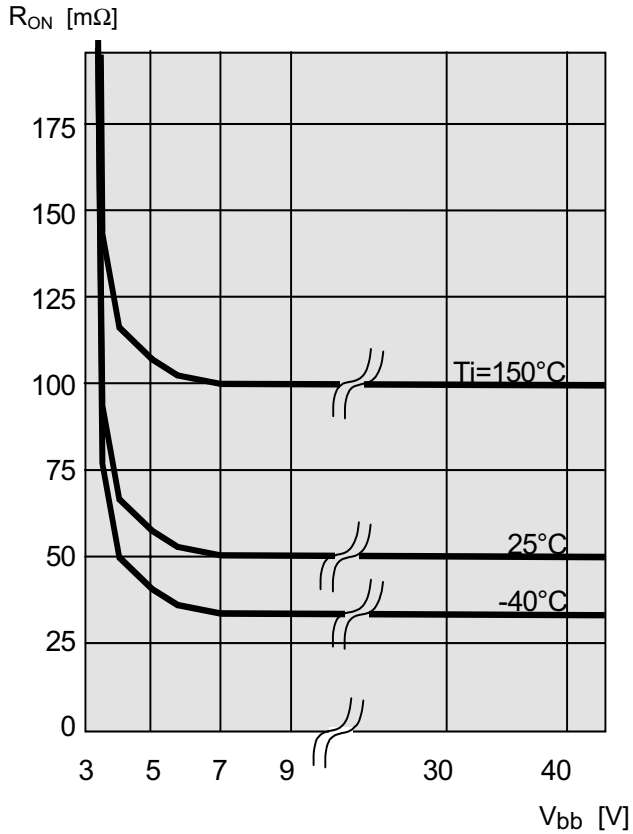
$V_{bb} = 12\text{V}$ ,  $R_L = 0 \Omega$

$Z_L$  [mH]



**Typ. on-state resistance**

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



**Typ. standby current**

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

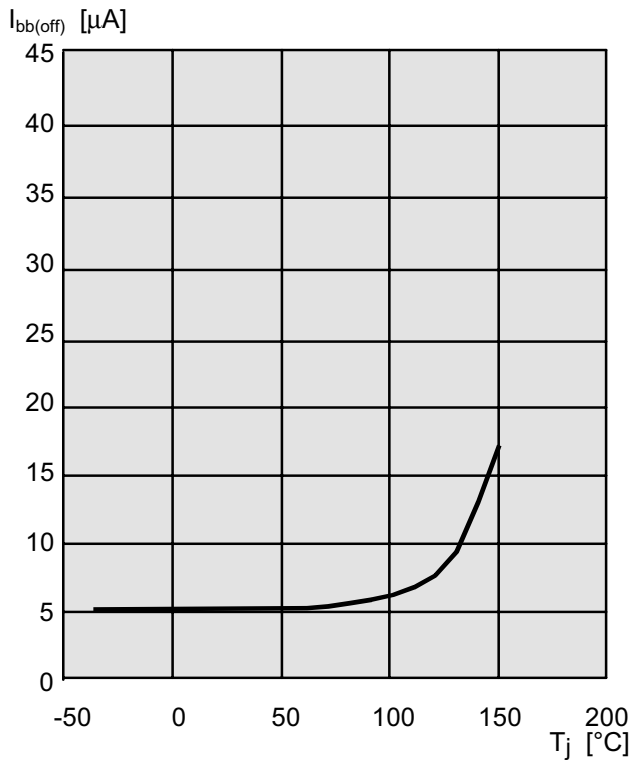
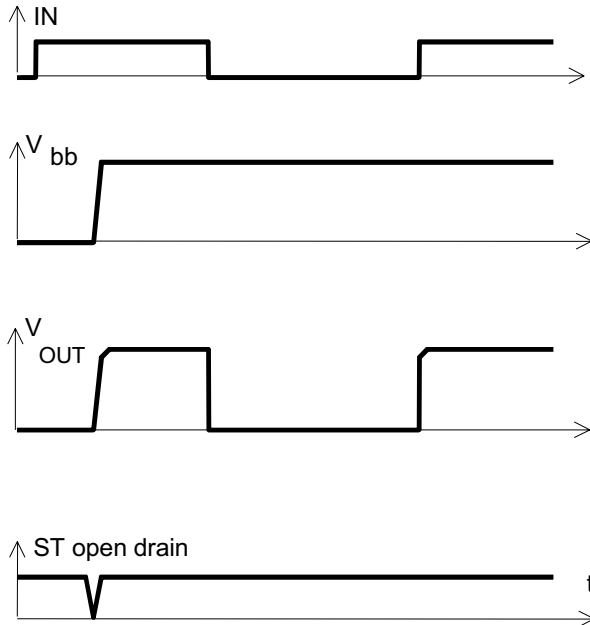
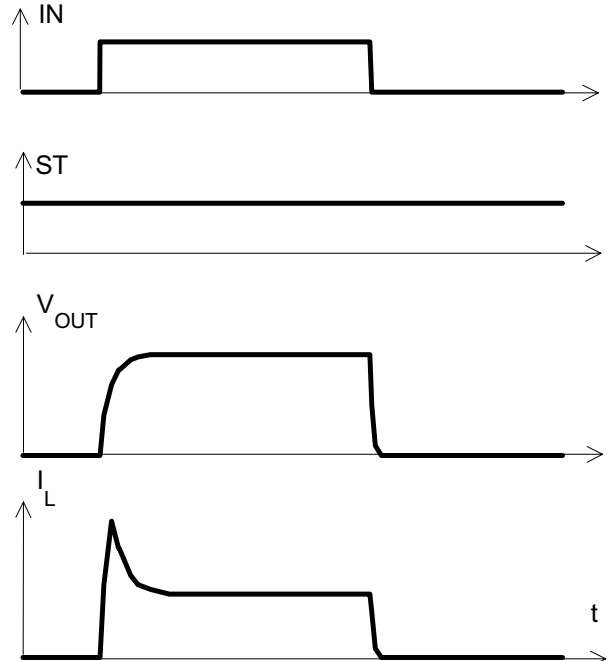


