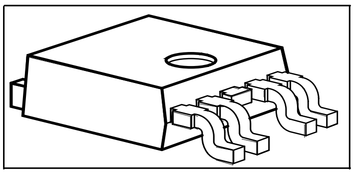
# Smart Power High-Side-Switch

## Features

- Overload protection
- Current limitation
- Short circuit protection
- Thermal shutdown with restart
- Overvoltage protection (including load dump)
- Fast demagnetization of inductive loads
- Reverse battery protection with external resistor
- CMOS compatible input
- Loss of GND and loss of $V_{bb}$ protection
- ESD - Protection
- Very low standby current

## Product Summary

| | | | |
|---|---|---|---|
| Overvoltage protection | $V_{bb(AZ)}$ | 41 | V |
| Operating voltage | $V_{bb(on)}$ | 5...34 | V |
| On-state resistance | $R_{ON}$ | 100 | mΩ |
| Nominal load current | $I_{L(ISO)}$ | 3.5 | A |



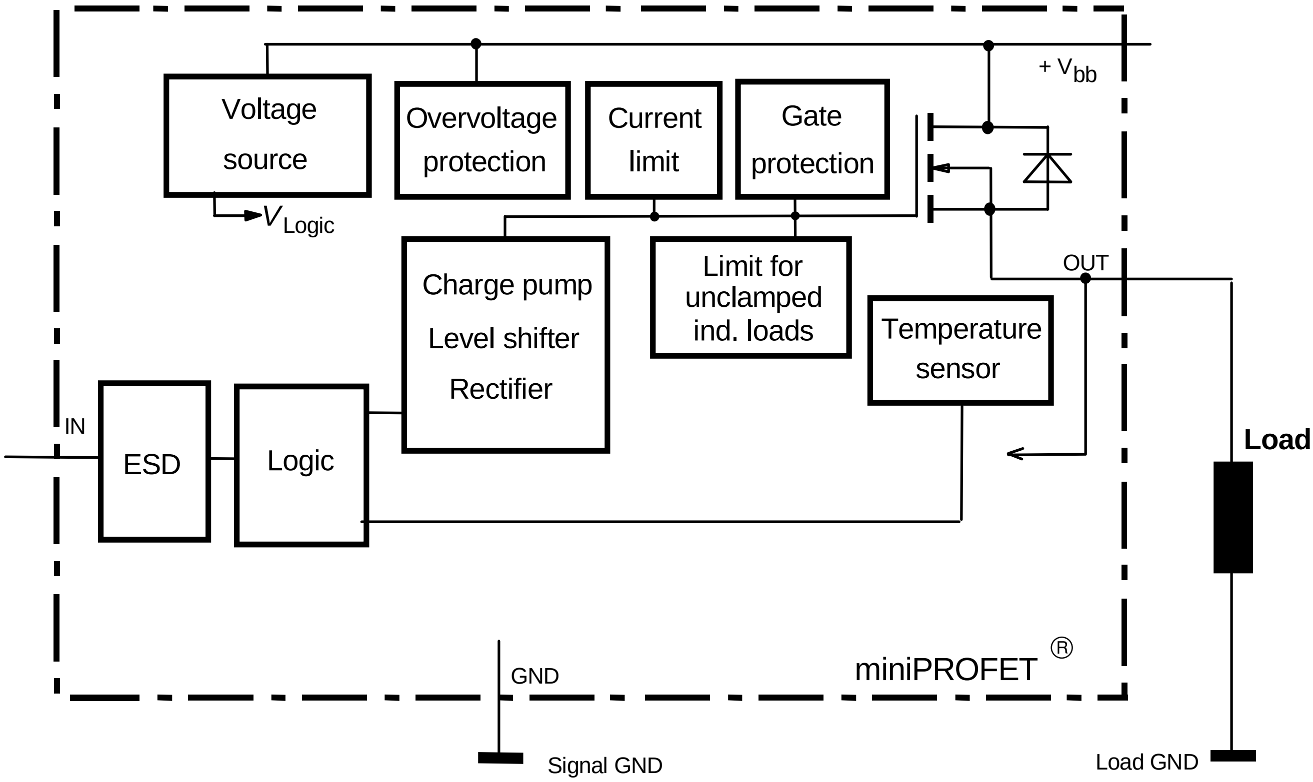
## Application

- All types of resistive, inductive and capacitive loads
- µC compatible power switch for 12 V and 24 V DC applications
- Replaces electromechanical relays and discrete circuits

## General Description

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

## Block Diagram




| Pin | Symbol | Function |
|---|---|---|
| 1 | GND | Logic ground |
| 2 | IN | Input, activates the power switch in case of logic high signal |
| 3 | Vbb | Positive power supply voltage |
| 4 | NC | not connected |
| 5 | OUT | Output to the load |
| TAB | Vbb | Positive power supply voltage |

**Maximum Ratings** at $T_j$ = 25°C, unless otherwise specified

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Supply voltage | $V_{bb}$ | 40 | V |
| Supply voltage for full short circuit protection<br>$T_j$ = -40...+150 °C | $V_{bb(SC)}$ | 30 | |
| Continuous input voltage | $V_{IN}$ | -10 ... +16 | |
| Load current (Short - circuit current, see page 5) | $I_L$ | self limited | A |
| Current through input pin (DC) | $I_{IN}$ | ± 5 | mA |
| Operating temperature | $T_j$ | -40 ...+150 | °C |
| Storage temperature | $T_{stg}$ | -55 ... +150 | |
| Power dissipation [1] | $P_{tot}$ | 41.6 | W |
| Inductive load switch-off energy dissipation[1][2]<br>single pulse, (see page 8)<br>Tj =150 °C, $V_{bb}$ = 13.5 V, $I_L$ = 1 A | $E_{AS}$ | 4.4 | J |
| Load dump protection[2] $V_{LoadDump}$[3]= $V_A$ + $V_S$<br>$R_I$=2Ω, $t_d$=400ms, $V_{IN}$= low or high, $V_A$=13,5V<br>$R_L$ = 13.5 Ω | $V_{Loaddump}$ | 75 | V |
| **E**lectro**s**tatic **d**ischarge voltage (Human Body Model)<br>according to MIL STD 883D, method 3015.7 and<br>EOS/ESD assn. standard S5.1 - 1993<br>Input pin<br>all other pins | $V_{ESD}$ | <br><br><br>± 1<br>± 2 | kV |

**Thermal Characteristics**

| | | | | | |
|---|---|---|---|---|---|
| junction - case: | $R_{thJC}$ | - | - | 3 | K/W |
| Thermal resistance @ min. footprint | $R_{th(JA)}$ | - | 80 | - | |
| Thermal resistance @ 6 cm$^2$ cooling area [1] | $R_{th(JA)}$ | - | 45 | 60 | |

1 Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6 cm2 (one layer, 70µm thick) copper area for drain connection. PCB is vertical without blown air. (see page 16)

2 not tested, specified by design

3 $V_{Loaddump}$ is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839 .
Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND pin, e.g. with a 150Ω resistor in GND connection. A resistor for the protection of the input is integrated.

