

## Smart Highside Power Switch

### Features

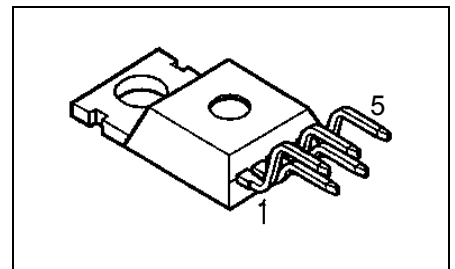
- Clamp of negative voltage at output
- Short-circuit protection
- Current limitation
- Thermal shutdown
- Diagnostic feedback
- Open load detection in ON-state
- CMOS compatible input
- **Electrostatic Discharge (ESD)** protection
- Loss of ground and loss of  $V_{bb}$  protection<sup>1)</sup>
- Reverse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

### 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

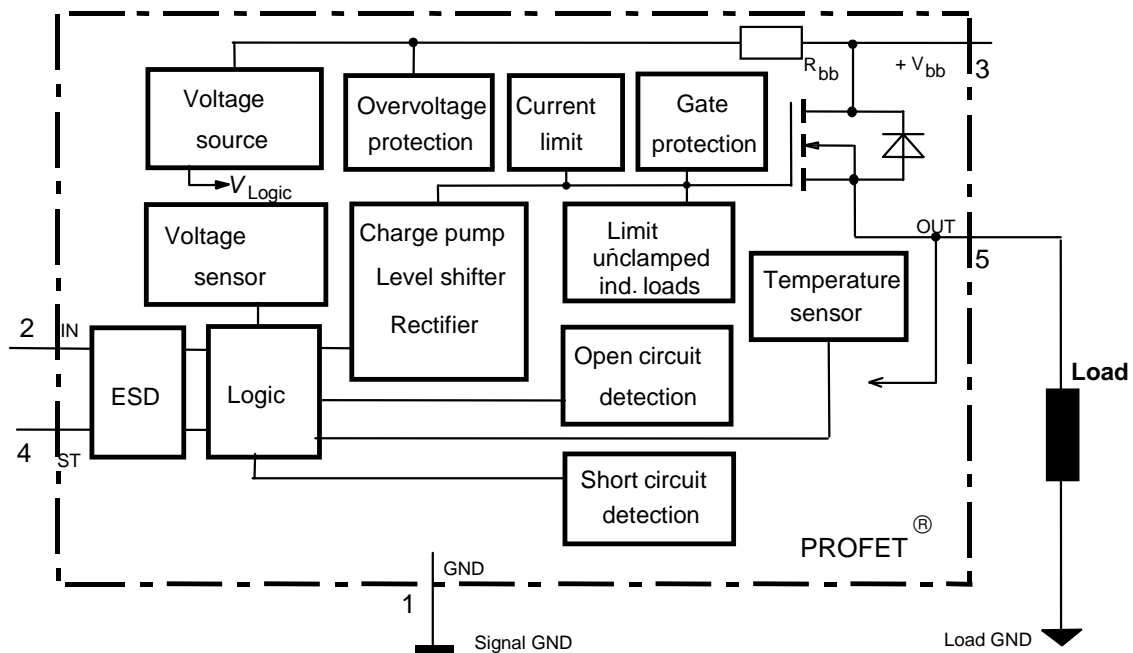
### Product Summary

$V_{bb} - V_{OUT}$ 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



### General Description

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



<sup>1)</sup> 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>	≤ 1	K/W
	chip - ambient: R <sub>thJA</sub>	≤ 75	

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

### Operating Parameters

Operating voltage $T_j = -40\text{...}+150\text{ °C}$ :	$V_{bb(on)}$	4.5	--	32	V
Undervoltage shutdown $T_j = -40\text{...}+150\text{ °C}$ :	$V_{bb(under)}$	2.4	--	4.5	V
Undervoltage restart $T_j = -40\text{...}+150\text{ °C}$ :	$V_{bb(u\text{ rst})}$	--	--	4.5	V
Undervoltage restart of charge pump see diagram page 11	$V_{bb(ucp)}$	--	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 $T_j = -40\text{...}+150\text{ °C}$ :	$V_{bb(over)}$	32	--	46	V
Overvoltage restart $T_j = -40\text{...}+150\text{ °C}$ :	$V_{bb(o\text{ rst})}$	32	--	--	V
Overvoltage hysteresis $T_j = -40\text{...}+150\text{ °C}$ :	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection <sup>2)</sup> $I_{bb} = 4\text{ mA}$	$V_{bb(AZ)}$	50	57	--	V
Standby current (pin 3) $V_{IN} = 0$	$I_{bb(off)}$	--	12 18	25 60	μA
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	
<b>Protection Functions<sup>4)</sup></b>					
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>5)</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>6)</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) 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.

