

# Smart High-Side 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
- 
- Green Product (RoHS compliant)
  - AEC Qualified

## Product Summary

Overvoltage protection	$V_{bb(AZ)}$	65	V
Operating voltage	$V_{bb(on)}$	5.8 ... 58	V
On-state resistance	$R_{ON}$	250	m $\Omega$
Load current (ISO)	$I_{L(ISO)}$	1.7	A

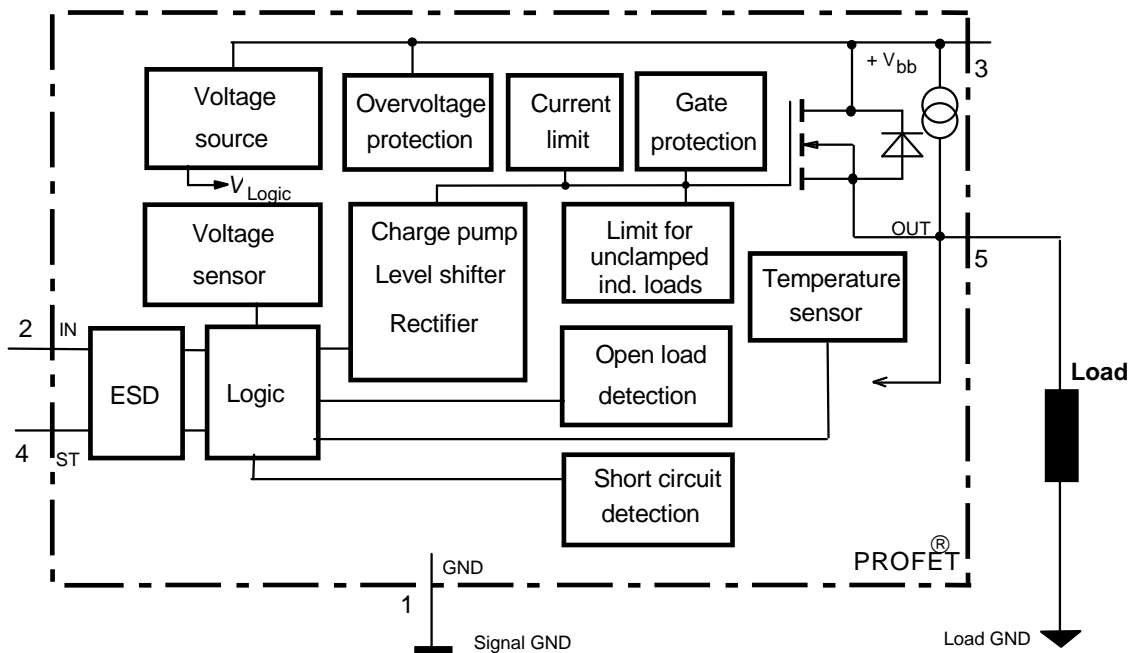


## Application

- $\mu$ 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<sup>®</sup> technology. Providing embedded protective functions.



<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.

Pin	Symbol		Function
1	GND	-	Logic ground
2	IN	I	Input, activates the power switch in case of logical high signal
3	V <sub>bb</sub>	+	Positive power supply voltage, the tab is shorted to this pin
4	ST	S	Diagnostic feedback
5	OUT (Load, L)	O	Output to the load

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

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 3)	$V_{bb}$	65	V
Supply voltage for short circuit protection <sup>2)</sup> $T_{j\text{ start}} = -40 \dots +150\text{ °C}$	$V_{bb}$	40	V
Load current (Short circuit current, see page 4)	$I_L$	self-limited	A
Operating temperature range	$T_j$	-40 ... +150	°C
Storage temperature range	$T_{stg}$	-55 ... +150	
Power dissipation (DC), $T_C \leq 25\text{ °C}$	$P_{tot}$	50	W
Electrostatic discharge capability (ESD) (Human Body Model)	IN, ST: $V_{ESD}$ all other pins:	1.0 tbd (>1.0)	kV
Input voltage (DC)	$V_{IN}$	-0.5 ... +36	V
Current through input pin (DC)	$I_{IN}$	$\pm 2.0$	mA
Current through status pin (DC)	$I_{ST}$	$\pm 5.0$	

see internal circuit diagrams page 5

**Thermal Characteristics**

Parameter and Conditions	Symbol	Values			Unit
		min	typ	max	
Thermal resistance	chip - case: $R_{thJC}$	--	--	2.5	K/W
	junction - ambient (free air): $R_{thJA}$	--	--	75	

<sup>2)</sup> Status fault signal in case of short to GND. Internal thermal shutdown after several milliseconds. External shutdown in response to the status fault signal in less than about 1 ms necessary, if the device is used with higher  $V_{bb}$ .

