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Smart Highside Power Switch

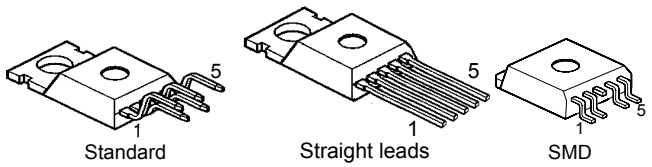
Features

- Overload protection
- Current limitation
- Short circuit protection
- Thermal shutdown
- Overvoltage protection (including load dump)
- Fast demagnetization of inductive loads
- Reverse battery protection[1)]
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis
- Open drain diagnostic output
- Open load detection in OFF-state
- CMOS compatible input
- Loss of ground and loss of V_{bb} protection
- **E**lectro**s**tatic **d**ischarge (**ESD**) protection

Product Summary

Overvoltage protection	$V_{bb(AZ)}$	60	V
Operating voltage	$V_{bb(on)}$	4.7 ... 34	V
On-state resistance	R_{ON}	300	mΩ
Load current (ISO)	$I_{L(ISO)}$	1.3	A

TO-220AB/5

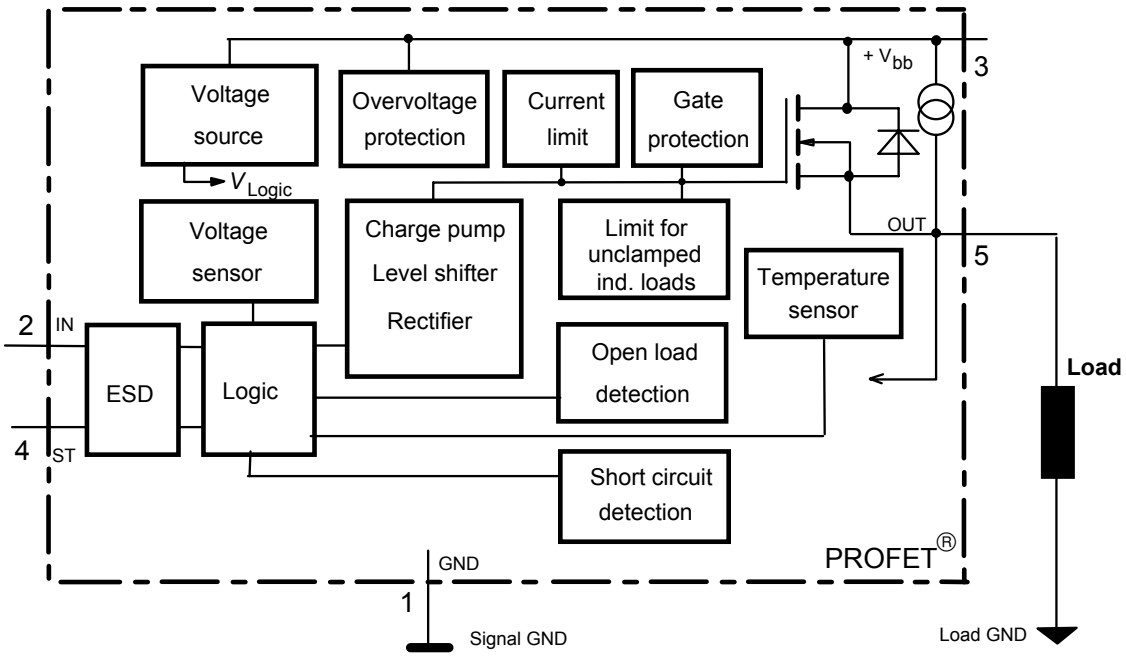


Application

- µC compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- Most suitable for inductive loads
- Replaces electromechanical relays, fuses and discrete circuits
- Fast switching
- Not suitable for lamp loads

General Description

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



[1)] With external current limit (e.g. resistor R_{GND}=150 Ω) in GND connection, resistor in series with ST connection, reverse load current limited by connected load.

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}	60	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), $T_C \leq 25$ °C	P_{tot}	50	W
Electrostatic discharge capability (ESD) IN, ST: (Human Body Model) all other pins:	V_{ESD}	1 tbd (>1)	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}	≤ 2.5	K/W
junction - ambient (free air):	R_{thJA}	≤ 75	

