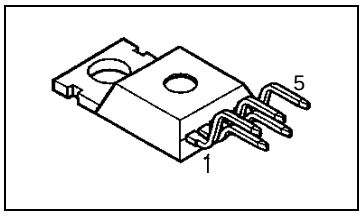
Smart Highside Power Switch

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
- **E**lectro**s**tatic **D**ischarge (**ESD**) protection
- Loss of ground and loss of V_{bb} protection[1)]
- 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	mΩ
$I_{L(lim)}$	36	A
$I_{L(ISO)}$	11	A

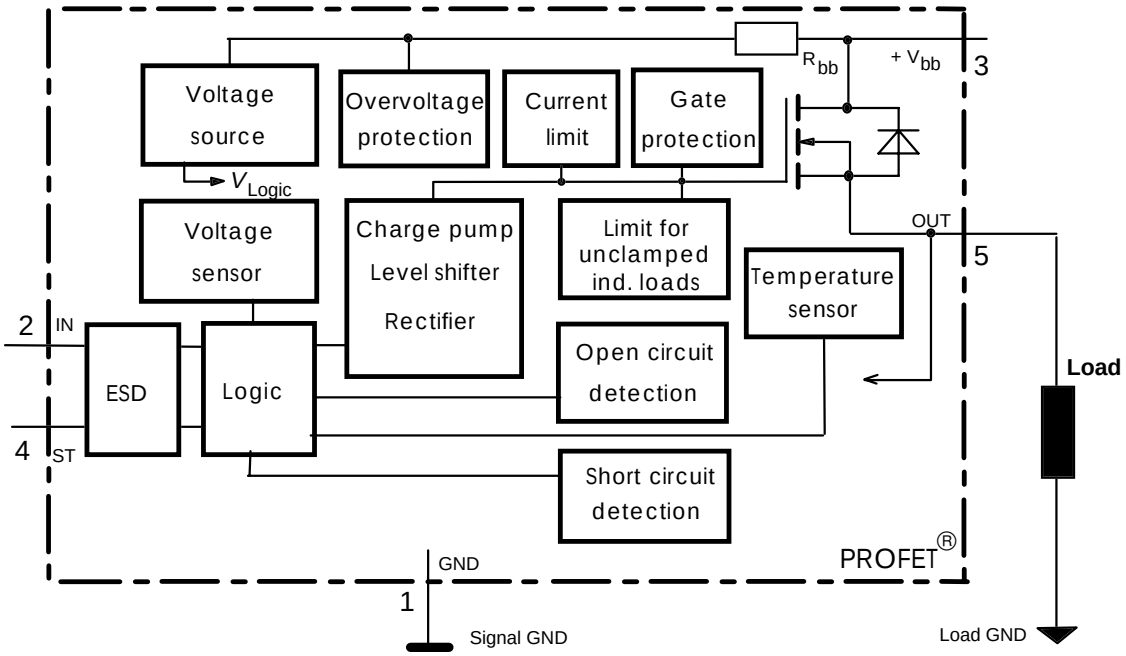


Application

- µC compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- All types of resistive, inductive and capacitve 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	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 °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) see internal circuit diagrams page 6...	I_{ST}	±5.0	

Thermal resistance chip - case:	R_{thJC}	≤ 1	K/W
chip - ambient:	R_{thJA}	≤ 75	

Electrical Characteristics

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12 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 A T_j=25 °C:	R_{ON}	--	30	38	mΩ
T_j=150 °C:			55	70	
Nominal load current (pin 3 to 5) ISO Proposal: V_{ON} = 0.5 V, T_C = 85 °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}: R_L = 12 Ω	t_{off}	10	--	60	
Slew rate on 10 to 30% V_{OUT}, R_L = 12 Ω	dV/dt_{on}	0.4	--	2	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 12 Ω	$-dV/dt_{off}$	1	--	4	V/µs
Operating Parameters					
Operating voltage T_j =-40...+150°C:	$V_{bb(on)}$	4.5	--	32	V
Undervoltage shutdown T_j =-40...+150°C:	$V_{bb(under)}$	2.4	--	4.5	V
Undervoltage restart T_j =-40...+150°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...+150°C:	$V_{bb(over)}$	32	--	46	V
Overvoltage restart T_j =-40...+150°C:	$V_{bb(o\ rst)}$	32	--	--	V
Overvoltage hysteresis T_j =-40...+150°C:	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection[2] T_j =-40...+150°C: I_{bb}=4 mA	$V_{bb(AZ)}$	50	57	--	V
Standby current (pin 3)	$I_{bb(off)}$				µA
V_{IN}=0 T_j=-40...+25°C:		--	12	25	
T_j=150°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. Meassured without load.
3) Add I_{ST}, if I_{ST} > 0

