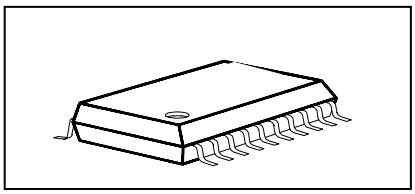
# Smart High-Side Power Switch
# Four Channels: 4 x 90mΩ
# Status Feedback

RoHS AEC Qualified

## Product Summary

| | | | |
|---|---|---|---|
| Operating Voltage | $V_{bb}$ | 5.5...40V | |
| | Active channels | one | four parallel |
| On-state Resistance | $R_{ON}$ | 90mΩ | 22.5mΩ |
| Nominal load current | $I_{L(NOM)}$ | 3.3A | 7.3A |
| Current limitation | $I_{L(SCr)}$ | 12A | 12A |

## Package



PG-DSO20

## General Description

- N channel vertical power MOSFET with charge pump, ground referenced CMOS compatible input and diagnostic feedback, monolithically integrated in Smart SIPMOS® technology.
- Providing embedded protective functions

## Applications

- µC compatible high-side power switch with diagnostic feedback for 12V and 24V grounded loads
- All types of resistive, inductive and capacitve loads
- Most suitable for loads with high inrush currents, so as lamps
- Replaces electromechanical relays, fuses and discrete circuits

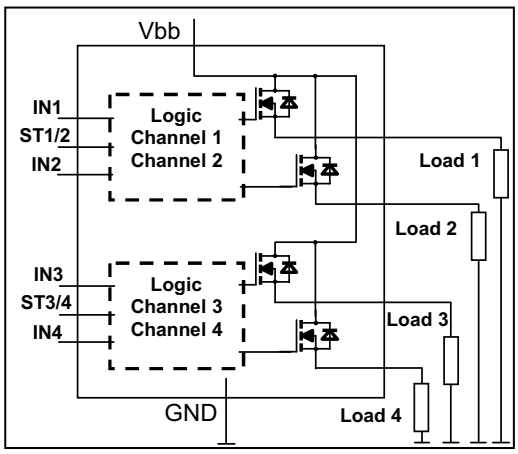
## Basic Functions

- Very low standby current
- CMOS compatible input
- Improved electromagnetic compatibility (EMC)
- Fast demagnetization of inductive loads
- Stable behaviour at undervoltage
- Wide operating voltage range
- Logic ground independent from load ground

## Protection Functions

- Short circuit protection
- Overload protection
- Current limitation
- Thermal shutdown
- Overvoltage protection (including load dump) with external resistor
- Reverse battery protection with external resistor
- Loss of ground and loss of $V_{bb}$ protection
- Electrostatic discharge protection (ESD)

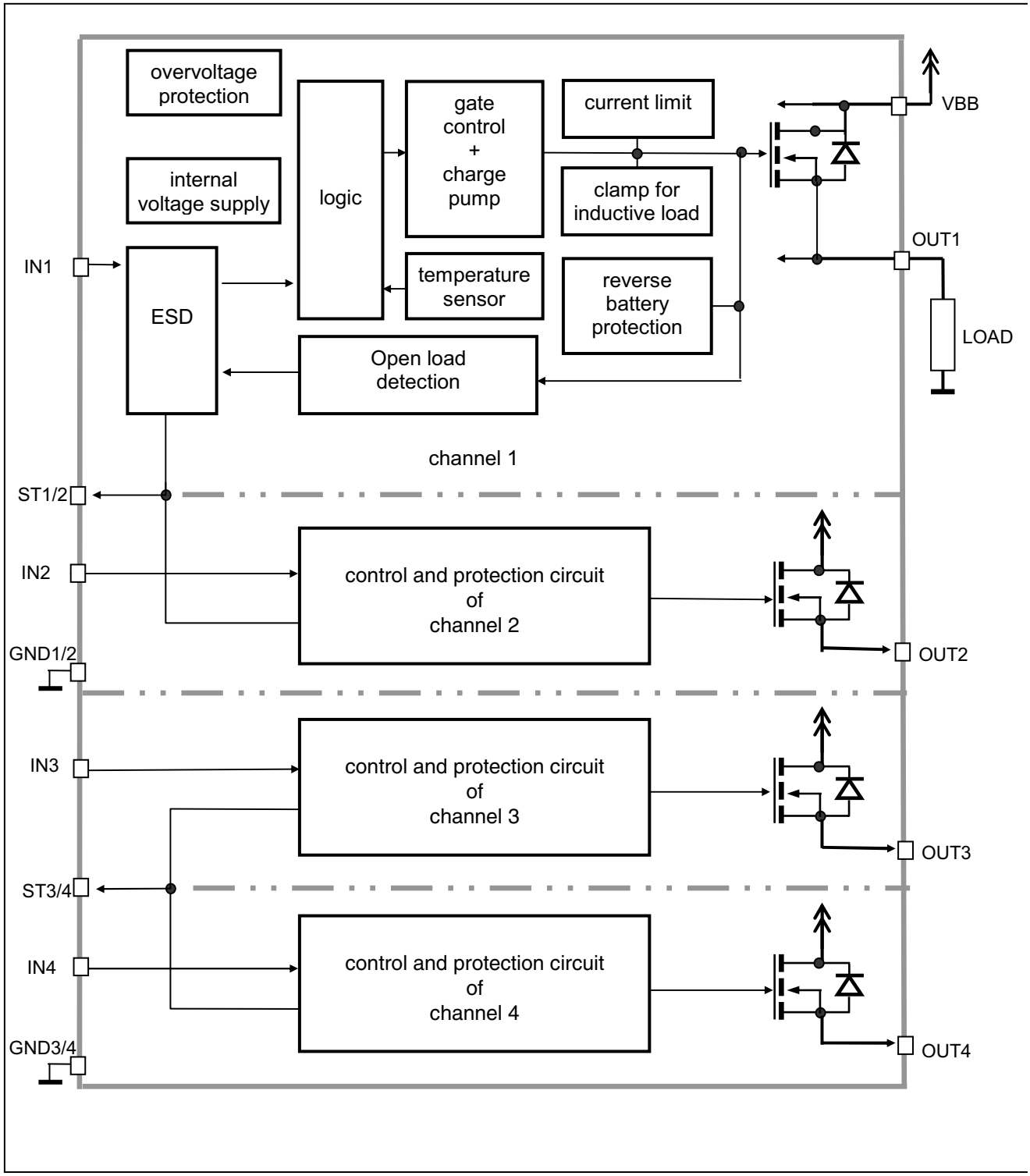
## Block Diagram




## Diagnostic Function

- Diagnostic feedback with open drain output
- Open load detection in OFF-state
- Feedback of thermal shutdown in ON-state