Electrical Characteristics

Parameter and Conditions at T_j = 25 °C, V_{bb} = 24 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Load Switching Capabilities and Characteristics					
On-state resistance (pin 3 to 5) I_L = 0.8 A, V_{bb} = 12V T_j=25 °C: T_j=150 °C:	R_{ON}	--	270 540	300 600	mΩ
Nominal load current, ISO Norm (pin 3 to 5) V_{ON} = 0.5 V, T_C = 85 °C	$I_{L(ISO)}$	1.18	1.3	--	A
Output current (pin 5) while GND disconnected or GND pulled up, V_{bb}=30 V, V_{IN}= 0, see diagram page 7	$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time to 90% V_{OUT}: Turn-off time to 10% V_{OUT}: R_L = 47 Ω, V_{bb} = 12V, T_j =-40...+150°C	t_{on} t_{off}	-- --	-- --	50 55	µs
Slew rate on, 10 to 30% V_{OUT}, R_L = 47 Ω, V_{bb} = 12V, T_j =-40...+150°C	dV/dt_{on}	1	--	10	V/µs
Slew rate off, 10 to 30% V_{OUT}, R_L = 47 Ω, V_{bb} = 12V, T_j =-40...+150°C	$-dV/dt_{off}$	2	--	15	V/µs
Operating Parameters					
Operating voltage[2] T_j =-40...+150°C:	$V_{bb(on)}$	4.7	--	34	V
Operating voltage slew rate	dV_{bb}/dt	-1		+1	V/µs
Undervoltage shutdown T_j =25°C: T_j =-40...+150°C:	$V_{bb(under)}$	2.9 2.7	-- --	4.5 4.7	V
Undervoltage restart T_j =-40...+150°C:	$V_{bb(u\ rst)}$	--	--	4.9	V
Undervoltage restart of charge pump see diagram page 11 T_j =-40...+150°C:	$V_{bb(ucp)}$	--	4.9	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:	$V_{bb(over)}$	34	--	46	V
Overvoltage restart T_j =-40...+150°C:	$V_{bb(o\ rst)}$	34	--	--	V
Overvoltage hysteresis T_j =-40...+150°C:	$\Delta V_{bb(over)}$	--	0.5	--	V
Overvoltage protection[3] T_j =-40...+150°C: I_{bb}=10 mA	$V_{bb(AZ)}$	59	70	--	V
Standby current (pin 3), V_{IN}=0 T_j=-40...+150°C:	$I_{bb(off)}$	--	40	50	µA
Operating current (Pin 1)[4], V_{IN}=5 V	I_{GND}	--	2	4	mA

[2] At supply voltage increase up to V_{bb}= 4.9 V typ without charge pump, $V_{OUT} \approx V_{bb}$ - 2 V
[3] Meassured without load. See also $V_{ON(CL)}$ in table of protection functions and circuit diagram page 7.
[4] Add I_{ST}, if I_{ST} > 0, add I_{IN}, if V_{IN}>5.5 V

Parameter and Conditions at T_j = 25 °C, V_{bb} = 24 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Protection Functions[5]					
Initial peak short circuit current limit (pin 3 to 5)[6], (max 100 µs if $V_{ON} > V_{ON(SC)}$)	$I_{L(SCp)}$				
V_{bb} = 12V T_j =-40°C:		--	--	10	A
T_j =25°C:		--	5	--	
T_j =+150°C:		2.5	--	--	
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 60 µs	$t_{d(SC)}$	15	--	100	µs
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$ I_L= 1 A, T_j =-40..+150°C:	$V_{ON(CL)}$	59	67	75	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	3.5	--	V
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Reverse battery (pin 3 to 1) [7]	$-V_{bb}$	--	--	32	V
Diagnostic Characteristics					
Open load detection current T_j=-40...+150°C: (included in standby current $I_{bb(off)}$)	$I_{L(off)}$	0	--	30	µA
Open load detection voltage T_j=-40..150°C:	$V_{OUT(OL)}$	2	3	4	V

[5] 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.

[6] Short circuit current limit for max. duration of $t_{d(SC)\ max}$=100 µs, prior to shutdown

[7] Requires 150 Ω resistor in GND connection. Reverse load current (through intrinsic drain-source diode) is normally limited by the connected load. 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} = 24 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Input and Status Feedback[8)]					
Input resistance see circuit page 6	R_I	--	4	--	kΩ
Input turn-on threshold voltage T_j =-40..+150	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage T_j =-40..+150°	$V_{IN(T-)}$	0.8	--	--	V
Input threshold hysteresis, T_j =-40..+150°C	$\Delta V_{IN(T)}$	0.2	--	--	V
Off state input current (pin 2), V_{IN} = 0.4 V, T_j =-40..+150°C	$I_{IN(off)}$	8	--	30	µA
On state input current (pin 2), V_{IN} = 3.5 V, T_j =-40..+150°C	$I_{IN(on)}$	10	22	50	µA
Delay time for status with open load after Input neg. slope (see diagram page 11)	$t_{d(ST\ OL3)}$	50	--	400	µs
Status invalid after positive input slope (short circuit) T_j=-40 ... +150°C:	$t_{d(ST\ SC)}$	15	50	100	µs
Status output (open drain)					
Zener limit voltage T_j =-40...+150°C, I_{ST} = +50 uA:	$V_{ST(high)}$	5.4	6	--	V
ST low voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.4	

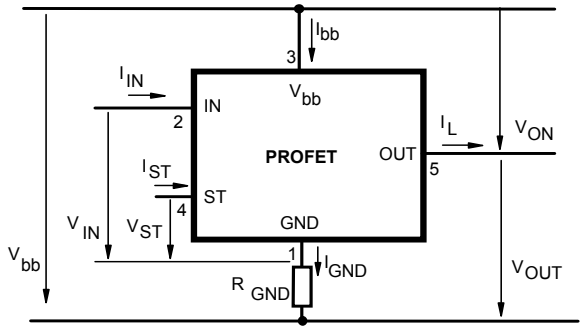
8) If a ground resistor R_{GND} is used, add the voltage drop across this resistor.