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Protection Functions					
Overload current limit (pin 3 to 5) T_j=-40...+150°C	$I_{L(lim)}$	19	36	57	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$, T_j =-40..+150°C: min value valid only, if input "low" time exceeds 30 µs	$t_{d(SC)}$	80	--	400	µs
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$	$V_{ON(CL)}$	--	50	--	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.3	--	V
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Inductive load switch-off energy dissipation[4], $T_{j\,Start}$ = 150 °C V_{bb} = 12 V: V_{bb} = 24 V:	E_{AS} E_{Load12} E_{Load24}	--	--	1.7 1.3 1.0	J
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 T_j=25..150°C: (on-condition,) T_j=-40 °C:	$I_{L\,(OL)}$	10 10	-- --	500 600	mA
Leakage output current (off-condition)	$I_{L(off)}$	--	6	--	µA

4) While demagnetizing load inductance, dissipated energy in PROFET is $E_{AS} = \int V_{ON(CL)} * i_L(t)\,dt$, approx. $E_{AS} = {}^1/_2 * L * I_L^2 * \left(\frac{V_{ON(CL)}}{V_{ON(CL)} - V_{bb}}\right)$, 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 ≈ 0.3 A at V_{bb}= -32 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 Ω). Input and Status currents have to be limited (see max. ratings page 2 and circuit page 7).

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Input and Status Feedback[6)]					
Input resistance see circuit page 6	R_I	--	10	--	kΩ
Input turn-on threshold voltage  T_j =-40..+150°C:	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage  T_j =-40..+150°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 V:	$I_{IN(off)}$	1	--	30	µA
On state input current (pin 2) V_{IN} = 3.5 V:	$I_{IN(on)}$	10	25	50	
Status valid after input slope (short circuit) T_j=-40 ... +150°C:	$t_{d(ST\ SC)}$	80	200	400	µs
Status valid after input slope (open load) T_j=-40 ... +150°C:	$t_{d(ST)}$	350	--	1600	µs
Status output (open drain)					
Zener limit voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(high)}$	5.4	6.1	6.9	V
ST low voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.4	
Status voltage while V_{bb} <2.4 V T_j=25 ... +150°C:	V_{ST}	--	--	1.0	V
I_{ST} = 500 µA T_j=40°C:				1.2	

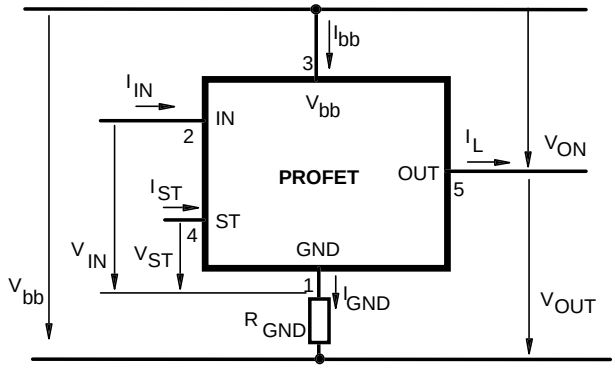
6) If a ground resistor R_{GND} is used, add the voltage drop across this resistor. Internal Z-diode typ. 6.1 V, see maximum ratings page 2, circuit page 7

Truth Table

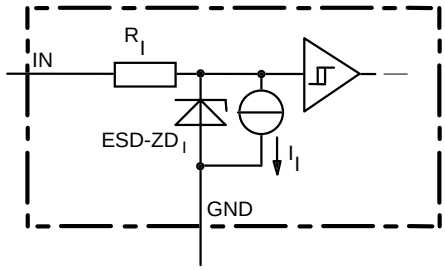
	Input-level	Output level	Status 432 D2	432 E2/F2	432 I2	**430 K2**
Normal operation	**L** **H**	**L** **H**	H H	H H	H H	**H** **H**
Open load	**L** **H**	[7] **H**	H L	H L	L H	**H** **L**
Short circuit to GND	**L** **H**	**L** **L**	H L	H L	H L	[8] **L**
Short circuit to V_{bb}	**L** **H**	**H** **H**	H H (L[9])	H H (L[9])	L H	**H** **H (L[9])**
Overtem-perature	**L** **H**	**L** **L**	L L	L L	L L	**L** **L**
Under-voltage	**L** **H**	**L** **L**	L[10] L[10]	H H	L[10] L[10]	**L[11]** **L[11]**
Overvoltage	**L** **H**	**L** **L**	L L	H H	L L	**L** **L**

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

Terms

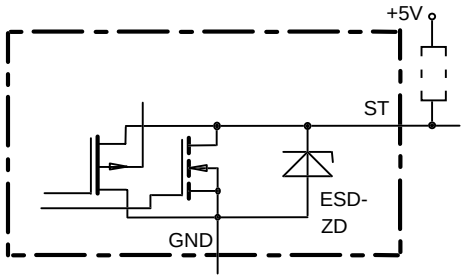


Input circuit (ESD protection)



