Smart Highside Power Switch

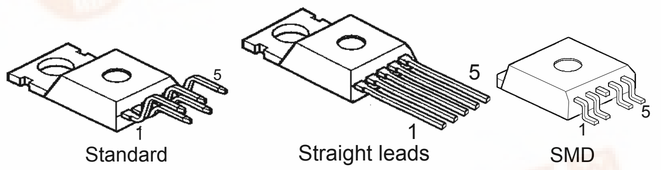
Features

- 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 ON-state
- CMOS compatible input
- Loss of ground and loss of V_{bb} protection[2)]
- **E**lectro**st**atic **d**ischarge (**ESD**) protection

Product Summary

Overvoltage protection	$V_{bb(AZ)}$	63	V
Operating voltage	$V_{bb(on)}$	4.5 ... 42	V
On-state resistance	R_{ON}	18	mΩ
Load current (ISO)	$I_{L(ISO)}$	21	A
Current limitation	$I_{L(SCr)}$	70	A

TO-220AB/5

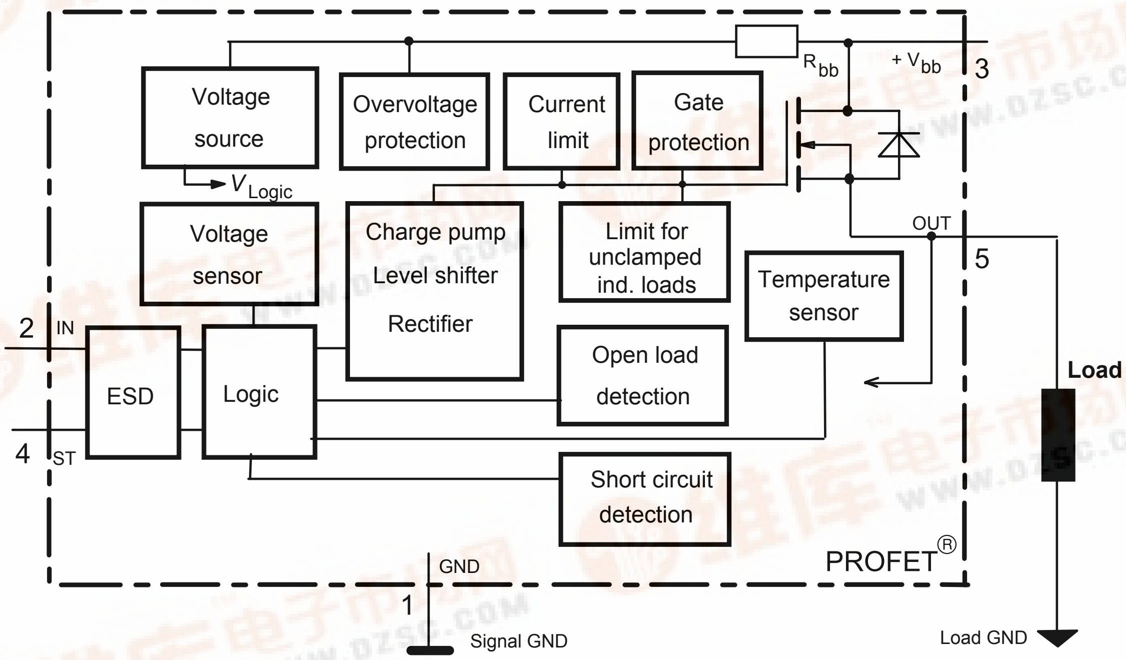


Application

- 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, integrated in Smart SIPMOS® chip on chip technology. Providing embedded protective functions.



1) No external components required, reverse load current limited by connected load.
2) 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}	63	V
Load dump protection $V_{LoadDump} = U_A + V_s$, U_A = 13.5 V R_I= 2 Ω, R_L= 1.1 Ω, t_d= 200 ms, IN= low or high	$V_{Load\ dump}$[3)]	80	V
Load current (Short-circuit current, see page 4)	I_L	self-limited	A
Operating temperature range Storage temperature range	T_j T_{stg}	-40 ...+150 -55 ...+150	°C
Power dissipation (DC)	P_{tot}	167	W
Inductive load switch-off energy dissipation, single pulse T_j=150 °C:	E_{AS}	2.1	J
Electrostatic discharge capability (ESD) (Human Body Model)	V_{ESD}	2.0	kV
Input voltage (DC) Current through input pin (DC) Current through status pin (DC) see internal circuit diagrams page 6...	V_{IN} I_{IN} I_{ST}	-0.5 ... +6 ±5.0 ±5.0	V mA

Thermal resistance chip - case: junction - ambient (free air): SMD version, device on pcb[4)]:	R_{thJC} R_{thJA}	≤ 0.75 ≤ 75 ≤ tbd	K/W