Truth Table

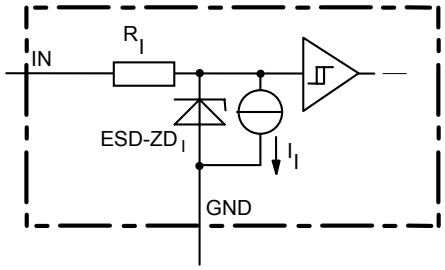
	Input-level	Output level	Status BTS 308
Normal operation	**L** **H**	**L** **H**	**H** **H**
Open load	**L** **H**	[9]) **H**	**L** **H**
Short circuit to GND	**L** **H**	**L** **L**	**H** **L**
Short circuit to V_{bb}	**L** **H**	**H** **H**	**L** **H**
Overtem-perature	**L** **H**	**L** **L**	**L** **L**
Under-voltage	**L** **H**	**L** **L**	**H** **H**
Overvoltage	**L** **H**	**L** **L**	**H** **H**

L = "Low" Level X = don't care Z = high impedance, potential depends on external circuit
H = "High" Level Status signal after the time delay shown in the diagrams (see fig 5. page 11)

Terms

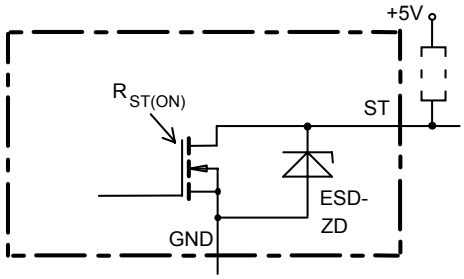


Input circuit (ESD protection)



ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

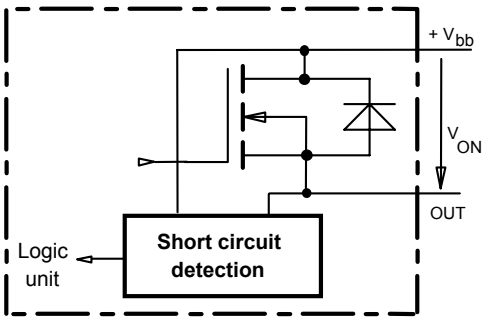
Status output



ESD-Zener diode: 6 V typ., max 5 mA;
$R_{ST(ON)}$ < 250 Ω at 1.6 mA, ESD zener diodes are not to be used as voltage clamp at DC conditions.
Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

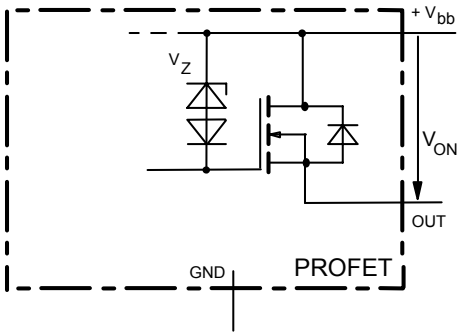
Short circuit detection

Fault Condition: V_{ON} > 3.5 V typ.; IN high



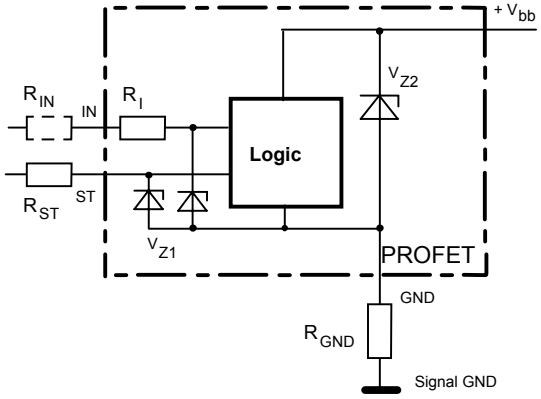
[9]) Power Transistor off, high impedance, internal pull up current source for open load detection.

Inductive and overvoltage output clamp



V_{ON} clamped to 67 V typ.

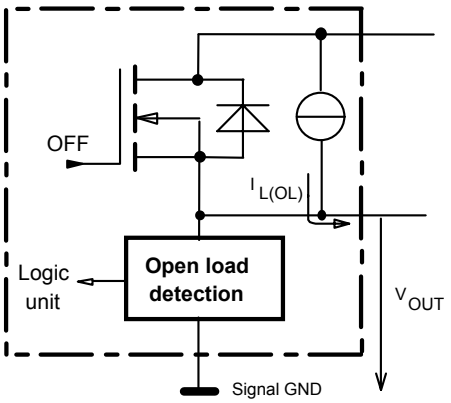
Overvolt. and reverse batt. protection



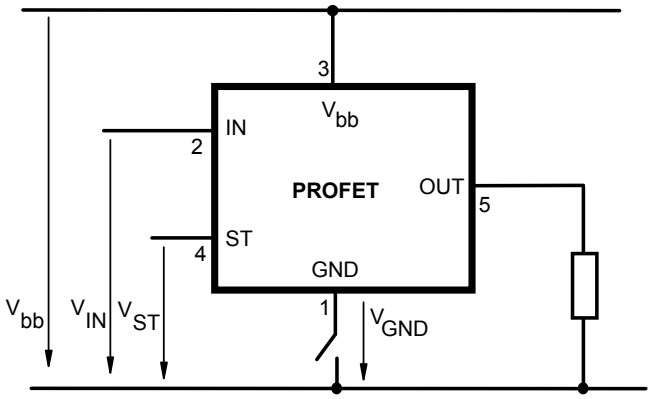
V_{Z1} = 6.2 V typ., V_{Z2} = 70 V typ., R_{GND} = 150 Ω, R_{ST}= 15 kΩ, R_I= 4 kΩ typ.