ESD zener diodes are not designed for continuous current

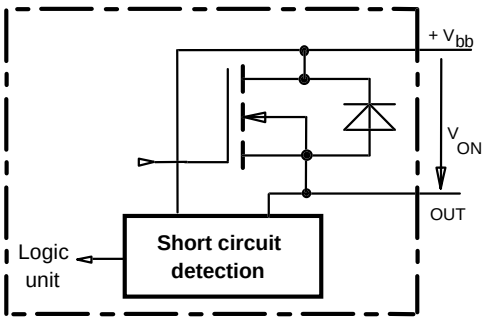
Status output



ESD zener diodes are not designed for continuous current

Short Circuit detection

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



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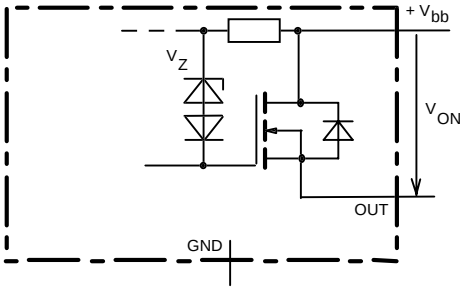
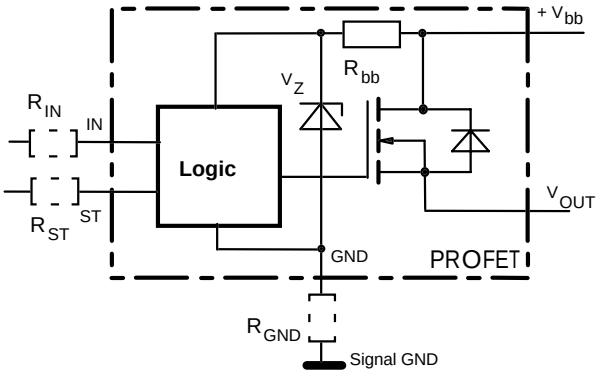
7) Power Transistor off, high impedance
8) The short circuit signal from last ON state is latched until next turn-on, see timing diagram page 10
9) Low resistance short V_{bb} to output may be detected by no-load-detection
10) No current sink capability during undervoltage shutdown
11) Current sink capability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

Inductive and overvoltage output clamp



V_{ON} clamped to 50 V typ.

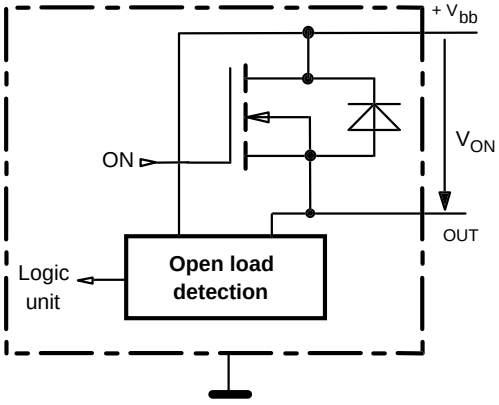
Overvolt. and reverse batt. protection



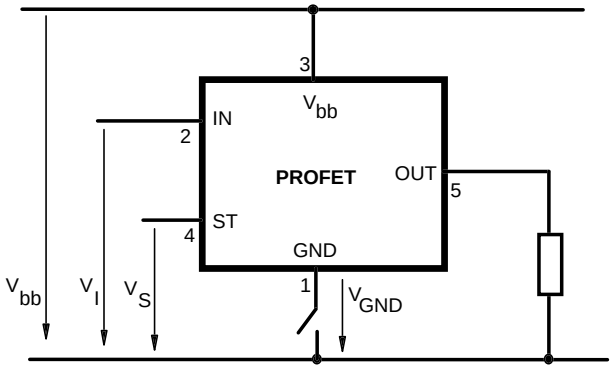
R_{bb} 120 Ω typ., V_Z 57 V typ., , add R_{GND}, R_{IN}, R_{ST} for extended protection

Open-load detection

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

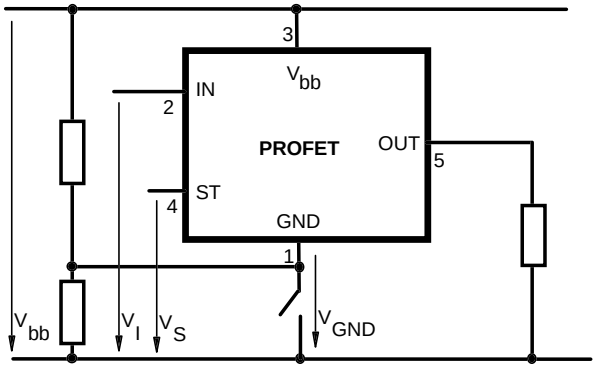


GND disconnect



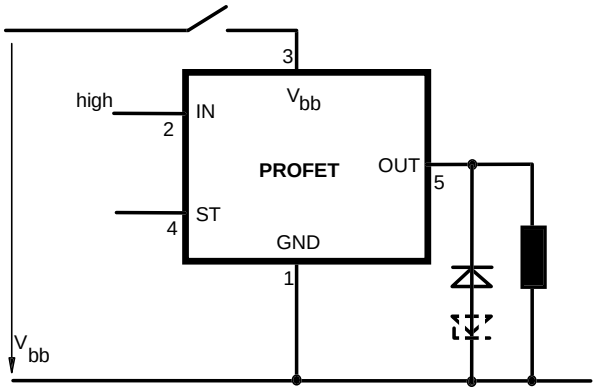
Any kind of load. In case of Input=high $V_{OUT} \approx V_I - V_{IN(T+)}$
Due to V_{GND} >0, no V_S = low signal available.

