

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 protection¹⁾
- 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} protection²⁾
- Electrostatic discharge (ESD) protection

Product Summary

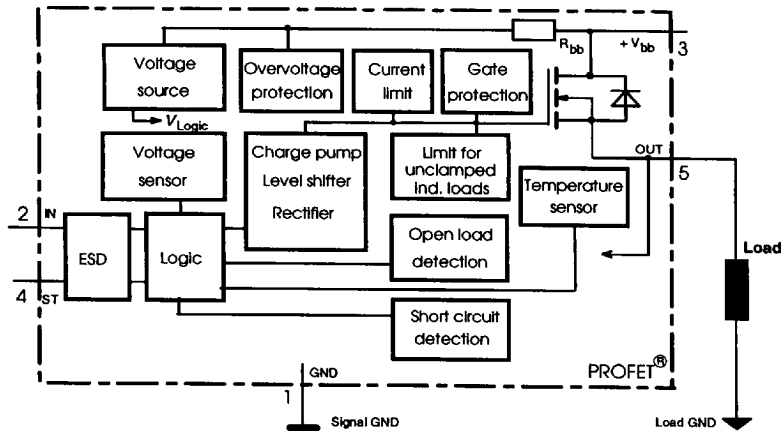
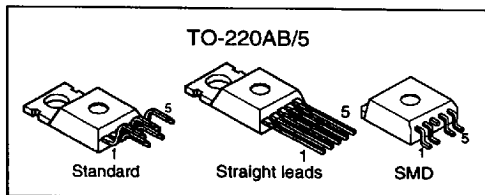
Overvoltage protection	$V_{bb}(AZ)$	63 V
Operating voltage	$V_{bb(on)}$	4.5 ... 42 V
On-state resistance	R_{ON}	18 mΩ
Load current (ISO)	$I_L(ISO)$	21 A
Current limitation	$I_L(SCr)$	70 A

Application

- μC 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 feedback, integrated in Smart SIPMOS® chip on chip technology. Fully protected by embedded protection 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 $T_j = 25\text{ }^{\circ}\text{C}$ unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 521)	V_{bb}	63	V
Load dump protection $V_{LoadDump} = U_A + V_S$, $U_A = 13.5\text{ V}$ $R_I = 2\ \Omega$, $R_L = 1.1\ \Omega$, $t_d = 200\text{ ms}$, IN= low or high	$V_{Load\ dump}^{3)}$	80	V
Load current (Short-circuit current, see page 522)	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}	167	W
Inductive load switch-off energy dissipation, single pulse $T_j=150\text{ °C}$:	E_{AS}	2.1	J
Electrostatic discharge capability (ESD) (Human Body Model)	V_{ESD}	2.0	kV
Input voltage (DC)	V_{IN}	-0.5 ... +6	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 524...			
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 6cm² (one layer, 70µm thick) copper area for V_{bb} connection. PCB is vertical without blown air.

Electrical Characteristics

Parameter and Conditions at $T_j = 25^\circ\text{C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

Load Switching Capabilities and Characteristics

On-state resistance (pin 3 to 5) $I_L = 5\text{ A}$ $T_j = 25^\circ\text{C}$: $T_j = 150^\circ\text{C}$:	R_{ON}	--	15 28	18 35	m Ω
Nominal load current (pin 3 to 5) ISO Proposal: $V_{ON} = 0.5\text{ V}$, $T_C = 85^\circ\text{C}$	$I_{L(ISO)}$	17	21	--	A
Output current (pin 5) while GND disconnected or GND pulled up, $V_{IN} = 0$, see diagram page 525, $T_j = -40\ldots+150^\circ\text{C}$	$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time Turn-off time $R_L = 12\ \Omega$, $T_j = -40\ldots+150^\circ\text{C}$	t_{on} t_{off}	100 10	-- --	350 130	μs
Slew rate on 10 to 30% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\ldots+150^\circ\text{C}$	dV/dt_{on}	0.2	--	2	V/ μs
Slew rate off 70 to 40% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\ldots+150^\circ\text{C}$	$-dV/dt_{off}$	0.4	--	5	V/ μs