Open-load detection

OFF-state diagnostic condition: V_{OUT} > 3 V typ.; IN low

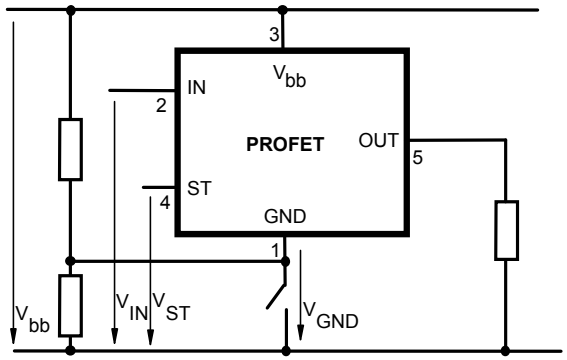


GND disconnect



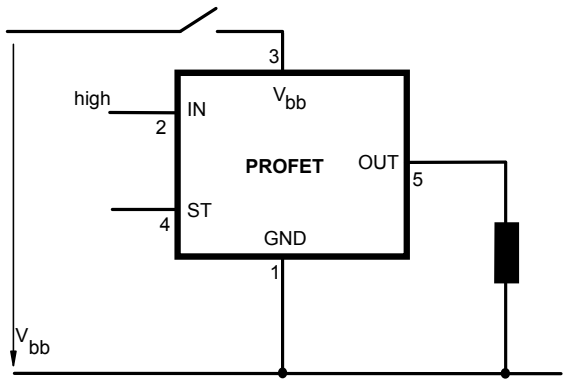
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN}$ - $V_{IN(T+)}$.
Due to V_{GND} >0, no V_{ST} = low signal available.

GND disconnect with GND pull up



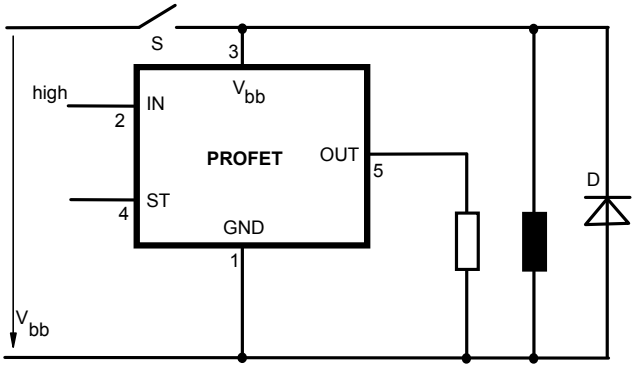
Any kind of load. If V_{GND} > V_{IN} - $V_{IN(T+)}$ device stays off
Due to V_{GND} >0, no V_{ST} = low signal available.

V_{bb} disconnect with charged inductive load



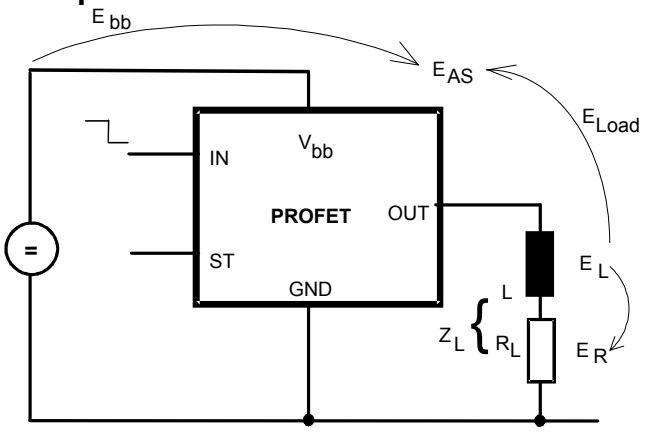
Normal load current can be handled by the PROFET itself.

V_{bb} disconnect with charged external inductive load



If other external inductive loads L are connected to the PROFET, additional elements like D are necessary.

Inductive Load switch-off energy dissipation



Energy stored in load inductance:

$$E_L = {}^1/_2 \cdot L \cdot I_L^2$$

While demagnetizing load inductance, the energy dissipated in PROFET is

$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t)\, dt,$$

with an approximate solution for $R_L > 0\,\Omega$:

$$E_{AS} = \frac{I_L \cdot L}{2 \cdot R_L} \cdot (V_{bb} + |V_{OUT(CL)}|) \cdot ln\,(1 + \frac{I_L \cdot R_L}{|V_{OUT(CL)}|})$$

Options Overview

all versions: High-side switch, Input protection, ESD protection, load dump and reverse battery protection with 150 Ω in GND connection, protection against loss of ground