## Functional diagram

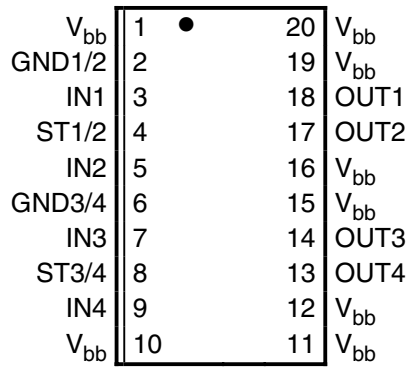


## Pin Definitions and Functions

| Pin | Symbol | Function |
|---|---|---|
| 1,10, 11,12, 15,16, 19,20 | $V_{bb}$ | **Positive power supply voltage**. Design the wiring for the simultaneous max. short circuit currents from channel 1 to 2 and also for low thermal resistance |
| 3 | IN1 | **Input 1,2,3,4** activates channel 1,2,3,4 in case of logic high signal |
| 5 | IN2 | |
| 7 | IN3 | |
| 9 | IN4 | |
| 18 | OUT1 | **Output 1,2,3,4** protected high-side power output of channel 1,2,3,4. Design the wiring for the max. short circuit current |
| 17 | OUT2 | |
| 14 | OUT3 | |
| 13 | OUT4 | |
| 4 | ST1/2 | **Diagnostic feedback 1/2,3/4** of channel 1,2,3,4 open drain, low on failure |
| 8 | ST3/4 | |
| 2 | GND1/2 | **Ground** of chip 1 (channel 1,2) |
| 6 | GND3/4 | **Ground** of chip 2 (channel 3,4) |

## Pin configuration

(top view)



| Parameter | Symbol | Values | Unit |
|---|---|---|---|
| Supply voltage (overvoltage protection see page 6) | $V_{bb}$ | 43 | V |
| Supply voltage for full short circuit protection<br>$T_{j,start}$ = -40 ...+150°C | $V_{bb}$ | 36 | V |
| Load current (Short-circuit current, see page 6) | $I_L$ | self-limited | A |
| Load dump protection[1] $V_{LoadDump} = V_A + V_s$, $V_A$ = 13.5 V<br>$R_I$[2] = 2 Ω, $t_d$ = 400 ms; IN = low or high,<br>each channel loaded with $R_L$ = 13.5 Ω, | $V_{Load\,dump}$[3] | 60 | V |
| Operating temperature range<br>Storage temperature range | $T_j$<br>$T_{stg}$ | -40 ...+150<br>-55 ...+150 | °C |
| Power dissipation (DC)[4] $T_a$ = 25°C:<br>(all channels active) $T_a$ = 85°C: | $P_{tot}$ | 3.6<br>1.9 | W |
| Maximal switchable inductance, single pulse<br>$V_{bb}$ = 12V, $T_{j,start}$ = 150°C[4], see diagrams on page 10<br>$I_L$ = 3.3 A, $E_{AS}$ = 120 mJ, 0 Ω one channel:<br>$I_L$ = 4.7 A, $E_{AS}$ = 140 mJ, 0 Ω two parallel channels:<br>$I_L$ = 7.3 A, $E_{AS}$ = 160 mJ, 0 Ω four parallel channels: | $Z_L$ | <br><br>16,5<br>19<br>18 | <br><br>mH |
| Electrostatic discharge capability (ESD) IN:<br>(Human Body Model) ST:<br>out to all other pins shorted:<br>acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993<br>R=1.5kΩ; C=100pF | $V_{ESD}$ | 1.0<br>4.0<br>8.0 | kV |
| Input voltage (DC) see internal circuit diagram page 9 | $V_{IN}$ | -10 ... +16 | V |
| Current through input pin (DC) | $I_{IN}$ | ±0.3 | mA |
| Pulsed current through input pin[5] | $I_{INp}$ | ±5.0 | |
| Current through status pin (DC) | $I_{ST}$ | ±5.0 | |

1) Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins (a 150Ω resistor for the GND connection is recommended.

2) $R_I$ = internal resistance of the load dump test pulse generator

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. See page 14

5) only for testing

| Parameter and Conditions | Symbol | Values | | | Unit |
|---|---|---|---|---|---|
| | | min | typ | max | |
| Thermal resistance | | | | | |
| junction - soldering point[6)7)] each channel: | $R_{thjs}$ | -- | -- | 15 | K/W |
| junction – ambient[6)] | $R_{thja}$ | | | | |
| @ 6 cm² cooling area one channel active: | | -- | 42 | -- | |
| all channels active: | | -- | 34 | -- | |

