Smart Highside Power Switch

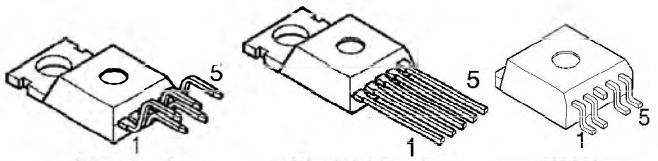
Features

- 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
- CMOS diagnostic output
- Open load detection in OFF-state
- CMOS compatible input
- Loss of ground and loss of V_{bb} protection
- Electrostatic discharge (**ESD**) protection

Product Summary

Overvoltage protection	$V_{bb(AZ)}$	65	V
Operating voltage	$V_{bb(on)}$	4.7 ... 42	V
On-state resistance	R_{ON}	220	mΩ
Load current (ISO)	$I_{L(ISO)}$	1.8	A
Current limitation	$I_{L(SCr)}$	5	A

TO-220AB/5

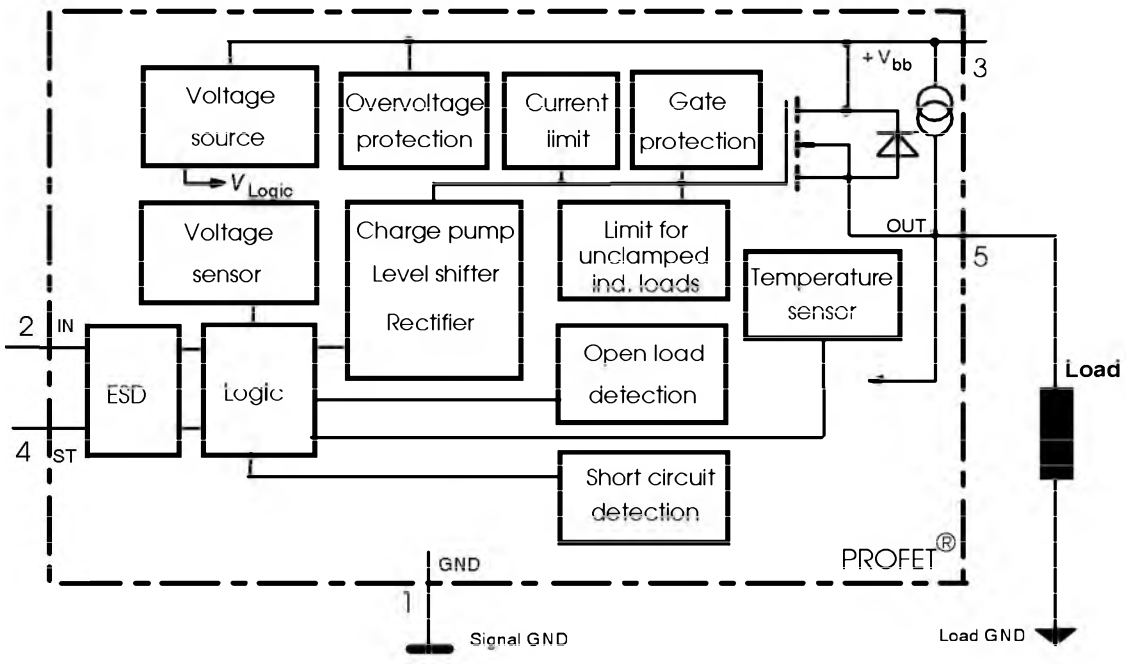


Application

- 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 feedback, monolithically integrated in Smart SIPMOS® technology. Fully protected by embedded protection 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	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}	65	V
Load dump protection[2] $V_{LoadDump} = U_A + V_s$, U_A = 13.5 V R_I[3]= 0.5 Ω, R_L= 6.6 Ω, t_d= 400 ms, IN= low or high	$V_{Load\ dump}$[4]	100	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
Inductive load switch-off energy dissipation, single pulse T_j=150 °C:	E_{AS}	tbd	J
Electrostatic discharge capability (ESD) (Human Body Model)	V_{ESD}	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)	I_{ST}	±5.0	
see internal circuit diagrams page 6			

Thermal resistance chip - case:	R_{thJC}	≤ 2.5	K/W
junction - ambient (free air):	R_{thJA}	≤ 75	
SMD version, device on PCB[5]:		≤ tbd	

2) Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins, e.g. with a 150 Ω resistor in the GND connection and a 15 kΩ resistor in series with the status pin. A resistor for the protection of the input is integrated.

3) R_I = internal resistance of the load dump test pulse generator

4) $V_{Load\ dump}$ is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839

5) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70µm thick) copper area for V_{bb} connection. PCB is vertical without blown air.