## Electrical Characteristics

| Parameter<br>at $T_j$ = -40...+150°C, $V_{bb}$=13.5V, unless otherwise specified | Symbol | Values | | | Unit |
|---|---|---|---|---|---|
| | | min. | typ. | max. | |
| **Load Switching Capabilities and Characteristics** | | | | | |
| On-state resistance<br>$T_j$ = 25 °C, $I_L$ = 2 A<br>$T_j$ = 150 °C | $R_{ON}$ | <br>-<br> | <br>70<br>140 | <br>100<br>200 | mΩ |
| Nominal load current; Device on PCB [1)]<br>$T_C$ = 85 °C, $V_{ON}$ = 0.5 V | $I_{L(ISO)}$ | 3.5 | 4.4 | - | A |
| Turn-on time to 90% $V_{OUT}$<br>$R_L$ = 47 Ω | $t_{on}$ | - | 90 | 170 | µs |
| Turn-off time to 10% $V_{OUT}$<br>$R_L$ = 47 Ω | $t_{off}$ | - | 90 | 230 | µs |
| Slew rate on 10 to 30% $V_{OUT}$,<br>$R_L$ = 47 Ω | $dV/dt_{on}$ | - | 0.8 | 1.7 | V/µs |
| Slew rate off 70 to 40% $V_{OUT}$,<br>$R_L$ = 47 Ω | $-dV/dt_{off}$ | - | 0.8 | 1.7 | |

## Operating Parameters

| Parameter | Symbol | min. | typ. | max. | Unit |
|---|---|---|---|---|---|
| Operating voltage | $V_{bb(on)}$ | 5 | - | 34 | V |
| Undervoltage shutdown of charge pump<br>$T_j$ = -40...+85 °C<br>$T_j$ = 150 °C | $V_{bb(under)}$ | <br>-<br>- | <br>-<br>- | <br>4<br>tbd | |
| Undervoltage restart of charge pump | $V_{bb(u\ cp)}$ | - | 4 | 5.5 | V |
| Standby current<br>$V_{IN}$ = 0 V, $T_j$ = -40 ... +85 °C<br>$V_{IN}$ = 0 V, $T_j$ = 150°C [2)] | $I_{bb(off)}$ | <br>-<br>- | <br>-<br>- | <br>10<br>15 | µA |
| Leakage output current (included in $I_{bb(off)}$)<br>$V_{IN}$ = 0 V | $I_{L(off)}$ | - | - | 5 | |
| Operating current<br>$V_{IN}$ = 5 V | $I_{GND}$ | - | 0.5 | 1.3 | mA |

1 Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6 cm2 (one layer, 70µm thick) copper area for drain connection. PCB is vertical without blown air. (see page 16)

2higher current due temperature sensor

## Electrical Characteristics

| Parameter and Conditions<br>at $T_j$ = -40...+150°C, $V_{bb}$=13.5V, unless otherwise specified | Symbol | Values min. | Values typ. | Values max. | Unit |
|---|---|---|---|---|---|
| **Protection Functions** | | | | | |
| Initial peak short circuit current limit (pin 3 to 5) | $I_{L(SCp)}$ | | | | A |
| $T_j$ = -40 °C, $V_{bb}$ = 20 V, $t_m$ = 300 µs | | - | - | 18 | |
| $T_j$ = 25 °C | | - | 13 | - | |
| $T_j$ = 150 °C | | 7 | - | - | |
| Repetitive short circuit current limit<br>$T_j = T_{jt}$ (see timing diagrams) | $I_{L(SCr)}$ | - | 10 | - | |
| Output clamp (inductive load switch off)<br>at $V_{OUT} = V_{bb} - V_{ON(CL)}$,<br>$I_{bb}$ = 4 mA | $V_{ON(CL)}$ | 41 | 47 | - | V |
| Overvoltage protection [1]<br>$I_{bb}$ = 4 mA | $V_{bb(AZ)}$ | 41 | - | - | |
| Thermal overload trip temperature | $T_{jt}$ | 150 | - | - | °C |
| Thermal hysteresis | $\Delta T_{jt}$ | - | 10 | - | K |

### Reverse Battery

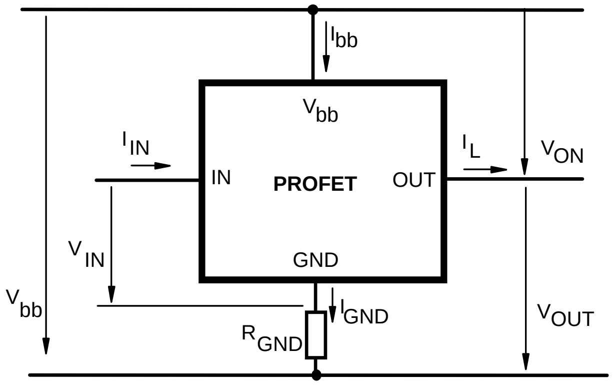
| Parameter | Symbol | min. | typ. | max. | Unit |
|---|---|---|---|---|---|
| Reverse battery[2] | $-V_{bb}$ | - | - | 32 | V |
| Drain-source diode voltage ($V_{OUT} > V_{bb}$) | $-V_{ON}$ | - | 600 | - | mV |

[1] see also $V_{ON(CL)}$ in circuit diagram on page 7

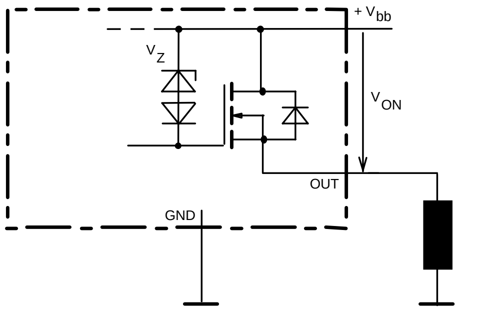
[2] Requires a 150 Ω resistor in GND connection. The reverse load current through the intrinsic drain-source diode has to be limited by the connected load. Power dissipation is higher compared to normal operating conditions due to the voltage drop across the drain-source diode. The temperature protection is not active during reverse current operation! Input current has to be limited (see max. ratings page 3).

| Parameter and Conditions<br>at $T_j$ = -40...+150°C, $V_{bb}$=13.5V, unless otherwise specified | Symbol | Values | | | Unit |
|---|---|---|---|---|---|
| | | min. | typ. | max. | |
| **Input** | | | | | |
| Input turn-on threshold voltage<br>(see page 12) | $V_{IN(T+)}$ | - | - | 2.2 | V |
| Input turn-off threshold voltage<br>(see page 12) | $V_{IN(T-)}$ | 0.8 | - | - | |
| Input threshold hysteresis | $\Delta V_{IN(T)}$ | - | 0.3 | - | V |
| Off state input current (see page 12)<br>$V_{IN}$ = 0.7 V | $I_{IN(off)}$ | 1 | - | 25 | µA |
| On state input current (see page 12)<br>$V_{IN}$ = 5 V | $I_{IN(on)}$ | 3 | - | 25 | |
| Input resistance (see page 7) | $R_I$ | 1.5 | 3.5 | 5 | kΩ |

## Terms

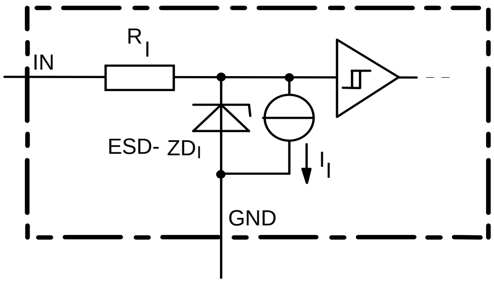



## Inductive and overvoltage output clamp



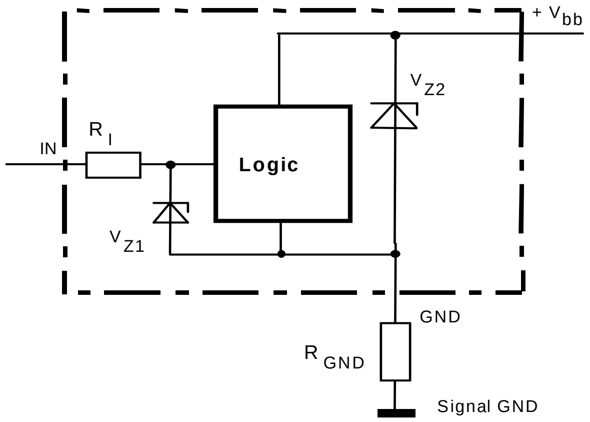

$V_{ON}$ clamped to 47 V typ.

