

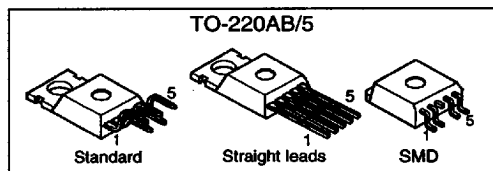
## Smart Highside Power Switch

### Features

- Overload protection
- Current limitation
- Short circuit protection
- Thermal shutdown
- Overvoltage protection
- Fast demagnetization of inductive loads
- Reverse battery protection<sup>1)</sup>
- Open drain diagnostic output
- Open load detection in OFF-state
- CMOS compatible input
- Loss of ground and loss of  $V_{bb}$  protection
- Electrostatic discharge (ESD) protection

### Product Summary

|                        |              |              |
|------------------------|--------------|--------------|
| Overvoltage protection | $V_{bb(AZ)}$ | 65 V         |
| Operating voltage      | $V_{bb(on)}$ | 5.8 ... 58 V |
| On-state resistance    | $R_{ON}$     | 250 mΩ       |
| Load current (ISO)     | $I_L(ISO)$   | 1.7 A        |

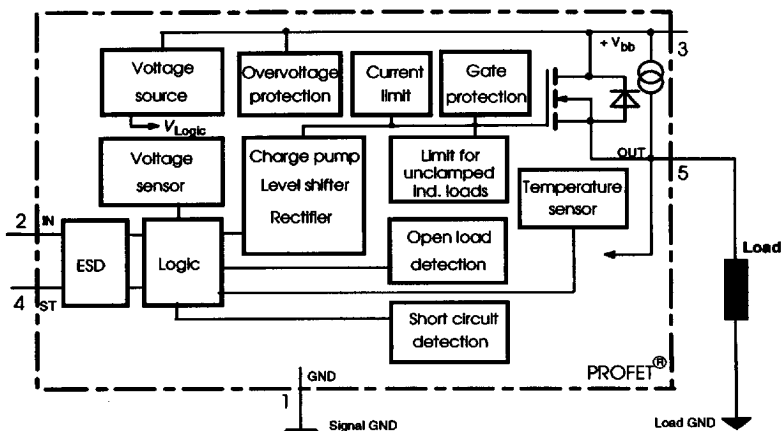


### Application

- $\mu C$  compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- Most suitable for inductive 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.



<sup>1)</sup> 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   | Vbb +           | Positive power supply voltage, the tab is shorted to this pin    |
| 4   | ST S            | Diagnostic feedback                                              |
| 5   | OUT (Load, L) O | 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 350)                                                                  | $V_{bb}$                             | 65                    | V                |
| Supply voltage for full short circuit protection <sup>2)</sup><br>$T_{j\text{ Start}} = -40 \dots +150^\circ\text{C}$ | $V_{bb}$                             | 40                    | V                |
| Load current (Short circuit current, see page 351)                                                                    | $I_L$                                | self-limited          | A                |
| Operating temperature range                                                                                           | $T_j$                                | $-40 \dots +150$      | $^\circ\text{C}$ |
| Storage temperature range                                                                                             | $T_{stg}$                            | $-55 \dots +150$      |                  |
| Power dissipation (DC), $T_c \leq 25^\circ\text{C}$                                                                   | $P_{tot}$                            | 50                    | W                |
| Electrostatic discharge capability (ESD)<br>(Human Body Model)                                                        | IN, ST: $V_{ESD}$<br>all other pins: | 1.0<br>tbd ( $>1.0$ ) | kV               |
| Input voltage (DC)                                                                                                    | $V_{IN}$                             | $-0.5 \dots +36$      | V                |
| Current through input pin (DC)                                                                                        | $I_{IN}$                             | $\pm 2.0$             | mA               |
| Current through status pin (DC)                                                                                       | $I_{ST}$                             | $\pm 5.0$             |                  |
| see internal circuit diagrams page 353                                                                                |                                      |                       |                  |

