

## Smart Highside Power Switch

### Features

- Load dump and reverse battery protection<sup>1)</sup>
- Clamp of negative voltage at output
- Short-circuit protection
- Current limitation
- Thermal shutdown
- Diagnostic feedback
- Open load detection in ON-state
- CMOS compatible input
- **Electrostatic discharge (ESD)** protection
- Loss of ground and loss of  $V_{bb}$  protection<sup>2)</sup>
- Overvoltage protection
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis

### Application

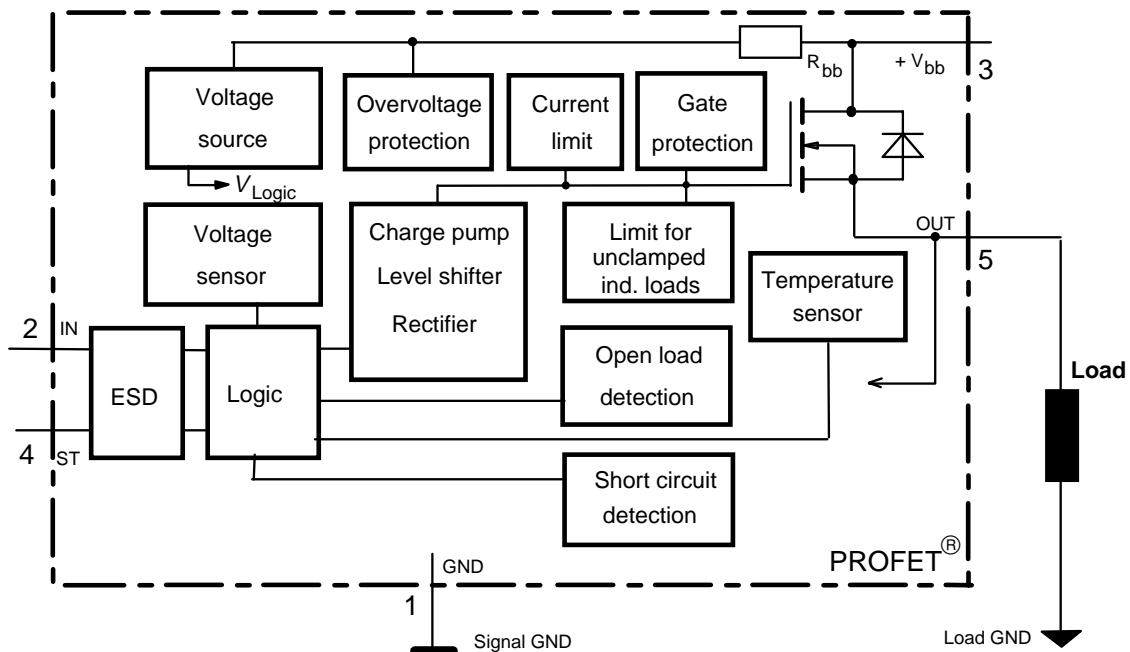
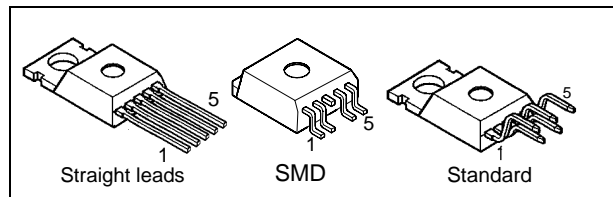
- $\mu$ C compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- Most suitable for inductive loads
- Replaces electromechanical relays and discrete circuits

### General Description

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

### Product Summary

$V_{Load\ dump}$	80	V
$V_{bb} - V_{OUT}$ Avalanche Clamp	58	V
$V_{bb}$ (operation)	4.5 ... 42	V
$V_{bb}$ (reverse)	-32	V
$R_{ON}$	38	m $\Omega$
$I_L(SCp)$	21	A
$I_L(SCr)$	10	A
$I_L(ISO)$	11	A



1) No external components required, reverse load current limited by connected load.

2) Additional external diode required for charged inductive loads

Pin	Symbol		Function
1	GND	-	Logic ground
2	IN	I	Input, activates the power switch in case of logical high signal
3	Vbb	+	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)	$V_{bb}$	63	V	
Load dump protection $V_{LoadDump} = U_A + V_S$ , $U_A = 13.5\text{ V}$ $R_I = 2\ \Omega$ , $R_L = 1.1\ \Omega$ , $t_d = 200\text{ ms}$ , IN= low or high	$V_S^{3)}$	66.5	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)	$P_{tot}$	125	W	
Inductive load switch-off energy dissipation, single pulse $T_j = 150\text{ °C}$ :	$E_{AS}$	1.7	J	
Electrostatic discharge capability (ESD) (Human Body Model)	$V_{ESD}$	2.0	kV	
Input voltage (DC)	$V_{IN}$	-0.5 ... +6	V	
Current through input pin (DC)	$I_{IN}$	$\pm 5.0$	mA	
Current through status pin (DC)	$I_{ST}$	$\pm 5.0$		
see internal circuit diagrams page 6...				
Thermal resistance	chip - case: junction - ambient (free air): SMD version, device on pcb <sup>4)</sup> :	$R_{thJC}$ $R_{thJA}$	$\leq 1$ $\leq 75$ $\leq tbd$	K/W

3)  $V_S$  is setup without DUT connected to the generator per ISO 7637-1 and DIN 40839

