

PIP3221-DC

Dual channel high-side TOPFET™

Rev. 01 — 20 February 2004

Product data

1. Product profile

1.1 Description

Monolithic temperature and overload protected dual high-side power switch based on TOPFET™ Trench technology in a 7-pin surface mount plastic package.

1.2 Features

- Very low quiescent current
- Power TrenchMOS™
- Overtemperature protection
- Over and undervoltage protection
- Reverse battery protection
- Low charge pump noise
- Loss of ground protection
- Negative load clamping
- CMOS logic compatibility
- Current limitation
- Soft latched overload protection
- ESD protection for all pins
- Diagnostic status indication
- Off-state open load detection
- Load dump protection
- Internal ground resistor.

1.3 Applications

- 12 and 24 V grounded loads
- Inductive loads
- High inrush current loads
- Replacement for relays and fuses.

1.4 Quick reference data

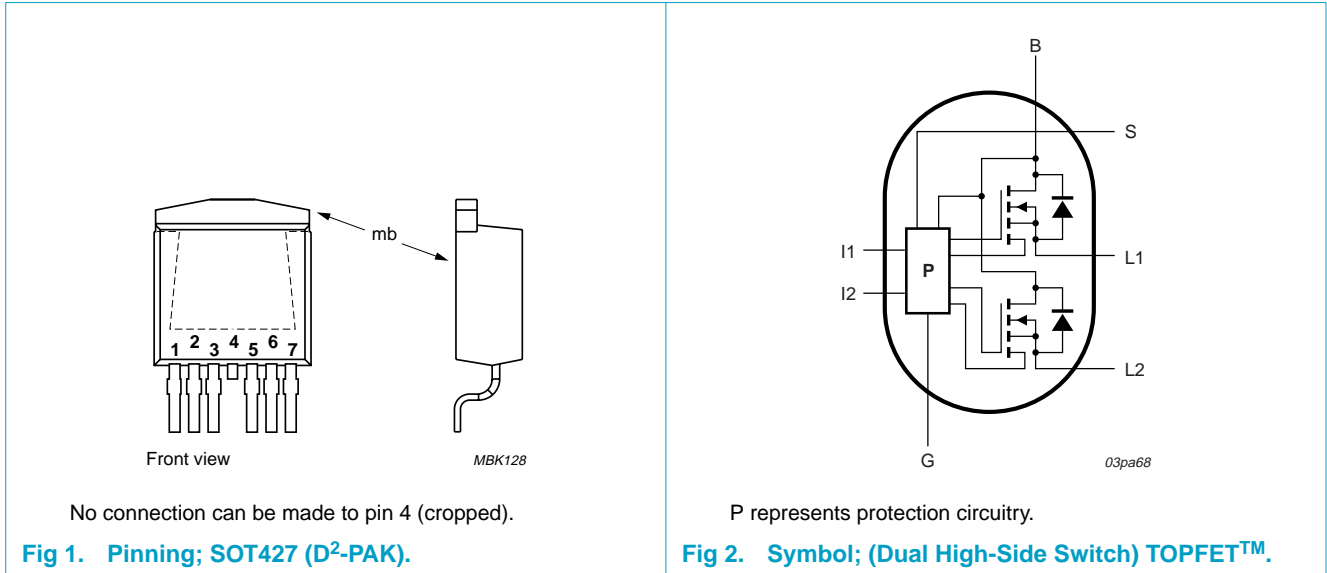
Table 1: Quick reference data

| Symbol | Parameter | Min | Max | Units |
|----------------|----------------------------------|-----|-----|-------|
| R_{BLon} | battery-load on-state resistance | - | 90 | mΩ |
| I_L | load current | - | 4 | A |
| $I_{L(nom)}$ | nominal load current (ISO) | 3.6 | - | A |
| $I_{L(lim)}$ | self-limiting load current | 8 | 16 | A |
| $V_{BG(oper)}$ | battery-ground operating voltage | 5.5 | 35 | V |



PHILIPS

2. Pinning information



2.1 Pin description

Table 2: Pin description

| Symbol | Pin | I/O | Description |
|--------|-----|-----|---------------------------------------|
| L1 | 1 | O | load 1 |
| G | 2 | - | circuit common ground |
| I1 | 3 | I | input 1 |
| B | 4 | - | battery ^[1] ^[2] |
| S | 5 | O | status |
| I2 | 6 | I | input 2 |
| L2 | 7 | O | load 2 |
| - | mb | - | mounting base ^[2] |

[1] Pin 4 is cropped and cannot be connected to the PCB by surface mounting.

[2] The battery is connected to the mounting base.

3. Ordering information

Table 3: Ordering information

| Type number | Package | | Version |
|-------------|---------------------|---|---------|
| | Name | Description | |
| PIP3221-DC | D ² -PAK | Plastic single-ended surface mounted package (Philips version of D ² -PAK); 7 leads (one lead cropped) | SOT427 |