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

4) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm^2 (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 min	Values typ	Values max	Unit
Load Switching Capabilities and Characteristics					
On-state resistance (pin 3 to 5) I_L = 5 A T_j=25 °C: T_j=150 °C:	R_{ON}	--	15 28	18 35	mΩ
Nominal load current (pin 3 to 5) ISO Proposal: V_{ON} = 0.5 V, T_C = 85 °C	$I_{L(ISO)}$	17	21	--	A
Output current (pin 5) while GND disconnected or GND pulled up, V_{IN}= 0, see diagram page 7, T_j =-40...+150°C	$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time to 90% V_{OUT}: Turn-off time to 10% V_{OUT}: R_L = 12 Ω, T_j =-40...+150°C	t_{on} t_{off}	100 10	-- --	350 130	µs
Slew rate on 10 to 30% V_{OUT}, R_L = 12 Ω, T_j =-40...+150°C	dV /dt$_{on}$	0.2	--	2	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 12 Ω, T_j =-40...+150°C	-dV/dt$_{off}$	0.4	--	5	V/µs
Operating Parameters					
Operating voltage [5] T_j =-40...+150°C:	$V_{bb(on)}$	4.5	--	42	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 T_j =-40...+150°C:	$V_{bb(ucp)}$	--	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:	$V_{bb(over)}$	42	--	52	V
Overvoltage restart T_j =-40...+150°C:	$V_{bb(o\ rst)}$	42	--	--	V
Overvoltage hysteresis T_j =-40...+150°C:	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection[6] T_j =-40°C: I_{bb}=40 mA T_j =25...+150°C:	$V_{bb(AZ)}$	60 63	-- 67	--	V
Standby current (pin 3) T_j=-40...+25°C: V_{IN}=0 T_j=150°C:	$I_{bb(off)}$	-- --	12 18	25 60	µA
Leakage output current (included in $I_{bb(off)}$) V_{IN}=0	$I_{L(off)}$	--	6	--	µA
Operating current (Pin 1)[7], V_{IN}=5 V	I_{GND}	--	1.1	--	mA

[5] At supply voltage increase up to V_{bb}= 6.5 V typ without charge pump, $V_{OUT} \approx V_{bb}$ - 2 V

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

[7] 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[8]					
Initial peak short circuit current limit (pin 3 to 5)[9], (max 400 µs if $V_{ON} > V_{ON(SC)}$) T_j =-40°C: T_j =25°C: T_j =+150°C:	$I_{L(SCp)}$	 -- -- 45	 -- 95 --	 140 -- --	A
Repetitive short circuit current limit $T_j = T_{jt}$ (see timing diagrams, page 10)	$I_{L(SCr)}$	30	70	--	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 $V_{OUT} = V_{bb} - V_{ON(CL)}$, I_L= 30 mA	$V_{ON(CL)}$	--	58	--	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[10], $T_{j\ Start}$ = 150 °C, single pulse V_{bb} = 12 V: V_{bb} = 24 V:	E_{AS} E_{Load12} E_{Load24}	--	--	2.1 1.7 1.2	J
Reverse battery (pin 3 to 1) [11]	$-V_{bb}$	--	--	32	V
Integrated resistor in V_{bb} line	R_{bb}	--	120	--	Ω

Diagnostic Characteristics

Open load detection current T_j=-40 °C: (on-condition) T_j=25..150°C:	$I_{L\ (OL)}$	2 2	-- --	1900 1500	mA

8) 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.

9) Short circuit current limit for max. duration of $t_{d(SC)\ max}$=400 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) 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 min	Values typ	Values max	Unit
Input and Status Feedback[12]					
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	µA
Status invalid after positive input slope (short circuit) T_j=-40 ... +150°C:	$t_{d(ST SC)}$	80	200	400	µs
Status invalid after positive 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	--	V
ST low voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.4	

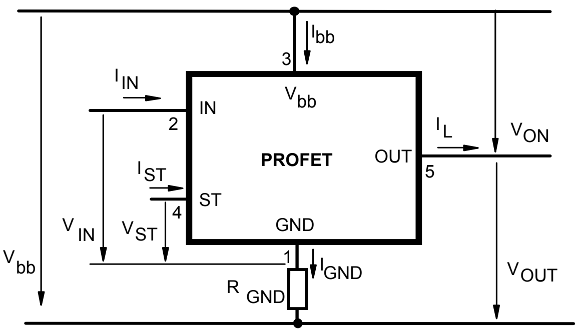
12) If a ground resistor R_{GND} is used, add the voltage drop across this resistor.

Truth Table

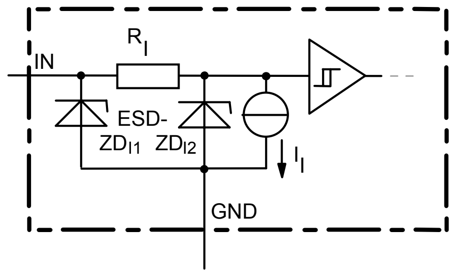
	Input-level	Output level	Status 442 D2	Status 442 E2
Normal operation	**L** **H**	**L** **H**	H H	**H** **H**
Open load	**L** **H**	[13] **H**	H L	**H** **L**
Short circuit to GND	**L** **H**	**L** **L**	H L	**H** **L**
Short circuit to V_{bb}	**L** **H**	**H** **H**	H H (L[14])	**H** **H (L[14])**
Overtem-perature	**L** **H**	**L** **L**	L L	**L** **L**
Under-voltage	**L** **H**	**L** **L**	L[15] L[15]	**H** **H**
Overvoltage	**L** **H**	**L** **L**	L L	**H** **H**

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

Terms



Input circuit (ESD protection)



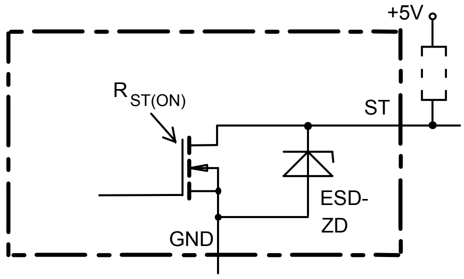
ZD_{I1} 6.1 V typ., ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

