

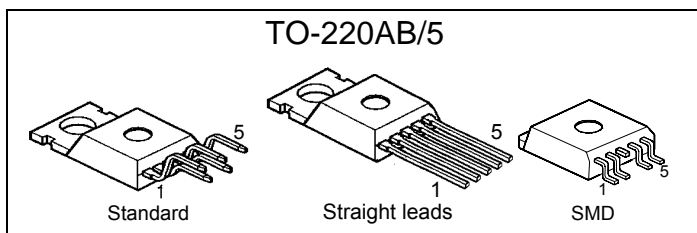
# Smart Highside Power Switch

## Features

- Overload protection
- Current limitation
- Short circuit protection
- Thermal shutdown
- Overvoltage protection (including load dump)
- Fast demagnetization of inductive loads
- Reverse battery protection<sup>1)</sup>
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis
- 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	$V_{bb(AZ)}$	60	V
Operating voltage	$V_{bb(on)}$	4.7 ... 34	V
On-state resistance	$R_{ON}$	300	mΩ
Load current (ISO)	$I_{L(ISO)}$	1.3	A

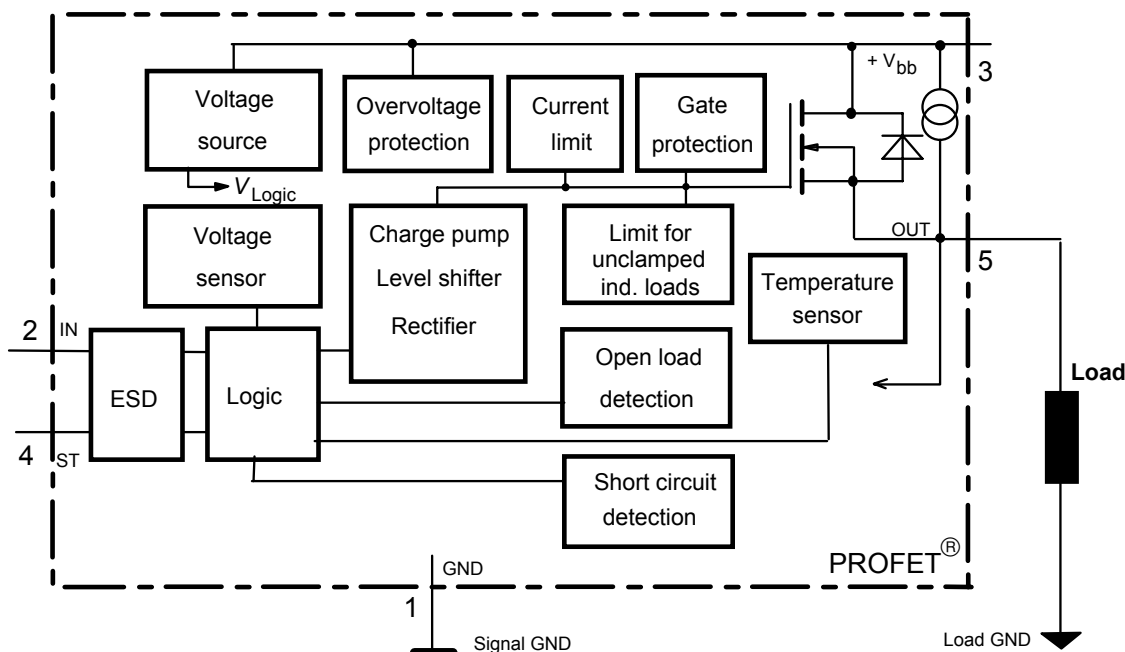


## Application

- $\mu$ 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
- Fast switching
- Not suitable for lamp loads

## 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.



<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, low on failure
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)	$V_{bb}$	60	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 tbd (>1)	kV	
Input voltage (DC)	$V_{IN}$	-10 ... +16	V	
Current through input pin (DC)	$I_{IN}$	±5.0	mA	
Current through status pin (DC)	$I_{ST}$	±5.0		
see internal circuit diagrams page 6				
Thermal resistance	chip - case: junction - ambient (free air):	$R_{thJC}$ $R_{thJA}$	≤ 2.5 ≤ 75	K/W

## Electrical Characteristics

Parameter and Conditions at $T_j = 25^\circ\text{C}$ , $V_{bb} = 24\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

### Load Switching Capabilities and Characteristics

On-state resistance (pin 3 to 5) $I_L = 0.8\text{ A}$ , $V_{bb} = 12\text{ V}$ $T_j = 25^\circ\text{C}$ :  $T_j = 150^\circ\text{C}$ :	$R_{ON}$	--	270 540	300 600	$\text{m}\Omega$
Nominal load current, ISO Norm (pin 3 to 5) $V_{ON} = 0.5\text{ V}$ , $T_C = 85^\circ\text{C}$	$I_{L(ISO)}$	1.18	1.3	--	A
Output current (pin 5) while GND disconnected or GND pulled up, $V_{bb} = 30\text{ V}$ , $V_{IN} = 0$ , see diagram page 7	$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time to 90% $V_{OUT}$ : Turn-off time to 10% $V_{OUT}$ : $R_L = 47\ \Omega$ , $V_{bb} = 12\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$	$t_{on}$ $t_{off}$	-- --	-- --	50 55	$\mu\text{s}$
Slew rate on, 10 to 30% $V_{OUT}$ , $R_L = 47\ \Omega$ , $V_{bb} = 12\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$	$dV/dt_{on}$	1	--	10	$\text{V}/\mu\text{s}$
Slew rate off, 10 to 30% $V_{OUT}$ , $R_L = 47\ \Omega$ , $V_{bb} = 12\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$	$-dV/dt_{off}$	2	--	15	$\text{V}/\mu\text{s}$

