

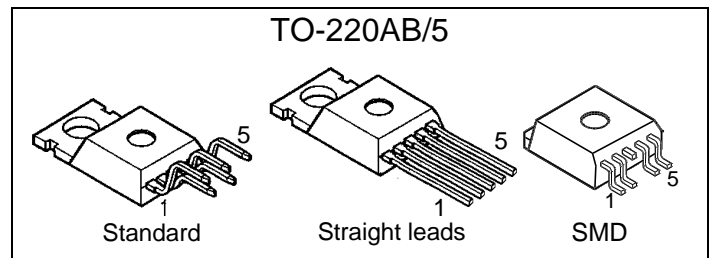
Smart Highside Power Switch

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} protection
- Electrostatic discharge (ESD) protection

Product Summary

| | | | |
|------------------------|--------------|------------|------------|
| Overvoltage protection | $V_{bb(AZ)}$ | 43 | V |
| Operating voltage | $V_{bb(on)}$ | 5.0 ... 34 | V |
| On-state resistance | R_{ON} | 200 | m Ω |
| Load current (ISO) | $I_{L(ISO)}$ | 2.3 | A |
| Current limitation | $I_{L(SCr)}$ | 4 | A |

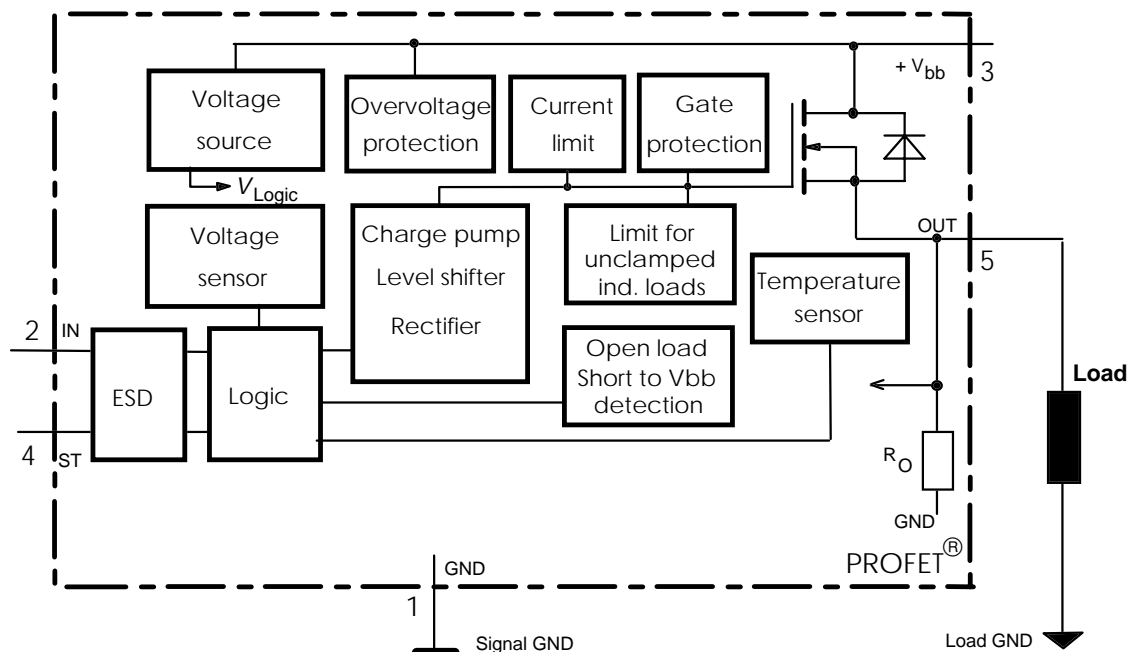


Application

- 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, fuses 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 $R_{GND}=150 \Omega$) 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 | 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} | 43 | V |
| Supply voltage for full short circuit protection $T_{j\text{ start}} = -40 \dots +150\text{ °C}$ | V_{bb} | 34 | V |
| Load dump protection ²⁾ $V_{\text{LoadDump}} = U_A + V_s$, $U_A = 13.5\text{ V}$ $R_l^3 = 2\ \Omega$, $R_L = 5.3\ \Omega$, $t_d = 200\text{ ms}$, IN= low or high | $V_{\text{Load dump}}^4)$ | 60 | 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), $T_C \leq 25\text{ °C}$ | P_{tot} | 18 | W |
| Inductive load switch-off energy dissipation, single pulse $V_{bb} = 12\text{ V}$, $T_{j,\text{start}} = 150\text{ °C}$, $T_C = 150\text{ °C}$ const. $I_L = 2.3\text{ A}$, $Z_L = 98\text{ mH}$, $0\ \Omega$: | E_{AS} | 335 | mJ |
| Electrostatic discharge capability (ESD) (Human Body Model) acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993 | IN: V_{ESD} all other pins: | 1.0 2.0 | kV |
| Input voltage (DC) | V_{IN} | -10 ... +16 | V |
| Current through input pin (DC) | I_{IN} | ± 2.0 | mA |
| Current through status pin (DC) | I_{ST} | ± 5.0 | |
| see internal circuit diagrams page 6 | | | |

Thermal Characteristics

| Parameter and Conditions | Symbol | Values | | | Unit |
|--|-------------------|--------|-----|-----|------|
| | | min | typ | max | |
| Thermal resistance chip - case: | R_{thJC} | -- | -- | 7 | K/W |
| junction - ambient (free air): | R_{thJA} | -- | -- | 75 | |
| SMD version, device on PCB ⁵⁾ : | | | 39 | | |

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_l = internal resistance of the load dump test pulse generator

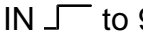

4) $V_{\text{Load dump}}$ is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839

5) Device on $50\text{ mm} \times 50\text{ mm} \times 1.5\text{ mm}$ epoxy PCB FR4 with 6 cm^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 $T_j = 25\text{ °C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified | Symbol | Values | | | Unit |
|---|--------|--------|-----|-----|------|
| | | min | typ | max | |

