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Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

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Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



# 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

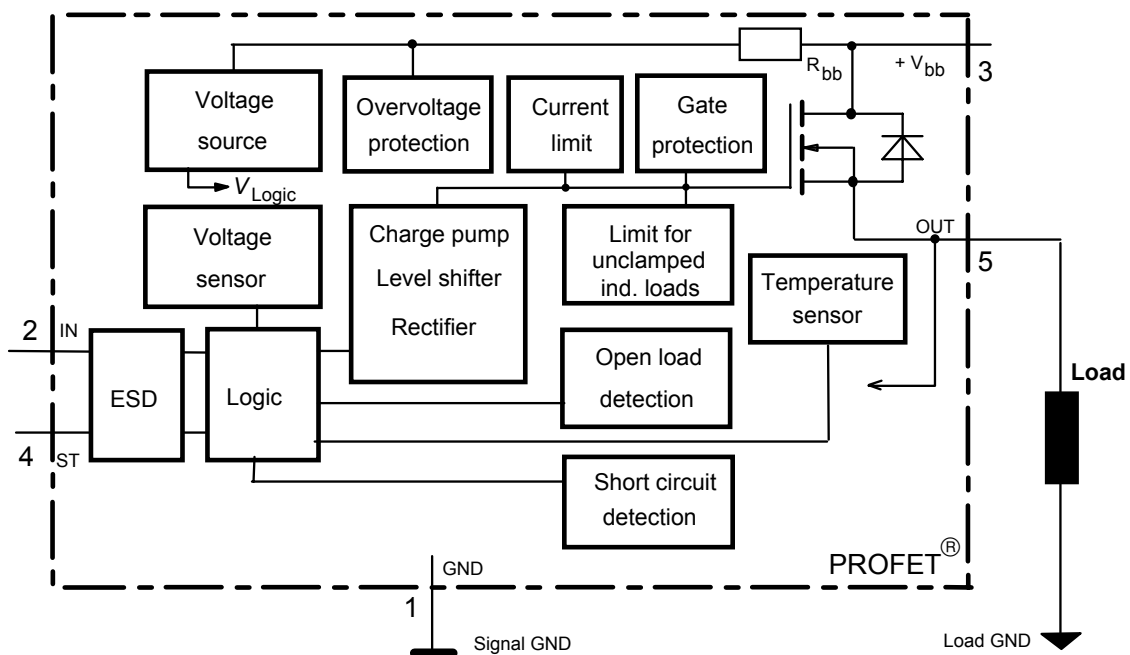
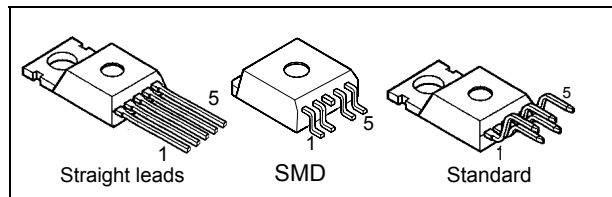
- $\mu$ C compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- All types of resistive, inductive and capacitive loads
- Replaces electromechanical relays and discrete circuits

## 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. Providing protective 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 $\Omega$
$I_L(SCp)$	44	A
$I_L(SCr)$	35	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	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<sub>j</sub> = 25 °C unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 3)	V <sub>bb</sub>	63	V
Load dump protection V <sub>LoadDump</sub> = U <sub>A</sub> + V <sub>S</sub> , U <sub>A</sub> = 13.5 V R <sub>I</sub> = 2 Ω, R <sub>L</sub> = 1.1 Ω, t <sub>d</sub> = 200 ms, IN = low or high	V <sub>S</sub> <sup>3)</sup>	66.5	V
Load current (Short-circuit current, see page 4)	I <sub>L</sub>	self-limited	A
Operating temperature range	T <sub>j</sub>	-40 ... +150	°C
Storage temperature range	T <sub>stg</sub>	-55 ... +150	
Power dissipation (DC)	P <sub>tot</sub>	125	W
Inductive load switch-off energy dissipation, single pulse T <sub>j</sub> = 150 °C:	E <sub>AS</sub>	1.7	J
Electrostatic discharge capability (ESD) (Human Body Model)	V <sub>ESD</sub>	2.0	kV
Input voltage (DC)	V <sub>IN</sub>	-0.5 ... +6	V
Current through input pin (DC)	I <sub>IN</sub>	±5.0	mA
Current through status pin (DC) see internal circuit diagrams page 6...	I <sub>ST</sub>	±5.0	
Thermal resistance			
chip - case:	R <sub>thJC</sub>	≤ 1	K/W
junction - ambient (free air):	R <sub>thJA</sub>	≤ 75	
SMD version, device on pcb <sup>4)</sup> :		≤ tbd	

<sup>3)</sup> V<sub>S</sub> is setup without DUT connected to the generator per ISO 7637-1 and DIN 40839

<sup>4)</sup> Device on 50mm\*50mm\*1.5mm epoxy PCB FR4 with 6cm<sup>2</sup> (one layer, 70μm thick) copper area for V<sub>bb</sub> 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	$m\Omega$
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	$\mu s$
Turn-off time to 10% $V_{OUT}$ :		$t_{off}$	10	--	80	$\mu s$
Slew rate on 10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$ , $T_j = -40\dots+150\text{ °C}$		$dV/dt_{on}$	0.4	--	2.5	$V/\mu s$
Slew rate off 70 to 40% $V_{OUT}$ , $R_L = 12\ \Omega$ , $T_j = -40\dots+150\text{ °C}$		$-dV/dt_{off}$	1	--	5	$V/\mu s$