## Electrical Characteristics

| **Parameter and Conditions,** each of the four channels at $T_j$ = -40...+150°C, $V_{bb}$ = 12 V unless otherwise specified | Symbol | Values | | | Unit |
|---|---|---|---|---|---|
| | | min | typ | max | |
| **Load Switching Capabilities and Characteristics** | | | | | |
| On-state resistance ($V_{bb}$ to OUT); $I_L$ = 2 A | | | | | |
| each channel, $T_j$ = 25°C: | $R_{ON}$ | -- | 70 | 90 | mΩ |
| $T_j$ = 150°C: | | -- | 140 | 180 | |
| two parallel channels, $T_j$ = 25°C: | | -- | 35 | 45 | |
| four parallel channels, $T_j$ = 25°C: | | -- | 17.5 | 22.5 | |
| see diagram, page 11 | | | | | |
| Nominal load current one channel active: | $I_{L(NOM)}$ | 3.0 | 3.3 | -- | A |
| two parallel channels active: | | 4.3 | 4.7 | -- | |
| four parallel channels active: | | 6.5 | 7.3 | -- | |
| Device on PCB[6)], $T_a$ = 85°C, $T_j \leq$ 150°C | | | | | |
| Output current while GND disconnected or pulled up[8)]; $V_{bb}$ = 32 V, $V_{IN}$ = 0, see diagram page 9 | $I_{L(GNDhigh)}$ | -- | -- | 2 | mA |
| Turn-on time[9)] IN ⌐ to 90% $V_{OUT}$: | $t_{on}$ | -- | 100 | 250 | µs |
| Turn-off time IN ¬ to 10% $V_{OUT}$: | $t_{off}$ | -- | 100 | 270 | |
| $R_L$ = 12 Ω | | | | | |
| Slew rate on[9)] 10 to 30% $V_{OUT}$, $R_L$ = 12 Ω: | $dV/dt_{on}$ | 0.2 | -- | 1.0 | V/µs |
| Slew rate off[9)] 70 to 40% $V_{OUT}$, $R_L$ = 12 Ω: | $-dV/dt_{off}$ | 0.2 | -- | 1.1 | V/µs |

6) 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. See page 14

7) Soldering point: upper side of solder edge of device pin 15. See page 14

8) not subject to production test, specified by design

9) See timing diagram on page 12.

| **Parameter and Conditions,** each of the four channels at $T_j$ = -40...+150°C, $V_{bb}$ = 12 V unless otherwise specified | **Symbol** | **Values** | | | **Unit** |
|---|---|---|---|---|---|
| | | min | typ | max | |
| **Operating Parameters** | | | | | |
| Operating voltage | $V_{bb(on)}$ | 5.5 | -- | 40 | V |
| Undervoltage switch off[10] $T_j$ =-40°C...25°C: | $V_{bb(u\ so)}$ | -- | -- | 4.5 | V |
| $T_j$ =125°C: | | -- | -- | 4.5[11] | |
| Overvoltage protection[12] $I_{bb}$ = 40 mA | $V_{bb(AZ)}$ | 41 | 47 | 52 | V |
| Standby current[13] $T_j$ =-40°C...25°C: | $I_{bb(off)}$ | -- | 9 | 20 | µA |
| $V_{IN}$ = 0; see diagram page 11 $T_j$ =150°C: | | -- | -- | 30 | |
| $T_j$ =125°C: | | -- | -- | 20[11] | |
| Off-State output current (included in $I_{bb(off)}$) $V_{IN}$ = 0; each channel | $I_{L(off)}$ | -- | 1 | 5 | µA |
| Operating current [14], $V_{IN}$ = 5V, $I_{GND}$ = $I_{GND1}$ + $I_{GND2}$, one channel on: | $I_{GND}$ | -- | 0.6 | 1.2 | mA |
| all channels on: | | -- | 2.4 | 4.8 | |
| **Protection Functions[15]** | | | | | |
| Current limit, $V_{out}$ = 0V, (see timing diagrams, page 12) $T_j$ =-40°C: | $I_{L(lim)}$ | -- | -- | 23 | A |
| $T_j$ =25°C: | | -- | 15 | -- | |
| $T_j$ =+150°C: | | 9 | -- | -- | |
| Repetitive short circuit current limit, $T_j$ = $T_{jt}$ each channel | $I_{L(SCr)}$ | -- | 12 | -- | A |
| two,three or four parallel channels | | -- | 12 | -- | |
| (see timing diagrams, page 12) | | | | | |
| Initial short circuit shutdown time $T_{j,start}$ =25°C: $V_{out}$ = 0V (see timing diagrams on page 12) | $t_{off(SC)}$ | -- | 2 | -- | ms |
| Output clamp (inductive load switch off)[16] at $V_{ON(CL)}$ = $V_{bb}$ - $V_{OUT}$, $I_L$= 40 mA | $V_{ON(CL)}$ | 41 | 47 | 52 | V |
| Thermal overload trip temperature | $T_{jt}$ | 150 | -- | -- | °C |
| Thermal hysteresis | $\Delta T_{jt}$ | -- | 10 | -- | K |

10) is the voltage, where the device doesn´t change it´s switching condition for 15ms after the supply voltage falling below the lower limit of Vbb(on)

11) not subject to production test, specified by design

12) Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins (a 150Ω resistor for the GND connection is recommended). See also $V_{ON(CL)}$ in table of protection functions and circuit diagram on page 9.

13) Measured with load; for the whole device; all channels off

14) Add $I_{ST}$, if $I_{ST}$ > 0

15) Integrated protection functions are designed to prevent IC destruction under fault conditions described in the data sheet. Fault conditions are considered as "outside" normal operating range. Protection functions are not designed for continuous repetitive operation.

16) If channels are connected in parallel, output clamp is usually accomplished by the channel with the lowest $V_{ON(CL)}$

| **Parameter and Conditions,** each of the four channels at $T_j$ = -40...+150°C, $V_{bb}$ = 12 V unless otherwise specified | **Symbol** | **Values** | | | **Unit** |
|---|---|---|---|---|---|
| | | min | typ | max | |
| **Reverse Battery** | | | | | |
| Reverse battery voltage [17] | $-V_{bb}$ | -- | -- | 32 | V |
| Drain-source diode voltage ($V_{out} > V_{bb}$) $I_L$ = -2.0 A, $T_j$ = +150°C | $-V_{ON}$ | -- | 600 | -- | mV |
| **Diagnostic Characteristics** | | | | | |
| Open load detection voltage | $V_{OUT(OL)}$ | 1.7 | 2.8 | 4.0 | V |
| **Input and Status Feedback [18]** | | | | | |
| Input resistance (see circuit page 9) | $R_I$ | 2.5 | 4.0 | 6.0 | kΩ |
| Input turn-on threshold voltage | $V_{IN(T+)}$ | -- | -- | 2.5 | V |
| Input turn-off threshold voltage | $V_{IN(T-)}$ | 1.0 | -- | -- | V |
| Input threshold hysteresis | $\Delta V_{IN(T)}$ | -- | 0.2 | -- | V |
| Status change after positive input slope [19] with open load | $t_{d(STon)}$ | -- | 10 | 20 | µs |
| Status change after positive input slope [19] with overload | $t_{d(STon)}$ | 30 | -- | -- | µs |
| Status change after negative input slope with open load | $t_{d(SToff)}$ | -- | -- | 500 | µs |
| Status change after negative input slope [19] with overtemperature | $t_{d(SToff)}$ | -- | -- | 20 | µs |
| Off state input current $V_{IN}$ = 0.4 V: | $I_{IN(off)}$ | 5 | -- | 20 | µA |
| On state input current $V_{IN}$ = 5 V: | $I_{IN(on)}$ | 10 | 35 | 60 | µA |
| Status output (open drain) | | | | | |
| Zener limit voltage $I_{ST}$ = +1.6 mA: | $V_{ST(high)}$ | 5.4 | -- | -- | V |
| ST low voltage $I_{ST}$ = +1.6 mA: | $V_{ST(low)}$ | -- | -- | 0.6 | |

