

## Automotive fully integrated H-bridge motor driver

### Features

| Type       | $R_{DS(on)}$            | $I_{out}$ | $V_{CCmax}$ |
|------------|-------------------------|-----------|-------------|
| VNH5180A-E | 180 mΩ max<br>(per leg) | 8 A       | 41 V        |

- Output current: 8 A
- 3 V CMOS compatible inputs
- Undervoltage shutdown
- Overvoltage clamp
- Thermal shutdown
- Cross-conduction protection
- Current and power limitation
- Very low standby power consumption
- PWM operation up to 20 KHz
- Protection against loss of ground and loss of  $V_{CC}$
- Current sense output proportional to motor current
- Output protected against short to ground and short to  $V_{CC}$
- Package: ECOPACK®

### Description

The VNH5180A-E is a full bridge motor driver intended for a wide range of automotive applications. The device incorporates a dual monolithic high-side driver and two low-side switches. Both switches are designed using STMicroelectronics' well known and proven



proprietary VIPower® M0 technology that allows to efficiently integrate on the same die a true Power MOSFET with an intelligent signal/protection circuitry. The three dies are assembled in PowerSSO-36 TP package on electrically isolated leadframes. This package, specifically designed for the harsh automotive environment offers improved thermal performance thanks to exposed die pads. Moreover, its fully symmetrical mechanical design allows superior manufacturability at board level. The input signals  $IN_A$  and  $IN_B$  can directly interface to the microcontroller to select the motor direction and the brake condition. The  $DIAG_A/EN_A$  or  $DIAG_B/EN_B$ , when connected to an external pull-up resistor, enables one leg of the bridge. Each  $DIAG_A/EN_A$  provides a feedback digital diagnostic signal as well. The normal operating condition is explained in the truth table. The CS pin allows to monitor the motor current by delivering a current proportional to its value when CS\_DIS pin is driven low or left open. When CS\_DIS is driven high, CS pin is in high impedance condition. The PWM, up to 20 KHz, allows to control the speed of the motor in all possible conditions. In all cases, a low level state on the PWM pin turns off both the  $LS_A$  and  $LS_B$  switches.

**Table 1. Device summary**

| Package        | Order codes |               |
|----------------|-------------|---------------|
|                | Tube        | Tape and reel |
| PowerSSO-36 TP | VNH5180A-E  | VNH5180ATR-E  |

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## 1 Block diagram and pin description

**Figure 1. Block diagram**

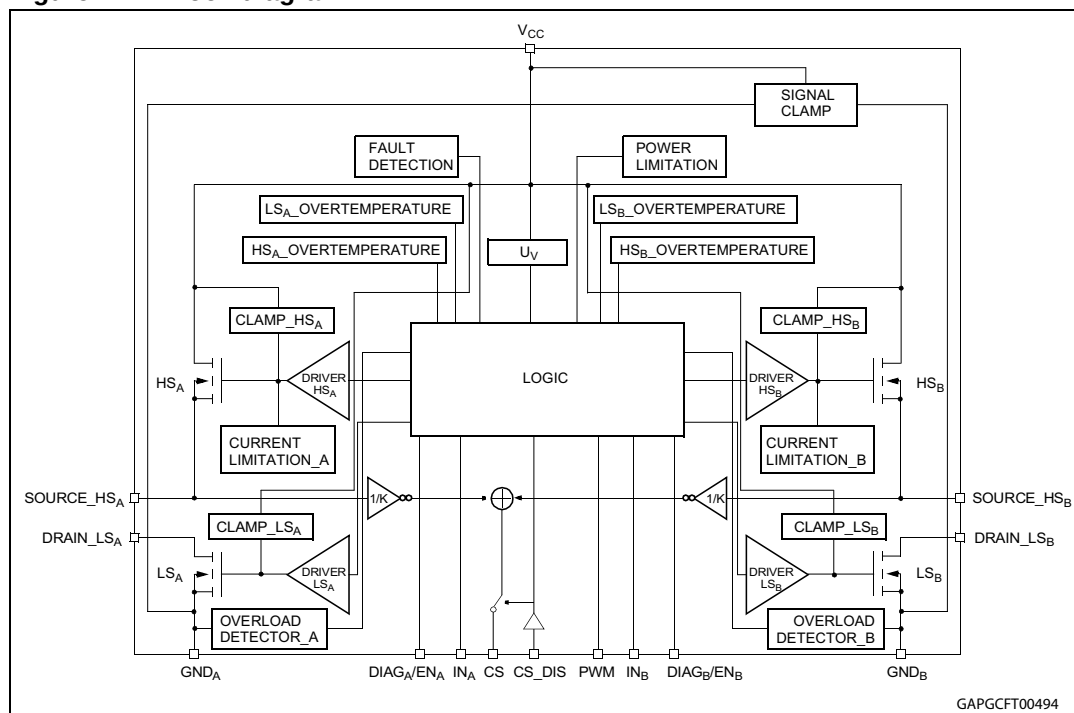


Table 2. Block description

| Name                                              | Description                                                                                                                                               |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Logic control                                     | Allows the turn-on and the turn-off of the high-side and the low-side switches according to the truth table.                                              |
| Undervoltage                                      | Shuts down the device for battery voltage lower than 5V.                                                                                                  |
| High-side and low-side clamp voltage              | Protect the high-side and the low-side switches from the high voltage on the battery line.                                                                |
| High-side and low-side driver                     | Drive the gate of the concerned switch to allow a proper $R_{DS(on)}$ for the leg of the bridge.                                                          |
| Current limitation                                | Limits the motor current in case of short circuit.                                                                                                        |
| High-side and low-side overtemperature protection | In case of short-circuit with the increase of the junction temperature, it shuts down the concerned driver to prevent degradation and to protect the die. |
| Low-side overload detector                        | Detects when low side current exceeds shutdown current and latches off the concerned Low side.                                                            |
| Fault detection                                   | Signalizes the abnormal behaviour of the switch (output shorted to ground or output shorted to battery) by pulling down the concerned ENx/DIAGx pin.      |
| Power limitation                                  | Limits the power dissipation of the high-side driver inside safe range in case of short to ground condition.                                              |

Figure 2. Configuration diagram (top view)

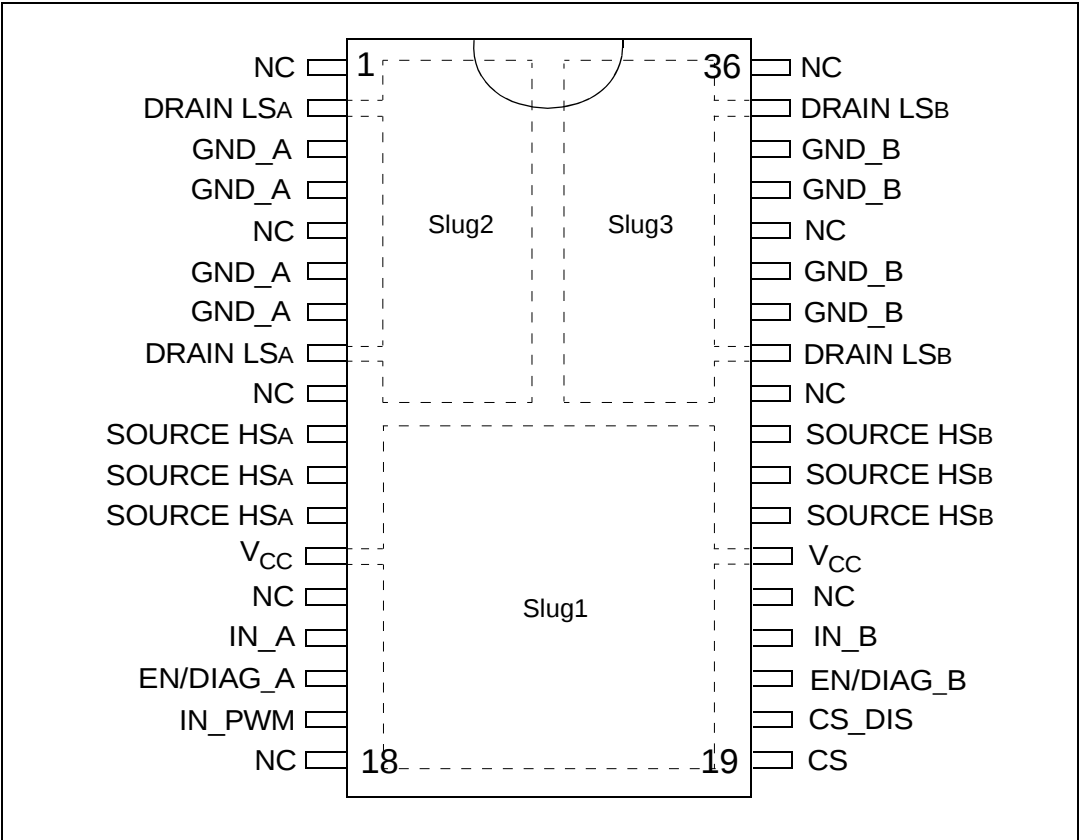


Table 3. Suggested connections for unused and not connected pins

| Connection / pin | Current sense         | N.C. | SOURCE_HSx  | DRAIN_LSx | INPUTx, PWM<br>DIAGx/ENx<br>CS_DIS |
|------------------|-----------------------|------|-------------|-----------|------------------------------------|
| Floating         | Not allowed           | X    | X           | X         | X                                  |
| To ground        | Through 1 kΩ resistor | X    | Not allowed | X         | Through 10 kΩ resistor             |

Table 4. Pin definitions and functions

| Pin N°                          | Symbol                       | Function                                                        |
|---------------------------------|------------------------------|-----------------------------------------------------------------|
| 13, 24                          | V <sub>CC</sub> , Heat Slug1 | Drain of high-side switches and power supply voltage.           |
| 1, 5, 9, 14, 18, 23, 28, 32, 36 | NC                           | Not connected.                                                  |
| 15                              | INA                          | Clockwise input                                                 |
| 16                              | ENA/DIAGA                    | Status of high-side and low-side switches A; open drain output. |
| 17                              | IN_PWM                       | PWM input.                                                      |
| 19                              | CS                           | Output of current sense.                                        |

**Table 4. Pin definitions and functions (continued)**

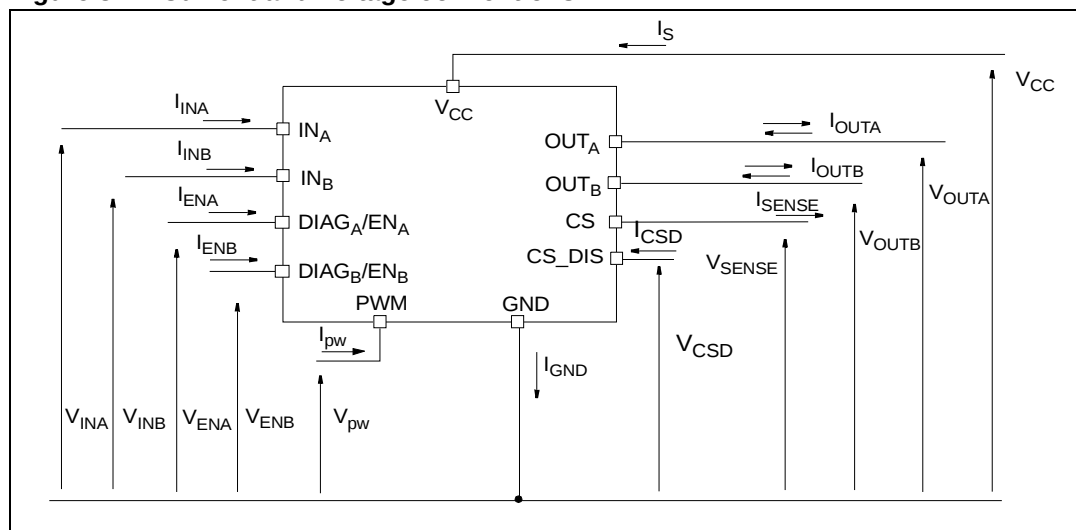
| Pin N°             | Symbol                             | Function                                                           |
|--------------------|------------------------------------|--------------------------------------------------------------------|
| 20                 | CS_DIS                             | Active high CMOS compatible pin to disable current sense pin.      |
| 21                 | EN <sub>B</sub> /DIAG <sub>B</sub> | Status of high-side and low-side switches b;<br>open drain output. |
| 22                 | IN <sub>B</sub>                    | Counter clockwise input.                                           |
| 25, 26, 27, 29, 35 | OUT <sub>B</sub> , Heat Slug3      | Source of high-side switch B / drain of low-side switch B.         |
| 30, 31, 33, 34     | GND <sub>B</sub>                   | Source of low-side switch B.                                       |
| 2, 8, 10, 11, 12   | OUT <sub>A</sub> , Heat Slug2      | Source of high-side switch A / drain of low-side switch A.         |
| 3, 4, 6, 7         | GND <sub>A</sub>                   | Source of low-side switch A.                                       |