**Electrical Characteristics**

Parameter and Conditions at $T_j = 25\text{ °C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

**Load Switching Capabilities and Characteristics**

On-state resistance (pin 3 to 5) $I_L = 2\text{ A}$ , $V_{bb} = 24\text{ V}$	$T_j = 25\text{ °C}$ : $T_j = 150\text{ °C}$ : $R_{ON}$	--	220 390	250 500	$m\Omega$
Nominal load current, ISO Norm (pin 3 to 5) $V_{ON} = 0.5\text{ V}$ , $T_C = 85\text{ °C}$	$I_{L(ISO)}$	1.4	1.7	--	A
Output current (pin 5) while GND disconnected or GND pulled up, $V_{bb} = 32\text{ V}$ , $V_{IN} = 0$ , see diagram page 6	$I_{L(GNDhigh)}$	--	--	1.1	mA
Turn-on time to 90% $V_{OUT}$ : Turn-off time to 10% $V_{OUT}$ : $R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150\text{ °C}$	$t_{on}$ $t_{off}$	15 20	-- --	80 70	$\mu\text{s}$
Slew rate on, 10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150\text{ °C}$	$dV/dt_{on}$	--	--	6	$\text{V}/\mu\text{s}$
Slew rate off, 10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150\text{ °C}$	$-dV/dt_{off}$	--	--	7	$\text{V}/\mu\text{s}$

**Operating Parameters**

Operating voltage <sup>3)</sup>	$T_j = -40\dots+150\text{ °C}$ : $V_{bb(on)}$	5.8	--	58	V
Undervoltage shutdown	$T_j = -40\dots+150\text{ °C}$ : $V_{bb(under)}$	2.7	--	4.7	V
Undervoltage restart	$T_j = -40\dots+150\text{ °C}$ : $V_{bb(u\ rst)}$	--	--	4.9	V
Undervoltage restart of charge pump see diagram page 10	$T_j = -40\dots+150\text{ °C}$ : $V_{bb(ucp)}$	--	5.6	7.5	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$	$\Delta V_{bb(under)}$	--	0.4	--	V
Oversvoltage protection <sup>4)</sup> $I_{bb} = 40\text{ mA}$	$T_j = -40\dots+150\text{ °C}$ : $V_{bb(AZ)}$	65	70	--	V
Standby current (pin 3), $V_{IN} = 0$	$T_j = -40\dots+150\text{ °C}$ : $I_{bb(off)}$	--	10	50	$\mu\text{A}$
Operating current (Pin 1) <sup>5)</sup> , $V_{IN} = 5\text{ V}$	$I_{GND}$	--	2.2	--	mA

<sup>3)</sup> At supply voltage increase up to  $V_{bb} = 5.6\text{ V}$  typ without charge pump,  $V_{OUT} \approx V_{bb} - 2\text{ V}$

<sup>4)</sup> See also  $V_{ON(CL)}$  in table of protection functions and circuit diagram page 6.



<sup>5)</sup> Add  $I_{ST}$ , if  $I_{ST} > 0$ , add  $I_{IN}$ , if  $V_{IN} > 5.5\text{ V}$

Parameter and Conditions at $T_j = 25\text{ °C}$ , $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
<b>Protection Functions<sup>6)</sup></b>					
Initial peak short circuit current limit (pin 3 to 5)	$I_{L(SCp)}$				
$T_j = -40\text{ °C}$ :		--	--	19	A
$T_j = 25\text{ °C}$ :		--	10	--	
$T_j = +150\text{ °C}$ :		4.0	--	--	
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$ $I_L = 1\text{ A}$ , $T_j = -40..+150\text{ °C}$ :	$V_{ON(CL)}$	59	--	75	V
Thermal overload trip temperature	$T_{jt}$	150	--	--	°C
Thermal hysteresis	$\Delta T_{jt}$	--	10	--	K
Reverse battery (pin 3 to 1) <sup>7)</sup>	$-V_{bb}$	--	--	32	V

**Diagnostic Characteristics**

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

**Input and Status Feedback<sup>8)</sup>**

Input resistance see circuit page 5	$R_i$	--	20	--	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 (pin 2), $V_{IN} = 0.4\text{ V}$	$I_{IN(off)}$	1	--	30	$\mu\text{A}$
On state input current (pin 2), $V_{IN} = 3.5\text{ V}$	$I_{IN(on)}$	10	25	70	$\mu\text{A}$
Delay time for status with open load after Input neg. slope (see diagram page 10)	$t_{d(ST\ OL3)}$	--	200	--	$\mu\text{s}$
Status output (open drain)					
Zener limit voltage $T_j = -40..+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage $T_j = -40..+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(low)}$	--	--	0.4	

<sup>6)</sup> 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.