Figure 1a:  $V_{bb}$  turn on:



proper turn on under all conditions

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:

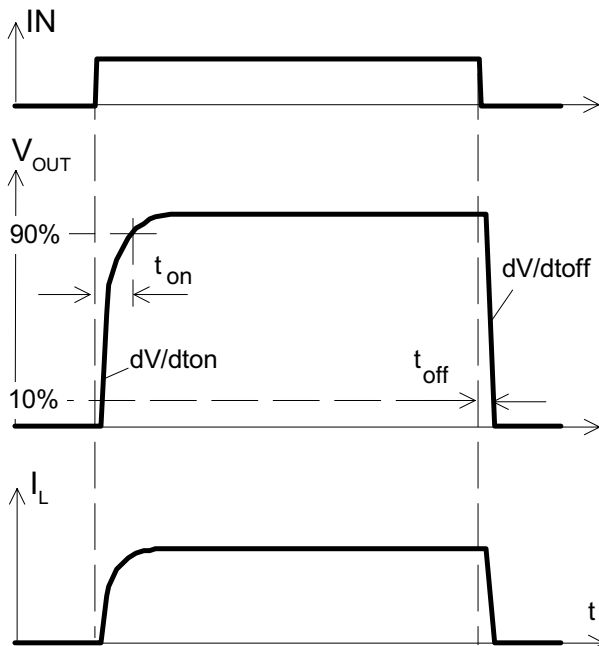
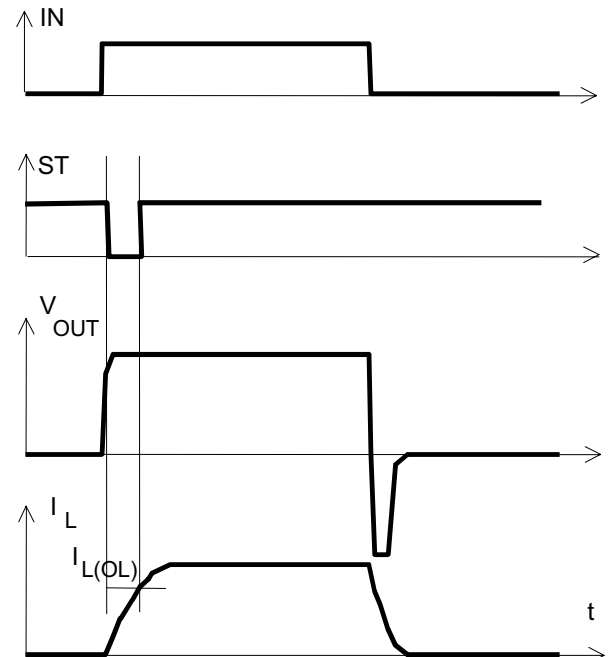
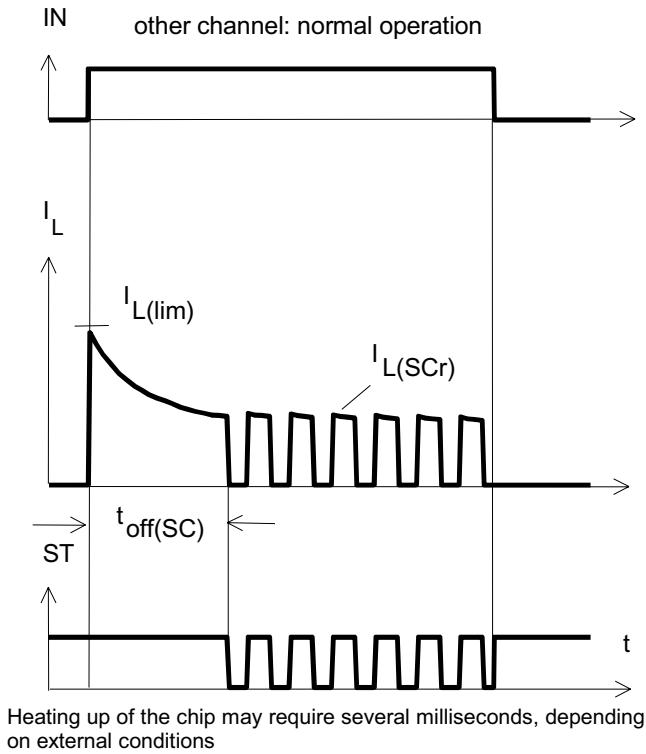


