

Smart Highside Power Switch

Features

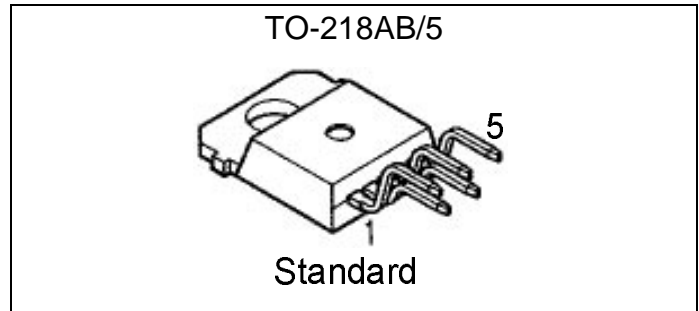
- Overload protection
- Current limitation
- Short-circuit protection
- Thermal shutdown
- Overvoltage protection (including load dump)
- Fast demagnetization of inductive loads
- Reverse battery protection¹⁾
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis
- Open drain diagnostic 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 | m Ω |
| Load current (ISO) | $I_L(ISO)$ | 21 | A |
| Current limitation | $I_L(SCr)$ | 70 | A |

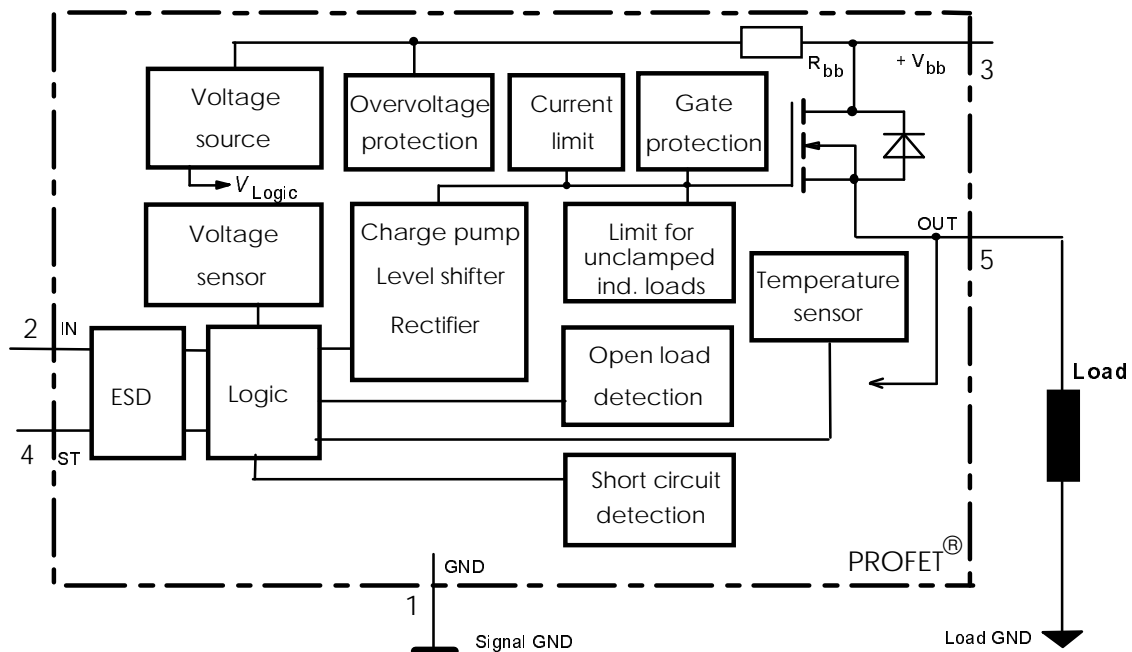
Application

- 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, 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 | 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 $T_j = 25\text{ °C}$ unless otherwise specified

| Parameter | Symbol | Values | Unit | |
|--|--|--------------------------|----------------|-----|
| Supply voltage (overvoltage protection see page 3) | V_{bb} | 63 | V | |
| Load dump protection $V_{LoadDump} = U_A + V_S$, $U_A = 13.5\text{ V}$ $R_I = 2\ \Omega$, $R_L = 1.1\ \Omega$, $t_d = 200\text{ ms}$, IN= low or high | $V_{Load\ dump}^{3)}$ | 80 | V | |
| Load current (Short-circuit current, see page 4) | 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 6... | | | | |
| Thermal resistance | chip - case: junction - ambient (free air): | R_{thJC} R_{thJA} | ≤ 0.75 ≤ 45 | K/W |