## Input circuit (ESD protection)



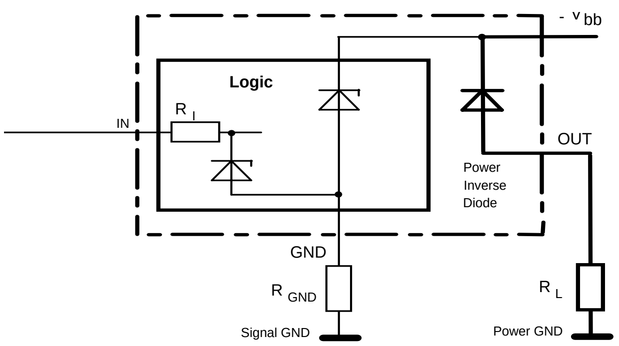

The use of ESD zener diodes as voltage clamp at DC conditions is not recommended

## Overvoltage protection of logic part



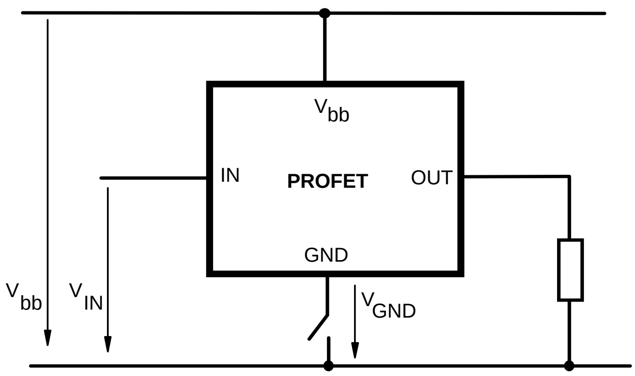

$V_{Z1}$=6.1V typ., $V_{Z2}$=$V_{bb(AZ)}$=47V typ.,
$R_I$=3.5 kΩ typ., $R_{GND}$=150Ω

## Reverse battery protection

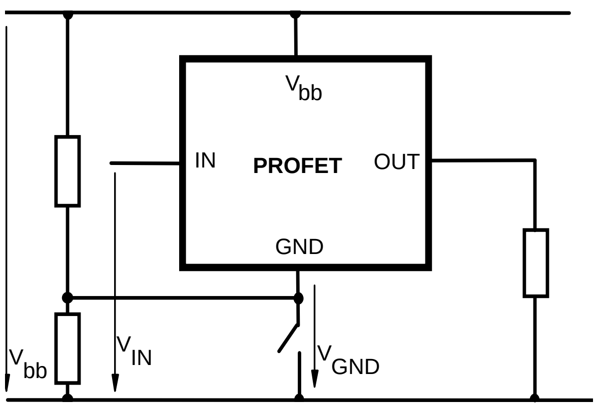



$R_{GND}$=150Ω, $R_I$=3.5kΩ typ.,
Temperature protection is not active during inverse current

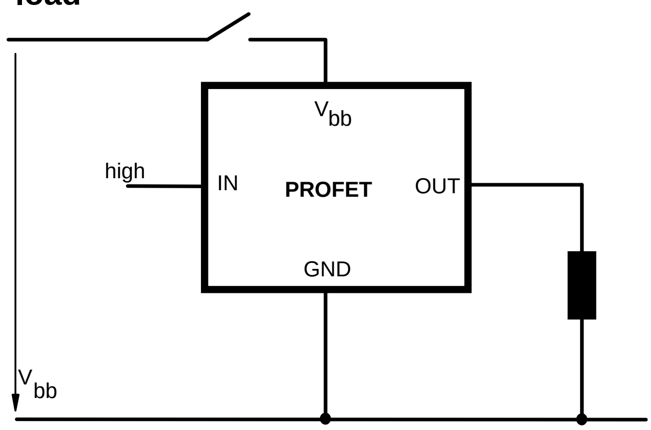
## GND disconnect



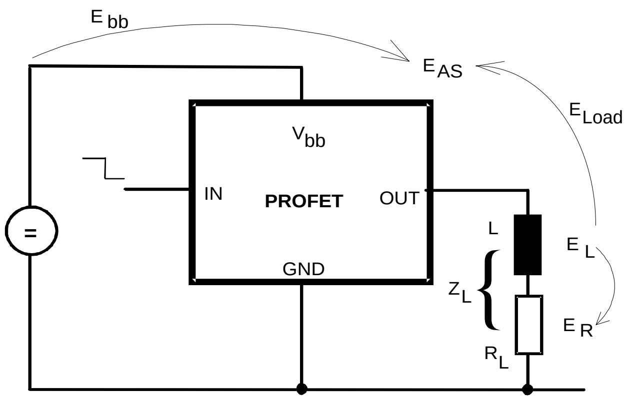

## GND disconnect with GND pull up




## $V_{bb}$ disconnect with charged inductive load




## Inductive Load switch-off energy dissipation



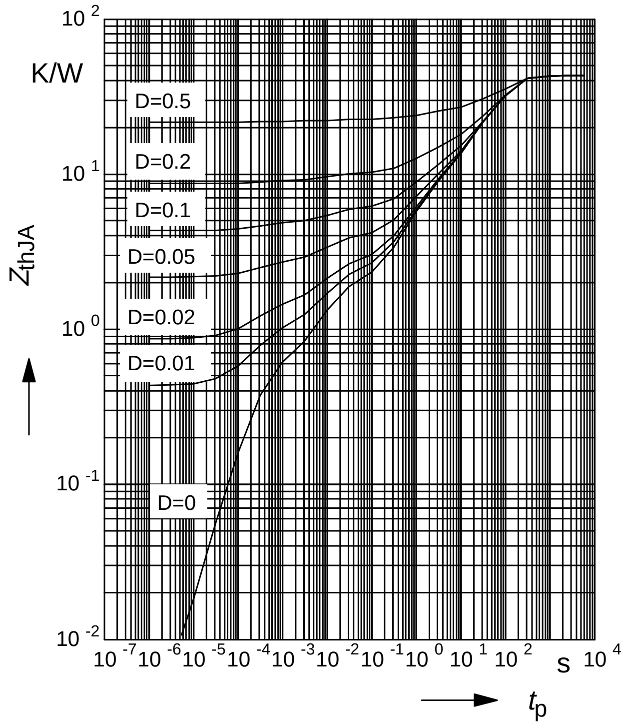

Energy stored in load inductance: $E_L = ½ * L * I_L^2$
While demagnetizing load inductance,
the enérgy dissipated in PROFET is
$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} * i_L(t)\,dt$,
with an approximate solution for $R_L > 0\Omega$:

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

**Typ. transient thermal impedance**

**$Z_{thJA}$=f($t_p$) @ 6cm² heatsink area**

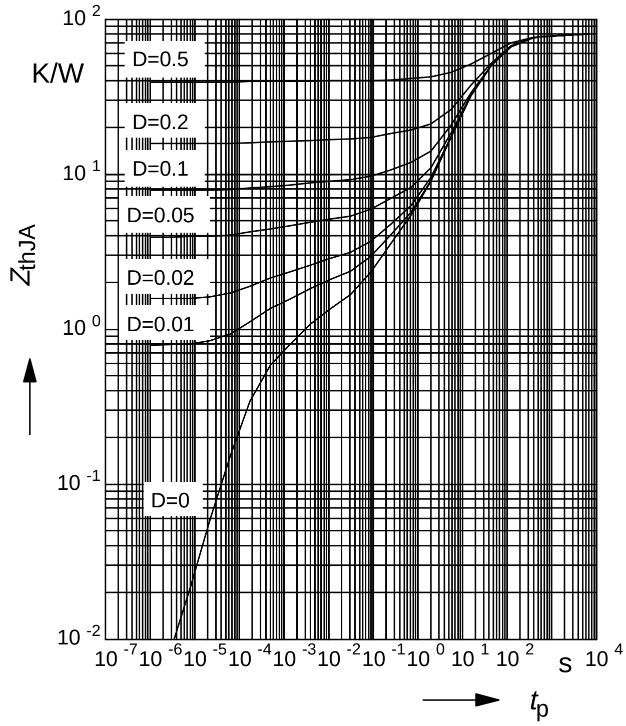
Parameter: $D=t_p/T$




**Typ. transient thermal impedance**

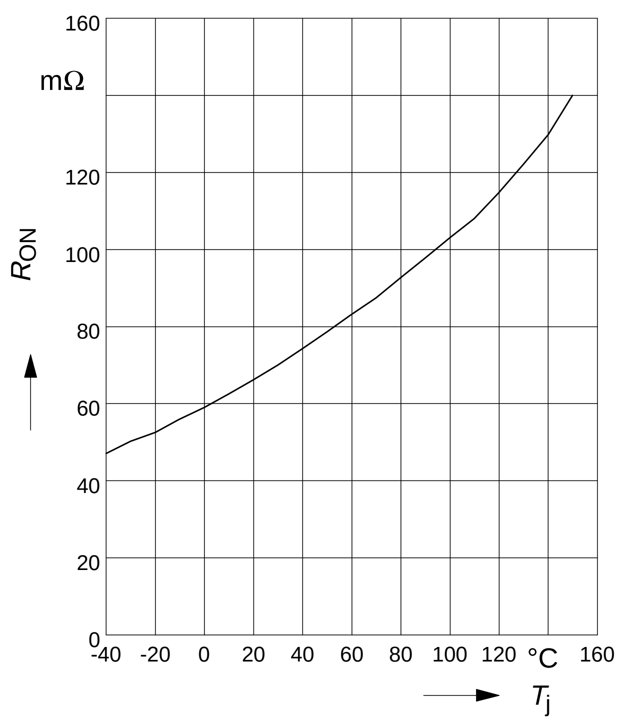
**$Z_{thJA}$=f($t_p$) @ min. footprint**