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

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

6) 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>7)</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	
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	
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

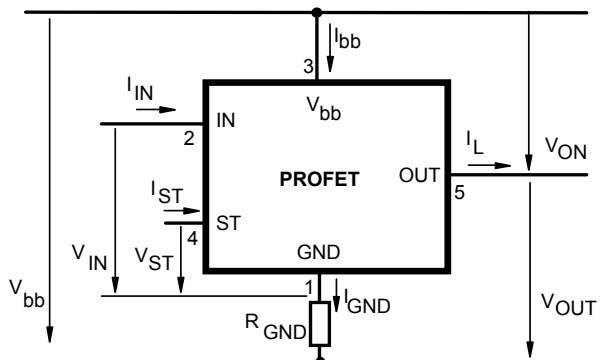
<sup>7)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor. Internal Z-diode typ. 6.1 V, see maximum ratings page 2, circuit page 7

**Truth Table**

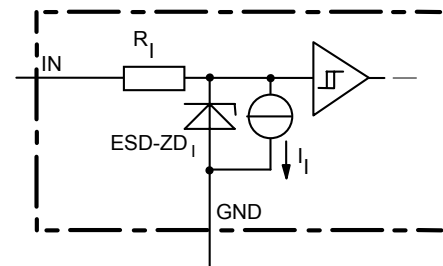
	Input-level	Output level	Status			
			432 D2	432 E2/F2	432 I2	430 K2
Normal operation	L	L	H	H	H	H
	H	H	H	H	H	H
Open load	L	8)	H	H	L	H
	H	H	L	L	H	L
Short circuit to GND	L	L	H	H	H	9)
	H	L	L	L	L	L
Short circuit to V <sub>bb</sub>	L	H	H	H	L	H
	H	H	H (L <sup>10</sup> )	H (L <sup>10</sup> )	H	H (L <sup>10</sup> )
Overtemperature	L	L	L	L	L	L
	H	L	L	L	L	L
Under-voltage	L	L	L <sup>11)</sup>	H	L <sup>11)</sup>	L <sup>12)</sup>
	H	L	L <sup>11)</sup>	H	L <sup>11)</sup>	L <sup>12)</sup>
Overvoltage	L	L	L	H	L	L
	H	L	L	H	L	L

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

**Terms**



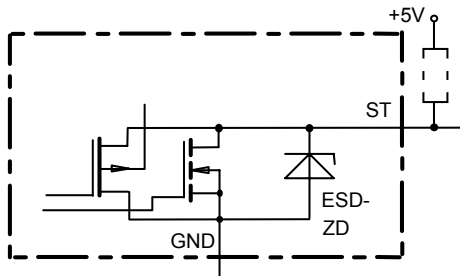
**Input circuit (ESD protection)**



ESD zener diodes are not designed for continuous current

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

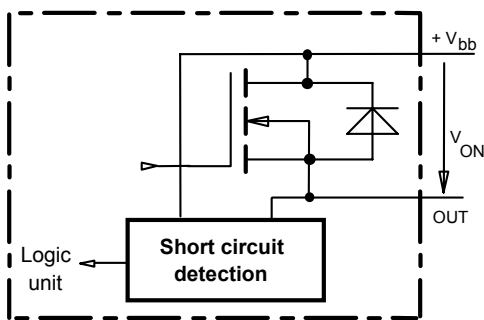
**Status output**



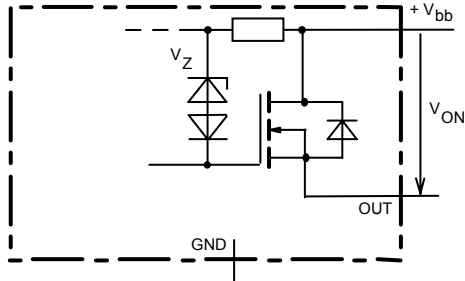
ESD zener diodes are not designed for continuous current