4. Block diagram

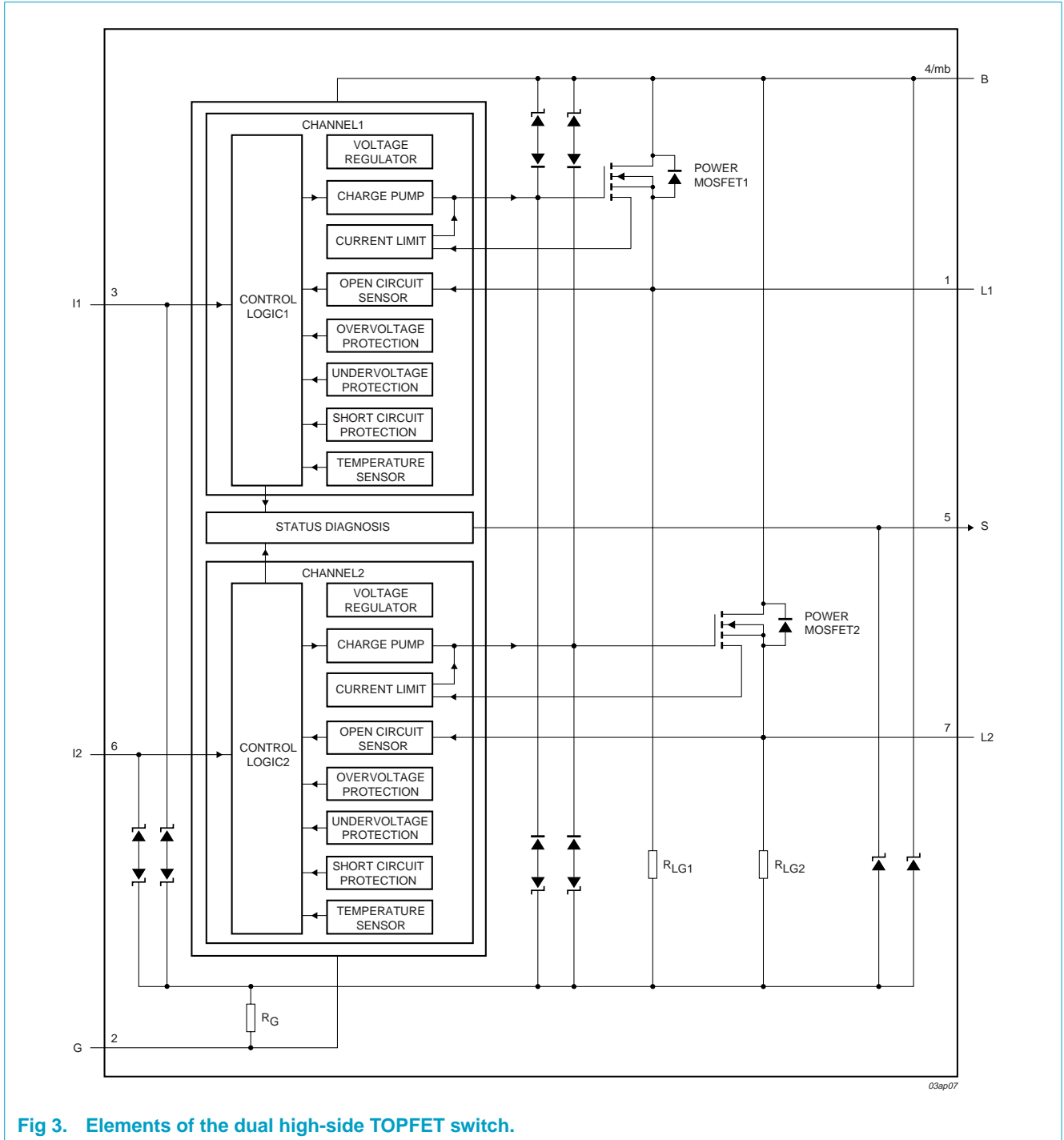


Fig 3. Elements of the dual high-side TOPFET switch.

5. Functional description

A diagnostic status ensures faster fault detection.

Active current limit is combined with a soft latched short circuit protection feature in order to protect the device in the event of a short circuit.

Thermal shutdown for high temperature conditions has an automatic restart at a lower temperature so providing protection against excessive power dissipation.

Active clamping protects the device against low energy spikes.

Undervoltage lockout means the device shuts down for low battery voltages, thus avoiding faulty operation.

Overvoltage shutdown in the on-state protects a load such as a lamp filament from potentially destructive voltage spikes.

Table 4: Truth table

Abbreviations: L = logic LOW; H = logic HIGH; X = don't care; 0 = condition not present; 1 = condition present; UV = undervoltage; OV = overvoltage; OC = open circuit load; SC = short circuit; OT = overtemperature [1].

| Input | | Supply | | Load 1 | | | Load 2 | | | Load output | | Status | Operating mode |
|-------|---|--------|----|--------|----|----|--------|----|----|-------------|-----|--------|--|
| 1 | 2 | UV | OV | OC | SC | OT | OC | SC | OT | 1 | 2 | | |
| L | L | 0 | X | 0 | X | X | 0 | X | X | OFF | OFF | H | both off & normal |
| L | L | 0 | X | 1 | X | X | X | X | X | OFF | OFF | L | both off, one/both OC or shorted to V_S or battery; Figure 10 |
| L | H | 0 | X | 1 | X | X | 0 | 0 | 0 | OFF | ON | L | one off & OC, with other on & normal |
| H | L | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ON | OFF | H | one on & normal, with other off & normal |
| H | H | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ON | ON | H | both on & normal |
| H | X | 1 | 0 | X | X | X | 0 | X | X | OFF | OFF | H | supply undervoltage lockout |
| H | X | 0 | 1 | X | 0 | 0 | X | 0 | 0 | OFF | OFF | H | supply overvoltage shutdown |
| H | X | 0 | 0 | 0 | 1 | X | X | X | X | OFF | X | L | one SC shutdown |
| H | L | 0 | 0 | 0 | 1 | X | 0 | 0 | X | OFF | OFF | L | one SC shutdown, with other off & normal |
| H | H | 0 | 0 | 0 | 1 | X | 0 | 0 | 0 | OFF | ON | L | one SC shutdown, with other on & normal |
| H | X | 0 | 0 | 0 | 0 | 1 | X | X | X | OFF | X | L | one OT shutdown |
| H | L | 0 | 0 | 0 | 0 | 1 | 0 | 0 | X | OFF | OFF | L | one OT shutdown, with other off & normal |
| H | H | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | OFF | ON | L | one OT shutdown, with other on & normal |

[1] The status will continue to indicate OT (even if the input goes LOW) until the device cools below the reset threshold temperature. See "Overtemperature protection" characteristics in [Table 7 "Static characteristics"](#).