Load Switching Capabilities and Characteristics

| | | | | | | |
|--|---|------------------|-----|------------|------------|-----------|
| On-state resistance (pin 3 to 5) $I_L = 1.8\text{ A}$ | $T_j = 25\text{ °C}$: $T_j = 150\text{ °C}$: | R_{ON} | -- | 160 320 | 200 400 | $m\Omega$ |
| Nominal load current, ISO Norm (pin 3 to 5) $V_{ON} = 0.5\text{ V}$, $T_C = 85\text{ °C}$ | | $I_{L(ISO)}$ | 1.8 | 2.3 | -- | A |
| Output current (pin 5) while GND disconnected or GND pulled up, $V_{bb} = 30\text{ V}$, $V_{IN} = 0$, see diagram page 7 | | $I_{L(GNDhigh)}$ | -- | -- | 10 | mA |
| Turn-on time IN  to 90% V_{OUT} : | | t_{on} | 80 | 200 | 400 | μs |
| Turn-off time IN  to 10% V_{OUT} : | | t_{off} | 80 | 200 | 400 | μs |
| Slew rate on 10 to 30% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\dots+150\text{ °C}$ | | dV/dt_{on} | 0.1 | -- | 1 | $V/\mu s$ |
| Slew rate off 70 to 40% V_{OUT} , $R_L = 12\ \Omega$, $T_j = -40\dots+150\text{ °C}$ | | $-dV/dt_{off}$ | 0.1 | -- | 1 | $V/\mu s$ |

Operating Parameters

| | | | | | | |
|--|---|------------------------|-----|----------|------------|---------|
| Operating voltage ⁶⁾ | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(on)}$ | 5.0 | -- | 34 | V |
| Undervoltage shutdown | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(under)}$ | 3.5 | -- | 5.0 | V |
| Undervoltage restart | $T_j = -40\dots+25\text{ °C}$: $T_j = +150\text{ °C}$: | $V_{bb(u\ rst)}$ | -- | -- | 5.0 7.0 | V |
| Undervoltage restart of charge pump see diagram page 11 | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(ucp)}$ | -- | 5.6 | 7.0 | V |
| Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$ | | $\Delta V_{bb(under)}$ | -- | 0.2 | -- | V |
| Overvoltage shutdown | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(over)}$ | 34 | -- | 43 | V |
| Overvoltage restart | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(o\ rst)}$ | 33 | -- | -- | V |
| Overvoltage hysteresis | $T_j = -40\dots+150\text{ °C}$: | $\Delta V_{bb(over)}$ | -- | 0.5 | -- | V |
| Overvoltage protection ⁷⁾ $I_{bb} = 40\text{ mA}$ | $T_j = -40\dots+150\text{ °C}$: | $V_{bb(AZ)}$ | 42 | 47 | -- | V |
| Standby current (pin 3) $V_{IN} = 0$ | $T_j = -40\dots+25\text{ °C}$: $T_j = 150\text{ °C}$: | $I_{bb(off)}$ | -- | 10 12 | 23 28 | μA |
| Leakage output current (included in $I_{bb(off)}$) $V_{IN} = 0$ | | $I_{L(off)}$ | -- | -- | 12 | μA |

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⁾ See also $V_{ON(CL)}$ in table of protection functions and circuit diagram 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 | |

| | | | | | |
|---|-----------|----|-----|-----|----|
| Operating current (Pin 1) ⁸⁾ , $V_{IN}=5\text{ V}$, $T_j = -40\dots+150\text{ °C}$ | I_{GND} | -- | 1.8 | 3.5 | mA |
|---|-----------|----|-----|-----|----|

Protection Functions

| | | | | | |
|--|-----------------|-------------------|-------------------|---------------|----|
| Initial peak short circuit current limit (pin 3 to 5) $T_j = -40\text{ °C}$: $T_j = 25\text{ °C}$: $T_j = +150\text{ °C}$: | $I_{L(SCp)}$ | 5.5 4.5 2.5 | 9.5 7.5 4.5 | 13 11 7 | A |
| Repetitive short circuit shutdown current limit $T_j = T_{jt}$ (see timing diagrams, page 9) | $I_{L(SCr)}$ | -- | 4 | -- | A |
| Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$ $I_L = 40\text{ mA}$: | $V_{ON(CL)}$ | 41 | 47 | 53 | V |
| Thermal overload trip temperature | T_{jt} | 150 | -- | -- | °C |
| Thermal hysteresis | ΔT_{jt} | -- | 10 | -- | K |
| Reverse battery (pin 3 to 1) ⁹⁾ | $-V_{bb}$ | -- | -- | 32 | V |



Diagnostic Characteristics

| | | | | | |
|--|---------------|----------|----------|------------|----|
| Open load detection current (on-condition) $T_j = -40\text{ °C}$: $T_j = 25\dots150\text{ °C}$: | $I_L(OL)$ | 10 10 | -- -- | 200 150 | mA |
| Open load detection voltage ¹⁰⁾ (off-condition) $T_j = -40\dots150\text{ °C}$: | $V_{OUT(OL)}$ | 2 | 3 | 4 | V |
| Internal output pull down (pin 5 to 1), $V_{OUT}=5\text{ V}$, $T_j=-40\dots150\text{ °C}$ | R_O | 4 | 10 | 30 | kΩ |

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

9) Requires $150\text{ }\Omega$ resistor in GND connection. The reverse load current through the intrinsic drain-source diode has to be limited by the connected load. Note that the power dissipation is higher compared to normal operating conditions due to the voltage drop across the intrinsic drain-source diode. The temperature protection is not active during reverse current operation! Input and Status currents have to be limited (see max. ratings page 2 and circuit page 7).