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

Electrical Characteristics

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

Load Switching Capabilities and Characteristics

| | | | | | | |
|---|---|------------------|-----|----------|----------|-----------------|
| On-state resistance (pin 3 to 5) $I_L = 5\text{ A}$ | $T_j = 25\text{ °C}$: $T_j = 150\text{ °C}$: | R_{ON} | -- | 15 28 | 18 35 | $m\Omega$ |
| Nominal load current (pin 3 to 5) ISO Proposal: $V_{ON} = 0.5\text{ V}$, $T_C = 85\text{ °C}$ | | $I_{L(ISO)}$ | 17 | 21 | -- | A |
| Output current (pin 5) while GND disconnected or GND pulled up, $V_{IN} = 0$, see diagram page 7, $T_j = -40\dots+150\text{ °C}$ | | $I_{L(GNDhigh)}$ | -- | -- | 1 | mA |
| Turn-on time to 90% V_{OUT} : | | t_{on} | 100 | -- | 350 | μs |
| Turn-off time to 10% V_{OUT} : | | t_{off} | 10 | -- | 130 | |
| Slew rate on 10 to 30% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\dots+150\text{ °C}$ | | dV/dt_{on} | 0.2 | -- | 2 | $V/\mu\text{s}$ |
| Slew rate off 70 to 40% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\dots+150\text{ °C}$ | | $-dV/dt_{off}$ | 0.4 | -- | 5 | $V/\mu\text{s}$ |

Operating Parameters

| | | | | | | |
|--|--|------------------------|----------|----------|----------|---------------|
| Operating voltage ⁴⁾ | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(on)}$ | 4.5 | -- | 42 | V |
| Undervoltage shutdown | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(under)}$ | 2.4 | -- | 4.5 | V |
| Undervoltage restart | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(u\ rst)}$ | -- | -- | 4.5 | V |
| Undervoltage restart of charge pump see diagram page 12 | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(ucp)}$ | -- | 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 | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(over)}$ | 42 | -- | 52 | V |
| Overvoltage restart | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(o\ rst)}$ | 42 | -- | -- | V |
| Overvoltage hysteresis | $T_j = -40\dots+150\text{ °C}$: | $\Delta V_{bb(over)}$ | -- | 0.2 | -- | V |
| Overvoltage protection ⁵⁾ $I_{bb} = 40\text{ mA}$ | $T_j = -40\text{ °C}$: $T_j = 25\dots+150\text{ °C}$: | $V_{bb(AZ)}$ | 60 63 | -- 67 | -- | V |
| Standby current (pin 3) $V_{IN} = 0$ | $T_j = -40\dots+25\text{ °C}$: $T_j = 150\text{ °C}$: | $I_{bb(off)}$ | -- -- | 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) ⁶⁾ , $V_{IN} = 5\text{ V}$ | | I_{GND} | -- | 1.1 | -- | mA |

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

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

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

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

Protection Functions

| | | | | | |
|--|------------------------------|-----|-----|------------|---------------|
| Initial peak short circuit current limit (pin 3 to 5) ⁷⁾ , (max 400 μs if $V_{ON} > V_{ON(SC)}$) | $I_{L(SCp)}$ | | | | |
| $T_j = -40\text{ °C}$: $T_j = 25\text{ °C}$: $T_j = +150\text{ °C}$: | | -- | -- | 140 | A |
| | | -- | 95 | -- | |
| | | 45 | -- | -- | |
| 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 $V_{ON} > V_{ON(SC)}$, $T_j = -40..+150\text{ °C}$: 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 | -- | -- | °C |
| Thermal hysteresis | ΔT_{jt} | -- | 10 | -- | K |
| Inductive load switch-off energy dissipation ⁸⁾ , $T_{j\text{ Start}} = 150\text{ °C}$, single pulse | E_{AS} | -- | -- | 2.1 | J |
| $V_{bb} = 12\text{ V}$: $V_{bb} = 24\text{ V}$: | E_{Load12} E_{Load24} | | | 1.7 1.2 | |
| Reverse battery (pin 3 to 1) ⁹⁾ | $-V_{bb}$ | -- | -- | 32 | V |
| Integrated resistor in V_{bb} line | R_{bb} | -- | 120 | -- | Ω |

Diagnostic Characteristics



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

7) Short circuit current limit for max. duration of $t_{d(SC)} \text{ max} = 400\text{ }\mu\text{s}$, prior to shutdown

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

$$E_{AS} = \frac{1}{2} * L * I_L^2 * \left(\frac{V_{ON(CL)}}{V_{ON(CL)} - V_{bb}} \right), \text{ see diagram page 8}$$

9) 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 2 and circuit page 7).

| Parameter and Conditions at $T_j = 25\text{ °C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified | Symbol | Values | | | Unit |
|---|---------------------------------|-----------|-----------|-----------|---------------|
| | | min | typ | max | |
| Input and Status Feedback¹⁰⁾ | | | | | |
| Input turn-on threshold voltage  $T_j = -40..+150\text{ °C}$: | $V_{IN(T+)}$ | 1.5 | -- | 2.4 | V |
| Input turn-off threshold voltage  $T_j = -40..+150\text{ °C}$: | $V_{IN(T-)}$ | 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) $T_j = -40 \dots +150\text{ °C}$: | $t_{d(ST\ SC)}$ | 80 | 200 | 400 | μs |
| Status invalid after positive input slope (open load) $T_j = -40 \dots +150\text{ °C}$: | $t_{d(ST)}$ | 350 | -- | 1600 | μs |
| Status output (open drain) Zener limit voltage $T_j = -40\dots+150\text{ °C}$, $I_{ST} = +1.6\text{ mA}$: ST low voltage $T_j = -40\dots+150\text{ °C}$, $I_{ST} = +1.6\text{ mA}$: | $V_{ST(high)}$ $V_{ST(low)}$ | 5.4 -- | 6.1 -- | -- 0.4 | V |