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

## 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) $I_L = 2\text{ A}$	$T_j = 25\text{ °C}$ : $T_j = 150\text{ °C}$ :	$R_{ON}$	--	30 55	38 70	mΩ
Nominal load current (pin 3 to 5) ISO Proposal: $V_{ON} = 0.5\text{ V}$ , $T_C = 85\text{ °C}$		$I_{L(ISO)}$	9	11	--	A
Output current (pin 5) while GND disconnected or GND pulled up, $V_{IN} = 0$ , see diagram page 7, $T_j = -40\dots+150\text{ °C}$		$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time to 90% $V_{OUT}$ :		$t_{on}$	50	160	300	μs
Turn-off time to 10% $V_{OUT}$ :		$t_{off}$	10	--	80	
$R_L = 12\text{ Ω}$ , $T_j = -40\dots+150\text{ °C}$						
Slew rate on 10 to 30% $V_{OUT}$ , $R_L = 12\text{ Ω}$ , $T_j = -40\dots+150\text{ °C}$		$dV/dt_{on}$	0.4	--	2.5	V/μs
Slew rate off 70 to 40% $V_{OUT}$ , $R_L = 12\text{ Ω}$ , $T_j = -40\dots+150\text{ °C}$		$-dV/dt_{off}$	1	--	5	V/μs

### Operating Parameters

Operating voltage <sup>5)</sup>	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(on)}$	4.5	--	42	V
Undervoltage shutdown	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(under)}$	2.4	--	4.5	V
Undervoltage restart	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(u\text{ rst})}$	--	--	4.5	V
Undervoltage restart of charge pump see diagram page 12	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(ucp)}$	--	6.5	7.5	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\text{ rst})} - V_{bb(under)}$		$\Delta V_{bb(under)}$	--	0.2	--	V
Overvoltage shutdown	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(over)}$	42	--	52	V
Overvoltage restart	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(o\text{ rst})}$	42	--	--	V
Overvoltage hysteresis	$T_j = -40\dots+150\text{ °C}$ :	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection <sup>6)</sup>	$T_j = -40\text{ °C}$ :	$V_{bb(AZ)}$	60	--	--	V
$I_{bb} = 40\text{ mA}$	$T_j = 25\dots+150\text{ °C}$ :		63	67		
Standby current (pin 3) $V_{IN} = 0$	$T_j = -40\dots+25\text{ °C}$ :	$I_{bb(off)}$	--	12	25	μA
	$T_j = 150\text{ °C}$ :		--	18	60	
Leakage output current (included in $I_{bb(off)}$ ) $V_{IN} = 0$		$I_{L(off)}$	--	6	--	μA
Operating current (Pin 1) <sup>7)</sup> , $V_{IN} = 5\text{ V}$		$I_{GND}$	--	1.1	--	mA

5) At supply voltage increase up to  $V_{bb} = 6.5\text{ V}$  typ without charge pump,  $V_{OUT} \approx V_{bb} - 2\text{ V}$

6) see also  $V_{ON(CL)}$  in table of protection functions and circuit diagram page 7. Measured without load.

7) 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</b>					
Initial peak short circuit current limit (pin 3 to 5) <sup>8)</sup> , (max 400 $\mu\text{s}$ if $V_{ON} > V_{ON(SC)}$ )	$I_{L(SCp)}$				A
$T_j = -40\text{ °C}$ :		--	--	35	
$T_j = 25\text{ °C}$ :		--	21	--	
$T_j = +150\text{ °C}$ :		7	--	--	
Repetitive short circuit current limit $T_j = T_{jt}$ (see timing diagrams, page 10)	$I_{L(SCr)}$	6	10	--	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$ , min value valid only, if input "low" time exceeds 30 $\mu\text{s}$	$t_{d(SC)}$	80	--	400	$\mu\text{s}$
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$ , $I_L = 30\text{ mA}$	$V_{ON(CL)}$	--	58	--	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.3	--	V
Thermal overload trip temperature	$T_{jt}$	150	--	--	$\text{°C}$
Thermal hysteresis	$\Delta T_{jt}$	--	10	--	K
Inductive load switch-off energy dissipation <sup>9)</sup> , $T_{j\text{ Start}} = 150\text{ °C}$ , single pulse	$E_{AS}$	--	--	1.7	J
$V_{bb} = 12\text{ V}$ :	$E_{Load12}$			1.3	
$V_{bb} = 24\text{ V}$ :	$E_{Load24}$			1.0	
Reverse battery (pin 3 to 1) <sup>10)</sup>	$-V_{bb}$	--	--	32	V
Integrated resistor in $V_{bb}$ line	$R_{bb}$	--	120	--	$\Omega$

### Diagnostic Characteristics

Open load detection current (on-condition)	$T_j = -40\text{ °C}$ : $T_j = 25\text{..}150\text{ °C}$ :	$I_{L(OL)}$	2 2	-- --	900 750	mA
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<sup>8)</sup> Short circuit current limit for max. duration of 400  $\mu\text{s}$ , prior to shutdown (see  $t_{d(SC)}$  page 4)



<sup>9)</sup> While demagnetizing load inductance, dissipated energy in PROFET is  $E_{AS} = \int V_{ON(CL)} * i_L(t) dt$ , approx.

$$E_{AS} = \frac{1}{2} * L * I_L^2 * \left( \frac{V_{ON(CL)}}{V_{ON(CL)} - V_{bb}} \right), \text{ see diagram page 8}$$

<sup>10)</sup> Reverse load current (through intrinsic drain-source diode) is normally limited by the connected load. Reverse current  $I_{GND}$  of  $\approx 0.3\text{ A}$  at  $V_{bb} = -32\text{ V}$  through the logic heats up the device. Time allowed under these condition is dependent on the size of the heatsink. Reverse  $I_{GND}$  can be reduced by an additional external GND-resistor (150  $\Omega$ ). Input and Status currents have to be limited (see max. ratings page 2 and circuit page 7).