**Table 5. Pin functions description**

| Name                                                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| V <sub>CC</sub>                                                          | Battery connection.                                                                                                                                                                                                                                                                                                                                                                                                                |
| GND                                                                      | Power ground.                                                                                                                                                                                                                                                                                                                                                                                                                      |
| OUT <sub>A</sub><br>OUT <sub>B</sub>                                     | Power connections to the motor.                                                                                                                                                                                                                                                                                                                                                                                                    |
| IN <sub>A</sub><br>IN <sub>B</sub>                                       | Voltage controlled input pins with hysteresis, CMOS compatible. These two pins control the state of the bridge in normal operation according to the truth table (brake to V <sub>CC</sub> , Brake to GND, clockwise and counterclockwise).                                                                                                                                                                                         |
| PWM                                                                      | Voltage controlled input pin with hysteresis, CMOS compatible. Gates of low-side FETS get modulated by the PWM signal during their ON phase allowing speed control of the motor.                                                                                                                                                                                                                                                   |
| EN <sub>A</sub> /DIAG <sub>A</sub><br>EN <sub>B</sub> /DIAG <sub>B</sub> | Open drain bidirectional logic pins. These pins must be connected to an external pull up resistor. When externally pulled low, they disable half-bridge A or B. In case of fault detection (thermal shutdown of a high-side FET or excessive ON-state voltage drop across a low-side FET), these pins are pulled low by the device (see <a href="#">Table 14: Truth table in fault conditions (detected on OUT<sub>A</sub>)</a> ). |
| CS                                                                       | Analog current sense output. This output delivers a current proportional to the motor current if CS_DIS is low or left open. The information can be read back as an analog voltage across an external resistor.                                                                                                                                                                                                                    |
| CS_DIS                                                                   | Active high CMOS compatible pin to disable the current sense pin.                                                                                                                                                                                                                                                                                                                                                                  |

## 2 Electrical specifications

Figure 3. Current and voltage conventions



### 2.1 Absolute maximum ratings

Stressing the device above the rating listed in the [Table 6: Absolute maximum ratings](#) may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the Operating sections of this specification is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE Program and other relevant quality document.

Table 6. Absolute maximum ratings

| Symbol        | Parameter                                                                                  | Value               | Unit |
|---------------|--------------------------------------------------------------------------------------------|---------------------|------|
| $V_{CC}$      | Supply voltage                                                                             | + 41                | V    |
| $I_{max}$     | Maximum output current (continuous)                                                        | Internally limited  | A    |
| $I_R$         | Reverse output current (continuous)                                                        | -15                 | A    |
| $I_{IN}$      | Input current ( $IN_A$ and $IN_B$ pins)                                                    | +/- 10              | mA   |
| $I_{EN}$      | Enable input current ( $DIAG_A/EN_A$ and $DIAG_B/EN_B$ pins)                               | +/- 10              | mA   |
| $I_{PW}$      | PWM Input current                                                                          | +/- 10              | mA   |
| $I_{CS\_DIS}$ | CS_DIS input current                                                                       | +/- 10              | mA   |
| $V_{CS}$      | Current sense maximum voltage                                                              | $V_{CC}-41/+V_{CC}$ | V    |
| $V_{ESD}$     | Electrostatic discharge<br>(Human body model: $R=1.5\text{ k}\Omega$ , $C=100\text{ pF}$ ) | 2                   | kV   |
| $T_c$         | Junction operating temperature                                                             | -40 to 150          | °C   |
| $T_{STG}$     | Storage temperature                                                                        | -55 to 150          | °C   |
| $I_{GND}$     | DC reverse ground pin current                                                              | 200                 | mA   |

## 2.2 Thermal data

**Table 7. Thermal data**

| Symbol         | Parameter                                  |     | Max. value                    | Unit |
|----------------|--------------------------------------------|-----|-------------------------------|------|
| $R_{thj-case}$ | Thermal resistance junction-case (per leg) | HSD | 4.8                           | °C/W |
|                |                                            | LSD | 4.6                           |      |
| $R_{thj-amb}$  | Thermal resistance junction-ambient        |     | See <a href="#">Figure 17</a> | °C/W |

## 2.3 Electrical characteristics

Values specified in this section are for  $V_{CC} = 9\text{ V}$  up to  $18\text{ V}$ ;  $-40\text{ °C} < T_j < 150\text{ °C}$ , unless otherwise specified.

**Table 8. Power section**

| Symbol     | Parameter                                     | Test conditions                                                                                                                                           | Min. | Typ. | Max. | Unit |
|------------|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| $V_{CC}$   | Operating supply voltage                      |                                                                                                                                                           | 5.5  |      | 18   | V    |
| $I_S$      | Supply current                                | Off-state with all fault cleared and $ENx = 0$ (standby)<br>$I_{NA} = I_{NB} = PWM = 0$ ; $T_j = 25\text{ °C}$ ;<br>$V_{CC} = 13\text{ V}$                |      | 3    | 6    | μA   |
|            |                                               | Off-state with all fault cleared and $ENx = 0$ (standby)<br>$I_{NA} = I_{NB} = PWM = 0$ ;<br>$V_{CC} = 13\text{ V}$ ; $T_j = -40\text{ to }150\text{ °C}$ |      |      | 10   | μA   |
|            |                                               | Off-state (no standby)<br>$I_{NA} = I_{NB} = PWM = 0$ ; $ENx = 5\text{ V}$ ;<br>$T_j = -40\text{ to }150\text{ °C}$                                       |      |      | 5    | mA   |
|            |                                               | On-state:<br>$I_{NA}$ or $I_{NB} = 5\text{ V}$ ; no PWM                                                                                                   |      | 3    | 6    | mA   |
|            |                                               | On-state:<br>$I_{NA}$ or $I_{NB} = 5\text{ V}$ ; PWM = 20 kHz                                                                                             |      |      | 6    | mA   |
| $R_{ONHS}$ | Static high-side resistance                   | $I_{OUT} = 2.5\text{ A}$ ; $T_j = -40\text{ °C}$                                                                                                          |      | 75   |      | mΩ   |
|            |                                               | $I_{OUT} = 2.5\text{ A}$ ; $T_j = 25\text{ °C}$                                                                                                           |      | 115  |      | mΩ   |
|            |                                               | $I_{OUT} = 2.5\text{ A}$ ; $T_j = 150\text{ °C}$                                                                                                          |      | 230  |      | mΩ   |
|            |                                               | $I_{OUT} = 2.5\text{ A}$ ; $T_j = -40\text{ to }150\text{ °C}$                                                                                            |      |      | 250  | mΩ   |
| $R_{ONLS}$ | Static low-side resistance                    | $I_{OUT} = 2.5\text{ A}$ ; $T_j = 25\text{ °C}$                                                                                                           |      | 53.5 |      | mΩ   |
|            |                                               | $I_{OUT} = 2.5\text{ A}$ ; $T_j = -40\text{ to }150\text{ °C}$                                                                                            |      |      | 110  | mΩ   |
| $V_f$      | High-side free-wheeling diode forward voltage | $I_{OUT} = -2.5\text{ A}$ ; $T_j = 150\text{ °C}$                                                                                                         |      | 0.7  | 0.9  | V    |

**Table 8. Power section (continued)**

| Symbol       | Parameter                                        | Test conditions                                                                               | Min. | Typ. | Max. | Unit          |
|--------------|--------------------------------------------------|-----------------------------------------------------------------------------------------------|------|------|------|---------------|
| $I_{L(off)}$ | High-side off-state output current (per channel) | $T_j = 25\text{ }^{\circ}\text{C}$ ; $V_{OUTX} = EN_X = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$  | 0    |      | 3    | $\mu\text{A}$ |
|              |                                                  | $T_j = 125\text{ }^{\circ}\text{C}$ ; $V_{OUTX} = EN_X = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ | 0    |      | 5    | $\mu\text{A}$ |
| $I_{RM}$     | Dynamic cross-conduction current                 | $I_{OUT} = 2.5\text{ A}$ (see <a href="#">Figure 6</a> )                                      |      | 0.6  |      | A             |

**Table 9. Logic inputs ( $IN_A$ ,  $IN_B$ ,  $EN_A$ ,  $EN_B$ , PWM, CS\_DIS)**

| Symbol      | Parameter                       | Test conditions                                                                       | Min. | Typ. | Max. | Unit          |
|-------------|---------------------------------|---------------------------------------------------------------------------------------|------|------|------|---------------|
| $V_{IL}$    | Input low level voltage         | Normal operation<br>( $DIAG_X/EN_X$ pin acts as an input pin)                         |      |      | 0.9  | V             |
| $V_{IH}$    | Input high level voltage        | Normal operation<br>( $DIAG_X/EN_X$ pin acts as an input pin)                         | 2.1  |      |      | V             |
| $V_{IHYST}$ | Input hysteresis voltage        | Normal operation<br>( $DIAG_X/EN_X$ pin acts as an input pin)                         | 0.15 |      |      | V             |
| $V_{ICL}$   | Input clamp voltage             | $I_{IN} = 1\text{ mA}$                                                                | 5.5  | 6.3  | 7.5  | V             |
|             |                                 | $I_{IN} = -1\text{ mA}$                                                               | -1.0 | -0.7 | -0.3 | V             |
| $I_{INL}$   | Input current                   | $V_{IN} = 0.9\text{ V}$                                                               | 1    |      |      | $\mu\text{A}$ |
| $I_{INH}$   | Input current                   | $V_{IN} = 2.1\text{ V}$                                                               |      |      | 10   | $\mu\text{A}$ |
| $V_{DIAG}$  | Enable output low level voltage | Fault operation<br>( $DIAG_X/EN_X$ pin acts as an output pin); $I_{EN} = 1\text{ mA}$ |      |      | 0.4  | V             |

**Table 10. Switching ( $V_{CC} = 13\text{ V}$ ,  $R_{LOAD} = 5\text{ }\Omega$ )**

| Symbol       | Parameter                                           | Test conditions                                                             | Min. | Typ. | Max. | Unit          |
|--------------|-----------------------------------------------------|-----------------------------------------------------------------------------|------|------|------|---------------|
| f            | PWM frequency                                       |                                                                             | 0    |      | 20   | kHz           |
| $t_{d(on)}$  | Turn-on delay time                                  | Input rise time $< 1\text{ }\mu\text{s}$<br>(see <a href="#">Figure 6</a> ) |      |      | 250  | $\mu\text{s}$ |
| $t_{d(off)}$ | Turn-off delay time                                 | Input rise time $< 1\text{ }\mu\text{s}$<br>(see <a href="#">Figure 6</a> ) |      |      | 250  | $\mu\text{s}$ |
| $t_r$        | Rise time                                           | See <a href="#">Figure 5</a>                                                |      | 1    | 2    | $\mu\text{s}$ |
| $t_f$        | Fall time                                           | See <a href="#">Figure 5</a>                                                |      | 1    | 2    | $\mu\text{s}$ |
| $t_{DEL}$    | Delay time during change of operating mode          | See <a href="#">Figure 4</a>                                                | 200  | 400  | 1600 | $\mu\text{s}$ |
| $t_{rr}$     | High-side free wheeling diode reverse recovery time | See <a href="#">Figure 7</a>                                                |      | 400  |      | ns            |

**Table 11. Protections and diagnostics**

| Symbol           | Parameter                                                             | Test conditions   | Min. | Typ. | Max. | Unit |
|------------------|-----------------------------------------------------------------------|-------------------|------|------|------|------|
| $V_{USD}$        | Undervoltage shutdown                                                 |                   |      | 3    | 5    | V    |
| $V_{USDhyst}$    | Undervoltage shutdown hysteresis                                      |                   |      | 0.5  |      | V    |
| $I_{LIM\_H}$     | High-side current limitation                                          |                   | 8    | 12   | 16   | A    |
| $I_{SD\_LS}$     | Shutdown LS current                                                   |                   | 16   | 30   | 52   | A    |
| $V_{CLPH}$       | High-side clamp voltage ( $V_{CC}$ to $OUT_A = 0$ or $OUT_B = 0$ )    | $I_{OUT} = 2.5$ A | 41   | 46   | 52   | V    |
| $V_{CLPLS}$      | Low-side clamp voltage ( $OUT_A = V_{CC}$ or $OUT_B = V_{CC}$ to GND) | $I_{OUT} = 2.5$ A | 41   | 46   | 52   | V    |
| $T_{TSD}^{(1)}$  | Thermal shutdown temperature                                          | $V_{IN} = 2.1$ V  | 150  | 175  | 200  | °C   |
| $T_{TR}^{(2)}$   | Thermal reset temperature                                             |                   | 135  |      |      | °C   |
| $T_{HYST}^{(2)}$ | Thermal hysteresis ( $T_{SD} - T_R$ )                                 |                   |      | 7    |      | °C   |
| $T_{TSD\_LS}$    | Low-side thermal shutdown temperature                                 | $V_{IN} = 2.1$ V  | 150  | 175  | 200  | °C   |
| $V_{CLP}$        | Total clamp voltage ( $V_{CC}$ to GND)                                | $I_{OUT} = 2.5$ A | 41   | 46   | 52   | V    |
| $t_{SD\_LS}$     | Time to shutdown for the low-side                                     |                   |      | 10   |      | μs   |