<sup>7)</sup> Requires 150  $\Omega$  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 2 and circuit page 6).

<sup>8)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor.

**Truth Table**

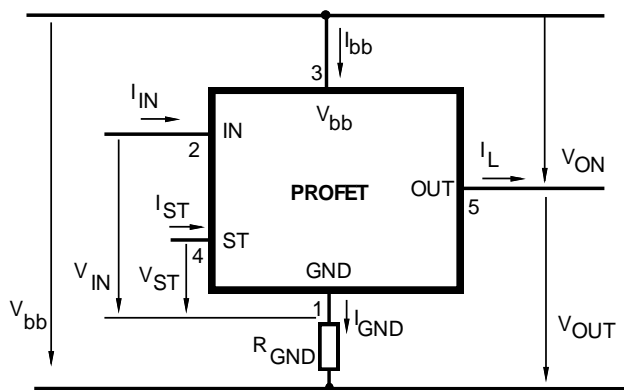
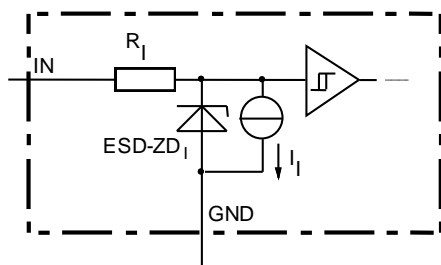
	Input- level	Output level	Status BTS307
<b>Normal operation</b>	L H	L H	L H
<b>Open load</b>	L H	<sup>9)</sup> H H	H H
<b>Short circuit to GND</b>	L H	L L	L L
<b>Short circuit to V<sub>bb</sub></b>	L H	H H	H H
<b>Overtem- perature</b>	L H	L L	L L
<b>Under- voltage</b>	L H	L L	L L
<b>Overvoltage</b>	<b>no overvoltage shutdown, see normal operation</b>		

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

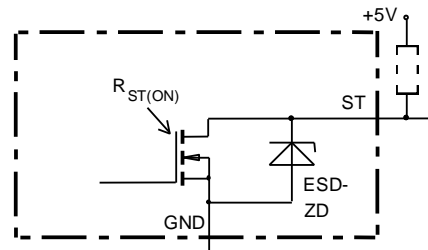
X = don't care

Z = high impedance, potential depends on external circuit

Status signal after the time delay shown in the diagrams (see fig 5. page 10)

**Terms**

**Input circuit (ESD protection)**


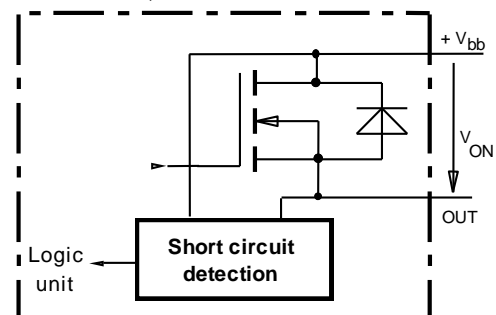
ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

**Status output**


ESD-Zener diode: 6.1 V typ., max 5 mA;  
R<sub>ST(ON)</sub> < 0 Ω 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).

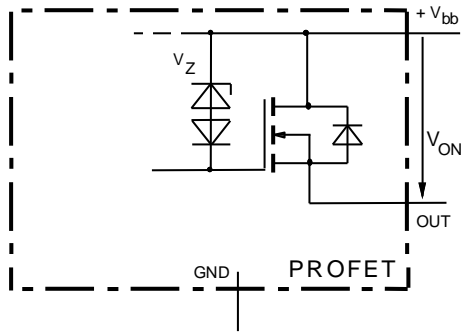
**Short circuit detection**

Fault Signal at ST-Pin: V<sub>ON</sub> > 2.5 V typ, no switch off by the PROFET itself, external switch off recommended!



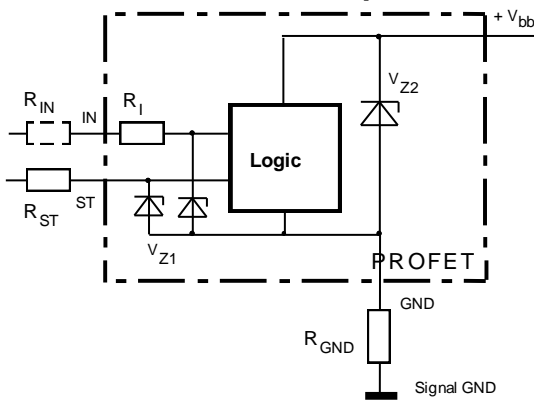
<sup>9)</sup> Power Transistor off, high impedance, internal pull up current source for open load detection.

**Inductive and overvoltage output clamp**



$V_{ON}$  clamped to  $-V$  typ.

