

Smart Highside Power Switch

Features

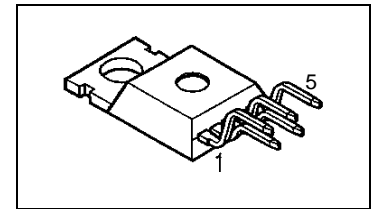
- Clamp of negative voltage at output
- Short-circuit protection
- Current limitation
- Thermal shutdown
- Diagnostic feedback
- Open load detection in ON-state
- CMOS compatible input
- **Electrostatic Discharge (ESD)** protection
- Loss of ground and loss of V_{bb} protection¹⁾
- Reverse battery protection
- 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 Ω
I_L (lim)	36	A
I_L (ISO)	11	A

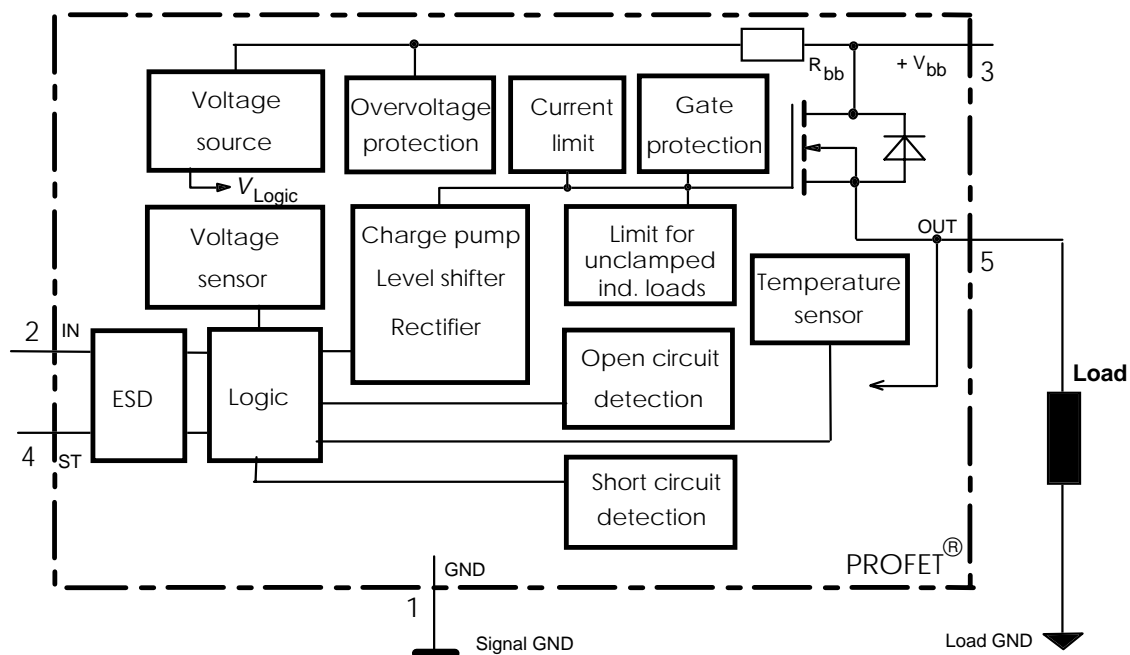
Application

- μ 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[®] 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 _{bb}	+	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 °C unless otherwise specified

Parameter	Symbol	Values	Unit	
Supply voltage (overvoltage protection see page 3)	V _{bb}	54	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	E _{AS}	1.7	J	
Electrostatic discharge capability (ESD)	V _{ESD}	2.0	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: chip - ambient:	R _{thJC} R _{thJA}	≤ 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	μs
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 ²⁾ $I_{bb} = 4\text{ mA}$	$V_{bb(AZ)}$	50	57	--	V
Standby current (pin 3) $V_{IN} = 0$	$I_{bb(off)}$				μA
	$T_j = -40\dots+25\text{ °C}$:	--	12	25	
	$T_j = 150\text{ °C}$:	--	18	60	
Operating current (Pin 1) ³⁾ , $V_{IN} = 5$	I_{GND}	--	1.1	--	mA

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

³⁾ 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 μs $T_j = -40\dots+150\text{ °C}$:	$t_{d(\text{SC})}$	80	--	400	μs
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	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Inductive load switch-off energy dissipation ⁴⁾ , $T_{j\text{ Start}} = 150\text{ °C}$	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) ⁵⁾	$-V_{bb}$	--	--	32	V
Integrated resistor in V_{bb} line	R_{bb}	--	120	--	Ω