Figure 2c: Switching an inductive load

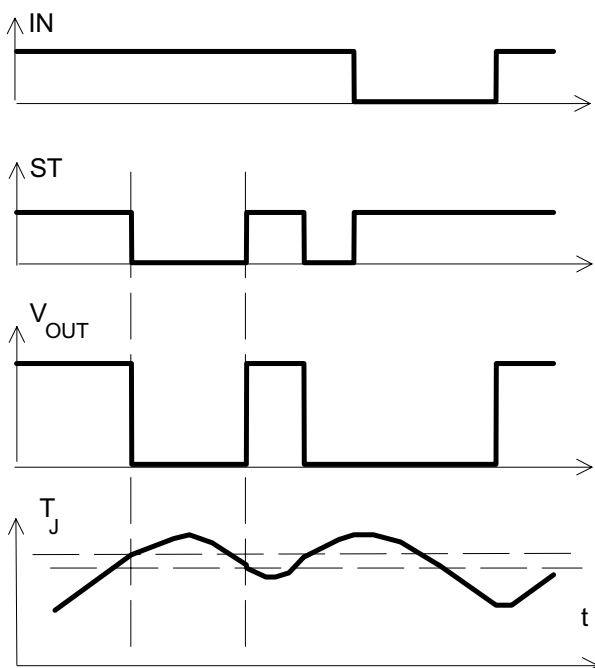


\*) if the time constant of load is too large, open-load-status may occur

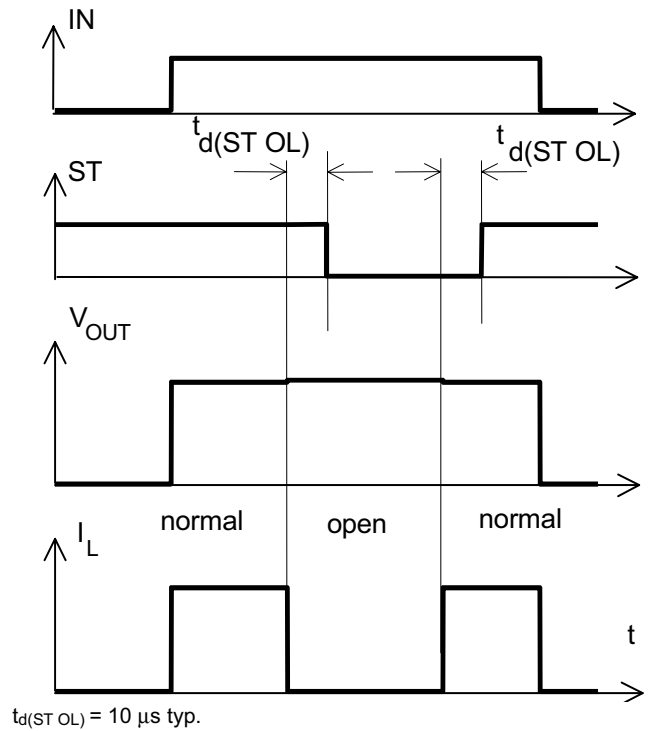
**Figure 3a:** Short circuit  
shut down by overtemperature, reset by cooling