Type BTS	410D2	410E2	410G2	410H2	307	**308**
Logic version	D	E	G	H		
Overtemperature protection with hysteresis						
T_j >150 °C, latch function[10)11)]	X			X		**X**
T_j >150 °C, with auto-restart on cooling		X	X		X	
Short circuit to GND protection						
switches off when V_{ON}>3.5 V typ. and V_{bb}> 8 V typ[10)]				X		
switches off when V_{ON}>3.5 V typ.						**X**
switches off when V_{ON}>8.5 V typ.[10)] (when first turned on after approx. 0 µs)	X	X				
Achieved through overtemperature protection			X		X	
Open load detection						
in OFF-state with sensing current -- µA typ.				X	X	**X**
in ON-state with sensing voltage drop across power transistor	X	X	X			
Undervoltage shutdown with auto restart	X	X	X	X	X	**X**
Overvoltage shutdown with auto restart[12)]	X	X	X	X	-	**X**
Status feedback for						
overtemperature	X	X	X	X	X	**X**
short circuit to GND	X	X	-	X	X	**X**
short to V_{bb}	-[13)]	-[13)]	-[13)]	X	X	**X**
open load	X	X	X	X	X	**X**
undervoltage	X	-	-	-	X	**-**
overvoltage	X	-	-	-	-	**-**
Status output type						
CMOS	X					
Open drain		X	X	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				
low level (better protection of application)			X	X	X	**X**
Protection against loss of GND	X	X	X	X	X	**X**

[10)] 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 $t_{d(SC)}$.

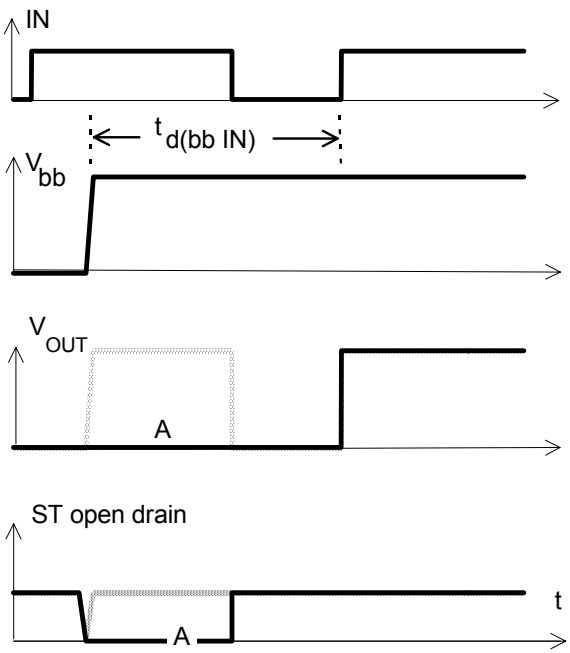
[11)] With latch function. Reseted by a) Input low, b) Undervoltage

[12)] No auto restart after overvoltage in case of short circuit

[13)] Low resistance short V_{bb} to output may be detected in ON-state by the 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 µs

Figure 2a: Switching an inductive load

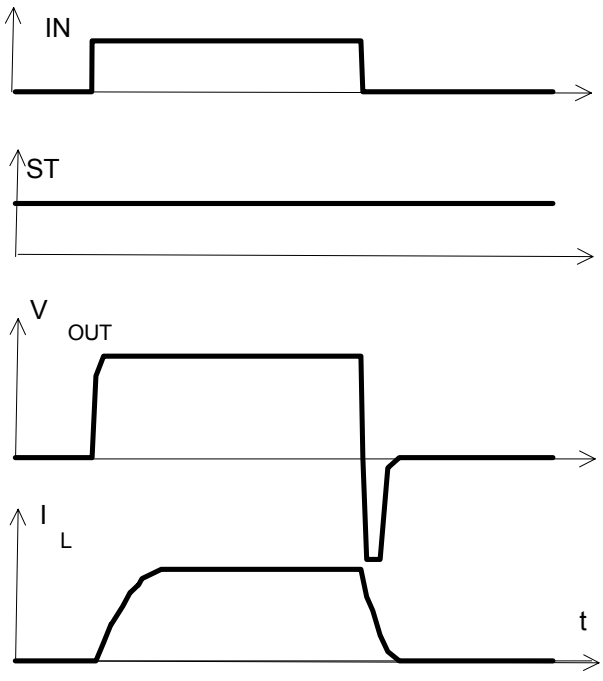
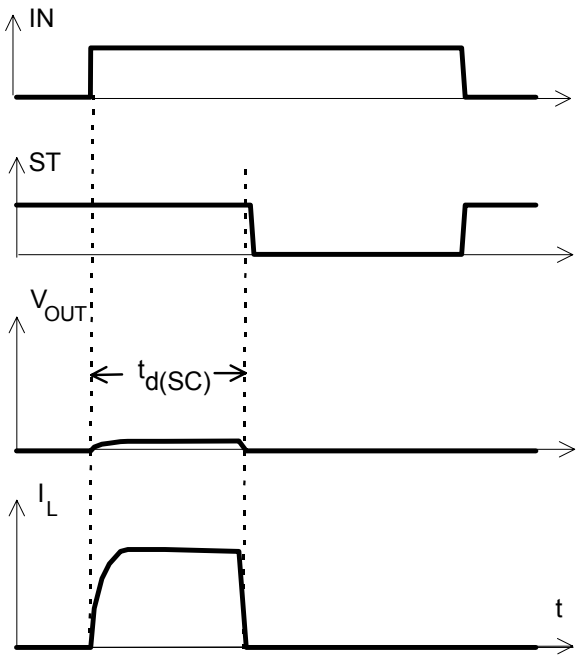
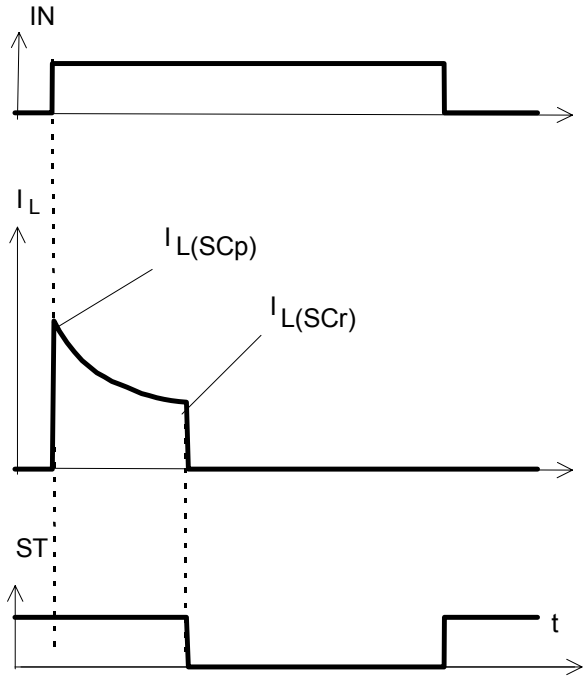