Operating Parameters

Operating voltage ⁵⁾ $T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(on)}$	4.5	--	42	V
Undervoltage shutdown $T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(under)}$	2.4	--	4.5	V
Undervoltage restart $T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(u\ rst)}$	--	--	4.5	V
Undervoltage restart of charge pump see diagram page 530 $T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(ucp)}$	--	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 $T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(over)}$	42	--	52	V
Overvoltage restart $T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(o\ rst)}$	42	--	--	V
Overvoltage hysteresis $T_j = -40\ldots+150^\circ\text{C}$:	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection ⁶⁾ $I_{bb} = 40\text{ mA}$ $T_j = -40^\circ\text{C}$: $T_j = 25\ldots+150^\circ\text{C}$:	$V_{bb(AZ)}$	60 63	-- 67	--	V
Standby current (pin 3) $V_{IN} = 0$ $T_j = -40\ldots+25^\circ\text{C}$: $T_j = 150^\circ\text{C}$:	$I_{bb(off)}$	-- --	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⁾ , $V_{IN} = 5\text{ V}$	I_{GND}	--	1.1	--	mA

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

⁶⁾ see also $V_{ON(CL)}$ in table of protection functions and circuit diagram page 525. Measured without load.

⁷⁾ Add I_{ST} , if $I_{ST} > 0$, add I_{IN} , if $V_{IN} > 5.5\text{ V}$

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Parameter and Conditions at $T_j = 25^\circ\text{C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

Protection Functions

Initial peak short circuit current limit (pin 3 to 5) ⁹⁾ , (max 400 μs if $V_{ON} > V_{ON(SC)}$)	$I_{L(SCP)}$				
$T_j = -40^\circ\text{C}$: $T_j = 25^\circ\text{C}$: $T_j = +150^\circ\text{C}$:		-- -- 45	-- 95 --	140 -- --	A
Repetitive short circuit current limit $T_j = T_{jt}$ (see timing diagrams, page 528)	$I_{L(SCR)}$	30	70	--	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$, $T_j = -40 \dots +150^\circ\text{C}$: min value valid only, if input "low" time exceeds 30 μs	$t_d(SC)$	80	--	400	μs
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$, $I_L = 30\text{ mA}$	$V_{ON(CL)}$	--	58	--	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.3	--	V
Thermal overload trip temperature	T_{jt}	150	--	--	$^\circ\text{C}$
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Inductive load switch-off energy dissipation ⁹⁾ , $T_{j\text{start}} = 150^\circ\text{C}$, single pulse $V_{bb} = 12\text{ V}$: $V_{bb} = 24\text{ V}$:	E_{AS} E_{Load12} E_{Load24}	-- -- --	-- -- --	2.1 1.7 1.2	J
Reverse battery (pin 3 to 1) ¹⁰⁾	$-V_{bb}$	--	--	32	V
Integrated resistor in V_{bb} line	R_{bb}	--	120	--	Ω

Diagnostic Characteristics

Open load detection current (on-condition)	$T_j = -40^\circ\text{C}$: $T_j = 25 \dots 150^\circ\text{C}$:	$I_L(OL)$	2 2	-- --	1900 1500	mA
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⁹⁾ Short circuit current limit for max. duration of $t_d(SC)$ max=400 μs , prior to shutdown

⁹⁾ While demagnetizing load inductance, dissipated energy in PROFET is $E_{AS} = \int V_{ON(CL)} \cdot I_L(t) dt$, approx.

$$E_{AS} = \frac{1}{2} \cdot L \cdot I_L^2 \cdot \left(\frac{V_{ON(CL)}}{V_{ON(CL)} - V_{bb}} \right), \text{ see diagram page 526}$$

¹⁰⁾ 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 Ω). Input and Status currents have to be limited (see max. ratings page 520 and circuit page 525).

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Parameter and Conditions at $T_j = 25^\circ\text{C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

Input and Status Feedback¹¹⁾

Input turn-on threshold voltage  $T_j = -40...+150^\circ\text{C}$:	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage  $T_j = -40...+150^\circ\text{C}$:	$V_{IN(T-)}$	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 invalid after positive input slope (short circuit) $T_j = -40...+150^\circ\text{C}$:	$t_{d(ST\ SC)}$	80	200	400	μs
Status invalid after positive input slope (open load) $T_j = -40...+150^\circ\text{C}$:	$t_{d(ST)}$	350	--	1600	μs
Status output (open drain)					
Zener limit voltage $T_j = -40...+150^\circ\text{C}$, $I_{ST} = +1.6\text{ mA}$:	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage $T_j = -40...+150^\circ\text{C}$, $I_{ST} = +1.6\text{ mA}$:	$V_{ST(low)}$	--	--	0.4	

¹¹⁾ If a ground resistor R_{GND} is used, add the voltage drop across this resistor.