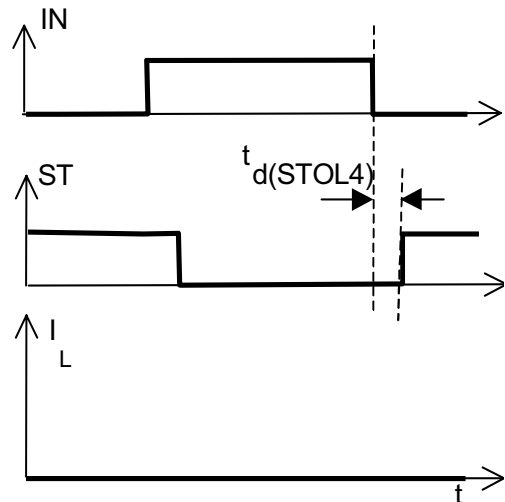
**Figure 4a:** Overtemperature:  
Reset if  $T_j < T_{jt}$



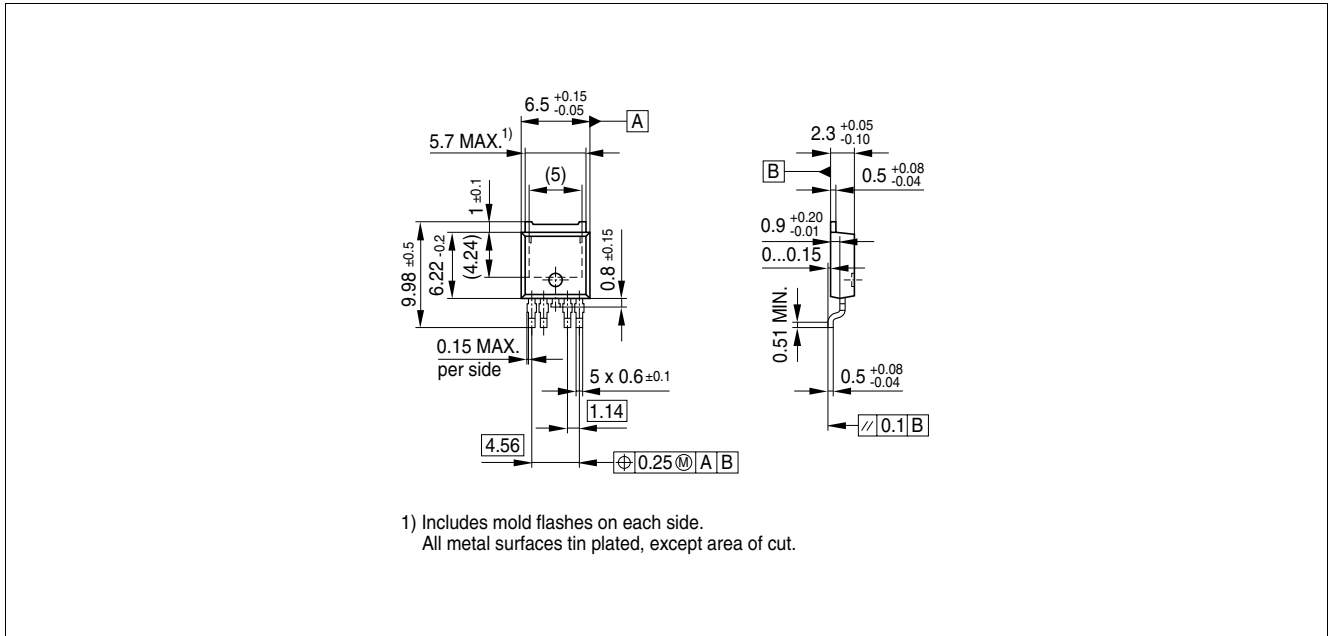
**Figure 5a:** Open load: detection in ON-state, open load occurs in on-state



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



## Package Outlines



**Figure 1** PG-TO-252 (Plastic Dual Small Outline Package) (RoHS-compliant)

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).

Please specify the package needed (e.g. green package) when placing an order

## Revision History

Version	Date	Changes
V1.1	2007-05-29	Creation of the green datasheet. First page : Adding the green logo and the AEC qualified Adding the bullet AEC qualified and the RoHS compliant features Package page Modification of the package to be green.

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