**Short Circuit detection**

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

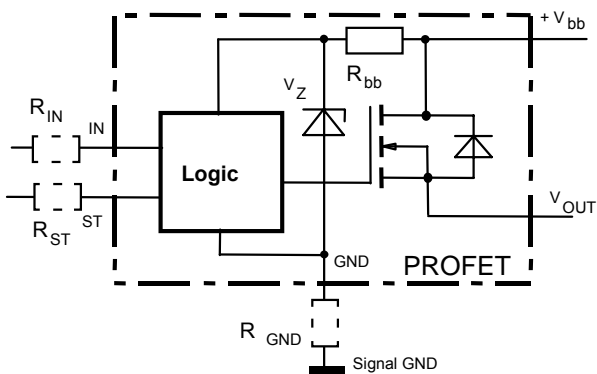


**Inductive and overvoltage output clamp**



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

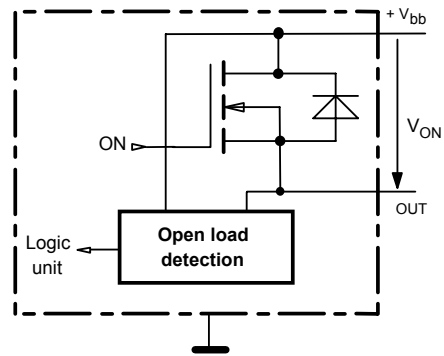
**Overvolt. and reverse batt. protection**



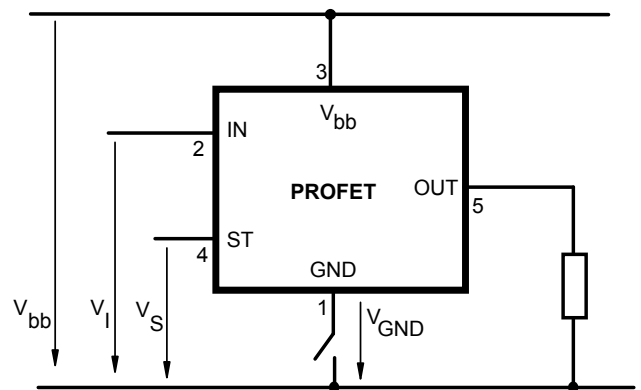
$R_{bb}$  120  $\Omega$  typ.,  $V_z$  57 V typ., , add  $R_{GND}$ ,  $R_{IN}$ ,  $R_{ST}$  for extended protection

**Open-load detection**

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

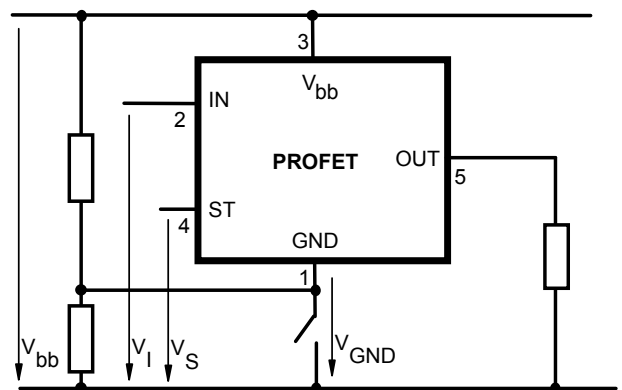


**GND disconnect**



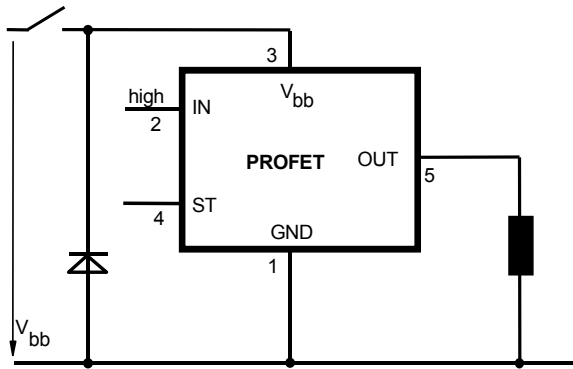
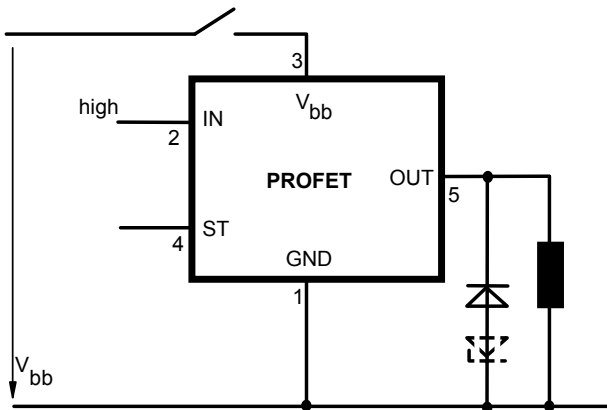
Any kind of load. In case of Input=high  $V_{OUT} \approx V_I - V_{IN(T+)}$   
Due to  $V_{GND} > 0$ , no  $V_S = \text{low signal}$  available.

