

## Smart Highside Power Switch

### Features

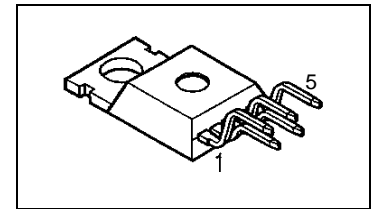
- Clamp of negative voltage at output
- Short-circuit protection
- Current limitation
- Thermal shutdown
- Diagnostic feedback
- Open load detection in ON-state
- CMOS compatible input
- **Electrostatic Discharge (ESD)** protection
- Loss of ground and loss of  $V_{bb}$  protection<sup>1)</sup>
- Reverse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

### Product Summary

$V_{bb}-V_{OUT}$ Avalanche Clamp	50	V
$V_{bb}$ (operation)	4.5 ... 32	V
$V_{bb}$ (reverse)	-32	V
$R_{ON}$	38	m $\Omega$
$I_L$ (lim)	36	A
$I_L$ (ISO)	11	A

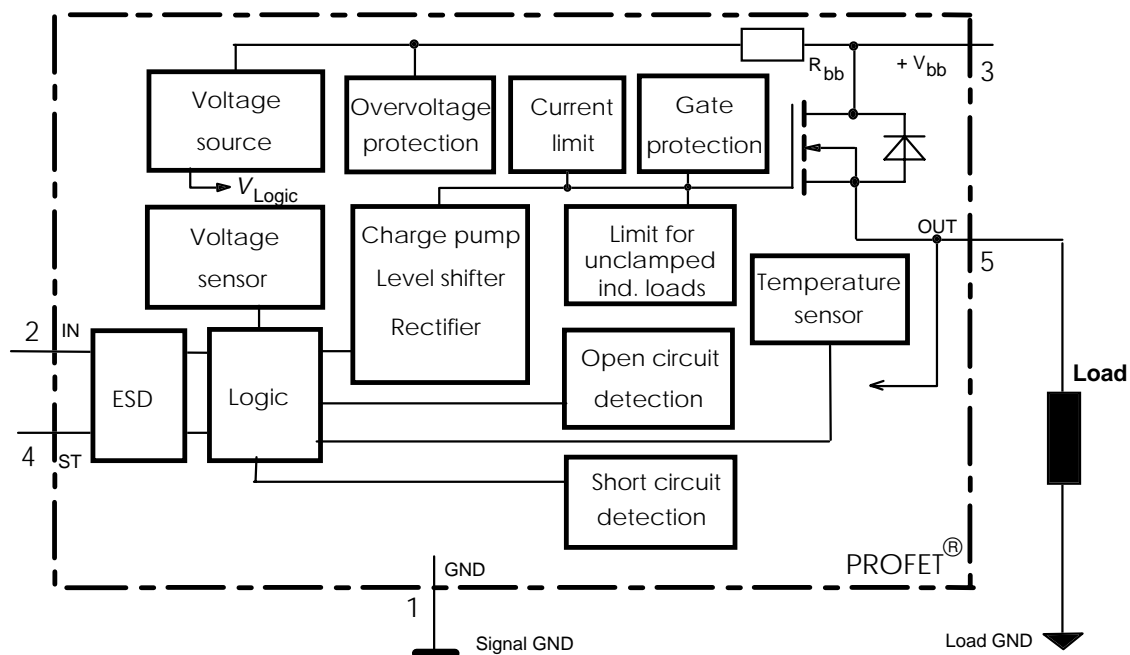
### Application

- $\mu$ 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 fault feedback, integrated in Smart SIPMOS<sup>®</sup> chip on chip technology. Fully protected by embedded protection functions.



1) 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>	54	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	E <sub>AS</sub>	1.7	J
Electrostatic discharge capability (ESD)	V <sub>ESD</sub>	2.0	kV
Input voltage (DC)	V <sub>IN</sub>	-10 ... +16	V
Current through input pin (DC)	I <sub>IN</sub>	±5.0	mA
Current through status pin (DC)	I <sub>ST</sub>	±5.0	
see internal circuit diagrams page 6...			
Thermal resistance	chip - case: R <sub>thJC</sub> chip - ambient: R <sub>thJA</sub>	≤ 1 ≤ 75	K/W

## 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, see diagram page 7		$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time to 90% $V_{OUT}$ :		$t_{on}$	50	160	260	$\mu s$
Turn-off time to 10% $V_{OUT}$ :		$t_{off}$	10	--	60	
Slew rate on 10 to 30% $V_{OUT}$ , $R_L = 12\ \Omega$		$dV/dt_{on}$	0.4	--	2	$V/\mu s$
Slew rate off 70 to 40% $V_{OUT}$ , $R_L = 12\ \Omega$		$-dV/dt_{off}$	1	--	4	$V/\mu s$

## Operating Parameters

Operating voltage $T_j = -40\dots+150\text{ °C}$ :	$V_{bb(on)}$	4.5	--	32	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	$V_{bb(ucp)}$	--	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 $T_j = -40\dots+150\text{ °C}$ :	$V_{bb(over)}$	32	--	46	V
Overvoltage restart $T_j = -40\dots+150\text{ °C}$ :	$V_{bb(o\ rst)}$	32	--	--	V
Overvoltage hysteresis $T_j = -40\dots+150\text{ °C}$ :	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection <sup>2)</sup> $I_{bb} = 4\text{ mA}$	$V_{bb(AZ)}$	50	57	--	V
Standby current (pin 3) $V_{IN} = 0$	$I_{bb(off)}$				$\mu A$
	$T_j = -40\dots+25\text{ °C}$ :	--	12	25	
	$T_j = 150\text{ °C}$ :	--	18	60	
Operating current (Pin 1) <sup>3)</sup> , $V_{IN} = 5$	$I_{GND}$	--	1.1	--	mA

<sup>2)</sup> see also  $V_{ON(CL)}$  in table protection functions and circuit diagram page 7. Measured without load.