### Operating Parameters

Operating voltage <sup>2)</sup> $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(on)}$	4.7	--	34	V
Operating voltage slew rate	$dV_{bb}/dt$	-1		+1	$\text{V}/\mu\text{s}$
Undervoltage shutdown $T_j = 25^\circ\text{C}$ : $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(under)}$	2.9 2.7	-- --	4.5 4.7	V
Undervoltage restart $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(u\ rst)}$	--	--	4.9	V
Undervoltage restart of charge pump see diagram page 11 $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(ucp)}$	--	4.9	7.5	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$	$\Delta V_{bb(under)}$	--	0.2	--	V
Overvoltage shutdown $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(over)}$	34	--	46	V
Overvoltage restart $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(o\ rst)}$	34	--	--	V
Overvoltage hysteresis $T_j = -40\dots+150^\circ\text{C}$ :	$\Delta V_{bb(over)}$	--	0.5	--	V
Overvoltage protection <sup>3)</sup> $I_{bb} = 10\text{ mA}$ $T_j = -40\dots+150^\circ\text{C}$ :	$V_{bb(AZ)}$	59	70	--	V
Standby current (pin 3), $V_{IN} = 0$ $T_j = -40\dots+150^\circ\text{C}$ :	$I_{bb(off)}$	--	40	50	$\mu\text{A}$
Operating current (Pin 1) <sup>4)</sup> , $V_{IN} = 5\text{ V}$	$I_{GND}$	--	2	4	mA

<sup>2)</sup> At supply voltage increase up to  $V_{bb} = 4.9\text{ V}$  typ without charge pump,  $V_{OUT} \approx V_{bb} - 2\text{ V}$

<sup>3)</sup> Measured without load. See also  $V_{ON(CL)}$  in table of protection functions and circuit diagram page 7.

<sup>4)</sup> Add  $I_{ST}$ , if  $I_{ST} > 0$ , add  $I_{IN}$ , if  $V_{IN} > 5.5\text{ V}$

Parameter and Conditions at $T_j = 25\text{ °C}$ , $V_{bb} = 24\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

**Protection Functions<sup>5)</sup>**

Initial peak short circuit current limit (pin 3 to 5) <sup>6)</sup> , (max 100 $\mu\text{s}$ if $V_{ON} > V_{ON(SC)}$ ) $V_{bb} = 12\text{V}$	$I_{L(SCp)}$				
$T_j = -40\text{ °C}$ :		--	--	10	A
$T_j = 25\text{ °C}$ :		--	5	--	
$T_j = +150\text{ °C}$ :		2.5	--	--	
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$ , min value valid only, if input "low" time exceeds 60 $\mu\text{s}$	$t_{d(SC)}$	15	--	100	$\mu\text{s}$
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	67	75	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	3.5	--	V
Thermal overload trip temperature	$T_{jt}$	150	--	--	$\text{°C}$
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 $I_{bb(off)}$ )	$T_j = -40..+150\text{ °C}$ : $I_{L(off)}$	0	--	30	$\mu\text{A}$
Open load detection voltage	$T_j = -40..150\text{ °C}$ : $V_{OUT(OL)}$	2	3	4	V

<sup>5)</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>6)</sup> Short circuit current limit for max. duration of  $t_{d(SC)}$  max=100  $\mu\text{s}$ , prior to shutdown

<sup>7)</sup> Requires 150  $\Omega$  resistor in GND connection. Reverse load current (through intrinsic drain-source diode) is normally limited by the connected load. Input and Status currents have to be limited (see max. ratings page 2 and circuit page 7).

Parameter and Conditions at $T_j = 25\text{ }^\circ\text{C}$ , $V_{bb} = 24\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
<b>Input and Status Feedback<sup>8)</sup></b>					
Input resistance see circuit page 6	$R_I$	--	4	--	k $\Omega$
Input turn-on threshold voltage  $T_j = -40..+150^\circ\text{C}$	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage  $T_j = -40..+150^\circ\text{C}$	$V_{IN(T-)}$	0.8	--	--	V
Input threshold hysteresis, $T_j = -40..+150^\circ\text{C}$	$\Delta V_{IN(T)}$	0.2	--	--	V
Off state input current (pin 2), $V_{IN} = 0.4\text{ V}$ , $T_j = -40..+150^\circ\text{C}$	$I_{IN(off)}$	8	--	30	$\mu\text{A}$
On state input current (pin 2), $V_{IN} = 3.5\text{ V}$ , $T_j = -40..+150^\circ\text{C}$	$I_{IN(on)}$	10	22	50	$\mu\text{A}$
Delay time for status with open load after Input neg. slope (see diagram page 11)	$t_{d(ST\ OL3)}$	50	--	400	$\mu\text{s}$
Status invalid after positive input slope (short circuit) $T_j = -40 \dots +150^\circ\text{C}$ :	$t_{d(ST\ SC)}$	15	50	100	$\mu\text{s}$
Status output (open drain)					
Zener limit voltage $T_j = -40..+150^\circ\text{C}$ , $I_{ST} = +50\text{ }\mu\text{A}$ :	$V_{ST(high)}$	5.4	6	--	V
ST low voltage $T_j = -40..+150^\circ\text{C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(low)}$	--	--	0.4	

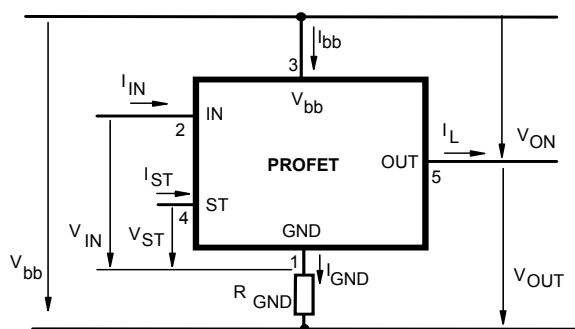
<sup>8)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor.