10) External pull up resistor required for open load detection in off state.

| 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 Feedback¹¹⁾ | | | | | |
| Input resistance see circuit page 6 | R_I | 2.5 | 3.5 | 6 | k Ω |
| Input turn-on threshold voltage  $T_j = -40..+150\text{ °C}$: | $V_{IN(T+)}$ | 1.7 | -- | 3.5 | V |
| Input turn-off threshold voltage  $T_j = -40..+150\text{ °C}$: | $V_{IN(T-)}$ | 1.5 | -- | -- | V |
| Input threshold hysteresis | $\Delta V_{IN(T)}$ | -- | 0.5 | -- | V |
| Off state input current (pin 2), $V_{IN} = 0.4\text{ V}$, $T_j = -40..+150\text{ °C}$ | $I_{IN(off)}$ | 1 | -- | 50 | μA |
| On state input current (pin 2), $V_{IN} = 3.5\text{ V}$, $T_j = -40..+150\text{ °C}$ | $I_{IN(on)}$ | 20 | 50 | 90 | μA |
| Delay time for status with open load after switch off (see timing diagrams, page 10), $T_j = -40..+150\text{ °C}$ | $t_{d(ST\ OL4)}$ | 100 | 400 | 800 | μs |
| Status invalid after positive input slope (open load) $T_j = -40 \dots +150\text{ °C}$: | $t_{d(ST)}$ | -- | 250 | 600 | μs |
| Status output (open drain) | | | | | |
| Zener limit voltage $T_j = -40..+150\text{ °C}$, $I_{ST} = +1.6\text{ mA}$: | $V_{ST(high)}$ | 5.4 | 6.1 | -- | V |
| ST low voltage $T_j = -40..+25\text{ °C}$, $I_{ST} = +1.6\text{ mA}$: | $V_{ST(low)}$ | -- | -- | 0.4 | |
| $T_j = +150\text{ °C}$, $I_{ST} = +1.6\text{ mA}$: | | -- | -- | 0.6 | |

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

Truth Table

| | Input-level | Output level | Status |
|---------------------------|-------------|------------------|-----------------------|
| Normal operation | L | L | H |
| | H | H | H |
| Open load | L | ¹²⁾ L | H (L ¹³⁾) |
| | H | H | L |
| Short circuit to V_{bb} | L | H | L ¹⁴⁾ |
| | H | H | H (L ¹⁵⁾) |
| Overtemperature | L | L | H |
| | H | L | L |
| Under-voltage | L | L | H |
| | H | L | H |
| Overvoltage | L | L | H |
| | H | L | H |

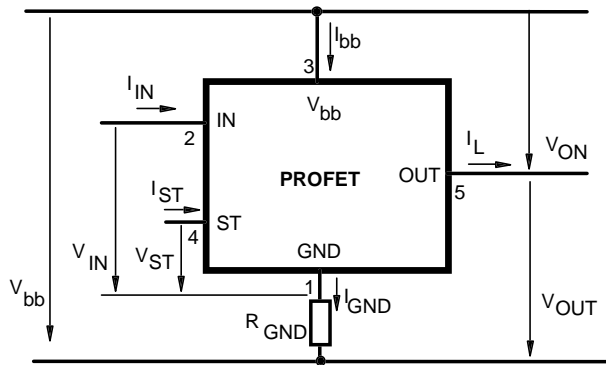
L = "Low" Level
H = "High" Level

X = don't care

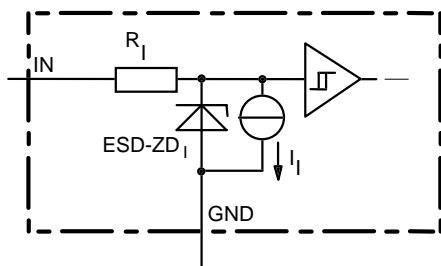
Z = high impedance, potential depends on external circuit

Status signal after the time delay shown in the diagrams (see fig 5. page 10...11)

Terms

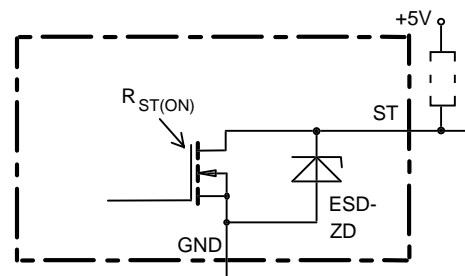


Input circuit (ESD protection)



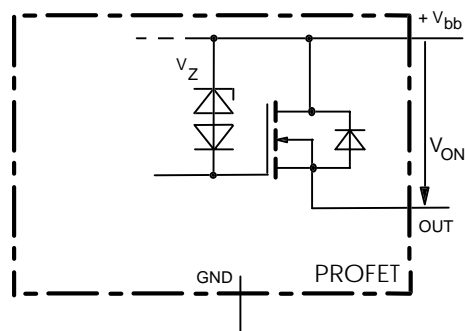
ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

Status output



ESD-Zener diode: 6.1 V typ., max 5 mA;
 $R_{ST(ON)} < 380 \Omega$ 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).

Inductive and overvoltage output clamp



V_{ON} clamped to 47 V typ.

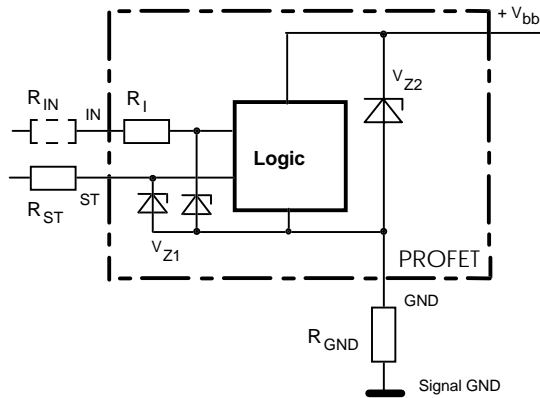
12) Power Transistor off, high impedance

13) with external resistor between pin 3 and pin 5

14) An external short of output to V_{bb} , in the off state, causes an internal current from output to ground. If R_{GND} is used, an offset voltage at the GND and ST pins will occur and the $V_{ST low}$ signal may be errorious.

