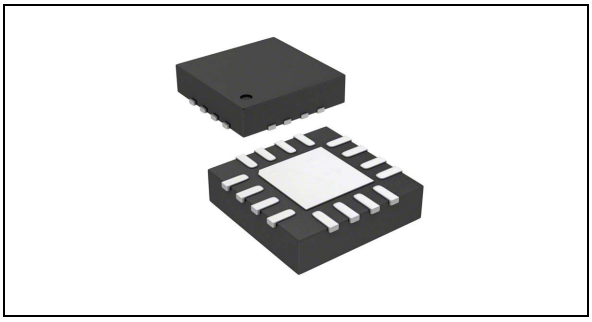
# STSPIN250

## Low voltage brush DC motor driver

**Datasheet - production data**



## Features

- Operating voltage from 1.8 to 10 V
- Maximum output current 2.6 $A_{rms}$ with OUTAx paralled to OUTBx
- $R_{DS(ON)}$ HS + LS = 0.2 Ω typ.
- Current control with programmable off-time
- Full protection set
  - Non-dissipative overcurrent protection
  - Short-circuit protection
  - Thermal shutdown
- Energy saving and long battery life with standby consumption less than 80 nA

## Applications

Battery-powered DC motor applications such as:

- Toys
- Portable printers
- Robotics
- Point of sales (POS) devices
- Portable medical equipment
- Healthcare and wellness devices (shavers and toothbrushes)

## Description

The STSPIN250 is a single brush DC motor driver integrating a low $R_{ds(ON)}$ power stage in a small VFQFPN 3 x 3 mm package.

The full-bridge implements a PWM current controller with fixed OFF time.

The device is designed to operate in battery-powered scenarios and can be forced in a zero-consumption state allowing a significant increase in battery life.

The device offers a complete set of protection features including overcurrent, overtemperature and short-circuit protection.

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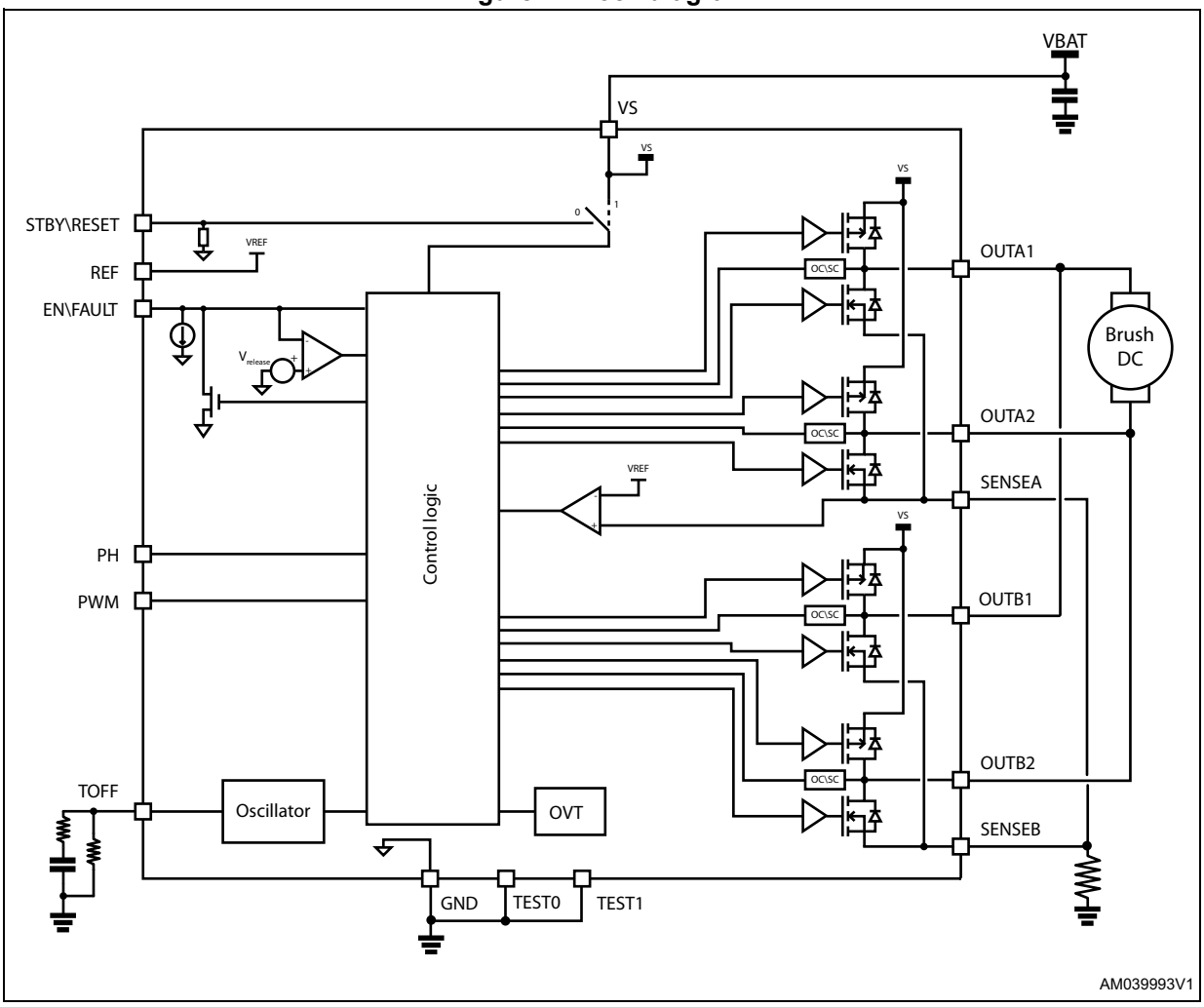
# 1 Block diagram