<sup>3)</sup> Add  $I_{ST}$ , if  $I_{ST} > 0$

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

### Protection Functions

Overload current limit (pin 3 to 5) $T_j = -40\dots+150\text{ °C}$	$I_{L(\text{lim})}$	19	36	57	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(\text{SC})}$ , min value valid only, if input "low" time exceeds 30 $\mu\text{s}$ $T_j = -40\dots+150\text{ °C}$ :	$t_{d(\text{SC})}$	80	--	400	$\mu\text{s}$
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(\text{CL})}$	$V_{ON(\text{CL})}$	--	50	--	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(\text{SC})}$	--	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>4)</sup> , $T_{j\text{ Start}} = 150\text{ °C}$	$E_{AS}$	--	--	1.7	J
$V_{bb} = 12\text{ V}$ :	$E_{\text{Load}12}$			1.3	
$V_{bb} = 24\text{ V}$ :	$E_{\text{Load}24}$			1.0	
Reverse battery (pin 3 to 1) <sup>5)</sup>	$-V_{bb}$	--	--	32	V
Integrated resistor in $V_{bb}$ line	$R_{bb}$	--	120	--	$\Omega$



### Diagnostic Characteristics

Open load detection current (on-condition, )	$T_j = 25\dots150\text{ °C}$ : $T_j = -40\text{ °C}$ :	$I_{L(\text{OL})}$	10 10	-- --	500 600	mA
Leakage output current (off-condition)		$I_{L(\text{off})}$	--	6	--	$\mu\text{A}$

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

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

5) 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>6)</sup></b>					
Input resistance see circuit page 6	$R_I$	--	10	--	$k\Omega$
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 valid after input slope (short circuit) $T_j = -40 \dots +150\text{ °C}$ :	$t_{d(ST\ SC)}$	80	200	400	$\mu\text{s}$
Status valid after 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	6.9	V
ST low voltage $T_j = -40\dots+150\text{ °C}$ , $I_{ST} = +1.6\text{ mA}$ :	$V_{ST(low)}$	--	--	0.4	V
Status voltage while $V_{bb} < 2.4\text{ V}$ $I_{ST} = 500\text{ }\mu\text{A}$ $T_j = 25 \dots +150\text{ °C}$ : $T_j = 40\text{ °C}$ :	$V_{ST}$	--	--	1.0 1.2	V

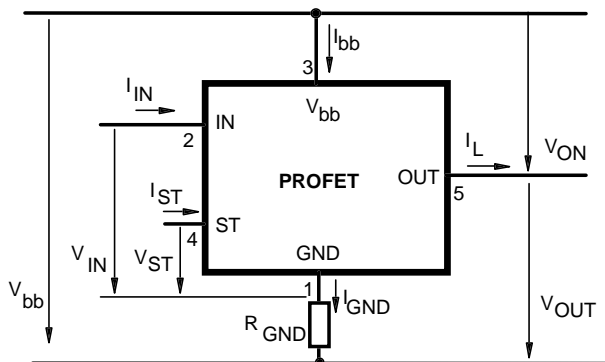
<sup>6)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor. Internal Z-diode typ. 6.1 V, see maximum ratings page 2, circuit page 7

## Truth Table

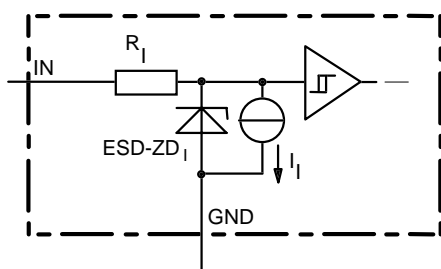
	Input-level	Output level	Status			
			432 D2	432 E2/F2	432 I2	430 K2
Normal operation	L	L	H	H	H	H
	H	H	H	H	H	H
Open load	L	7)	H	H	L	H
	H	H	L	L	H	L
Short circuit to GND	L	L	H	H	H	8)
	H	L	L	L	L	L
Short circuit to V <sub>bb</sub>	L	H	H	H	L	H
	H	H	H (L <sup>9</sup> )	H (L <sup>9</sup> )	H	H (L <sup>9</sup> )
Overtemperature	L	L	L	L	L	L
	H	L	L	L	L	L
Undervoltage	L	L	L <sup>10</sup>	H	L <sup>10</sup>	L <sup>11</sup>
	H	L	L <sup>10</sup>	H	L <sup>10</sup>	L <sup>11</sup>
Overvoltage	L	L	L	H	L	L
	H	L	L	H	L	L