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

### Input and Status Feedback<sup>11)</sup>

Input turn-on threshold voltage  $T_j = -40..+150\text{ °C}$ :	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage  $T_j = -40..+150\text{ °C}$ :	$V_{IN(T-)}$	1.0	--	--	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	50	$\mu\text{A}$
Status invalid after positive input slope (short circuit) $T_j = -40 \dots +150\text{ °C}$ :	$t_{d(ST\ SC)}$	80	200	400	$\mu\text{s}$
Status invalid after positive input slope (open load) $T_j = -40 \dots +150\text{ °C}$ :	$t_{d(ST)}$	350	--	1600	$\mu\text{s}$
Status output (open drain) Zener limit voltage $T_j = -40\dots+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage $T_j = -40\dots+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(low)}$	--	--	0.4	

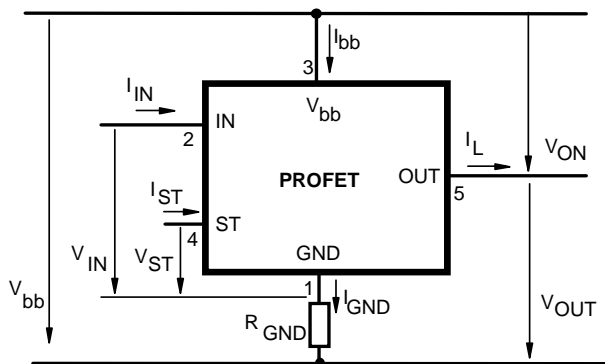
<sup>11)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor.

## Truth Table

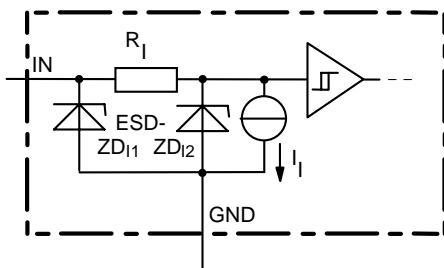
	Input-level	Output level	Status		
			432 D2	432 E2/F2	432 I2
Normal operation	L	L	H	H	H
	H	H	H	H	H
Open load	L	<sup>12)</sup> H	H	H	L
	H	H	L	L	H
Short circuit to GND	L	L	H	H	H
	H	L	L	L	L
Short circuit to V <sub>bb</sub>	L	H	H	H	L
	H	H	H (L <sup>13)</sup> )	H (L <sup>13)</sup> )	H
Overtemperature	L	L	L	L	L
	H	L	L	L	L
Under-voltage	L	L	L <sup>14)</sup>	H	L <sup>14)</sup>
	H	L	L <sup>14)</sup>	H	L <sup>14)</sup>
Overvoltage	L	L	L	H	L
	H	L	L	H	L

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

## Terms

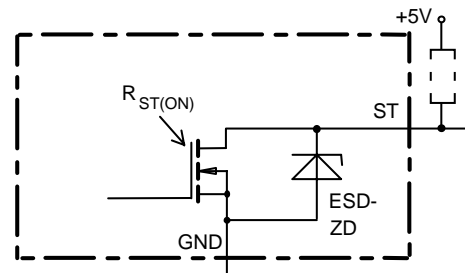


## Input circuit (ESD protection)



ZD<sub>1</sub> 6.1 V typ., ESD zener diodes are not designed for continuous current

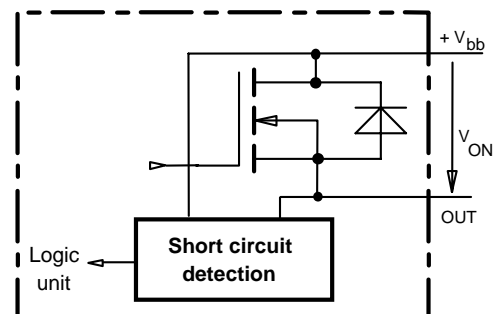
## Status output



ESD-Zener diode: 6.1 V typ., max 5 mA;  
R<sub>ST(ON)</sub> < 250 Ω at 1.6 mA, ESD zener diodes are not designed for continuous current

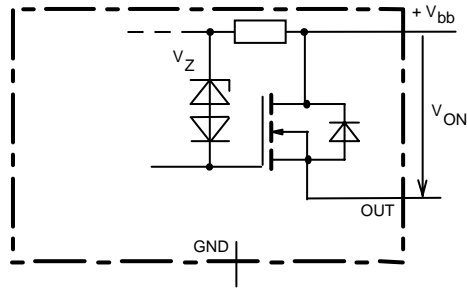
## Short Circuit detection

Fault Condition: V<sub>ON</sub> > 8.3 V typ.; IN high



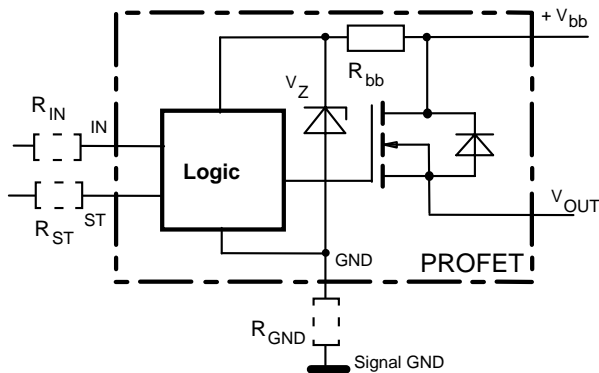
- 12) Power Transistor off, high impedance
- 13) Low resistance short V<sub>bb</sub> to output may be detected by no-load-detection
- 14) No current sink capability during undervoltage shutdown

## Inductive and overvoltage output clamp



$V_{ON}$  clamped to 58 V typ.