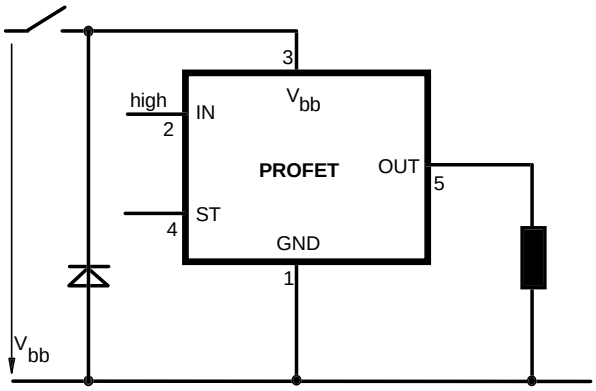
GND disconnect with GND pull up



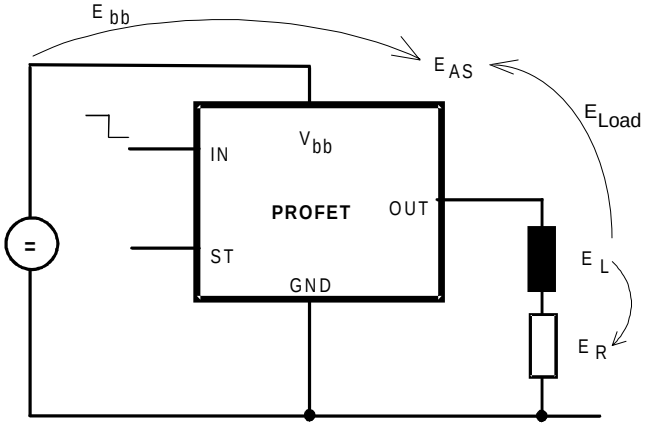
Any kind of load. If $V_{GND} > V_I - V_{IN(T+)}$ device stays off
Due to V_{GND} >0, no V_S = low signal available.

V_{bb} disconnect with charged inductive load





Inductive Load switch-off energy dissipation



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

$E_{Load} < E_L$, $E_L = {}^1/_2 * L * I_L^2$

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 °C, latch function[12)13)]	X		X	X	
T_j >150 °C, with auto-restart on cooling		X			**X**
Short-circuit to GND protection					
switches off when V_{ON}>8.3 V typ.[12)] (when first turned on after approx. 200 µs)	X	X	X	X	**X**
Open load detection					
in OFF-state with sensing current 30 µA typ.				X	
in ON-state with sensing voltage drop across power transistor	X	X	X		**X**
Undervoltage shutdown with auto restart	X	X	X	X	**X**
Overvoltage shutdown with auto restart	X	X	X	X	**X**
Status feedback for					
overtemperature	X	X	X	X	**X**
short circuit to GND	X	X	X	X	**X[15)]**
short to V_{bb}	-[14)]	-**[14)]**	-[14)]	X	-**[14)]**
open load	X	X	X	X	**X**
undervoltage	X	-	-	X	**X**
overvoltage	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**
Load current limit					
high level (can handle loads with high inrush currents)	X	X			
medium level				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 V after shutdown (V_{OUT} ≠ 0 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 $t_{d(SC)}$.

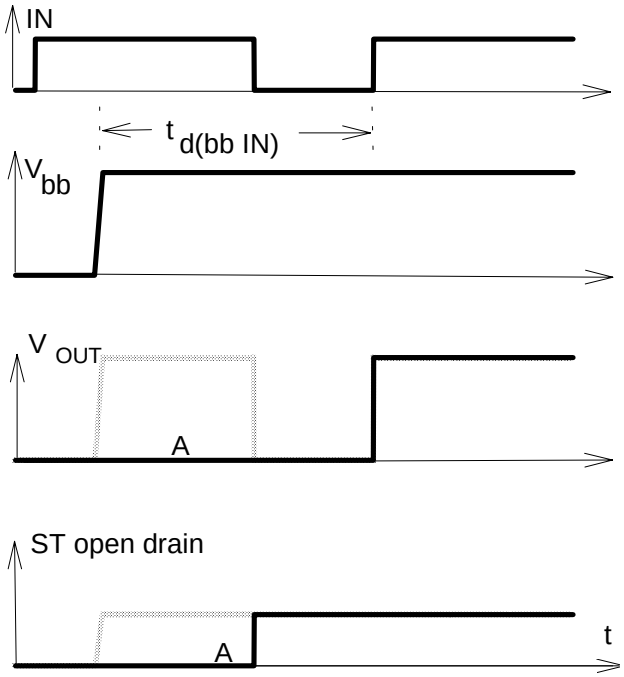
13) With latch function. Reseted by a) Input low, b) Undervoltage, c) Overvoltage