### 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	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(u\ rst)}$	--	--	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 $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$		$\Delta V_{bb(under)}$	--	0.2	--	V
Overvoltage shutdown	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(over)}$	42	--	52	V
Overvoltage restart	$T_j = -40\dots+150\text{ °C}$ :	$V_{bb(o\ rst)}$	42	--	--	V
Overvoltage hysteresis	$T_j = -40\dots+150\text{ °C}$ :	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection <sup>6)</sup> $I_{bb} = 40\text{ mA}$	$T_j = -40\text{ °C}$ : $T_j = 25\dots+150\text{ °C}$ :	$V_{bb(AZ)}$	60 63	--	--	V
Standby current (pin 3) $V_{IN} = 0$	$T_j = -40\dots+25\text{ °C}$ : $T_j = 150\text{ °C}$ :	$I_{bb(off)}$	--	12 18	25 60	$\mu A$
Leakage output current (included in $I_{bb(off)}$ ) $V_{IN} = 0$		$I_{L(off)}$	--	6	--	$\mu A$
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<sup>8)</sup></b>					
Initial peak short circuit current limit (pin 3 to 5) <sup>9)</sup> , ( max 400 $\mu\text{s}$ if $V_{ON} > V_{ON(SC)}$ )	$I_{L(SCp)}$				
$T_j = -40\text{ °C}$ :		--	--	74	A
$T_j = 25\text{ °C}$ :		--	44	--	
$T_j = +150\text{ °C}$ :		24	--	--	
Repetitive short circuit current limit $T_j = T_{jt}$ (see timing diagrams, page 10)	$I_{L(SCr)}$	22	35	--	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$ , $T_j = -40..+150\text{ °C}$ : 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>10)</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>11)</sup>	$-V_{bb}$	--	--	32	V
Integrated resistor in $V_{bb}$ line	$R_{bb}$	--	120	--	$\Omega$

### Diagnostic Characteristics

Open load detection current (on-condition)	$T_j = -40\text{ °C}$ : $T_j = 25..150\text{ °C}$ :	$I_L(OL)$	2 2	-- --	900 750	mA
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
8) 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.

9) Short circuit current limit for max. duration of 400  $\mu\text{s}$ , prior to shutdown (see  $t_{d(SC)}$  page 4)

10) While demagnetizing load inductance, dissipated energy in PROFET is  $E_{AS} = V_{ON(CL)} * \int I_L(t) dt$ , approx.

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

11) 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	
<b>Input and Status Feedback<sup>12)</sup></b>					
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 $T_j = -40\dots+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ : ST low voltage $T_j = -40\dots+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(high)}$ $V_{ST(low)}$	5.4 --	6.1 --	-- 0.4	V

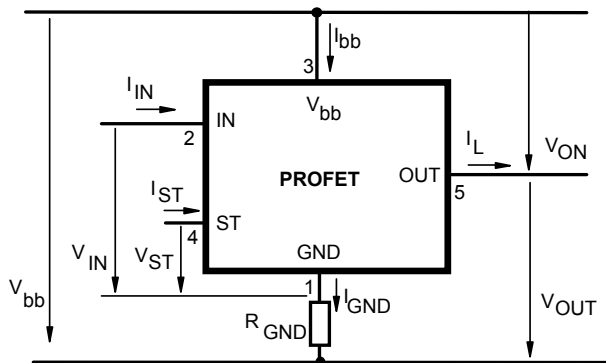
<sup>12)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor.

### Truth Table

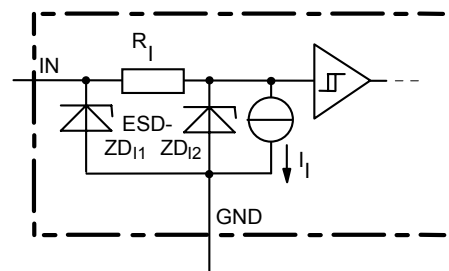
	Input-level	Output level	Status		
			432 D2	432 E2/F2	432 I2
Normal operation	L	L	H	H	H
	H	H	H	H	H
Open load	L	L <sup>13)</sup>	H	H	L
	H	H	L	L	H
Short circuit to GND	L	L	H	H	H
	H	L	L	L	L
Short circuit to V <sub>bb</sub>	L	H	H	H	L
	H	H	H (L <sup>14)</sup> )	H (L <sup>14)</sup> )	H
Overtemperature	L	L	L	L	L
	H	L	L	L	L
Undervoltage	L	L	L <sup>15)</sup>	H	L <sup>15)</sup>
	H	L	L <sup>15)</sup>	H	L <sup>15)</sup>
Overvoltage	L	L	L	H	L
	H	L	L	H	L

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

### Terms



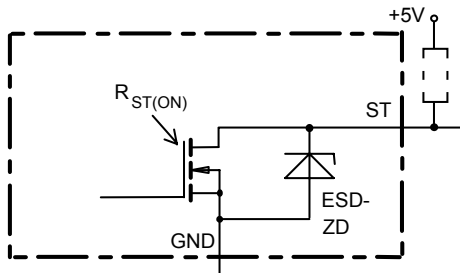
### Input circuit (ESD protection)