**Figure 1. Block diagram**



# 2 Electrical data

## 2.1 Absolute maximum ratings

**Table 1. Absolute maximum ratings**

| Symbol | Parameter | Test condition | Value | Unit |
|---|---|---|---|---|
| $V_S$ | Supply voltage | - | -0.3 to 11 | V |
| $V_{IN}$ | Logic input voltage | - | -0.3 to 5.5 | V |
| $V_{OUT}$ - $V_{SENSE}$ | Output to sense voltage drop | - | up to 12 | V |
| $V_S$ - $V_{OUT}$ | Supply to output voltage drop | - | up to 12 | V |
| $V_{SENSE}$ | Sense pins voltage | - | -1 to 1 | V |
| $V_{REF}$ | Reference voltage input | - | -0.3 to 1 | V |
| $I_{OUT,RMS}$ | Continuous power stage output current (OUTAx // OUTBx) | - | 2.6 | Arms |
| $T_{j,OP}$ | Operative junction temperature | - | -40 to 150 | °C |
| $T_{j,STG}$ | Storage junction temperature | - | -55 to 150 | °C |

## 2.2 Recommended operating conditions

**Table 2. Recommended operating conditions**

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_S$ | Supply voltage | - | 1.8 | - | 10 | V |
| $V_{IN}$ | Logic input voltage | - | 0 | - | 5 | V |
| $V_{REF}$ | Reference voltage input | - | 0.1 | - | 0.5 | V |
| $t_{INw}$ | Logic input positive/negative pulse width | - | 300 | - | - | ns |

## 2.3 Thermal data

**Table 3. Thermal data**

| Symbol | Parameter | Conditions | Value | Unit |
|---|---|---|---|---|
| $R_{thJA}$ | Junction to ambient thermal resistance | Natural convection, according to JESD51-2A(1) | 57.1 | °C/W |
| $R_{thJCtop}$ | Junction to case thermal resistance (top side) | Simulation with cold plate on package top | 67.3 | °C/W |
| $R_{thJCbot}$ | Junction to case thermal resistance (bottom side) | Simulation with cold plate on exposed pad | 9.1 | °C/W |
| $R_{thJB}$ | Junction to board thermal resistance | According to JESD51-8(1) | 23.3 | °C/W |
| $\Psi_{JT}$ | Junction to top characterization | According to JESD51-2A(1) | 3.3 | °C/W |
| $\Psi_{JB}$ | Junction to board characterization | According to JESD51-2A(1) | 22.6 | °C/W |