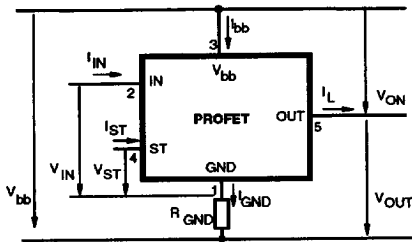
Truth Table

	Input- level	Output level	Status	
			442 D2	442 E2
Normal operation	L	L	H	H
	H	H	H	H
Open load	L	¹²⁾	H	H
	H	H	L	L
Short circuit to GND	L	L	H	H
	H	L	L	L
Short circuit to V_{bb}	L	H	H	H
	H	H	H (L ¹³⁾)	H (L ¹³⁾)
Overtem- perature	L	L	L	L
	H	L	L	L
Under- voltage	L	L	L ¹⁴⁾	H
	H	L	L ¹⁴⁾	H
Overvoltage	L	L	L	H
	H	L	L	H

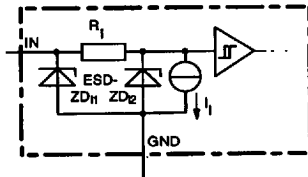
L = "Low" Level

H = "High" Level

Terms

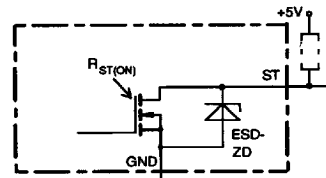


Input circuit (ESD protection)



ZD1 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).

Status output

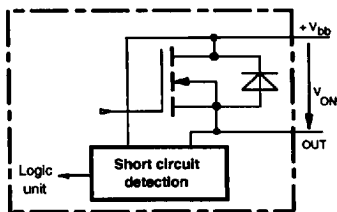


ESD-Zener diode: 6.1 V typ., max 5 mA;
R_{ST(ON)} < 250 Ω at 1.6 mA, ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

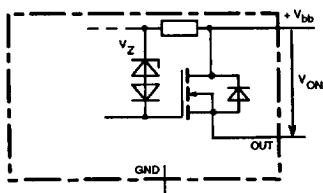
- ¹²⁾ Power Transistor off, high impedance
¹³⁾ Low resistance short V_{bb} to output may be detected by no-load-detection
¹⁴⁾ No current sink capability during undervoltage shutdown

Short Circuit detection

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

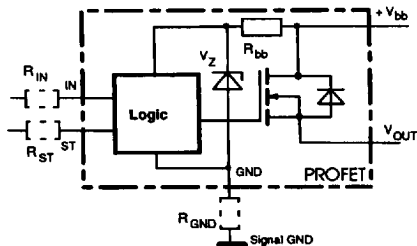


Inductive and overvoltage output clamp



V_{ON} clamped to 58 V typ.

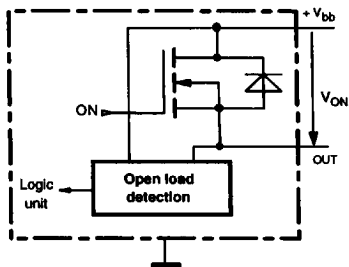
Overvolt. and reverse batt. protection



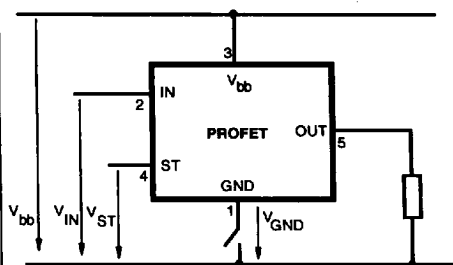
$R_{bb} = 120 \Omega \text{ typ.}$, $V_Z + R_{bb} \cdot 40 \text{ mA} = 67 \text{ V typ.}$, add R_{GND} , R_{IN} , R_{ST} for extended protection