ZD11 6.1 V typ., ESD zener diodes are not designed for continuous current

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

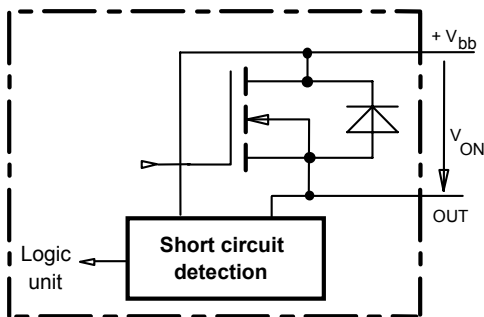
**Status output**



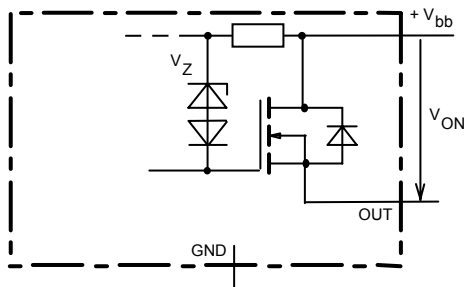
ESD-Zener diode: 6.1 V typ., max 5 mA;  
 $R_{ST(ON)} < 250 \Omega$  at 1.6 mA, ESD zener diodes are not designed for continuous current

**Short Circuit detection**

Fault Condition:  $V_{ON} > 8.3 \text{ V typ.};$  IN high

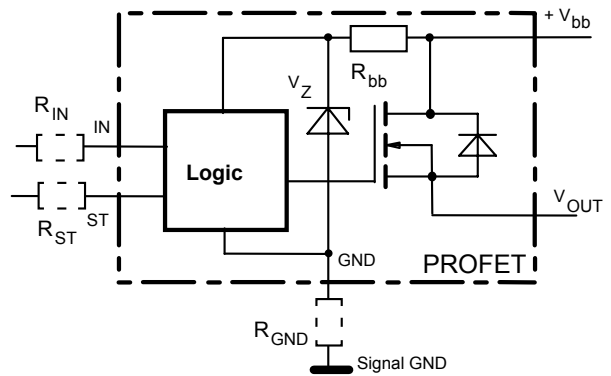


**Inductive and overvoltage output clamp**



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

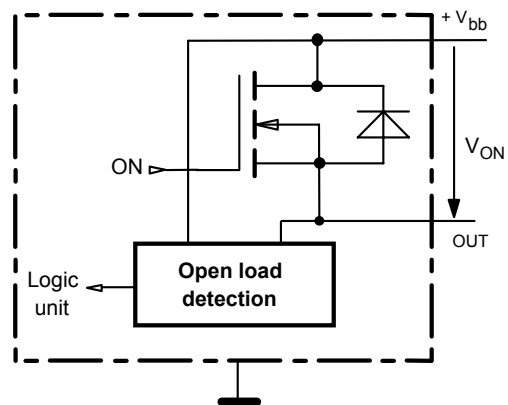
**Overvolt. and reverse batt. protection**



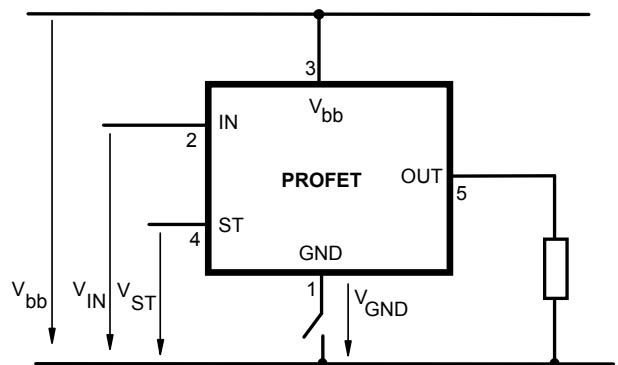
$R_{bb} = 120 \Omega$  typ.,  $V_Z + R_{bb} * 40 \text{ mA} = 67 \text{ V typ.}$ , add  $R_{GND}$ ,  $R_{IN}$ ,  $R_{ST}$  for extended protection

**Open-load detection**

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



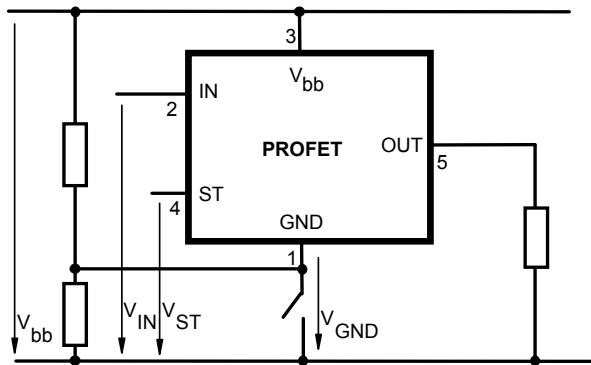
**GND disconnect**



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.