**Truth Table**

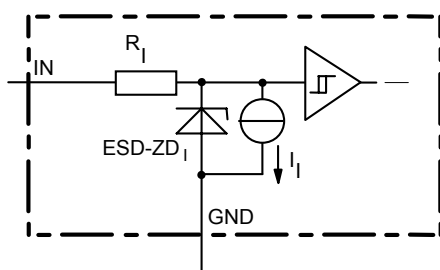
	Input-level	Output level	Status
			BTS 308
Normal operation	L	L	H
	H	H	H
Open load	L	<sup>9)</sup>	L
	H	H	H
Short circuit to GND	L	L	H
	H	L	L
Short circuit to V <sub>bb</sub>	L	H	L
	H	H	H
Overtemperature	L	L	L
	H	L	L
Under-voltage	L	L	H
	H	L	H
Overvoltage	L	L	H
	H	L	H

L = "Low" Level      X = don't care      Z = high impedance, potential depends on external circuit  
H = "High" Level      Status signal after the time delay shown in the diagrams (see fig 5. page 11)

**Terms**

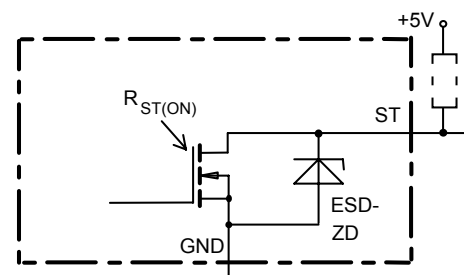


**Input circuit (ESD protection)**



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).

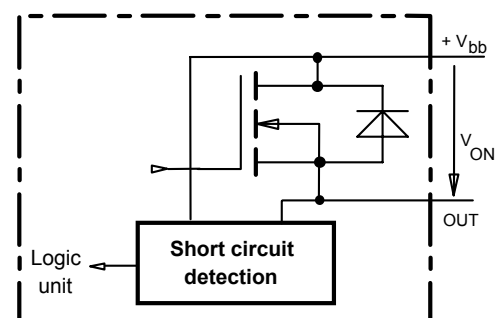
**Status output**



ESD-Zener diode: 6 V typ., max 5 mA;  
 $R_{ST(ON)} < 250 \Omega$  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).

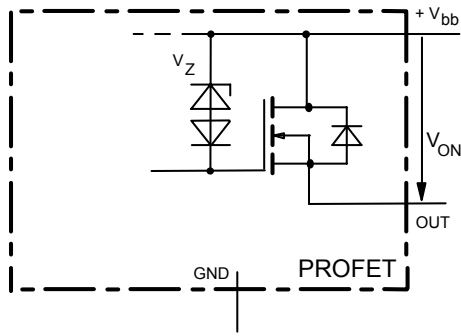
**Short circuit detection**

Fault Condition:  $V_{ON} > 3.5 \text{ V typ.};$  IN high



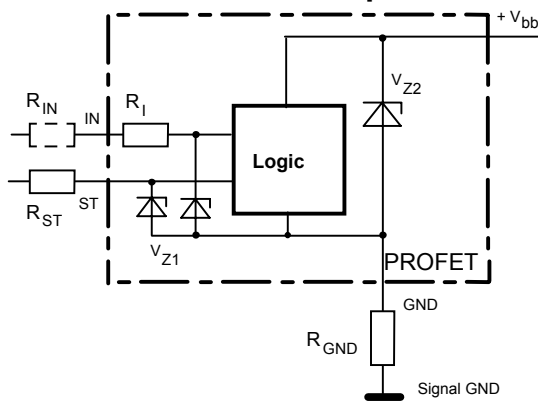
<sup>9)</sup> Power Transistor off, high impedance, internal pull up current source for open load detection.

**Inductive and overvoltage output clamp**



$V_{ON}$  clamped to 67 V typ.

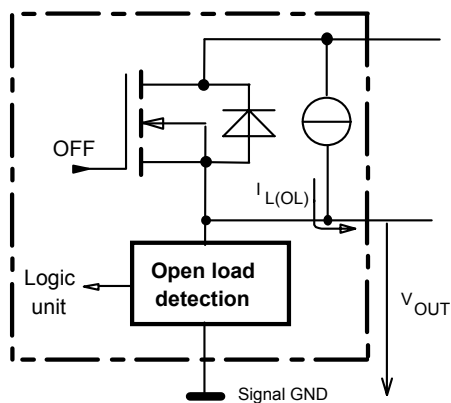
**Overvolt. and reverse batt. protection**