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	--	μA

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	
Input and Status Feedback⁶⁾					
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	μA
On state input current (pin 2) $V_{IN} = 3.5\text{ V}$:	$I_{IN(on)}$	10	25	50	μA
Status valid after input slope (short circuit) $T_j = -40 \dots +150\text{ °C}$:	$t_{d(ST\ SC)}$	80	200	400	μs
Status valid after input slope (open load) $T_j = -40 \dots +150\text{ °C}$:	$t_{d(ST)}$	350	--	1600	μs
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

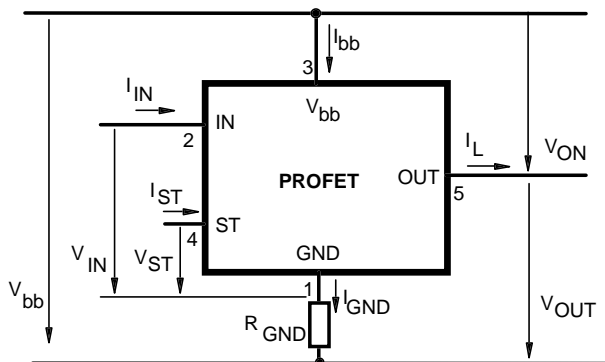
⁶⁾ If a ground resistor R_{GND} is used, add the voltage drop across this resistor. Internal Z-diode typ. 6.1 V, see maximum ratings page 2, circuit page 7

Truth Table

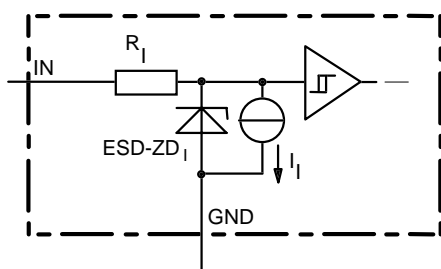
	Input-level	Output level	Status			
			432 D2	432 E2/F2	432 I2	430 K2
Normal operation	L	L	H	H	H	H
	H	H	H	H	H	H
Open load	L	7)	H	H	L	H
	H	H	L	L	H	L
Short circuit to GND	L	L	H	H	H	8)
	H	L	L	L	L	L
Short circuit to V _{bb}	L	H	H	H	L	H
	H	H	H (L ⁹)	H (L ⁹)	H	H (L ⁹)
Overtemperature	L	L	L	L	L	L
	H	L	L	L	L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

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

Terms

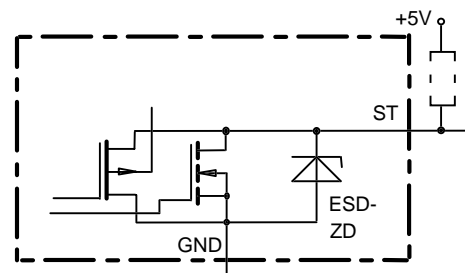


Input circuit (ESD protection)



ESD zener diodes are not designed for continuous current

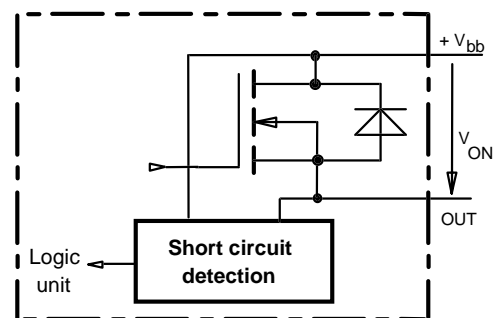
Status output



ESD zener diodes are not designed for continuous current

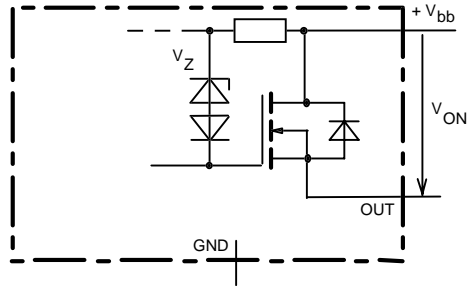
Short Circuit detection

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



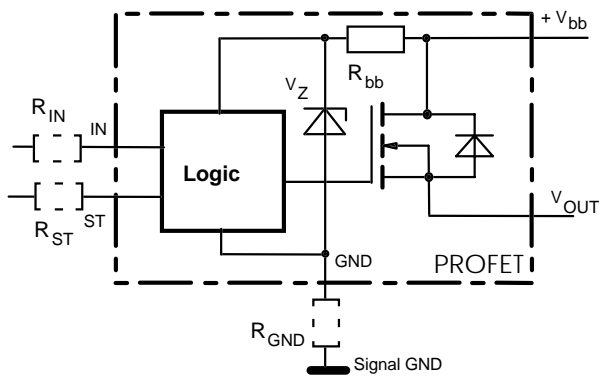
- 7) Power Transistor off, high impedance
- 8) The short circuit signal from last ON state is latched until next turn-on, see timing diagram page 10
- 9) Low resistance short V_{bb} to output may be detected by no-load-detection
- 10) No current sink capability during undervoltage shutdown
- 11) Current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

Inductive and overvoltage output clamp



V_{ON} clamped to 50 V typ.