**GND disconnect with GND pull up**

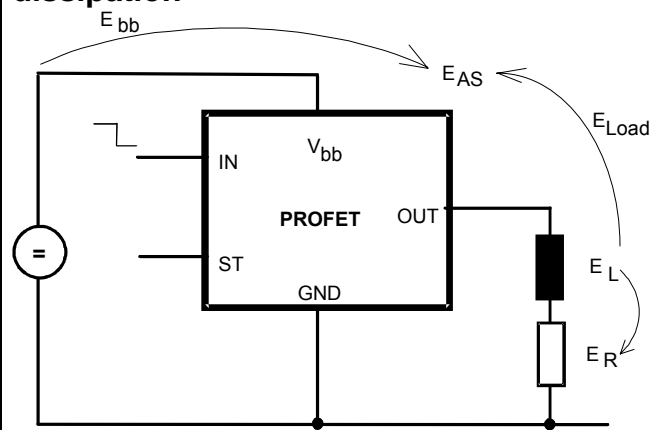


Any kind of load. If  $V_{GND} > V_I - V_{IN(T+)}$  device stays off  
Due to  $V_{GND} > 0$ , no  $V_S = \text{low signal}$  available.

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



**Inductive Load switch-off energy dissipation**



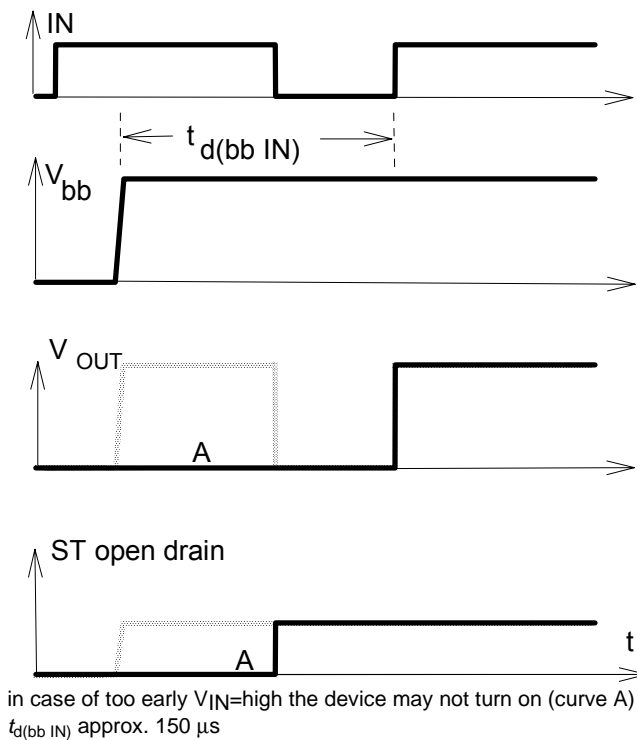
Energy dissipated in PROFET  $E_{AS} = E_{bb} + E_L - E_R$ .