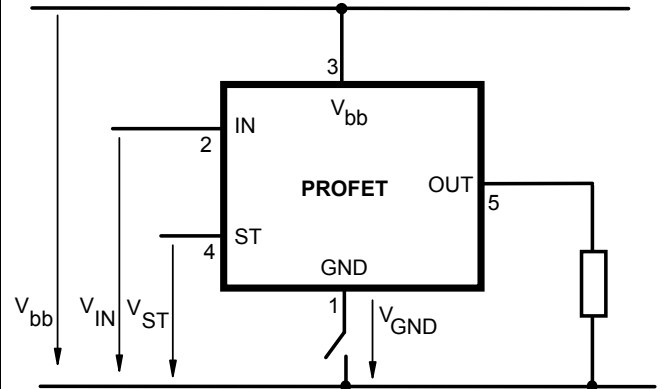
$V_{Z1} = 6.2$  V typ.,  $V_{Z2} = 70$  V typ.,  $R_{GND} = 150$   $\Omega$ ,  $R_{ST} = 15$  k $\Omega$ ,  $R_I = 4$  k $\Omega$  typ.

**Open-load detection**

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

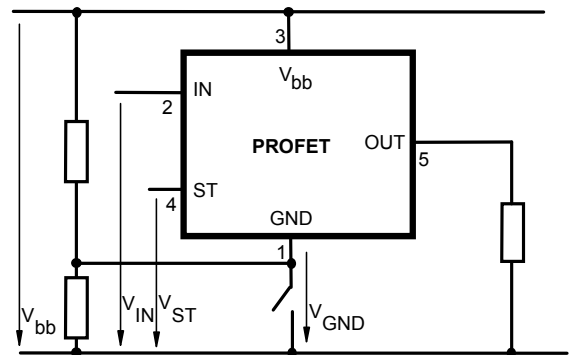


**GND disconnect**



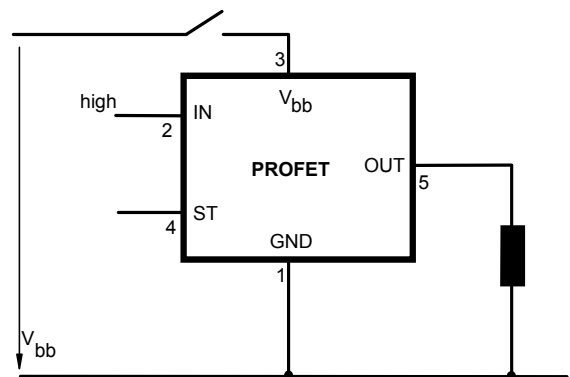
Any kind of load. In case of Input=high is  $V_{OUT} \approx V_{IN} - V_{IN(T+)}$ . Due to  $V_{GND} > 0$ , no  $V_{ST} =$  low signal available.

**GND disconnect with GND pull up**



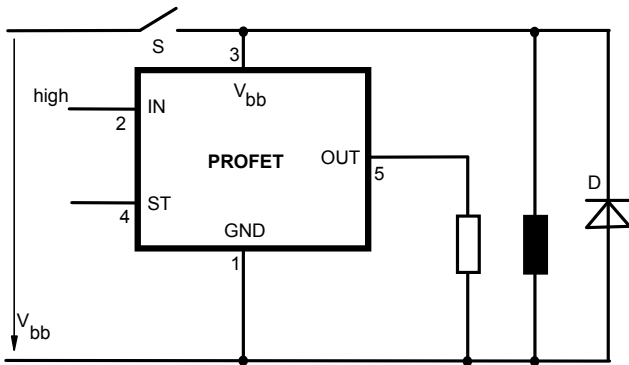
Any kind of load. If  $V_{GND} > V_{IN} - V_{IN(T+)}$  device stays off. Due to  $V_{GND} > 0$ , no  $V_{ST} =$  low signal available.

**Vbb disconnect with charged inductive load**



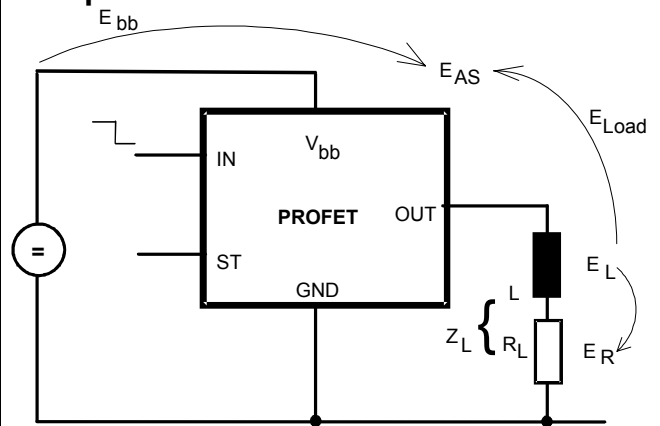
Normal load current can be handled by the PROFET itself.

**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:

$$E_L = 1/2 \cdot L \cdot I_L^2$$

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, load dump 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)</sup> <sup>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>					X		
switches off when $V_{ON} > 3.5\text{ V}$ typ. switches off when $V_{ON} > 8.5\text{ V}$ typ. <sup>10)</sup> (when first turned on after approx. 0 μs)		X	X				X
Achieved through overtemperature protection				X		X	
Open load detection in OFF-state with sensing current -- 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
Overvoltage shutdown with auto restart <sup>12)</sup>		X	X	X	X	-	X
Status feedback for							
overtemperature		X	X	X	X	X	X
short circuit to GND		X	X	-	X	X	X
short to $V_{bb}$		- <sup>13)</sup>	- <sup>13)</sup>	- <sup>13)</sup>	X	X	X
open load		X	X	X	X	X	X
undervoltage		X	-	-	-	X	-
overvoltage		X	-	-	-	-	-
Status output type							
CMOS		X					
Open drain			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
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

<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  $t_{d(SC)}$ .