Open-load detection

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

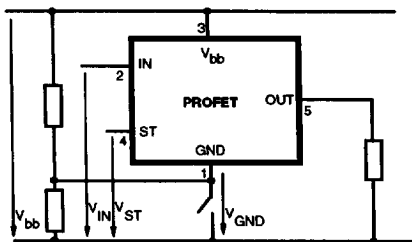


GND disconnect



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

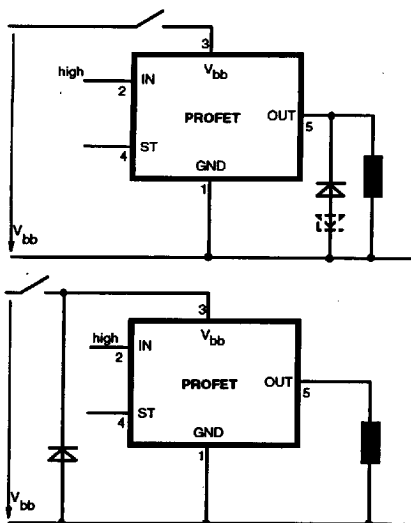
GND disconnect with GND pull up



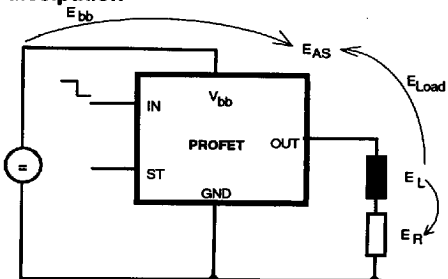
Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off. Due to $V_{GND} > 0$, no V_{ST} = low signal available.

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V_{bb} disconnect with charged inductive load



Inductive Load switch-off energy dissipation



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

$E_{Load} < E_L$, $E_L = \frac{1}{2} \cdot L \cdot I_L^2$

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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			
$T_j > 150^\circ\text{C}$, latch function ¹⁵⁾ ¹⁶⁾		X	
$T_j > 150^\circ\text{C}$, with auto-restart on cooling			X
Short-circuit to GND protection			
switches off when $V_{ON} > 8.3\text{ V typ.}^{15)}$ (when first turned on after approx. 200 μs)		X	X
Open load detection			
in OFF-state with sensing current 30 $\mu\text{A typ.}$ 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}		¹⁷⁾	¹⁷⁾
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)			

¹⁵⁾ 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 522). No latch between turn on and $t_{d(SC)}$.

¹⁶⁾ With latch function. Reset by a) Input low, b) Undervoltage, c) Overvoltage

¹⁷⁾ Low resistance short V_{bb} to output may be detected by no-load-detection

Timing diagrams

Figure 1a: V_{bb} turn on:

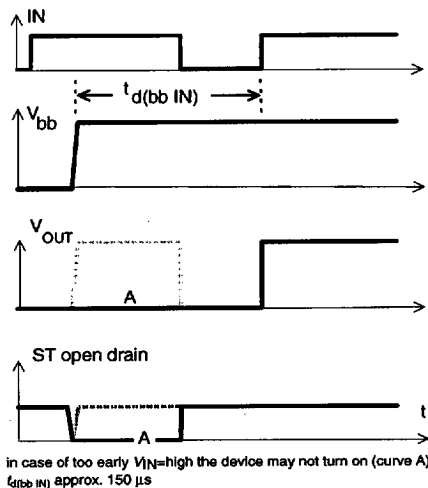


Figure 2a: Switching a lamp,

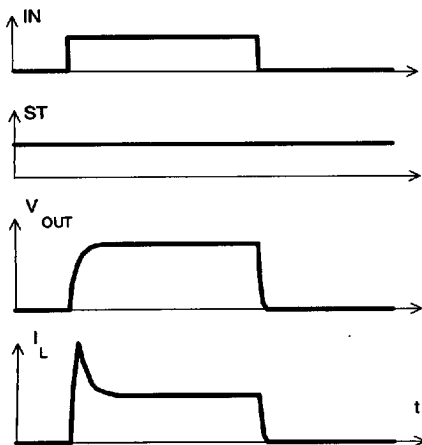
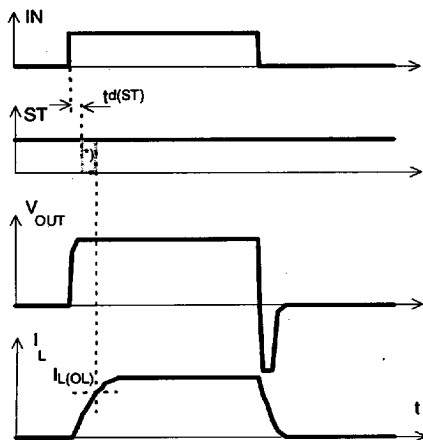
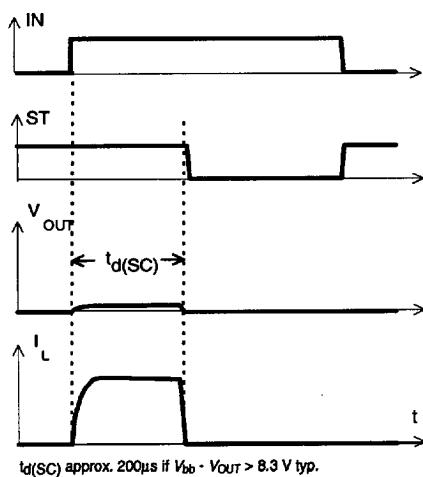