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

## Terms

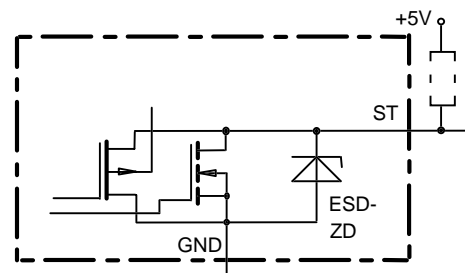


## Input circuit (ESD protection)



ESD zener diodes are not designed for continuous current

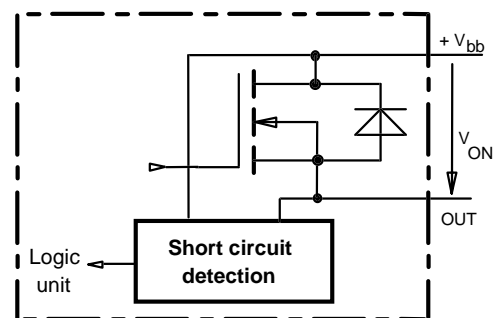
## Status output



ESD zener diodes are not designed for continuous current

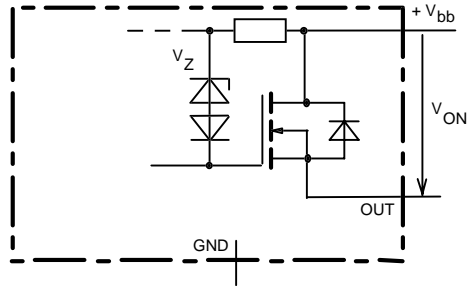
## Short Circuit detection

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



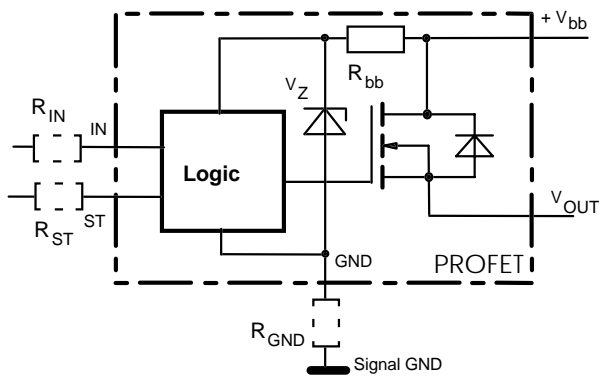
- 7) Power Transistor off, high impedance
- 8) The short circuit signal from last ON state is latched until next turn-on, see timing diagram page 10
- 9) Low resistance short  $V_{bb}$  to output may be detected by no-load-detection
- 10) No current sink capability during undervoltage shutdown
- 11) Current sink capability see page 5

## Inductive and overvoltage output clamp



$V_{ON}$  clamped to 50 V typ.

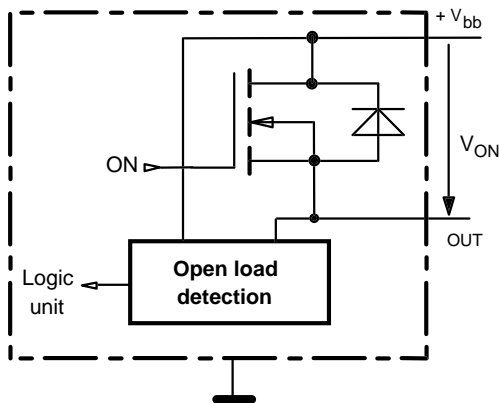
## Overvolt. and reverse batt. protection



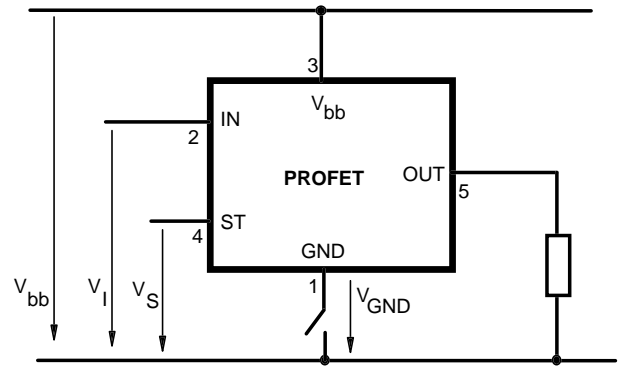
$R_{bb}$  120  $\Omega$  typ.,  $V_Z$  57 V typ., add  $R_{GND}$ ,  $R_{IN}$ ,  $R_{ST}$  for extended protection