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 = 1.6 A T_j=25 °C:	R_{ON}	--	190	220	mΩ
T_j=150 °C:			390	440	
Nominal load current (pin 3 to 5) ISO Proposal: V_{ON} = 0.5 V, T_C = 85 °C	$I_{L(ISO)}$	1.6	1.8	--	A
Output current (pin 5) while GND disconnected or GND pulled up, V_{bb}=30 V, V_{IN}= 0, see diagram page 7	$I_{L(GNDhigh)}$	--	--	10	mA
Turn-on time to 90% V_{OUT}:	t_{on}	15	--	60	µs
Turn-off time to 10% V_{OUT}: R_L = 12 Ω	t_{off}	5	--	50	
Slew rate on 10 to 30% V_{OUT}, R_L = 12 Ω	dV/dt_{on}	--	--	3	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 12 Ω	$-dV/dt_{off}$	--	--	6	V/µs
Operating Parameters					
Operating voltage [6] T_j =-40...+150°C:	$V_{bb(on)}$	4.7	--	42	V
Undervoltage shutdown T_j =25°C:	$V_{bb(under)}$	2.9	--	4.5	V
T_j =-40...+150°C:		2.7	--	4.7	
Undervoltage restart T_j =-40...+150°C:	$V_{bb(u\ rst)}$	--	--	4.9	V
Undervoltage restart of charge pump see diagram page 12	$V_{bb(ucp)}$	--	5.6	6.0	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$	$\Delta V_{bb(under)}$	--	0.1	--	V
Overvoltage shutdown T_j =-40...+150°C:	$V_{bb(over)}$	42	--	52	V
Overvoltage restart T_j =-40...+150°C:	$V_{bb(o\ rst)}$	40	--	--	V
Overvoltage hysteresis T_j =-40...+150°C:	$\Delta V_{bb(over)}$	--	0.1	--	V
Overvoltage protection[7] T_j =-40...+150°C: I_{bb}=40 mA	$V_{bb(AZ)}$	65	70	--	V
Standby current (pin 3), V_{IN}=0, $I_{ST} \leq 0$ T_j=-40...+150°C:	$I_{bb(off)}$	--	40	70	µA
Operating current (Pin 1)[8], V_{IN}=5 V	I_{GND}	--	1	--	mA

6) At supply voltage increase up to V_{bb}= 5.6 V typ without charge pump, $V_{OUT} \approx V_{bb}$ - 2 V

7) Meassured without load. See also $V_{ON(CL)}$ in table of protection functions and circuit diagram page 7.

8) 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} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Protection Functions					
Initial peak short circuit current limit (pin 3 to 5)[9], (max 450 µs if $V_{ON} > V_{ON(SC)}$)	$I_{L(SCp)}$				
T_j =-40°C:		9	--	23	A
T_j =25°C:		--	12	--	
T_j =+150°C:		4	--	15	
Overload shutdown current limit V_{ON}= 8 V, T_j = T_{jt} (see timing diagrams, page 10)	$I_{L(SCr)}$	--	5	--	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 60 µs	$t_{d(SC)}$	--	--	450	µs
Output clamp (inductive load switch off) $V_{OUT} = V_{bb} - V_{ON(CL)}$ I_L= 40 mA, T_j =-40..+150°C:	$V_{ON(CL)}$	61	68	73	V
I_L= 1 A, T_j =-40..+150°C:		--	--	75	
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.5	--	V
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Inductive load switch-off energy dissipation[10],	E_{AS}	--	--	tbd	J
$T_{j\,Start}$ = 150 °C, single pulse V_{bb} = 12 V:	E_{Load12}			tbd	
V_{bb} = 24 V:	E_{Load24}			tbd	
Reverse battery (pin 3 to 1) [11]	$-V_{bb}$	--	--	32	V
Diagnostic Characteristics					
Open load detection current T_j=-40...+150°C: (included in standby current $I_{bb(off)}$)	$I_{L(off)}$	15	30	60	µA
Open load detection voltage T_j=-40..150°C:	$V_{OUT(OL)}$	2	3	4	V

9) Short circuit current limit for max. duration of $t_{d(SC)\,max}$=450 µs, prior to shutdown

10) 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 diagram page 8

11) 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} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Input and Status Feedback[12]					
Input resistance see circuit page 6	R_I	--	9	--	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	70	µA
Delay time for status with open load after Input neg. slope (see diagram page 11)	$t_{d(ST\ OL3)}$	--	200	--	µs
Status invalid after positive input slope (short circuit) T_j=-40 ... +150°C:	$t_{d(ST\ SC)}$	--	--	450	µs
Status output (CMOS) T_j =-40...+150°C, I_{ST}= - 50 µA:	$V_{ST(high)}$[13]	4.4	5.1	6.5	V
T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.4	
Max. status current for current source (out):	$-I_{ST}$	--	--	0.25	mA
valid status output, current sink (in) :	$+I_{ST}$[14]	--	--	1.6	
T_j =-40...+150°C					

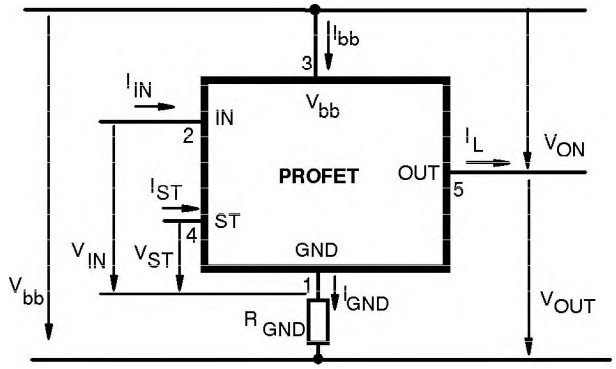
[12] If a ground resistor R_{GND} is used, add the voltage drop across this resistor.
[13] $V_{St\ high} \approx V_{bb}$ during undervoltage shutdown
[14] No current sink capability during undervoltage shutdown