1.  $T_{TSD}$  is the minimum threshold temperature between HS and LS

2. Valid for both HSD and LSD.

**Table 12. Current sense (9 V <  $V_{CC}$  < 18 V)**

| Symbol           | Parameter                       | Test conditions                                                                    | Min. | Typ. | Max. | Unit |
|------------------|---------------------------------|------------------------------------------------------------------------------------|------|------|------|------|
| $K_0$            | $I_{OUT}/I_{SENSE}$             | $I_{OUT} = 0.35$ A; $V_{SENSE} = 0.32$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C | 645  | 840  | 1140 |      |
| $K_1$            | $I_{OUT}/I_{SENSE}$             | $I_{OUT} = 1$ A; $V_{SENSE} = 0.98$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C    | 700  | 820  | 955  |      |
| $K_2$            | $I_{OUT}/I_{SENSE}$             | $I_{OUT} = 2.5$ A; $V_{SENSE} = 2.4$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C   | 710  | 810  | 900  |      |
| $K_3$            | $I_{OUT}/I_{SENSE}$             | $I_{OUT} = 4$ A; $V_{SENSE} = 4$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C       | 690  | 790  | 900  |      |
| $dK_0/K_0^{(1)}$ | Analog sense current drift      | $I_{OUT} = 0.35$ A; $V_{SENSE} = 0.32$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C | -18  |      | 18   | %    |
| $dK_1/K_1^{(1)}$ | Analog sense current drift      | $I_{OUT} = 1$ A; $V_{SENSE} = 0.98$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C    | -13  |      | 13   | %    |
| $dK_2/K_2^{(1)}$ | Analog sense current drift      | $I_{OUT} = 2.5$ A; $V_{SENSE} = 2.4$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C   | -13  |      | 13   | %    |
| $dK_3/K_3^{(1)}$ | Analog sense current drift      | $I_{OUT} = 4$ A; $V_{SENSE} = 4$ V; $V_{CSD} = 0$ V; $T_j = -40$ to $150$ °C       | -13  |      | 13   | %    |
| $V_{SENSE}$      | Max analog sense output voltage | $I_{OUT} = 2.5$ A; $V_{CSD} = 0$ V; $R_{SENSE} = 2$ kΩ                             | 5    |      |      | V    |

**Table 12. Current sense ( $9\text{ V} < V_{CC} < 18\text{ V}$ ) (continued)**

| Symbol               | Parameter                                           | Test conditions                                                                                                                                                                       | Min. | Typ. | Max. | Unit          |
|----------------------|-----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|---------------|
| $I_{\text{SENSE0}}$  | Analog sense leakage current                        | $I_{\text{OUT}} = 0\text{ A}$ ; $V_{\text{SENSE}} = 0\text{ V}$ ; $V_{\text{CSD}} = 5\text{ V}$ ; $V_{\text{IN}} = 0\text{ V}$ ; $T_j = -40\text{ to }150\text{ }^{\circ}\text{C}$    | 0    |      | 5    | $\mu\text{A}$ |
|                      |                                                     | $V_{\text{CSD}} = 0\text{ V}$ ; $V_{\text{IN}} = 5\text{ V}$ ; $T_j = -40\text{ to }150\text{ }^{\circ}\text{C}$                                                                      | 0    |      | 180  | $\mu\text{A}$ |
|                      |                                                     | $V_{\text{CSD}} = 5\text{ V}$ ; $V_{\text{IN}} = 5\text{ V}$ ; $I_{\text{OUT}} = 2.5\text{ A}$ ; $T_j = -40\text{ to }150\text{ }^{\circ}\text{C}$                                    | 0    |      | 5    | $\mu\text{A}$ |
| $t_{\text{DSENSEH}}$ | Delay response time from falling edge of CS_DIS pin | $V_{\text{IN}} = 5\text{ V}$ ; $V_{\text{SENSE}} < 4\text{ V}$ ; $I_{\text{OUT}} = 2.5\text{ A}$ ; $I_{\text{SENSE}} = 90\%$ of $I_{\text{SENSEmax}}$ (see <a href="#">Figure 8</a> ) |      |      | 50   | $\mu\text{s}$ |
| $t_{\text{DSENSEL}}$ | Delay response time from rising edge of CS_DIS pin  | $V_{\text{IN}} = 5\text{ V}$ ; $V_{\text{SENSE}} < 4\text{ V}$ ; $I_{\text{OUT}} = 2.5\text{ A}$ ; $I_{\text{SENSE}} = 10\%$ of $I_{\text{SENSEmax}}$ (see <a href="#">Figure 8</a> ) |      |      | 20   | $\mu\text{s}$ |

1. Analog sense current drift is deviation of factor K for a given device over  $(-40\text{ }^{\circ}\text{C}$  to  $150\text{ }^{\circ}\text{C}$  and  $9\text{ V} < V_{CC} < 18\text{ V}$ ) with respect to its value measured at  $T_j = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 13\text{ V}$ .

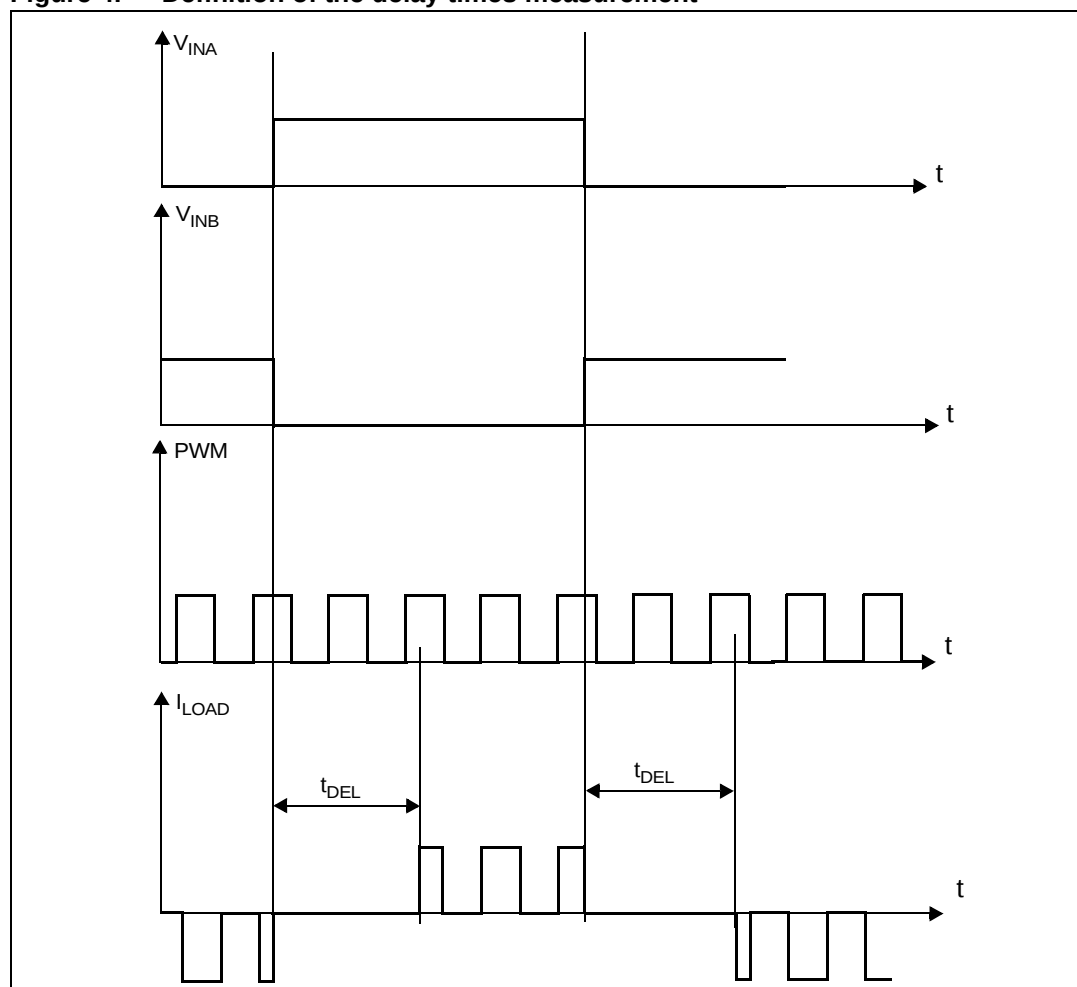
**Figure 4. Definition of the delay times measurement**