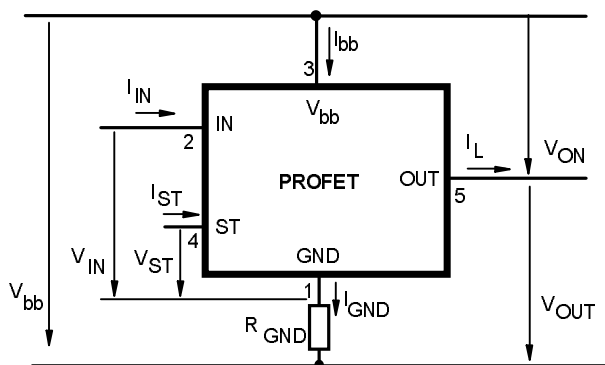
¹⁰⁾ If a ground resistor R_{GND} is used, add the voltage drop across this resistor.

Truth Table

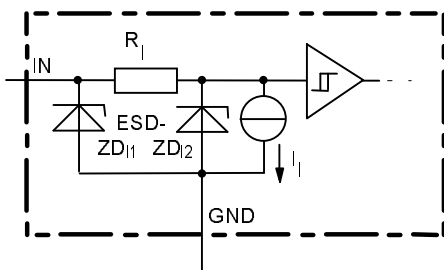
| | Input-level | Output level | Status | |
|----------------------------------|-------------|------------------|-----------------------|-----------------------|
| | | | 542 D2 | 542 E2 |
| Normal operation | L | L | H | H |
| | H | H | H | H |
| Open load | L | ¹¹⁾ H | H | H |
| | H | H | L | L |
| 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 ¹²⁾) | H (L ¹²⁾) |
| Overtemperature | L | L | L | L |
| | H | L | L | L |
| Undervoltage | L | L | L ¹³⁾ | H |
| | H | L | L ¹³⁾ | H |
| Overvoltage | L | L | L | H |
| | H | L | L | H |

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

Terms

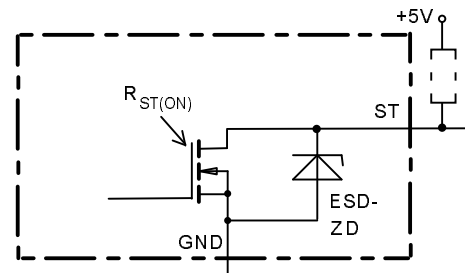


Input circuit (ESD protection)



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

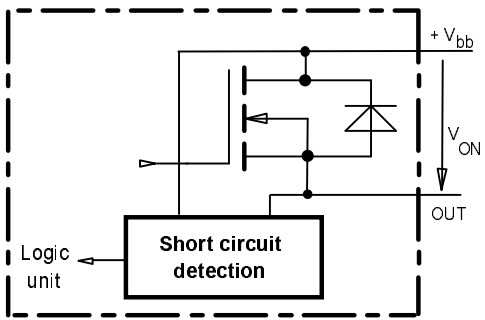


ESD-Zener diode: 6.1 V typ., max 5 mA;
 $R_{ST(ON)} < 250 \Omega$ at 1.6 mA, ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

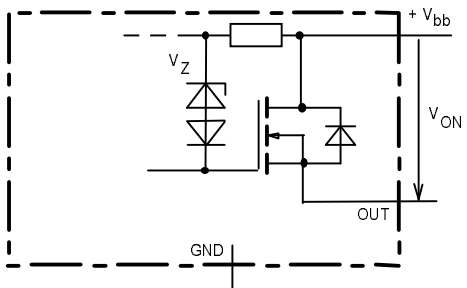
- 11) Power Transistor off, high impedance
- 12) Low resistance short V_{bb} to output may be detected by no-load-detection
- 13) No current sink capability during undervoltage shutdown

Short Circuit detection

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

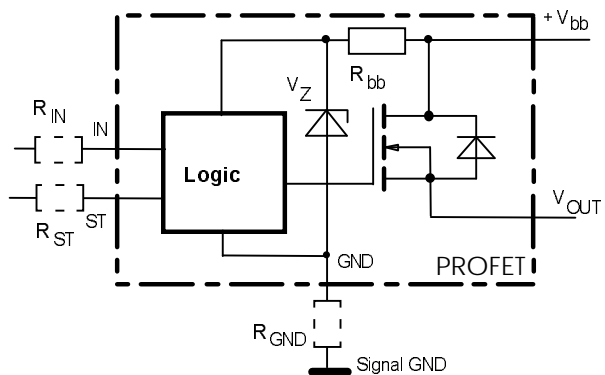


Inductive and overvoltage output clamp



V_{ON} clamped to 58 V typ.