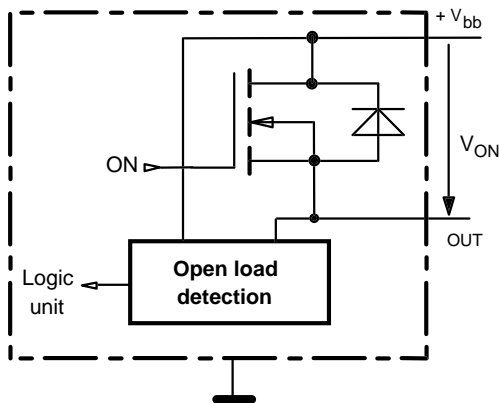
Overvolt. and reverse batt. protection



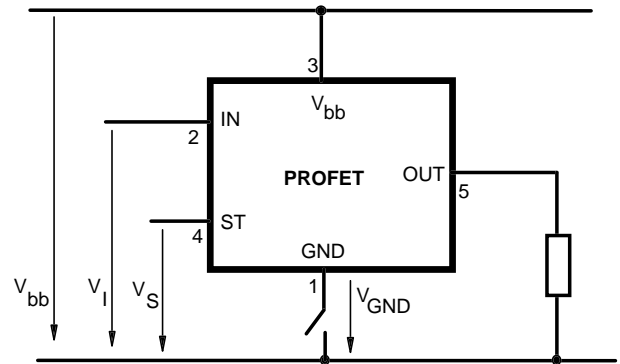
R_{bb} 120 Ω typ., V_Z 57 V typ., add R_{GND} , R_{IN} , R_{ST} for extended protection

Open-load detection

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

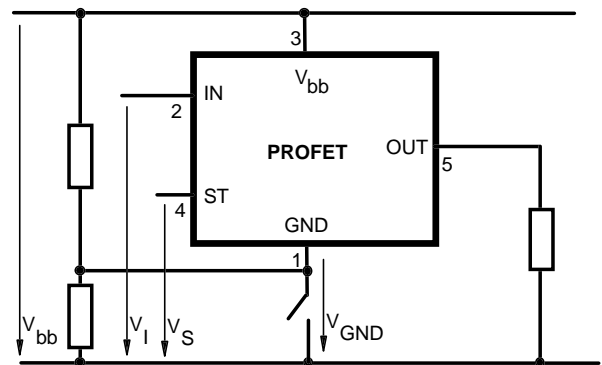


GND disconnect



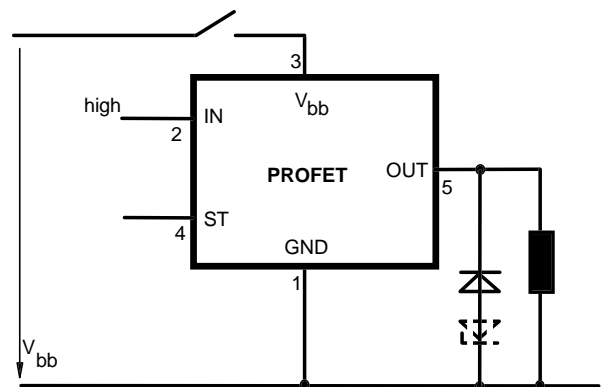
Any kind of load. In case of Input=high $V_{OUT} \approx V_I - V_{IN(T+)}$
Due to $V_{GND} > 0$, no $V_S =$ low signal available.