[13] Power Transistor off, high impedance

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

[15] No current sink capability during undervoltage shutdown

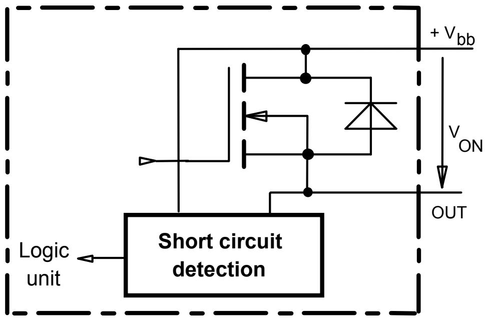
Status output



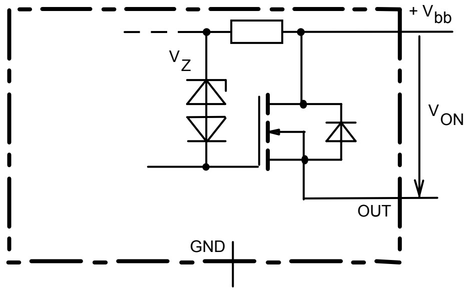
ESD-Zener diode: 6.1 V typ., max 5 mA;
$R_{ST(ON)}$ < 250 Ω at 1.6 mA, ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

Short Circuit detection

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

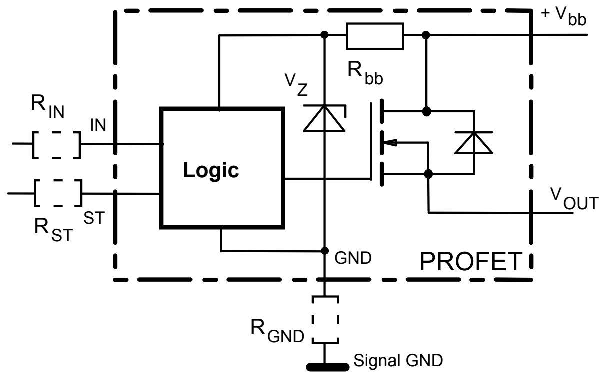


Inductive and overvoltage output clamp



V_{ON} clamped to 58 V typ.

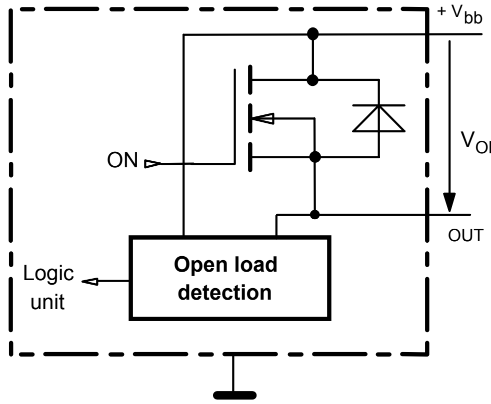
Overvolt. and reverse batt. protection



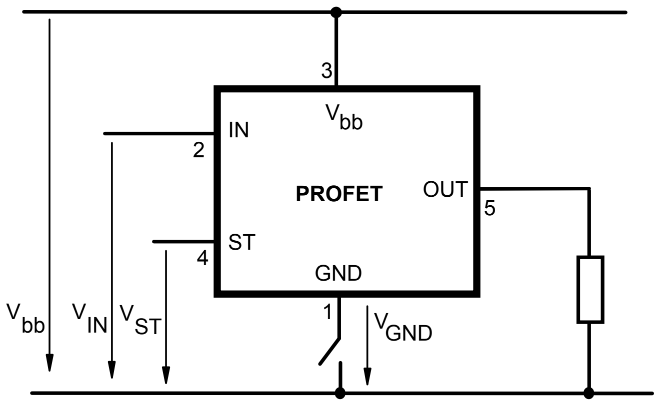
R_{bb} = 120 Ω typ., V_Z +R_{bb}*40 mA = 67 V typ., add R_{GND}, R_{IN}, R_{ST} for extended protection

Open-load detection

ON-state diagnostic condition: V_{ON} < R_{ON} * $I_{L(OL)}$; IN high

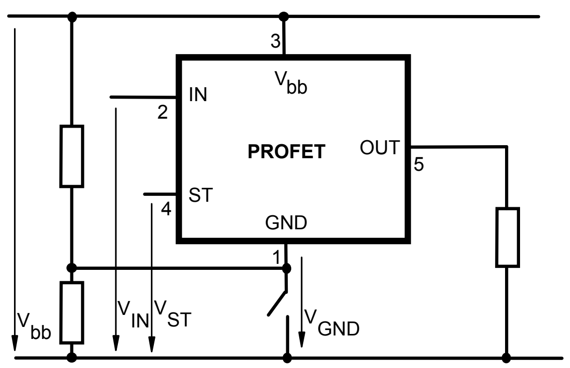


GND disconnect



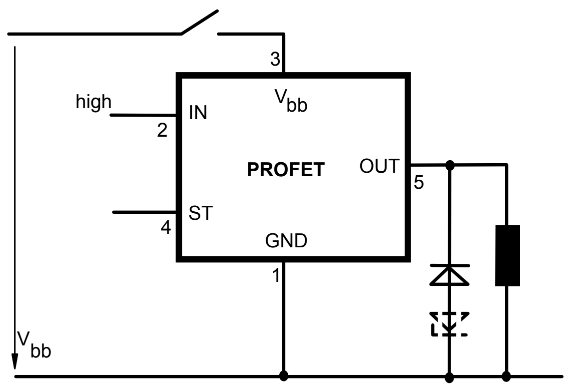
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
Due to V_{GND} >0, no V_{ST} = low signal available.