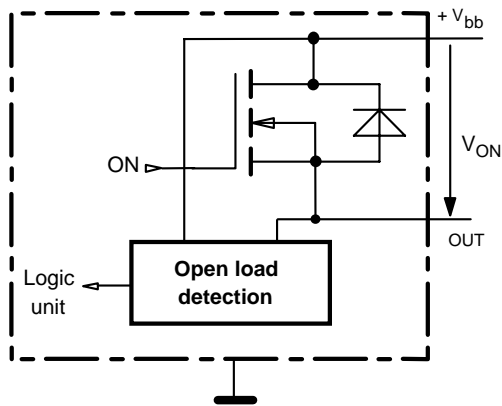
## Overvolt. and reverse batt. protection



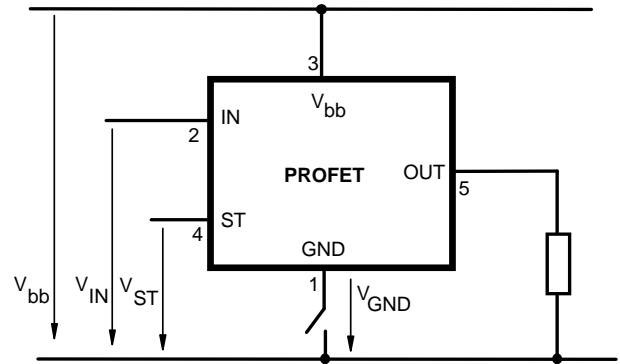
$R_{bb} = 120 \Omega$  typ.,  $V_Z + R_{bb} \cdot 40 \text{ mA} = 67 \text{ V}$  typ., add  $R_{GND}$ ,  $R_{IN}$ ,  $R_{ST}$  for extended protection

## Open-load detection

ON-state diagnostic condition:  $V_{ON} < R_{ON} \cdot I_{L(OL)}$ ; IN high

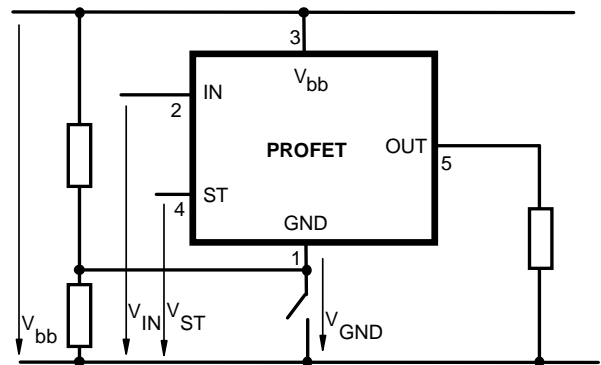


## GND disconnect



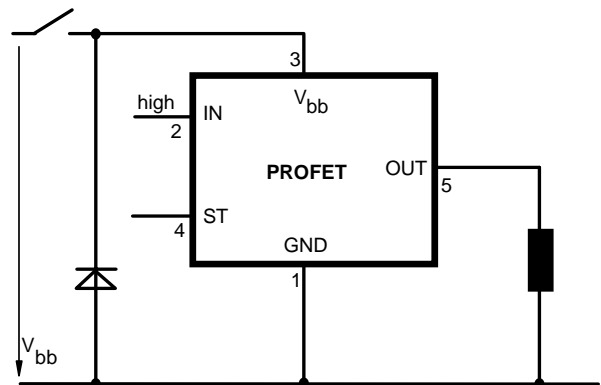
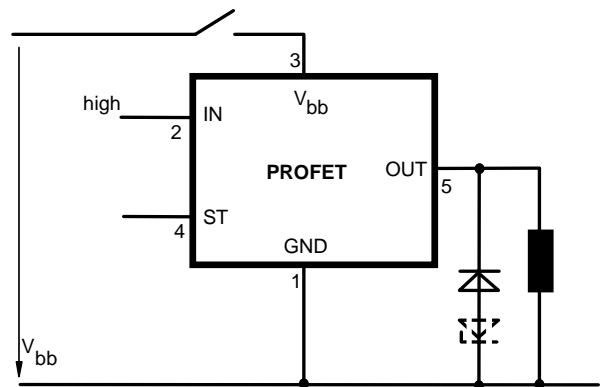
Any kind of load. In case of Input=high is  $V_{OUT} \approx V_{IN} - V_{IN(T+)}$ . Due to  $V_{GND} > 0$ , no  $V_{ST} = \text{low}$  signal available.

## GND disconnect with GND pull up

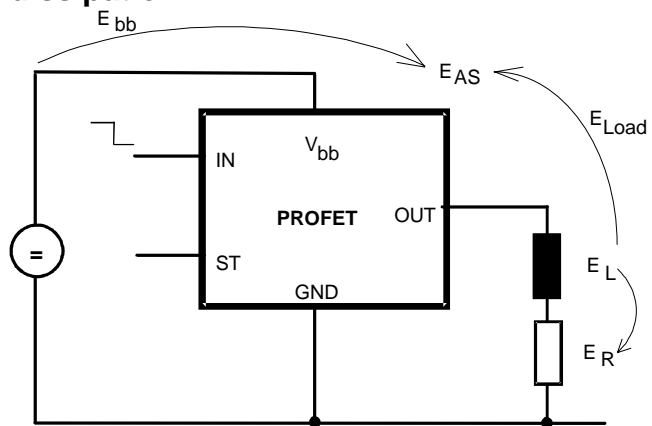


Any kind of load. If  $V_{GND} > V_{IN} - V_{IN(T+)}$  device stays off. Due to  $V_{GND} > 0$ , no  $V_{ST} = \text{low}$  signal available.