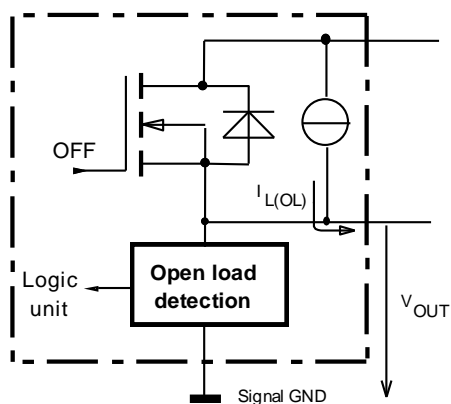
**Overvolt. and reverse batt. protection**



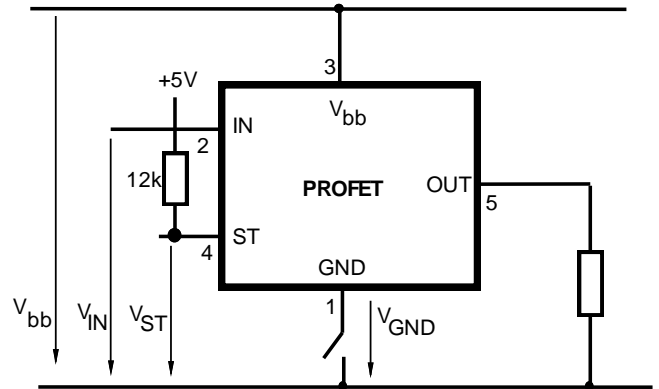
$V_{Z1} = 6.2 \text{ V typ.}$ ,  $V_{Z2} = 70 \text{ V typ.}$ ,  $R_{GND} = 150 \Omega$ ,  $R_{ST} = 15 \text{ k}\Omega$ ,  $R_I = 20 \text{ k}\Omega \text{ typ.}$

**Open-load detection**

OFF-state diagnostic condition:  $V_{OUT} > 3 \text{ V typ.}$ ; IN low

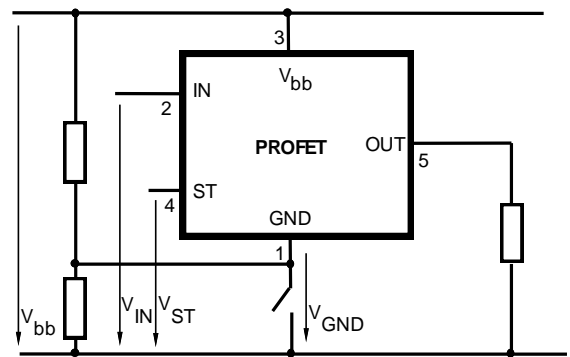


**GND disconnect**



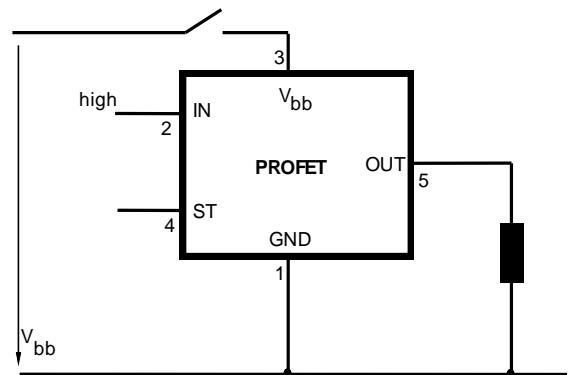
For  $V_{bb}=24\text{V}$  and  $V_{IN}=0\text{V}$ :  $V_{ST}>2.8\text{V}$  @  $I_{ST} \geq 0$  if pulled up as shown. Any kind of load. In case of Input=high is  $V_{OUT} \approx V_{IN} - V_{IN(T+)}$ .

**GND disconnect with GND pull up**

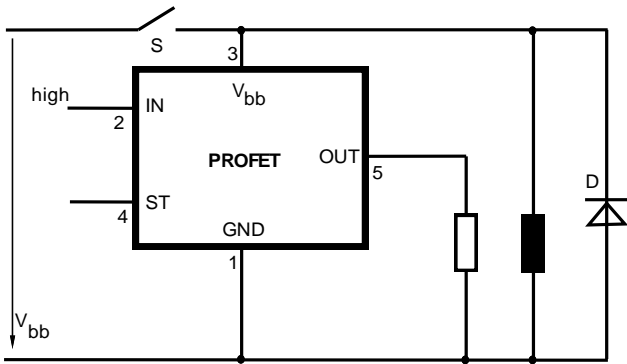


Any kind of load. If  $V_{GND} > V_{IN} - V_{IN(T+)}$  device stays off. Due to  $V_{GND} > 0$ , no  $V_{ST} = \text{low}$  signal available.

