

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

Application

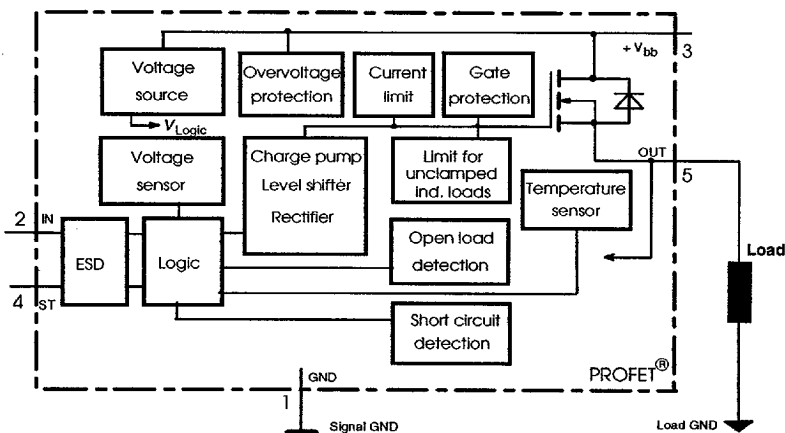
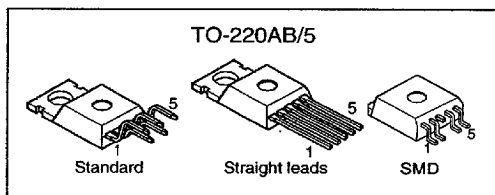
- μ C compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- All types of resistive, inductive and capacitive loads
- Replaces electromechanical relays and discrete circuits

General Description

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

Product Summary

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



¹⁾ With external current limit (e.g. resistor $R_{GND}=150\ \Omega$) in GND connection, resistors in series with IN and ST connections, 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 O (Load, L)	Output to the load

Maximum Ratings at $T_j = 25^\circ\text{C}$ unless otherwise specified

Parameter	Symbol	Values	Unit	
Supply voltage (overvoltage protection see page 278)	V_{bb}	65	V	
Load dump protection ²⁾ $V_{LoadDump} = U_A + V_S$, $U_A = 13.5\text{ V}$ $R_i^3 = 2\ \Omega$, $R_L = 6.6\ \Omega$, $t_d = 400\text{ ms}$, $I_N = \text{low or high}$	$V_{Load\ dump}^4$	100	V	
Load current (Short circuit current, see page 279)	I_L	self-limited	A	
Operating temperature range	T_j	-40 ...+150	°C	
Storage temperature range	T_{stg}	-55 ...+150		
Power dissipation (DC), $T_C \leq 25\text{ °C}$	P_{tot}	50	W	
Inductive load switch-off energy dissipation, single pulse $T_j = 150\text{ °C}$:	E_{AS}	tbd	J	
Electrostatic discharge capability (ESD) (Human Body Model)	V_{ESD}	1	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 281				
Thermal resistance	chip - case: junction - ambient (free air): SMD version, device on PCB ⁵⁾ :	R_{thJC} R_{thJA}	≤ 2.5 ≤ 75 ≤ tbd	K/W

²⁾ Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins, e.g. with a $150\ \Omega$ resistor in the GND connection and a $15\text{ k}\Omega$ 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 $50\text{mm} \times 50\text{mm} \times 1.5\text{mm}$ epoxy PCB FR4 with 6cm^2 (one layer, $70\ \mu\text{m}$ 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) $I_L = 1.6\text{ A}$	$T_j = 25^\circ\text{C}$: $T_j = 150^\circ\text{C}$:	R_{ON}	--	190 390	220 440	$\text{m}\Omega$
Nominal load current (pin 3 to 5) ISO Proposal: $V_{ON} = 0.5\text{ V}$, $T_C = 85^\circ\text{C}$		$I_{L(ISO)}$	1.6	1.8	--	A
Output current (pin 5) while GND disconnected or GND pulled up, $V_{bb} = 30\text{ V}$, $V_{IN} = 0$, see diagram page 282, $T_j = -40\ldots+150^\circ\text{C}$		$I_{L(GNDhigh)}$	--	--	10	mA
Turn-on time	to 90% V_{OUT} :	t_{on}	12	--	125	μs
Turn-off time	to 10% V_{OUT} :	t_{off}	5	--	85	
$R_L = 12\ \Omega$, $T_j = -40\ldots+150^\circ\text{C}$						
Slew rate on 10 to 30% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\ldots+150^\circ\text{C}$		dV/dt_{on}	--	--	3	$\text{V}/\mu\text{s}$
Slew rate off 70 to 40% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\ldots+150^\circ\text{C}$		$-dV/dt_{off}$	--	--	6	$\text{V}/\mu\text{s}$