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

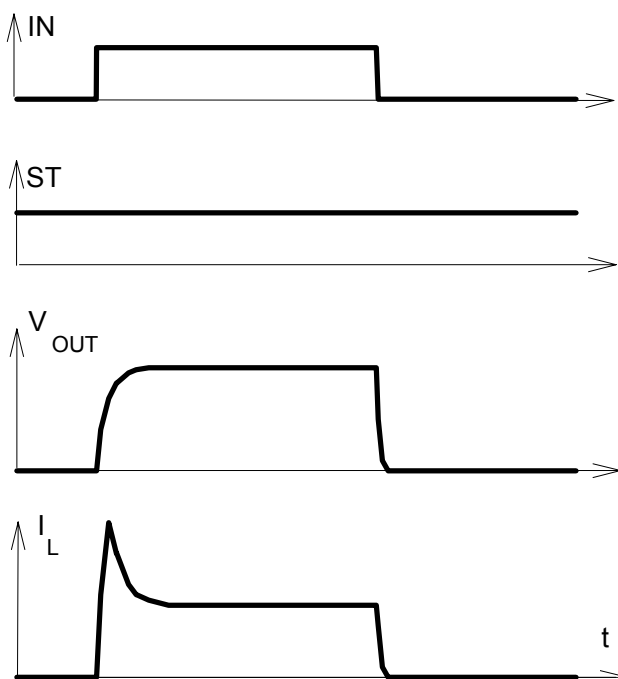


# Timing diagrams

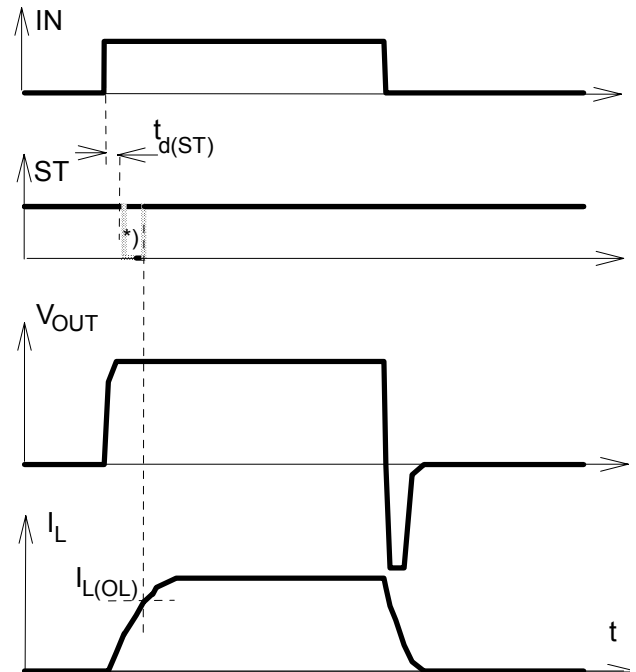
**Figure 1a:**  $V_{bb}$  turn on, :



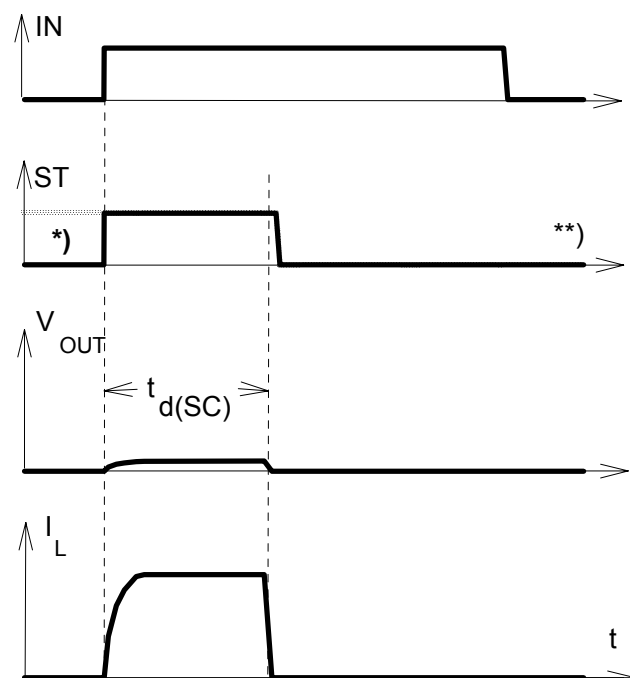
**Figure 2a:** Switching a lamp,



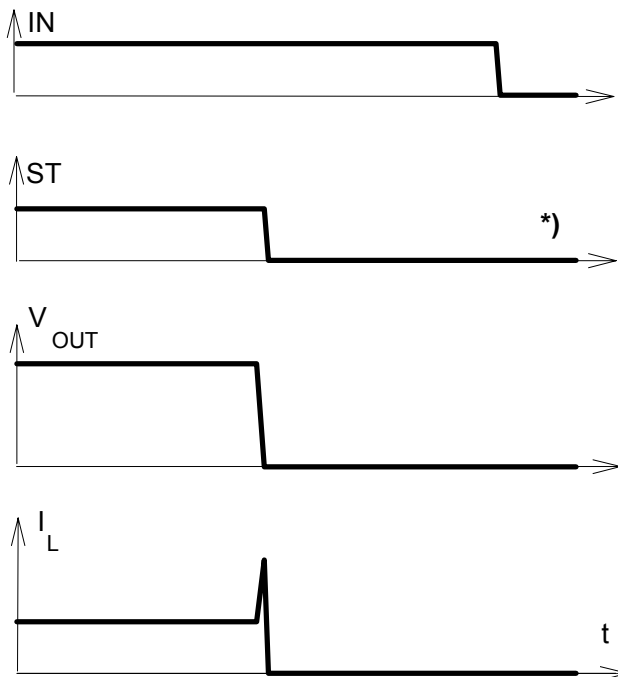
**Figure 2b:** Switching an inductive load