## Vbb disconnect with charged inductive load



## Inductive Load switch-off energy dissipation



Energy dissipated in PROFET  $E_{AS} = E_{bb} + E_L - E_R$ .

$$E_{Load} < E_L, E_L = \frac{1}{2} * L * I_L^2$$



### Options Overview

**all versions: High-side switch, Input protection, ESD protection, load dump and reverse battery protection , protection against loss of ground**

Type	BTS	432D2	432E2	<b>432F2</b>	432I2
Logic version		D	E	<b>F</b>	I
Overtemperature protection $T_j > 150\text{ °C}$ , latch function <sup>15)16)</sup> $T_j > 150\text{ °C}$ , with auto-restart on cooling		X		<b>X</b>	X
Short-circuit to GND protection switches off when $V_{ON} > 8.3\text{ V typ.}^{15)}$ (when first turned on after approx. 200 $\mu\text{s}$ )		X	X	<b>X</b>	X
Open load detection in OFF-state with sensing current 30 $\mu\text{A typ.}$ in ON-state with sensing voltage drop across power transistor		X	X	<b>X</b>	X
Undervoltage shutdown with auto restart		X	X	<b>X</b>	X
Overvoltage shutdown with auto restart		X	X	<b>X</b>	X
Status feedback for					
overtemperature		X	X	<b>X</b>	X
short circuit to GND		X	X	<b>X</b>	X
short to $V_{bb}$		- <sup>17)</sup>	- <sup>17)</sup>	- <sup>17)</sup>	X
open load		X	X	<b>X</b>	X
undervoltage		X	-	-	X
overvoltage		X	-	-	X
Status output type					
CMOS		X			X
Open drain			X	<b>X</b>	
Output negative voltage transient limit (fast inductive load switch off)					
to $V_{bb} - V_{ON(CL)}$		X	X	<b>X</b>	X
Load current limit					
high level (can handle loads with high inrush currents)		X	X		
medium level					X
low level (better protection of application)				<b>X</b>	

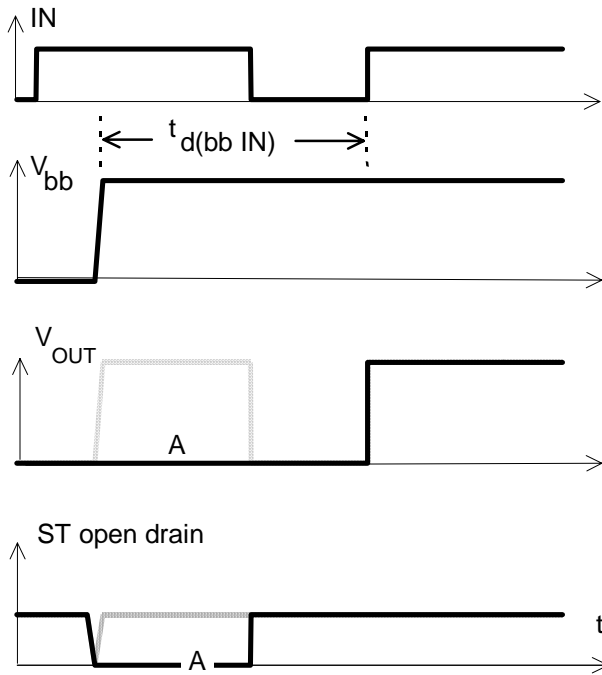
<sup>15)</sup> Latch except when  $V_{bb} - V_{OUT} < V_{ON(SC)}$  after shutdown. In most cases  $V_{OUT} = 0\text{ V}$  after shutdown ( $V_{OUT} \neq 0\text{ V}$  only if forced externally). So the device remains latched unless  $V_{bb} < V_{ON(SC)}$  (see page 4). No latch between turn on and  $t_d(SC)$ .

<sup>16)</sup> With latch function. Reset by a) Input low, b) Undervoltage, c) Overvoltage

<sup>17)</sup> Low resistance short  $V_{bb}$  to output may be detected by no-load-detection

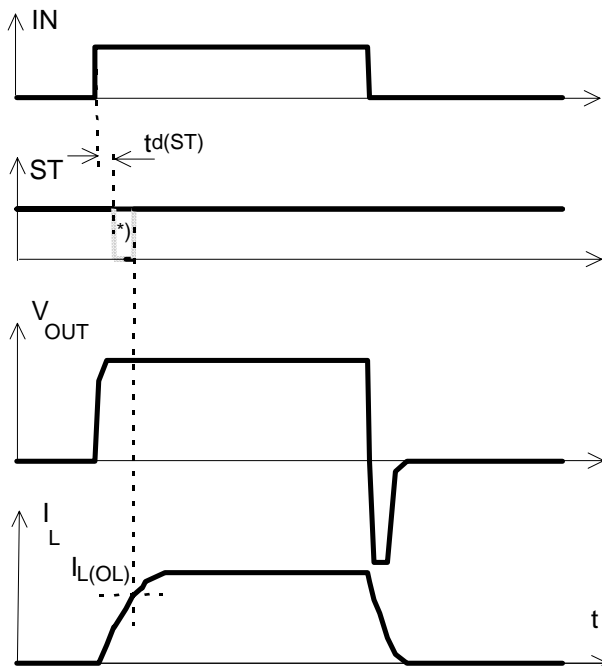
## Timing diagrams

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



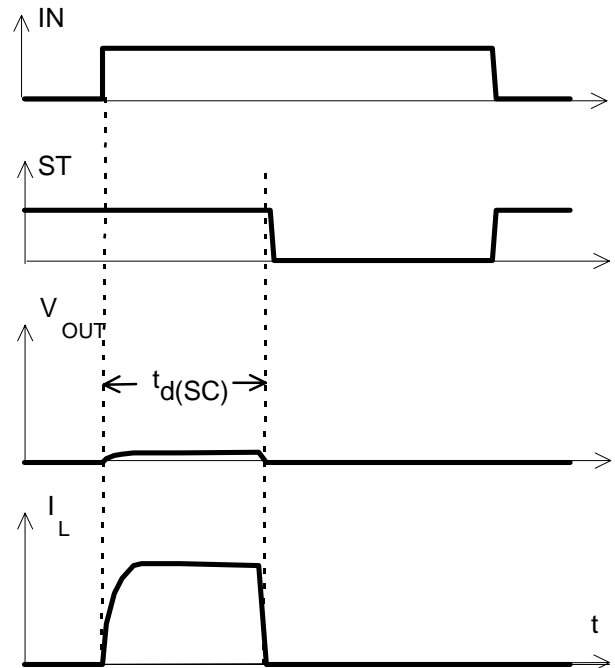
in case of too early  $V_{IN}$ =high the device may not turn on (curve A)  
 $t_{d(bb\ IN)}$  approx. 150  $\mu s$