Figure 5. Definition of the low-side switching times

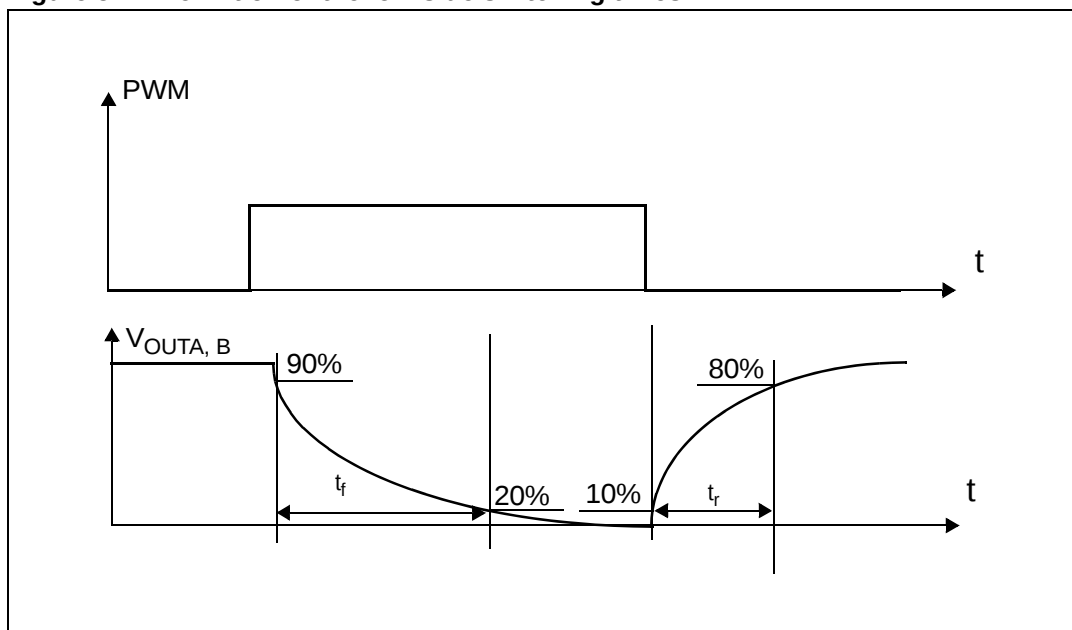


Figure 6. Definition of the high-side switching times

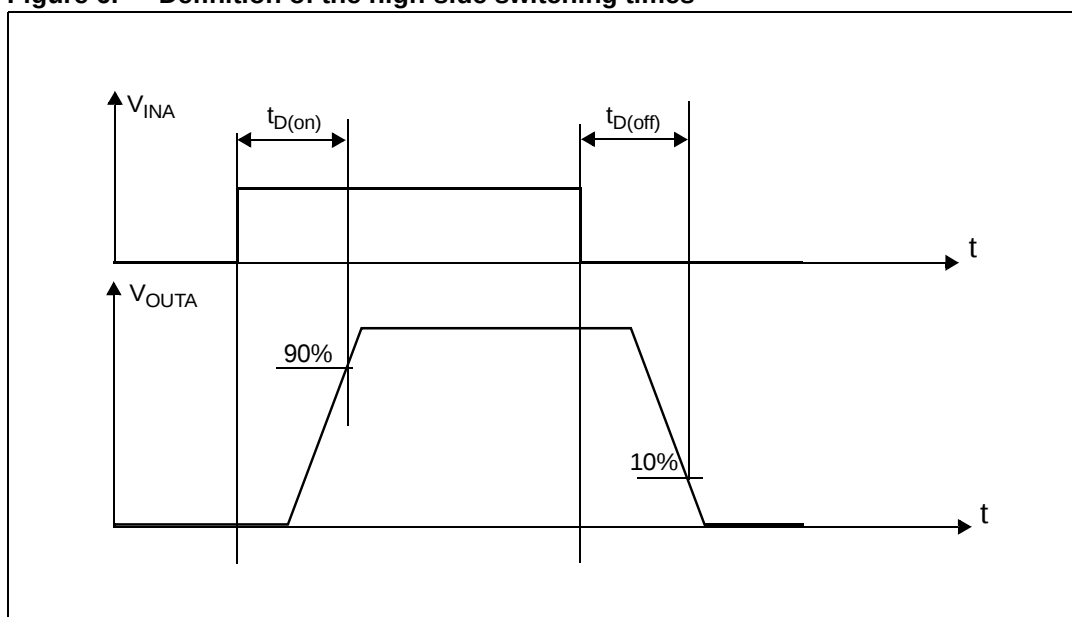


Figure 7. Definition of dynamic cross conduction current during a PWM operation

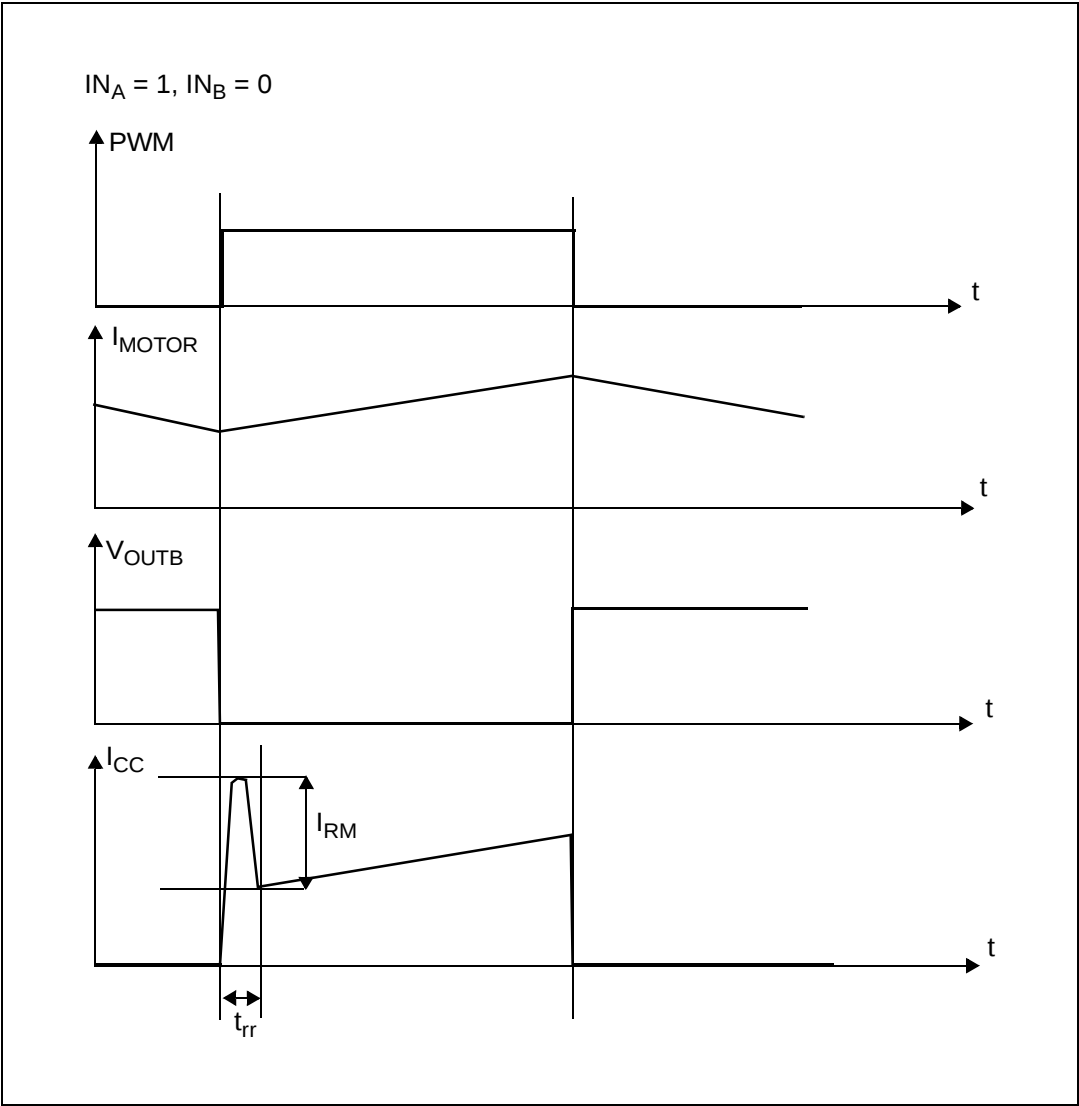
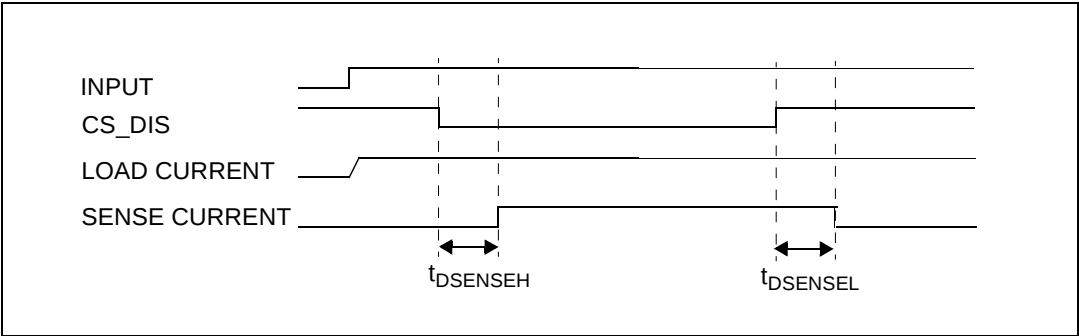


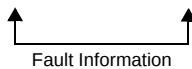
Figure 8. Definition of delay response time of sense current



**Table 13. Truth table in normal operating conditions**

| IN <sub>A</sub> | IN <sub>B</sub> | DIAG <sub>A</sub> /EN <sub>A</sub> | DIAG <sub>B</sub> /EN <sub>B</sub> | OUT <sub>A</sub> | OUT <sub>B</sub> | CS                      | Operating mode           |
|-----------------|-----------------|------------------------------------|------------------------------------|------------------|------------------|-------------------------|--------------------------|
| 1               | 1               | 1                                  | 1                                  | H                | H                | High Imp.               | Brake to V <sub>CC</sub> |
|                 | 0               |                                    |                                    |                  | L                | $I_{SENSE} = I_{OUT}/K$ | Clockwise (CW)           |
| 0               | 1               |                                    |                                    | L                | H                |                         | Counterclockwise (CCW)   |
|                 | 0               |                                    |                                    |                  | L                | High Imp.               | Brake to GND             |

**Table 14. Truth table in fault conditions (detected on OUT<sub>A</sub>)**

| IN <sub>A</sub>                                                                                                                                                                                                                                      | IN <sub>B</sub> | DIAG <sub>A</sub> /EN <sub>A</sub> | DIAG <sub>B</sub> /EN <sub>B</sub> | OUT <sub>A</sub> | OUT <sub>B</sub> | CS (V <sub>CSD</sub> =0V) |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------------------|------------------------------------|------------------|------------------|---------------------------|
| 1                                                                                                                                                                                                                                                    | 1               | 0                                  | 1                                  | OPEN             | H                | High Imp.                 |
|                                                                                                                                                                                                                                                      | 0               |                                    |                                    |                  | L                |                           |
| 0                                                                                                                                                                                                                                                    | 1               |                                    |                                    |                  | H                | I <sub>OUTB</sub> /K      |
|                                                                                                                                                                                                                                                      | 0               |                                    |                                    |                  | L                | High Imp.                 |
| X                                                                                                                                                                                                                                                    | X               |                                    | 0                                  |                  | OPEN             |                           |
| <div><div><p>Fault Information</p></div><div><p>Protection Action</p></div></div> |                 |                                    |                                    |                  |                  |                           |

*Note:* In normal operating conditions the DIAG<sub>X</sub>/EN<sub>X</sub> pin is considered as an input pin by the device. This pin must be externally pulled high.

**Table 15. Electrical transient requirements (part 1)**

| ISO 7637-2:<br>2004(E)<br>Test pulse | Test levels <sup>(1)</sup> |       | Number of<br>pulses or<br>test times | Burst cycle/pulse<br>repetition time |       | Delays and<br>Impedance |
|--------------------------------------|----------------------------|-------|--------------------------------------|--------------------------------------|-------|-------------------------|
|                                      | III                        | IV    |                                      | Min.                                 | Max.  |                         |
| 1                                    | -75V                       | -100V | 5000 pulses                          | 0.5s                                 | 5s    | 2 ms, 10Ω               |
| 2a                                   | +37V                       | +50V  | 5000 pulses                          | 0.2s                                 | 5s    | 50μs, 2Ω                |
| 3a                                   | -100V                      | -150V | 1h                                   | 90ms                                 | 100ms | 0.1μs, 50Ω              |
| 3b                                   | +75V                       | +100V | 1h                                   | 90ms                                 | 100ms | 0.1μs, 50Ω              |
| 4                                    | -6V                        | -7V   | 1 pulse                              |                                      |       | 100ms, 0.01Ω            |
| 5b <sup>(2)</sup>                    | +65V                       | +87V  | 1 pulse                              |                                      |       | 400ms, 2Ω               |

1. The above test levels must be considered referred to  $V_{CC} = 13.5$  V except for pulse 5b.

2. Valid in case of external load dump clamp: 40V maximum referred to ground.

**Table 16. Electrical transient requirements (part 2)**

| ISO 7637-2:<br>2004(E)<br>Test pulse | Test level results <sup>(1)</sup> |    |
|--------------------------------------|-----------------------------------|----|
|                                      | III                               | IV |
| 1                                    | C                                 | C  |
| 2a                                   | C                                 | C  |
| 3a                                   | C                                 | C  |
| 3b                                   | C                                 | C  |
| 4                                    | C                                 | C  |
| 5b <sup>(2)</sup>                    | C                                 | C  |

1. The above test levels must be considered referred to  $V_{CC} = 13.5$  V except for pulse 5b.

2. Valid in case of external load dump clamp: 40V maximum referred to ground.

**Table 17. Electrical transient requirements (part 3)**

| Class | Contents                                                                                                                                                                 |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| C     | All functions of the device are performed as designed after exposure to disturbance.                                                                                     |
| E     | One or more functions of the device are not performed as designed after exposure to disturbance and cannot be returned to proper operation without replacing the device. |