Truth Table

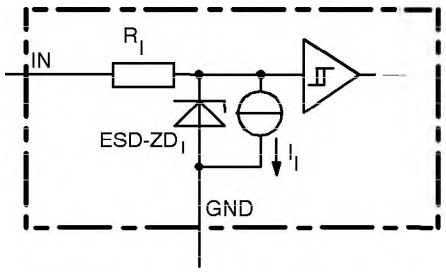
	Input-level	Output level	Status				
			412 B2	410 D2	410 E2/F2	410 G2	410 H2
Normal operation	L H	L H	H H	H H	H H	H H	H H
Open load	L H	15) H	L H	H L	H L	H L	L H
Short circuit to GND	L H	L L	H L	H L	H L	H H	H L
Short circuit to V_{bb}	L H	H H	L H	H H (L[16])	H H (L[16])	H H (L[16])	L H
Overtem-perature	L H	L L	L L	L L	L L	L L	L L
Under-voltage	L H	L L	L[17] L[17]	L[17] L[17]	H H	H H	H H
Overvoltage	L H	L L	L L	L L	H H	H H	H H

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

Terms

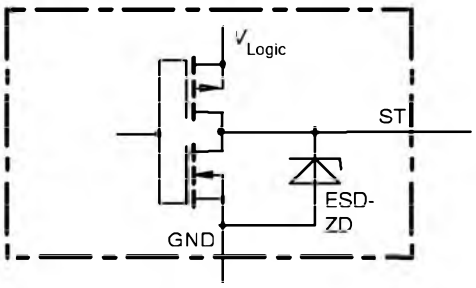


Input circuit (ESD protection)



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).

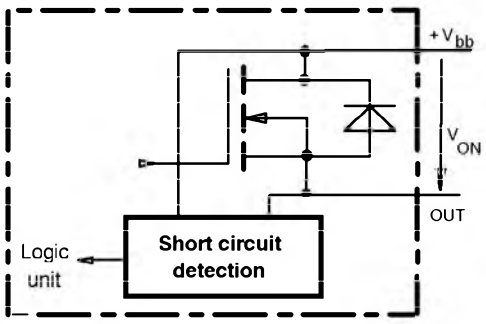
Status output



Zener diode: 6 V typ., max 5.0 mA, V_{Logic} 5 V typ, 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).

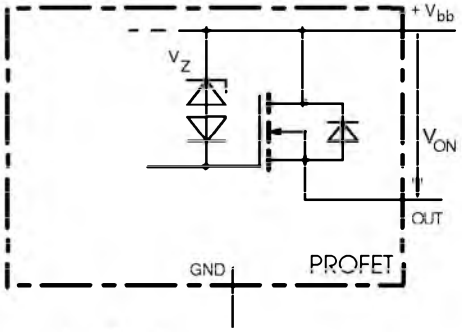
Short circuit detection

Fault Condition: V_{ON} > 8.5 V typ.; IN high



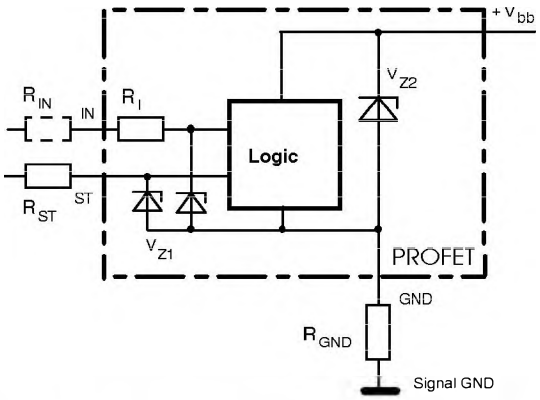
15) Power Transistor off, high impedance, versions BTS 410H, BTS 412B: internal pull up current source for open load detection.
16) Low resistance short V_{bb} to output may be detected by no-load-detection
17) No current sink capability during undervoltage shutdown

Inductive and overvoltage output clamp



V_{ON} clamped to 68 V typ.

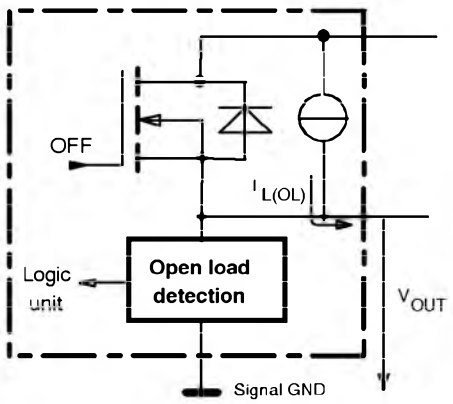
Overvolt. and reverse batt. protection



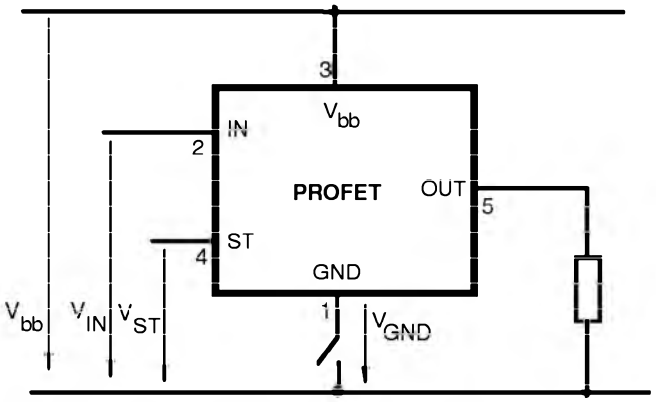
V_{Z1} = 6.2 V typ., V_{Z2} = 70 V typ., R_{GND} = 150 Ω, R_{ST}= 15 kΩ, R_I= 9 kΩ typ.