## Open-load detection

Fault Condition:  $V_{ON} < R_{ON} \cdot I_{L(OL)}$ ; IN high

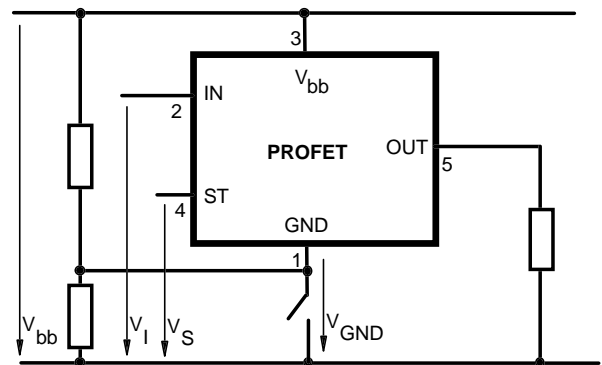


## GND disconnect



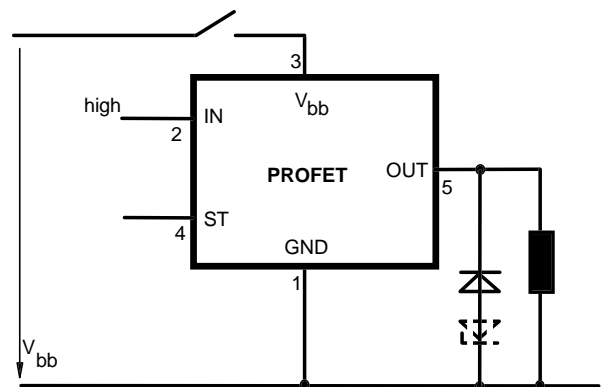
Any kind of load. In case of Input=high  $V_{OUT} \approx V_I - V_{IN(T+)}$   
Due to  $V_{GND} > 0$ , no  $V_S = \text{low}$  signal available.

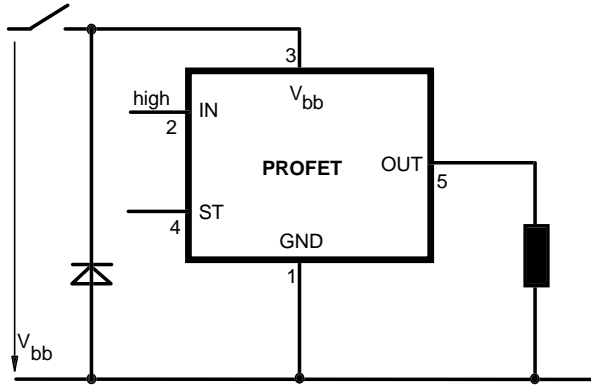
## GND disconnect with GND pull up



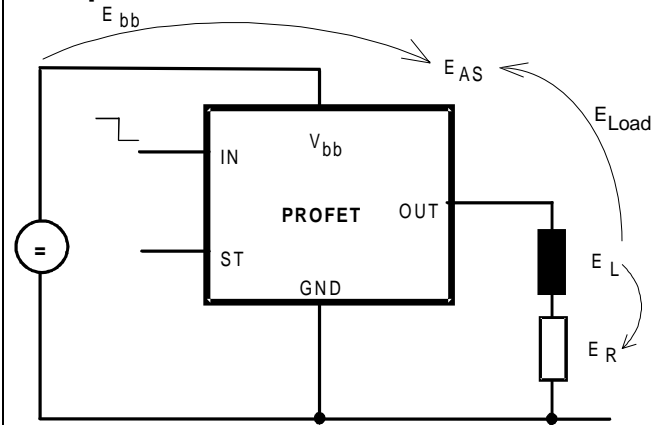
Any kind of load. If  $V_{GND} > V_I - V_{IN(T+)}$  device stays off  
Due to  $V_{GND} > 0$ , no  $V_S = \text{low}$  signal available.

## 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**

Type	BTS	432D2	432E2	432F2	432I2	430K2
Logic version	D	E	F	I	K	
Overtemperature protection $T_j > 150\text{ °C}$ , latch function <sup>12)13)</sup> $T_j > 150\text{ °C}$ , with auto-restart on cooling	X		X	X		X
Short-circuit to GND protection switches off when $V_{ON} > 8.3\text{ V}$ typ. <sup>12)</sup> (when first turned on after approx. 200 $\mu\text{s}$ )	X	X	X	X	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	X	X		X	X
Undervoltage shutdown with auto restart	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
short circuit to GND	X	X	X	X	X	X <sup>15)</sup>
short to $V_{bb}$	- <sup>14)</sup>	- <sup>14)</sup>	- <sup>14)</sup>	X	X	- <sup>14)</sup>
open load	X	X	X	X	X	X
undervoltage	X	-	-	X	X	X
overvoltage	X	-	-	X	X	X
Status output type						
CMOS	X				X	
Open drain		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
Load current limit						
high level (can handle loads with high inrush currents)	X	X				
medium level				X	X	X
low level (better protection of application)			X			

<sup>12)</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  $t_{d(SC)}$ .