## 2.4 Waveforms

Figure 9. Waveforms in full-bridge operation

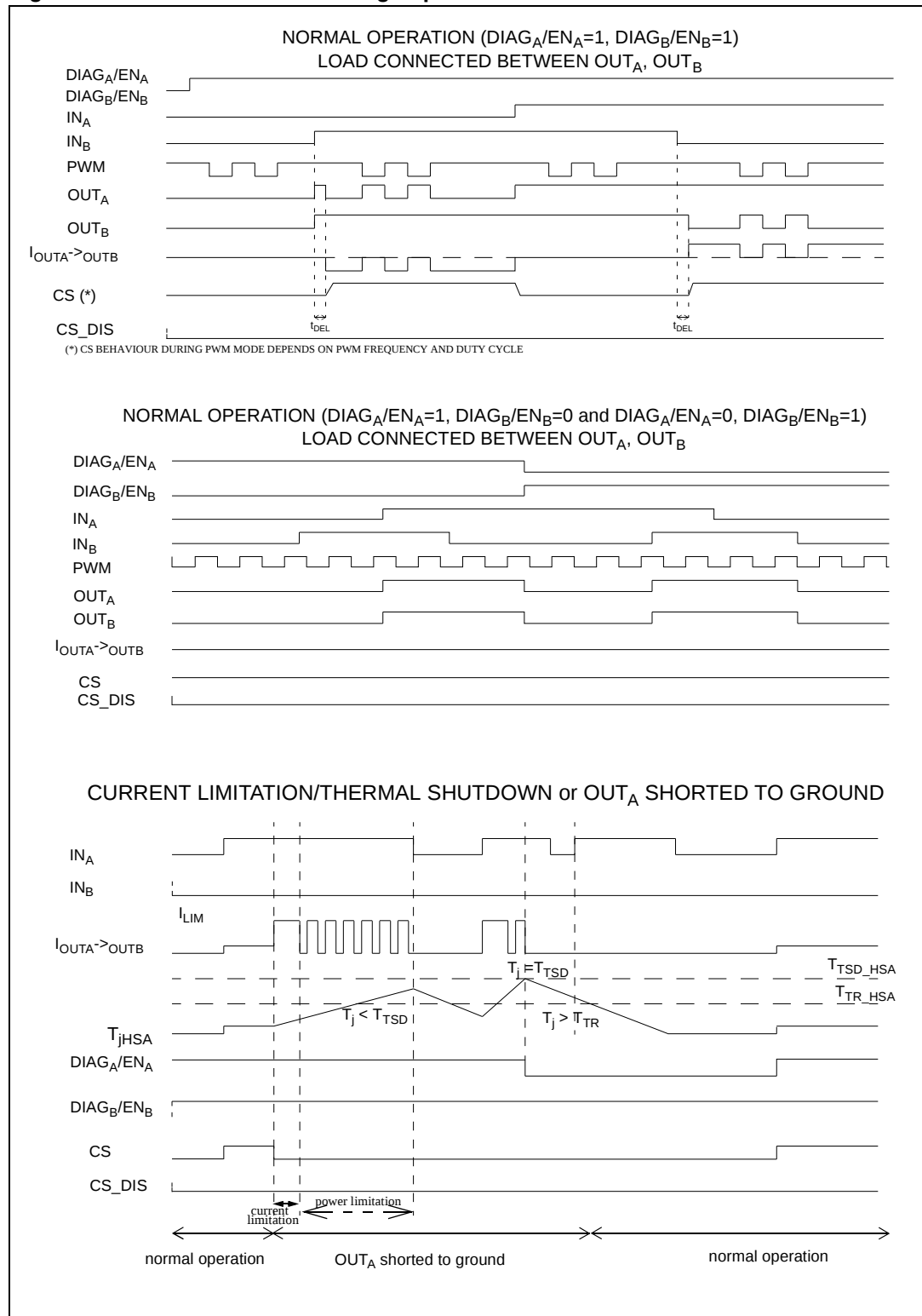
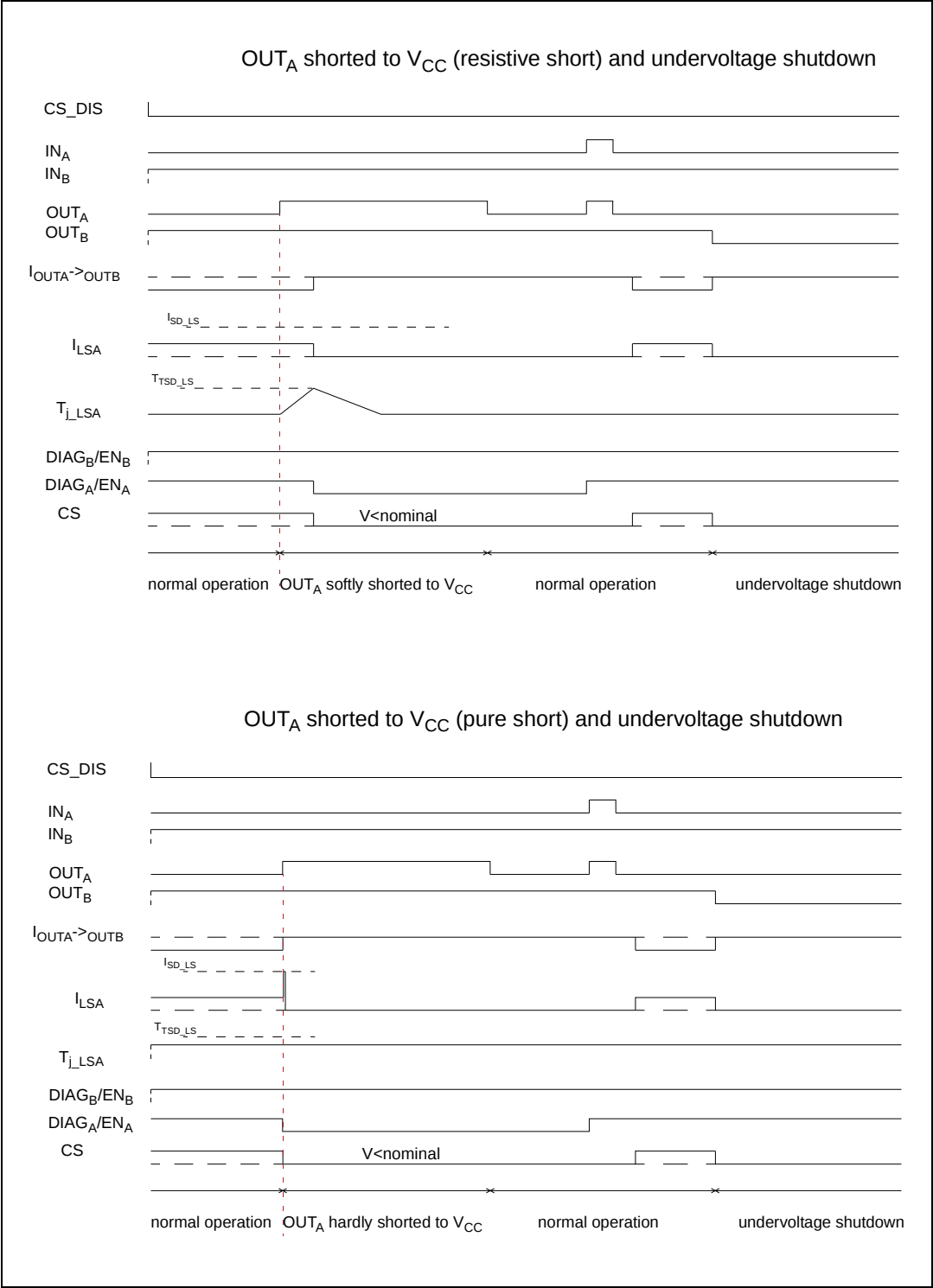


Figure 10. Waveforms in full-bridge operation (continued)

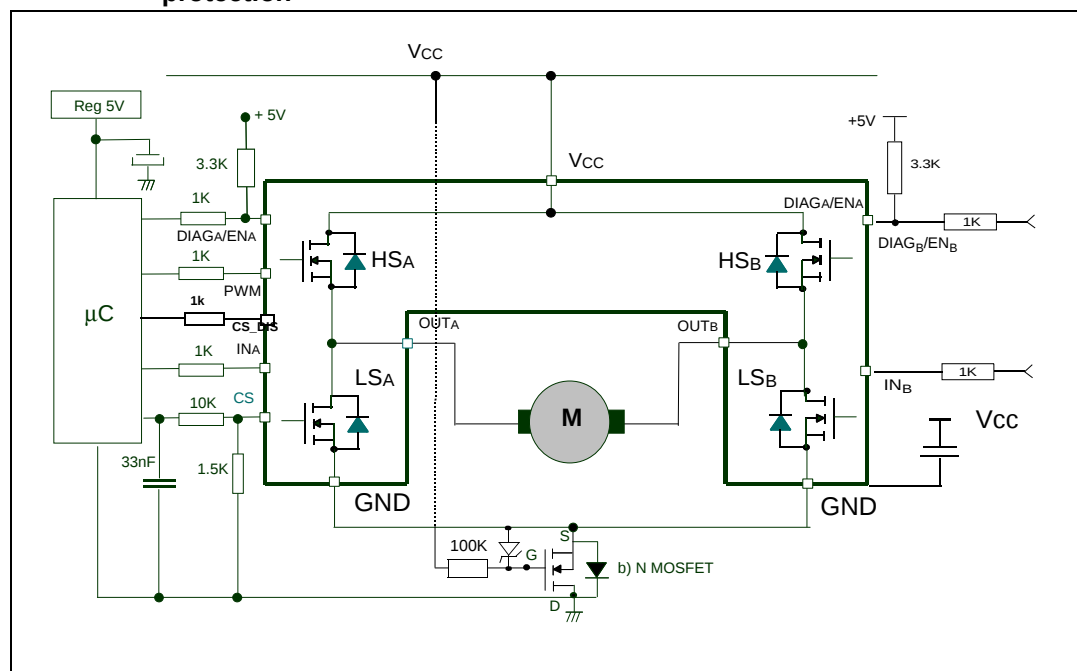


### 3 Application information

In normal operating conditions the DIAG<sub>X</sub>/EN<sub>X</sub> pin is considered as an input pin by the device. This pin must be externally pulled high.

PWM pin usage: In all cases, a “0” on the PWM pin turns off both LS<sub>A</sub> and LS<sub>B</sub> switches. When PWM rises back to “1”, LS<sub>A</sub> or LS<sub>B</sub> turn on again depending on the input pin state.

**Figure 11. Typical application circuit for DC to 20 kHz PWM operation short circuit protection**



*Note:*

*The value of the blocking capacitor (C) depends on the application conditions and defines voltage and current ripple on supply line at PWM operation. Stored energy of the motor inductance may fly back into the blocking capacitor, if the bridge driver goes into 3-state. This causes a hazardous overvoltage if the capacitor is not big enough. As basic orientation, 500  $\mu$ F per 10 A load current is recommended.*

In case of a fault condition the DIAG<sub>x</sub>/EN<sub>x</sub> pin is considered as an output pin by the device.

The fault conditions are:

- Overtemperature on one or both high-sides
- Short to battery condition on the output (overcurrent detection on the low-side Power MOSFET)

Possible origins of fault conditions may be:

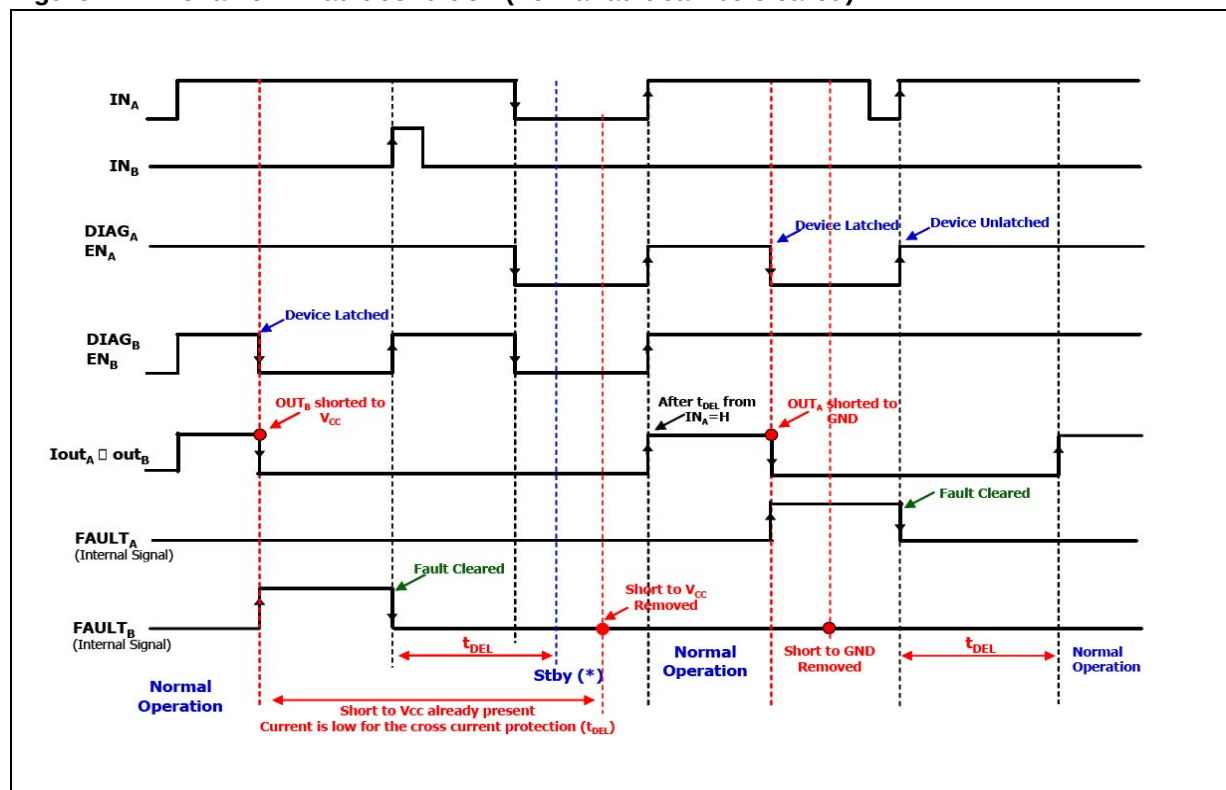
OUT<sub>A</sub> is shorted to ground → overtemperature detection on high-side A

OUT<sub>A</sub> is shorted to V<sub>CC</sub> → low-side Power MOSFET overcurrent detection

When a fault condition is detected, the user can identify which power element is in fault by monitoring the IN<sub>A</sub>, IN<sub>B</sub>, DIAG<sub>A</sub>/EN<sub>A</sub> and DIAG<sub>B</sub>/EN<sub>B</sub> pins.