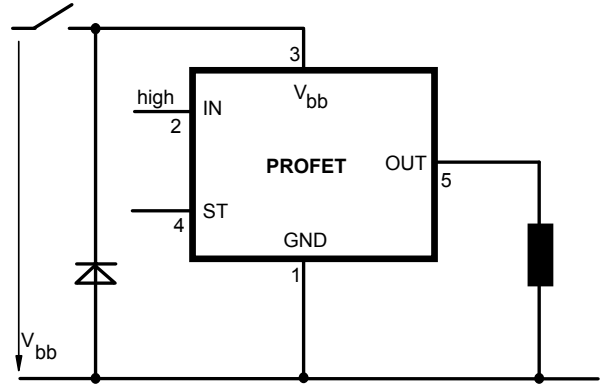
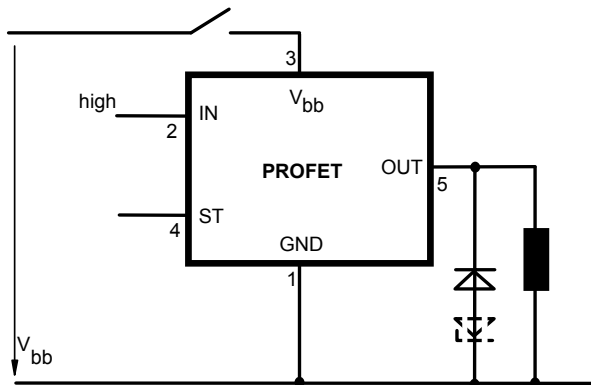


**GND disconnect with GND pull up**

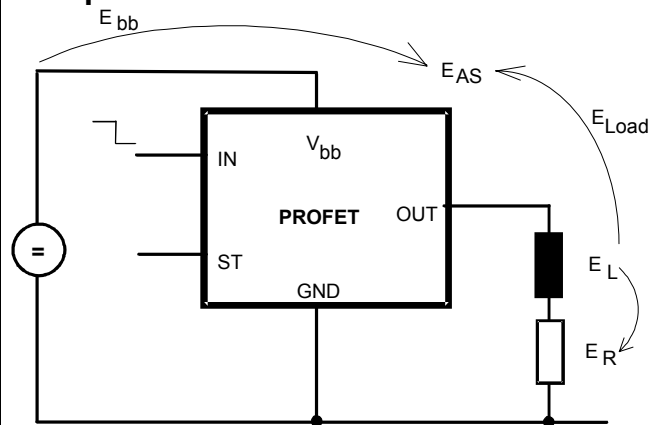


Any kind of load. If  $V_{GND} > V_{IN} - V_{IN(T+)}$  device stays off  
 Due to  $V_{GND} > 0$ , no  $V_{ST} = \text{low}$  signal available.

**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	<b>432E2</b>	432F2	432I2
Logic version		D	<b>E</b>	F	I
Overtemperature protection $T_j > 150\text{ °C}$ , latch function <sup>16)17)</sup> $T_j > 150\text{ °C}$ , with auto-restart on cooling		X	<b>X</b>	X	X
Short-circuit to GND protection switches off when $V_{ON} > 8.3\text{ V}$ typ. <sup>16)</sup> (when first turned on after approx. 200 $\mu\text{s}$ )		X	<b>X</b>	X	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	<b>X</b>	X	X
Undervoltage shutdown with auto restart		X	<b>X</b>	X	X
Overvoltage shutdown with auto restart		X	<b>X</b>	X	X
Status feedback for					
overtemperature		X	<b>X</b>	X	X
short circuit to GND		X	<b>X</b>	X	X
short to $V_{bb}$		- <sup>18)</sup>	<b>-18)</b>	- <sup>18)</sup>	X
open load		X	<b>X</b>	X	X
undervoltage		X	-	-	X
overvoltage		X	-	-	X
Status output type					
CMOS		X			X
Open drain			<b>X</b>	X	
Output negative voltage transient limit (fast inductive load switch off) to $V_{bb} - V_{ON(CL)}$		X	<b>X</b>	X	X
Load current limit					
high level (can handle loads with high inrush currents)		X	<b>X</b>		
medium level					X
low level (better protection of application)				X	

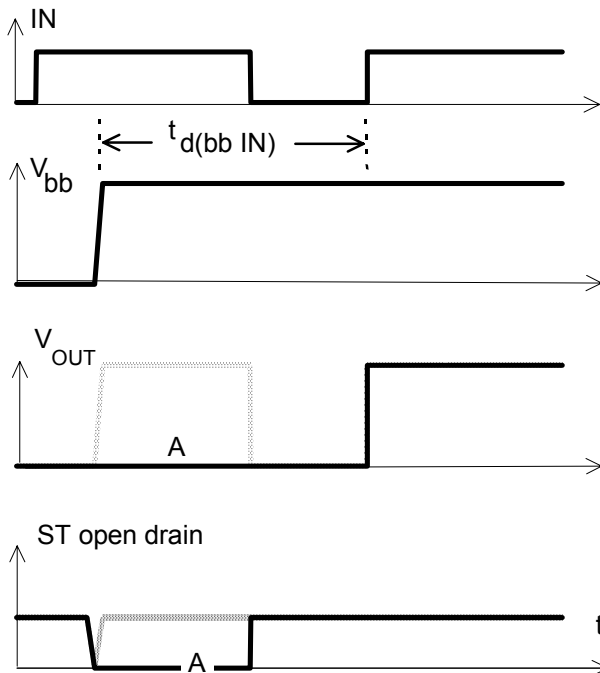
<sup>16)</sup> Latch except when  $V_{bb} - V_{OUT} < V_{ON(SC)}$  after shutdown. In most cases  $V_{OUT} = 0\text{ V}$  after shutdown ( $V_{OUT} \neq 0\text{ V}$  only if forced externally). So the device remains latched unless  $V_{bb} < V_{ON(SC)}$  (see page 4). No latch between turn on and  $t_{d(SC)}$ .