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

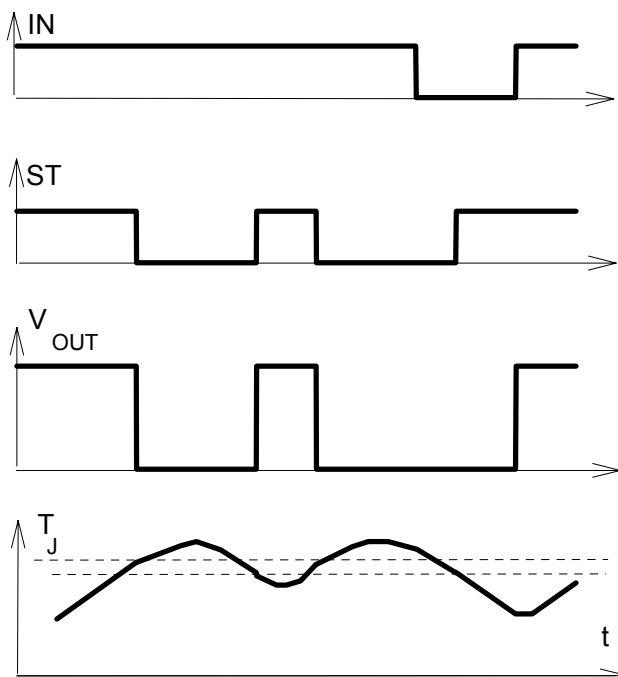


**Figure 3b:** Short circuit while on:

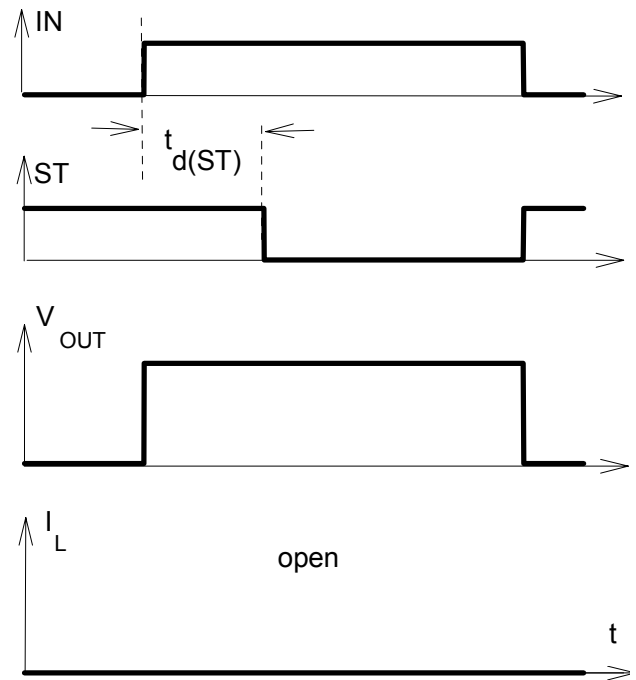


\*) error signal latched until next turn on

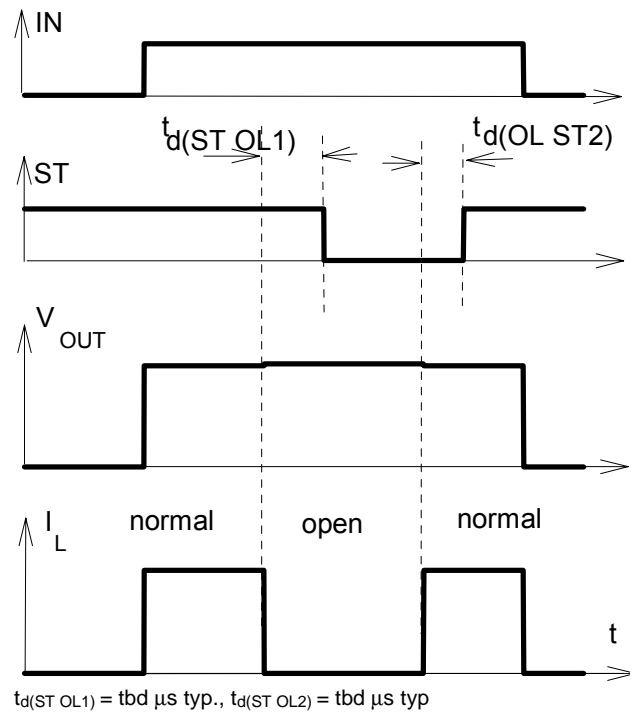
**Figure 4a:** Overtemperature:  
Reset if  $T_j < T_{jt}$



**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



$t_{d(ST OL1)} = t_{bd} \mu s \text{ typ.}$ ,  $t_{d(ST OL2)} = t_{bd} \mu s \text{ typ}$