6. Limiting values

Table 5: Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

| Symbol | Parameter | Conditions | Min | Max | Unit |
|--|--|---|-------|------|------|
| V_{BG} | battery-ground supply voltage | | [1] - | 45 | V |
| I_L | load current | $T_{mb} \leq 130\text{ °C}$ | - | 4 | A |
| P_{tot} | total power dissipation | $T_{mb} \leq 25\text{ °C}$ | - | 44.6 | W |
| T_{stg} | storage temperature | | -55 | +175 | °C |
| T_j | junction temperature | | -40 | +150 | °C |
| T_{mb} | mounting base temperature | during soldering ($\leq 10\text{ s}$) | - | 260 | °C |
| Reverse battery voltage | | | | | |
| V_{BGR} | reverse battery-ground supply voltage | $R_l \geq 3.3\text{ k}\Omega$; $R_{SS} \geq 3.3\text{ k}\Omega$; Figure 10 | [2] - | 16 | V |
| V_{BGRR} | repetitive reverse battery-ground supply voltage | | - | 32 | V |
| Input current | | | | | |
| I_I | input current | | -5 | +5 | mA |
| I_{IRM} | repetitive peak input current | $\delta \leq 0.1$; $t_p = 300\text{ }\mu\text{s}$ | -50 | +50 | mA |
| Status current | | | | | |
| I_S | status current | | -5 | +5 | mA |
| I_{SRM} | repetitive peak status current | $\delta \leq 0.1$; $t_p = 300\text{ }\mu\text{s}$ | -50 | +50 | mA |
| Inductive load clamping | | | | | |
| $E_{BL(CL)S}$ | non-repetitive battery-load clamping energy | $T_j = 150\text{ °C}$ prior to turn-off; $V_{BG} = 13\text{ V}$; $I_L = 5\text{ A}$; (one channel) Figure 13 | - | 60 | mJ |
| Electrostatic discharge voltage | | | | | |
| V_{esd} | electrostatic discharge voltage | Human Body Model 1; $C = 100\text{ pF}$; $R = 1.5\text{ k}\Omega$ | - | 2 | kV |

- [1] The device will not be harmed by exposure to the maximum supply voltage, but normal operation is not possible because of overvoltage shutdown - see **Table 7 “Static characteristics”** for the operating range.
- [2] Reverse battery voltage is only allowed with external resistors to limit the input and status currents to a safe value. The connected load must limit the reverse load current. The internal ground resistor limits the reverse battery ground current. See **Figure 10 “Typical dynamic response circuit diagram including reverse supply protection and open load detection.”**

7. Thermal characteristics

Table 6: Thermal characteristics

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|----------------|---|---|-----|-----|-----|------|
| $R_{th(j-mb)}$ | thermal resistance from junction to mounting base | per channel | - | 4 | 5.6 | K/W |
| | | both channels | - | 2 | 2.8 | K/W |
| $R_{th(j-a)}$ | thermal resistance from junction to ambient | mounted on printed circuit board; minimum footprint | - | 50 | - | K/W |

8. Static characteristics

Table 7: Static characteristics

Limits are valid for $-40\text{ °C} \leq T_{mb} \leq +150\text{ °C}$ and typical values for $T_{mb} = 25\text{ °C}$ unless otherwise specified.

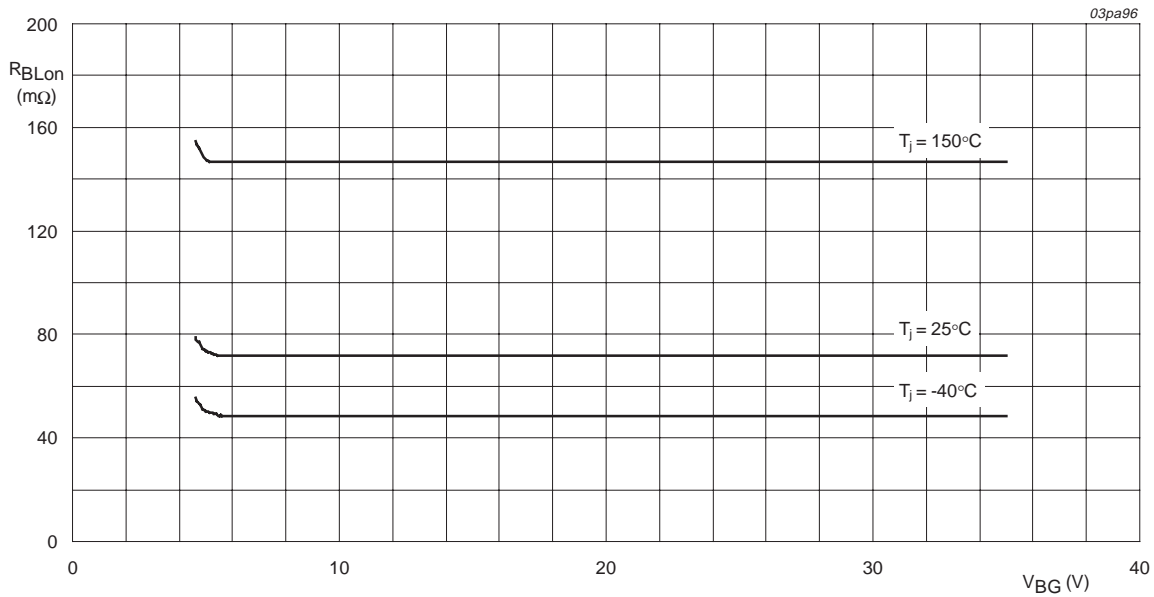
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit | |
|--------------------------------------|----------------------------------|---|-----|------|-----|------|---------------|
| Clamping voltage | | | | | | | |
| $V_{BG(CL)}$ | battery-ground clamping voltage | $I_G = 1\text{ mA}$ | 45 | 55 | 65 | V | |
| $V_{BL(CL)}$ | battery-load clamping voltage | $I_L = I_G = 1\text{ mA}$ | 50 | 55 | 65 | V | |
| $V_{LG(CL)}$ | load-ground clamping voltage | $I_L = 10\text{ mA}$; Figure 13 | [1] | -18 | -23 | -28 | V |
| | | $I_L = 4\text{ A}$; $t_p = 300\text{ }\mu\text{s}$ | | -20 | -25 | -30 | V |
| Supply voltage | | | | | | | |
| $V_{BG(oper)}$ | battery-ground operating voltage | | 5.5 | - | 35 | V | |
| Current [2] | | | | | | | |
| I_B | battery quiescent current | $V_{LG} = V_{IG} = 0\text{ V}$; Figure 9 | [3] | | | | |
| | | $T_{mb} = 150\text{ °C}$ | | - | - | 20 | μA |
| | | $T_{mb} = 25\text{ °C}$ | | - | 0.1 | 1 | μA |
| $I_{L(off)}$ | off-state load current | $V_{BL} = V_{BG}$; per channel | | | | | |
| | | $T_{mb} = 150\text{ °C}$ | | - | - | 10 | μA |
| | | $T_{mb} = 25\text{ °C}$ | | - | 0.1 | 1 | μA |
| $I_{G(on)}$ | operating current | one channel on; Figure 5 | | - | 2 | 3 | mA |
| | | both channels on | | - | 4 | 6 | mA |
| $I_{L(nom)}$ | nominal load current (ISO) | $V_{BL} = 0.5\text{ V}$; $T_{mb} = 85\text{ °C}$ | [4] | 3.6 | - | - | A |
| Resistance | | | | | | | |
| R_{BLon} | battery-load on-state resistance | $9 \leq V_{BG} \leq 35\text{ V}$; $I_L = 4\text{ A}$; Figure 4 | [5] | | | | |
| | | $T_{mb} = 25\text{ °C}$ | | - | 73 | 90 | m Ω |
| | | $T_{mb} = 150\text{ °C}$ | | - | 146 | 180 | m Ω |
| | | $V_{BG} = 5.5\text{ V}$; $I_L = 4\text{ A}$ | | | | | |
| | | $T_{mb} = 25\text{ °C}$ | | - | 76 | 120 | m Ω |
| | | $T_{mb} = 150\text{ °C}$ | | - | 150 | 240 | m Ω |
| R_G | ground resistor | $I_G = -200\text{ mA}$; $t_p = 300\text{ }\mu\text{s}$ | [6] | 40 | 75 | 100 | Ω |
| Input [7] | | | | | | | |
| I_I | input current | $V_{IG} = 5\text{ V}$ | | 20 | 60 | 160 | μA |
| $V_{IG(CL)}$ | input-ground clamping voltage | $I_I = 200\text{ }\mu\text{A}$ | | 5.5 | 7 | 8.5 | V |
| $V_{IG(on)}$ | input-ground turn-on voltage | Figure 8 | | - | 2.1 | 3 | V |
| $V_{IG(off)}$ | input-ground turn-off voltage | | | 1.2 | 1.8 | - | V |
| $V_{IG(on)(hys)}$ | input-ground turn-on hysteresis | | | 0.15 | 0.3 | 0.5 | V |
| $I_{I(on)}$ | input turn-on current | $V_{IG} = 3\text{ V}$ | | - | - | 100 | μA |
| $I_{I(off)}$ | input turn-off current | $V_{IG} = 1.2\text{ V}$ | | 12 | - | - | μA |
| Open current detection [8][9] | | | | | | | |
| $V_{LG(oc)}$ | load-ground open circuit voltage | $V_{BG} \geq 9\text{ V}$ | | 1.5 | 2.5 | 3.5 | V |
| $I_{G(oc)}$ | open-circuit operating current | $V_{BG} = V_{LG} = 16\text{ V}$ open load detected; other channel is off | | - | 0.8 | 1.5 | mA |