<sup>17)</sup> With latch function. Reseted by a) Input low, b) Undervoltage, c) Overvoltage

<sup>18)</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 a lamp,

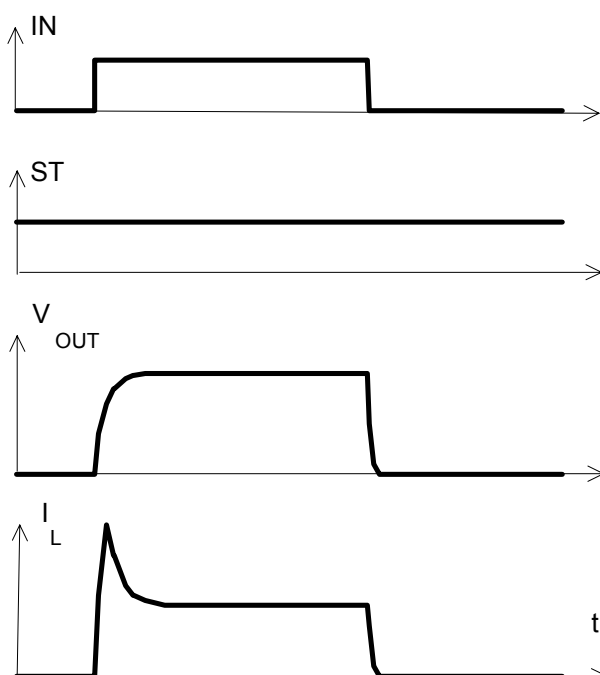
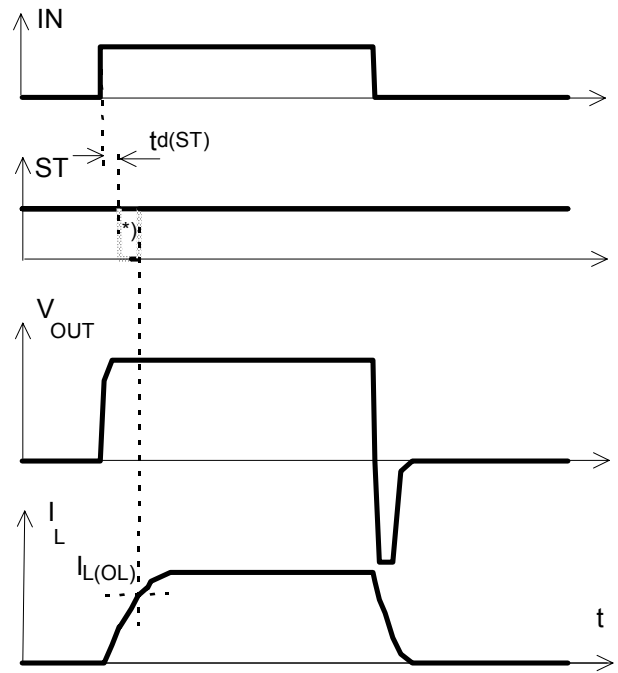
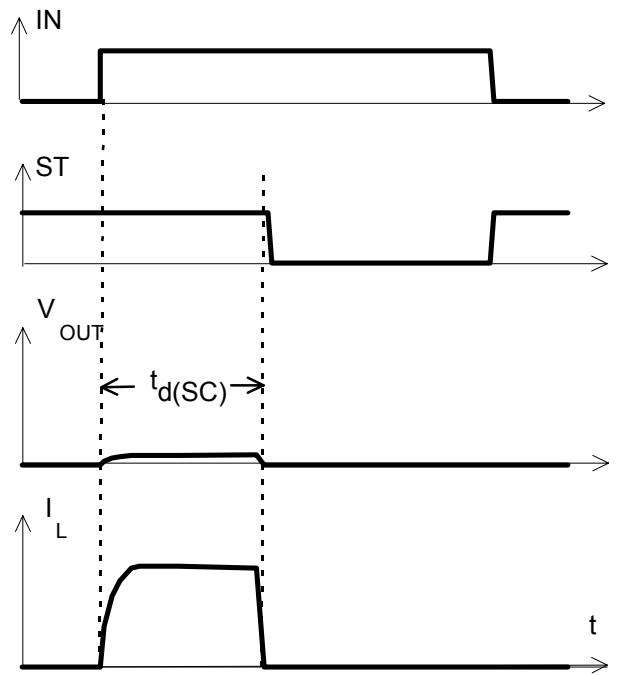


Figure 2b: Switching an inductive load



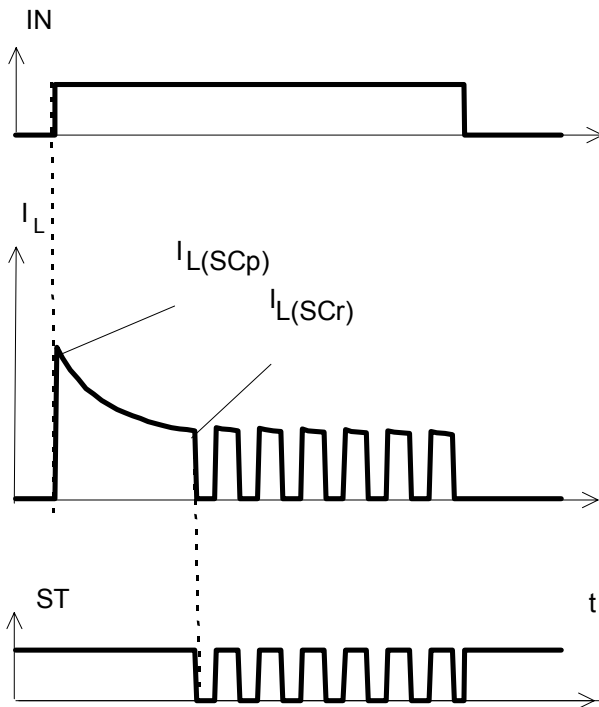
\*) if the time constant of load is too large, open-load-status may occur