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, :



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

Figure 2a: Switching a lamp,

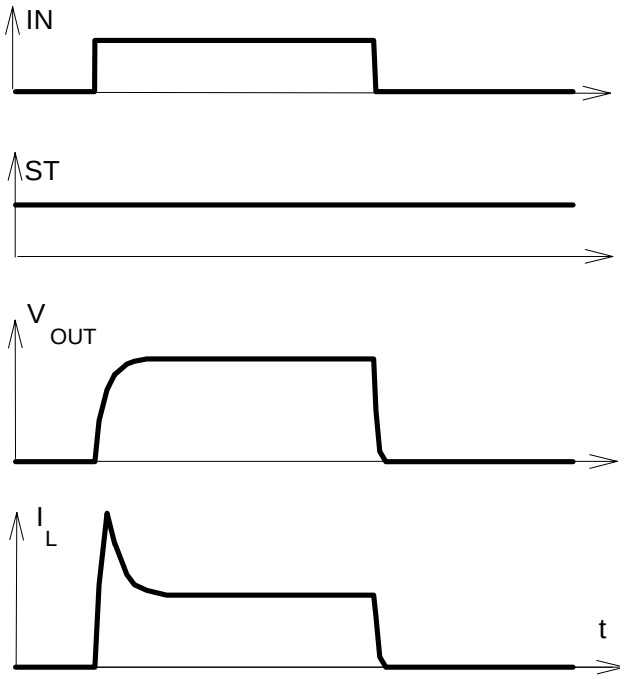
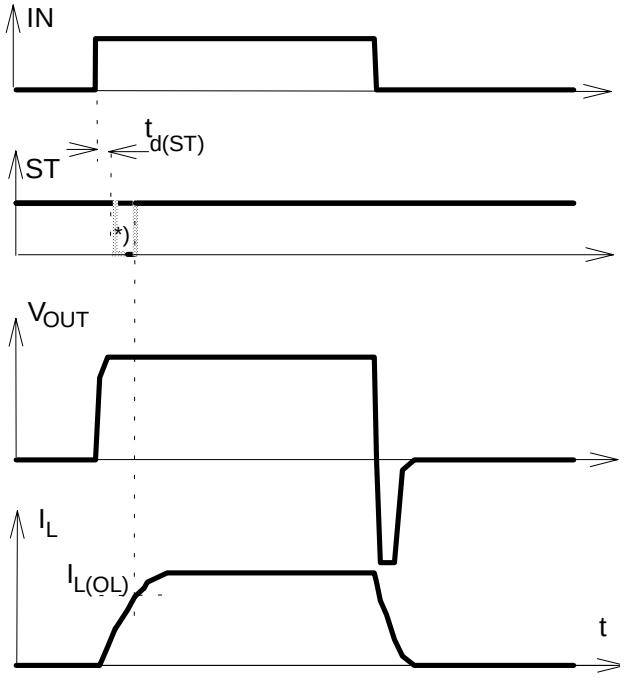
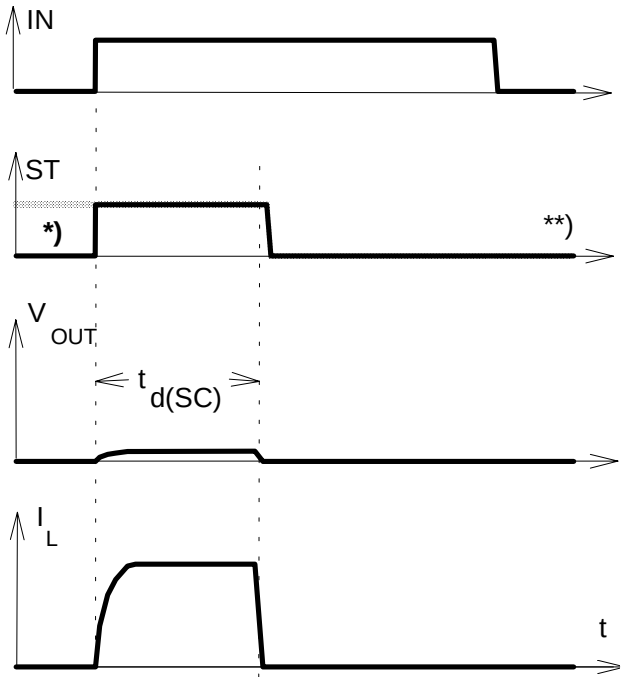