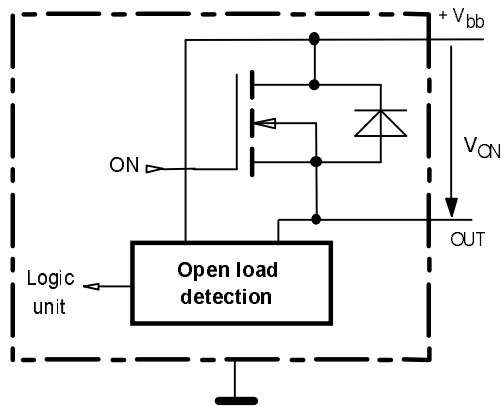
Overvolt. and reverse batt. protection



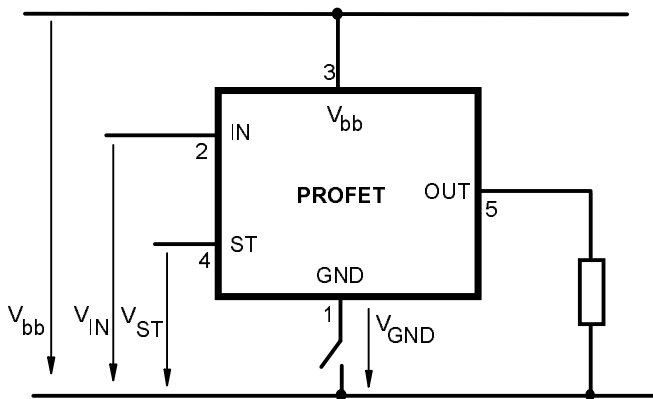
$R_{bb} = 120 \Omega \text{ typ.}, V_Z + R_{bb} * 40 \text{ mA} = 67 \text{ V typ.},$ add R_{GND}, R_{IN}, R_{ST} for extended protection

Open-load detection

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

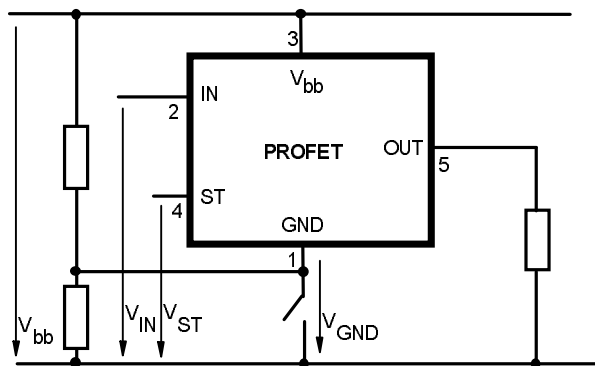


GND disconnect



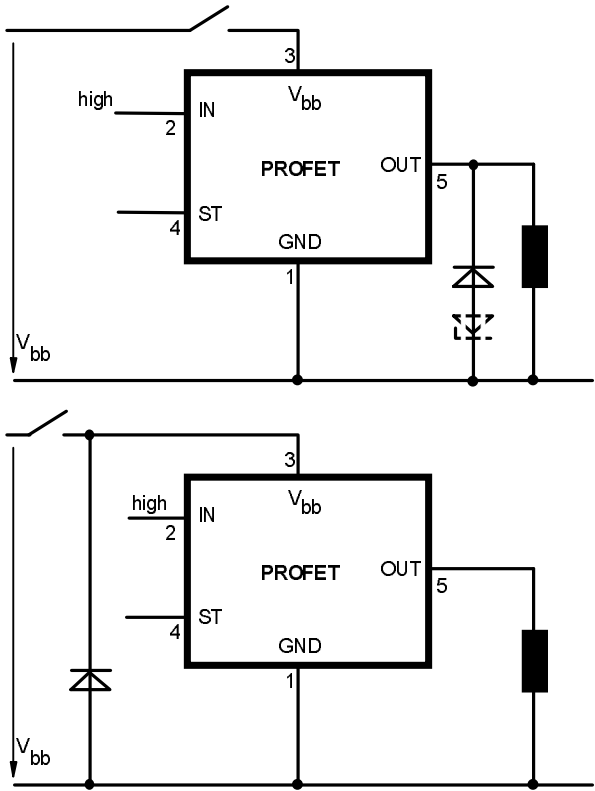
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
Due to $V_{GND} > 0$, no $V_{ST} = \text{low}$ signal available.

GND disconnect with GND pull up

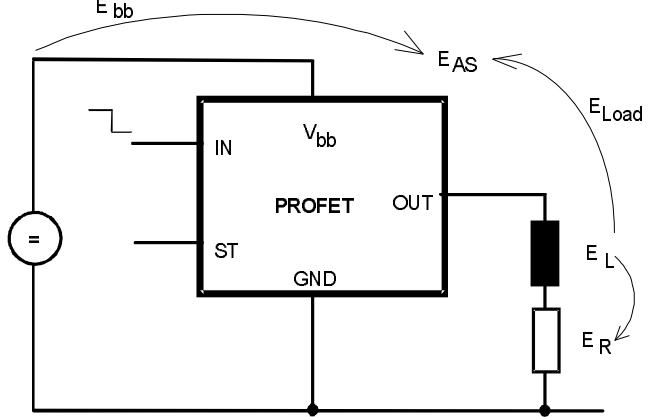


Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
Due to $V_{GND} > 0$, no $V_{ST} = \text{low}$ signal available.