Figure 3a: Turn on into short circuit,



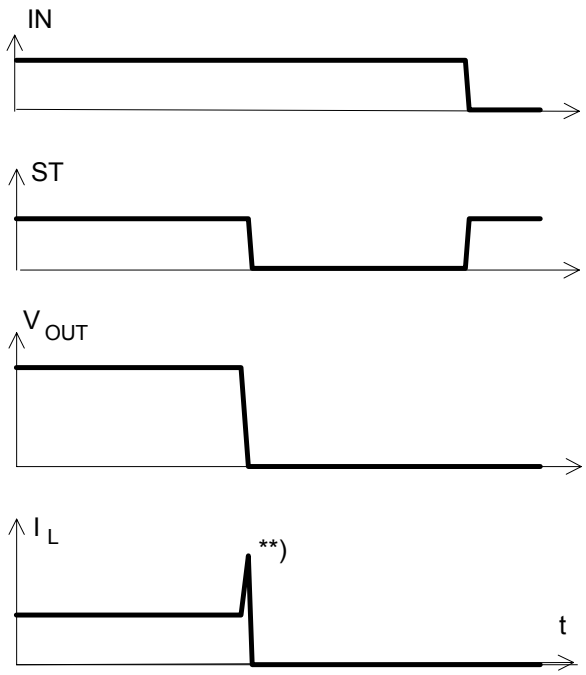
$t_{d(SC)}$ approx. 200µs if V_{bb} - V_{OUT} > 3.5 V typ.

Figure 3b: Turn on into overload,



Heating up may require several seconds,
V_{bb} - V_{OUT} < 3.5 V typ.

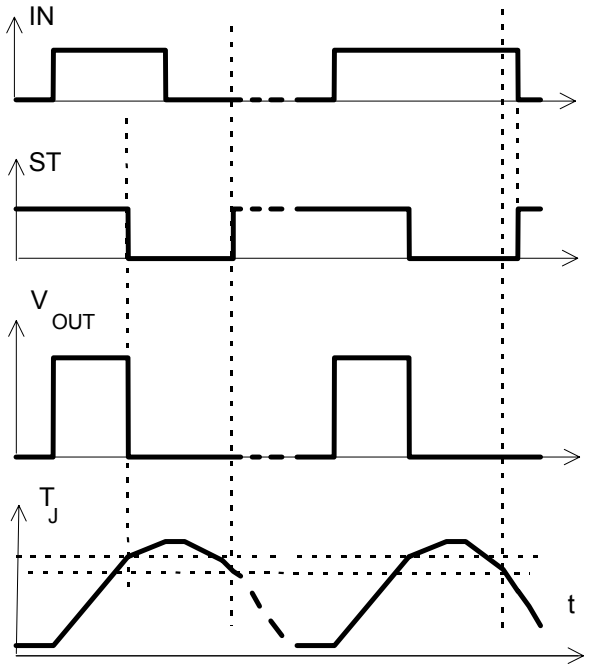
Figure 3c: Short circuit while on:



**) current peak approx. 20 µs

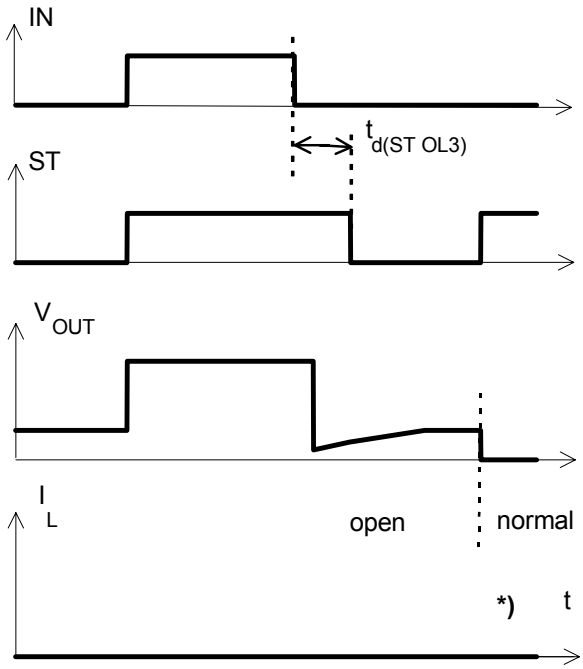
Figure 4a: Overtemperature,

Reset if (IN=low) and ($T_j < T_{jt}$)