Figure 2b: Switching an inductive load



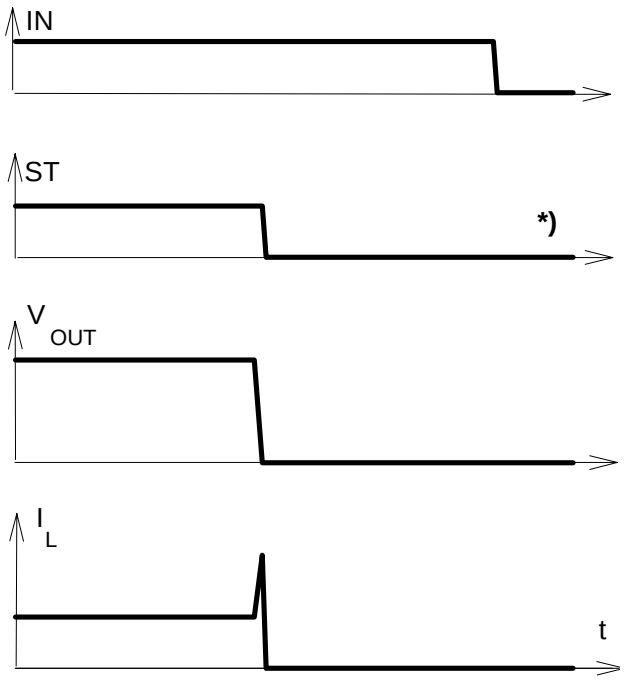
*) if the time constant of load is too large, open-load-status may occur

Figure 3a: Turn on into short circuit,



typ. $t_{d(SC)}$ approx. 200µs, *) 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 $T_j < T_{jt}$

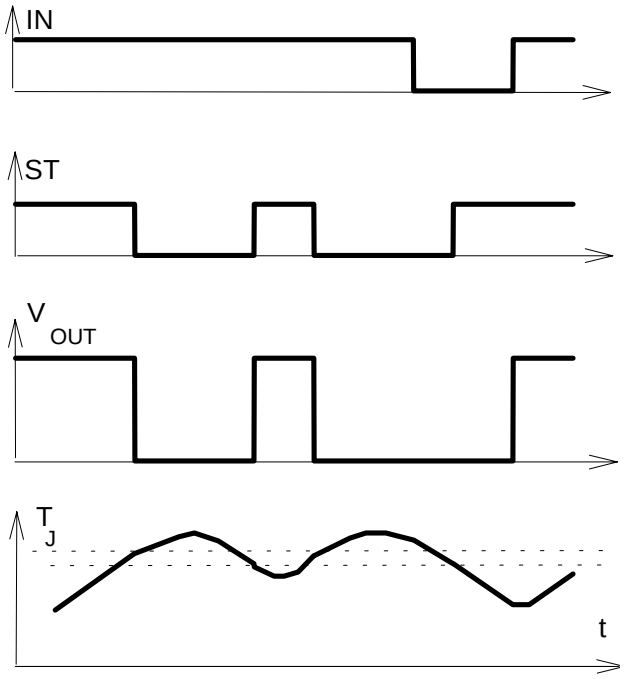


Figure 5a: Open load: detection in ON-state, turn on/off to open load

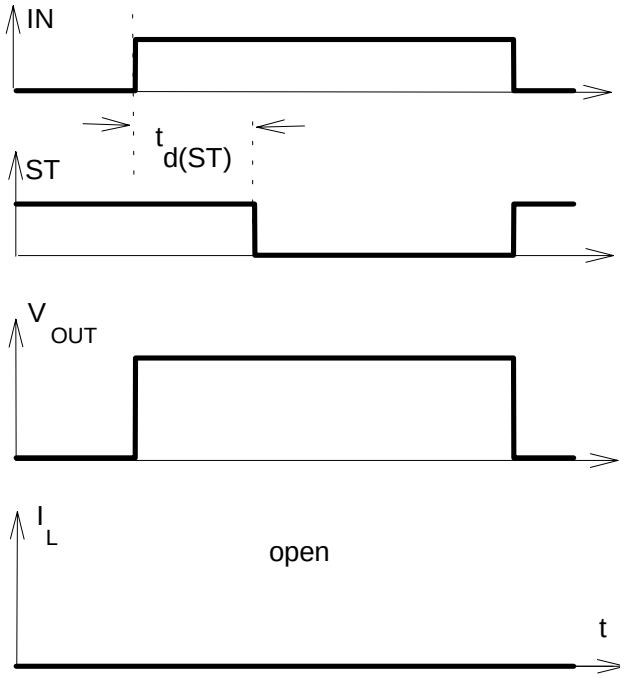
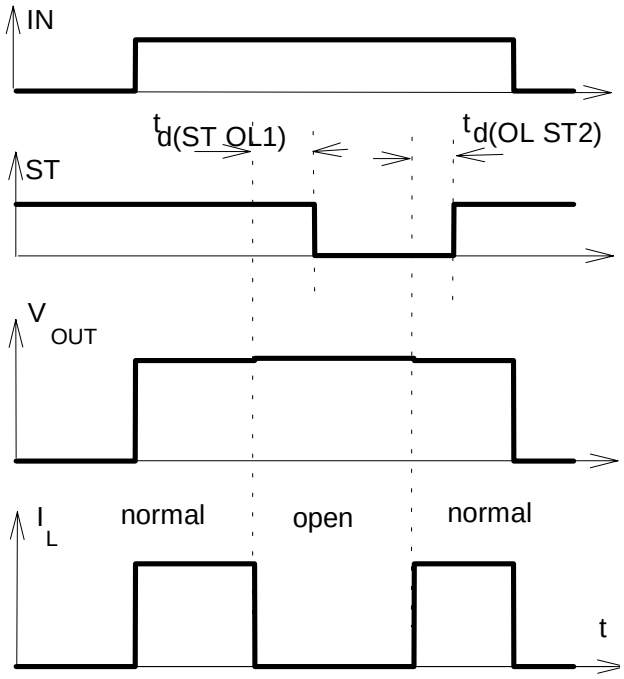