Parameter: $D=t_p/T$



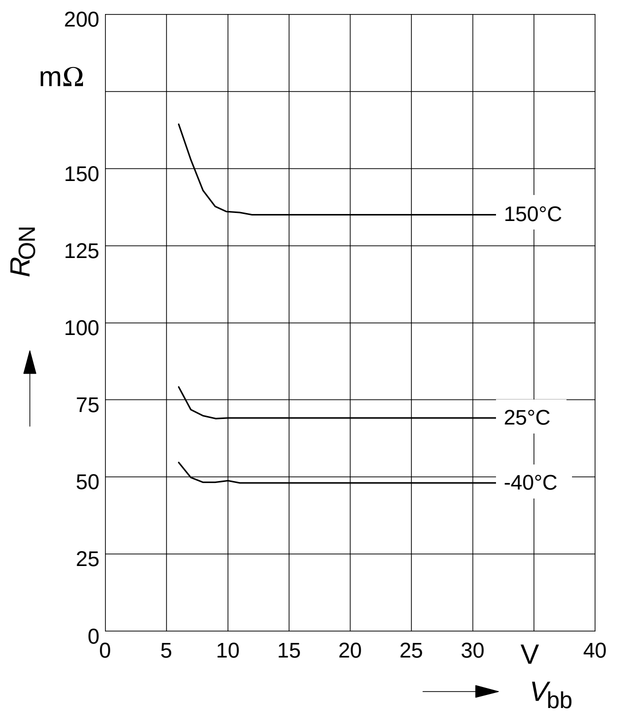

**Typ. on-state resistance**

**$R_{ON}$ = f($T_j$)** ; $V_{bb}$ = 13,5V ; $V_{in}$ = high



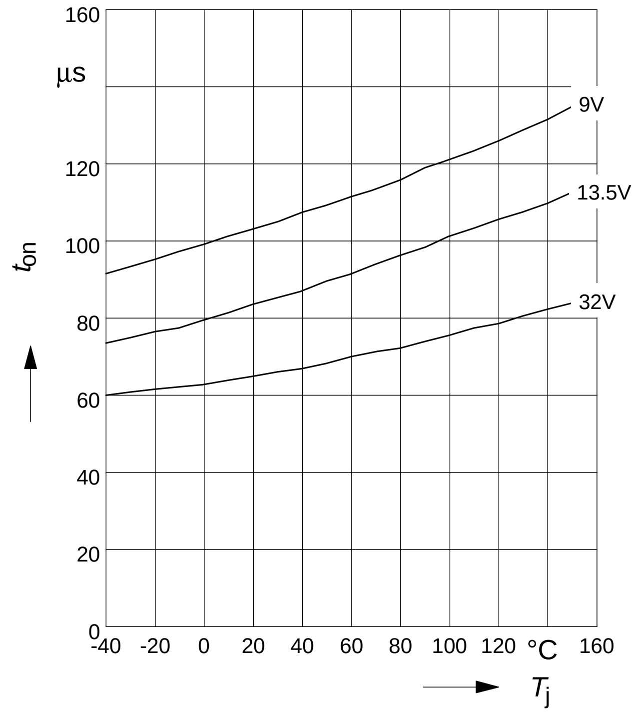

**Typ. on-state resistance**

**$R_{ON}$ = f($V_{bb}$)**; $I_L$ = 0.5A ; $V_{in}$ = high



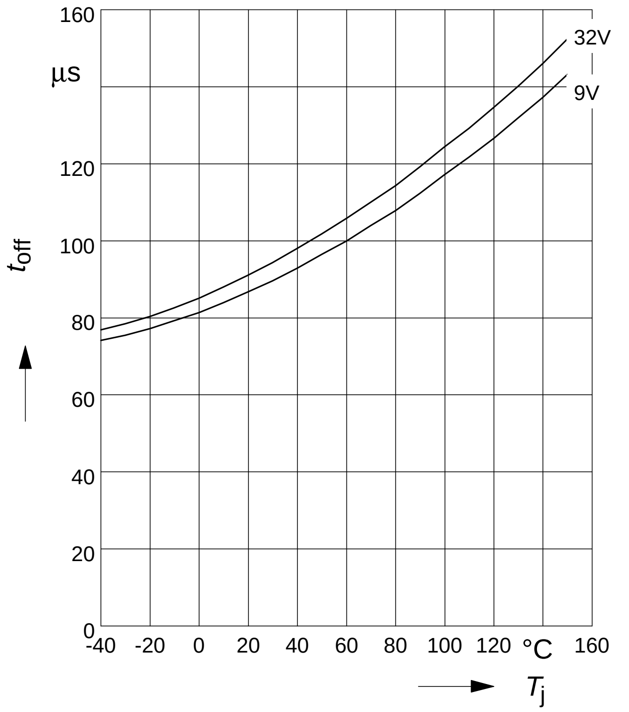
**Typ. turn on time**

$t_{on} = f(T_j)$; $R_L = 47\Omega$



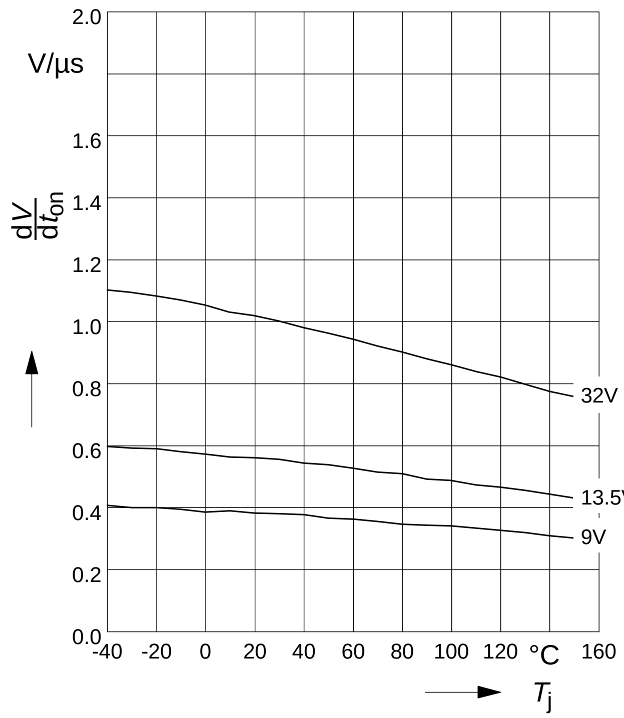

**Typ. turn off time**

$t_{off} = f(T_j)$; $R_L = 47\Omega$



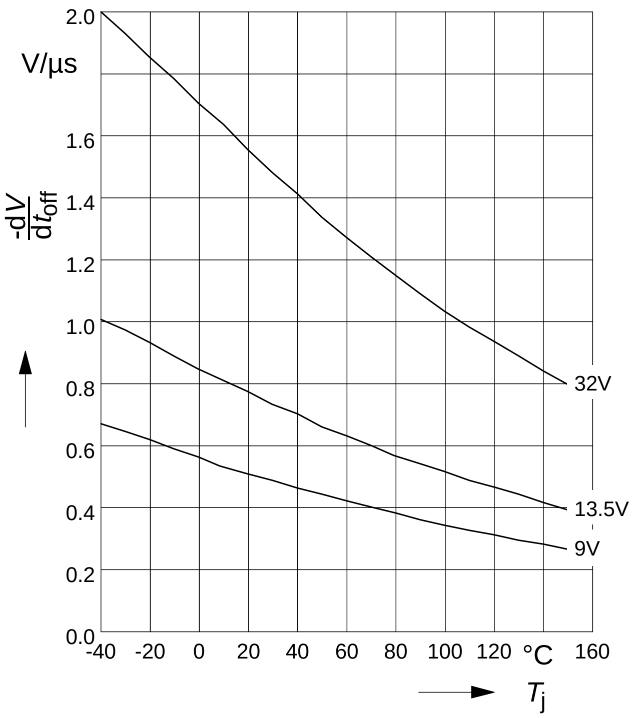

**Typ. slew rate on**

$dV/dt_{on} = f(T_j)$ ; $R_L = 47\ \Omega$



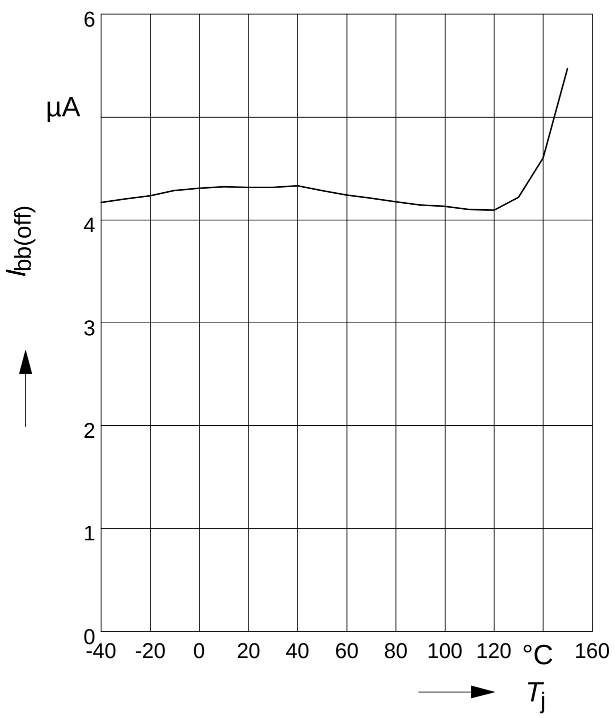

**Typ. slew rate off**

$dV/dt_{off} = f(T_j)$; $R_L = 47\ \Omega$