Table 7: Static characteristics...continued

Limits are valid for $-40\text{ °C} \leq T_{mb} \leq +150\text{ °C}$ and typical values for $T_{mb} = 25\text{ °C}$ unless otherwise specified.

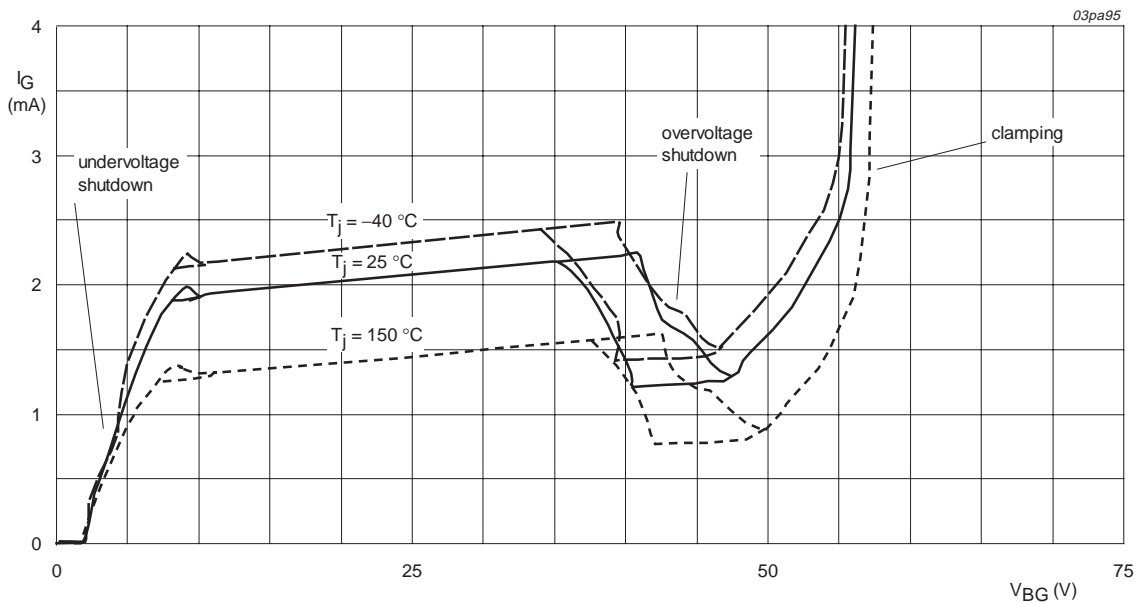
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|--|------|------|------|--------------------|
| $I_{L(oc)}$ | load open circuit current | $V_{LG} = 3.5\text{ V}$; per channel | - | -22 | -40 | μA |
| | | $V_{LG} = 16\text{ V}$; per channel | - | -200 | -300 | μA |
| $R_{L(oc)}$ | open circuit load resistor | $V_S = 5\text{ V}$; connected externally; per channel; Figure 10 | - | 10 | - | $\text{k}\Omega$ |
| Undervoltage [9] | | | | | | |
| $V_{BG(uv)}$ | battery-ground undervoltage | | [11] | 2 | 4.2 | 5.3 V |
| $V_{BG(uv)(hys)}$ | battery-ground undervoltage hysteresis | | - | 0.5 | 1.5 | V |
| Overvoltage [9] | | | | | | |
| $V_{BG(ov)}$ | battery-ground overvoltage | | [12] | 35 | 40 | 45 V |
| $V_{BG(ov)(hys)}$ | battery-ground overvoltage hysteresis | | 0.2 | 1 | 2 | V |
| $I_{G(ov)}$ | overvoltage operating current | $V_{BG} = 45\text{ V}$; per channel | - | 1 | 2.5 | mA |
| Overload protection | | | | | | |
| $I_{L(lim)}$ | self-limiting load current | $V_{BG} \geq 8\text{ V}$; $V_{BL} = V_{BG}$; Figure 7 | 8 | 12 | 16 | A |
| Overtemperature protection [9][10] | | | | | | |
| $T_{j(th)}$ | threshold junction temperature | | [13] | 150 | 170 | 190 °C |
| $T_{j(th)(hys)}$ | threshold junction temperature hysteresis | | 3 | 10 | 20 | °C |
| Status [9] | | | | | | |
| $V_{SG(CL)}$ | status-ground clamping voltage | $I_S = 100\text{ }\mu\text{A}$ | 5.5 | 7 | 8.5 | V |
| $V_{SG(L)}$ | status-ground low voltage | $I_S = 100\text{ }\mu\text{A}$; Figure 6 | - | 0.7 | 0.9 | V |
| | | $I_S = 250\text{ }\mu\text{A}$ | - | - | 1.1 | V |
| $I_{S(off)}$ | status leakage current | $V_{SG} = 5\text{ V}$ | | | | |
| | | $T_{mb} = 150\text{ °C}$ | - | - | 10 | μA |
| | | $T_{mb} = 25\text{ °C}$ | - | 0.1 | 1 | μA |
| R_S | status resistor | $V_{SG} = 5\text{ V}$; connected externally; Figure 10 | [14] | - | 47 | - $\text{k}\Omega$ |