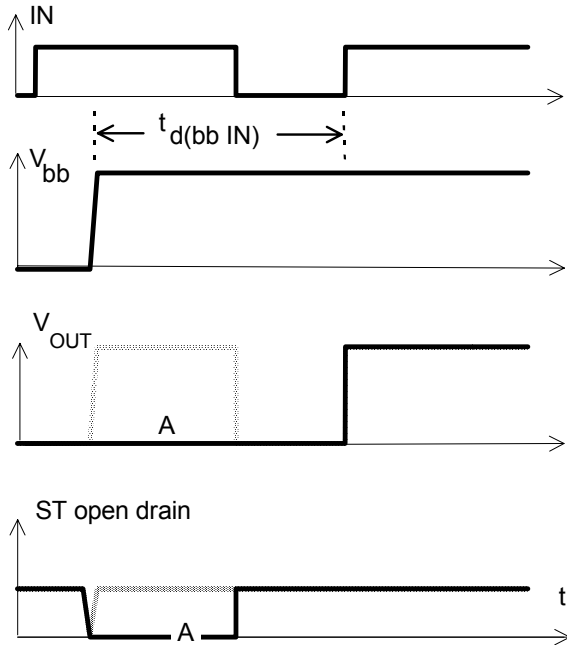
<sup>11)</sup> With latch function. Reset by a) Input low, b) Undervoltage

<sup>12)</sup> No auto restart after overvoltage in case of short circuit

<sup>13)</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:



in case of too early  $V_{IN}$ =high the device may not turn on (curve A)  
 $t_{d(bb IN)}$  approx. 150  $\mu$ s

Figure 2a: Switching an inductive load

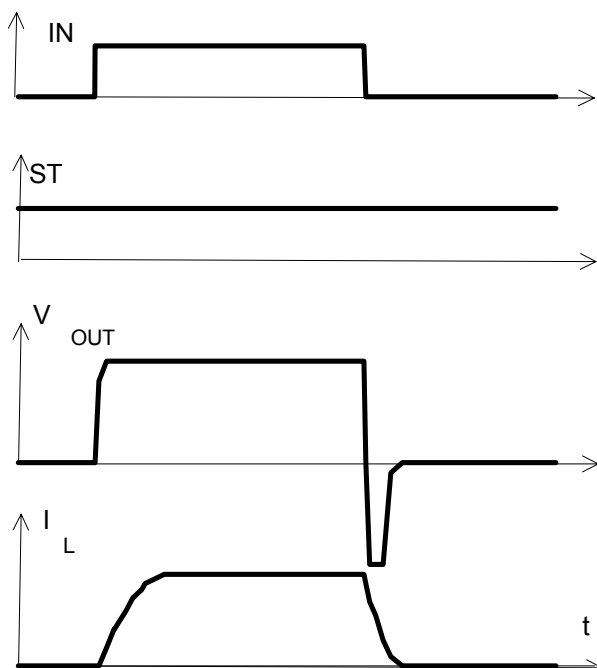
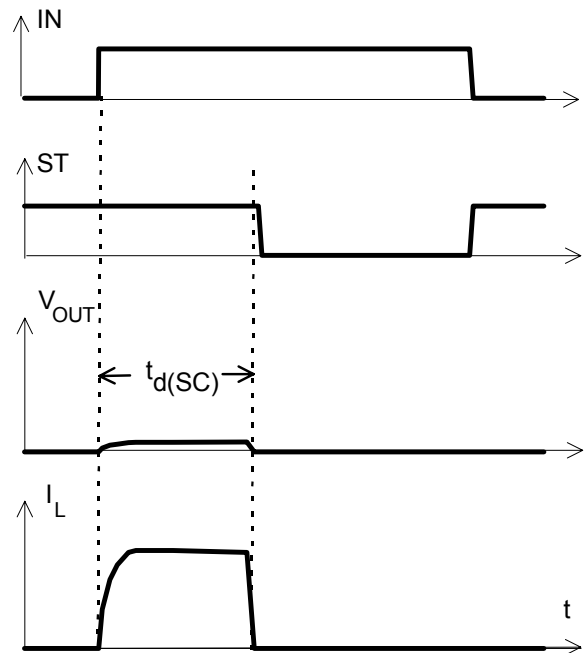
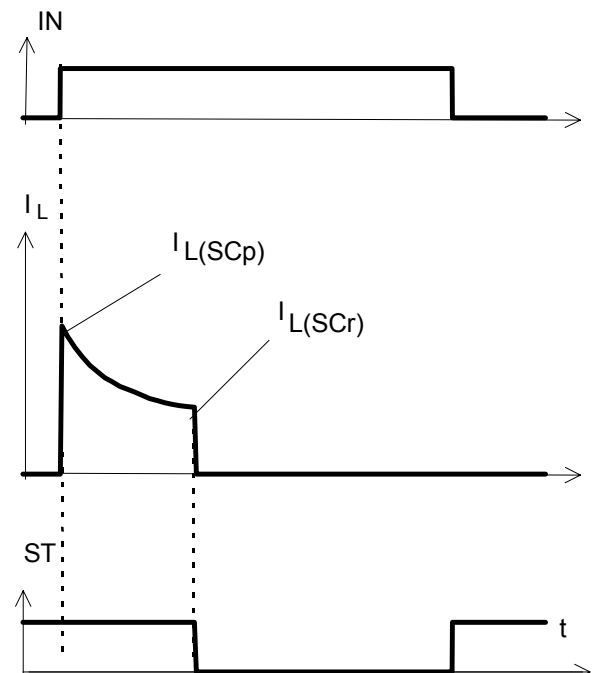