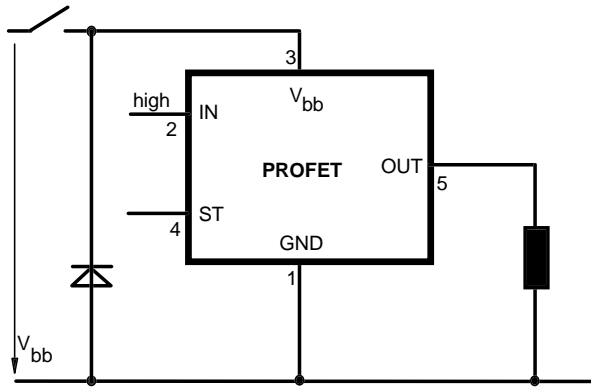
GND disconnect with GND pull up



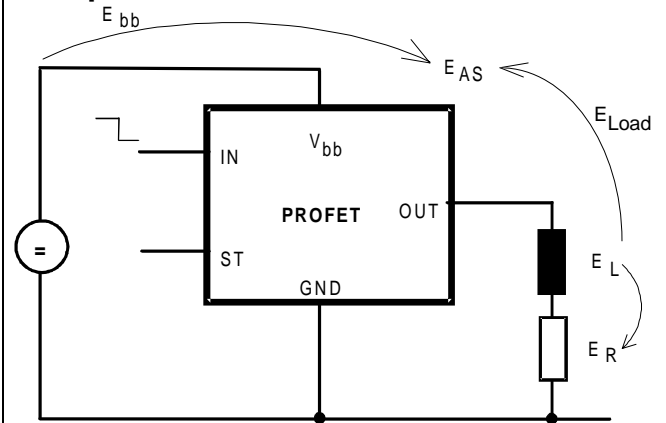
Any kind of load. If $V_{GND} > V_I - V_{IN(T+)}$ device stays off
Due to $V_{GND} > 0$, no $V_S =$ low signal available.

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 ¹²⁾¹³⁾ $T_j > 150\text{ °C}$, with auto-restart on cooling	X		X	X		X
Short-circuit to GND protection switches off when $V_{ON} > 8.3\text{ V}$ typ. ¹²⁾ (when first turned on after approx. 200 μs)	X	X	X	X	X	X
Open load detection in OFF-state with sensing current 30 μA 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 ¹⁵⁾
short to V_{bb}	- ¹⁴⁾	- ¹⁴⁾	- ¹⁴⁾	X	- ¹⁴⁾	- ¹⁴⁾
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			

¹²⁾ 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 $t_{d(SC)}$.