Figure 2b: Switching an inductive load



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

Figure 3a: Turn on into short circuit,



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Figure 3b: Turn on into overload,

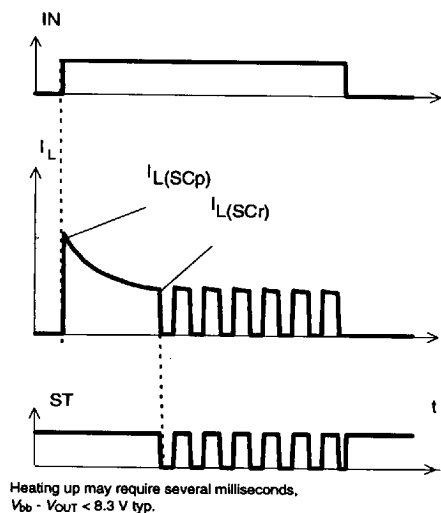


Figure 3c: Short circuit while on:

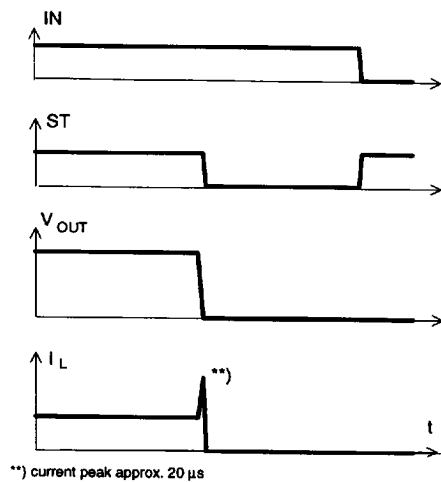


Figure 4a: Overtemperature:
 Reset if $T_j < T_{jt}$

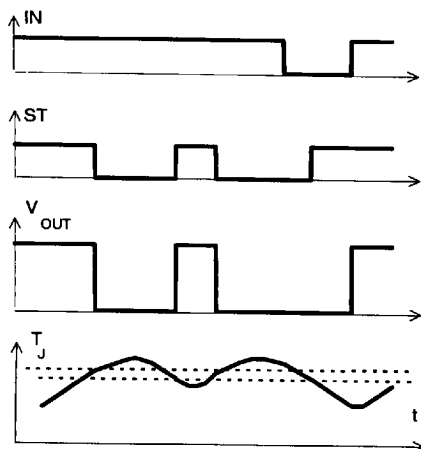
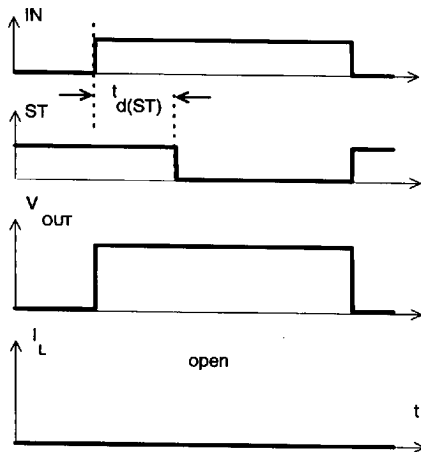