Figure 3a: Turn on into short circuit,



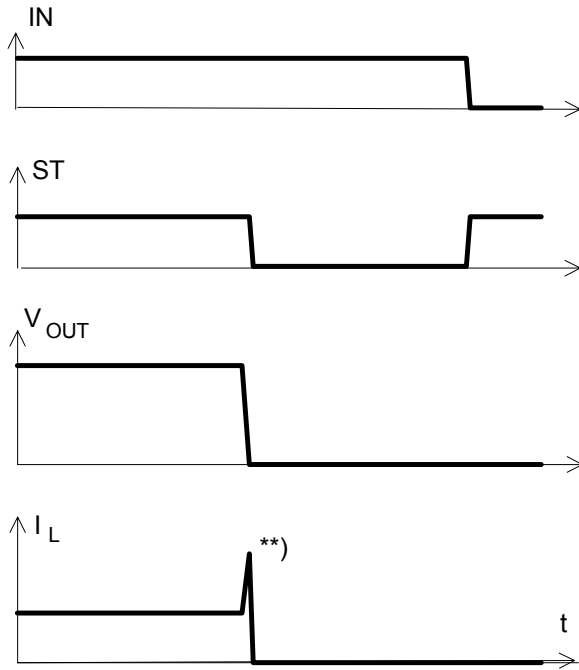
$t_{d(SC)}$  approx. 200 $\mu$ s if  $V_{bb} - V_{OUT} > 3.5$  V typ.

Figure 3b: Turn on into overload,



Heating up may require several seconds,  
 $V_{bb} - V_{OUT} < 3.5$  V typ.

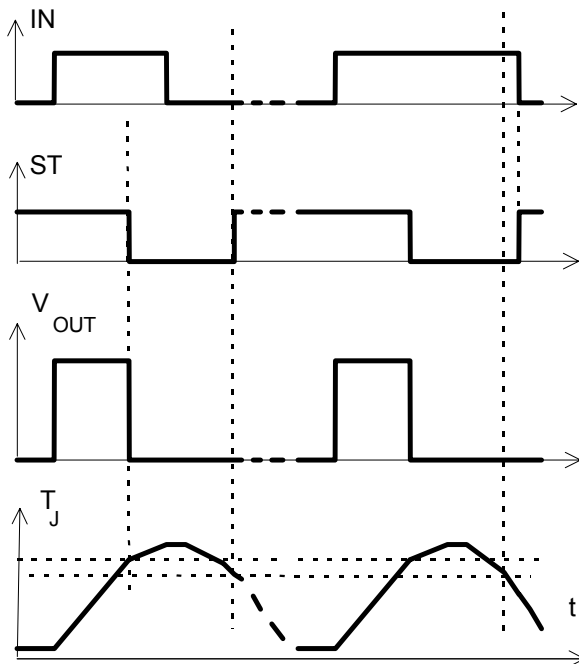
**Figure 3c:** Short circuit while on:



\*\*\*) current peak approx. 20  $\mu$ s

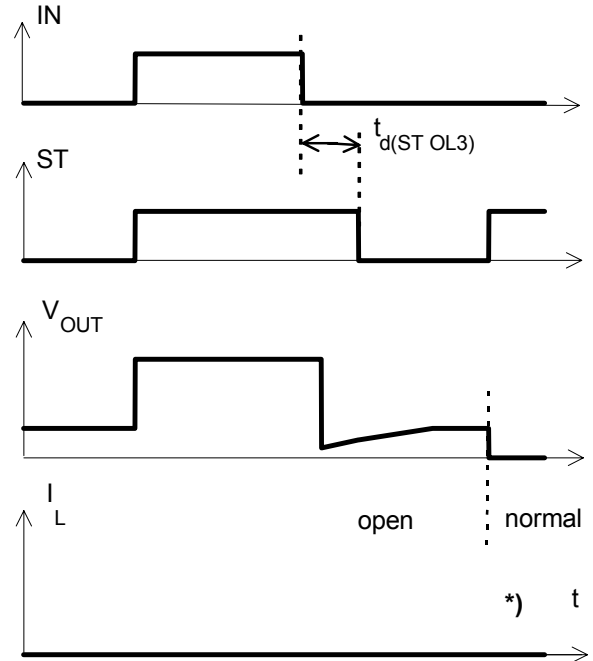
**Figure 4a:** Overtemperature,

Reset if (IN=low) and ( $T_j < T_{jt}$ )