Figure 5b: Open load: detection in ON-state, open load occurs in on-state



$t_{d(ST\ OL1)}$ = tbd µs typ., $t_{d(ST\ OL2)}$ = tbd µs typ

Figure 6a: Undervoltage:

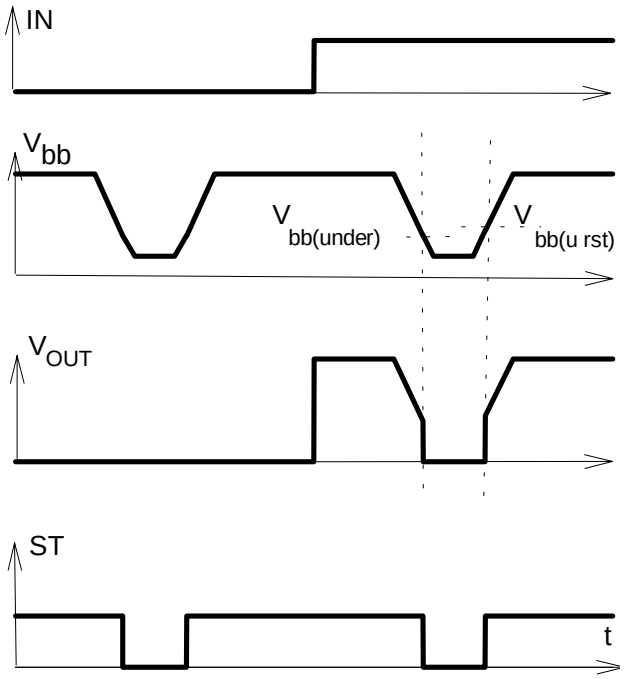


Figure 7a: Overvoltage:

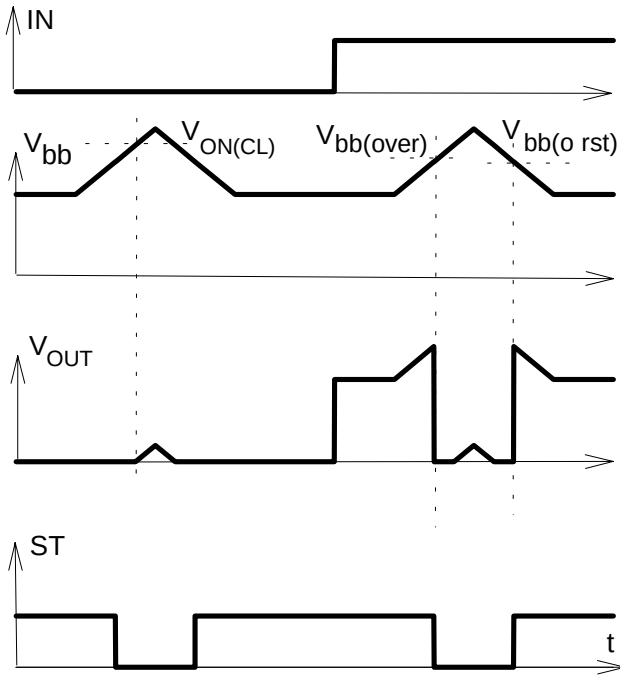
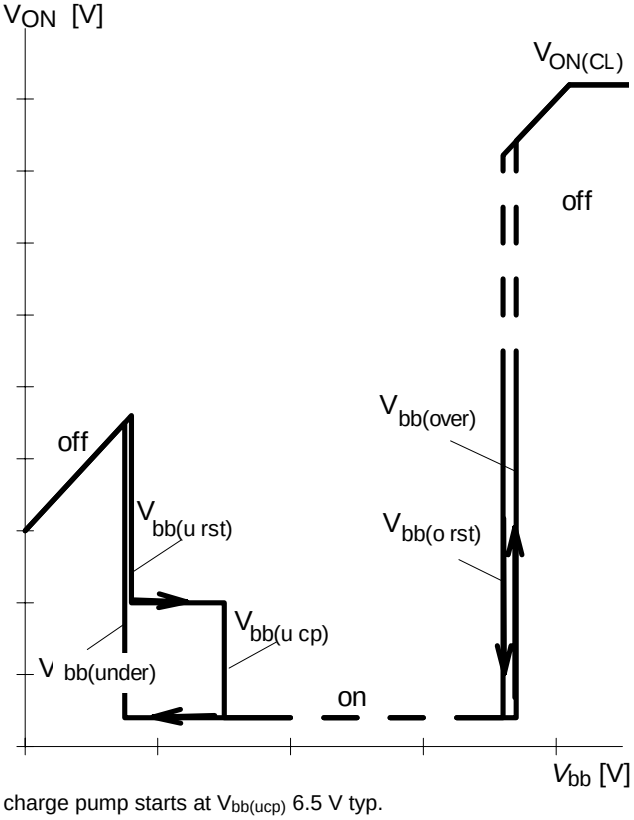