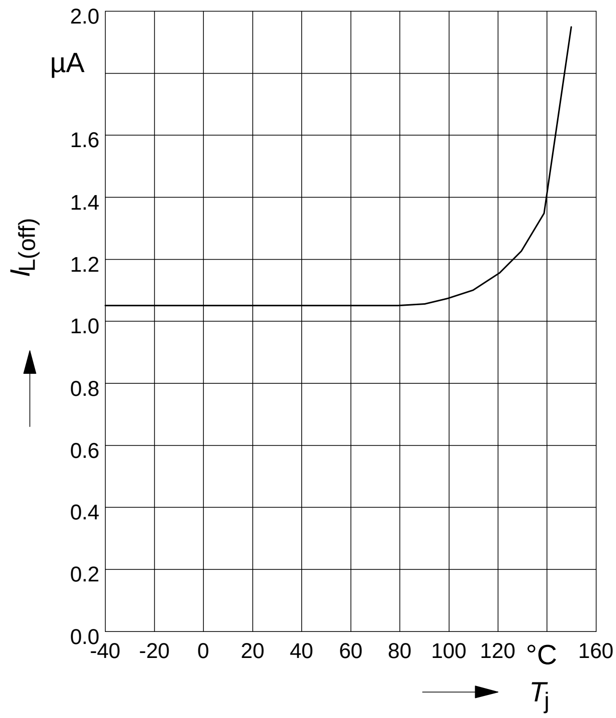
**Typ. standby current**

$I_{bb(off)} = f(T_j)$ ; $V_{bb}$ = 32V ; $V_{IN}$ = low



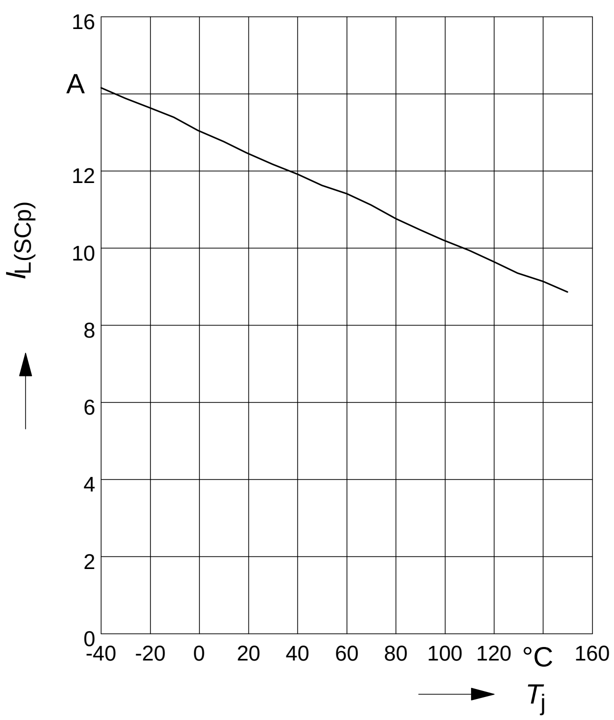

**Typ. leakage current**

$I_{L(off)} = f(T_j)$ ; $V_{bb}$ = 32V ; $V_{IN}$ = low



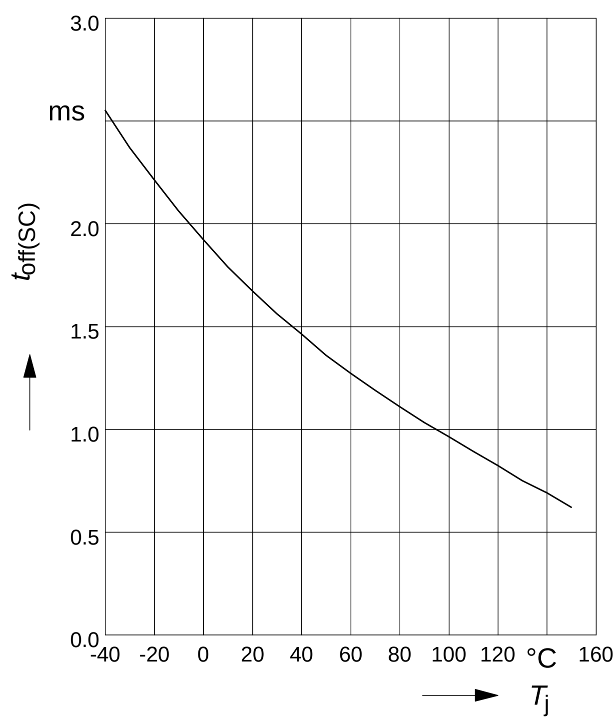

**Typ. initial peak short circuit current limit**

$I_{L(SCp)} = f(T_j)$ ; $V_{bb}$ = 20V



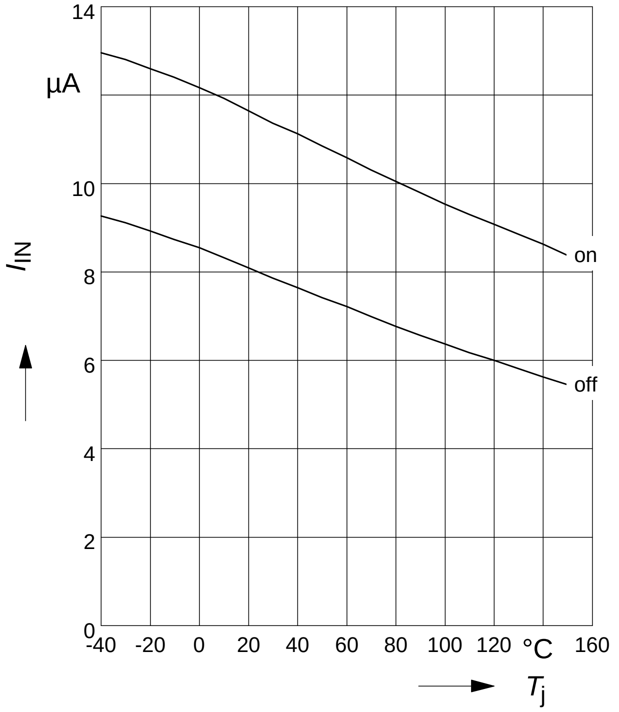

**Typ. initial short circuit shutdown time**

$t_{off(SC)} = f(T_{j,start})$ ; $V_{bb}$ = 20V



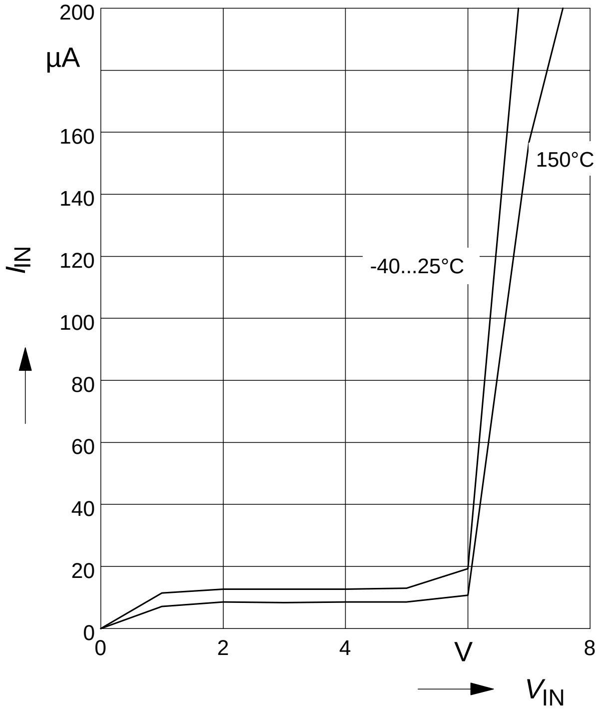
## Typ. input current

$I_{IN(on/off)} = f(T_j)$; $V_{bb}$ = 13,5V; $V_{IN}$ = low/high
$V_{INlow} \leq$ 0,7V; $V_{INhigh}$ = 5V