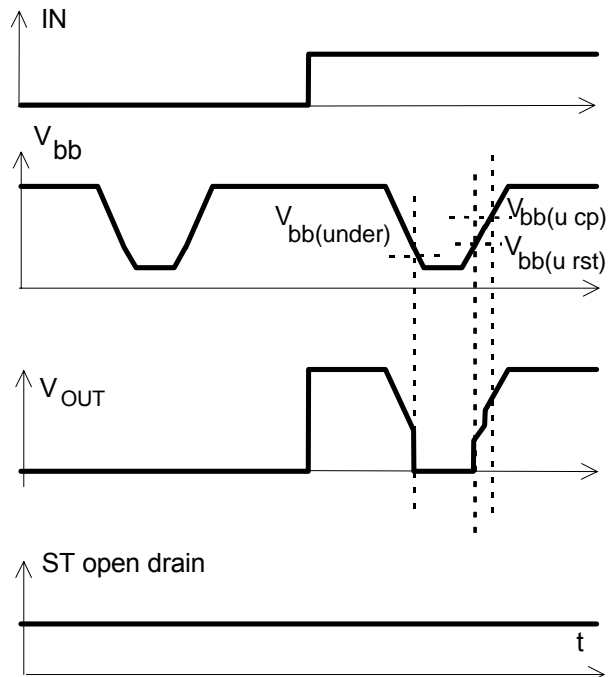
\*) ST goes high, when  $V_{IN}$ =low and  $T_j < T_{jt}$

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

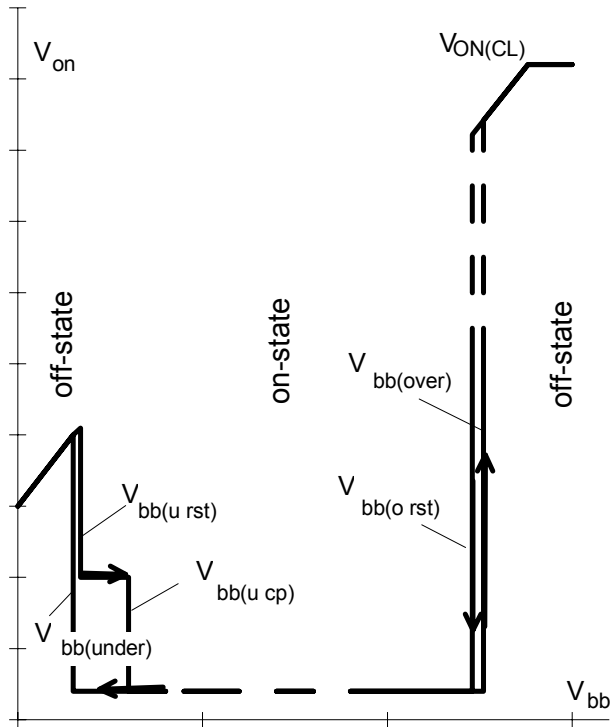


in case of external capacity  $t_{d(ST,OL3)}$  may be higher due to high impedance \*)  $I_L = - \mu$ A typ

**Figure 6a:** Undervoltage:

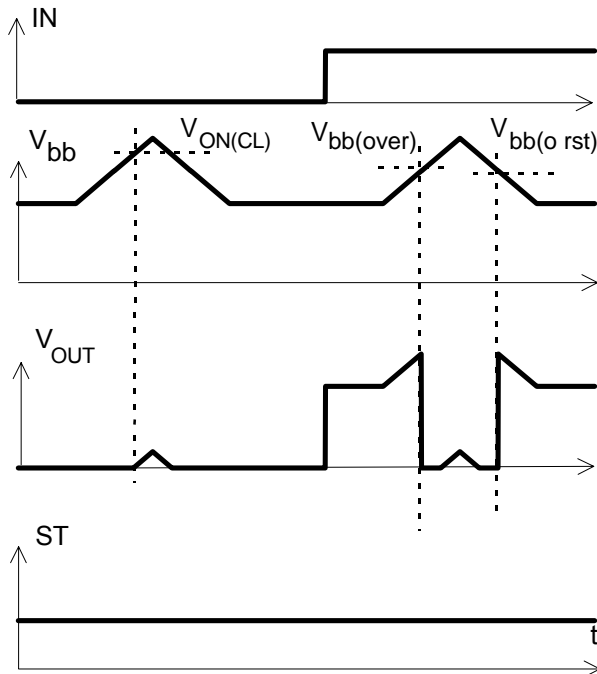


**Figure 6b:** Undervoltage restart of charge pump

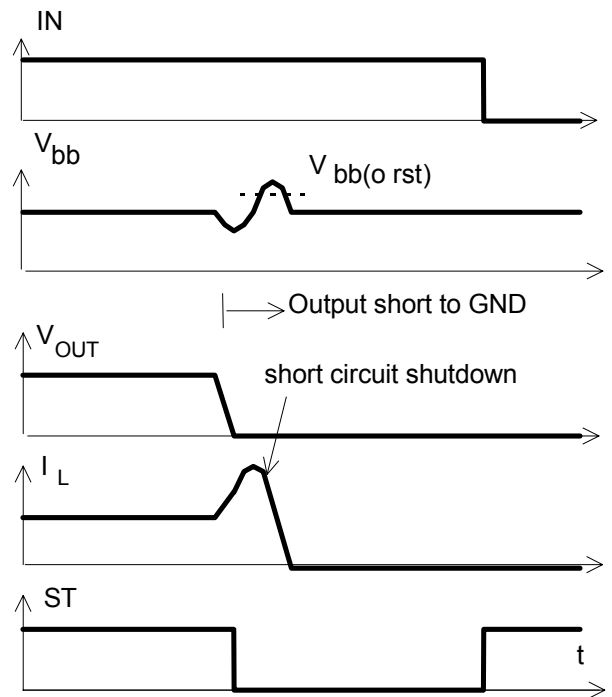


charge pump starts at  $V_{bb(ucp)} = 4.9$  V typ.

**Figure 7a:** Overvoltage:



**Figure 8a:** Overvoltage at short circuit shutdown:



Overvoltage due to power line inductance. No overvoltage auto-restart of PROFET after short circuit shutdown.