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

¹⁴⁾ Low resistance short V_{bb} to output may be detected by no-load-detection

¹⁵⁾ with status latch until next turn on

Timing diagrams

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

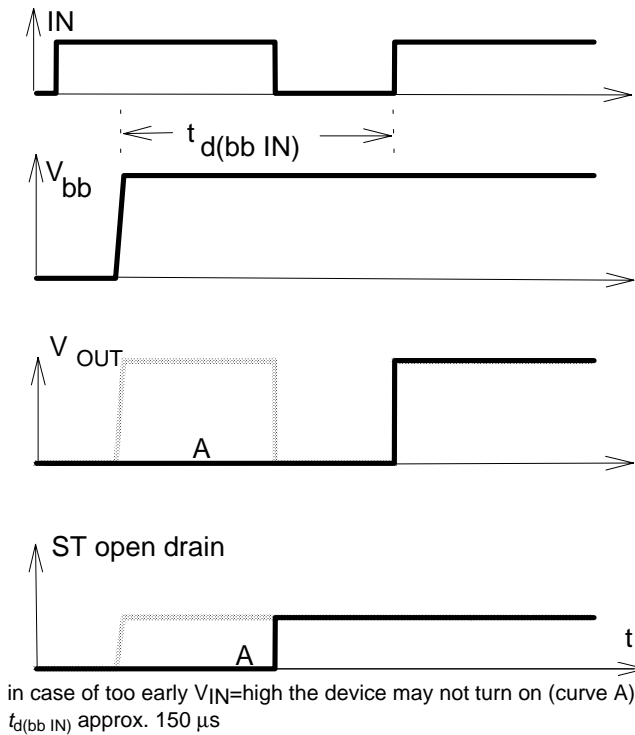


Figure 2a: Switching a lamp,

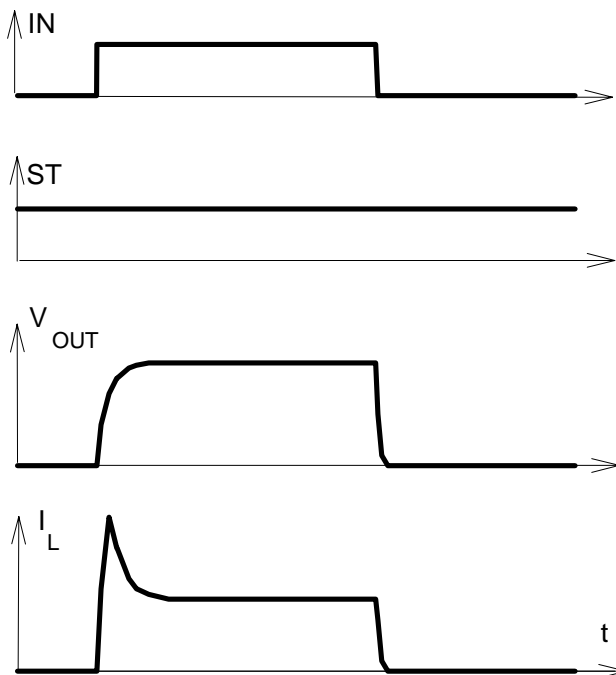
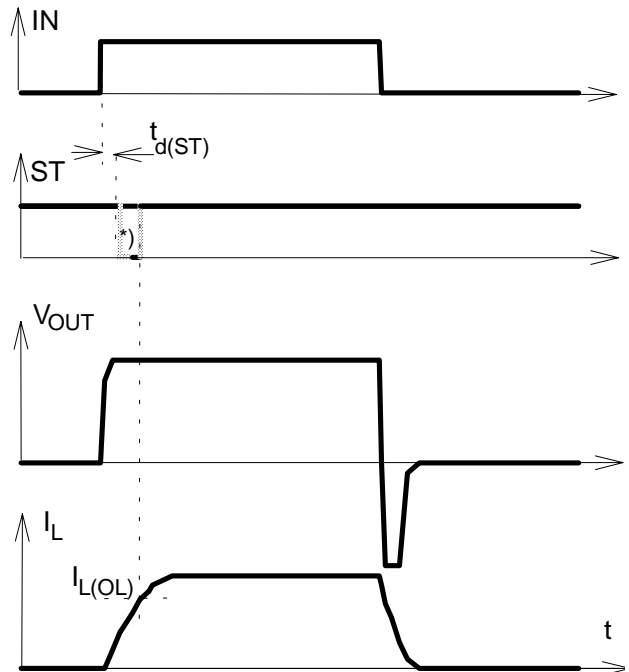
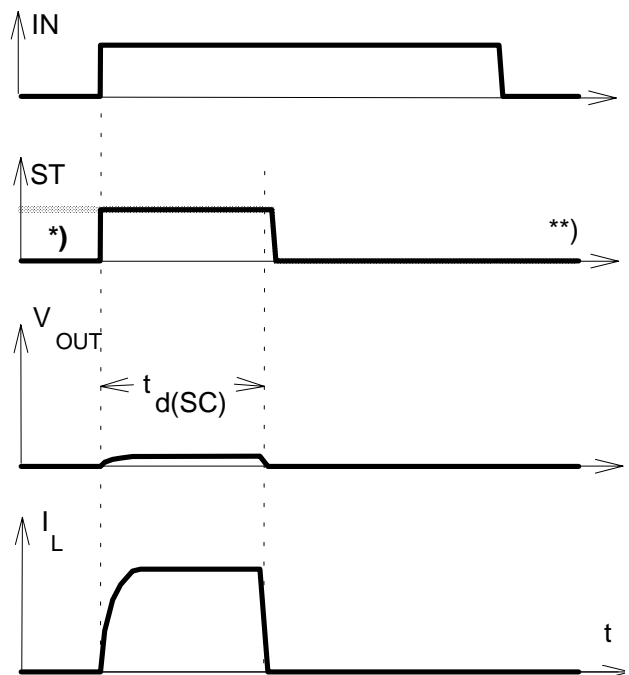


Figure 2b: Switching an inductive load



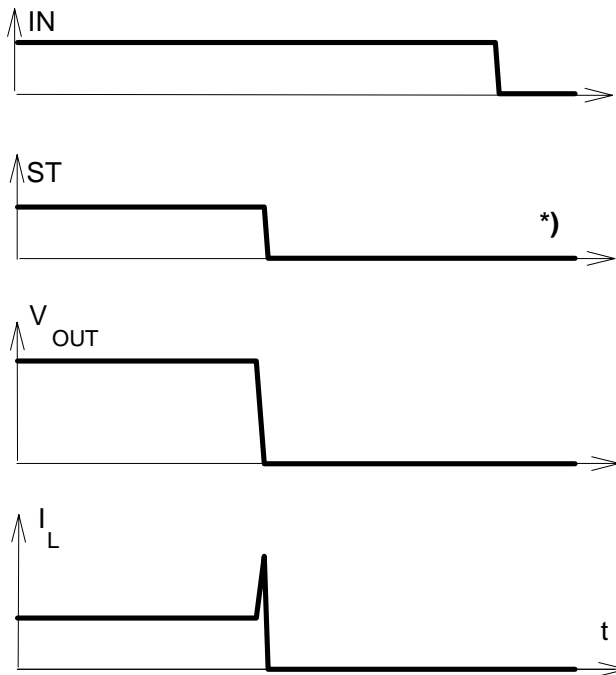
*) if the time constant of load is too large, open-load-status may occur