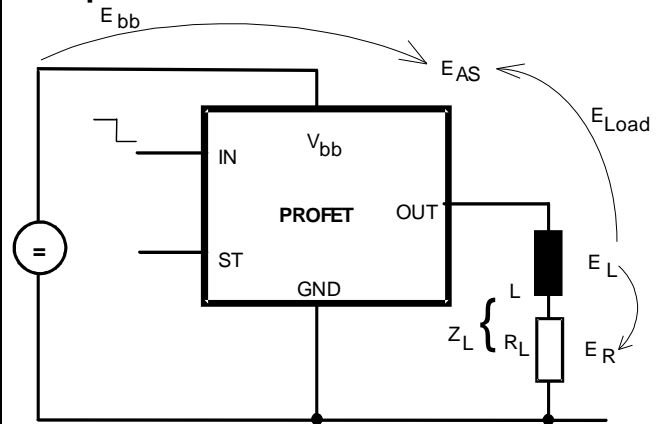
**Vbb disconnect with energized inductive load**



Normal load current can be handled by the PROFET itself.

**V<sub>bb</sub> disconnect with charged external inductive load**


If other external inductive loads L are connected to the PROFET, additional elements like D are necessary.

**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  $R_L > 0 \Omega$ :

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

## Options Overview

**all versions: High-side switch, Input protection, ESD protection and reverse battery protection with 150 Ω in GND connection, protection against loss of ground**

Type	BTS	410D2	410E2	410G2	410H2	307	308
Logic version	D	E	G	H			
Overtemperature protection with hysteresis							
$T_j > 150\text{ °C}$ , latch function <sup>10),11)</sup>	X				X		X
$T_j > 150\text{ °C}$ , with auto-restart on cooling		X	X			X	
Short circuit to GND protection							
switches off when $V_{ON} > 3.5\text{ V}$ typ. and $V_{bb} > 8\text{ V}$ typ. <sup>10)</sup> (when first turned on after approx. 150 μs)					X		X
switches off when $V_{ON} > 8.5\text{ V}$ typ. <sup>10)</sup> (when first turned on after approx. 150 μs)	X	X					
Achieved through overtemperature protection				X		X	
Open load detection							
in OFF-state with sensing current 6 μA typ. in ON-state with sensing voltage drop across power transistor	X	X	X		X	X	X
Undervoltage shutdown with auto restart	X	X	X	X	X	X	X
Overvoltage shutdown with auto restart	X	X	X	X	X	-	X
Status feedback for							
overtemperature	X	X	X	X	X	X	X
short circuit to GND	X	X	-	X	X	X	X
short to $V_{bb}$	- <sup>12)</sup>	- <sup>12)</sup>	- <sup>12)</sup>	X	X	X	X
open load	X	X	X	X	X	X	X
undervoltage	X	-	-	-	-	X	-
overvoltage	X	-	-	-	-	-	-
Status output type							
CMOS	X						
Open drain		X	X	X	X	X	X
Output negative voltage transient limit (fast inductive load switch off)							
to $V_{bb} - V_{ON(CL)}$	X	X	X	X	X	X	X
Load current limit							
high level (can handle loads with high inrush currents)	X	X					
low level (better protection of application)				X	X	X	X
Protection against loss of GND	X	X	X	X	X	X	X

<sup>10)</sup> Latch except when  $V_{bb} - V_{OUT} < V_{ON(SC)}$  after shutdown. In most cases  $V_{OUT} = 0\text{ V}$  after shutdown ( $V_{OUT} \neq 0\text{ V}$  only if forced externally). So the device remains latched unless  $V_{bb} < V_{ON(SC)}$  (see page 4). No latch between turn on and  $t_{d(SC)}$ .

<sup>11)</sup> With latch function. Reseted by a) Input low, b) Undervoltage, c) Overvoltage

<sup>12)</sup> Low resistance short  $V_{bb}$  to output may be detected in ON-state by the no-load-detection