Operating Parameters

Operating voltage ⁶⁾	$T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(on)}$	4.7	--	42	V
Undervoltage shutdown	$T_j = 25^\circ\text{C}$:	$V_{bb(under)}$	2.9	--	4.5	V
	$T_j = -40\ldots+150^\circ\text{C}$:		2.7	--	4.7	
Undervoltage restart	$T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(u\ rst)}$	--	--	4.9	V
Undervoltage restart of charge pump see diagram page 287		$V_{bb(ucp)}$	--	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	$T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(over)}$	42	--	52	V
Overvoltage restart	$T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(o\ rst)}$	40	--	--	V
Overvoltage hysteresis	$T_j = -40\ldots+150^\circ\text{C}$:	$\Delta V_{bb(over)}$	--	0.1	--	V
Overvoltage protection ⁷⁾ $I_{bb} = 4\text{ mA}$	$T_j = -40\ldots+150^\circ\text{C}$:	$V_{bb(AZ)}$	65	70	--	V
Standby current (pin 3) $V_{IN} = 0$, $I_{ST} \leq 0$	$T_j = -40\ldots+25^\circ\text{C}$: $T_j = 150^\circ\text{C}$:	$I_{bb(off)}$	--	10 18	15 25	μA
Leakage output current (included in $I_{bb(off)}$) $V_{IN} = 0$		$I_{L(off)}$	--	--	20	μA
Operating current (Pin 1) ⁸⁾ , $V_{IN} = 5\text{ V}$, $T_j = -40\ldots+150^\circ\text{C}$		I_{GND}	--	1	2.1	mA

⁶⁾ At supply voltage increase up to $V_{bb} = 5.6\text{ V}$ typ without charge pump, $V_{OUT} \approx V_{bb} - 2\text{ V}$
⁷⁾ Measured without load. See also $V_{ON(CL)}$ in table of protection functions and circuit diagram page 282.

⁸⁾ Add I_{ST} , if $I_{ST} > 0$, add I_{IN} , if $V_{IN} > 5.5\text{ V}$

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BTS 410 D2

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 450 μs if $V_{ON} > V_{ON(SC)}$) $T_j = -40^\circ\text{C}$: $T_j = 25^\circ\text{C}$: $T_j = +150^\circ\text{C}$:	$I_{L(SC)}$	9 -- 4	-- 12 --	23 -- 15	A
Overload shutdown current limit $V_{ON} = 8\text{ V}$, $T_j = T_{jt}$ (see timing diagrams, page 285)	$I_{L(SCR)}$	--	5	--	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$, $T_j = -40..+150^\circ\text{C}$: min value valid only, if input "low" time exceeds 60 μs	$t_d(SC)$	--	--	450	μs
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$ $I_L = 40\text{ mA}$, $T_j = -40..+150^\circ\text{C}$: $I_L = 1\text{ A}$, $T_j = -40..+150^\circ\text{C}$:	$V_{ON(CL)}$	61 --	68 --	73 75	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.5	--	V
Thermal overload trip temperature	T_{jt}	150	--	--	$^\circ\text{C}$
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Inductive load switch-off energy dissipation ¹⁰⁾ , $T_{j\text{Start}} = 150^\circ\text{C}$, single pulse $V_{bb} = 12\text{ V}$: $V_{bb} = 24\text{ V}$:	E_{AS} E_{Load12} E_{Load24}	-- -- --	-- -- --	tbd tbd tbd	J
Reverse battery (pin 3 to 1) ¹¹⁾	$-V_{bb}$	--	--	32	V