17) 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 and Status currents have to be limited (see max. ratings page 4 and circuit page 9).

18) If ground resistors $R_{GND}$ are used, add the voltage drop across these resistors.

19) not subject to production test, specified by design

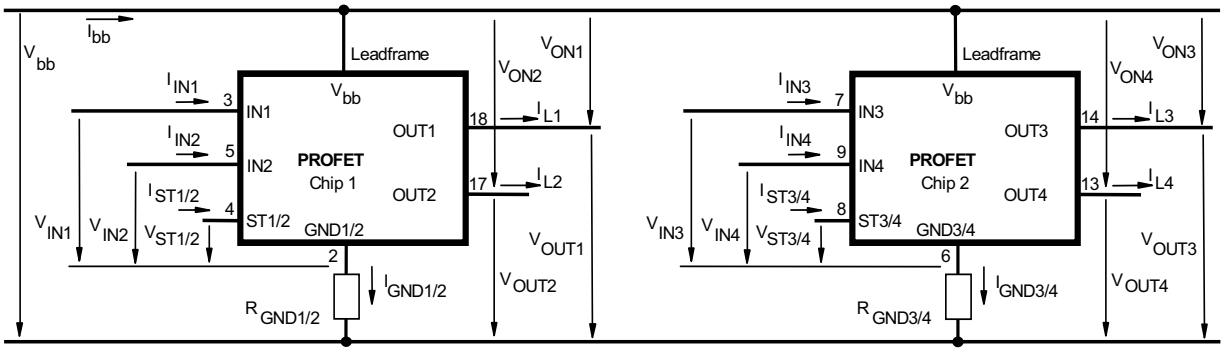
## Truth Table

| Channel 1 and 2<br>Channel 3 and 4<br>(equivalent to channel 1 and 2) | Chip 1<br>Chip 2 | IN1<br>IN3 | IN2<br>IN4 | OUT1<br>OUT3 | OUT2<br>OUT4 | ST1/2<br>ST3/4 |
|---|---|---|---|---|---|---|
| **Normal operation** | | L<br>L<br>H<br>H | L<br>H<br>L<br>H | L<br>L<br>H<br>H | L<br>H<br>L<br>H | H<br>H<br>H<br>H |
| **Open load** | Channel 1 (3) | L<br>H | X<br>X | Z<br>H | X<br>X | L[20)]<br>H |
| | Channel 2 (4) | X<br>X | L<br>H | X<br>X | Z<br>H | L[15)]<br>H |
| **Overtemperature** | both channel | L<br>X<br>H | L<br>H<br>X | L<br>L<br>L | L<br>L<br>L | H<br>L<br>L |
| | Channel 1 (3) | L<br>H | X<br>X | L<br>L | X<br>X | H<br>L |
| | Channel 2 (4) | X<br>X | L<br>H | X<br>X | L<br>L | H<br>L |

L = "Low" Level X = don't care Z = high impedance, potential depends on external circuit
H = "High" Level Status signal valid after the time delay shown in the timing diagrams

Parallel switching of channel 1 and 2 (also channel 3 and 4) is easily possible by connecting the inputs and outputs in parallel (see truth table). If switching channel 1 to 4 in parallel, the status outputs ST1/2 and ST3/4 have to be configured as a 'Wired OR' function with a single pull-up resistor.

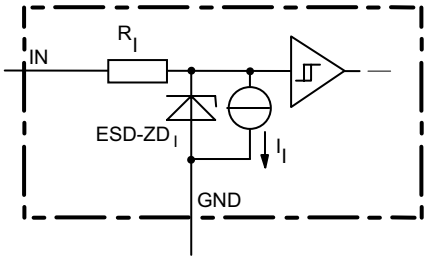
## Terms




Leadframe ($V_{bb}$) is connected to pin 1,10,11,12,15,16,19,20
External $R_{GND}$ optional; two resistors $R_{GND1}$, $R_{GND2}$ = 150 Ω or a single resistor $R_{GND}$ = 75 Ω for reverse battery protection up to the max. operating voltage.

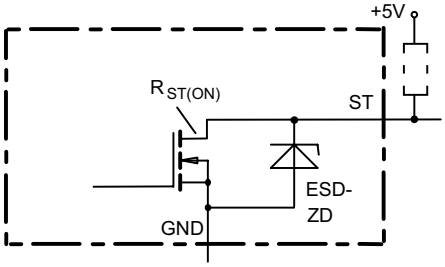
20) L, if potential at the Output exceeds the OpenLoad detection voltage