15) Low resistance to V_{bb} may be detected in ON-state by the no-load-detection

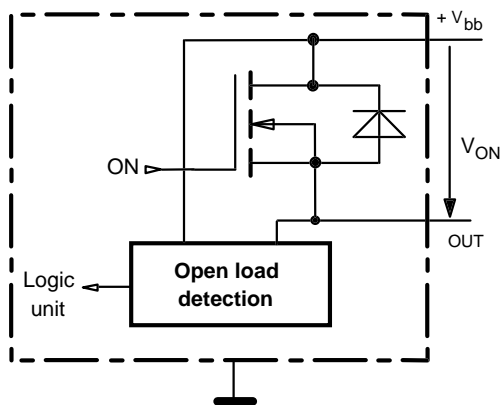
Overvolt. and reverse batt. protection



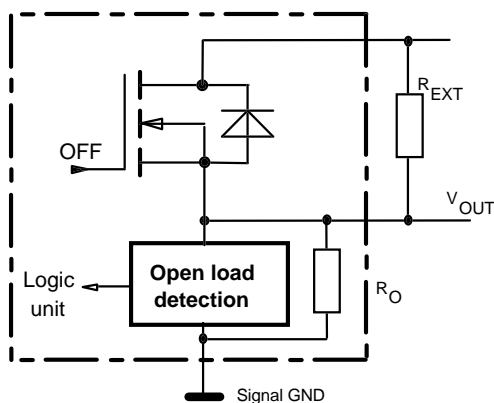
$V_{Z1} = 6.2 \text{ V typ.}$, $V_{Z2} = 47 \text{ V typ.}$, $R_{GND} = 150 \text{ } \Omega$,
 $R_{ST} = 15 \text{ k}\Omega$, $R_1 = 3.5 \text{ k}\Omega \text{ typ.}$

Open-load detection

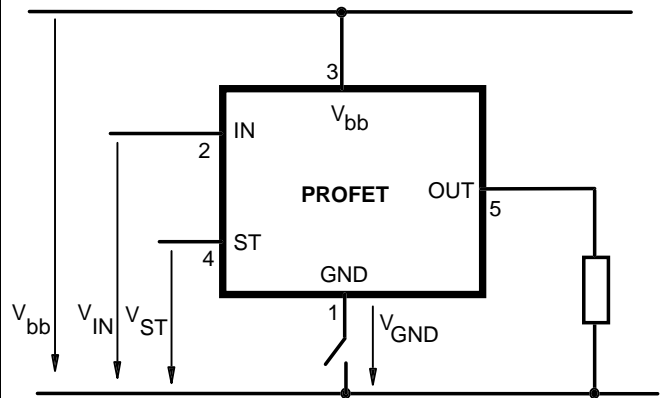
ON-state diagnostic condition: $V_{ON} < R_{ON} \cdot I_{L(OL)}$; IN high



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

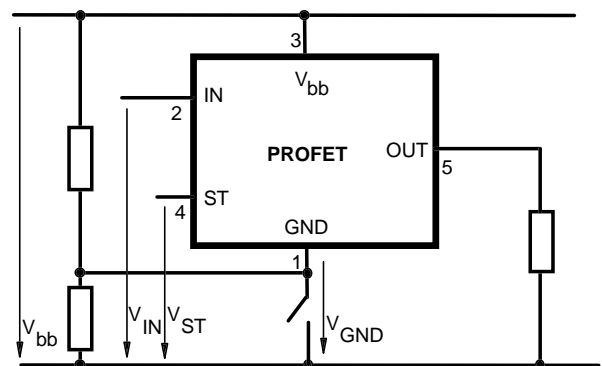


GND disconnect



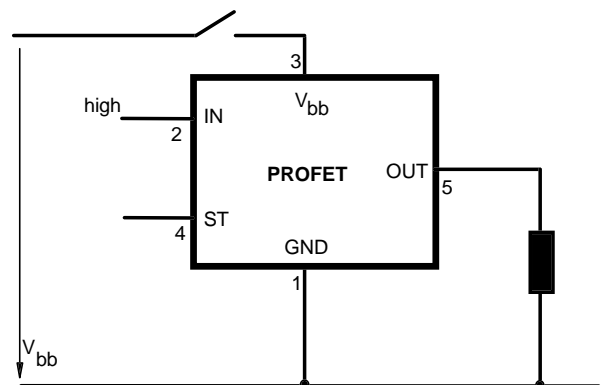
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
 Due to $V_{GND} > 0$, no $V_{ST} = \text{low}$ signal available.

GND disconnect with GND pull up



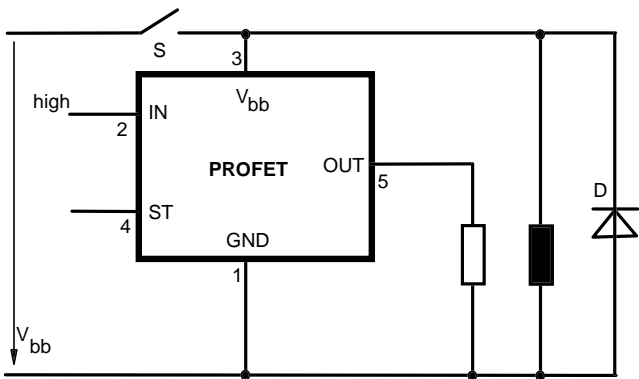
Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
 Due to $V_{GND} > 0$, no $V_{ST} = \text{low}$ signal available.

V_{bb} disconnect with energized inductive load



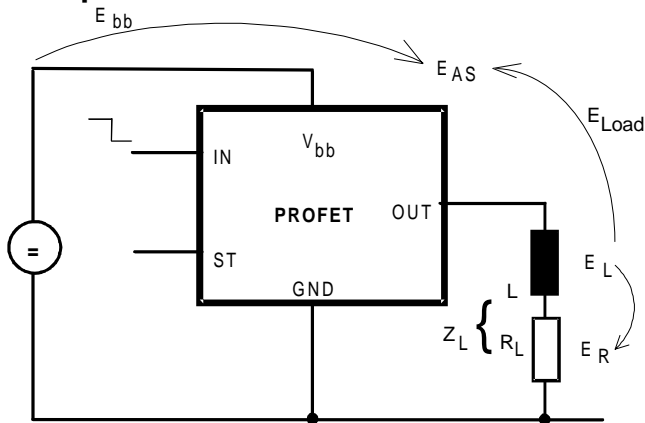
Normal load current can be handled by the PROFET itself.