Figure 3a: Turn on into short circuit,



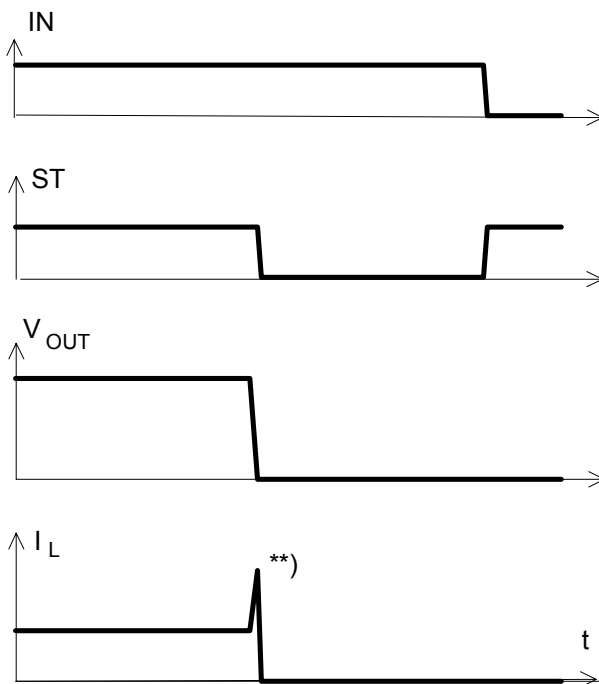
$t_{d(SC)}$  approx. 200 $\mu$ s if  $V_{bb} - V_{OUT} > 8.3$  V typ.

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



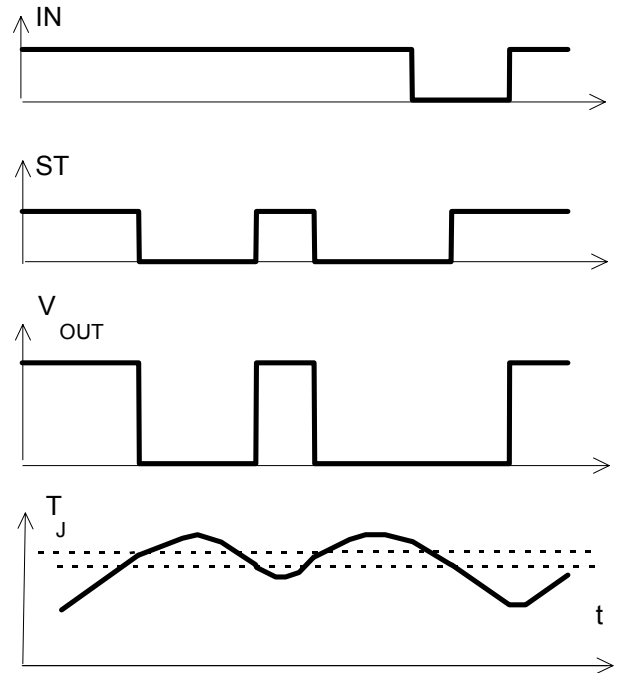
Heating up may require several milliseconds,  $V_{bb} - V_{OUT} < 8.3\text{ V}$  typ.