Open-load detection

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

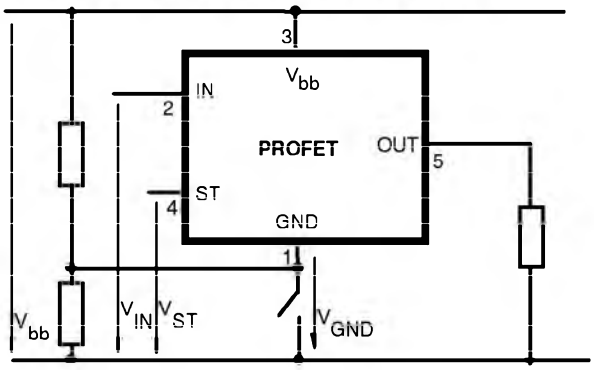


GND disconnect



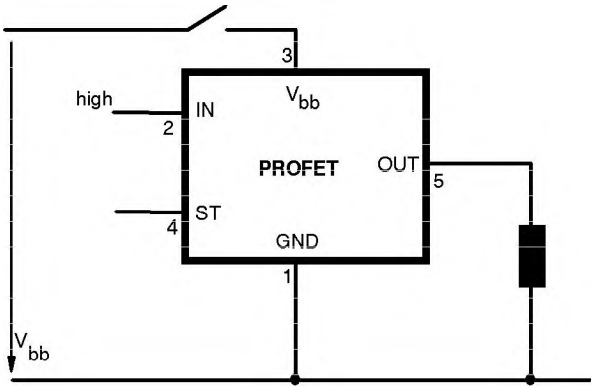
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
Due to V_{GND} >0, no V_{ST} = low signal available.

GND disconnect with GND pull up



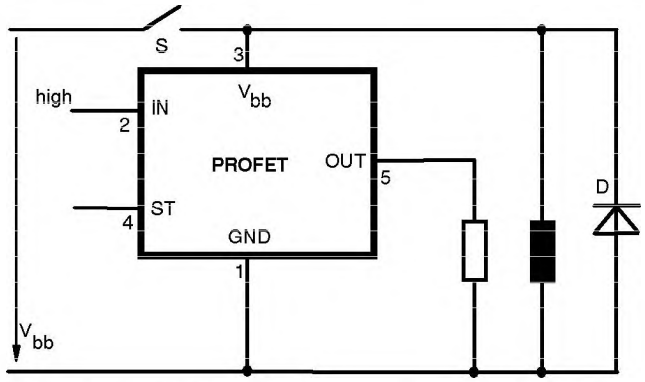
Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
Due to V_{GND} >0, no V_{ST} = low signal available.

V_{bb} disconnect with charged inductive load



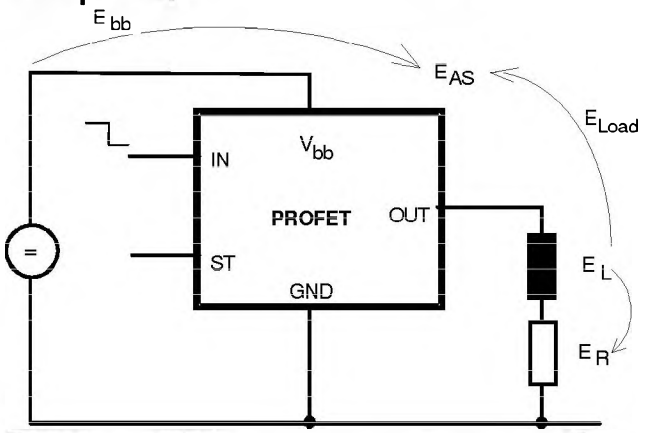
Normal load current can be handled by the PROFET itself.

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 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 with 150 Ω in GND connection, protection against loss of ground

Type BTS	**412 B2**	410D2	410E2	410F2	410G2	410H2
Logic version	**B**	D	E	F	G	H
Overtemperature protection with hysteresis						
T_j >150 °C, latch function[18)19)]	X	X		X		X
T_j >150 °C, with auto-restart on cooling			X		X	
Short circuit to GND protection						
switches off when V_{ON}>3.5 V typ. and V_{bb}> 8 V typ[18)] (when first turned on after approx. 210 µs)						X
switches off when V_{ON}>8.5 V typ.[18)] (when first turned on after approx. 210 µs)	X	X	X	X		
Achieved through overtemperature protection					X	
Open load detection						
in OFF-state with sensing current 30 µA typ.	X					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	X
Overvoltage shutdown with auto restart[20)]	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
short to V_{bb}	X	-[21)]	-[21)]	-[21)]	-[21)]	X
open load	X	X	X	X	X	X
undervoltage	X	X	-	-	-	-
overvoltage	X	X	-	-	-	-
Status output type						
CMOS	X	X				
Open drain			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	X
Load current limit						
high level (can handle loads with high inrush currents)	X	X	X			
low level (better protection of application)				X	X	X
Protection against loss of GND	X	X	X	X	X	X

18) 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 $t_{d(SC)}$.