## Timing diagrams

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

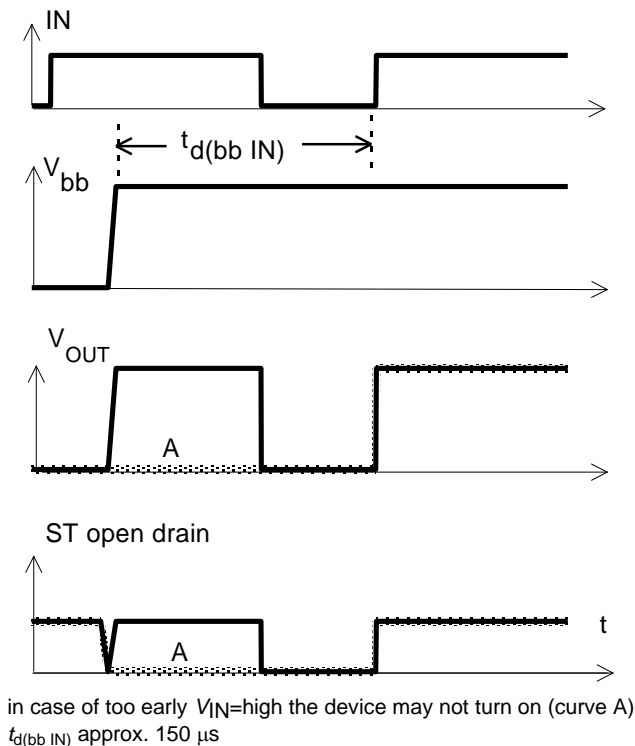


Figure 2a: Switching an inductive load,

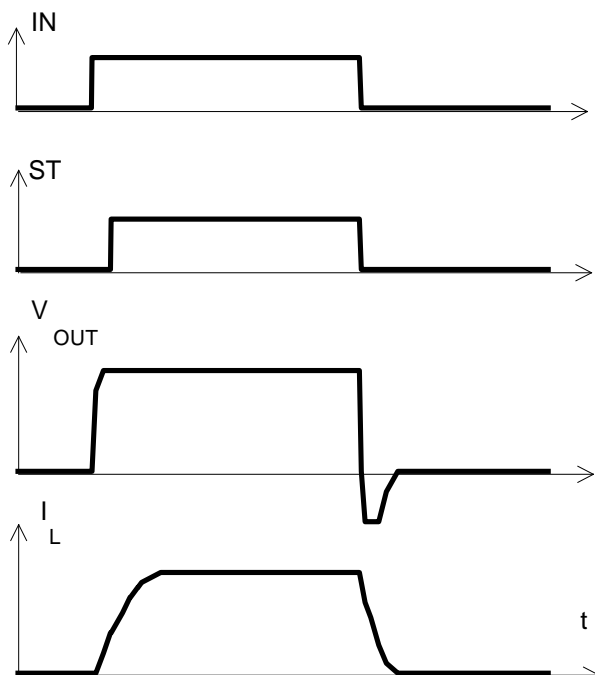
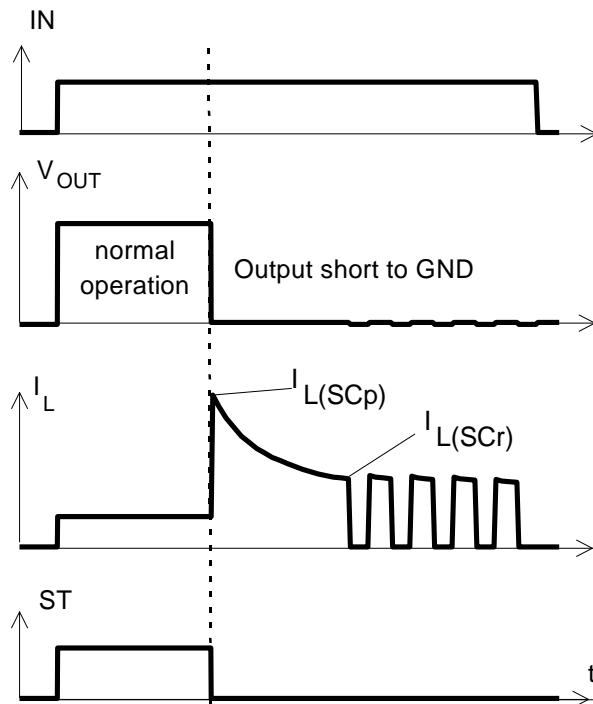
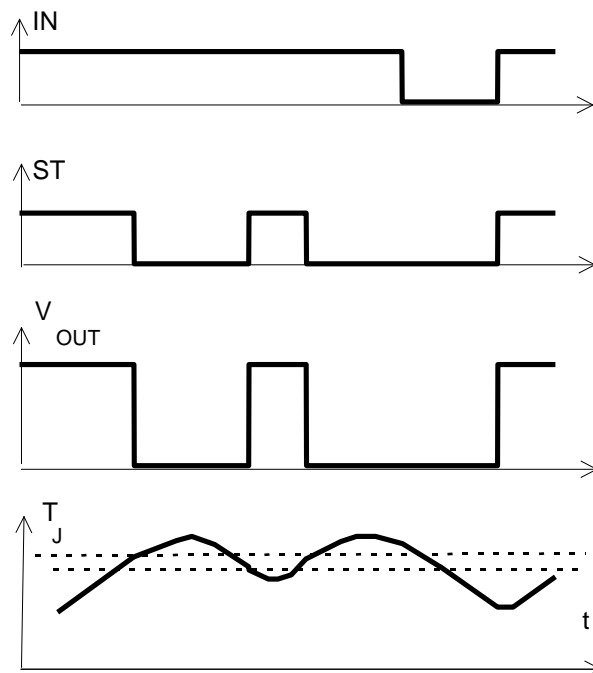