*) ST goes high , when V_{IN}=low **and** $T_j < T_{jt}$

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



in case of external capacity $t_{d(ST,OL3)}$ may be higher due to high impedance *) I_L = -- µA typ

Figure 6a: Undervoltage:

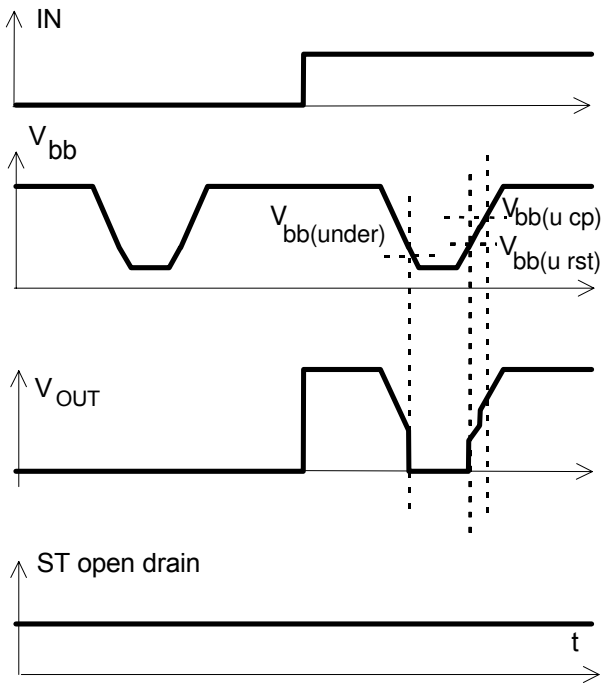
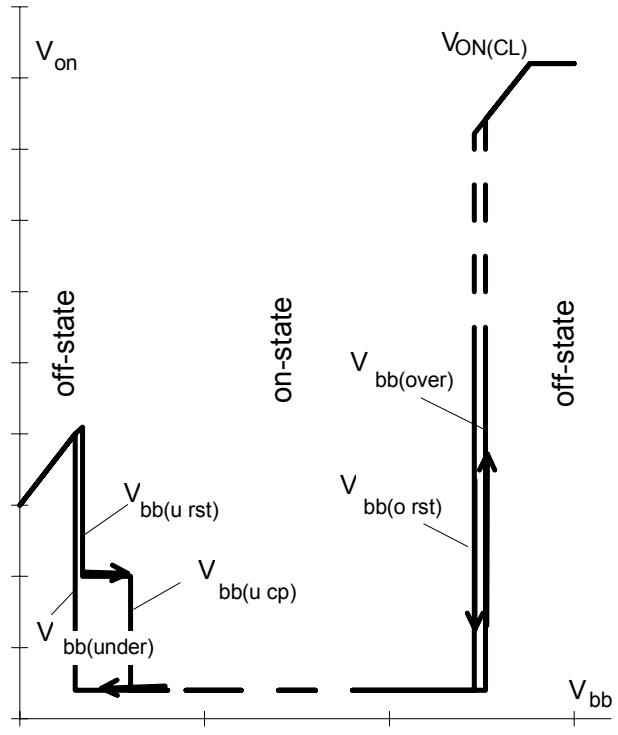


Figure 6b: Undervoltage restart of charge pump



charge pump starts at $V_{bb(ucp)}$ =4.9 V typ.

Figure 7a: Overvoltage:

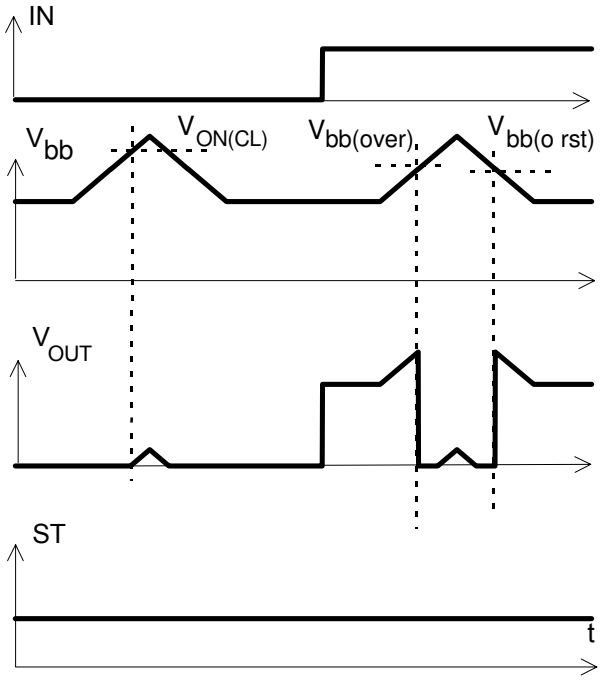
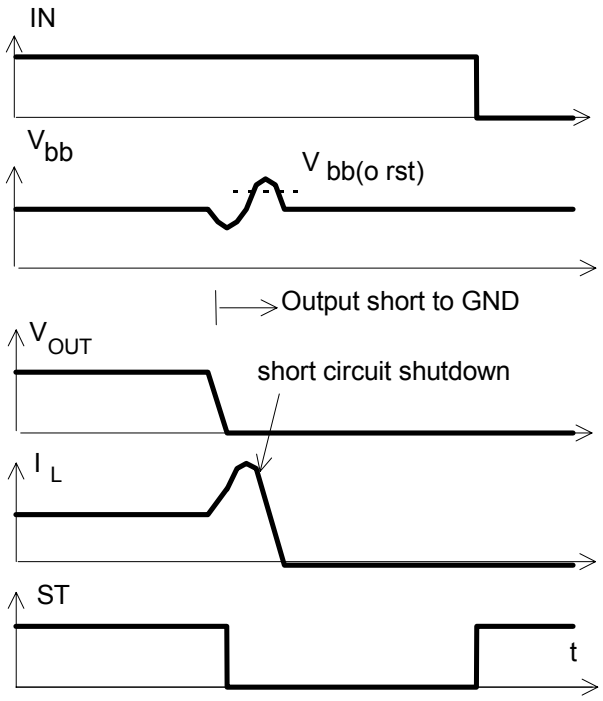


Figure 8a: Overvoltage at short circuit shutdown:



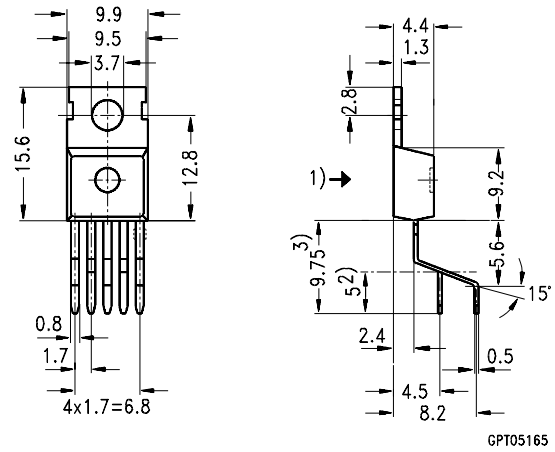
Overvoltage due to power line inductance. No overvoltage auto-restart of PROFET after short circuit shutdown.

Package and Ordering Code

All dimensions in mm

Standard TO-220AB/5 Ordering code

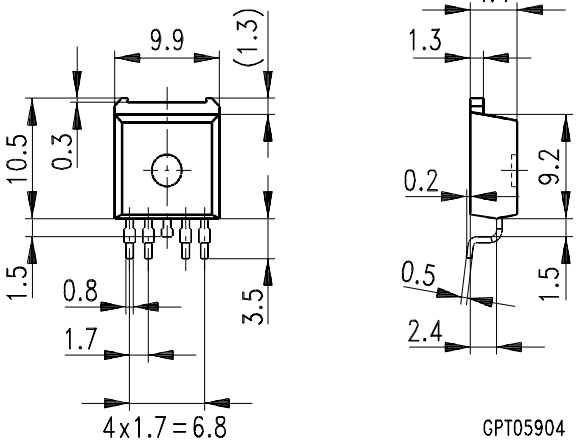
BTS 308	tbd



1) shear and punch direction no burrs this surface
2) min. length by tinning
3) max. 11 mm allowable by tinning

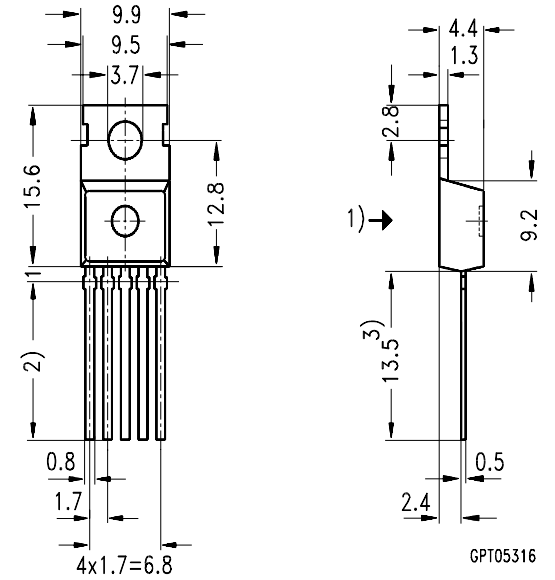
SMD TO-220AB/5, Opt. E3062 Ordering code

BTS 308 E3062A	T&R:	tbd



TO-220AB/5, Option E3043 Ordering code

BTS 308 E3043	tbd



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

Changed since 08.96

Date	Change
Dec 96	"suitable for PWM" deleted at Application List (Page 1) due to the fact, that where may occure problems with current limit.
	Initial short circuit current limit $I_{L(SCp)}$ "V_{ON}=3V" deleted
	Option overview, Short circuit to GND protection, "V_{bb}> 8 V typ" deletet for BTS308, only valid for BTS410H2

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