## Thermal Characteristics

| Parameter and Conditions | Symbol                                    | Values |     |     | Unit |
|--------------------------|-------------------------------------------|--------|-----|-----|------|
|                          |                                           | min    | typ | max |      |
| Thermal resistance       | chip - case: $R_{thJC}$                   | --     | --  | 2.5 | K/W  |
|                          | junction - ambient (free air): $R_{thJA}$ | --     | --  | 75  |      |

<sup>2)</sup> Status fault signal in case of short to GND. Internal thermal shutdown after several milliseconds. External shutdown in response to the status fault signal in less than about 1 ms necessary, if the device is used with higher  $V_{bb}$ .

# Electrical Characteristics

| Parameter and Conditions<br>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)<br>$I_L = 2\text{ A}$ , $V_{bb} = 24\text{ V}$<br>$T_j = 25^\circ\text{C}$ :<br>$T_j = 150^\circ\text{C}$ :            | $R_{ON}$              | --       | 220<br>390 | 250<br>500 | m $\Omega$       |
| Nominal load current, ISO Norm (pin 3 to 5)<br>$V_{ON} = 0.5\text{ V}$ , $T_C = 85^\circ\text{C}$                                                       | $I_{L(ISO)}$          | 1.4      | 1.7        | --         | A                |
| Output current (pin 5) while GND disconnected or<br>GND pulled up, $V_{bb} = 32\text{ V}$ , $V_{IN} = 0$ , see diagram<br>page 354                      | $I_{L(GNDhigh)}$      | --       | --         | 1.1        | mA               |
| Turn-on time to 90% $V_{OUT}$ :<br>Turn-off time to 10% $V_{OUT}$ :<br>$R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$ | $t_{on}$<br>$t_{off}$ | 15<br>20 | --<br>--   | 80<br>70   | $\mu\text{s}$    |
| Slew rate on, 10 to 30% $V_{OUT}$ ,<br>$R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$                                 | $dV/dt_{on}$          | --       | --         | 6          | V/ $\mu\text{s}$ |
| Slew rate off, 10 to 30% $V_{OUT}$ ,<br>$R_L = 12\ \Omega$ , $V_{bb} = 20\text{ V}$ , $T_j = -40\dots+150^\circ\text{C}$                                | $-dV/dt_{off}$        | --       | --         | 7          | V/ $\mu\text{s}$ |
|                                                                                                                                                         |                       |          |            |            |                  |

## Operating Parameters

|                                                                                                         |                        |     |     |     |               |
|---------------------------------------------------------------------------------------------------------|------------------------|-----|-----|-----|---------------|
| Operating voltage <sup>3)</sup><br>$T_j = -40\dots+150^\circ\text{C}$ :                                 | $V_{bb(on)}$           | 5.8 | --  | 58  | V             |
| Undervoltage shutdown<br>$T_j = -40\dots+150^\circ\text{C}$ :                                           | $V_{bb(under)}$        | 2.7 | --  | 4.7 | V             |
| Undervoltage restart<br>$T_j = -40\dots+150^\circ\text{C}$ :                                            | $V_{bb(u\text{ rst})}$ | --  | --  | 4.9 | V             |
| Undervoltage restart of charge pump<br>see diagram page 358<br>$T_j = -40\dots+150^\circ\text{C}$ :     | $V_{bb(ucp)}$          | --  | 5.6 | 7.5 | V             |
| Undervoltage hysteresis<br>$\Delta V_{bb(under)} = V_{bb(u\text{ rst})} - V_{bb(under)}$                | $\Delta V_{bb(under)}$ | --  | 0.4 | --  | V             |
| Overvoltage protection <sup>4)</sup><br>$I_{bb} = 40\text{ mA}$<br>$T_j = -40\dots+150^\circ\text{C}$ : | $V_{bb(AZ)}$           | 65  | 70  | --  | V             |
| Standby current (pin 3),<br>$V_{IN} = 0$<br>$T_j = -40\dots+150^\circ\text{C}$ :                        | $I_{bb(off)}$          | --  | 10  | 50  | $\mu\text{A}$ |
| Operating current (Pin 1) <sup>5)</sup> , $V_{IN} = 5\text{ V}$                                         | $I_{GND}$              | --  | 2.2 | --  | mA            |

<sup>3)</sup> At supply voltage increase up to  $V_{bb} = 5.6\text{ V}$  typ without charge pump,  $V_{OUT} = V_{bb} - 2\text{ V}$

<sup>4)</sup> See also  $V_{ON(CL)}$  in table of protection functions and circuit diagram page 354.