## Input circuit (ESD protection), IN1 to IN4



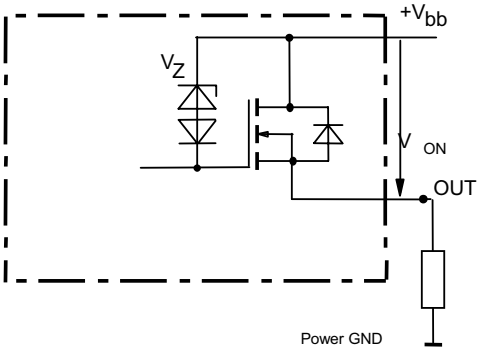

The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

## Status output, ST1/2 or ST3/4



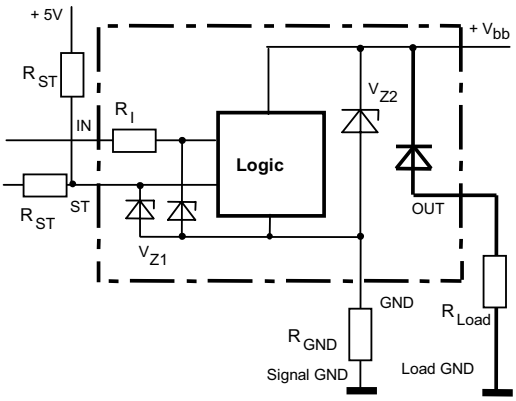

ESD-Zener diode: 6.1 V typ., max 0.3 mA; $R_{ST(ON)}$ < 375 Ω at 1.6 mA. The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

## Inductive and overvoltage output clamp, OUT1...4




$V_{ON}$ clamped to $V_{ON(CL)}$ = 47 V typ.

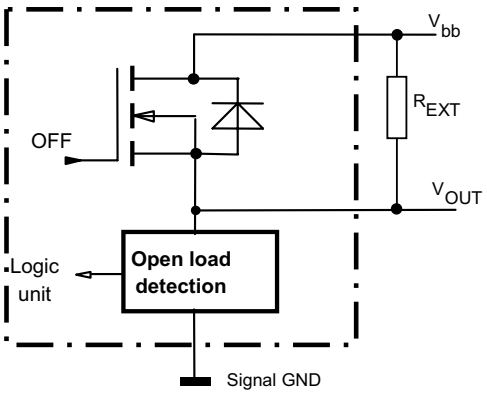
## Overvolt. and reverse batt. protection



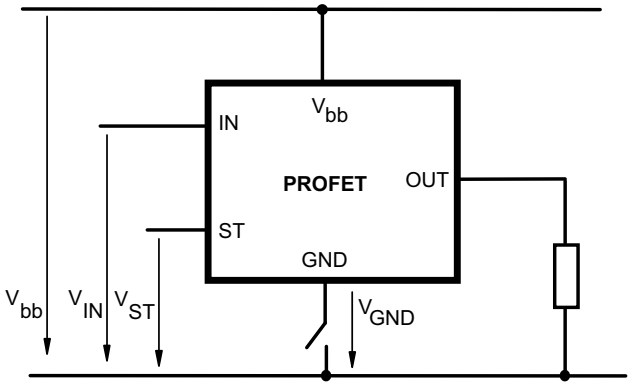

$V_{Z1}$ = 6.1 V typ., $V_{Z2}$ = 47 V typ., $R_{GND}$ = 150 Ω, $R_{ST}$= 15 kΩ, $R_I$= 3.5 kΩ typ.
In case of reverse battery the load current has to be limited by the load. Temperature protection is not active

## Open-load detection, OUT1...4

OFF-state diagnostic condition:
Open Load, if $V_{OUT}$ > 3 V typ.; IN low

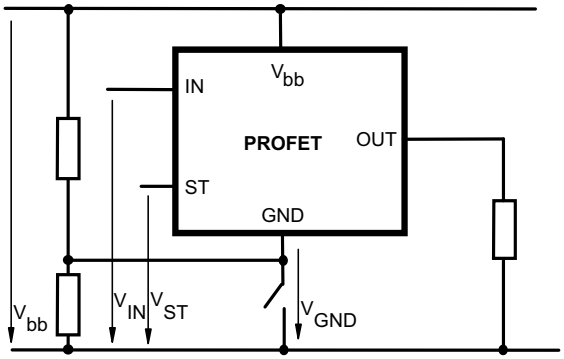



## GND disconnect



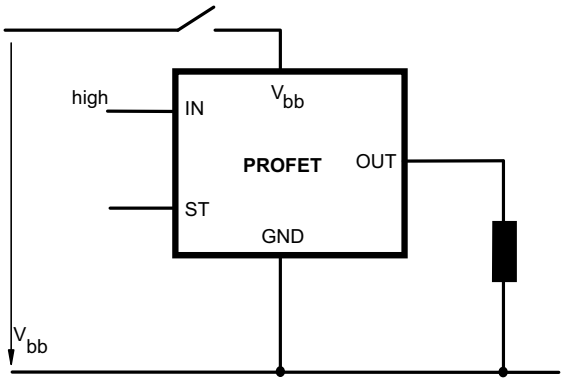

Any kind of load. In case of IN = high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
Due to $V_{GND}$ > 0, no $V_{ST}$ = low signal available.

## GND disconnect with GND pull up




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

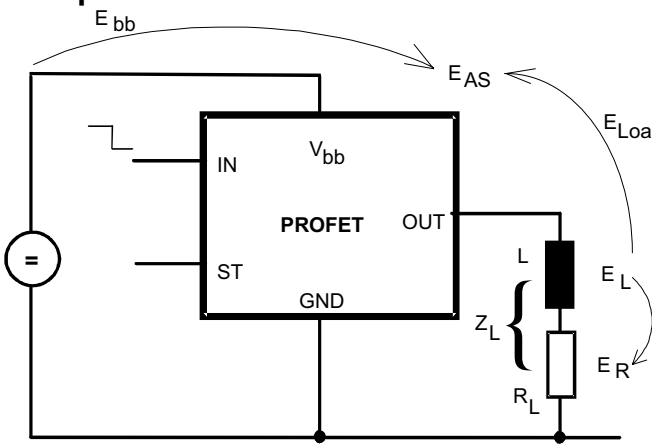
## Vbb disconnect with energized inductive load




For inductive load currents up to the limits defined by $Z_L$ (max. ratings and diagram on page 10) each switch is protected against loss of $V_{bb}$.

Consider at your PCB layout that in the case of Vbb disconnection with energized inductive load all the load current flows through the GND connection.