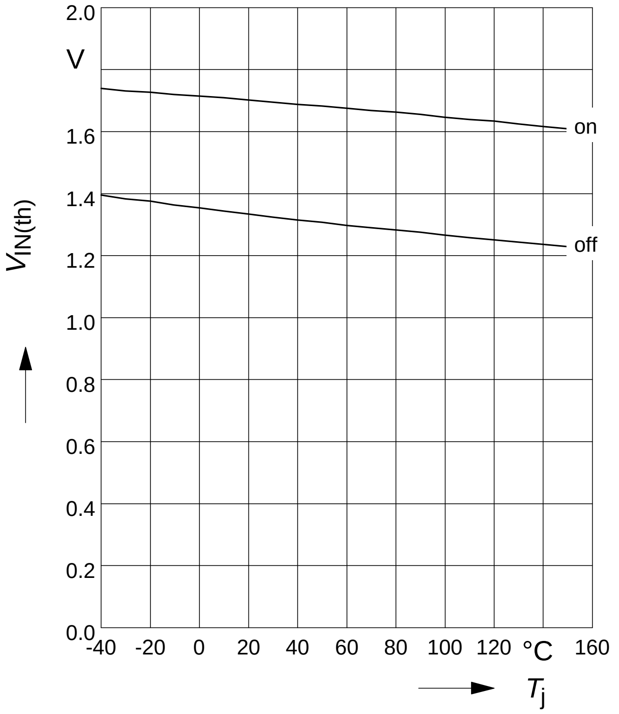

## Typ. input current

$I_{IN} = f(V_{IN})$; $V_{bb}$ = 13.5V



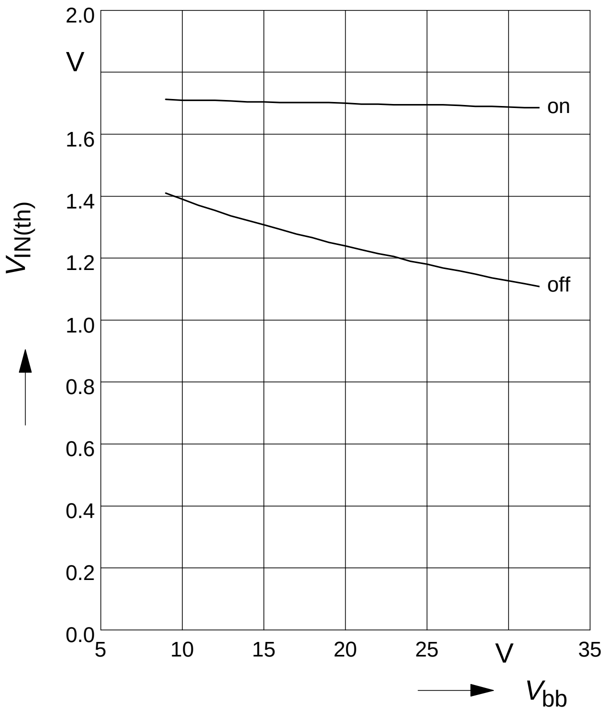

## Typ. input threshold voltage

$V_{IN(th)} = f(T_j)$ ; $V_{bb}$ = 13,5V



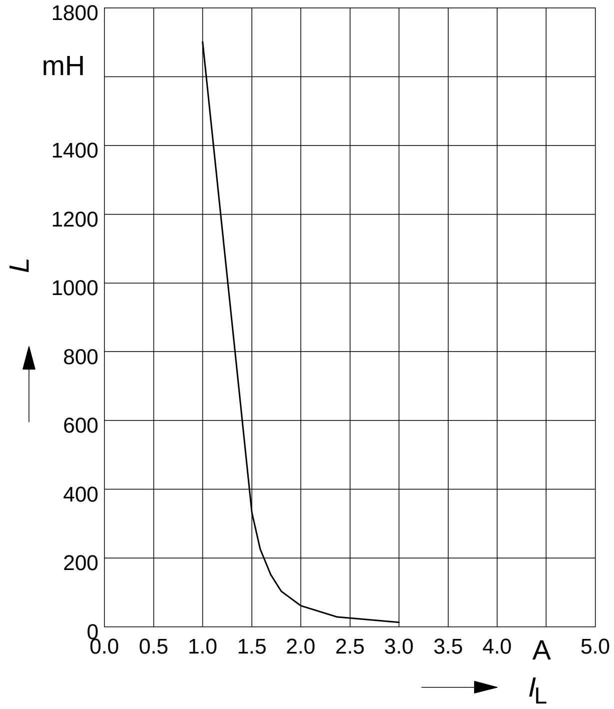

## Typ. input threshold voltage

$V_{IN(th)} = f(V_{bb})$ ; $T_j$ = 25°C



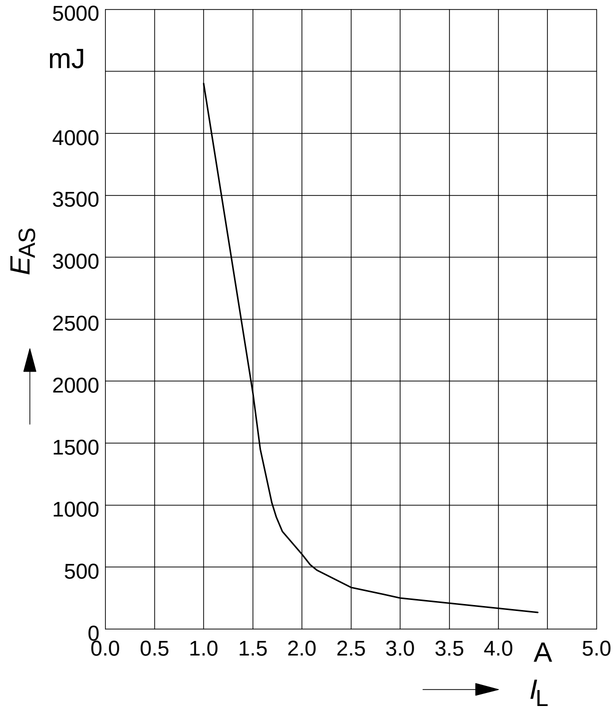
**Maximum allowable load inductance for a single switch off**