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



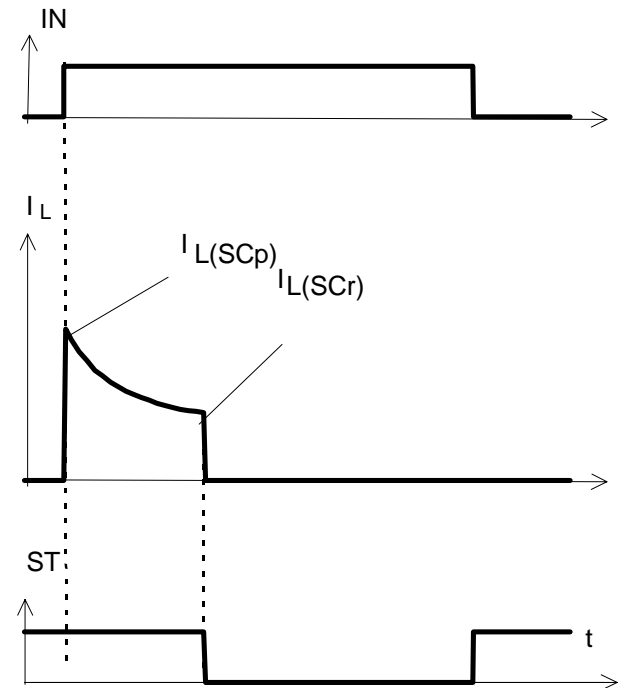
\*) if the time constant of load is too large, open-load-status may occur

**Figure 3a:** Turn on into short circuit,



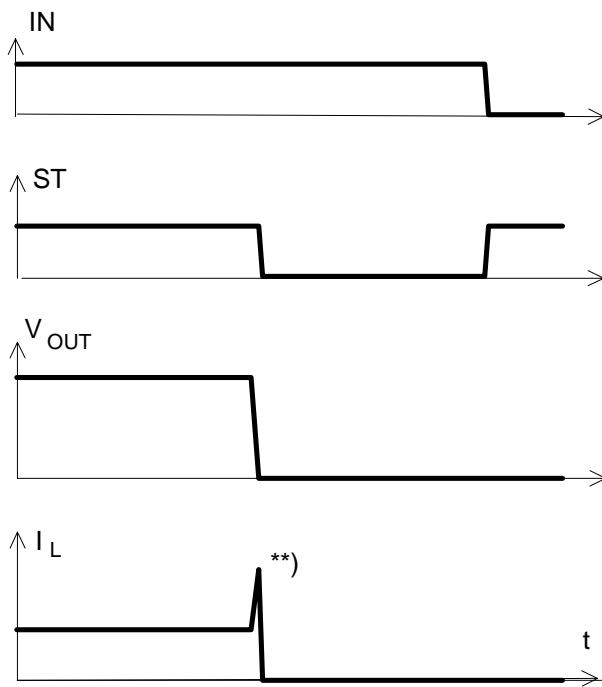
$t_d(SC)$  approx. 200  $\mu s$  if  $V_{bb} - V_{OUT} > 8.3\ V$  typ.

**Figure 3b:** Turn on into overload,



Heating up may require several milliseconds,  $V_{bb} - V_{OUT} < 8.3\ V$  typ.

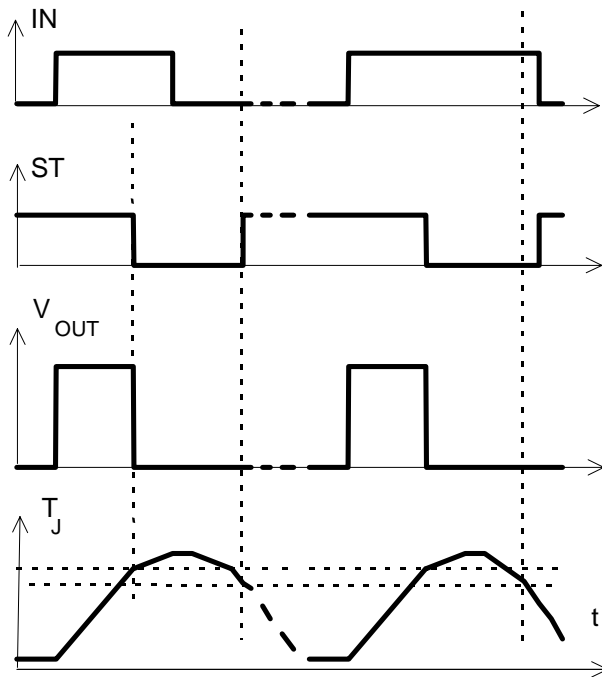
**Figure 3c:** Short circuit while on:



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

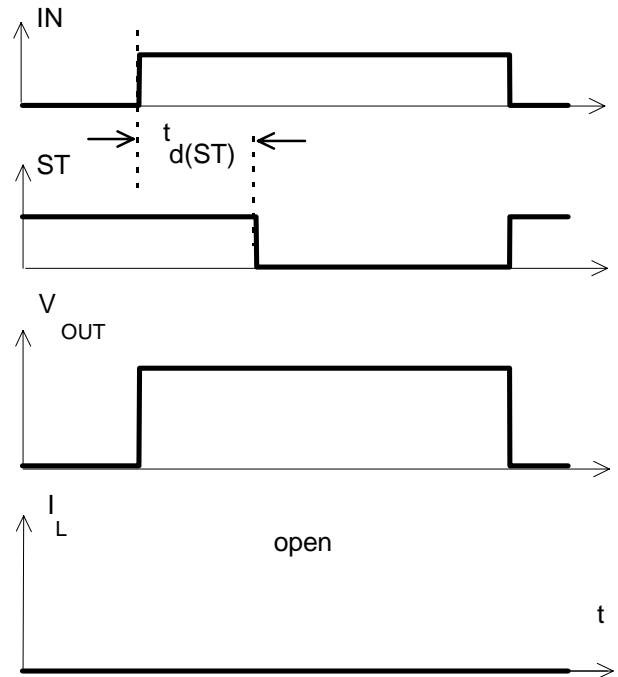
**Figure 4a:** Overtemperature,

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

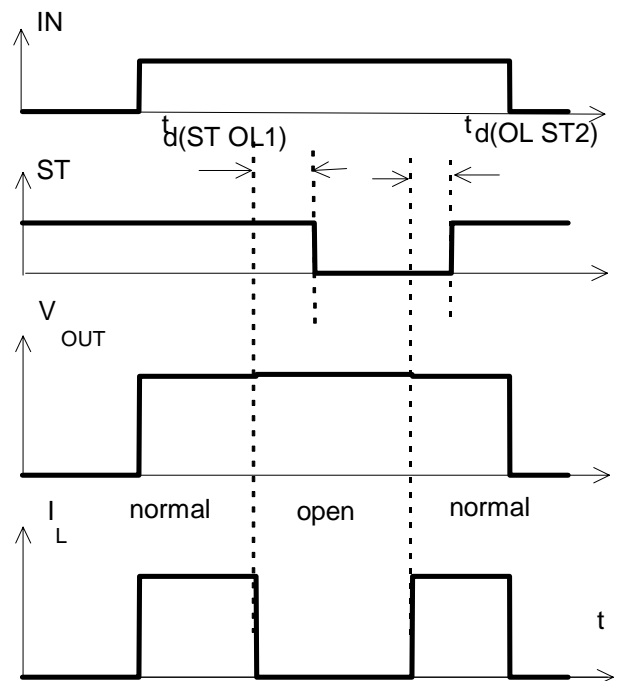


\*) ST goes high, when  $V_{IN}$ =low and  $T_j < T_{jt}$

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

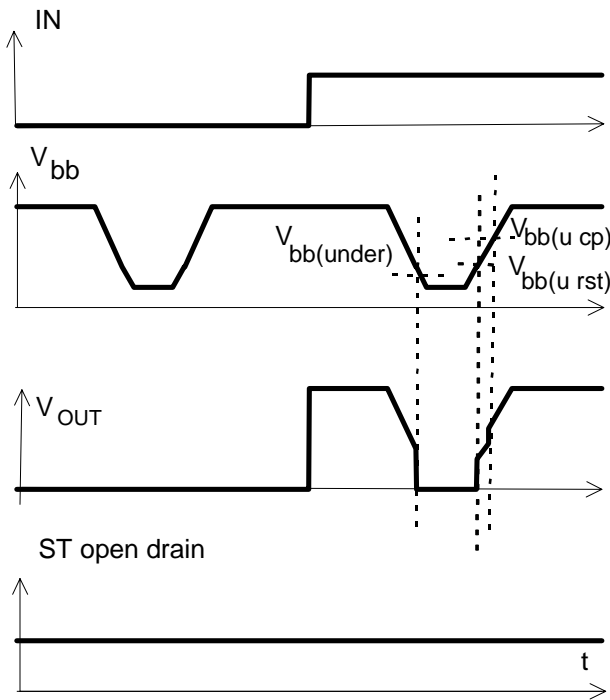


**Figure 5b:** Open load: detection in ON-state, open load occurs in on-state

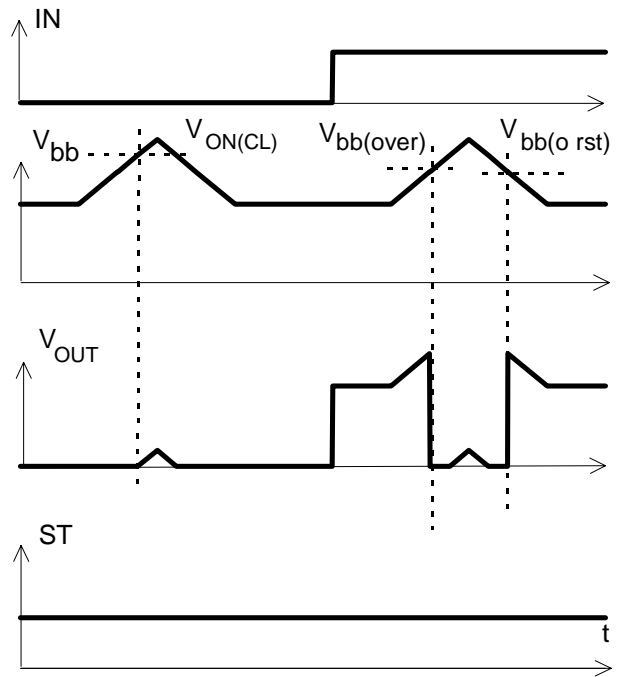


$t_{d(ST OL1)} = t_{bd} \mu$ s typ.,  $t_{d(OL ST2)} = t_{bd} \mu$ s typ

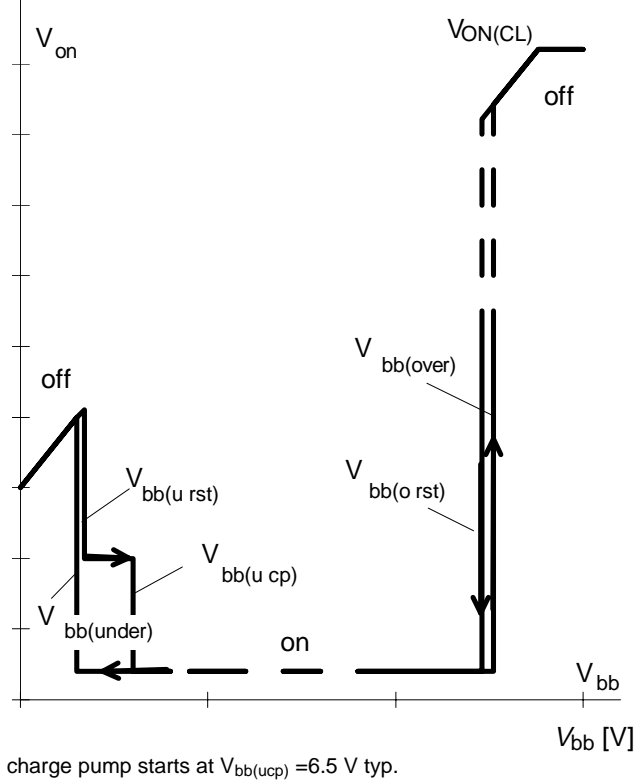