- [1] For a high-side switch, the load pin voltage goes negative with respect to the ground during the turn-off of an inductive load. This negative voltage is clamped by the device.
- [2] $9\text{ V} \leq V_{BG} \leq 35\text{ V}$
- [3] This is the current drawn from the supply when both inputs are LOW, and includes leakage current to the loads.
- [4] Defined as in ISO10483-1. For comparison purposes only.
- [5] This only applies to the R_{BLon} per channel. The supply and input voltages for the R_{BLon} tests are continuous. The specified pulse duration is $t_p = 300\text{ }\mu\text{s}$, and refers only to the applied load current.
- [6] R_G is a resistor incorporated internally into the package.
- [7] $5.5\text{ V} \leq V_{BG} \leq 35\text{ V}$
- [8] An open circuit load can be detected in the off-state and requires an external pull-up resistor, $R_{L(oc)}$.
- [9] See **Table 4 "Truth table"**
- [10] Overtemperature protection is not active during reverse current operation.
- [11] Undervoltage sensor causes each output channel to switch off and reset.
- [12] Overvoltage sensor causes each output channel to switch off to protect the load.
- [13] After cooling below the reset temperature the channel will resume normal operation.
- [14] The status output is an open drain transistor and requires an external pull-up resistor, R_S , to indicate a logic HIGH.



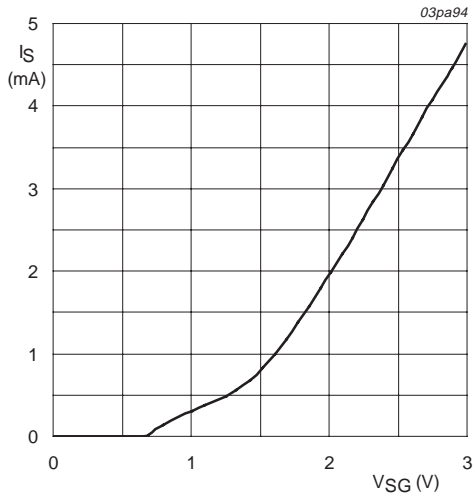
I_L = 4 A; V_{IG} = 5 V

Fig 4. Battery-load on-state resistance as a function of battery-ground voltage; typical values.



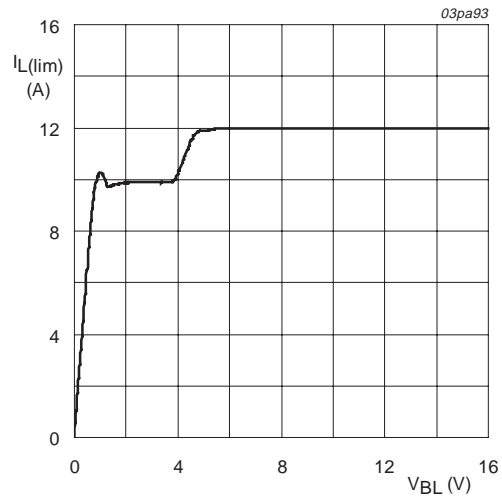
V_{IG} = 5 V

Fig 5. Supply current characteristics: operating current as a function of battery-ground voltage for one channel only; typical values.



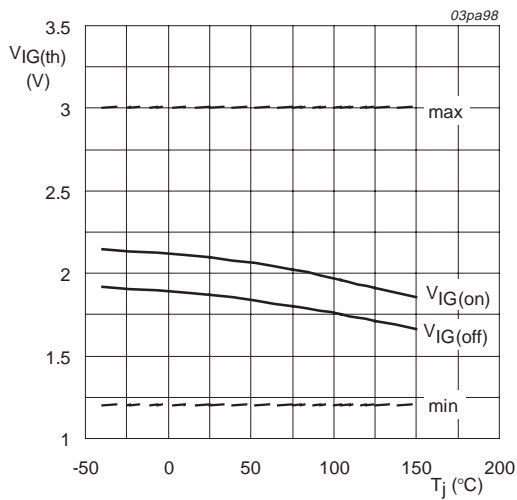
$V_{BG} = 13\text{ V}; V_{IG} = 5\text{ V}; T_j = 25\text{ }^\circ\text{C}$

Fig 6. Status current as a function of status-ground voltage; typical values.



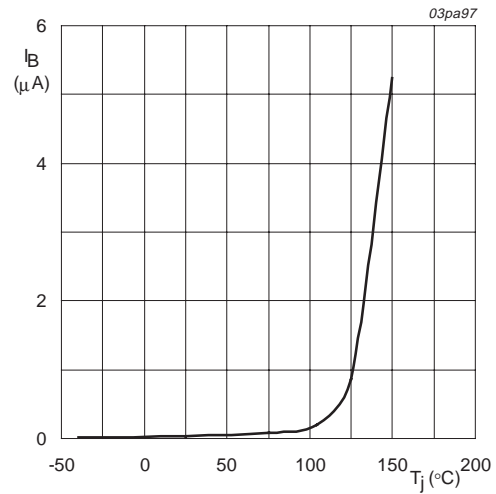
$V_{BG} = 16\text{ V}; V_{IG} = 5\text{ V}; T_{mb} = 25\text{ }^\circ\text{C}$

Fig 7. Self-limiting load current as a function of battery-load voltage; typical values.