$L = f(I_L)$; $T_{jstart}$=150°C, $V_{bb}$=13.5V, $R_L$=0Ω




**Maximum allowable inductive switch-off energy, single pulse**

$E_{AS} = f(I_L)$; $T_{jstart}$ = 150°C, $V_{bb}$ = 13,5V



## Timing diagrams

**Figure 1a:** Vbb turn on:

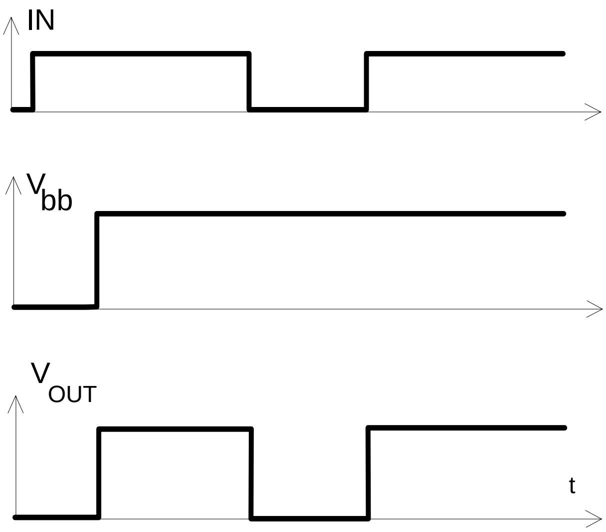



**Figure 2a:** Switching a resistive load,
turn-on/off time and slew rate definition

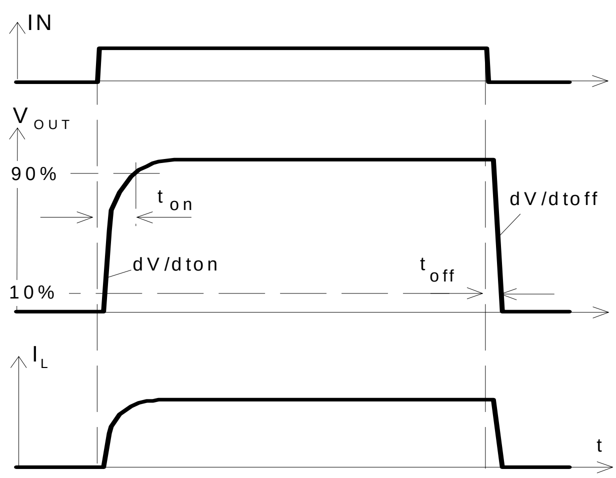



**Figure 2b:** Switching a lamp,

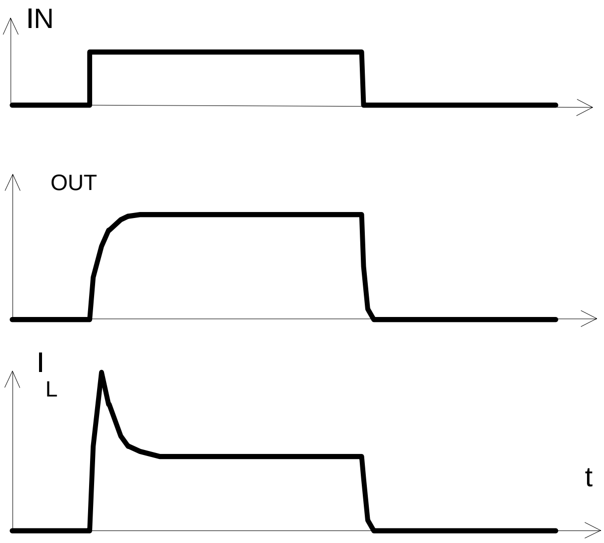



**Figure 2c:** Switching an inductive load

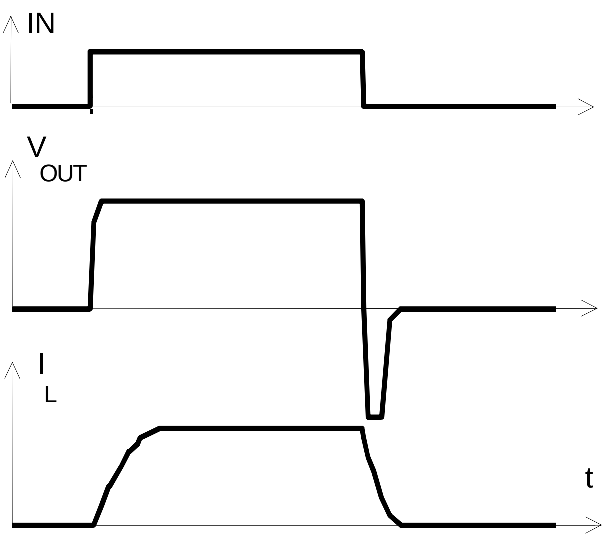
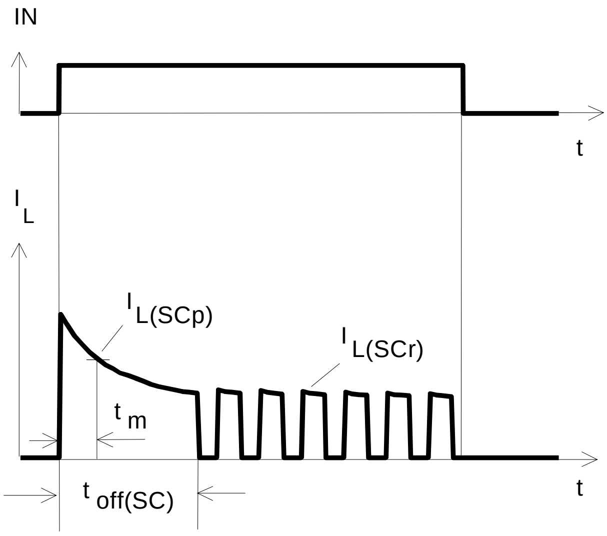


**Figure 3a:** Turn on into short circuit,
shut down by overtemperature, restart by cooling




Heating up of the chip may require several milliseconds, depending on external conditions.

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

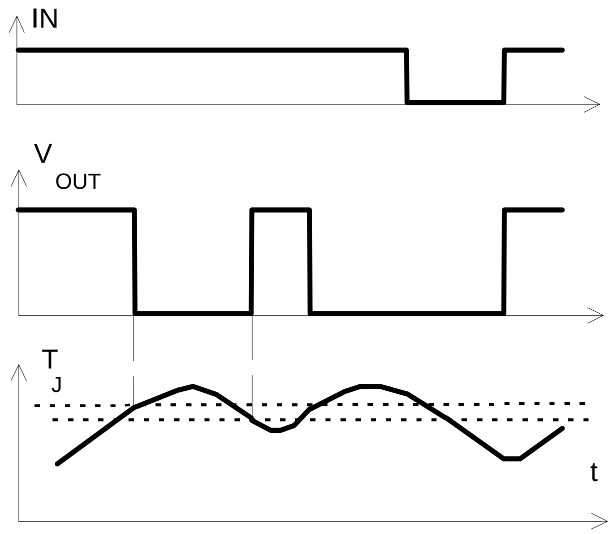
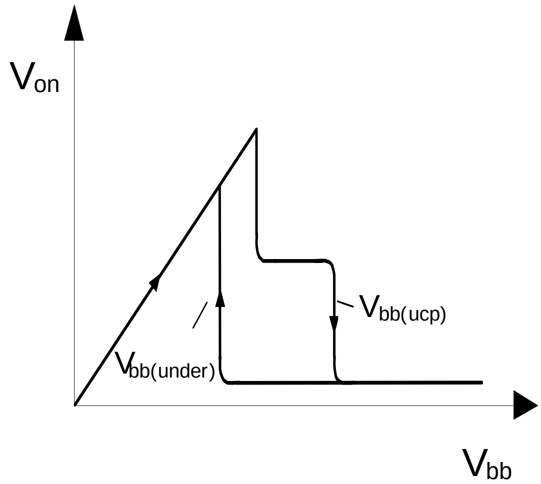



**Figure 5:** Undervoltage restart of charge pump

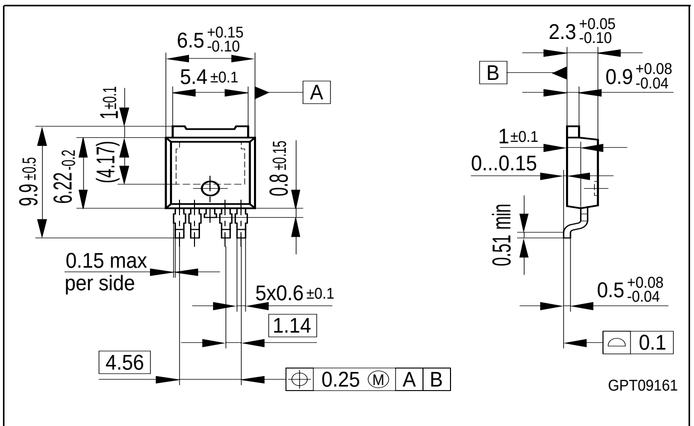


# Package and ordering code

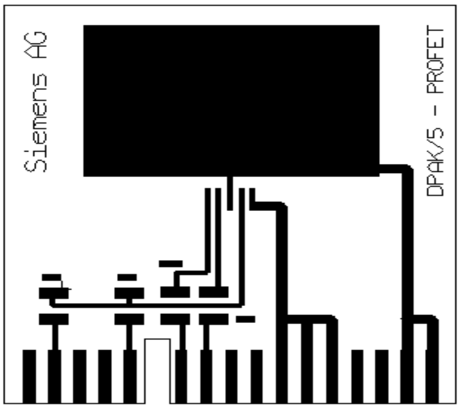
all dimensions in mm

Ordering code:

| | |
|---|---|
| | Q67060-S7402 |




All metal surfaces tin plated, except area of cut.




Printed circuit board (FR4, 1.5mm thick, one layer 70µm, 6cm$^2$ active heatsink area ) as a reference for max. power dissipation $P_{tot}$ nominal load current $I_{L(nom)}$ and thermal resistance $R_{thja}$

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**81541 München**


**Attention please!**

As far as patents or other rights of third parties are concerned, liability is only assumed for components, not for applications, processes and circuits implemented within components or assemblies.
The information describes a type of component and shall not be considered as warranted characteristics.
Terms of delivery and rights to change design reserved.
For questions on technology, delivery and prices please contact the Semiconductor Group Offices in Germany or the Siemens Companies and Representatives worldwide (see address list).
Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Siemens Office, Semiconductor Group.
Siemens AG is an approved CECC manufacturer.

**Packing**

Please use the recycling operators known to you. We can also help you - get in touch with your nearest sales office. By agreement we will take packing material back, if it is sorted. You must bear the costs of transport. For packing material that is returned to us unsorted or which we are not obliged to accept, we shall have to invoice you for any costs incurred.

**Components used in life-support devices or systems must be expressly authorized for such purpose!**

Critical components[1] of the Semiconductor Group of Siemens AG, may only be used in life-support devices or systems[2] with the express written approval of the Semiconductor Group of Siemens AG.

1)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.

2)Life support devices or systems are intended (a) to be implanted in the human body, or (b) to support and/or maintain and sustain and/or protecf human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.