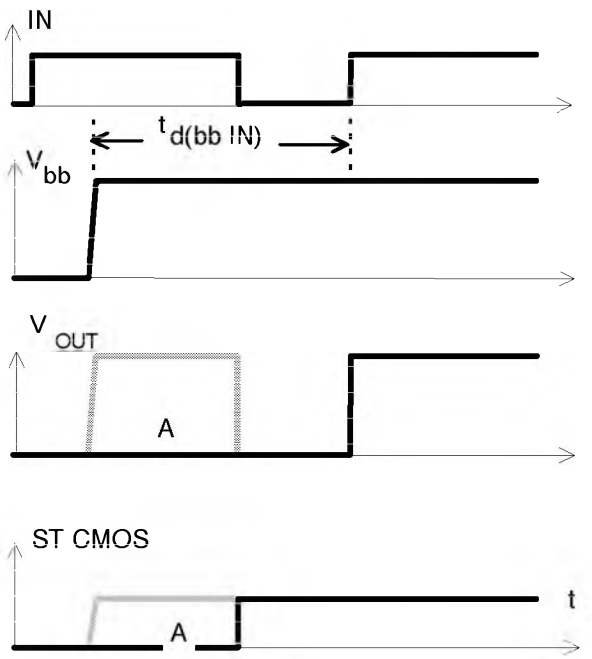
19) With latch function. Reseted by a) Input low, b) Undervoltage

20) No auto restart after overvoltage in case of short circuit

21) Low resistance short V_{bb} to output may be detected by 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 a lamp,