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 stored in load inductance:

$$E_L = \frac{1}{2} \cdot L \cdot I_L^2$$

While demagnetizing load inductance, the energy dissipated in PROFET is

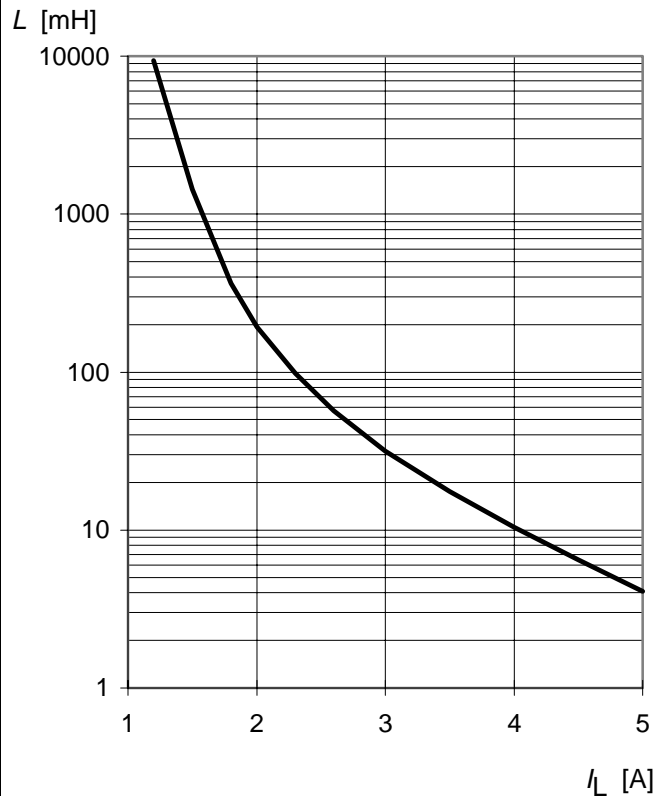
$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t) dt,$$

with an approximate solution for $R_L > 0 \Omega$:

$$E_{AS} = \frac{I_L \cdot L}{2 \cdot R_L} \cdot (V_{bb} + |V_{OUT(CL)}|) \cdot \ln \left(1 + \frac{I_L \cdot R_L}{|V_{OUT(CL)}|} \right)$$

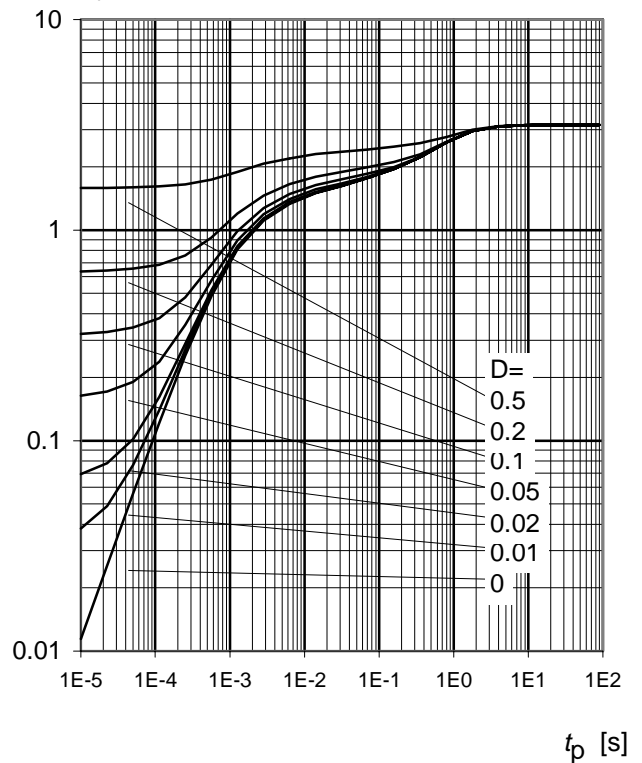
Maximum allowable load inductance for a single switch off

$L = f(I_L)$; $T_{j,start} = 150^\circ\text{C}$, $T_C = 150^\circ\text{C}$ const.,
 $V_{bb} = 12\text{V}$, $R_L = 0 \Omega$



Transient thermal impedance chip case

$Z_{thJC} = f(t_p) Z_{thJC} [K/W]$



Timing diagrams

Figure 1a: V_{bb} turn on:

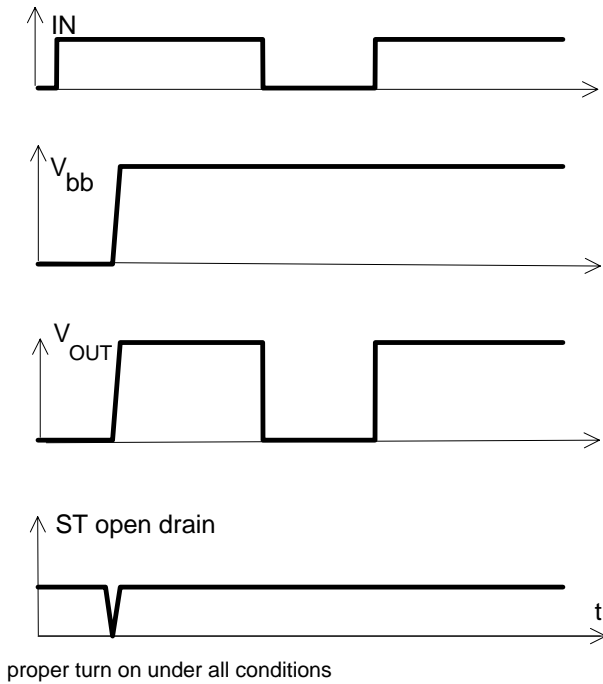


Figure 2a: Switching a lamp,

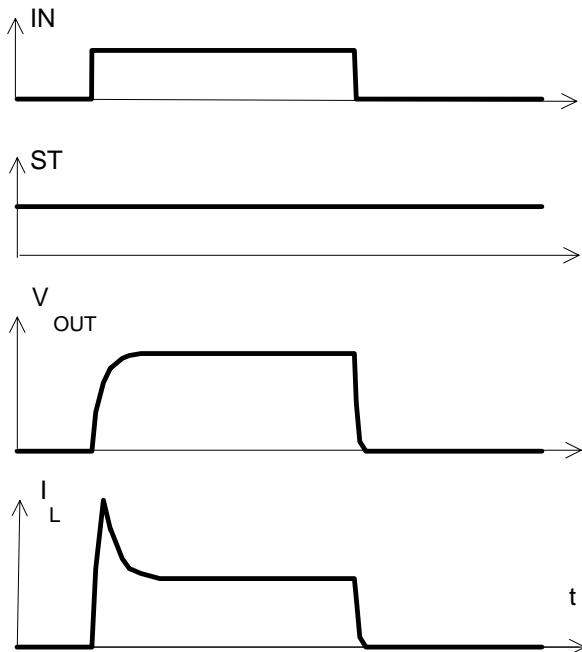
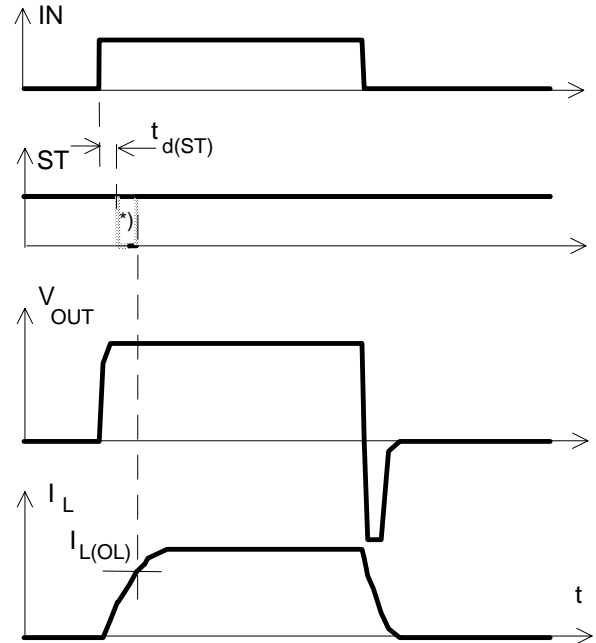
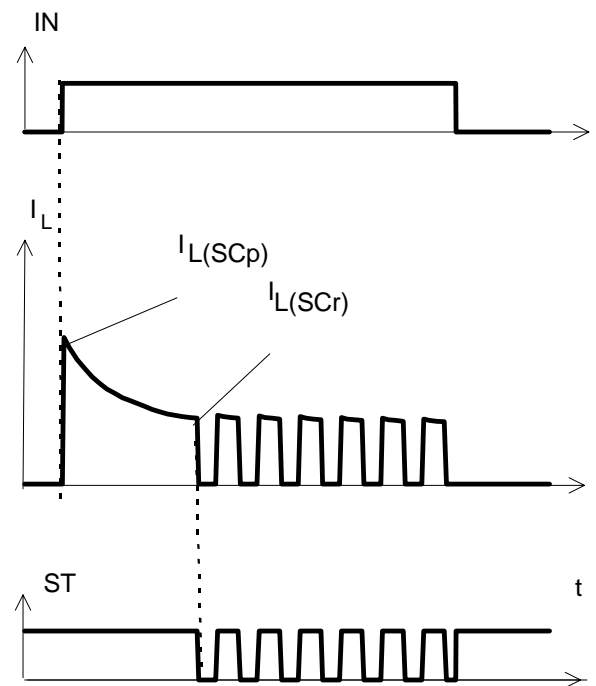


Figure 2b: Switching an inductive load



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

Figure 3a: Short circuit shut down by overtemperature, reset by cooling



Heating up may require several milliseconds, depending on external conditions

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

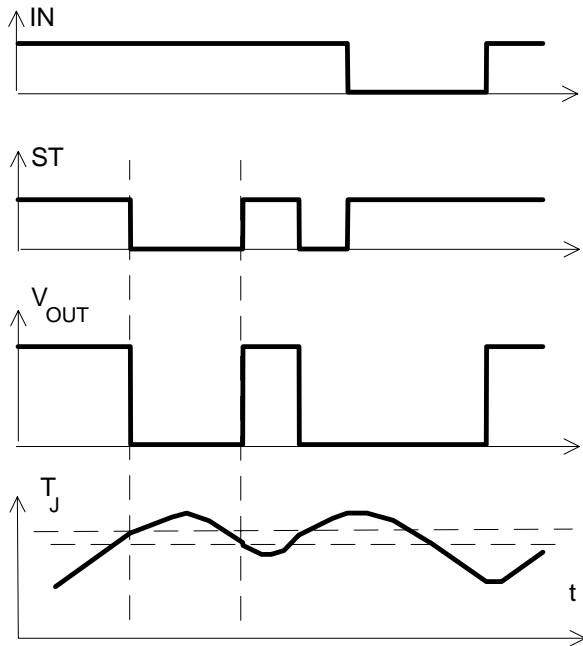
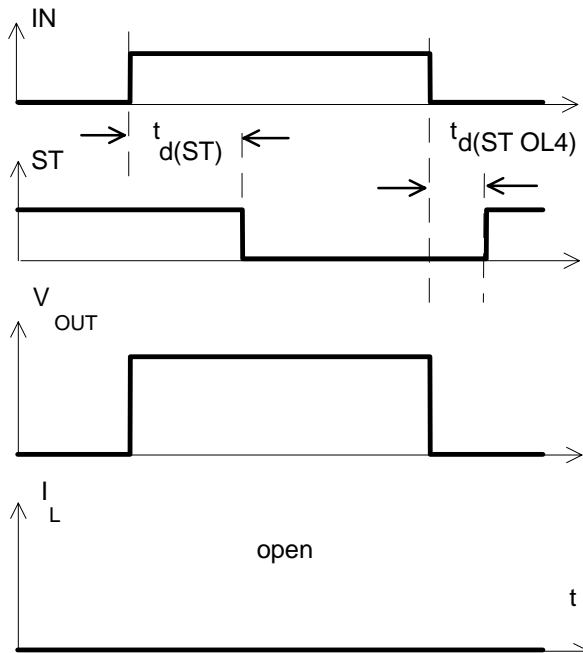
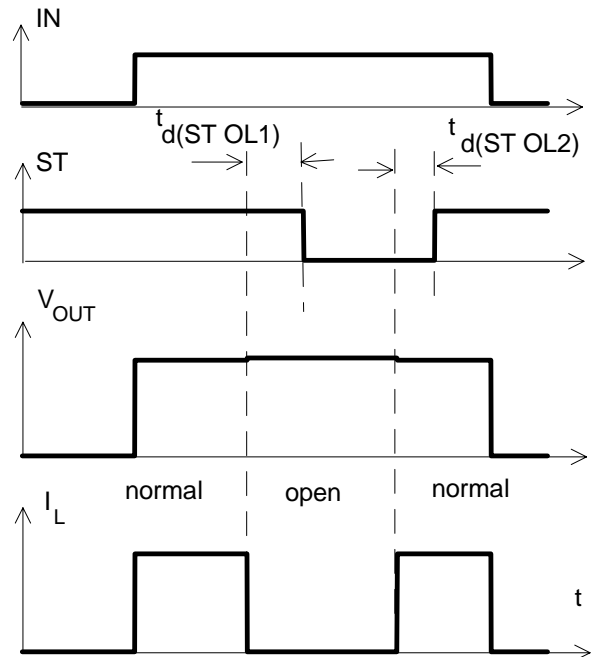