## Inductive load switch-off energy dissipation




Energy stored in load inductance:

$$E_L = {}^1/_2 \cdot L \cdot I_L^2$$

While demagnetizing load inductance, the energy dissipated in PROFET is

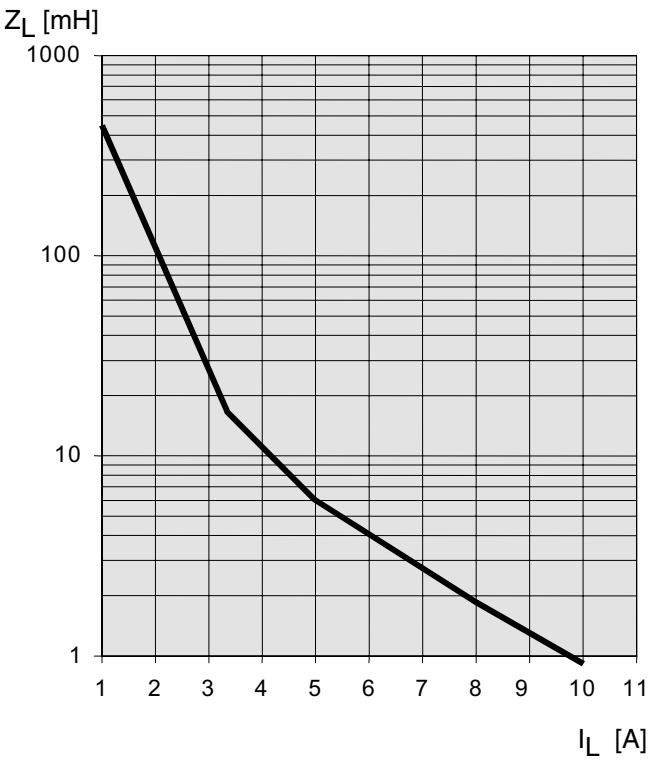
$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t)\, dt,$$

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

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

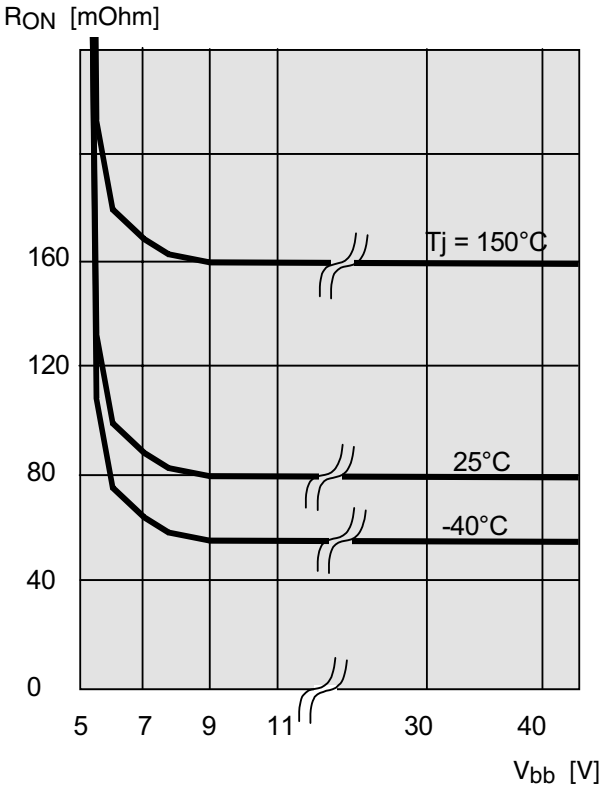
## Maximum allowable load inductance for a single switch off (one channel)[4)]

$L = f(I_L)$; $T_{j,start} = 150°C$, $V_{bb} = 12\,V$, $R_L = 0\,\Omega$



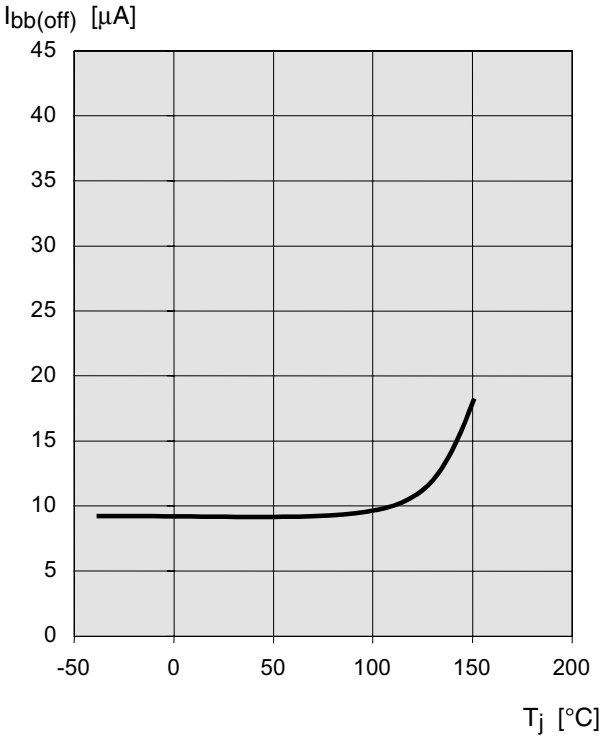
### Typ. on-state resistance

$R_{ON} = f(V_{bb}, T_j)$; $I_L$ = 2 A, IN = high




### Typ. standby current

$I_{bb(off)} = f(T_j)$; $V_{bb}$ = 9...34 V, IN1,2,3,4 = low



# Timing diagrams

All channels are symmetric and consequently the diagrams are valid for channel 1 to channel 4