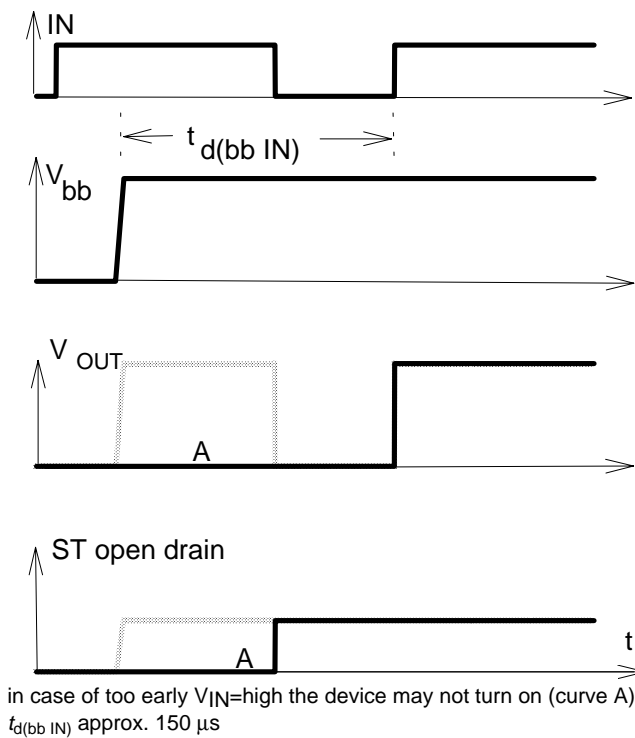
<sup>13)</sup> With latch function. Reseted by a) Input low, b) Undervoltage, c) Overvoltage

<sup>14)</sup> Low resistance short  $V_{bb}$  to output may be detected by no-load-detection

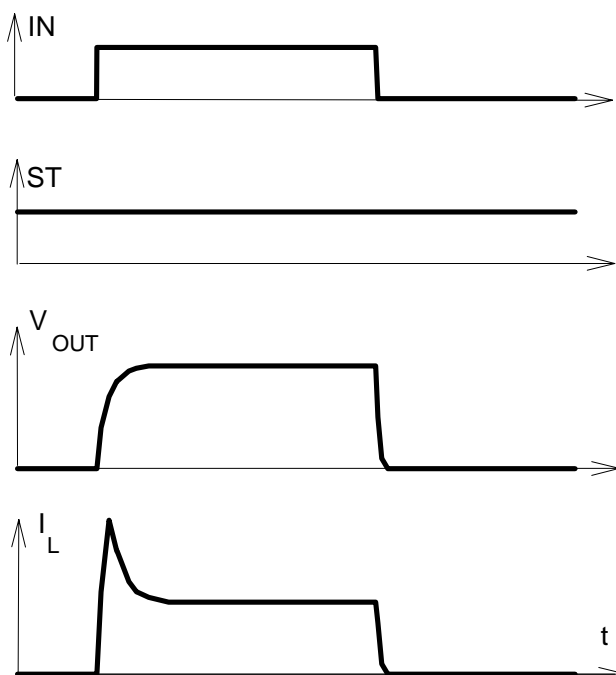
<sup>15)</sup> with status latch until next turn on

## Timing diagrams

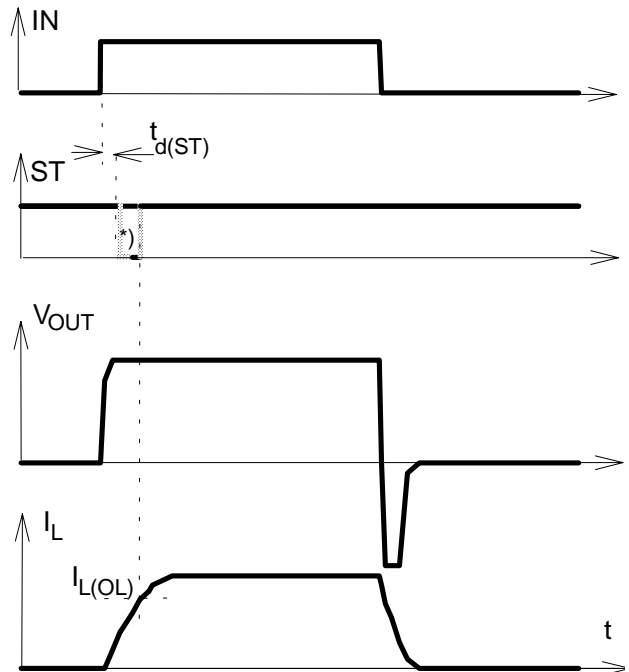
**Figure 1a:**  $V_{bb}$  turn on, :