Figure 3a: Short circuit:  
 shut down by overtemperature, reset by cooling

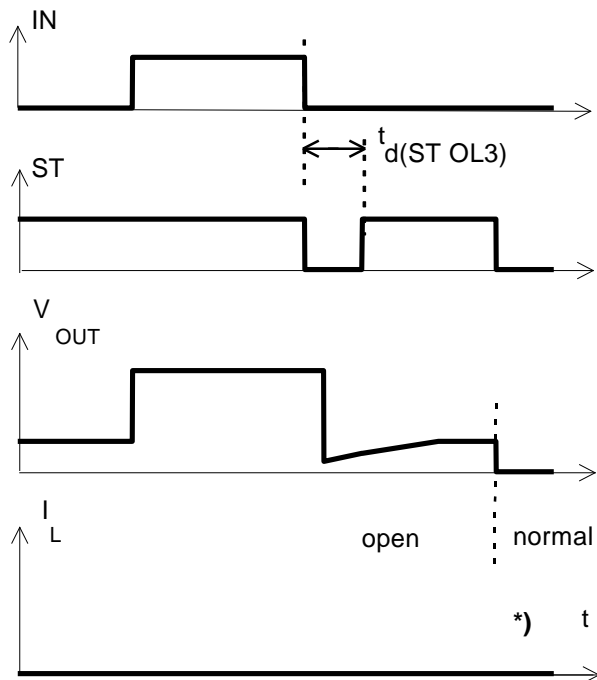


Heating up requires several milliseconds, depending on external conditions. External shutdown in response to status fault signal recommended.

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

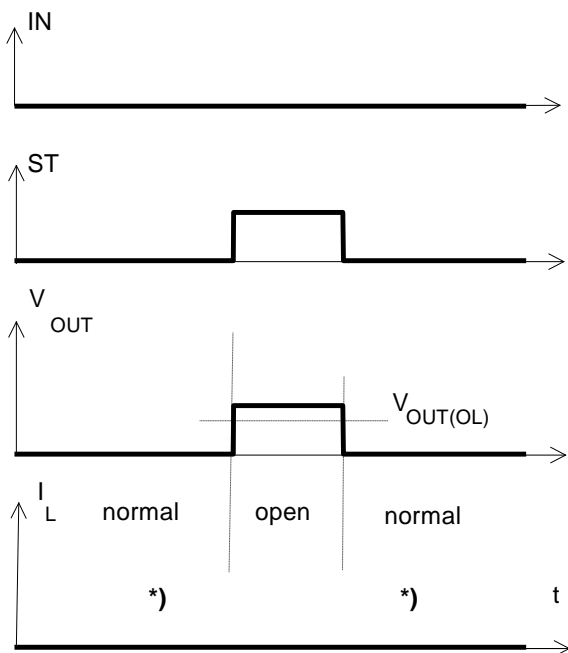


**Figure 5a:** Open load, : detection in OFF-state, turn on/off to open load



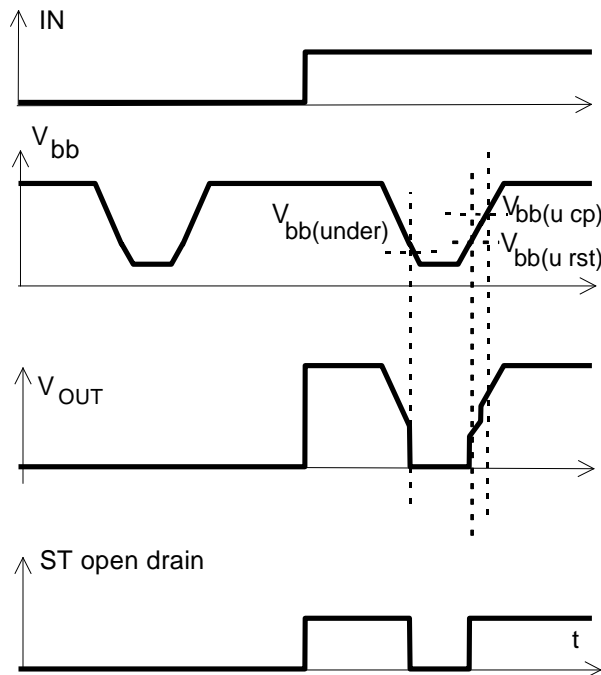
$t_{d(\text{ST,OL3})}$  depends on external circuitry because of high impedance  
 \*)  $I_L = 6 \mu\text{A typ}$