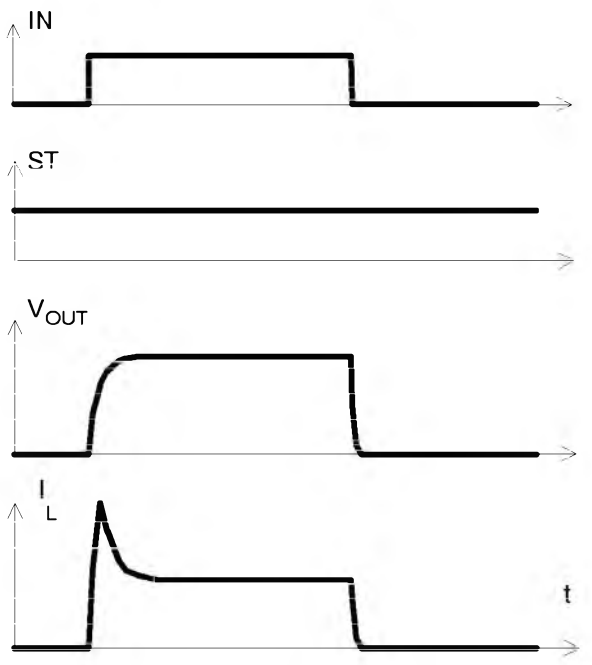


Figure 2b: Switching an inductive load

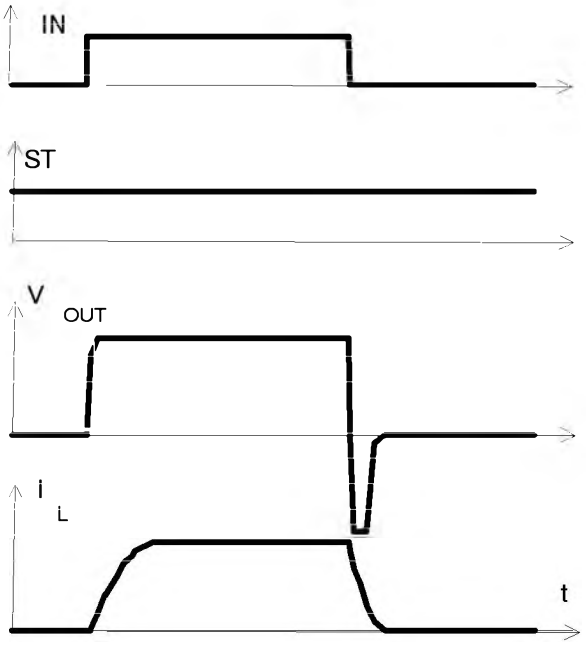
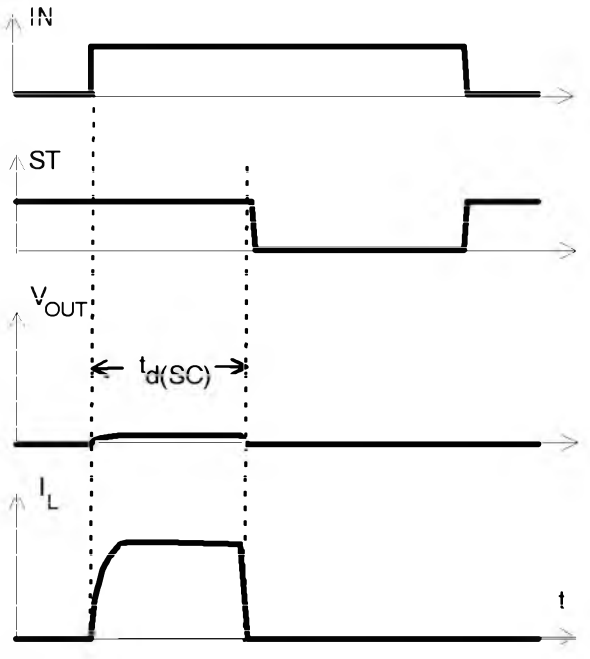
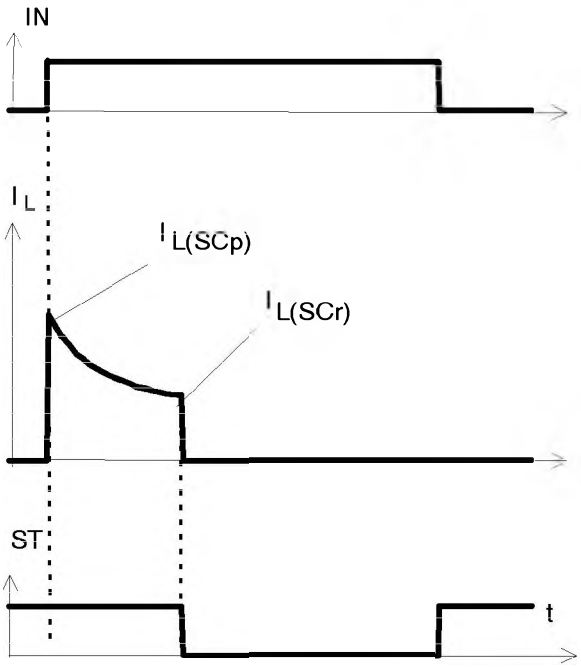


Figure 3a: Turn on into short circuit,



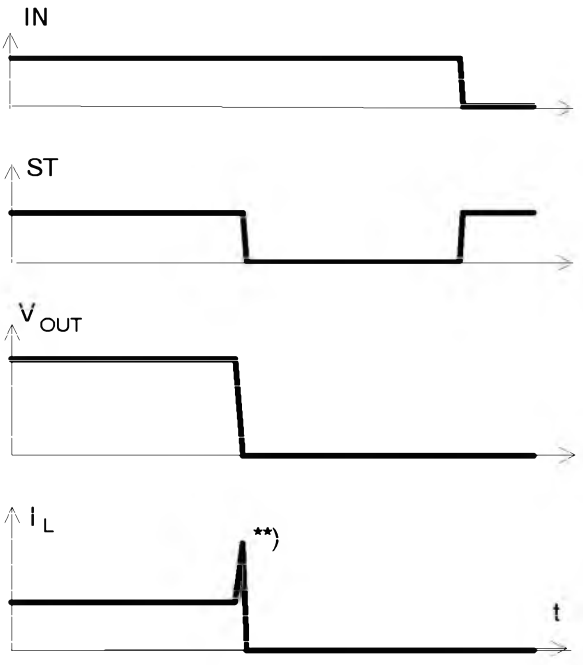
$t_{d(SC)}$ approx. 200µs if V_{bb} - V_{OUT} > 8.5 V typ.

Figure 3b: Turn on into overload,



Heating up may require several seconds,
V_{bb} - V_{OUT} < 8.5 V typ.

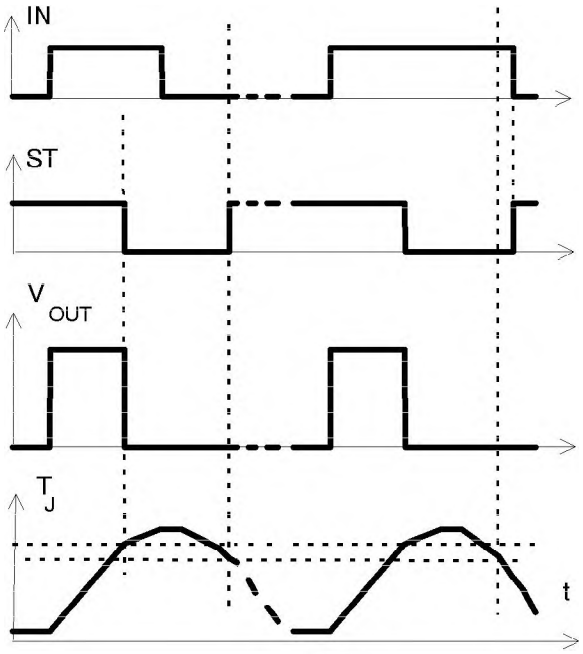
Figure 3c: Short circuit while on:



**) current peak approx. 20 µs

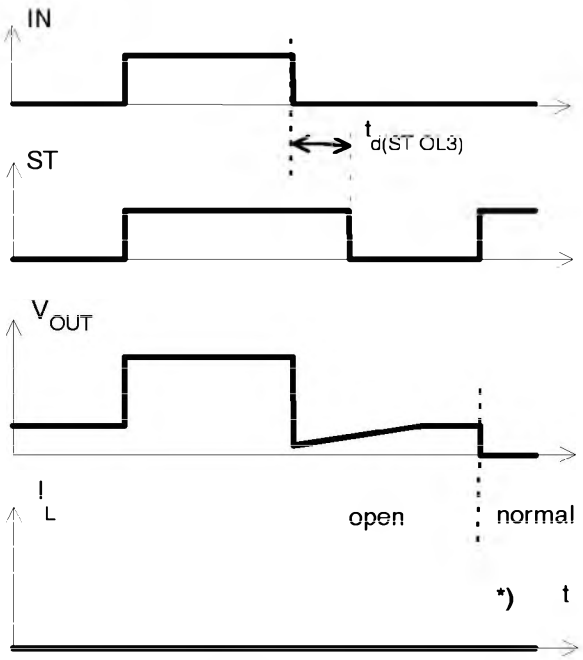
Figure 4a: Overtemperature,

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



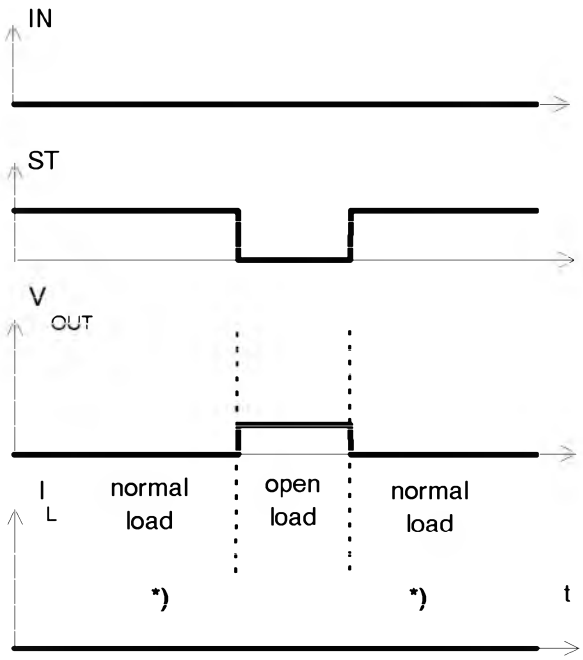
*) ST goes high , when V_{IN}=low **and** T_j<T_{jt}

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 = 30 µA typ

Figure 5b: Open load: detection in OFF-state, open load occurs in off-state



*) I_L = 30 µA typ

Figure 6a: Undervoltage:

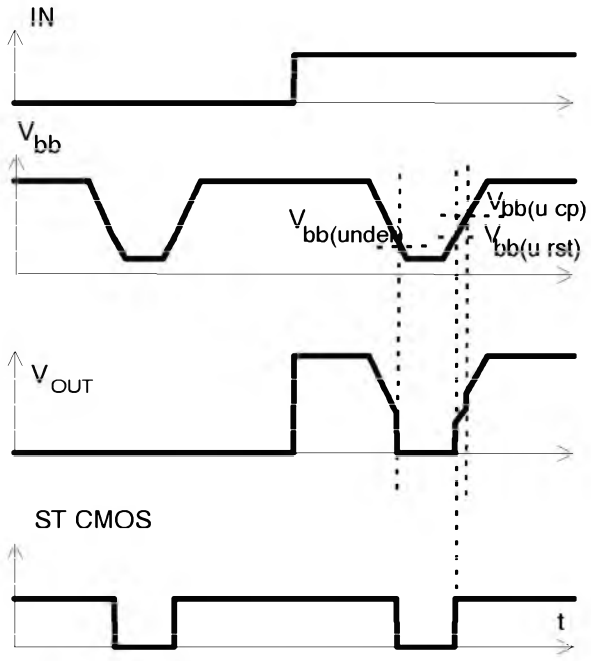
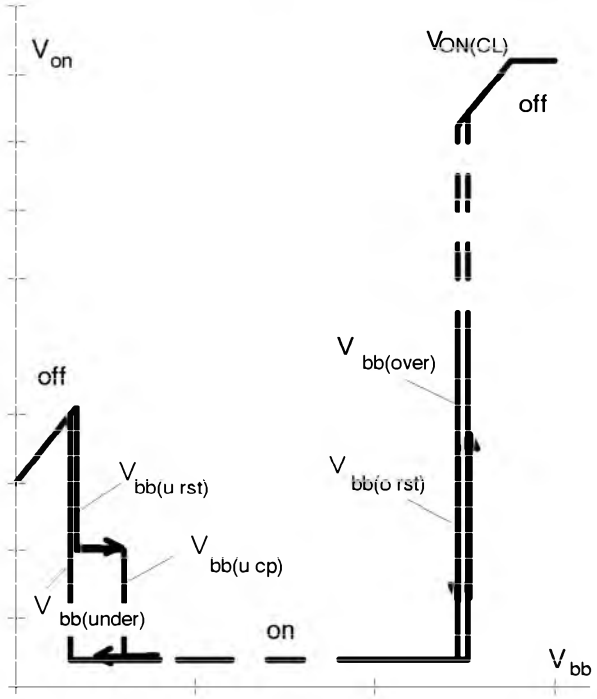
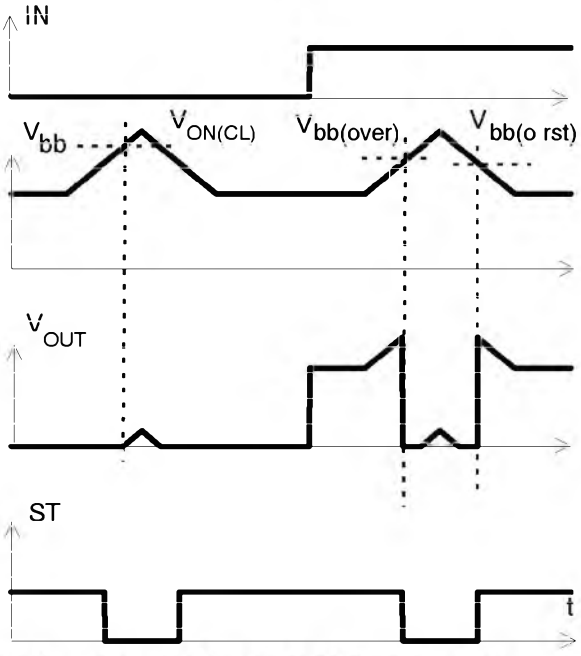