Figure 5a: Open load: detection in ON-state, turn on/off to open load



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

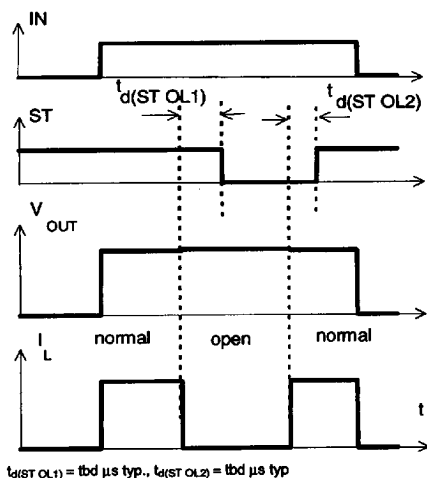


Figure 6a: Undervoltage:

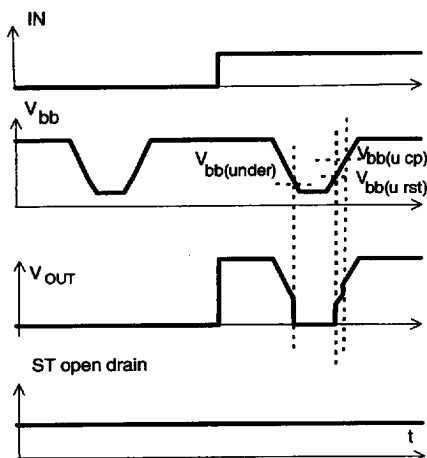


Figure 6b: Undervoltage restart of charge pump $V_{ON} [V]$

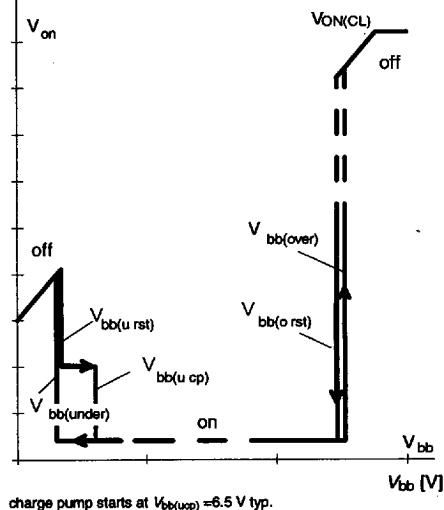
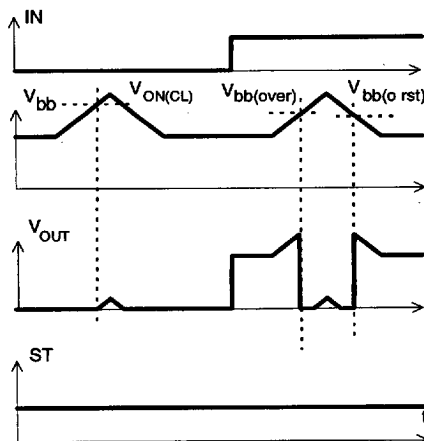


Figure 7a: Overvoltage:



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Package and Ordering Code

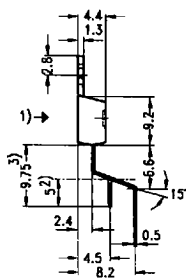
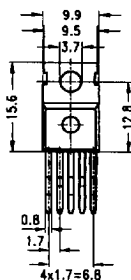
All dimensions in mm

Standard TO-220AB/5

Ordering code

BTS 442 E2

Q67060-S6206-A2



GPT05183

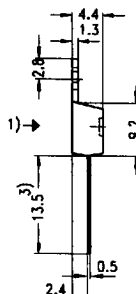
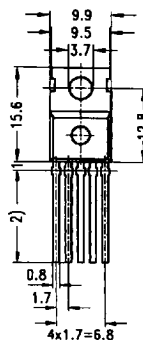
- 1) shear and punch direction no burrs this surface
- 2) min. length by finning
- 3) max. 11 mm allowable by finning

TO-220AB/5, Option E3043

Ordering code

BTS 442 E2 E3043

Q67060-S6206-A3



GPT05316

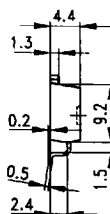
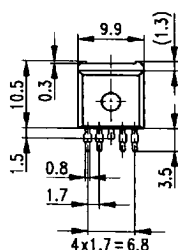
- 1) punch direction, burr max. 0.04
- 2) dip finning
- 3) max. 14.5 by dip finning press burr max. 0.05

SMD TO-220AB/5, Opt. E3062

Ordering code

BTS442E2 E3062A

T&R: Q67060-S6206-A4



GPT05904

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Semiconductor Group

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