Figure 3a: Turn on into short circuit,



typ. $t_{d(SC)}$ approx. 200 μ s, *) depends on history,
 **) error signal latched until next turn on

Figure 3b: Short circuit while on:



*) error signal latched until next turn on

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

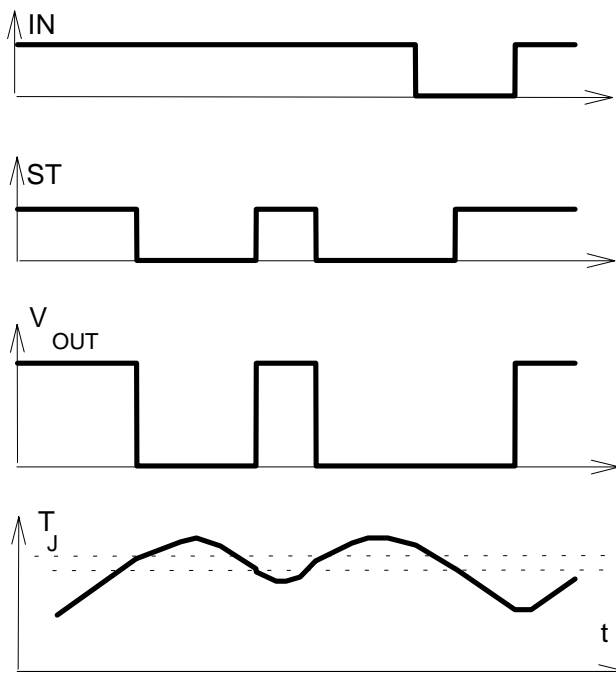


Figure 5a: Open load: detection in ON-state, turn on/off to open load

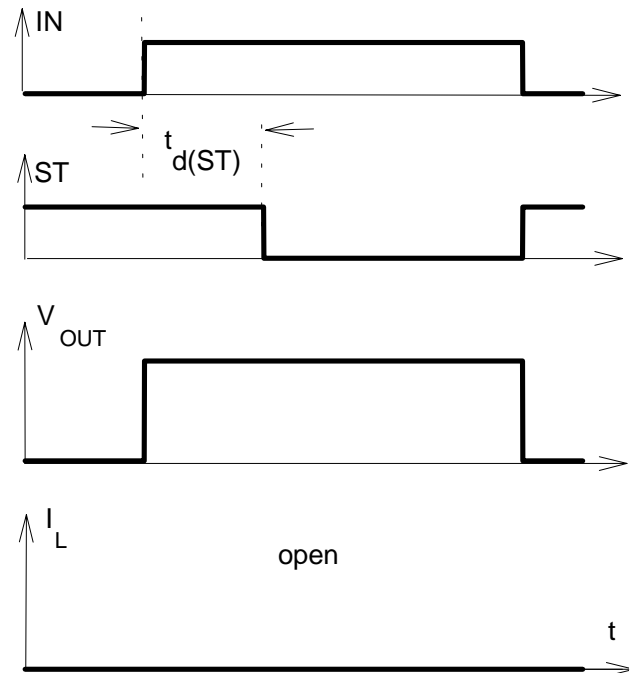
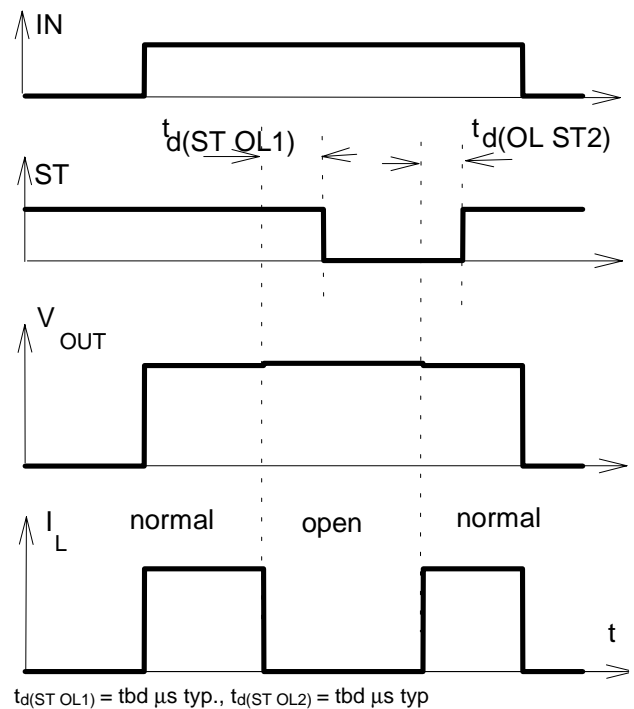