$5.5\text{ V} \leq V_{BG} \leq 35\text{ V}$

Fig 8. Input-ground threshold voltage as a function of junction temperature.



$V_{BG} = 35\text{ V}$

Fig 9. Battery quiescent current as a function of junction temperature; typical values.

9. Dynamic characteristics

Table 8: Switching characteristics

$T_{mb} = 25\text{ °C}$; $V_{BG} = 13\text{ V}$; resistive load $R_L = 13\text{ }\Omega$ per channel; *Figure 12*.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|-------------------------|------------------|-----|-----|-----|------------------------|
| Turn-on measured from the input going HIGH | | | | | | |
| $t_{d(on)}$ | turn-on delay time | to 10 % V_L | - | 30 | - | μs |
| dV/dt_{on} | rising slew rate | 30 to 70 % V_L | 0.5 | 1 | 2 | $\text{V}/\mu\text{s}$ |
| t_{on} | turn-on switching time | to 90 % V_L | - | 60 | 220 | μs |
| Turn-off measured from the input going LOW | | | | | | |
| $t_{d(off)}$ | turn-off delay time | to 90 % V_L | - | 20 | - | μs |
| dV/dt_{off} | falling slew rate | 70 to 30 % V_L | 0.5 | 1 | 2 | $\text{V}/\mu\text{s}$ |
| t_{off} | turn-off switching time | to 10 % V_L | - | 40 | 200 | μs |

Table 9: Capacitances

$T_{mb} = 25\text{ °C}$; $f = 1\text{ MHz}$; $V_{IG} = 0\text{ V}$.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------------------|---------------------------|------------------------|-----|-----|-----|-------------|
| C_{sg} | status-ground capacitance | $V_{SG} = 5\text{ V}$ | - | 11 | 15 | pF |
| Per channel | | | | | | |
| C_{ig} | input-ground capacitance | $V_{BG} = 13\text{ V}$ | - | 15 | 20 | pF |
| C_{bl} | battery-load capacitance | $V_{BL} = 13\text{ V}$ | - | 130 | 180 | pF |

Table 10: Short circuit load protection characteristics

$T_{mb} \leq 125\text{ °C}$ prior to the overload short circuit condition.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|--|--|---------|-----|-----|---------------|
| $P_{BL(OV)(th)}$ | battery-load overload power threshold | $5.5 \leq V_{BG} \leq 35\text{ V}$; device trips if | 10 | 55 | 100 | W |
| $t_{BL(d)(sc)}$ | battery-load short-circuit characteristic time | $P_{BL} > P_{BL(OV)(th)}$; <i>Figure 11</i> | [1] 200 | 350 | 800 | μs |

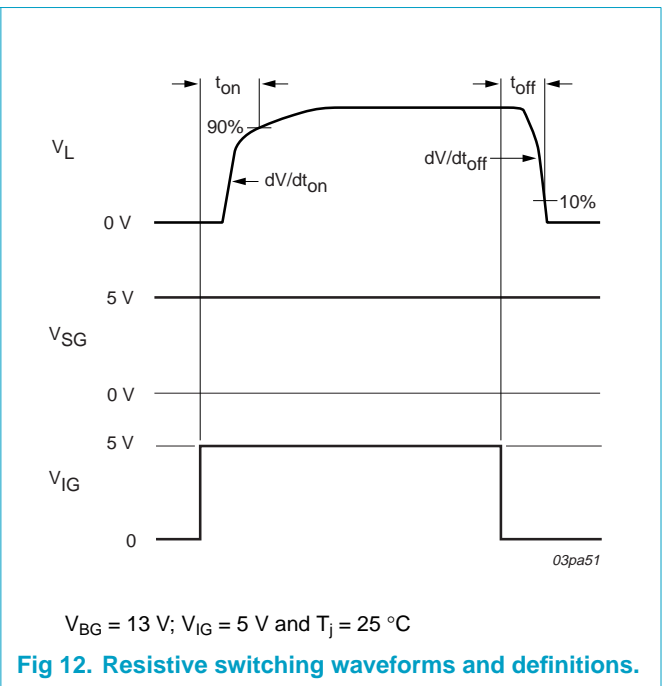
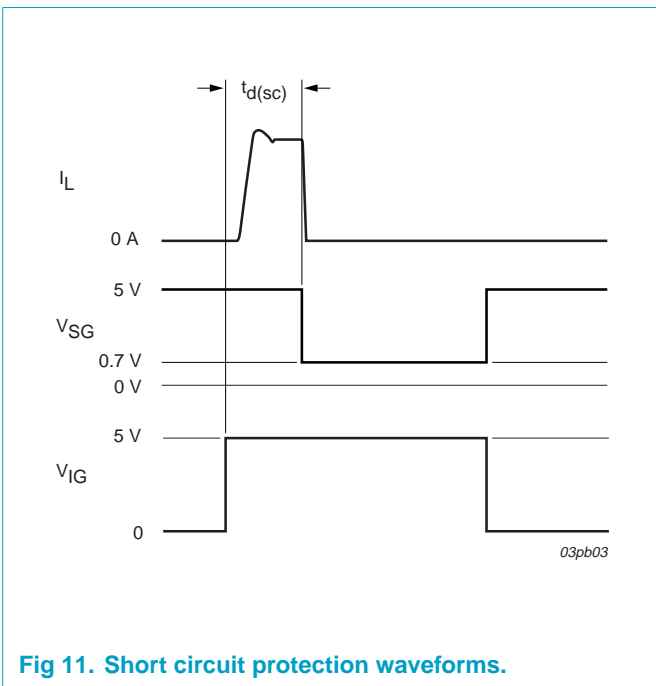
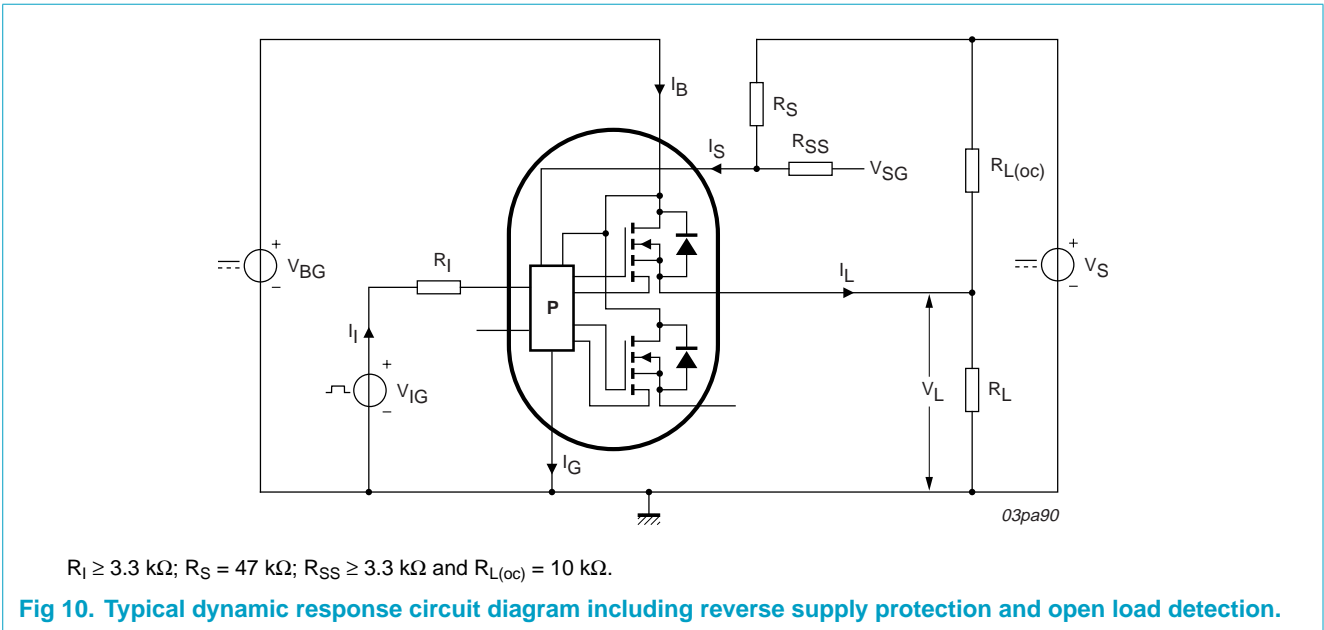
[1] Short circuit response time $t_{d(sc)}$ varies with battery-load power P_{BL} according to the **logarithmic model** equation:

$$t_{d(sc)} \approx \frac{t_{BL(d)(sc)}}{\ln\left(\frac{P_{BL}}{P_{BL(OV)(th)}}\right)}$$

Table 11: Status response times

Limits are valid for $-40\text{ °C} \leq T_{mb} \leq +150\text{ °C}$ and typical values for $T_{mb} = 25\text{ °C}$ unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--|----------------------------|-------------------------|-----|-----|-----|---------------|
| Measured from when the input goes LOW to when the status goes LOW | | | | | | |
| $t_{d(oc)}$ | open-circuit response time | <i>Figure 10 and 14</i> | - | 65 | 100 | μs |



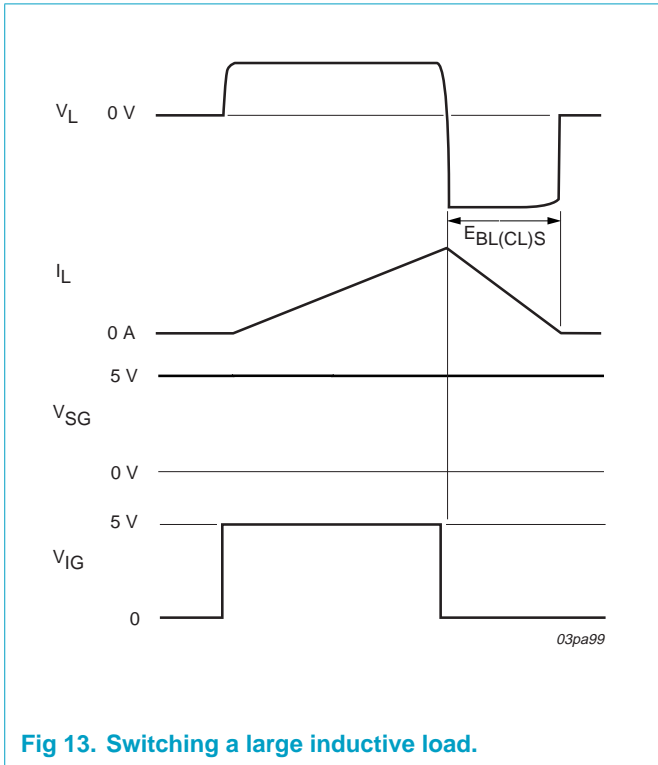


Fig 13. Switching a large inductive load.

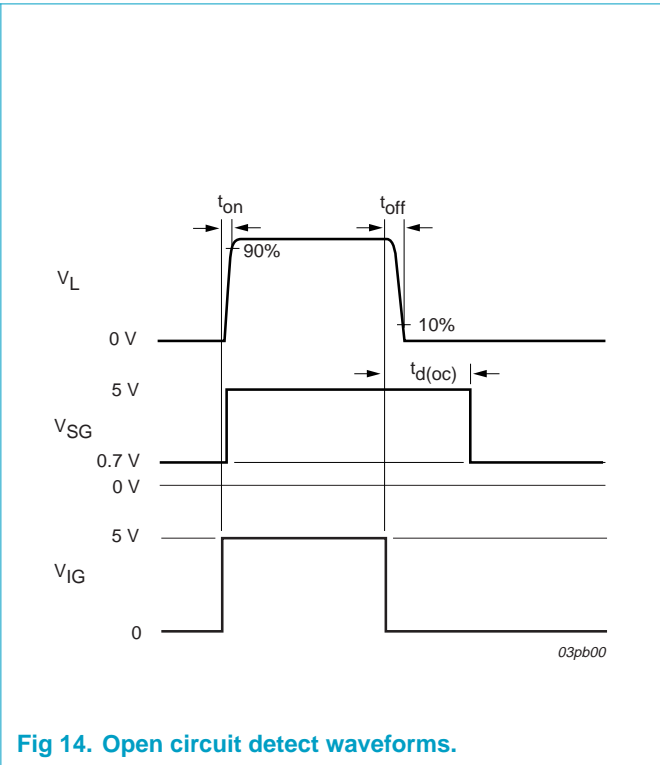


Fig 14. Open circuit detect waveforms.