In any case, when a fault is detected, the faulty leg of the bridge is latched off. To turn on the respective output ( $OUT_x$ ) again, the input signal must rise from low to high level.

**Figure 12. Behavior in fault condition (how a fault can be cleared)**



**Note:** In case of the fault condition is not removed, the procedure for unlatching and sending the device in Stby mode is:

- Clear the fault in the device (toggle:  $IN_A$  if  $EN_A = 0$  or  $IN_B$  if  $EN_B = 0$ )
- Pull low all inputs, PWM and Diag/EN pins within  $t_{DEL}$ .

If the Diag/En pins are already low, PWM = 0, the fault can be cleared simply toggling the input. The device enters in stby mode as soon as the fault is cleared.

### 3.1 Reverse battery protection

Three possible solutions can be considered:

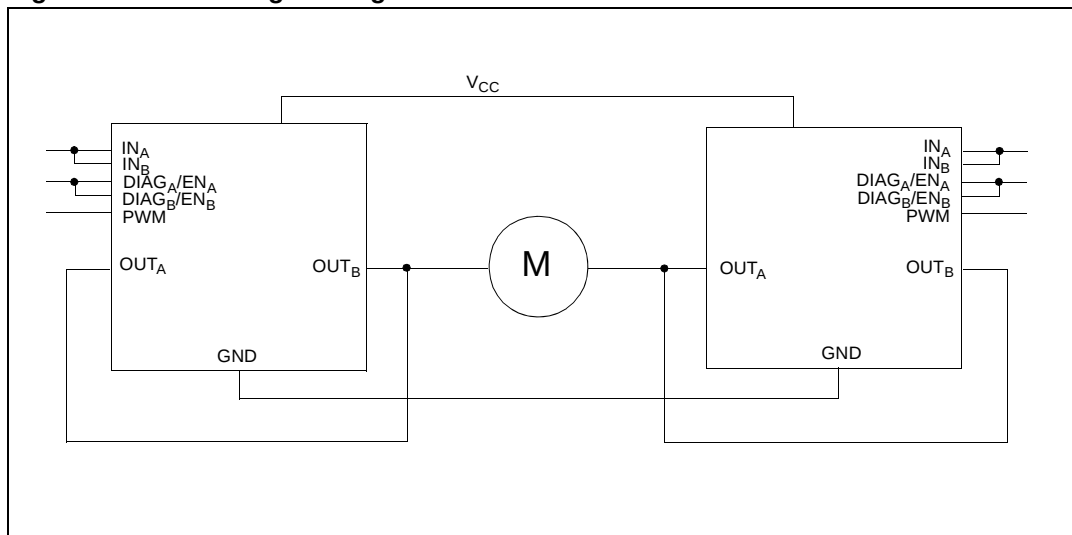
- A Schottky diode D connected to  $V_{CC}$  pin
- An N-channel MOSFET connected to the GND pin (see [Figure 11: Typical application circuit for DC to 20 kHz PWM operation short circuit protection](#))
- A P-channel MOSFET connected to the  $V_{CC}$  pin

The device sustains no more than -15 A in reverse battery conditions because of the two Body diodes of the Power MOSFETs. Additionally, in reverse battery condition the I/Os of VNH5180A-E is pulled down to the  $V_{CC}$  line (approximately -1.5 V).

Series resistor must be inserted to limit the current sunk from the microcontroller I/Os. If  $I_{Rmax}$  is the maximum target reverse current through microcontroller I/Os, series resistor is:

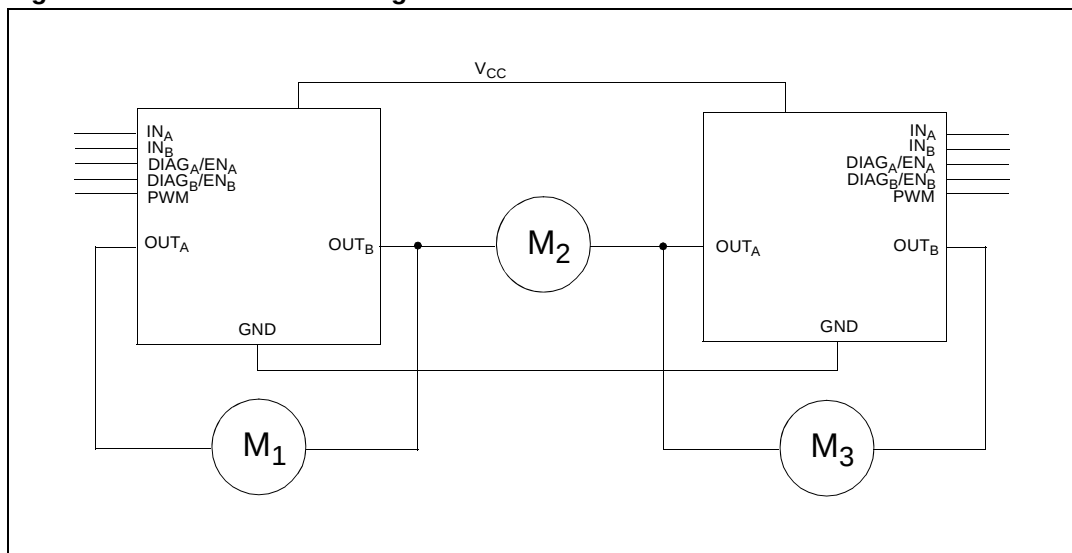
$$R = \frac{V_{IOs} - V_{CC}}{I_{Rmax}}$$

**Figure 13. Half-bridge configuration**



**Note:** The VNH5180A-E can be used as a high power half-bridge driver achieving an On resistance per leg of 90 mΩ.

**Figure 14. Multi-motors configuration**



**Note:** The VNH5180A-E can easily be designed in multi-motors driving applications such as seat positioning systems where only one motor must be driven at a time.  $DIAG_X/EN_X$  pins allow to put unused half-bridges in high impedance.

## 4 Package and PCB thermal data

### 4.1 PowerSSO-36 thermal data

Figure 15. PowerSSO-36™ PC board

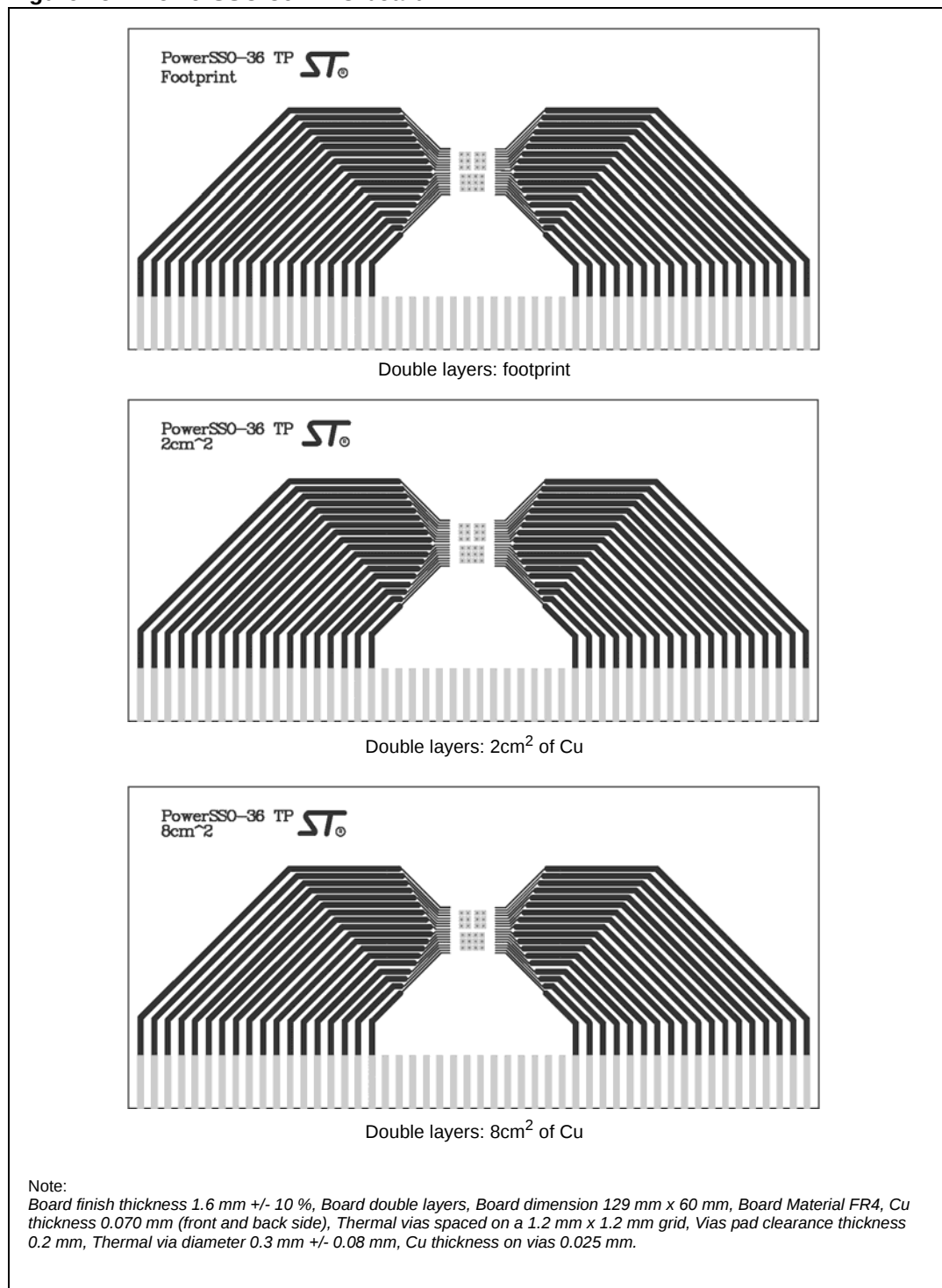


Figure 16. Chipset configuration

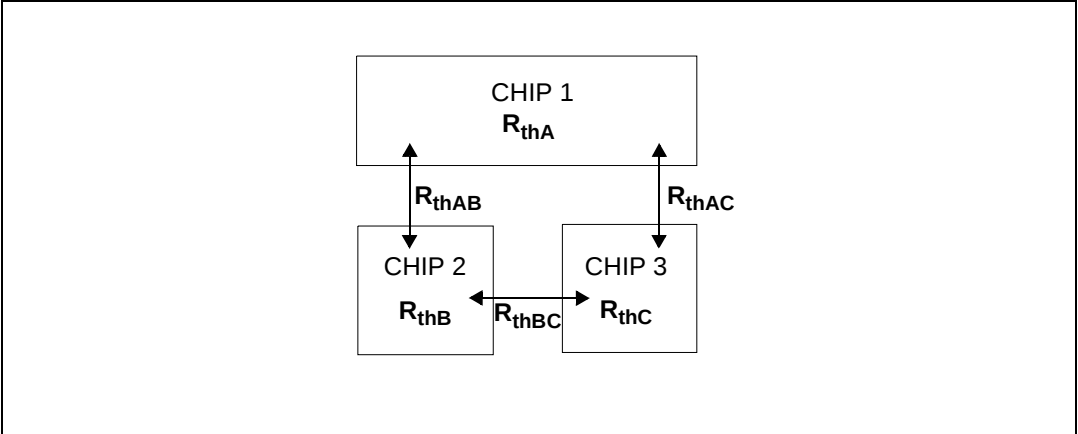
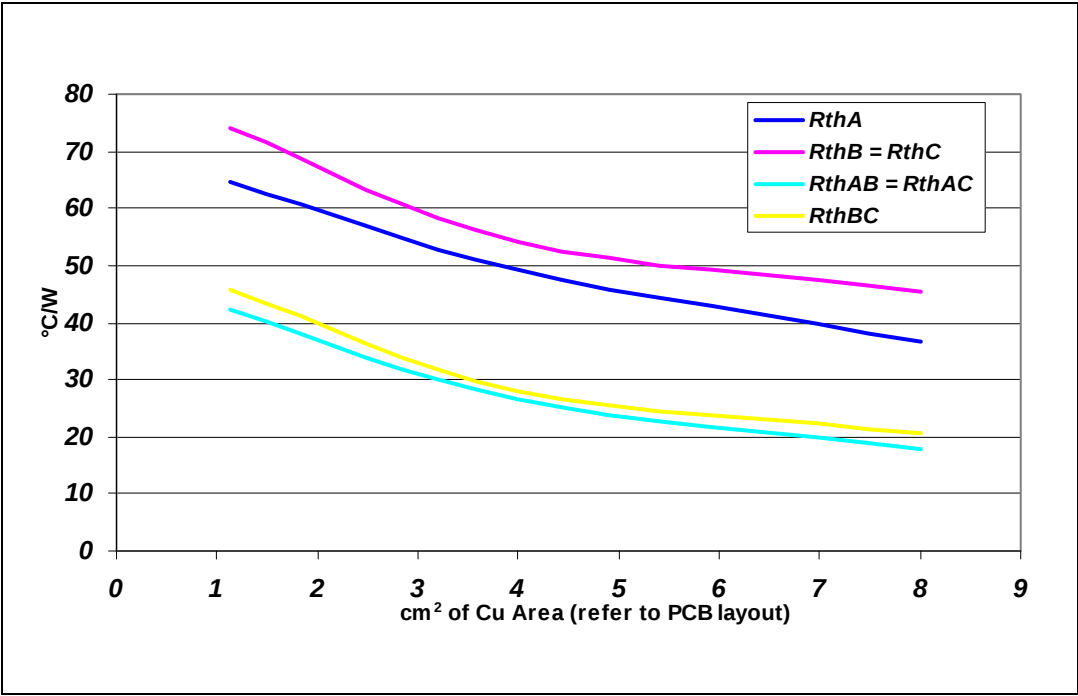