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

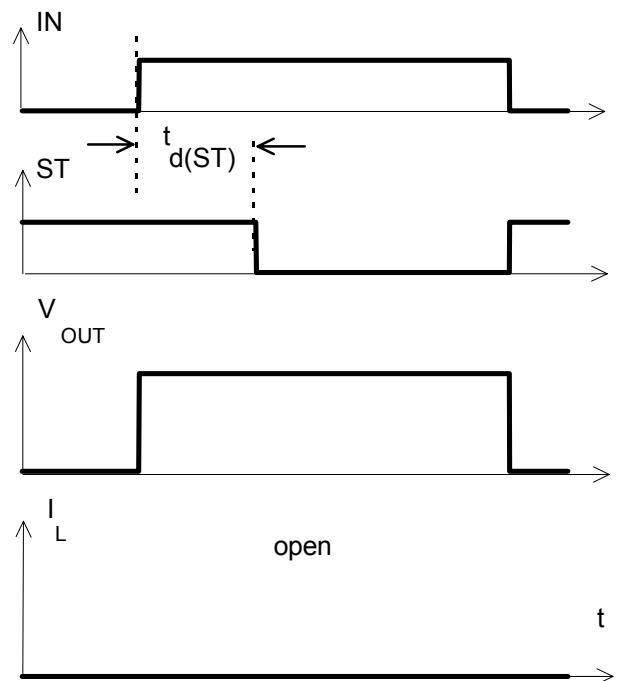


\*\* ) current peak approx. 20  $\mu\text{s}$

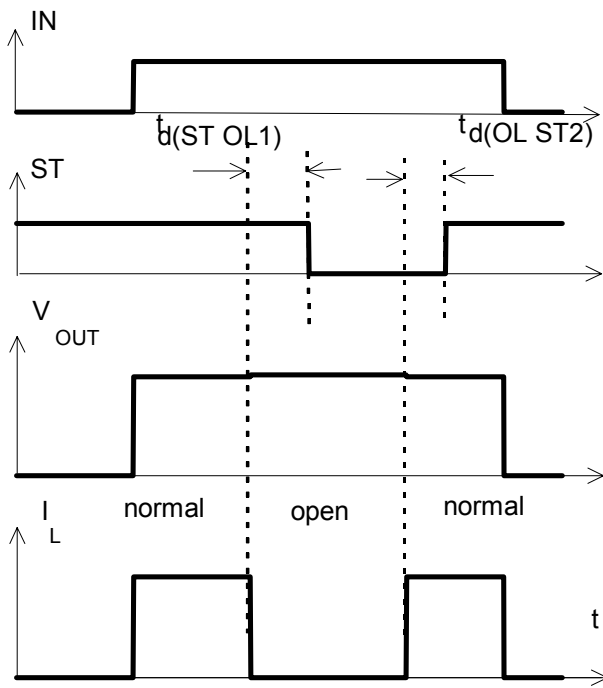
**Figure 4a:** Overtemperature:  
Reset if  $T_j < T_{jt}$



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

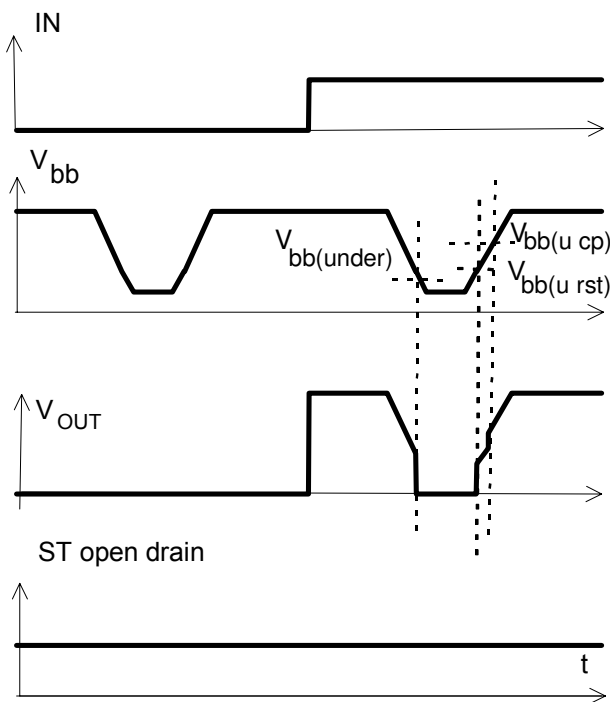


**Figure 5b:** Open load: detection in ON-state, open load occurs in on-state

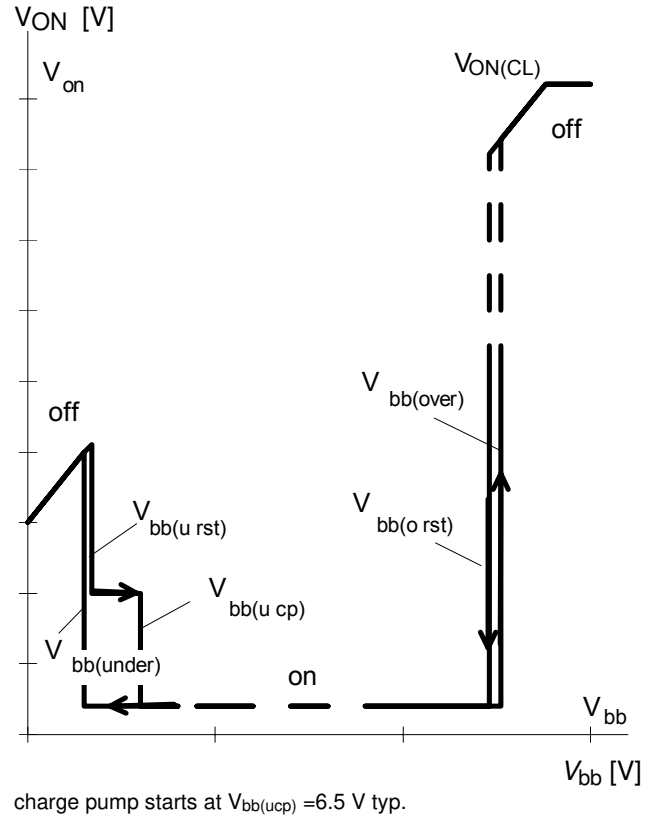


$t_d(ST OL1) = t_{bd} \mu s \text{ typ.}$ ,  $t_d(OL ST2) = t_{bd} \mu s \text{ typ.}$