Figure 6a: Undervoltage:

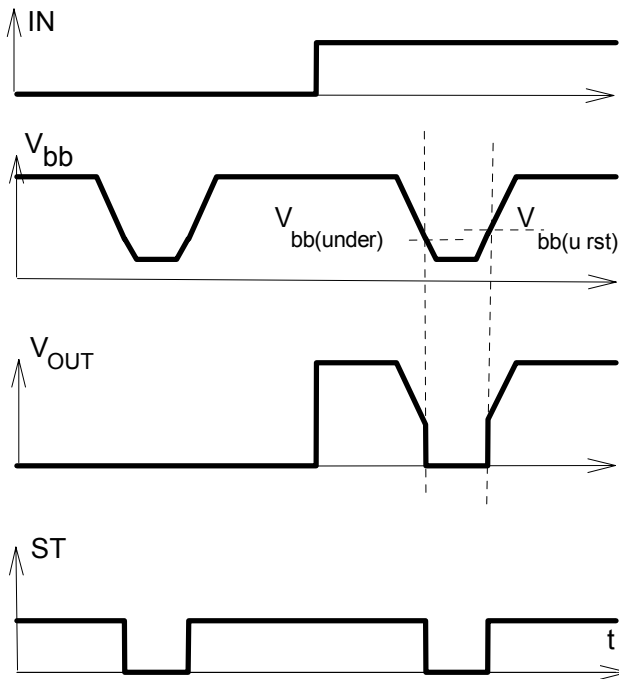


Figure 7a: Overvoltage:

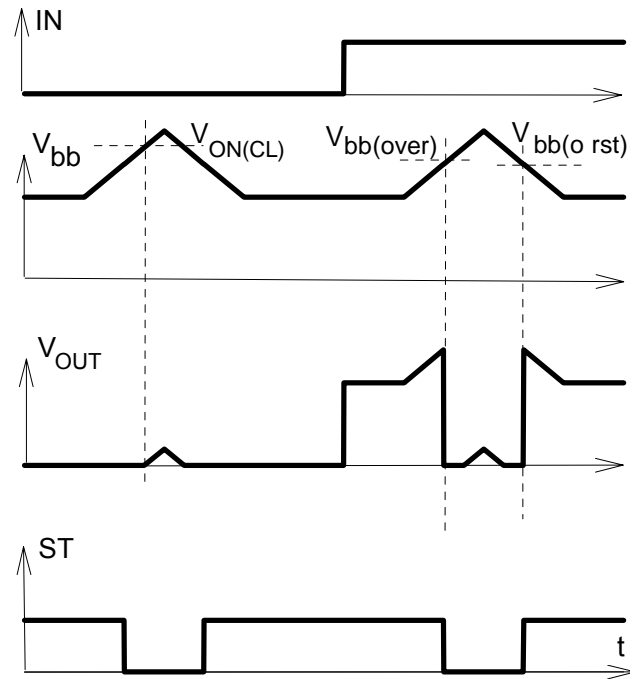
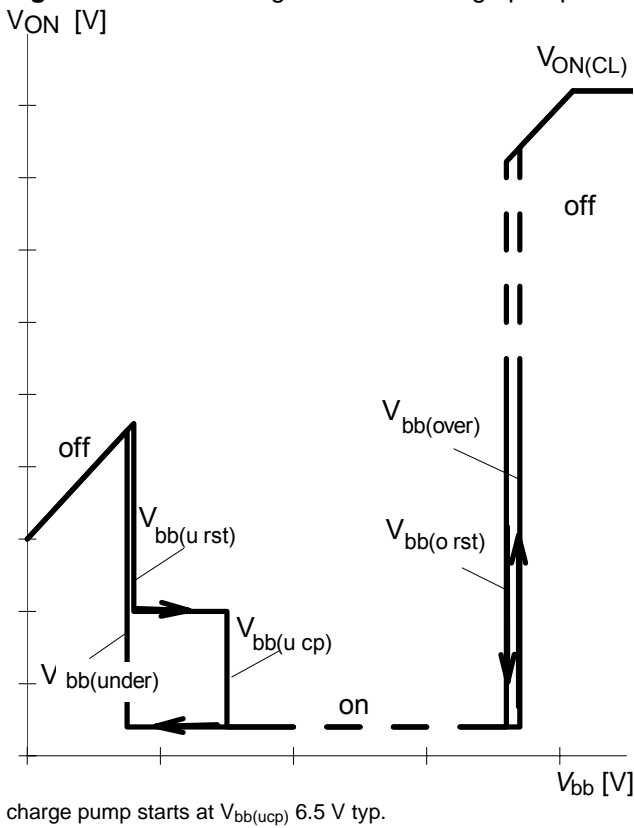