10. Package information for SOT427

Epoxy meets requirements of UL 94 V-0 at 1/8 inch thickness. Net mass: 1.5 g.
 For soldering guidelines and surface mount footprint design, please visit
<http://www.semiconductors.philips.com/package/>

11. Package outline

Plastic single-ended surface mounted package (Philips version of D²-PAK);
7 leads (one lead cropped)

SOT427

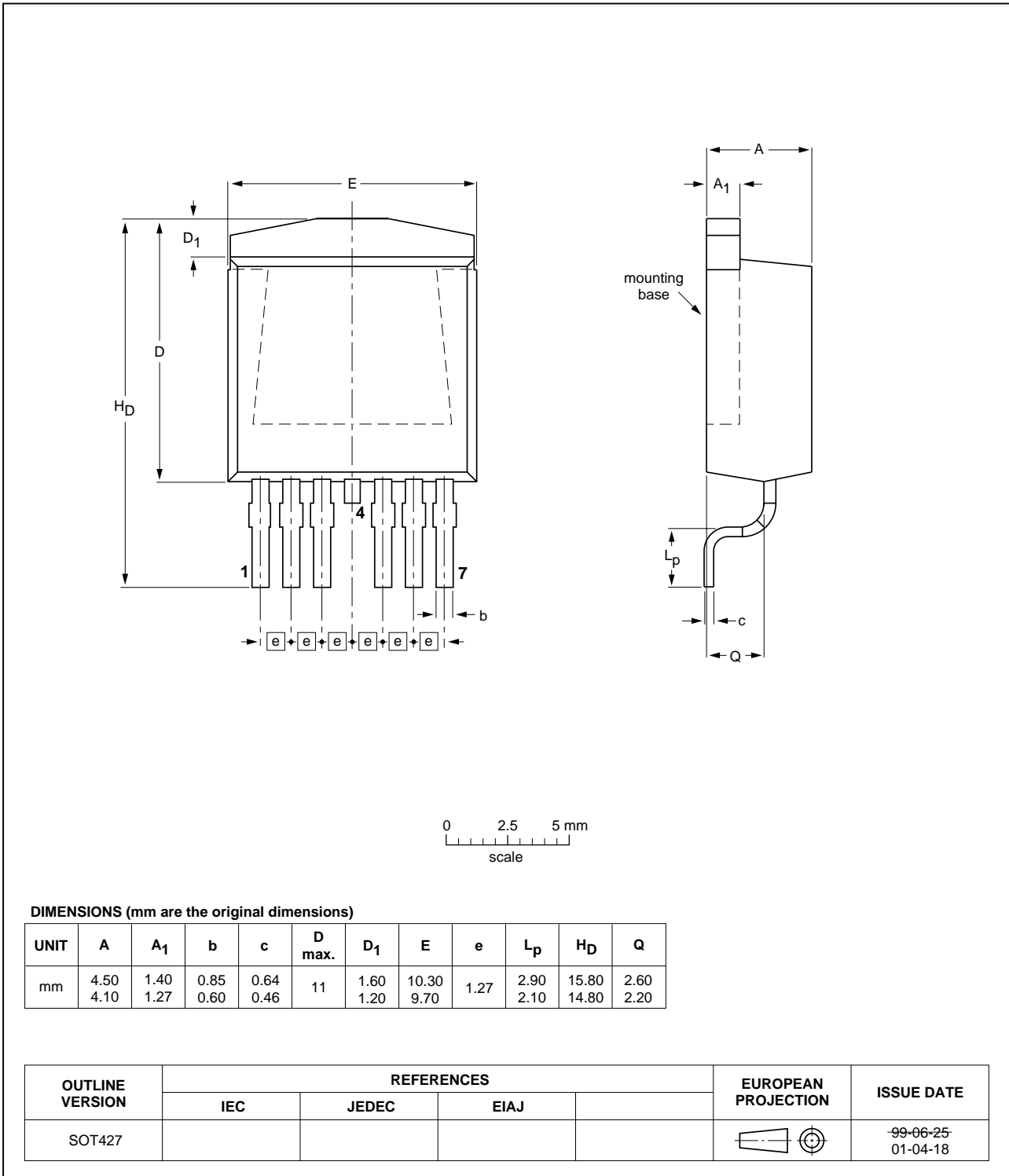


Fig 15. SOT427 (D²-PAK).

12. Revision history

Table 12: Revision history

| Rev | Date | CPCN | Description |
|-----|----------|------|-------------------------------|
| 01 | 20040220 | - | Product data (9397 750 12361) |

13. Data sheet status

| Level | Data sheet status ^[1] | Product status ^{[2][3]} | Definition |
|-------|----------------------------------|----------------------------------|--|
| I | Objective data | Development | This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice. |
| II | Preliminary data | Qualification | This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product. |
| III | Product data | Production | This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN). |

[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL <http://www.semiconductors.philips.com>.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

14. Definitions

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

Limiting values definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

Application information — Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

15. Disclaimers

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Contents

| | | |
|-----------|---|-----------|
| 1 | Product profile | 1 |
| 1.1 | Description | 1 |
| 1.2 | Features | 1 |
| 1.3 | Applications | 1 |
| 1.4 | Quick reference data | 1 |
| 2 | Pinning information | 2 |
| 2.1 | Pin description | 2 |
| 3 | Ordering information | 2 |
| 4 | Block diagram | 3 |
| 5 | Functional description | 4 |
| 6 | Limiting values | 5 |
| 7 | Thermal characteristics | 5 |
| 8 | Static characteristics | 6 |
| 9 | Dynamic characteristics | 10 |
| 10 | Package information for SOT427 | 12 |
| 11 | Package outline | 13 |
| 12 | Revision history | 14 |
| 13 | Data sheet status | 15 |
| 14 | Definitions | 15 |
| 15 | Disclaimers | 15 |
| 16 | Trademarks | 15 |

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