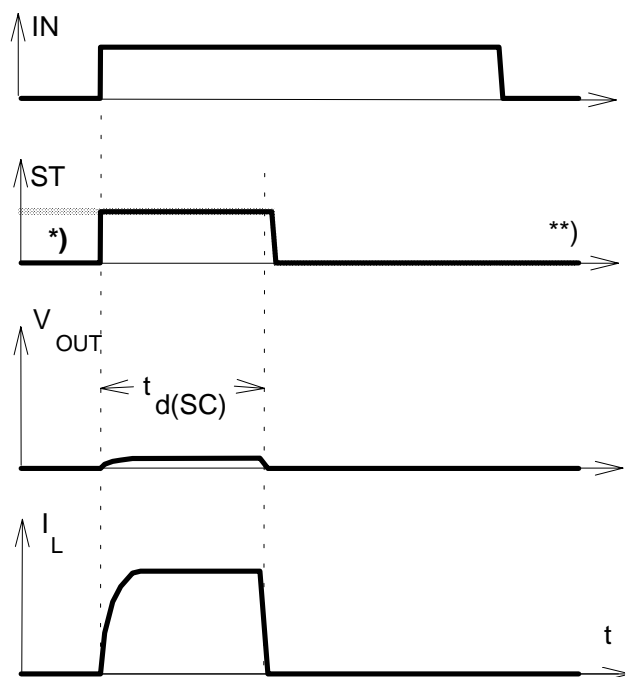
**Figure 2a:** Switching a lamp,



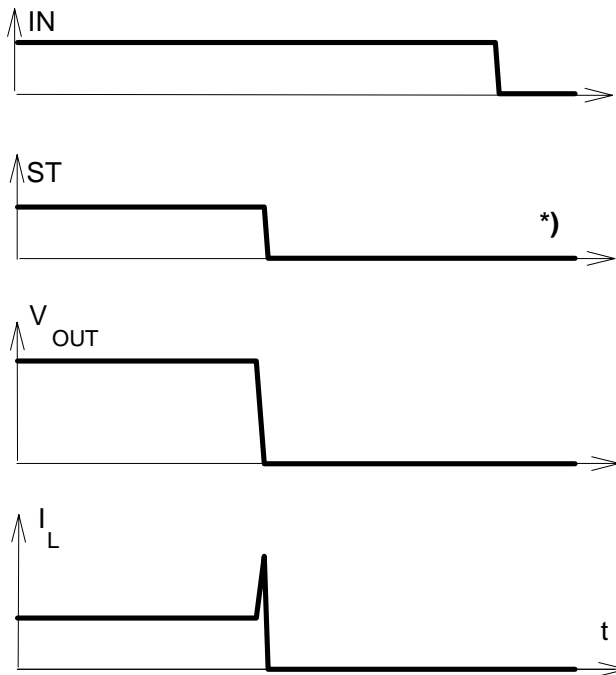
**Figure 2b:** Switching an inductive load



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



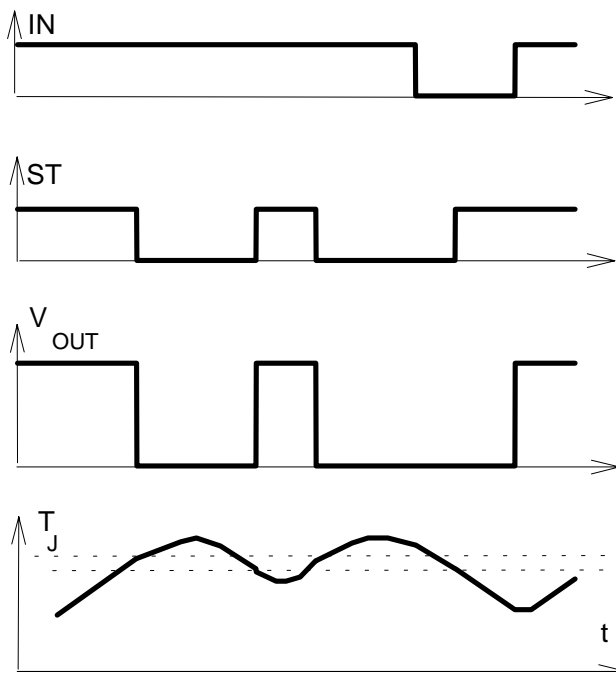
**Figure 3b:** Short circuit while on:



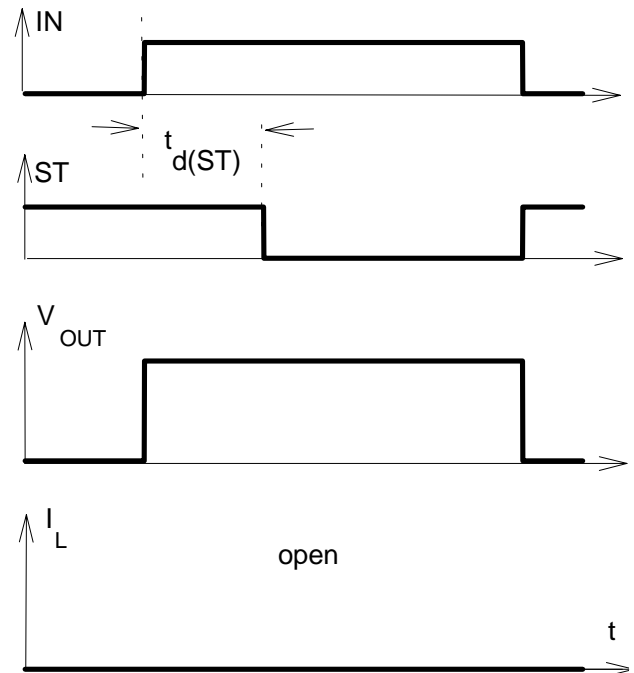
\*) error signal latched until next turn on