Figure 5a: Open load: detection in ON-state, turn on/off to open load



The status delay time $t_{d(ST OL4)}$ allows to distinguish between the failure modes "open load" and "overtemperature".

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



$t_{d(ST OL1)} = 30 \mu s$ typ., $t_{d(ST OL2)} = 20 \mu s$ typ

Figure 5c: Open load: detection in ON- and OFF-state (with R_{EXT}), turn on/off to open load

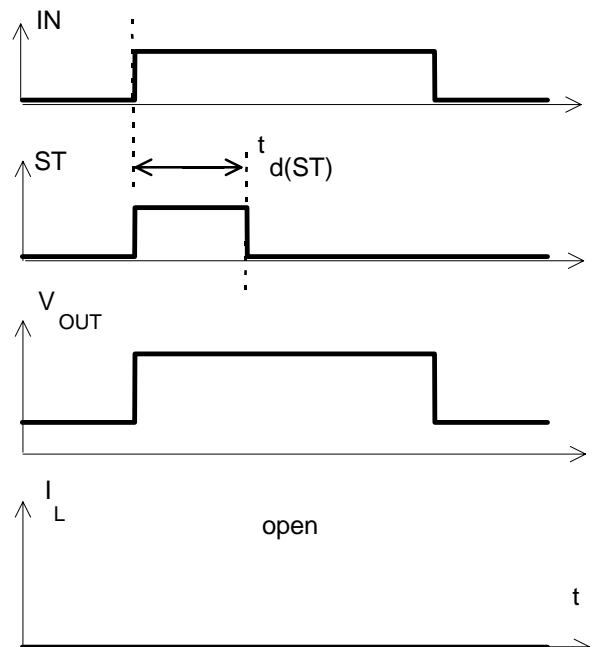


Figure 6a: Undervoltage:

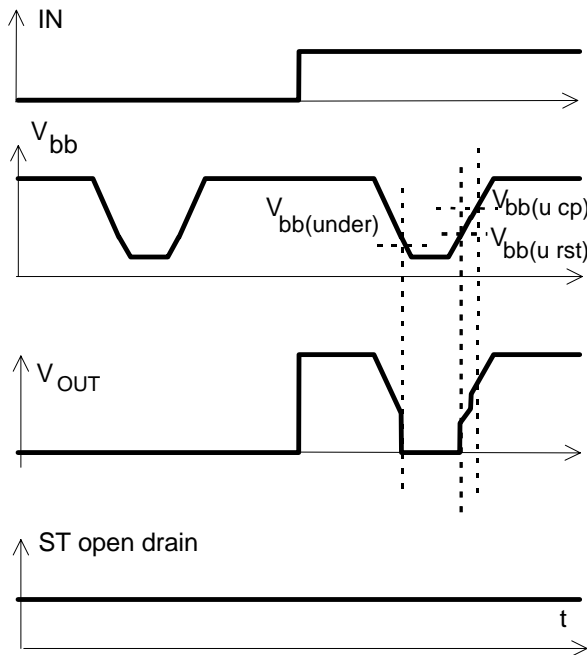


Figure 7a: Overvoltage:

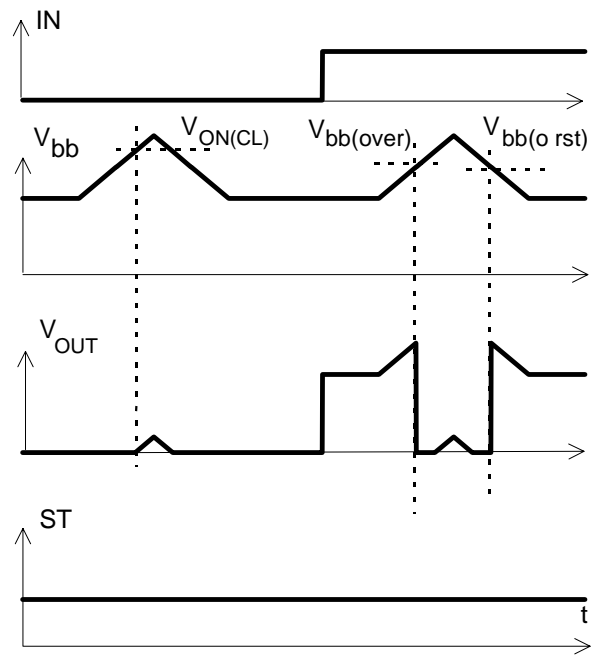
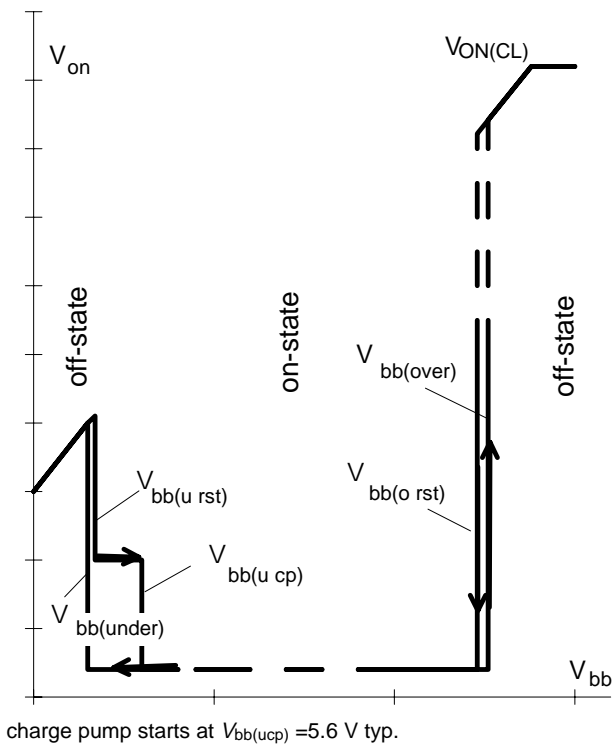