Diagnostic Characteristics

Open load detection current (on-condition) $T_j = -40..150^\circ\text{C}$:	$I_{L(OL)}$	2	--	150	mA
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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 $E_{AS} = \int V_{ON(CL)} \cdot I_L(t) dt$, approx.
 $E_{AS} = 1/2 \cdot L \cdot I_L^2 \cdot \left(\frac{V_{ON(CL)}}{V_{ON(CL)} - V_{bb}} \right)$, see diagram page 283

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 277 and circuit page 282).

SIEMENS

BTS 410 D2

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 Feedback¹²⁾

Input turn-on threshold voltage  $T_j = -40 \dots +150^\circ\text{C}$:	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage  $T_j = -40 \dots +150^\circ\text{C}$:	$V_{IN(T-)}$	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), $V_{IN} = 5\text{ V}$	$I_{IN(on)}$	10	25	70	μA
Status invalid after positive input slope (short circuit) $T_j = -40 \dots +150^\circ\text{C}$:	$t_{d(ST\ SC)}$	--	--	450	μs
Status invalid after positive input slope (open load) $T_j = -40 \dots +150^\circ\text{C}$:	$t_{d(ST)}$	300	--	1400	μs
Status output (CMOS) $T_j = -40 \dots +150^\circ\text{C}$, $I_{ST} = -50\text{ }\mu\text{A}$: $T_j = -40 \dots +150^\circ\text{C}$, $I_{ST} = +1.6\text{ mA}$:	$V_{ST(high)}^{13)}$ $V_{ST(low)}$	4.4 --	5.1 --	6.5 0.4	V
Max. status current for valid status output, $T_j = -40 \dots +150^\circ\text{C}$	current source (out): current sink (in) :	$-I_{ST}$ $+I_{ST}^{14)}$	-- --	0.25 1.6	mA

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

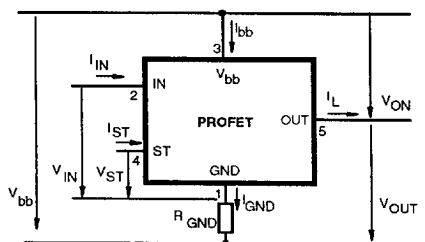
Truth Table

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

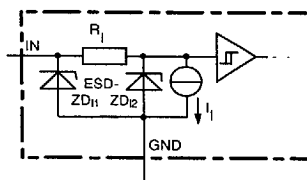
L = "Low" Level

H = "High" Level

Terms



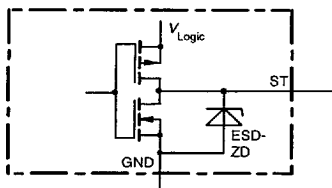
Input circuit (ESD protection)



ZD11 6 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).

- 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

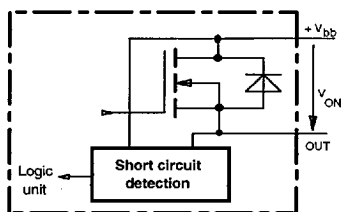
Status output



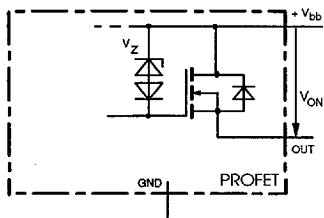
Zener diode: 6 V typ., max 5.0 mA, V_{Logic} 5 V typ, ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

Short circuit detection

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

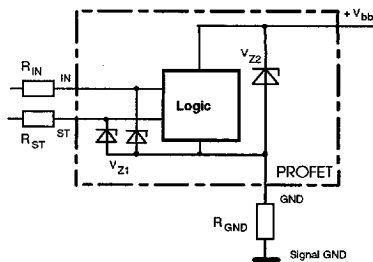


Inductive and overvoltage output clamp



V_{ON} clamped to 68 V typ.