Figure 5b: Open load: detection in ON-state, open load occurs in on-state



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

Figure 6a: Undervoltage:

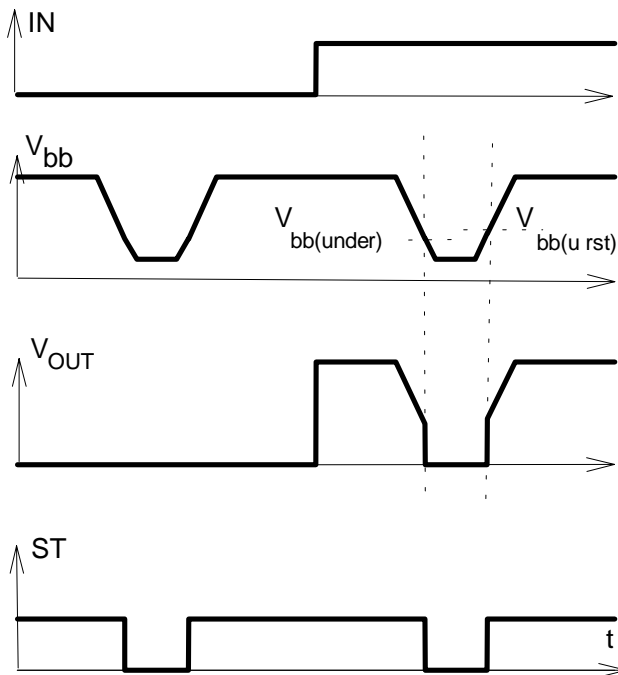


Figure 7a: Overvoltage:

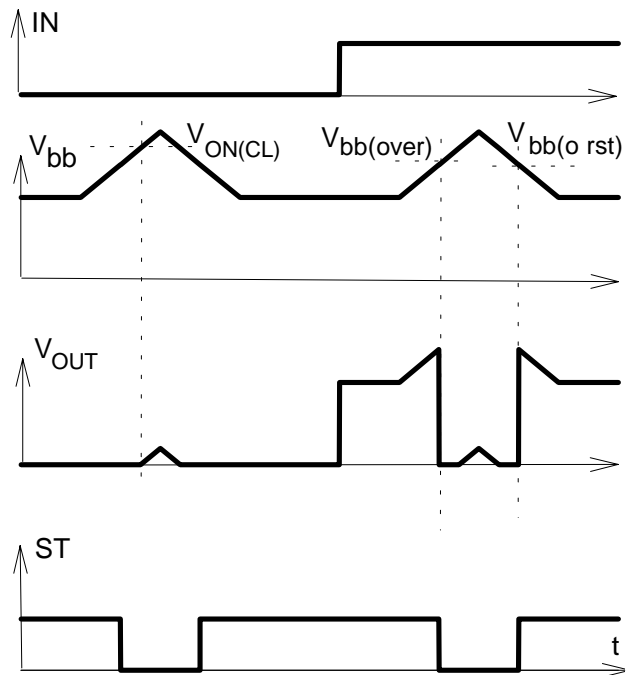
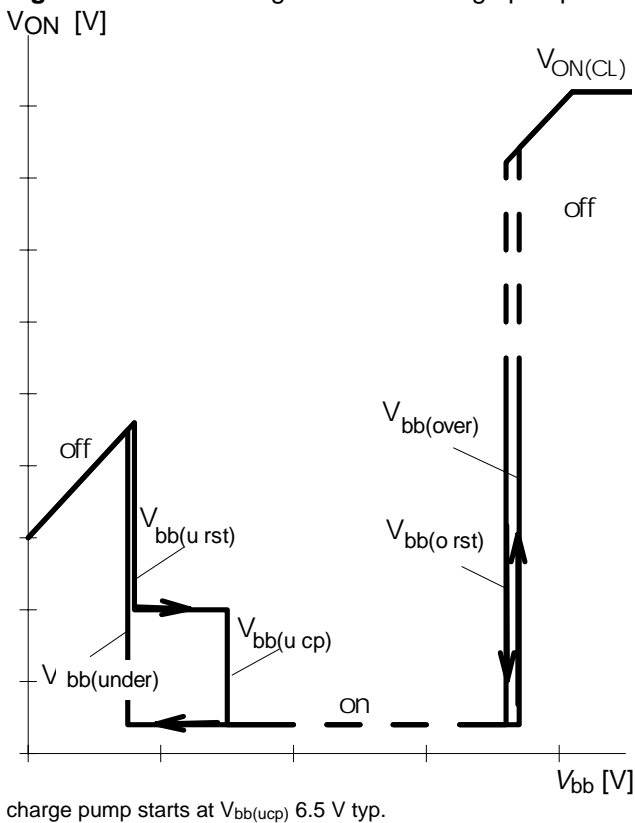