Figure 17. Auto and mutual  $R_{thj-amb}$  vs PCB copper area in open box free air condition



#### 4.1.1 Thermal calculation in clockwise and anti-clockwise operation in steady-state mode

Table 18. Thermal calculation in clockwise and anti-clockwise operation in steady-state mode

| HS <sub>A</sub> | HS <sub>B</sub> | LS <sub>A</sub> | LS <sub>B</sub> | T <sub>jHSAB</sub>                                               | T <sub>jLSA</sub>                                                  | T <sub>jLSB</sub>                                                  |
|-----------------|-----------------|-----------------|-----------------|------------------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------------------|
| ON              | OFF             | OFF             | ON              | $P_{dHSA} \times R_{thHS} + P_{dLSB} \times R_{thHLS} + T_{amb}$ | $P_{dHSA} \times R_{thHLS} + P_{dLSB} \times R_{thLSLS} + T_{amb}$ | $P_{dHSA} \times R_{thHLS} + P_{dLSB} \times R_{thLS} + T_{amb}$   |
| OFF             | ON              | ON              | OFF             | $P_{dHSB} \times R_{thHS} + P_{dLSA} \times R_{thHLS} + T_{amb}$ | $P_{dHSB} \times R_{thHLS} + P_{dLSA} \times R_{thLS} + T_{amb}$   | $P_{dHSB} \times R_{thHLS} + P_{dLSA} \times R_{thLSLS} + T_{amb}$ |

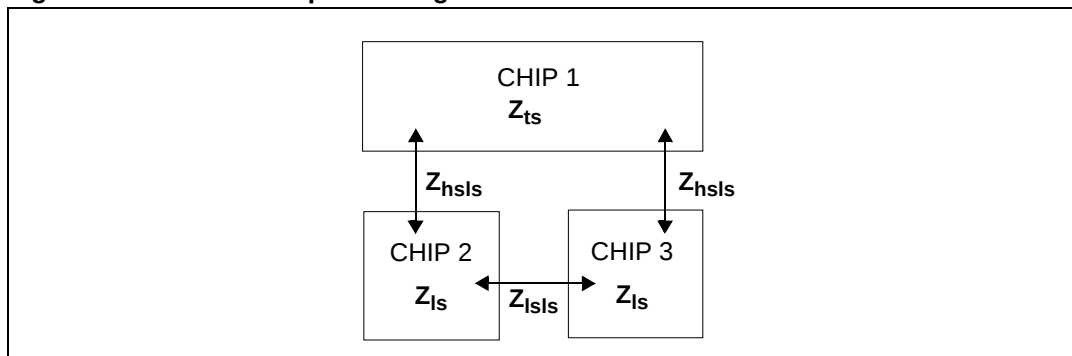
### 4.1.2 Thermal calculation in transient mode

$$T_{hs} = P_{dhs} \cdot Z_{hs} + Z_{hsIs} \cdot (P_{dIsA} + P_{dIsB}) + T_{amb}$$

$$T_{IsA} = P_{dIsA} \cdot Z_{Is} + P_{dhs} \cdot Z_{hsIs} + P_{dIsB} \cdot Z_{hsIs} + T_{amb}$$

$$T_{IsB} = P_{dIsB} \cdot Z_{Is} + P_{dhs} \cdot Z_{hsIs} + P_{dIsA} \cdot Z_{hsIs} + T_{amb}$$

**Figure 18. Detailed chipset configuration**



#### Equation 1: pulse calculation formula

$$Z_{TH\delta} = R_{TH} \cdot \delta + Z_{THtp}(1 - \delta)$$

where

$$\delta = t_p / T$$

Figure 19. PowerSSO-36 HSD thermal impedance junction ambient single pulse

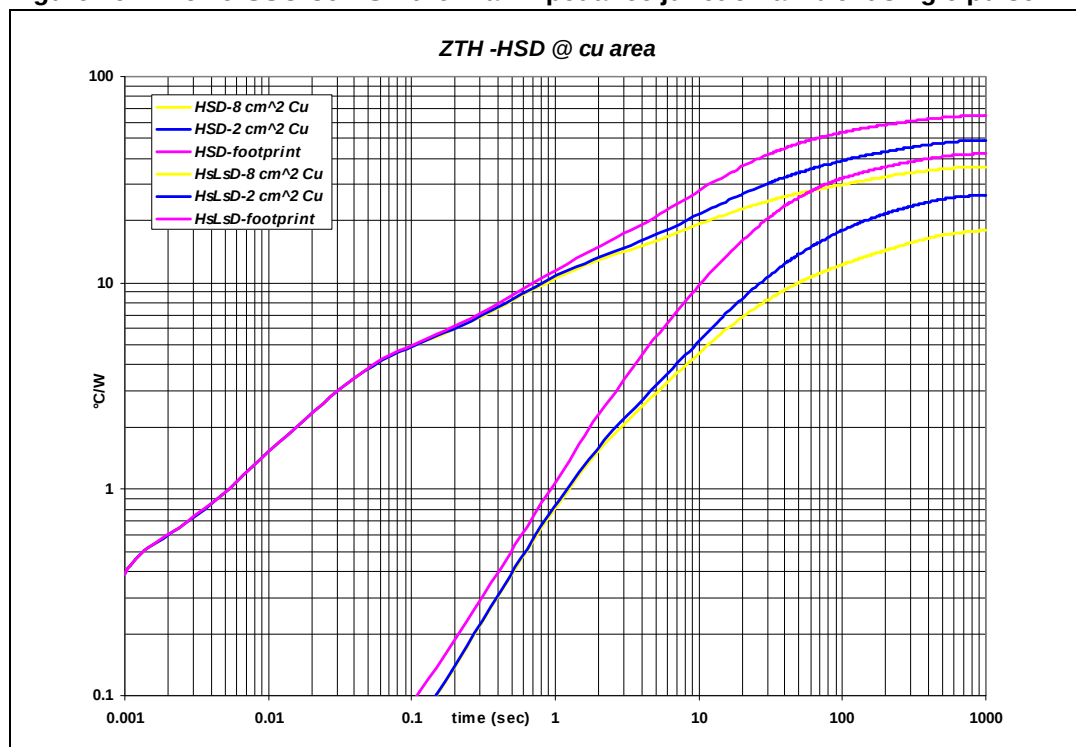


Figure 20. PowerSSO-36 LSD thermal impedance junction ambient single pulse

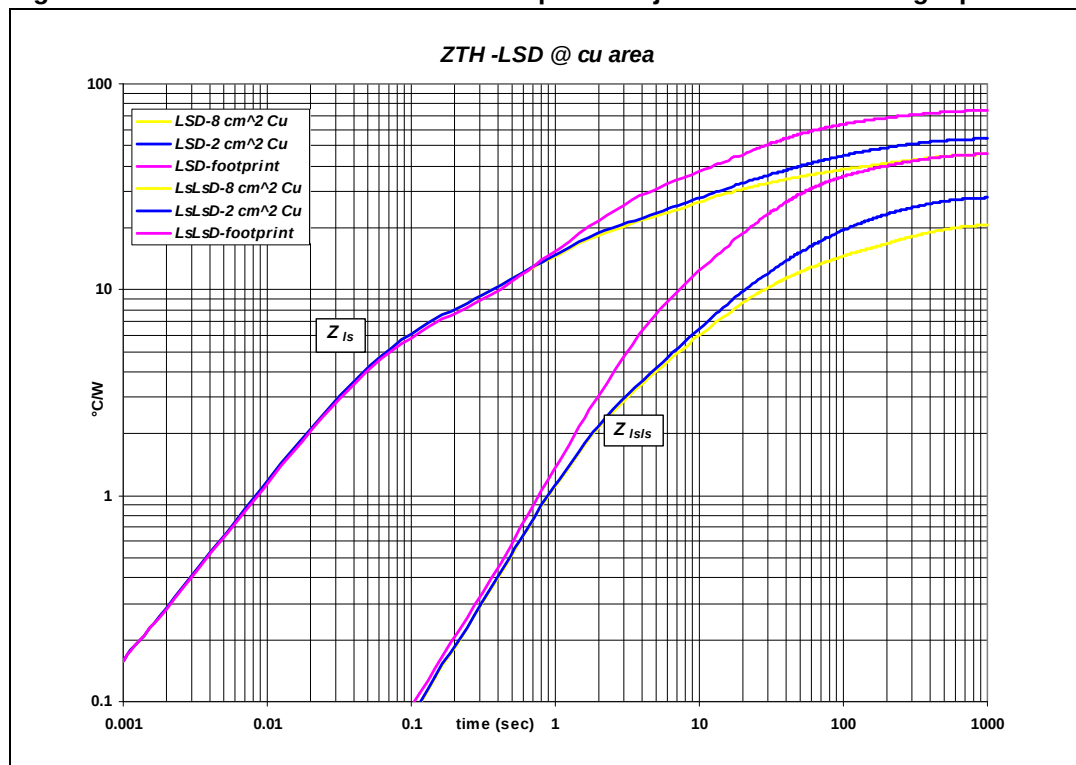
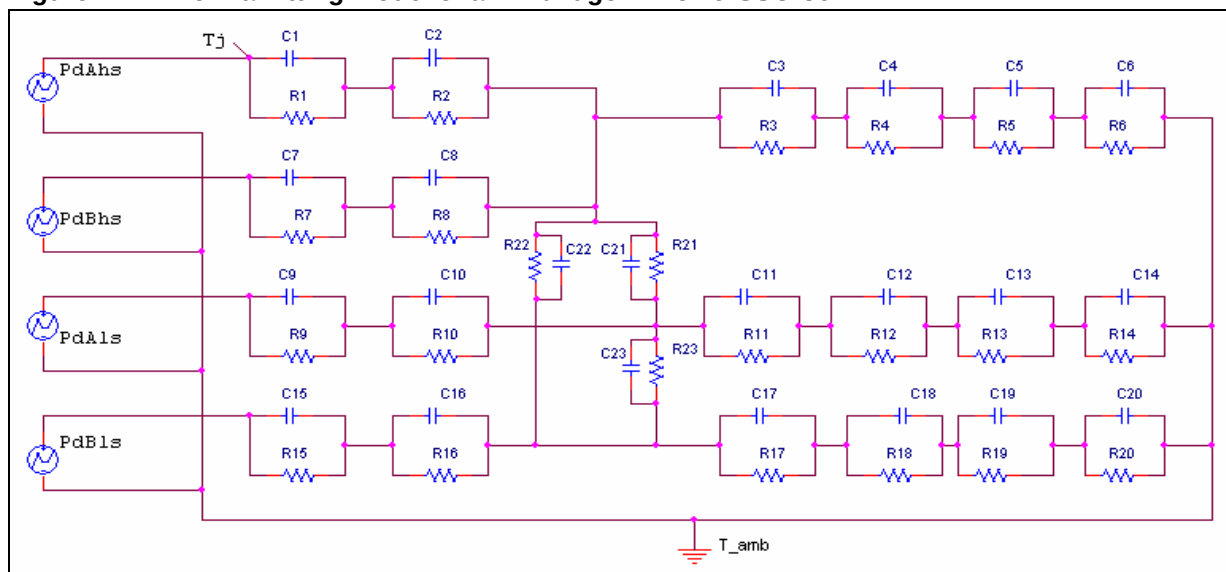


Figure 21. Thermal fitting model of an H-bridge in PowerSSO-36

Table 19. Thermal parameters<sup>(1)</sup>

| Area/island (cm <sup>2</sup> ) | Footprint | 2     | 8     |
|--------------------------------|-----------|-------|-------|
| R1 = R7 (°C/W)                 | 0.4       |       |       |
| R2 = R8 (°C/W)                 | 3.5       |       |       |
| R3 (°C/W)                      | 8         |       |       |
| R4 (°C/W)                      | 30        | 16    | 11    |
| R5 (°C/W)                      | 40        | 30    | 14    |
| R6 (°C/W)                      | 36        | 34    | 21    |
| R9 = R15 (°C/W)                | 0.1       |       |       |
| R10 = R16 (°C/W)               | 5.2       |       |       |
| R11 = R17 (°C/W)               | 32        | 14    | 14    |
| R12 = R18 (°C/W)               | 49        | 21    | 21    |
| R13 = R19 (°C/W)               | 52        | 36    | 24    |
| R14 = R20 (°C/W)               | 50        | 40    | 33    |
| R21 = R22 = R23 (°C/W)         | 80        | 77    | 75    |
| C1 = C7 = C9 = C15 (W.s/°C)    | 0.0005    |       |       |
| C2 = C8 (W.s/°C)               | 0.008     |       |       |
| C3 (W.s/°C)                    | 0.09      |       |       |
| C4 (W.s/°C)                    | 0.5       | 0.8   | 0.8   |
| C5 (W.s/°C)                    | 0.8       | 1.4   | 2     |
| C6 (W.s/°C)                    | 7         | 8     | 10    |
| C10 = C16 (W.s/°C)             | 0.009     |       |       |
| C11 = C17 (W.s/°C)             | 0.09      | 0.07  | 0.07  |
| C12 = C18 (W.s/°C)             | 0.45      | 0.45  | 0.45  |
| C13 = C19 (W.s/°C)             | 0.8       | 1.2   | 1.4   |
| C14 = C20 (W.s/°C)             | 4         | 5     | 8     |
| C21 = C22 = C23 (W.s/°C)       | 0.005     | 0.003 | 0.003 |

1. The blank space means that the value is the same as the previous one.

## 5 Package and packing information

### 5.1 ECOPACK®

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com).