**Figure 1a:** $V_{bb}$ turn on:

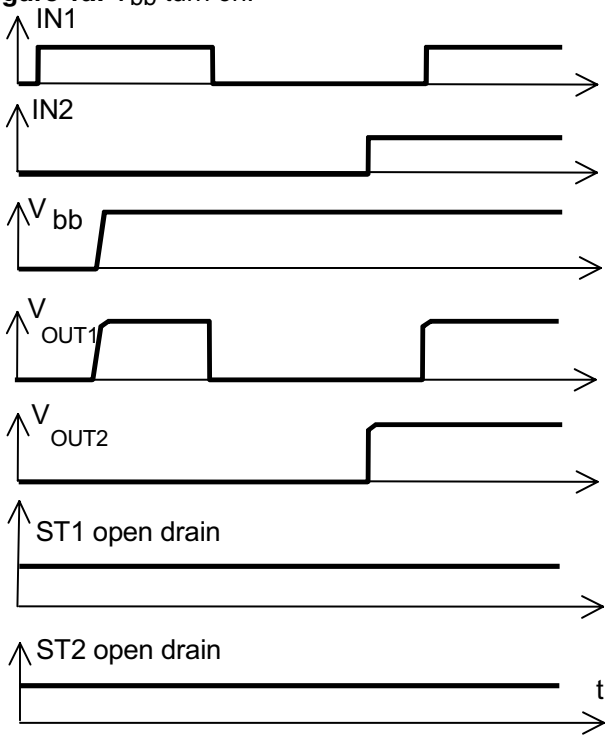



**Figure 2a:** Switching a resistive load, turn-on/off time and slew rate definition:

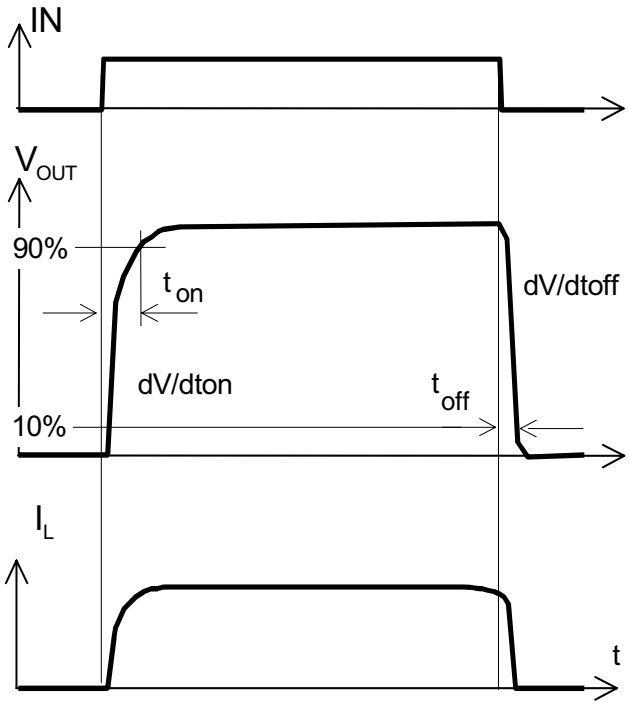



**Figure 2b:** Switching a lamp:

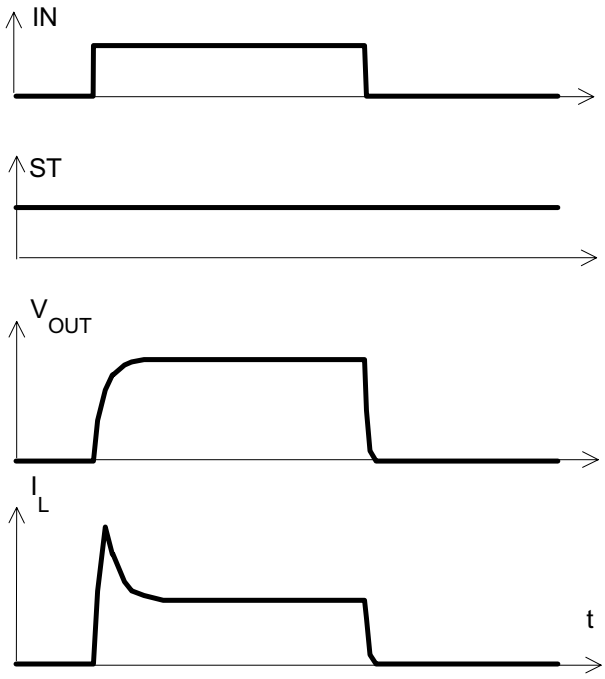
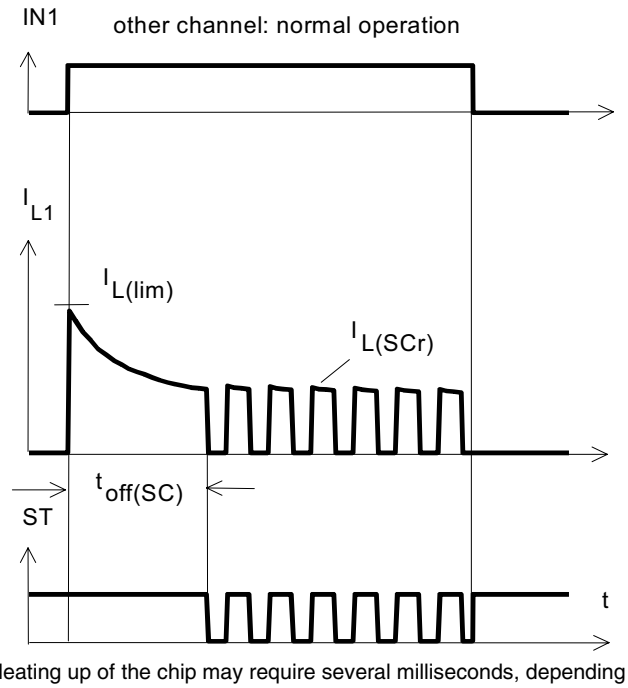
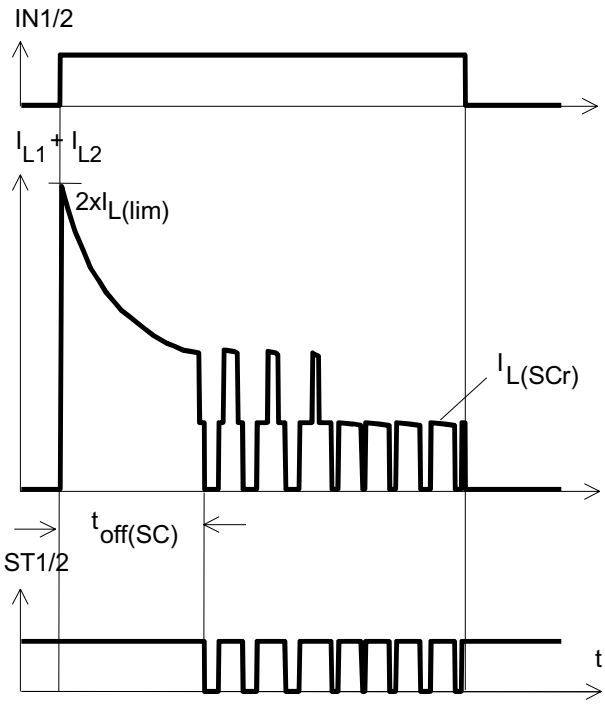



**Figure 3a:** Turn on into short circuit: shut down by overtemperature, restart by cooling




Heating up of the chip may require several milliseconds, depending

**Figure 3b:** Turn on into short circuit:
shut down by overtemperature, restart by cooling
(two parallel switched channels 1 and 2)




ST1 and ST2 have to be configured as a 'Wired OR' function ST1/2 with a single pull-up resistor.