**Figure 4a:** Overtemperature:

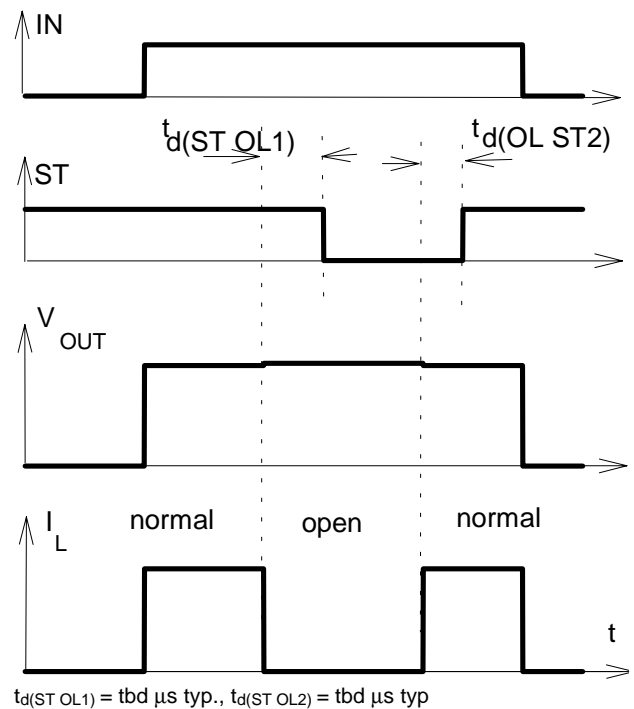
Reset if  $T_j < T_{jt}$



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

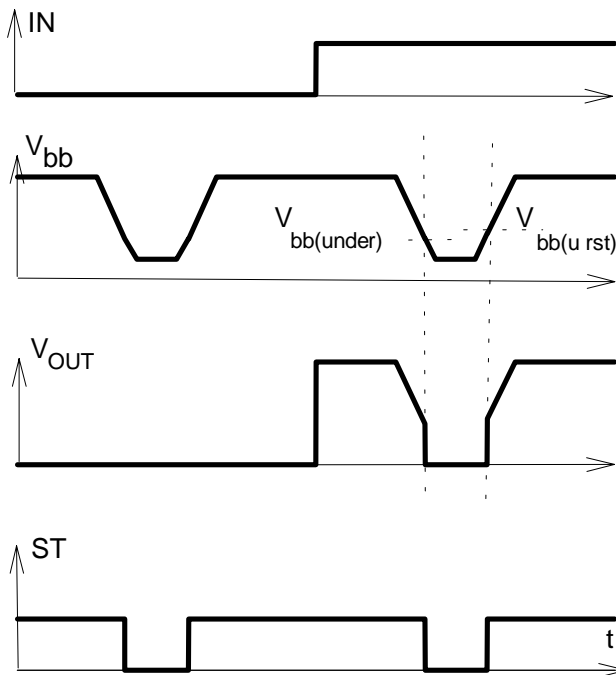


**Figure 5b:** Open load: detection in ON-state, open load occurs in on-state

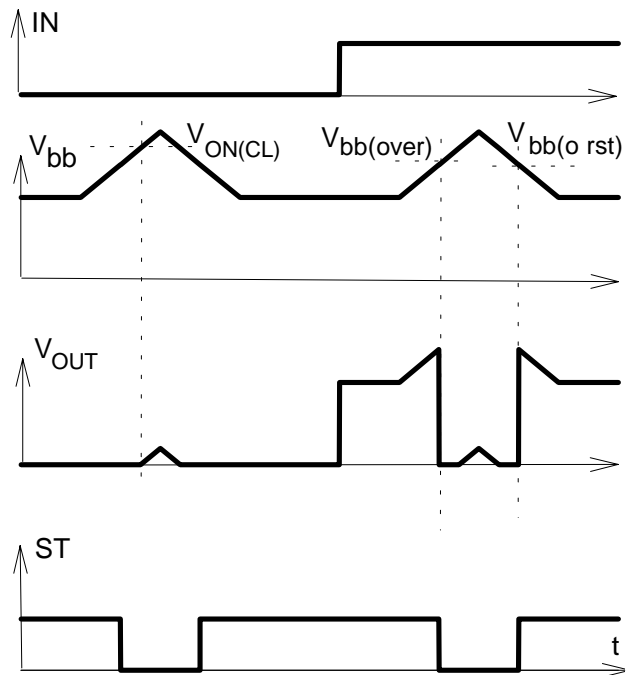


$t_{d(ST OL1)} = t_{bd} \mu s \text{ typ.}, t_{d(OL ST2)} = t_{bd} \mu s \text{ typ.}$