V_{bb} disconnect with charged inductive load



Inductive Load switch-off energy dissipation



Energy dissipated in PROFET $E_{AS} = E_{bb} + E_L - E_R$.
 $E_{Load} < E_L$, $E_L = \frac{1}{2} * L * I_L^2$

Options Overview

all versions: High-side switch, Input protection, ESD protection, load dump and reverse battery protection , protection against loss of ground

| Type | BTS | 542D2 | 542E2 |
|---|-----|------------------|------------------|
| Logic version | | D | E |
| Overtemperature protection $T_j > 150\text{ °C}$, latch function ¹⁴⁾¹⁵⁾ $T_j > 150\text{ °C}$, with auto-restart on cooling | | X | X |
| Short-circuit to GND protection switches off when $V_{ON} > 8.3\text{ V}$ typ. ¹⁴⁾ (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} | | . ¹⁶⁾ | . ¹⁶⁾ |
| 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) | | | |

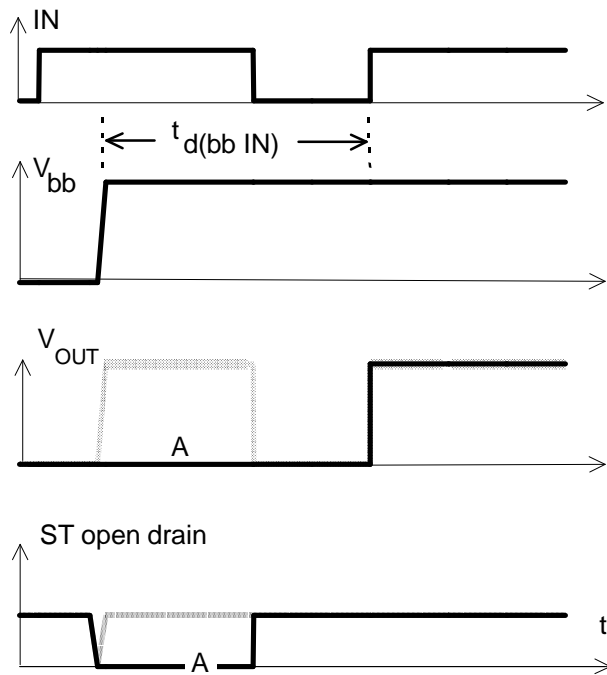
¹⁴⁾ Latch except when $V_{bb} - V_{OUT} < V_{ON(SC)}$ after shutdown. In most cases $V_{OUT} = 0\text{ V}$ after shutdown ($V_{OUT} \neq 0\text{ V}$ only if forced externally). So the device remains latched unless $V_{bb} < V_{ON(SC)}$ (see page 4). No latch between turn on and $t_{d(SC)}$.

¹⁵⁾ With latch function. Reseted by a) Input low, b) Undervoltage, c) Overvoltage