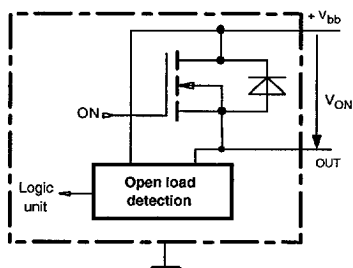
Overvolt. and reverse batt. protection



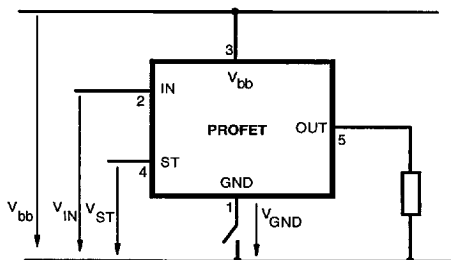
$V_{Z1} = 6.2$ V typ., $V_{Z2} = 70$ V typ., $R_{GND} = 150 \Omega$, R_{IN} , $R_{ST} = 15$ k Ω

Open-load detection

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

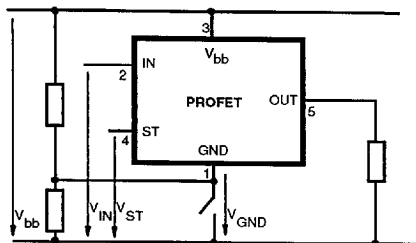


GND disconnect



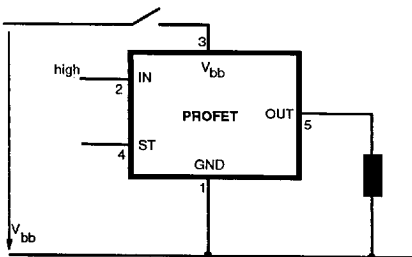
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)} -$. Due to $V_{GND} > 0$, no V_{ST} = low signal available.

GND disconnect with GND pull up



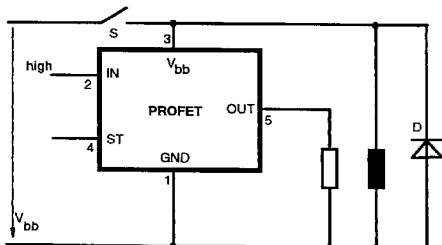
Any kind of load. If $V_{GND} > V_{IN} - V_{N(T)}$ device stays off. Due to $V_{GND} > 0$, no V_{ST} = low signal available.

Vbb disconnect with charged inductive load



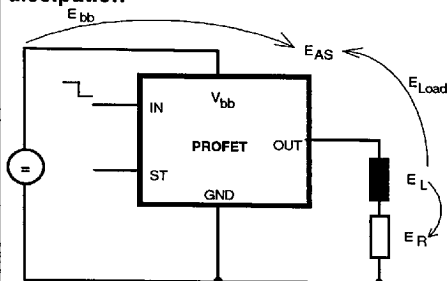
Normal load current can be handled by the PROFET itself.

Vbb 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 $E_{AS} = E_{bb} + E_L - E_R$.

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

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 $T_J > 150^\circ\text{C}$, latch function ¹⁸⁾ ¹⁹⁾	X	X		X		X	
$T_J > 150^\circ\text{C}$, with auto-restart on cooling			X		X		
Short circuit to GND protection switches off when $V_{ON} > 3.5\text{ V}$ typ. and $V_{bb} > 7\text{ V}$ typ. ¹⁸⁾ (when first turned on after approx. 150 μs) switches off when $V_{ON} > 8.5\text{ V}$ typ. ¹⁸⁾ (when first turned on after approx. 150 μs) Achieved through overtemperature protection	X	X	X	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	X	X	X		X
Undervoltage shutdown with auto restart	X	X	X	X	X	X	X
Overvoltage shutdown with auto restart ²⁰⁾	X	X	X	X	X	X	X
Status feedback for							
overtemperature	X	X	X	X	X	X	X
short circuit to GND	X	X	X	X	-	-	X
short to V_{bb}	X	²¹⁾	²¹⁾	²¹⁾	²¹⁾	²¹⁾	X
open load	X	X	X	X	X	X	X
undervoltage	X	X	-	-	-	-	-
overvoltage	X	X	-	-	-	-	-
Status output type							
CMOS	X	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	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	X