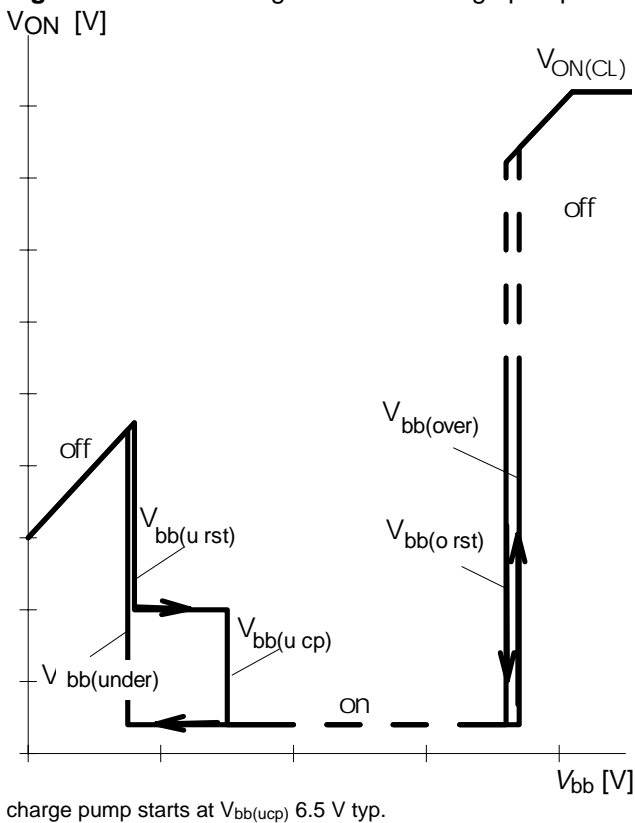
**Figure 6a: Undervoltage:**



**Figure 7a: Overvoltage:**



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

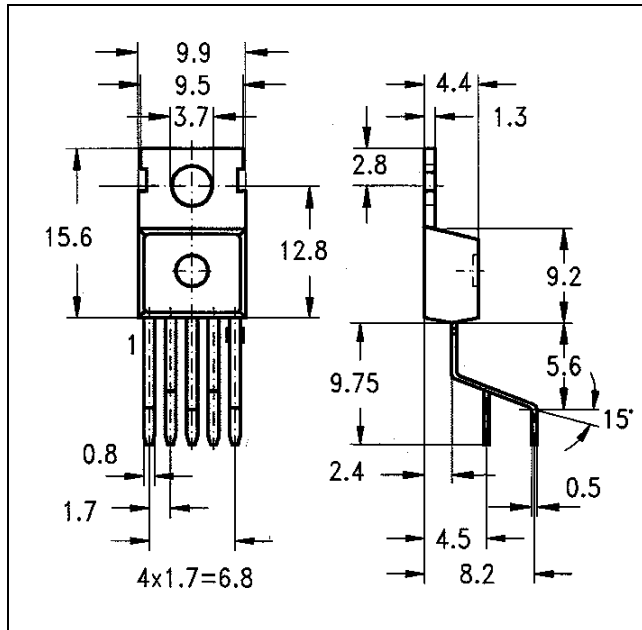


### Package and Ordering Code

All dimensions in mm

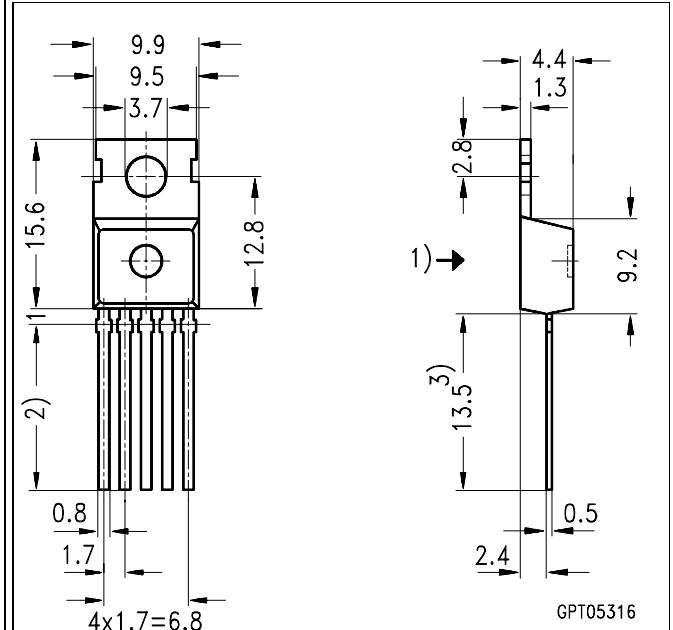
**Standard TO-220 AB/5**      Ordering code

BTS430K2	Q67060-S6200-A2
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**TO-220 AB/5, OPTION E3043**      Ordering code

BTS430K2 E3043	Q67060-S6200-A3
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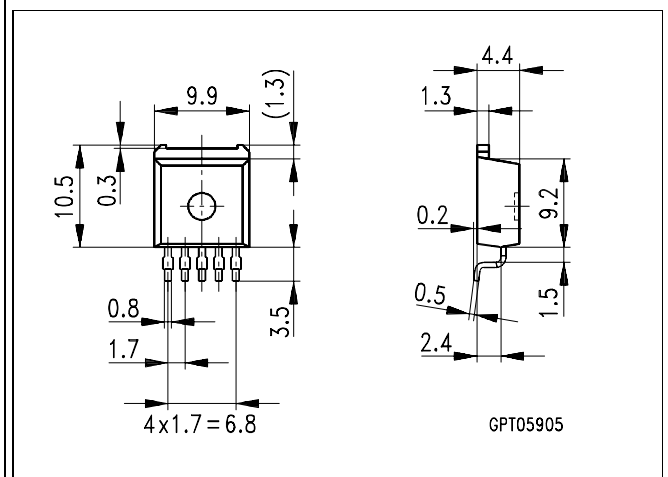


- 1) punch direction, burr max. 0.04
- 2) dip finning
- 3) max. 14.5 by dip finning press burr max. 0.05

### SMD TO-220 AB/5, OPTION E3122

Ordering code

BTS430K2 E3122A	T&R: Q67060-S6200-A4
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**Changed since 04/96**

Case E3122A drawing changed