Figure 6b: Undervoltage restart of charge pump



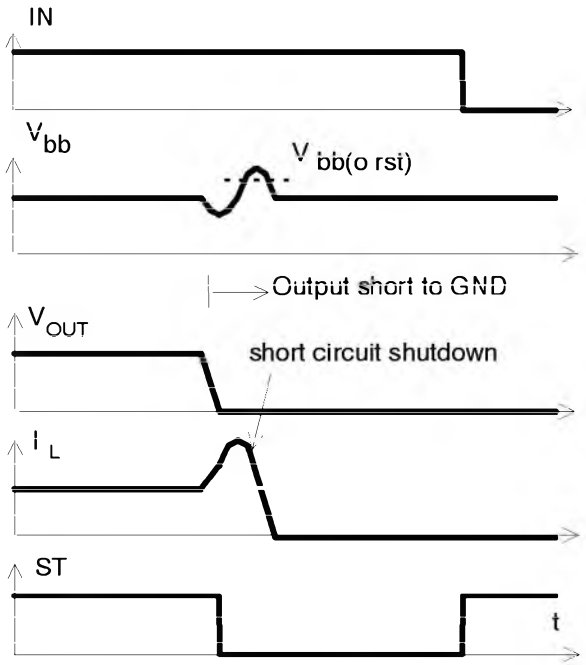
charge pump starts at $V_{bb(ucp)}$ =5.6 V typ.

Figure 7a: Overvoltage:



if $V_{bb} > V_{bb(AZ)}$ increase of V_{ST} due to GND resistor voltage.

Figure 9a: Overvoltage at short circuit shutdown:



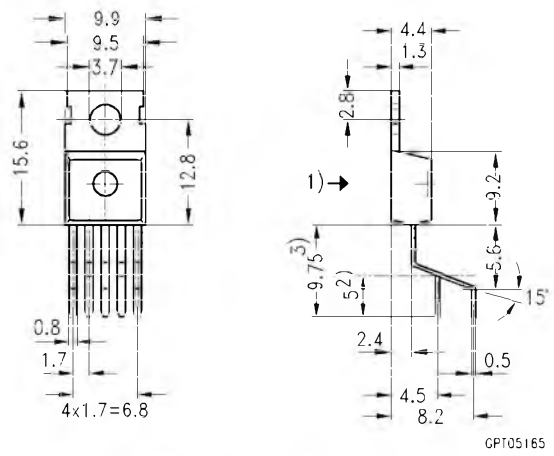
Overvoltage due to power line inductance. No overvoltage auto-restart of PROFET after short circuit shutdown.

Package and Ordering Code

All dimensions in mm

Standard TO-220AB/5 Ordering code

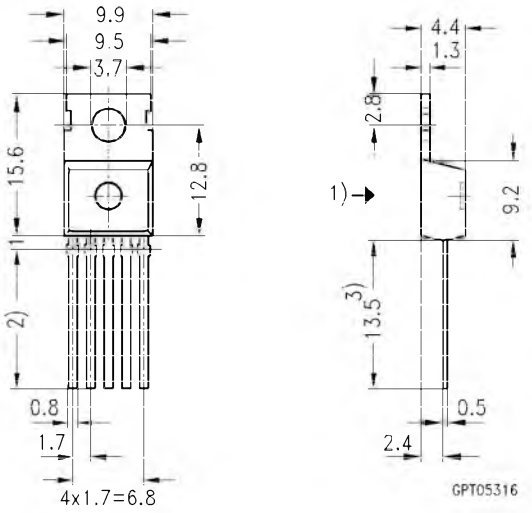
BTS 412B2	Q67060-S6109-A2



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

TO-220AB/5, Option E3043 Ordering code

BTS 412B2 E3043	Q67060-S6109-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-220AB/5, Opt. E3062 Ordering code

BTS 412B2 E3062A	T&R:	Q67060-S6109-A4