ECOPACK® is an ST trademark.

### 5.2 PowerSSO-36 TP package information

Figure 22. PowerSSO-36 TP package dimensions

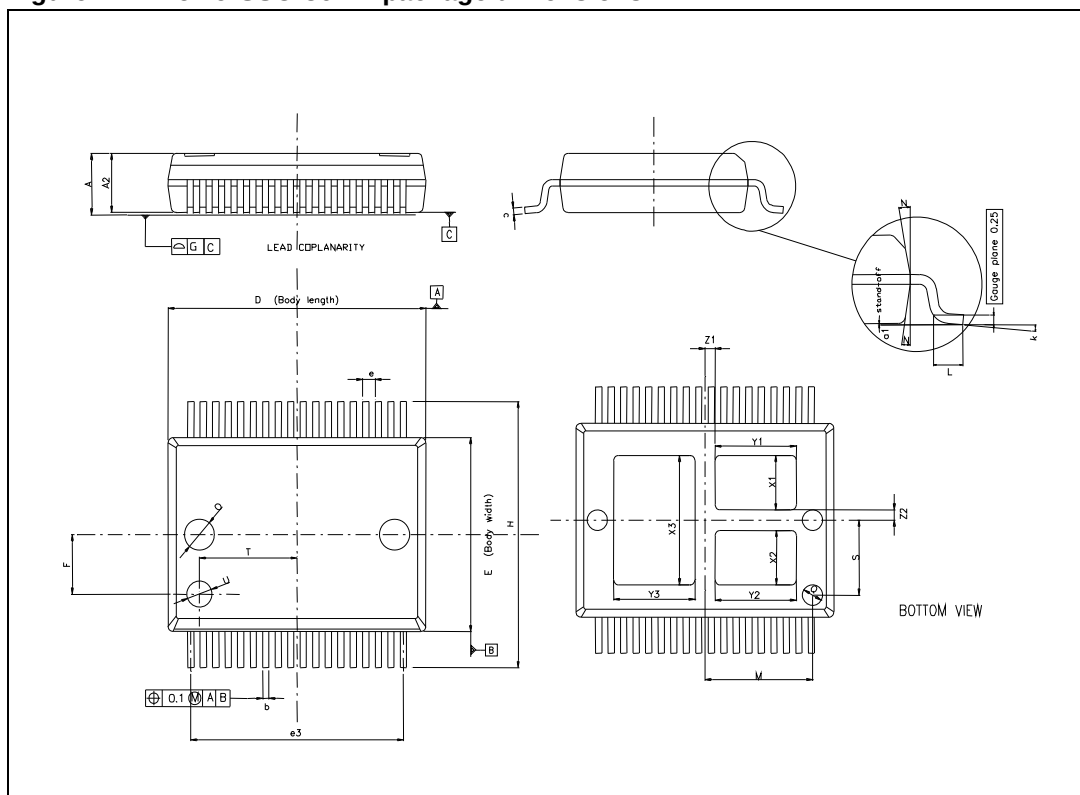


Table 20. PowerSSO-36 TP mechanical data

| Symbol | Millimeters |      |        |
|--------|-------------|------|--------|
|        | Min.        | Typ. | Max.   |
| A      | 2.15        | -    | 2.47   |
| A2     | 2.15        | -    | 2.40   |
| a1     | 0           | -    | 0.1    |
| b      | 0.18        | -    | 0.36   |
| c      | 0.23        | -    | 0.32   |
| D      | 10.10       | -    | 10.50  |
| E      | 7.4         | -    | 7.6    |
| e      | -           | 0.5  | -      |
| e3     | -           | 8.5  | -      |
| F      |             | 2.3  |        |
| G      | -           | -    | 0.1    |
| H      | 10.1        | -    | 10.5   |
| h      | -           | -    | 0.4    |
| k      | 0 deg       |      | 8 deg  |
| L      | 0.6         | -    | 1      |
| M      |             | 4.3  |        |
| N      | -           | -    | 10 deg |
| O      |             | 1.2  |        |
| Q      |             | 0.8  |        |
| S      |             | 2.9  |        |
| T      |             | 3.65 |        |
| U      |             | 1.0  |        |
| X1     | 1.85        |      | 2.35   |
| Y1     | 3           |      | 3.5    |
| X2     | 1.85        |      | 2.35   |
| Y2     | 3           |      | 3.5    |
| X3     | 4.7         | -    | 5.2    |
| Y3     | 3           | -    | 3.5    |
| Z1     |             | 0.4  |        |
| Z2     |             | 0.4  |        |

### 5.3 PowerSSO-36 TP packing information

Figure 23. PowerSSO-36 TP tube shipment (no suffix)

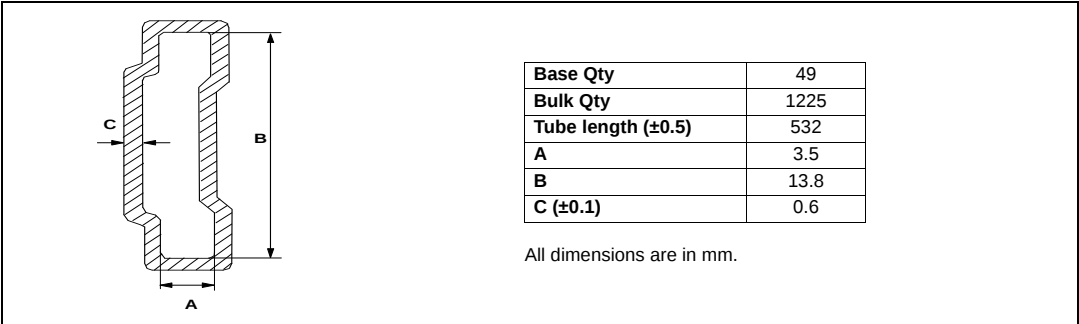
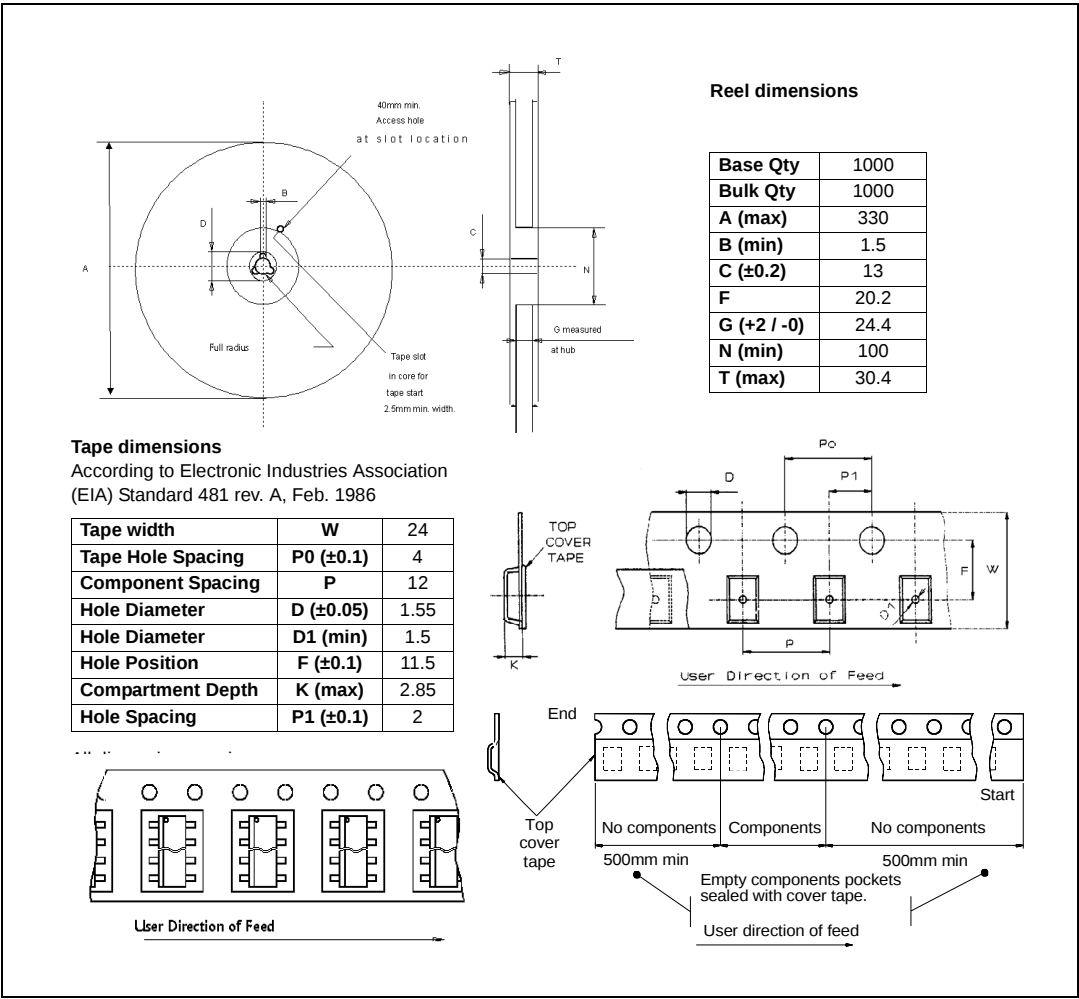


Figure 24. PowerSSO-36 TP tape and reel shipment (suffix “TR”)



## 6 Revision history

**Table 21. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11-Feb-2010 | 1        | Initial release.                                                                                                                                                                                                                                                                                                                                                                                               |
| 28-Sep-2010 | 2        | Updated following tables:<br>– <a href="#">Table 7: Thermal data</a><br>– <a href="#">Table 8: Power section</a><br>– <a href="#">Table 12: Current sense (<math>9\text{ V} &lt; V_{CC} &lt; 18\text{ V}</math>)</a>                                                                                                                                                                                           |
| 13-Oct-2010 | 3        | Updated <a href="#">Chapter 3: Application information</a><br>Updated following tables:<br>– <a href="#">Table 18: Thermal calculation in clockwise and anti-clockwise operation in steady-state mode</a><br>– <a href="#">Table 19: Thermal parameters</a>                                                                                                                                                    |
| 20-Oct-2010 | 4        | Changed document status from target specification to definitive datasheet                                                                                                                                                                                                                                                                                                                                      |
| 22-Dec-2011 | 5        | Updated <a href="#">Figure 1: Block diagram</a><br>Added <a href="#">Table 3: Suggested connections for unused and not connected pins</a><br><a href="#">Table 11: Protections and diagnostics</a> :<br>– $T_{TSD}$ , $T_{TR}$ , $T_{HYST}$ : added note<br>Updated <a href="#">Figure 9: Waveforms in full-bridge operation</a> and <a href="#">Figure 10: Waveforms in full-bridge operation (continued)</a> |
| 19-Sep-2013 | 6        | Updated Disclaimer.                                                                                                                                                                                                                                                                                                                                                                                            |

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