<sup>5)</sup> Add  $I_{ST}$ , if  $I_{ST} > 0$ , add  $I_{IN}$ , if  $V_{IN} > 5.5\text{ V}$

| Parameter and Conditions<br>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)                                                                                 | $I_{L(SCP)}$    |     |    |    |                  |
| $T_j = -40^\circ\text{C}$ :                                                                                                           |                 | --  | -- | 19 | A                |
| $T_j = 25^\circ\text{C}$ :                                                                                                            |                 | --  | 10 | -- |                  |
| $T_j = +150^\circ\text{C}$ :                                                                                                          |                 | 4.0 | -- | -- |                  |
| Output clamp (inductive load switch off)<br>at $V_{OUT} = V_{bb} - V_{ON(CL)}$ $I_L = 1\text{ A}$ , $T_j = -40..+150^\circ\text{C}$ : | $V_{ON(CL)}$    | 59  | -- | 75 | V                |
| Thermal overload trip temperature                                                                                                     | $T_{ft}$        | 150 | -- | -- | $^\circ\text{C}$ |
| Thermal hysteresis                                                                                                                    | $\Delta T_{ft}$ | --  | 10 | -- | K                |
| Reverse battery (pin 3 to 1) <sup>6)</sup>                                                                                            | $-V_{bb}$       | --  | -- | 32 | V                |

## Diagnostic Characteristics

|                                                                             |               |     |     |    |               |
|-----------------------------------------------------------------------------|---------------|-----|-----|----|---------------|
| Open load detection current<br>(included in standby current $I_{bb(off)}$ ) | $I_{L(off)}$  | --  | 6   | -- | $\mu\text{A}$ |
| Open load detection voltage $T_j = -40..150^\circ\text{C}$ :                | $V_{OUT(OL)}$ | 2.4 | 3   | 4  | V             |
| Short circuit detection voltage<br>(pin 3 to 5)                             | $V_{ON(SC)}$  | --  | 2.5 | -- | V             |

<sup>6)</sup> Requires 150  $\Omega$  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 349 and circuit page 354).

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

**Input and Status Feedback<sup>7)</sup>**

|                                                                                                                    |                    |     |     |     |               |
|--------------------------------------------------------------------------------------------------------------------|--------------------|-----|-----|-----|---------------|
| Input resistance<br>see circuit page 353                                                                           | $R_i$              | --  | 20  | --  | k $\Omega$    |
| Input turn-on threshold voltage   | $V_{IN(T+)}$       | 1   | --  | 2.5 | V             |
| Input turn-off threshold voltage  | $V_{IN(T-)}$       | 0.8 | --  | --  | 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  | $\mu\text{A}$ |
| On state input current (pin 2), $V_{IN} = 3.5\text{ V}$                                                            | $I_{IN(on)}$       | 10  | 25  | 70  | $\mu\text{A}$ |
| Delay time for status with open load<br>after input neg. slope (see diagram page 358)                              | $t_d(ST\ OL3)$     | --  | 200 | --  | $\mu\text{s}$ |
| Status output (open drain)                                                                                         |                    |     |     |     |               |
| Zener limit voltage $T_j = -40\dots+150^\circ\text{C}$ , $I_{ST} = +1.6\text{ mA}$ :                               | $V_{ST(high)}$     | 5.4 | 6.1 | --  | V             |
| ST low voltage $T_j = -40\dots+150^\circ\text{C}$ , $I_{ST} = +1.6\text{ mA}$ :                                    | $V_{ST(low)}$      | --  | --  | 0.4 |               |

<sup>7)</sup> If a ground resistor  $R_{GND}$  is used, add the voltage drop across this resistor.