**Figure 6a:** Undervoltage:



**Figure 7a:** Overvoltage:



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



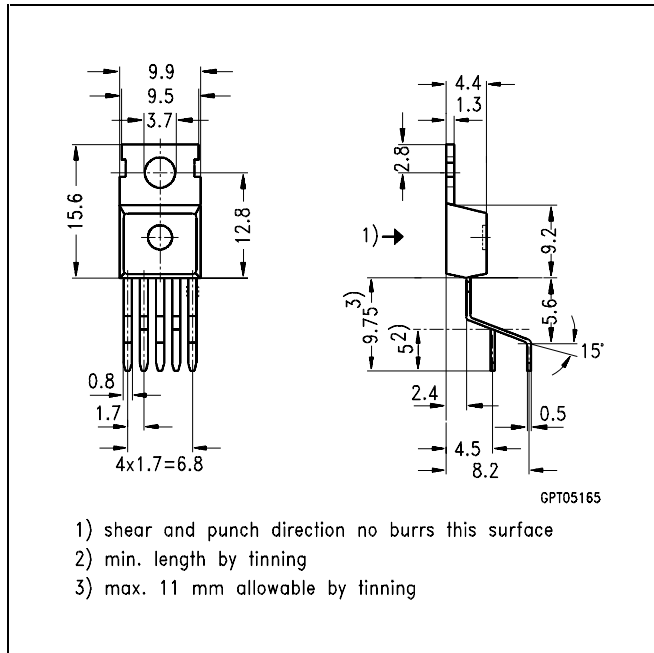
### Package and Ordering Code

All dimensions in mm

#### Standard TO-220AB/5

Ordering code

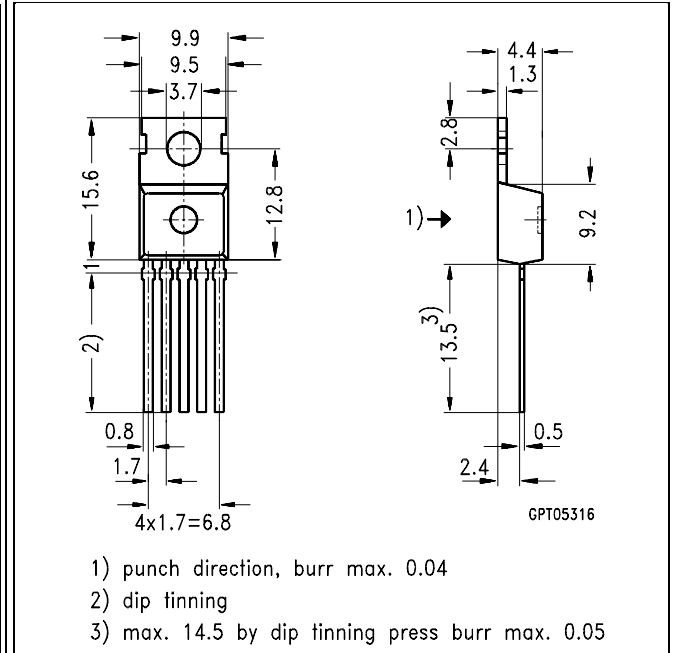
BTS 432 F2	Q67060-S6203-A2
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#### TO-220AB/5, Option E3043

Ordering code

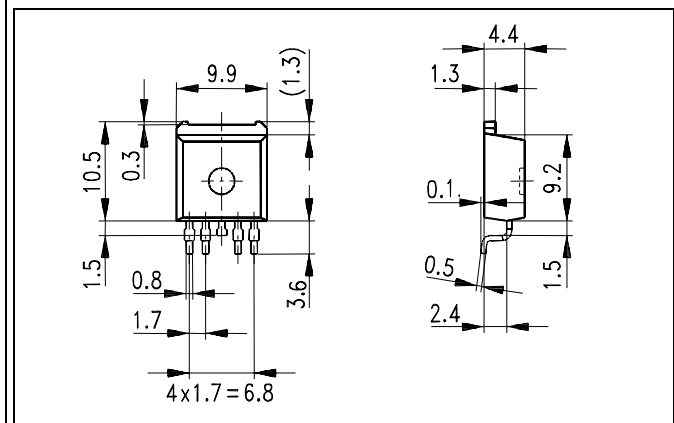
BTS 432 F2 E3043	Q67060-S6203-A4
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#### SMD TO-220AB/5, Opt. E3062

Ordering code

BTS432F2 E3062A	T&R: Q67060-S6203-A6
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