Figure 6b: Undervoltage restart of charge pump



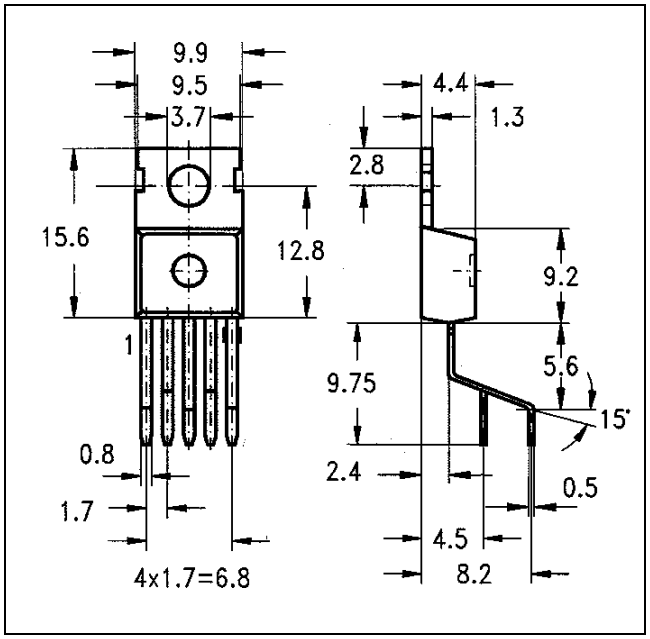
charge pump starts at $V_{bb(ucp)}$ 6.5 V typ.

Package and Ordering Code

All dimensions in mm

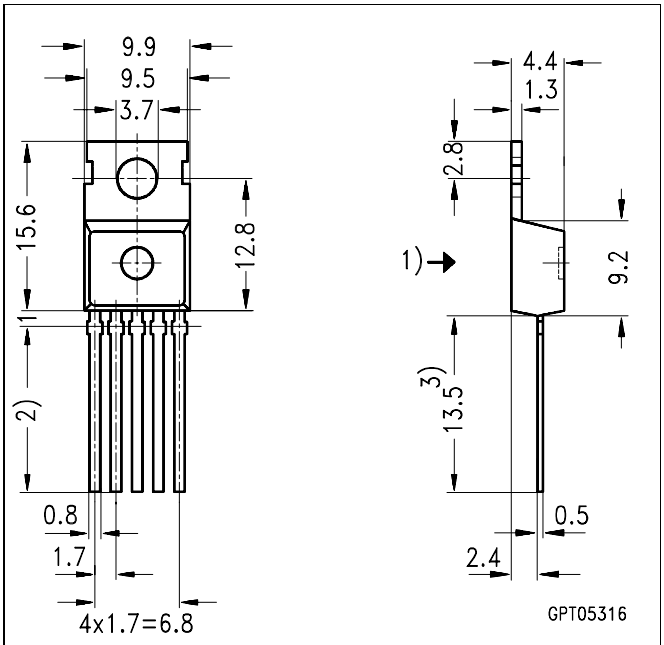
Standard TO-220 AB/5 Ordering code

BTS430K2	Q67060-S6200-A2



TO-220 AB/5, OPTION E3043 Ordering code

BTS430K2 E3043	Q67060-S6200-A3

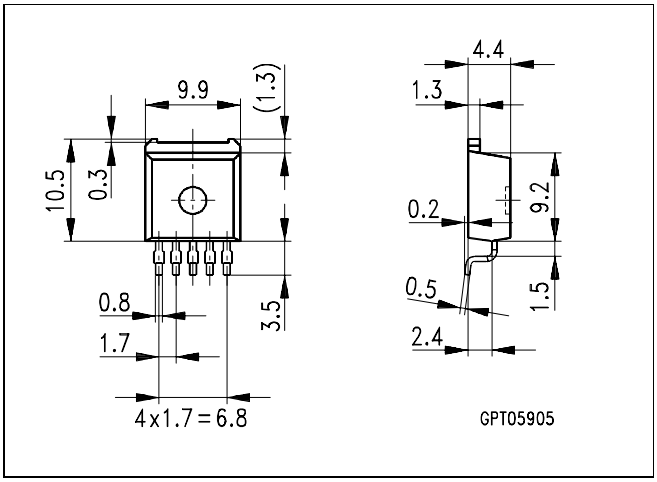


1) punch direction, burr max. 0.04
2) dip tinning
3) max. 14.5 by dip tinning press burr max. 0.05

SMD TO-220 AB/5, OPTION E3122

Ordering code

BTS430K2 E3122A	T&R:	Q67060-S6200-A4



Changed since 04/96

Case E3122A drawing changed