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Truth Table

|                           | Input-level                                   | Output level    | Status<br>BTS 307<br>BTS 707 |
|---------------------------|-----------------------------------------------|-----------------|------------------------------|
| Normal operation          | L                                             | L               | L                            |
|                           | H                                             | H               | H                            |
| Open load                 | L                                             | H <sup>b)</sup> | H                            |
|                           | H                                             | H               | H                            |
| Short circuit to GND      | L                                             | L               | L                            |
|                           | H                                             | L               | L                            |
| Short circuit to $V_{bb}$ | L                                             | H               | H                            |
|                           | H                                             | H               | H                            |
| Overtemperature           | L                                             | L               | L                            |
|                           | H                                             | L               | L                            |
| Under-voltage             | L                                             | L               | L                            |
|                           | H                                             | L               | L                            |
| Overvoltage               | no overvoltage shutdown, see normal operation |                 |                              |

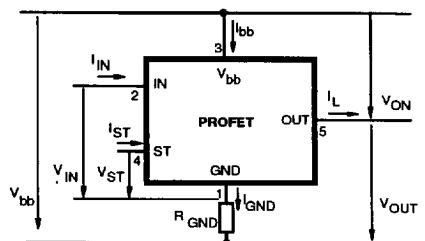
L = "Low" Level  
H = "High" Level

X = don't care

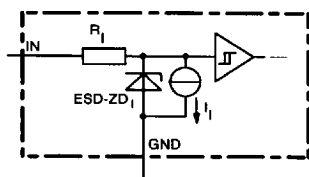
Z = high impedance, potential depends on external circuit

Status signal after the time delay shown in the diagrams (see fig 5, page 358)

## Terms

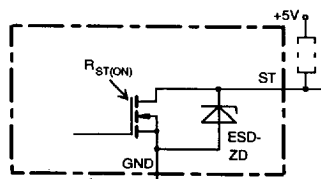


## Input circuit (ESD protection)



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).

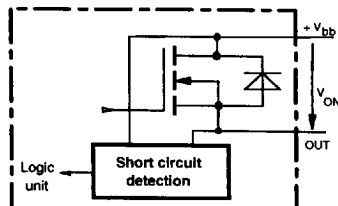
## Status output



ESD-Zener diode: 6.1 V typ., max 5 mA;  
 $R_{ST(ON)} < 0 \Omega$  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).

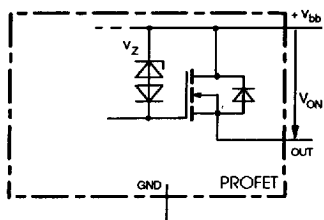
## Short circuit detection

Fault Signal at ST-Pin:  $V_{ON} > 2.5$  V typ, no switch off by the PROFET itself, external switch off recommended!



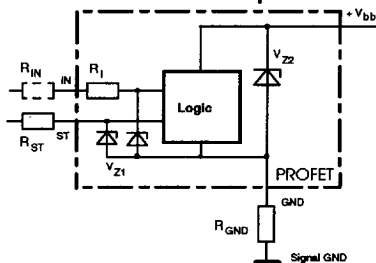
<sup>b)</sup> Power Transistor off, high impedance, internal pull up current source for open load detection.