Figure 6b: Undervoltage restart of charge pump

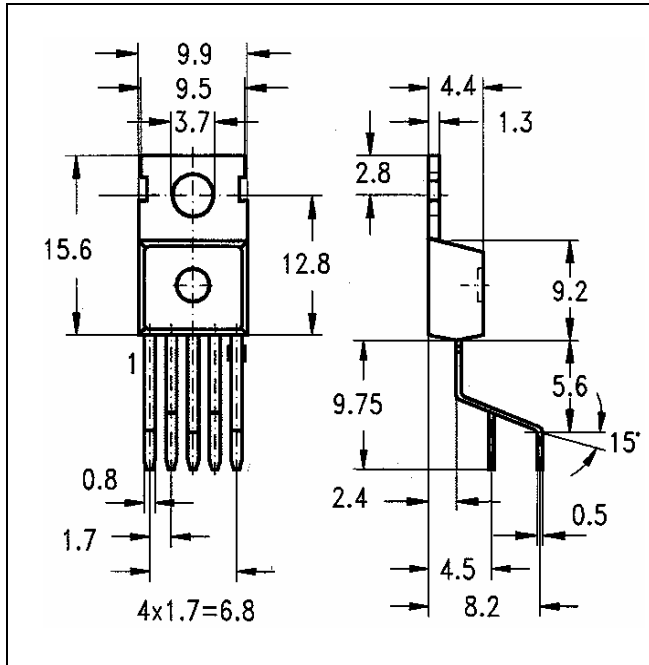


**Package and Ordering Code**

All dimensions in mm

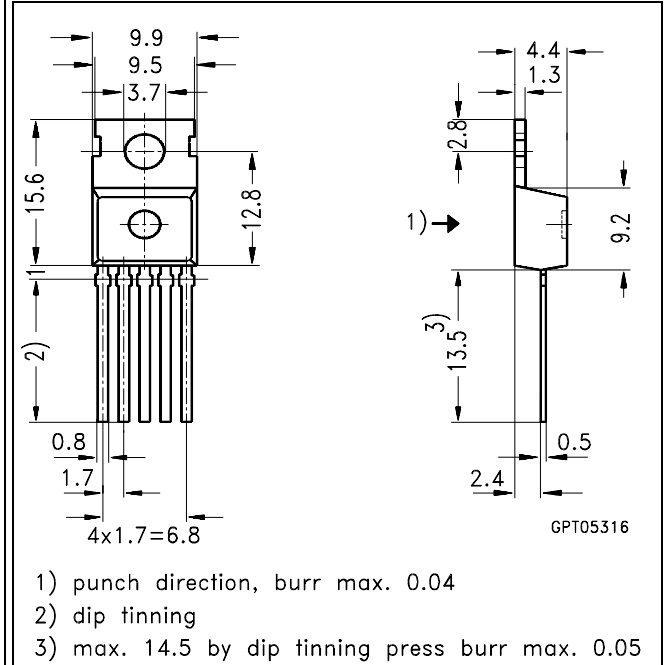
**Standard TO-220 AB/5** Ordering code

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

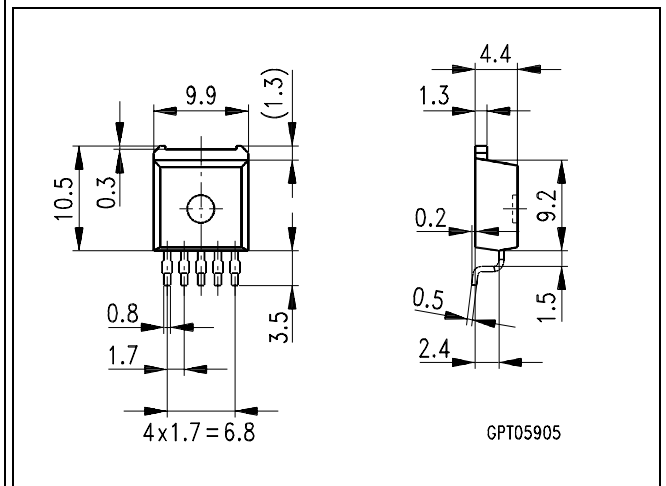
BTS430K2 E3043	Q67060-S6200-A3
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**SMD TO-220 AB/5, OPTION E3122**

Ordering code

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

Case E3122A drawing changed

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