¹⁶⁾ 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 μ s

Figure 2a: Switching a lamp,

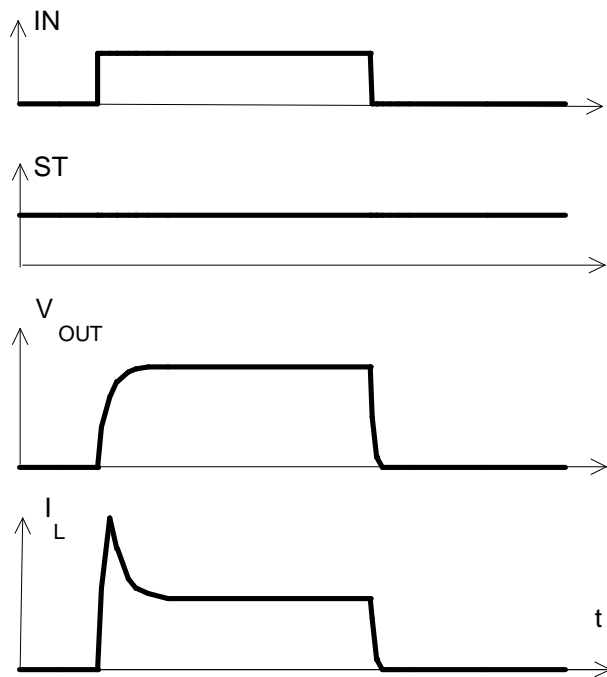
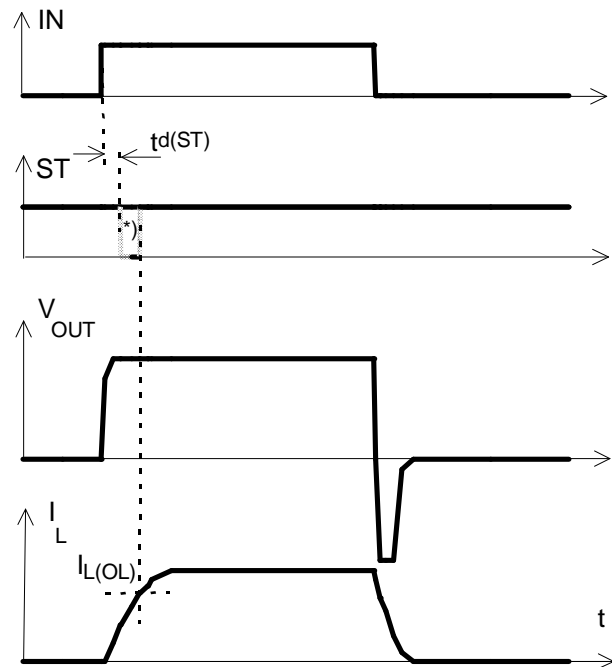
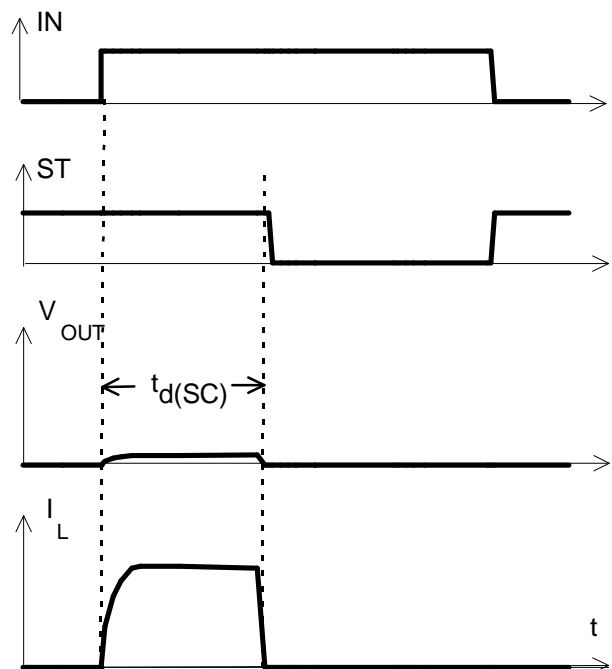


Figure 2b: Switching an inductive load



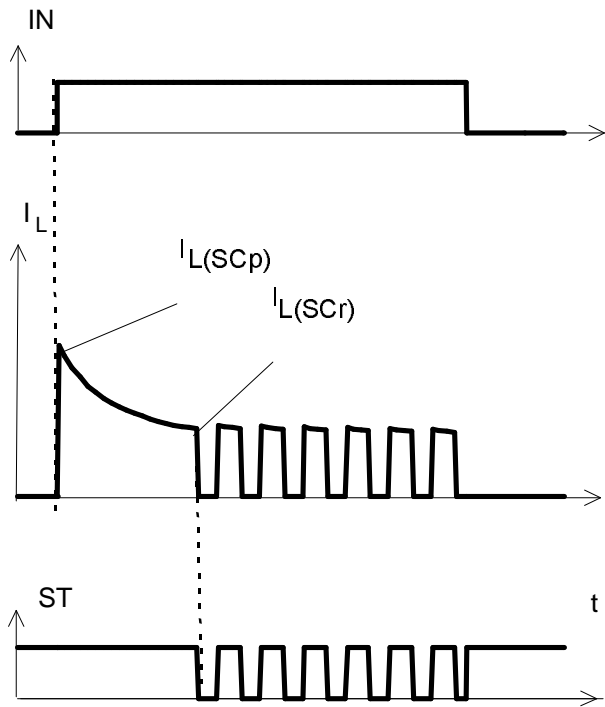
*) if the time constant of load is too large, open-load-status may occur

Figure 3a: Turn on into short circuit,



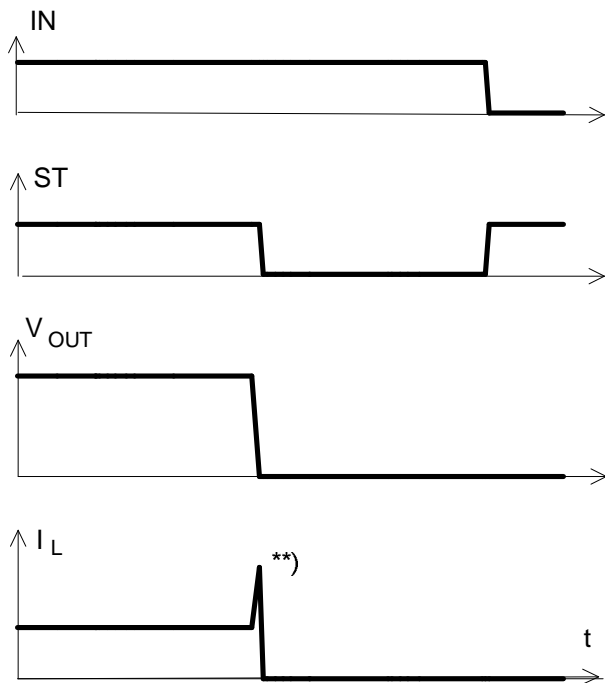
$t_{d(SC)}$ approx. 200 μ s if $V_{bb} - V_{OUT} > 8.3\ V$ typ.