## Inductive and overvoltage output clamp



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

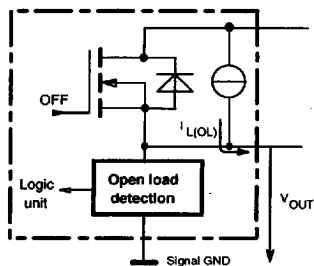
## Overvolt. and reverse batt. protection



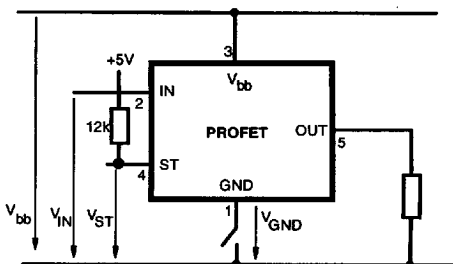
$V_{Z1} = 6.2 \text{ V typ.}$ ,  $V_{Z2} = 70 \text{ V typ.}$ ,  $R_{GND} = 150 \Omega$ ,  
 $R_{ST} = 15 \text{ k}\Omega$ ,  $R_1 = 20 \text{ k}\Omega \text{ typ.}$

## Open-load detection

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

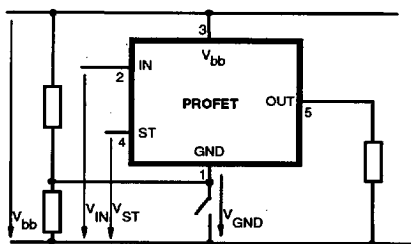


## GND disconnect



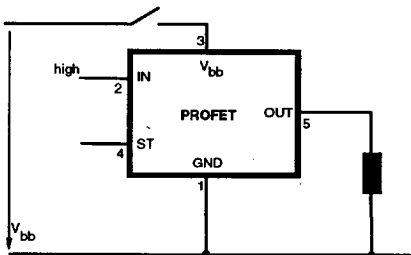
For  $V_{bb}=24\text{V}$  and  $V_{IN}=0\text{V}$ :  $V_{ST}>2.8\text{V}$  @  $I_{ST} \geq 0$  if pulled up as shown.  
 Any kind of load. In case of Input=high is  $V_{OUT} \approx V_{IN} - V_{IN(T+)}$ .

## 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.

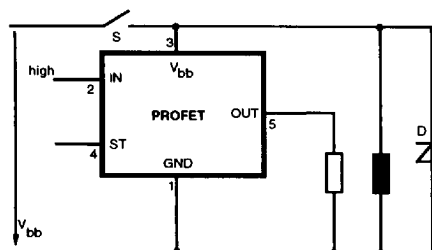
## Vbb disconnect with energized inductive load



Normal load current can be handled by the PROFET itself.

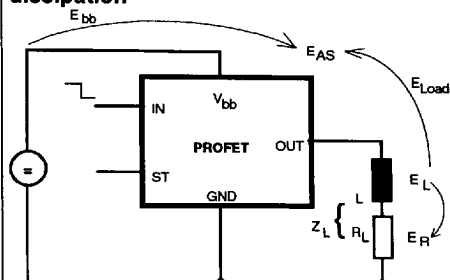
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## **V<sub>bb</sub> disconnect with charged external inductive load**



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  $R_L > 0 \Omega$ :

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

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## Options Overview

all versions: High-side switch, Input protection, ESD protection and reverse battery protection with 150  $\Omega$  in GND connection, protection against loss of ground