¹⁸⁾ 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 279). No latch between turn on and $t_{d(SC)}$.

¹⁹⁾ With latch function. Reset 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 1: V_{bb} turn on:

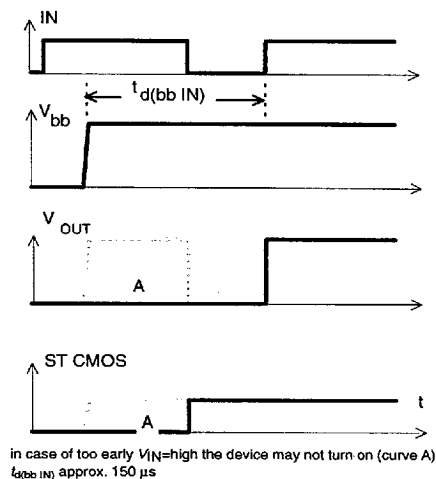


Figure 2a: Switching a lamp,

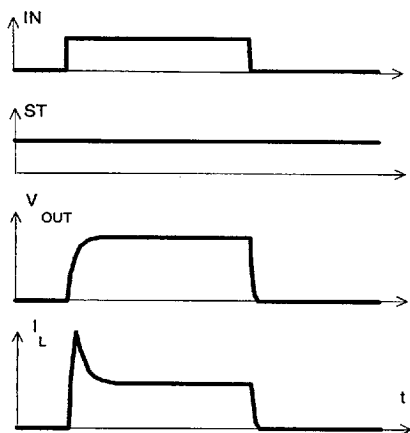
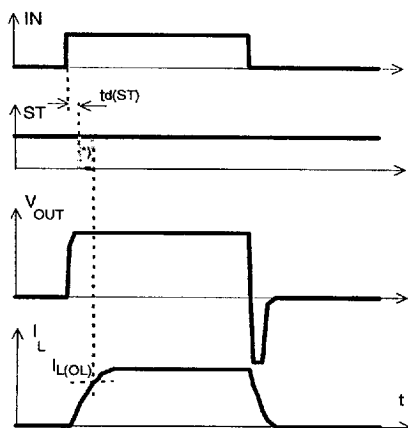


Figure 2b: Switching an inductive load



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

Figure 3a: Turn on into short circuit,

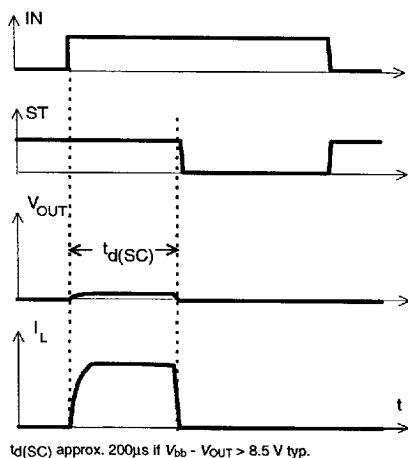
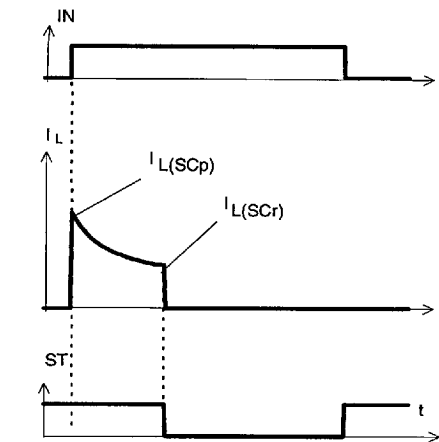
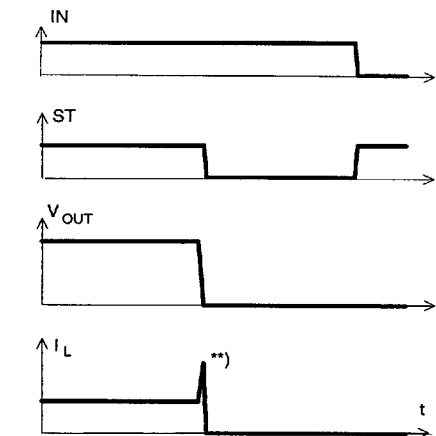