Figure 6b: Undervoltage restart of charge pump



Package and Ordering Code

All dimensions in mm

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

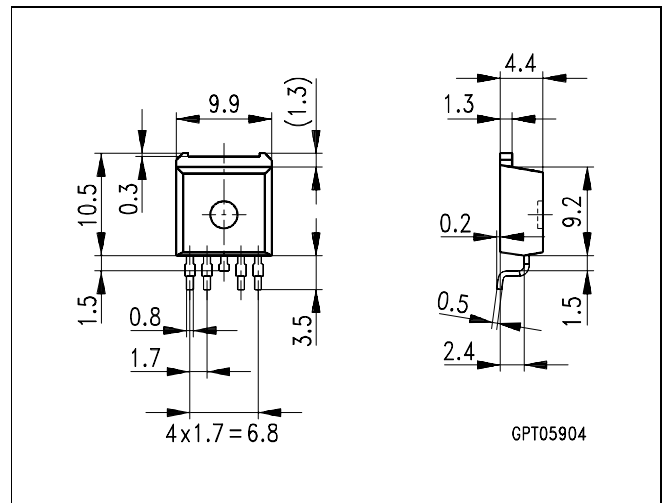
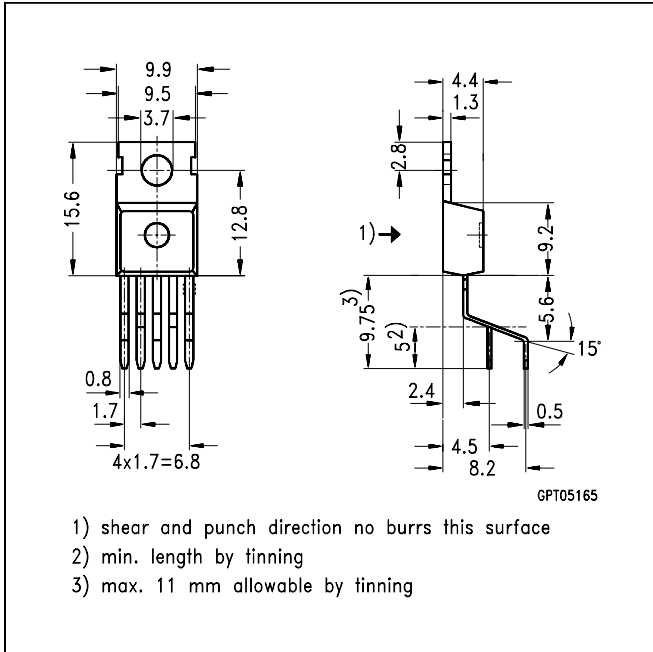
BTS409L1 E3062A T&R: Q67060-S6107-A4

Standard TO-220AB/5

Ordering code

BTS409L1

Q67060-S6107-A2



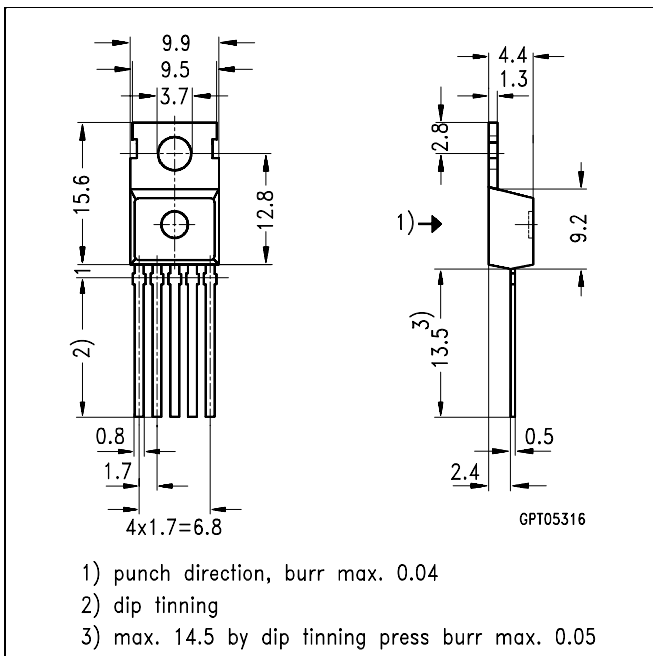
Changed since 04.96

| Date | Change |
|----------|---|
| Dec 1996 | Zth Specification added |
| | $t_{d(ST\ OL4)}$ max reduced from 1500 to 800 μ s |
| | ESD capability increased |
| | E_{AS} maximum rating and diagram added |

TO-220AB/5, Option E3043 Ordering code

BTS409L1 E3043

Q67060-S6107-A3



Components used in life-support devices or systems must be expressly authorised for such purpose! Critical components¹⁶⁾ of the Semiconductor Group of Siemens AG, may only be used in life supporting devices or systems¹⁷⁾ with the express written approval of the Semiconductor Group of Siemens AG.

- 16) A critical component is a component used in a life-support device or system whose failure can reasonably be expected to cause the failure of that life-support device or system, or to affect its safety or effectiveness of that device or system.
- 17) Life support devices or systems are intended (a) to be implanted in the human body or (b) support and/or maintain and sustain and/or protect human life. If they fail, it is reasonably to assume that the health of the user or other persons may be endangered.