| Type                                                                                                                                                                                                                                                                                                                                                          | BTS | 410D2 | 410E2 | 410G2 | 410H2 | 307 | 308 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-------|-------|-------|-------|-----|-----|
| Logic version                                                                                                                                                                                                                                                                                                                                                 |     | D     | E     | G     | H     |     |     |
| Overtemperature protection with hysteresis<br>$T_J > 150^\circ\text{C}$ , latch function <sup>9)10)</sup>                                                                                                                                                                                                                                                     |     | X     |       |       | X     |     | X   |
| $T_J > 150^\circ\text{C}$ , with auto-restart on cooling                                                                                                                                                                                                                                                                                                      |     |       | X     | X     |       | X   |     |
| Short circuit to GND protection<br>switches off when $V_{ON} > 3.5\text{ V typ.}$ and $V_{bb} > 8\text{ V typ.}$ <sup>9)</sup> (when first turned on after approx. 150 $\mu\text{s}$ )<br>switches off when $V_{ON} > 8.5\text{ V typ.}$ <sup>9)</sup> (when first turned on after approx. 150 $\mu\text{s}$ )<br>Achieved through overtemperature protection |     | X     | X     | X     |       | X   |     |
| Open load detection<br>in OFF-state with sensing current 6 $\mu\text{A typ.}$<br>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   |
| Overvoltage shutdown with auto restart                                                                                                                                                                                                                                                                                                                        |     | X     | X     | X     | X     | -   | X   |
| Status feedback for                                                                                                                                                                                                                                                                                                                                           |     |       |       |       |       |     |     |
| overtemperature                                                                                                                                                                                                                                                                                                                                               |     | X     | X     | X     | X     | X   | X   |
| short circuit to GND                                                                                                                                                                                                                                                                                                                                          |     | X     | X     | -     | X     | X   | X   |
| short to $V_{bb}$                                                                                                                                                                                                                                                                                                                                             |     | -11)  | -11)  | -11)  | X     | X   | X   |
| open load                                                                                                                                                                                                                                                                                                                                                     |     | X     | X     | X     | X     | X   | X   |
| undervoltage                                                                                                                                                                                                                                                                                                                                                  |     | X     | -     | -     | -     | X   | -   |
| overvoltage                                                                                                                                                                                                                                                                                                                                                   |     | X     | -     | -     | -     | -   | -   |
| Status output type                                                                                                                                                                                                                                                                                                                                            |     |       |       |       |       |     |     |
| CMOS                                                                                                                                                                                                                                                                                                                                                          |     | X     |       |       |       |     |     |
| Open drain                                                                                                                                                                                                                                                                                                                                                    |     |       | X     | X     | X     | X   | X   |
| Output negative voltage transient limit<br>(fast inductive load switch off)<br>to $V_{bb} - V_{ON(CL)}$                                                                                                                                                                                                                                                       |     | X     | X     | X     | X     | X   | X   |
| Load current limit                                                                                                                                                                                                                                                                                                                                            |     |       |       |       |       |     |     |
| high level (can handle loads with high inrush currents)                                                                                                                                                                                                                                                                                                       |     | X     | X     |       |       |     |     |
| low level (better protection of application)                                                                                                                                                                                                                                                                                                                  |     |       |       | X     | X     | X   | X   |
| Protection against loss of GND                                                                                                                                                                                                                                                                                                                                |     | X     | X     | X     | X     | X   | X   |

<sup>9)</sup> 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 351). No latch between turn on and  $t_d(SC)$ .

<sup>10)</sup> With latch function. Reset by a) Input low, b) Undervoltage, c) Overvoltage

<sup>11)</sup> Low resistance short  $V_{bb}$  to output may be detected in ON-state by the no-load-detection