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

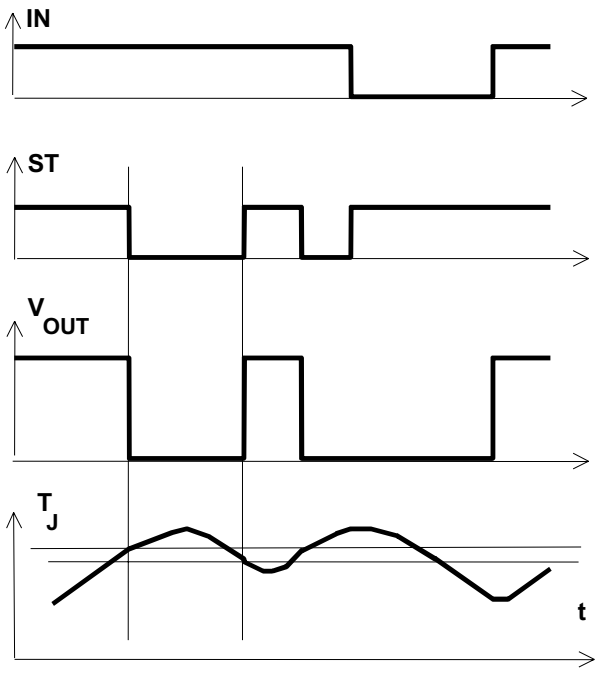



**Figure 5a:** Open load: detection in OFF-state, turn on/off to open load
Open load of channel 1; other channels normal operation

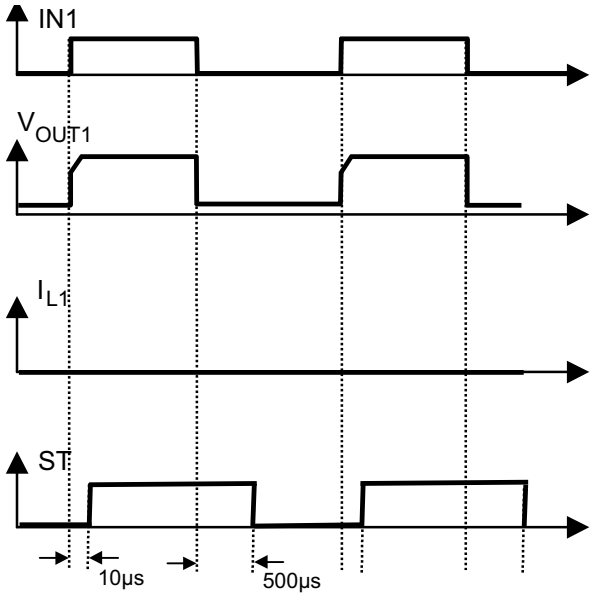
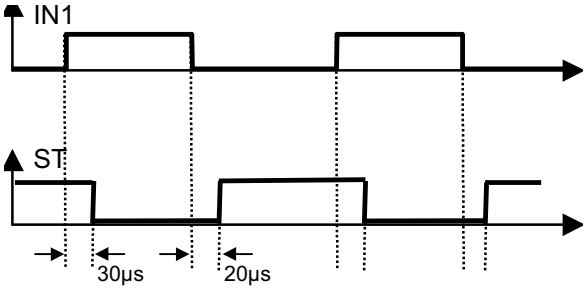
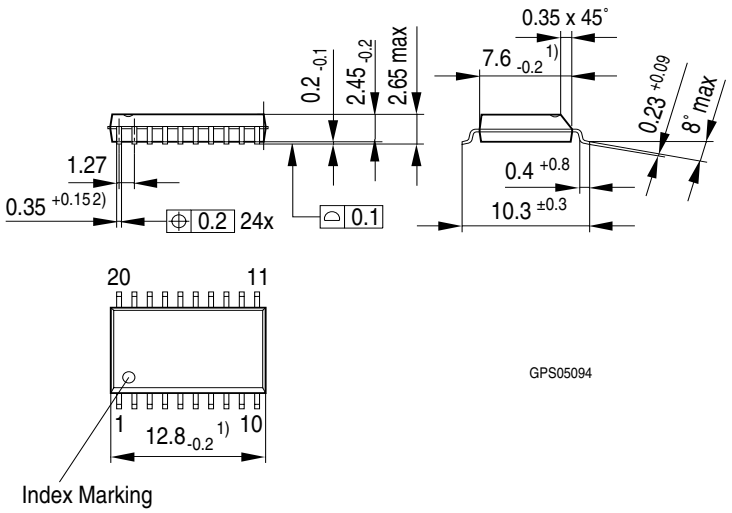



**Figure 6a:** Status change after, turn on/off to overtemperature
Overtemperature of channel 1; other channels normal operation



## Package Outlines




1) Does not include plastic or metal protrusions of 0.15 max per side
2) Does not include dambar protrusion of 0.05 max per side

**Figure 1** **PG-DSO-20** (Plastic Dual Small Outline Package) (RoHS-compliant)

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

Please specify the package needed (e.g. green package) when placing an order

You can find all of our packages, sorts of packing and others in our Infineon Internet Page “Products”: **http://www.infineon.com/products**.

Dimensions in mm

## Revision History

| Version | Date | Changes |
|---|---|---|
| 1.0 | 2007-05-13 | Creation of the green datasheet. |
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