Figure 6b: Undervoltage restart of charge pump

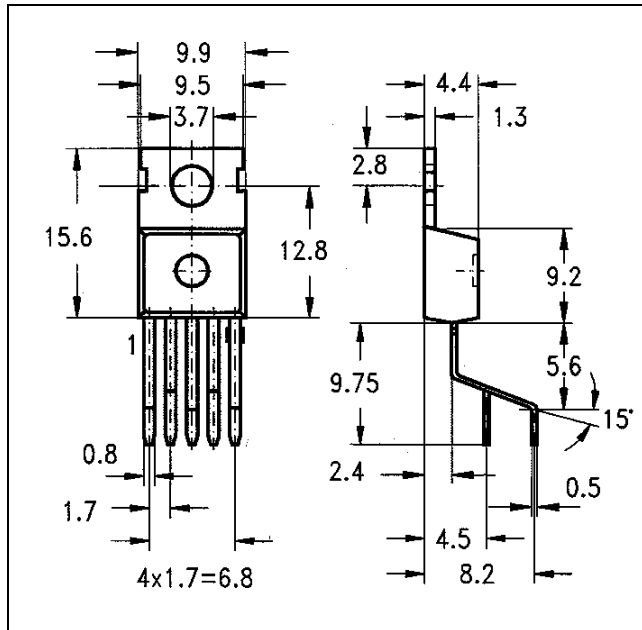


Package and Ordering Code

All dimensions in mm

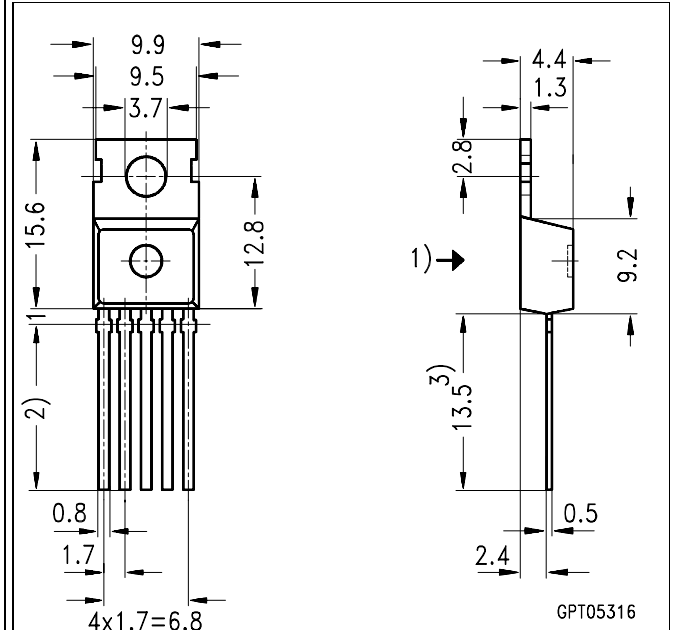
Standard TO-220 AB/5 Ordering code

BTS430K2	Q67060-S6200-A2
----------	-----------------



TO-220 AB/5, OPTION E3043 Ordering code

BTS430K2 E3043	Q67060-S6200-A3
----------------	-----------------

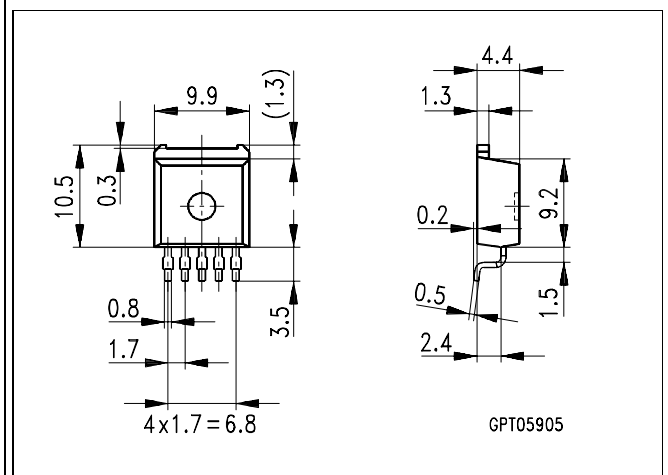


- 1) punch direction, burr max. 0.04
- 2) dip finning
- 3) max. 14.5 by dip finning press burr max. 0.05

SMD TO-220 AB/5, OPTION E3122

Ordering code

BTS430K2 E3122A	T&R: Q67060-S6200-A4
-----------------	----------------------



Changed since 04/96

Case E3122A drawing changed