## Timing diagrams

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

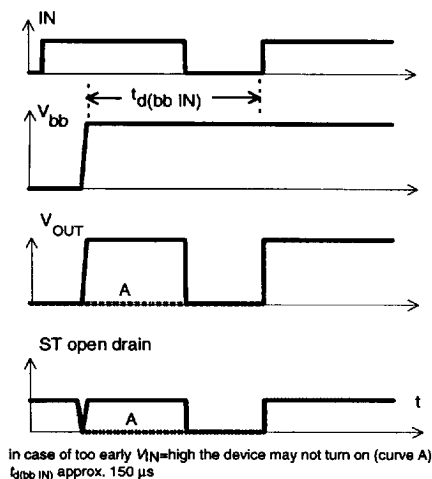


Figure 2a: Switching an inductive load,

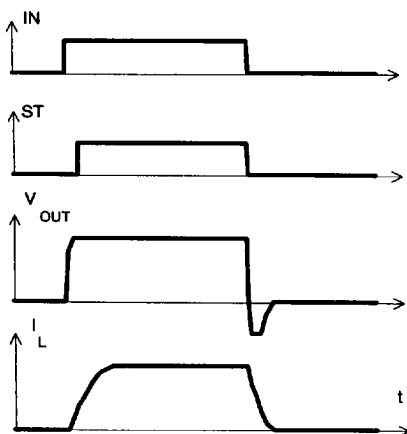


Figure 3a: Short circuit:  
shut down by overtemperature, reset by cooling

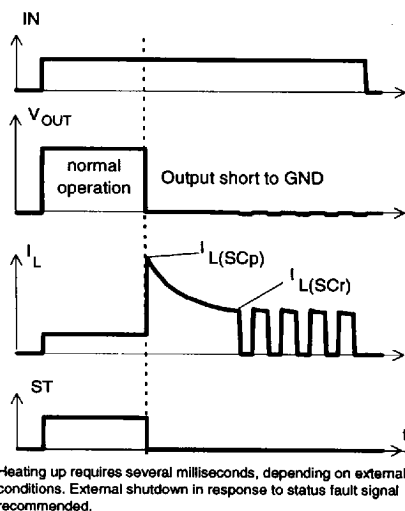
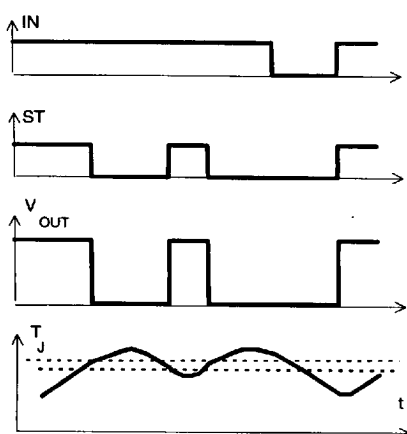
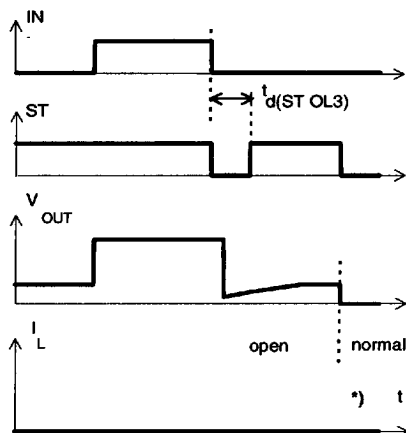


Figure 4a: Overtemperature:  
Reset if  $T_J < T_{Jt}$



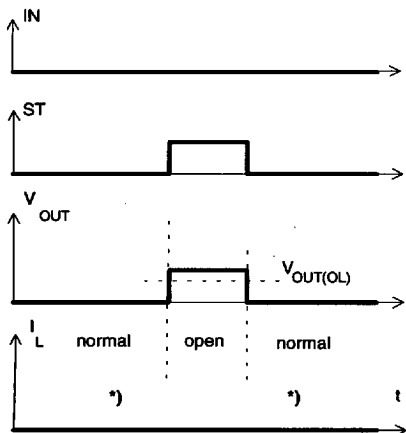
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**Figure 5a:** Open load, : detection in OFF-state, turn on/off to open load



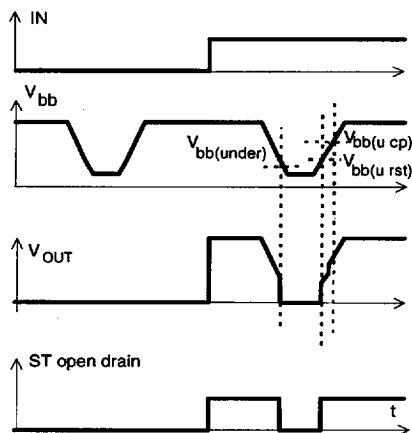
$t_d(ST, OL3)$  depends on external circuitry because of high impedance  
 \*)  $I_L = 6 \mu A$  typ