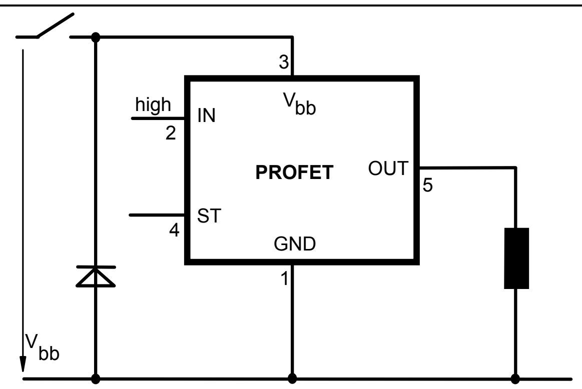
GND disconnect with GND pull up



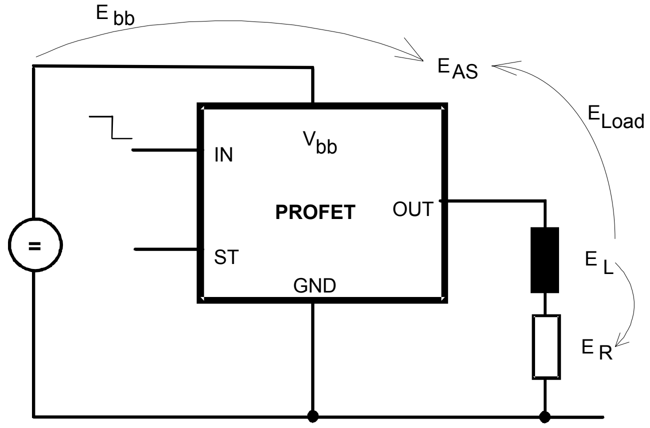
Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
Due to $V_{GND} > 0$, no V_{ST} = low signal available.

V_{bb} disconnect with charged inductive load





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 , protection against loss of ground

Type BTS	442D2	**442E2**
Logic version	D	**E**
Overtemperature protection		
T_j >150 °C, latch function[16][17]	X	
T_j >150 °C, with auto-restart on cooling		**X**
Short-circuit to GND protection		
switches off when V_{ON}>8.3 V typ.[16] (when first turned on after approx. 200 µs)	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**
Undervoltage shutdown with auto restart	X	**X**
Overvoltage shutdown with auto restart	X	**X**
Status feedback for		
overtemperature	X	**X**
short circuit to GND	X	**X**
short to V_{bb}	-[18]	**-[18]**
open load	X	**X**
undervoltage	X	**-**
overvoltage	X	**-**
Status output type		
CMOS	X	
Open drain		**X**
Output negative voltage transient limit (fast inductive load switch off)		
to V_{bb} - $V_{ON(CL)}$	X	**X**
Load current limit		
high level (can handle loads with high inrush currents)	X	**X**
medium level		
low level (better protection of application)		

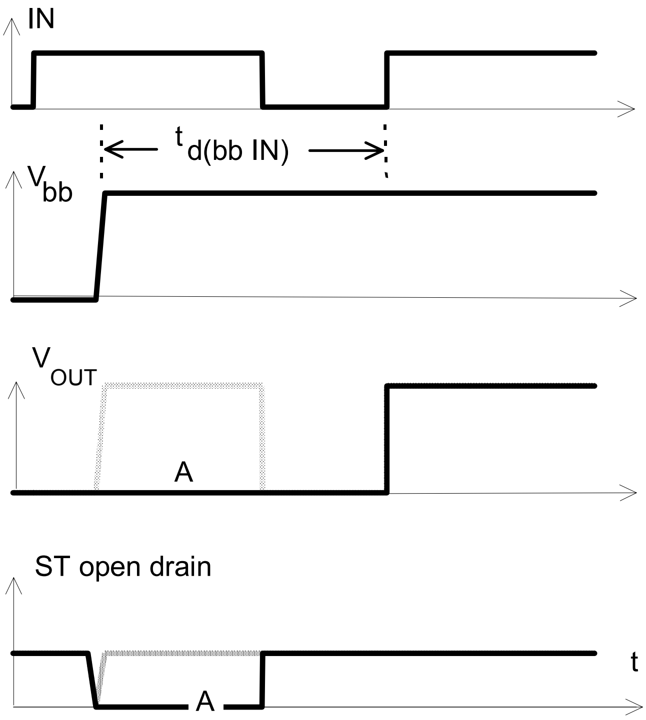
16) Latch except when V_{bb} -V_{OUT} < $V_{ON(SC)}$ after shutdown. In most cases V_{OUT} = 0 V after shutdown (V_{OUT} ≠ 0 V only if forced externally). So the device remains latched unless V_{bb} < $V_{ON(SC)}$ (see page 4). No latch between turn on and $t_{d(SC)}$.