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



\*)  $I_L = 6 \mu\text{A typ}$

**Figure 6a:** Undervoltage:



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

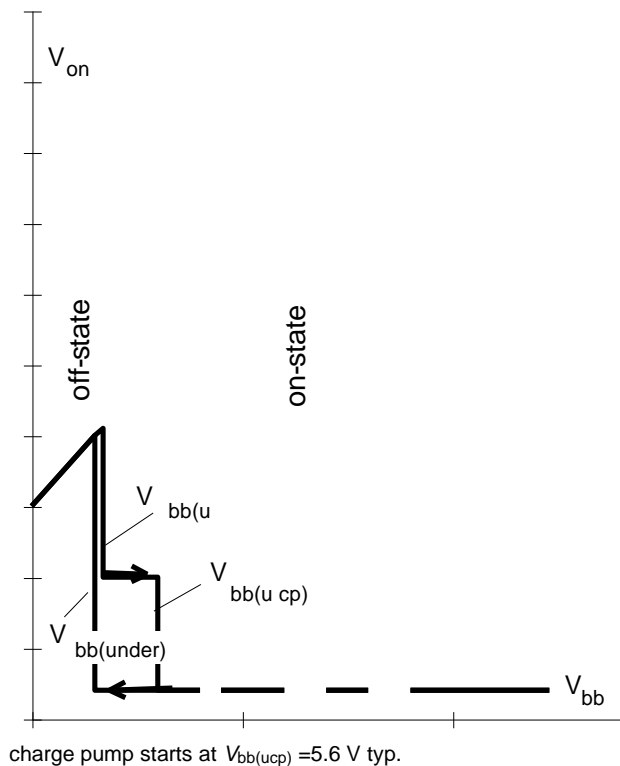
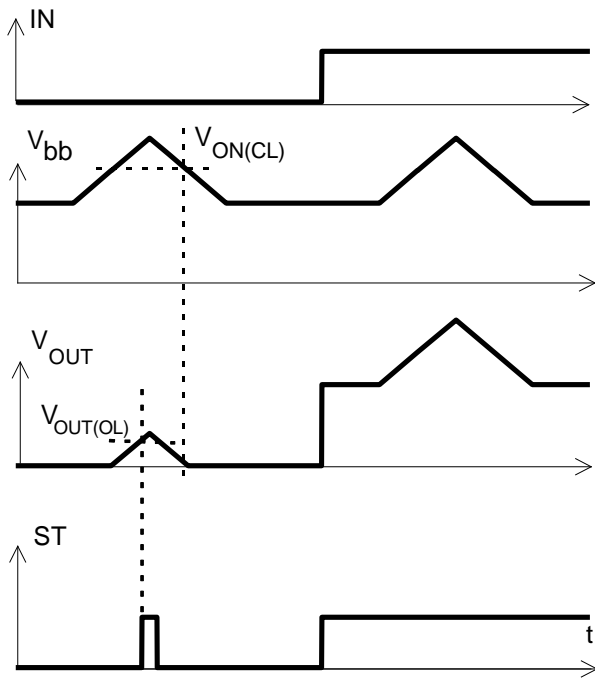


Figure 7a: Overvoltage, no shutdown:



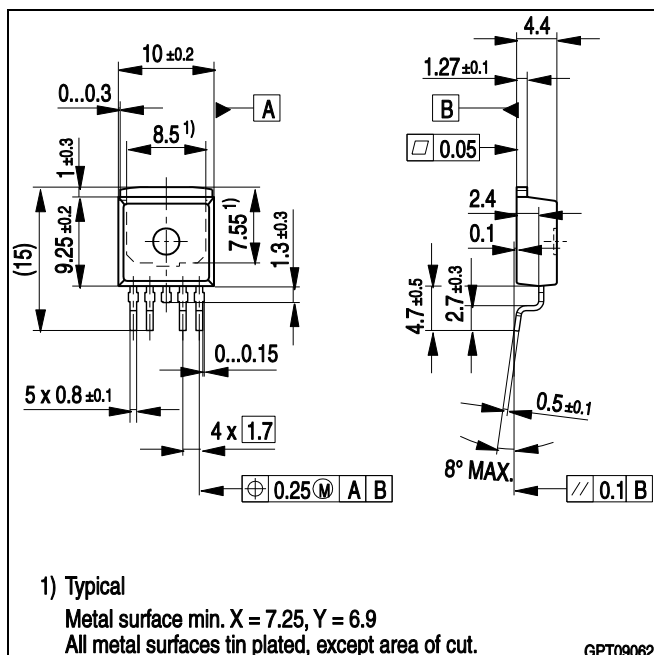
## Package and Ordering Code

All dimensions in mm

### PG-TO263-5-2

Ordering code

BTS307 E3062A	SP001104812
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