Figure 3b: Turn on into overload,



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

Figure 3c: Short circuit while on:



***) current peak approx. 20 μs

Figure 4a: Overtemperature:

Reset if $T_j < T_{jt}$

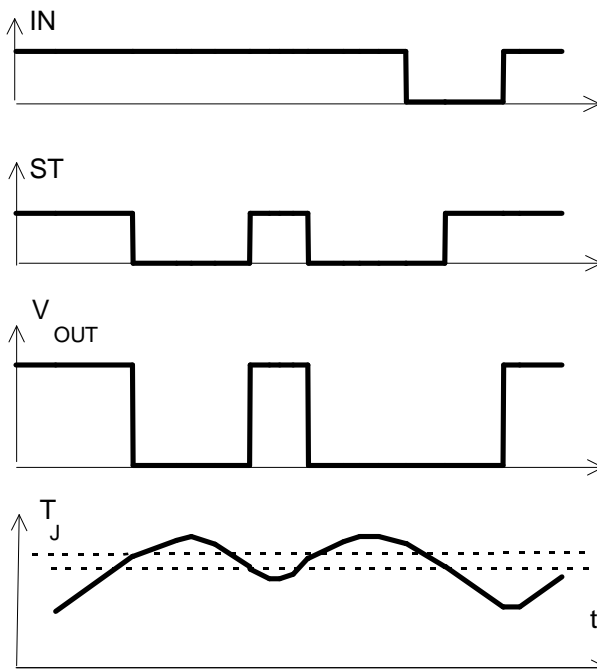


Figure 5a: Open load: detection in ON-state, turn on/off to open load

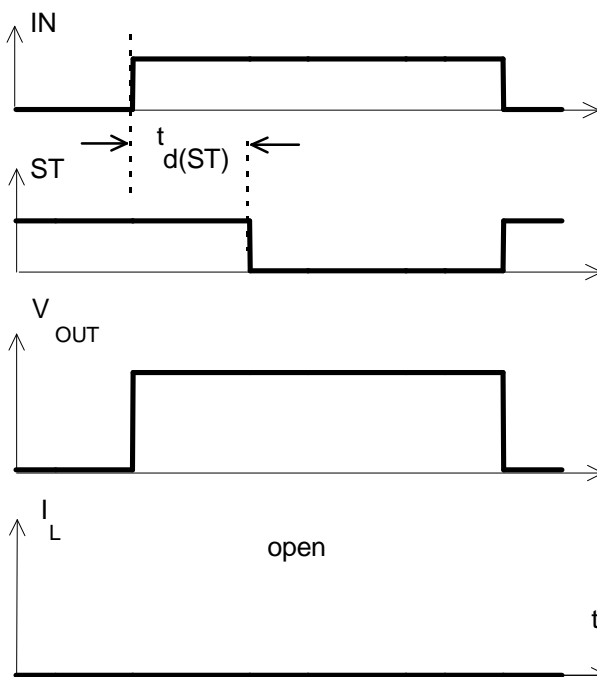


Figure 5b: Open load: detection in ON-state, open load occurs in on-state

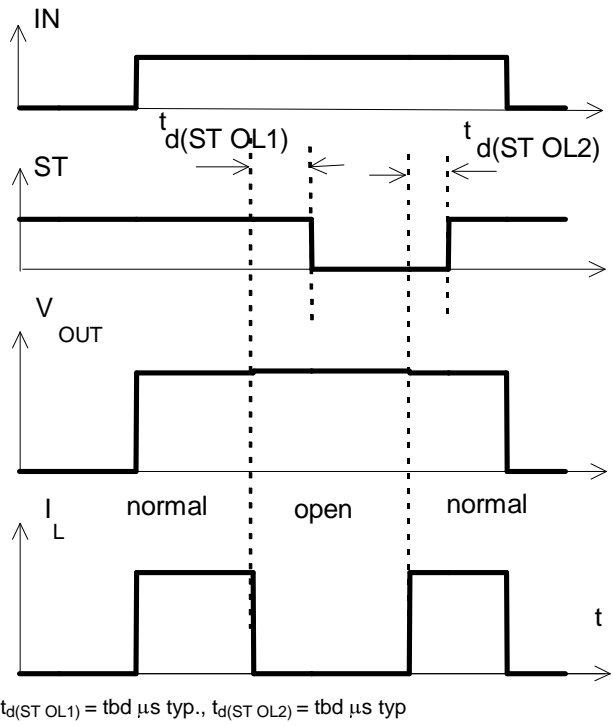


Figure 6a: Undervoltage:

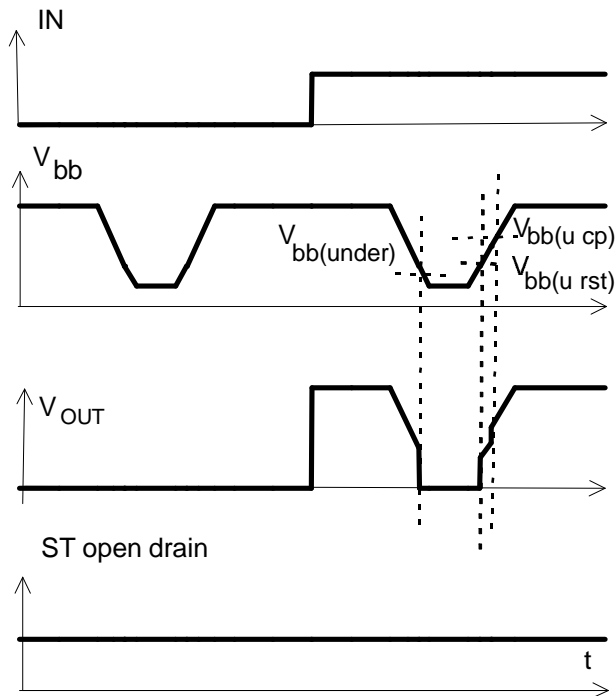


Figure 6b: Undervoltage restart of charge pump

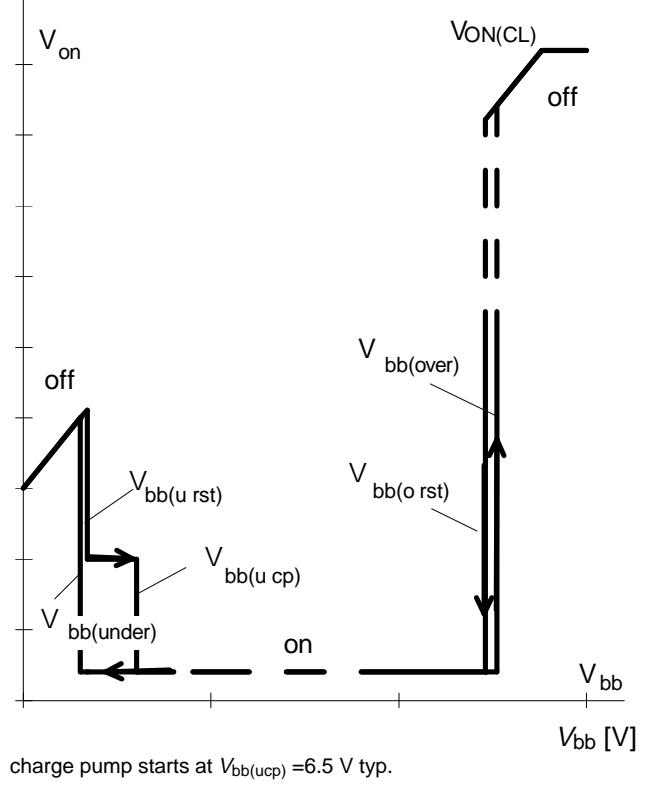
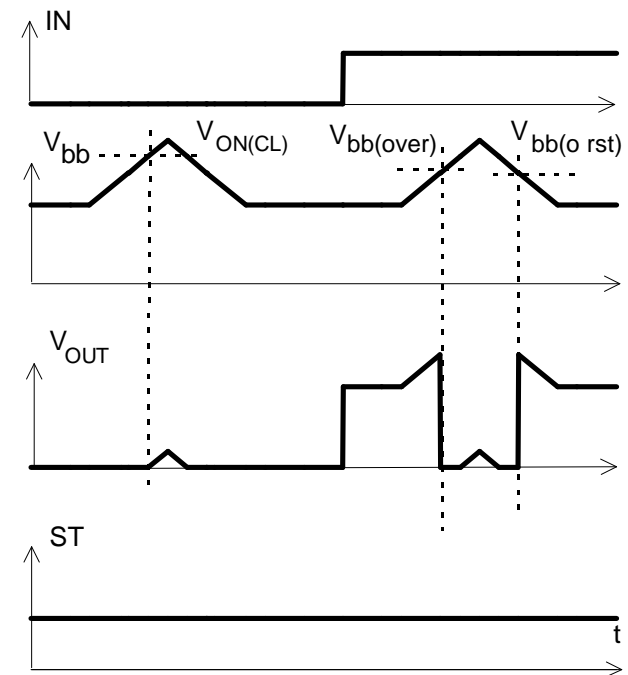


Figure 7a: Overvoltage:



Package and Ordering Code

All dimensions in mm

Standard TO-218AB/5 Ordering code

| | |
|------------|-----------------|
| BTS 542 E2 | Q67060-S6951-A2 |
|------------|-----------------|