Figure 3b: Turn on into overload,

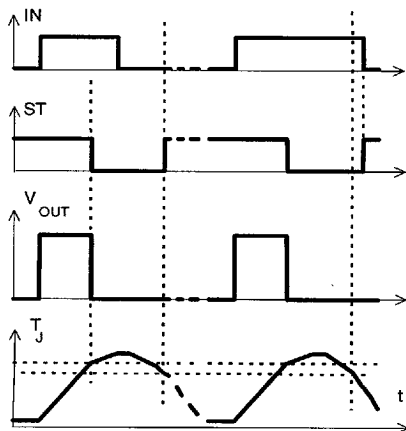


Heating up may require several seconds,
 $V_{bb} - V_{OUT} < 8.5 \text{ V typ.}$

Figure 3c: Short circuit while on:



** current peak approx. $20 \mu\text{s}$

Figure 4: Overtemperature,
Reset if $(I_N = \text{low})$ and $(T_J < T_{JT})$


*) ST goes high, when $V_{IN} = \text{low}$ and $T_J < T_{JT}$

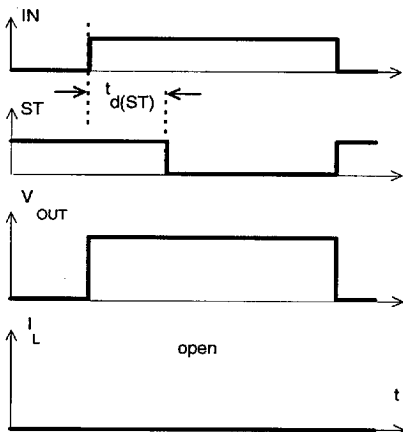
Figure 5a: Open load: detection in ON-state, turn
on/off to open load


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

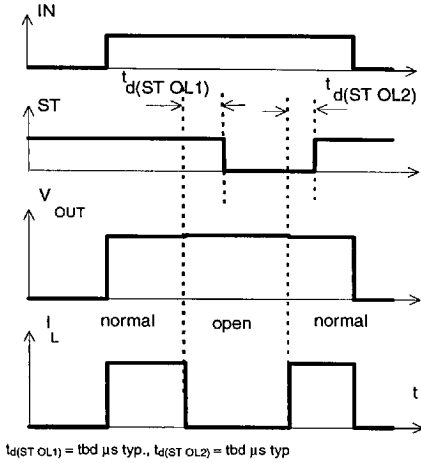


Figure 6: Undervoltage:

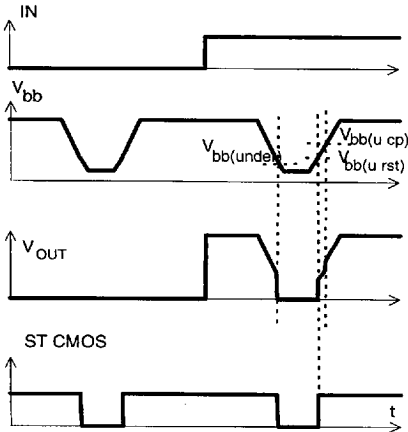
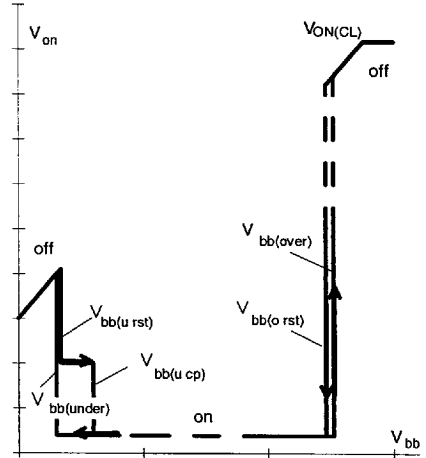