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

18) 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,

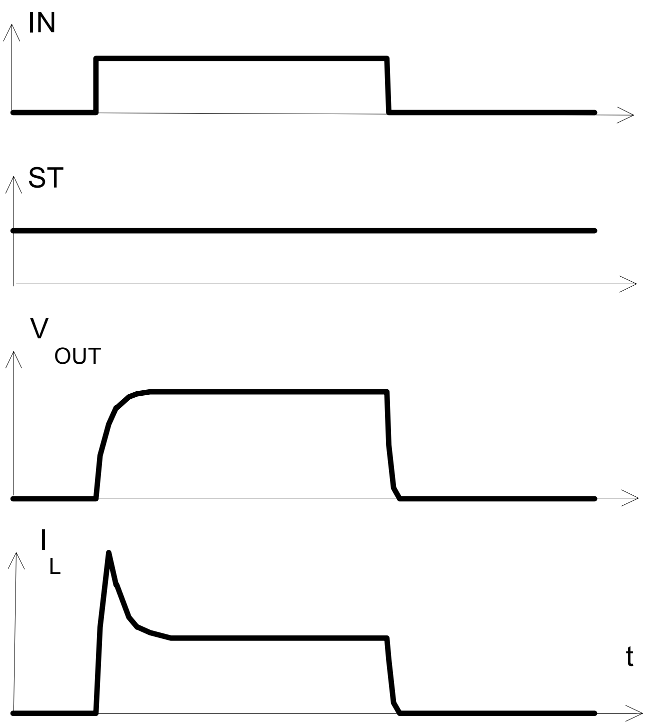
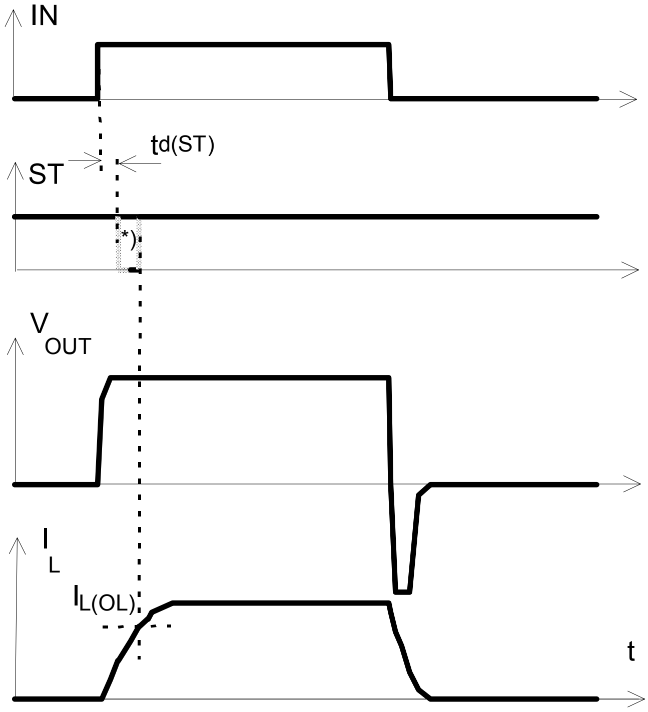
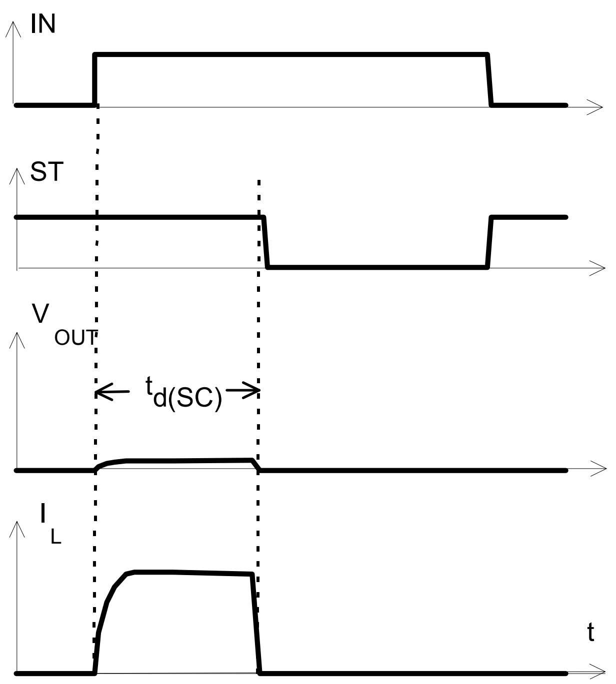


Figure 2b: Switching an inductive load



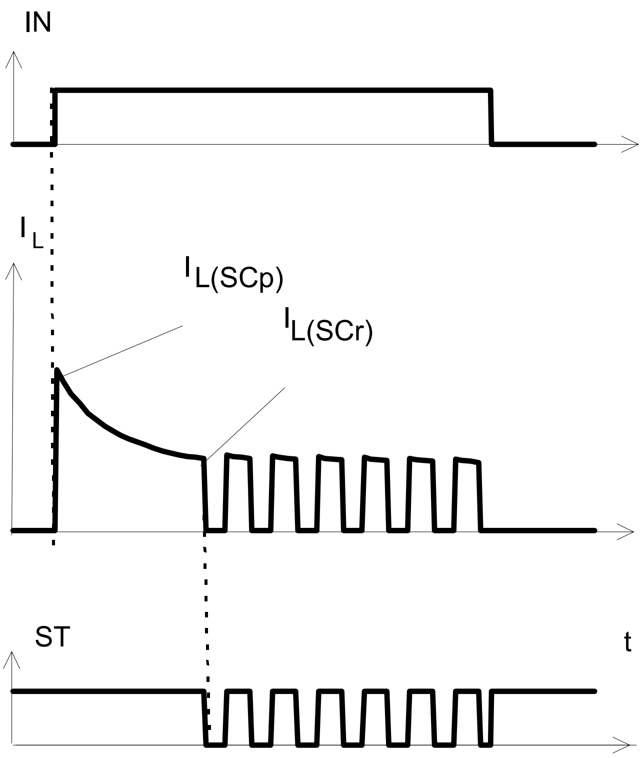
*) if the time constant of load is too large, open-load-status may occur