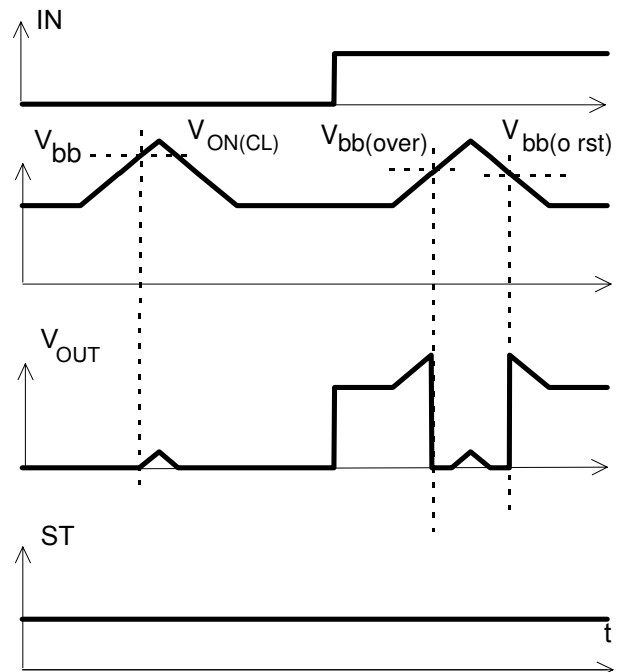
**Figure 6a:** Undervoltage:



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



**Figure 7a:** Overvoltage:



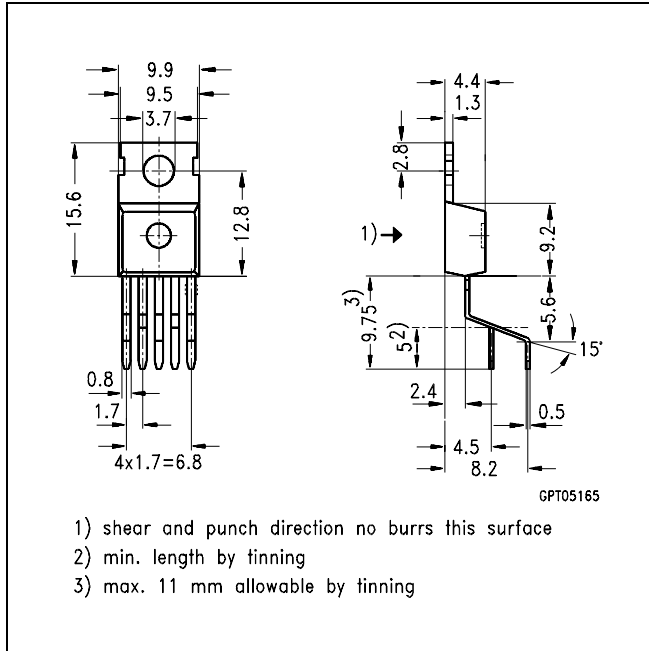
## Package and Ordering Code

All dimensions in mm

### Standard TO-220AB/5

Ordering code

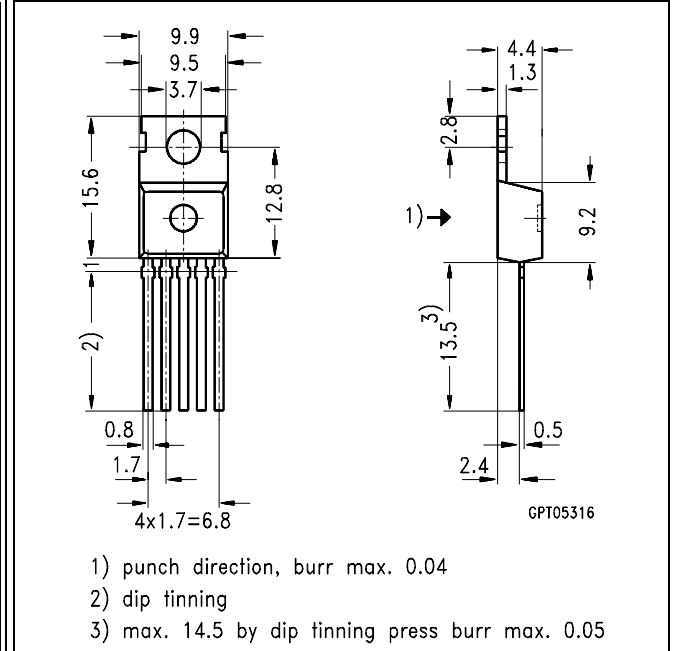
BTS 432 E2	Q67060-S6202-A2
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### TO-220AB/5, Option E3043

Ordering code

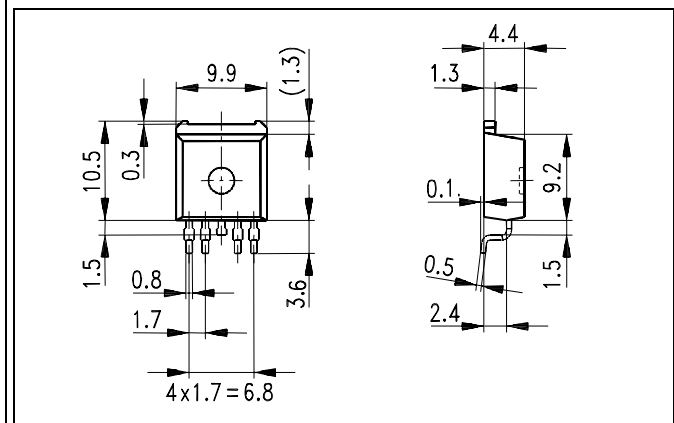
BTS 432 E2 E3043	Q67060-S6202-A4
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### SMD TO-220AB/5, Opt. E3062

Ordering code

BTS432E2 E3062A	T&R: Q67060-S6202-A6
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