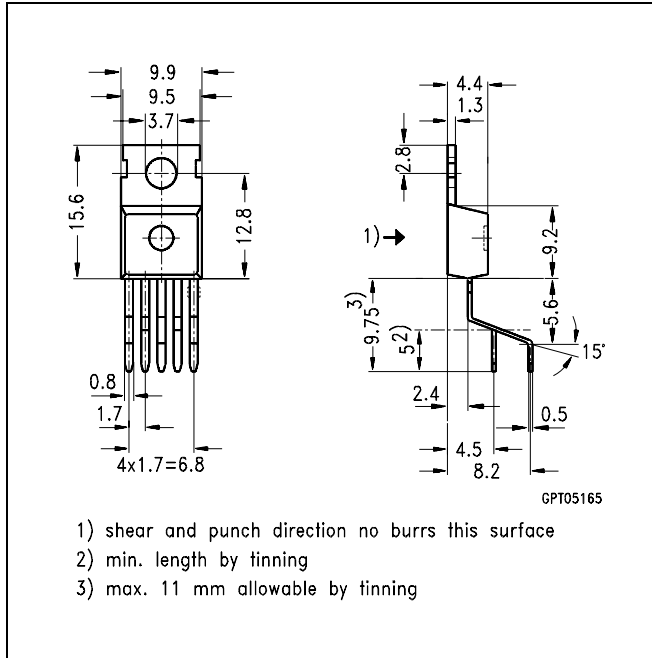
**Package and Ordering Code**

All dimensions in mm

**Standard TO-220AB/5**

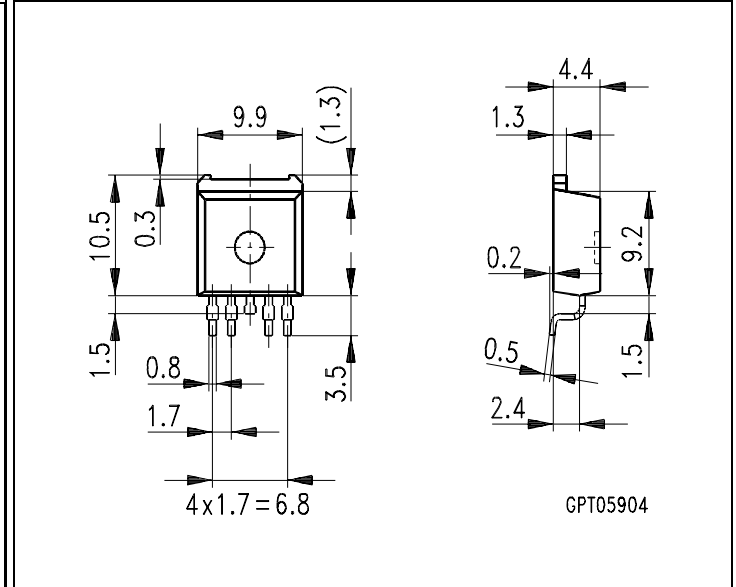
Ordering code

BTS 308	tbd
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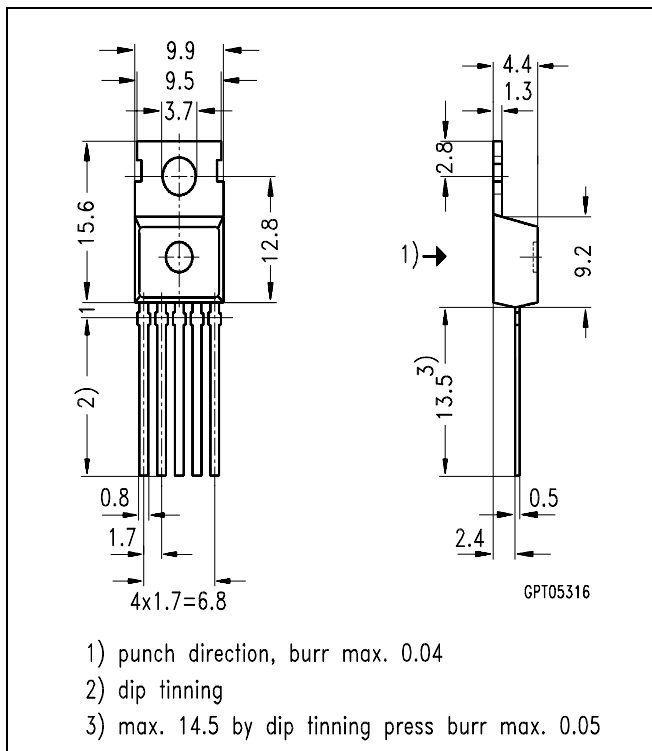
**SMD TO-220AB/5, Opt. E3062** Ordering code

BTS 308 E3062A	T&R:	tbd
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**TO-220AB/5, Option E3043** Ordering code

BTS 308 E3043	tbd
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**Changed since 08.96**

Date	Change
Dec 96	"suitable for PWM" deleted at Application List (Page 1) due to the fact, that where may occur problems with current limit.
	Initial short circuit current limit $I_{L(SCP)}$ "V <sub>ON</sub> =3V" deleted
	Option overview, Short circuit to GND protection, "V <sub>bb</sub> > 8 V typ" deleted for BTS308, only valid for BTS410H2

**Published by**  
**Infineon Technologies AG,**  
**St.-Martin-Strasse 53,**  
**D-81669 München**  
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