Figure 7: Undervoltage restart of charge pump



charge pump starts at $V_{bb(u cp)} = 5.6 \text{ V typ.}$

Figure 8: Overvoltage:

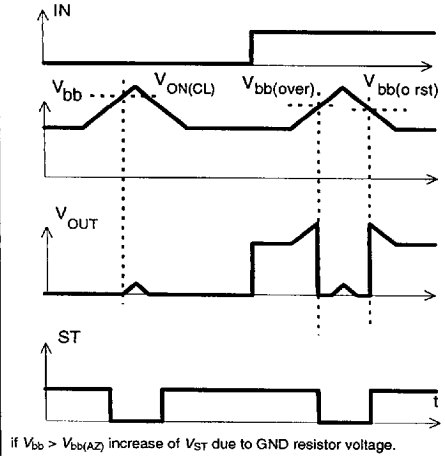
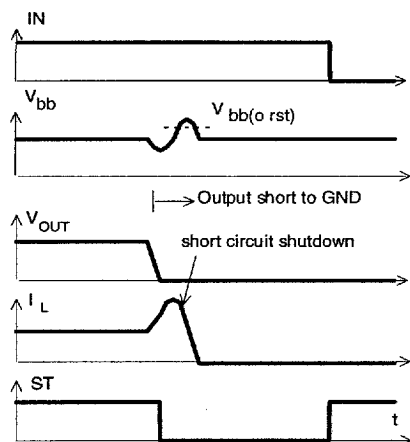


Figure 9: Overvoltage at short circuit shutdown:



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

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Package and Ordering Code

All dimensions in mm

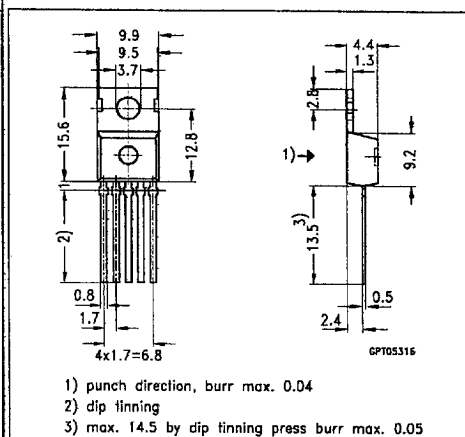
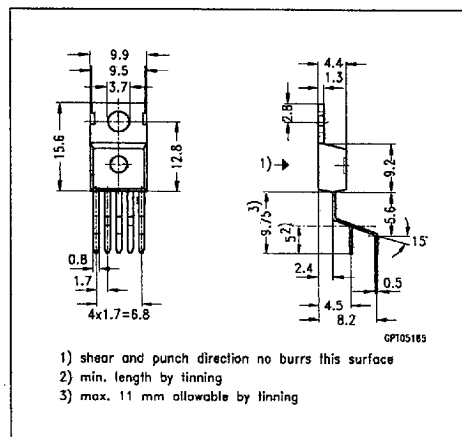
Standard TO-220AB/5

Ordering code

BTS 410 D2	Q67060-S6101-A2
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TO-220AB/5, Option E3043 Ordering code

BTS 410 D2 E3043	Q67060-S6101-A3
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SMD TO-220AB/5, Opt. E3062 Ordering code

BTS410D2 E3062A	T&R: Q67060-S6101-A4
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