**Figure 5b:** Open load, : detection in OFF-state, open load occurs in off-state

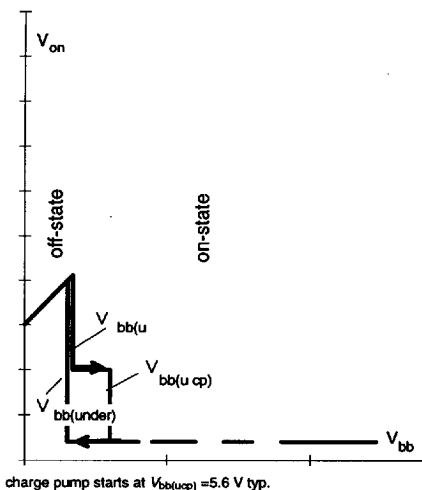


\*)  $I_L = 6 \mu A$  typ

**Figure 6a:** Undervoltage:



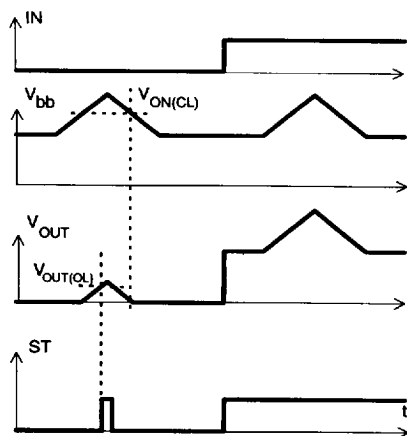
**Figure 6b:** Undervoltage restart of charge pump



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

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**Figure 7a:** Overvoltage, no shutdown:



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## Package and Ordering Code

All dimensions in mm

### Standard TO-220AB/5

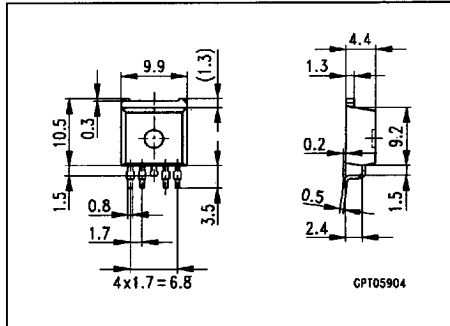
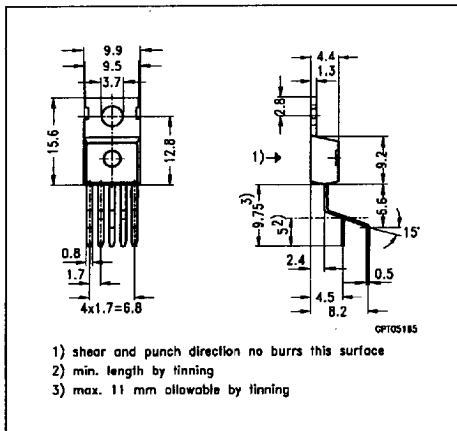
Ordering code

|         |     |
|---------|-----|
| BTS 307 | tbd |
|---------|-----|

### SMD TO-220AB/5, Opt. E3062

Ordering code

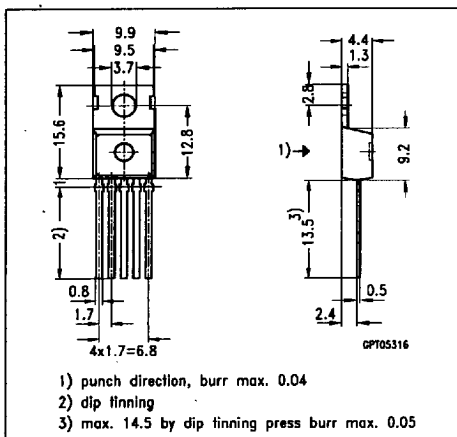
|                |                      |
|----------------|----------------------|
| BTS 307 E3062A | T&R: C67078-S5204-A4 |
|----------------|----------------------|



### TO-220AB/5, Option E3043

Ordering code

|               |                 |
|---------------|-----------------|
| BTS 307 E3043 | C67078-S5204-A3 |
|---------------|-----------------|



<sup>12)</sup> 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.

<sup>13)</sup> 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.

8235605 0092649 730

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360