Figure 3a: Turn on into short circuit,



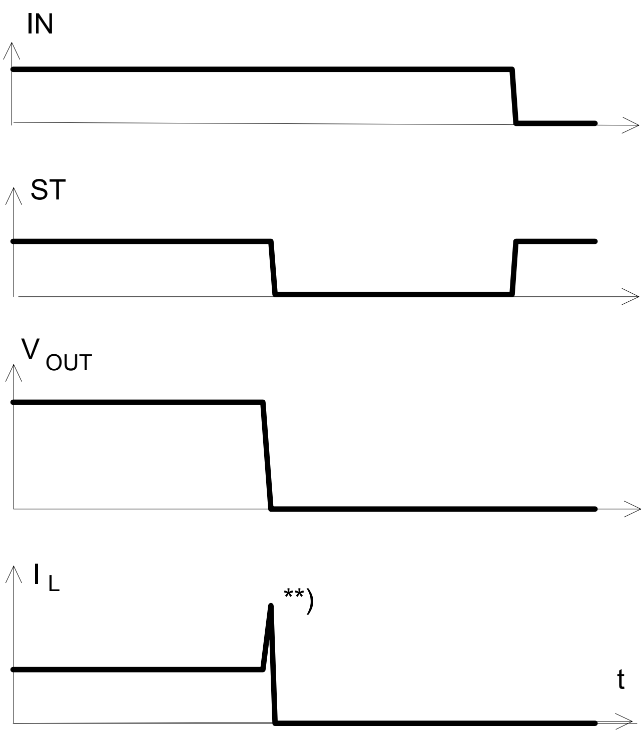
$t_{d(SC)}$ approx. 200µs if V_{bb} - V_{OUT} > 8.3 V typ.

Figure 3b: Turn on into overload,



Heating up may require several milliseconds,
V_{bb} - V_{OUT} < 8.3 V typ.

Figure 3c: Short circuit while on:



**) current peak approx. 20 µs

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

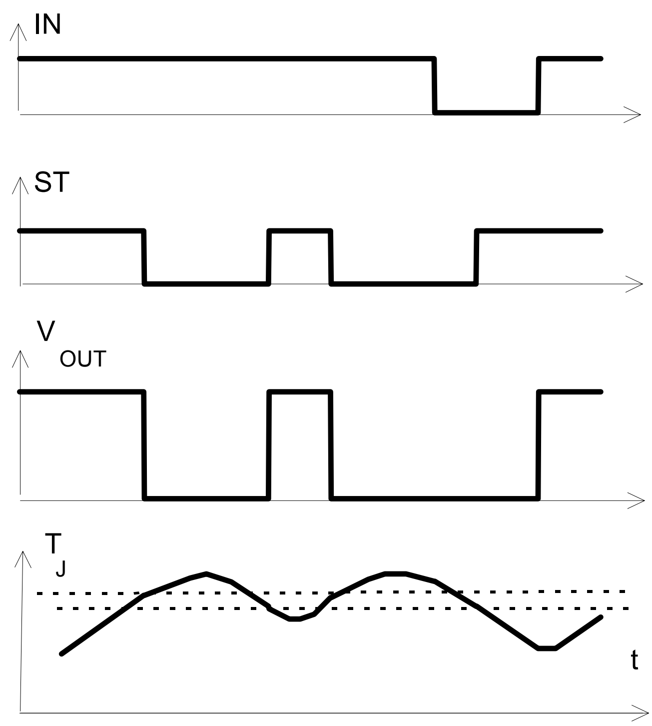


Figure 5a: Open load: detection in ON-state, turn on/off to open load

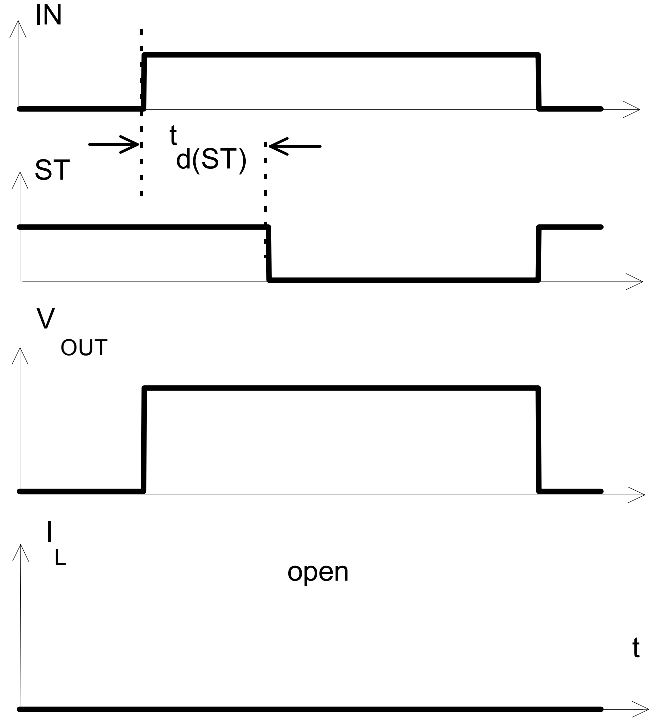
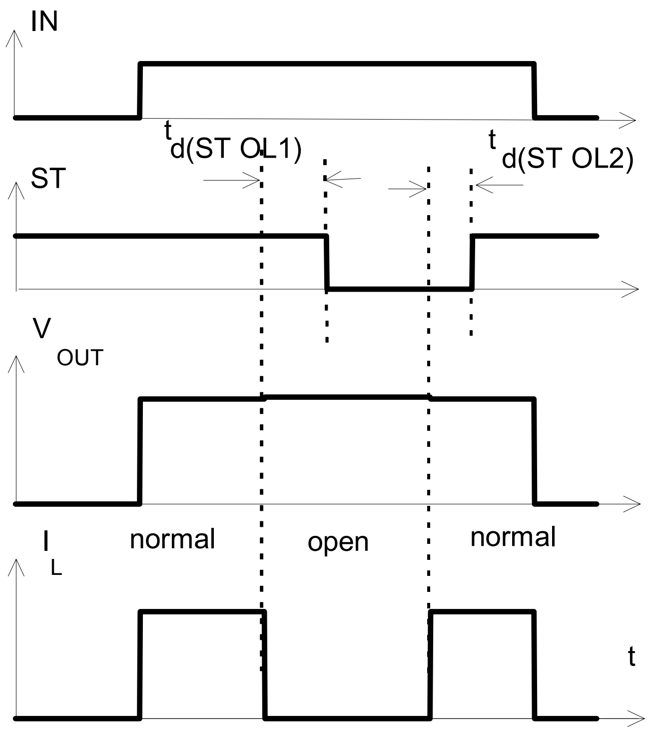
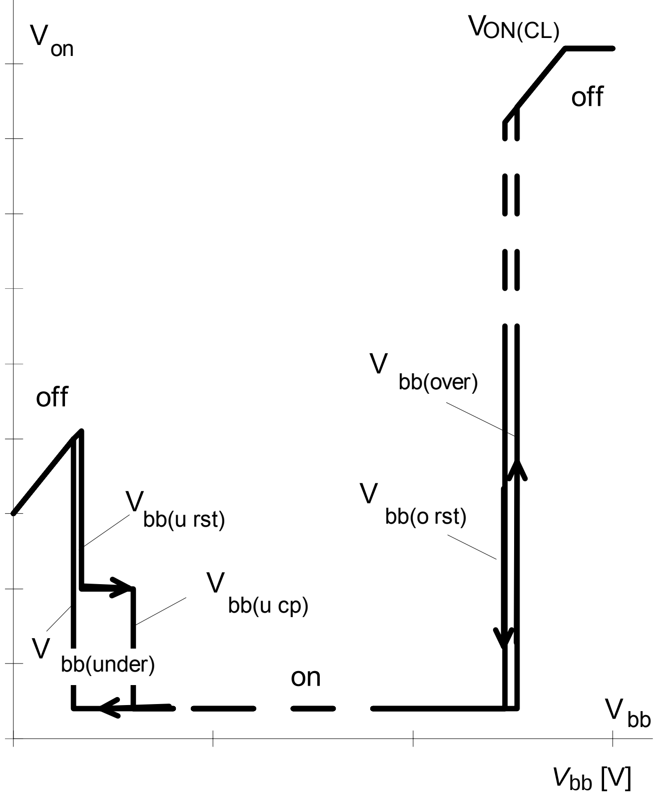


Figure 5b: Open load: detection in ON-state, open load occurs in on-state



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

Figure 6b: Undervoltage restart of charge pump



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

Figure 6a: Undervoltage:

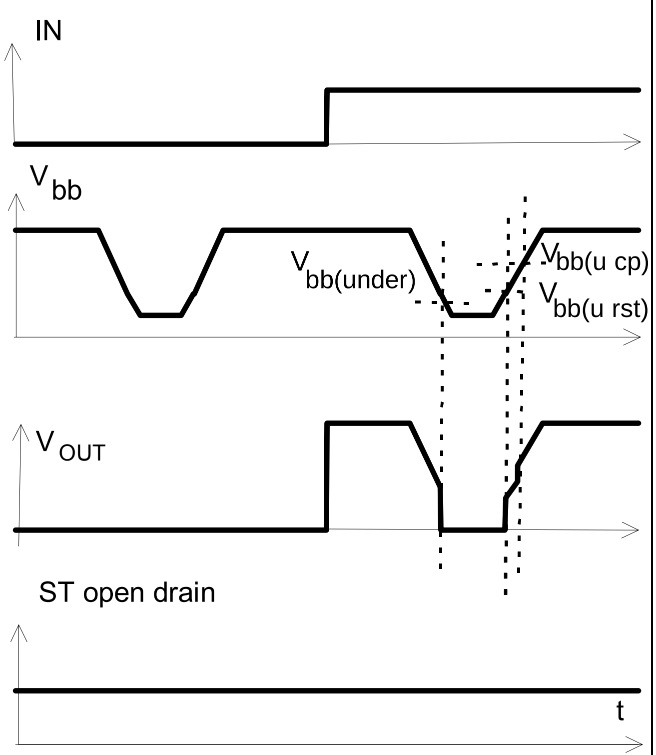
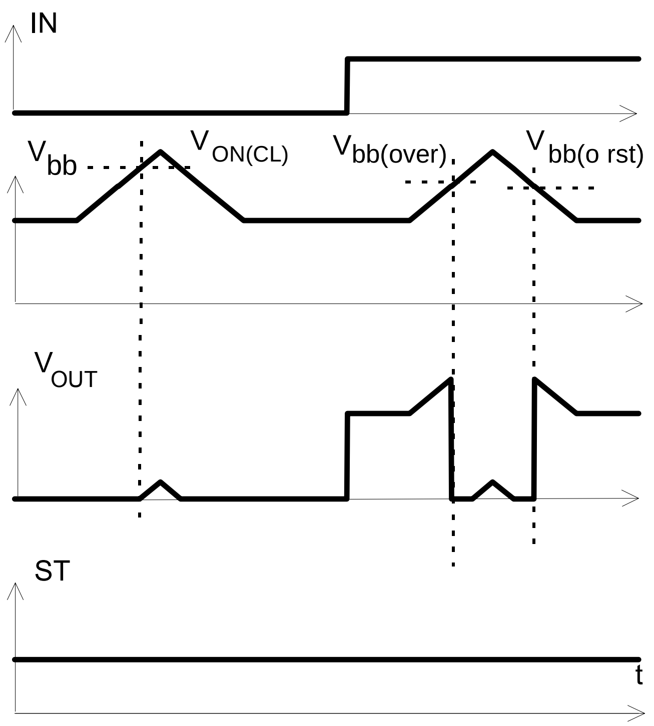


Figure 7a: Overvoltage:

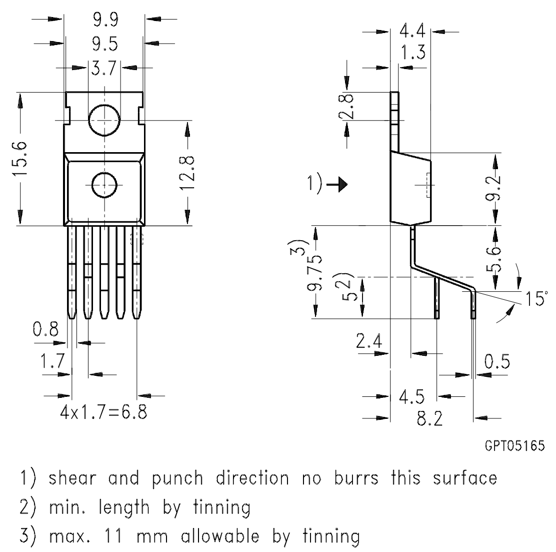


Package and Ordering Code

All dimensions in mm

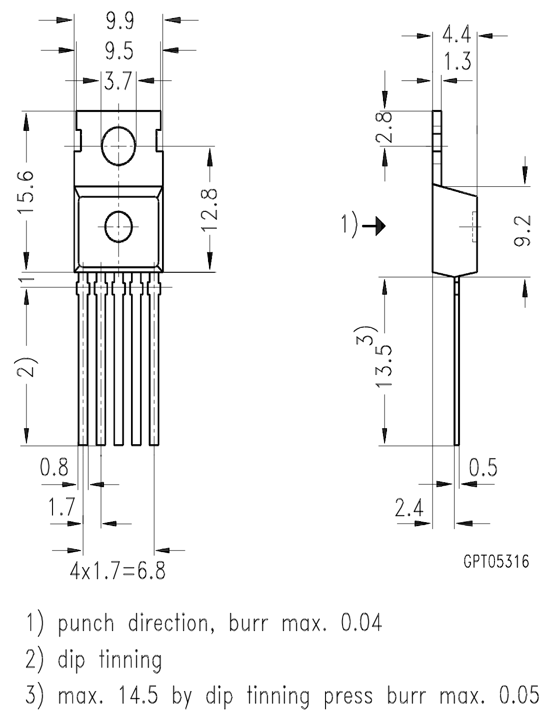
Standard TO-220AB/5 Ordering code

BTS 442 E2	Q67060-S6206-A2



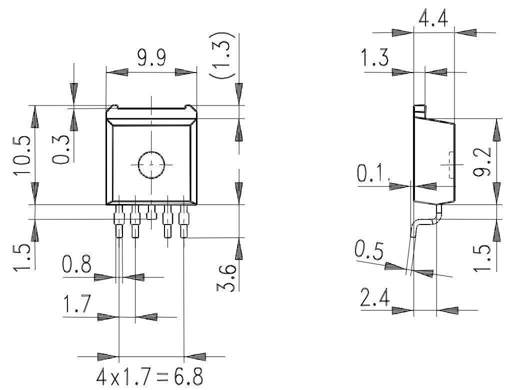
TO-220AB/5, Option E3043 Ordering code

BTS 442 E2 E3043	Q67060-S6206-A3



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

BTS442E2 E3062A	T&R:	Q67060-S6206-A4



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For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office in Germany or our Infineon Technologies Representatives worldwide (see address list).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office.
Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.