1. Simulated on a 21.2 x 21.2 mm board, 2s2p 1 Oz copper and four 300 µm via below exposed pad.

## 2.4 ESD protections

**Table 4. ESD protection ratings**

| Symbol | Parameter | Test condition | Class | Value | Unit |
|---|---|---|---|---|---|
| HBM | Human body model | Conforming to ANSI/ESDA/JEDEC JS-001-2014 | H2 | 2 | kV |
| CDM | Charge device model | Conforming to ANSI/ESDA/JEDEC JS-001-2014 | C2a | 500 | V |

# 3 Electrical characteristics

Testing conditions: $V_S$ = 5 V, $T_j$ = 25 °C, unless otherwise specified.

**Table 5. Electrical characteristics**

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Supply** | | | | | | |
| $V_{Sth(ON)}$ | $V_S$ turn-on voltage | $V_S$ rising from 0 V | 1.45 | 1.65 | 1.79 | V |
| $V_{Sth(OFF)}$ | $V_S$ turn-off voltage | $V_S$ falling from 5 V | 1.3 | 1.45 | 1.65 | V |
| $V_{Sth(HYS)}$ | $V_S$ hysteresis voltage | - | - | 180 | | mV |
| $I_S$ | $V_S$ supply current | No commutations<br>EN = 0<br>$R_{OFF}$ = 160 kΩ | - | 960 | 1300 | µA |
| | | No commutations<br>EN = 1<br>$R_{OFF}$ = 160 kΩ | - | 1500 | 1950 | µA |
| $I_{S,STBY}$ | $V_S$ standby current | STBY = 0 V | - | 10 | 80 | nA |
| $V_{STBYL}$ | Standby low logic level input voltage | - | - | - | 0.9 | V |
| $V_{STBYH}$ | Standby logic level input voltage | - | 1.48 | - | - | V |
| **Power stage** | | | | | | |
| $R_{DS(ON)HS+LS}$ | Total on resistance HS + LS(1)<br>(OUTAx // OUTBx) | $V_S$ = 10 V<br>$I_{OUT}$ = 1.3 A | - | 0.2 | 0.33 | Ω |
| | | $V_S$ = 10 V<br>$I_{OUT}$ = 1.3 A<br>Tj = 125 °C(2) | - | 0.27 | 0.44 | |
| | | $V_S$ = 3 V,<br>$I_{OUT}$ = 0.4 A | - | 0.27 | 0.4 | |
| $I_{DSS}$ | Leakage current | OUTx = $V_S$ | - | - | 1 | µA |
| | | OUTx = GND | - 1 | - | - | |
| $V_{DF}$ | Freewheeling diode forward voltage | $I_D$ = 1.3 A | - | 0.9 | - | V |
| $t_{rise}$ | Rise time | $V_S$ = 10 V; unloaded outputs | - | 10 | - | ns |
| $t_{fall}$ | Fall time | $V_S$ = 10 V; unloaded outputs | - | 10 | - | ns |
| $t_{DT}$ | Dead time | - | - | 50 | - | ns |
| **PWM current controller** | | | | | | |
| $V_{SNS,OFFSET}$ | Sensing offset | $V_{REF}$ = 0.5 V<br>Internal reference 20% $V_{REF}$ | -15 | - | +15 | mV |
| $t_{OFF}$ | Total OFF time | $R_{OFF}$ = 10 kΩ | - | 9 | - | µs |
| | | $R_{OFF}$ = 160 kΩ | - | 125 | - | µs |

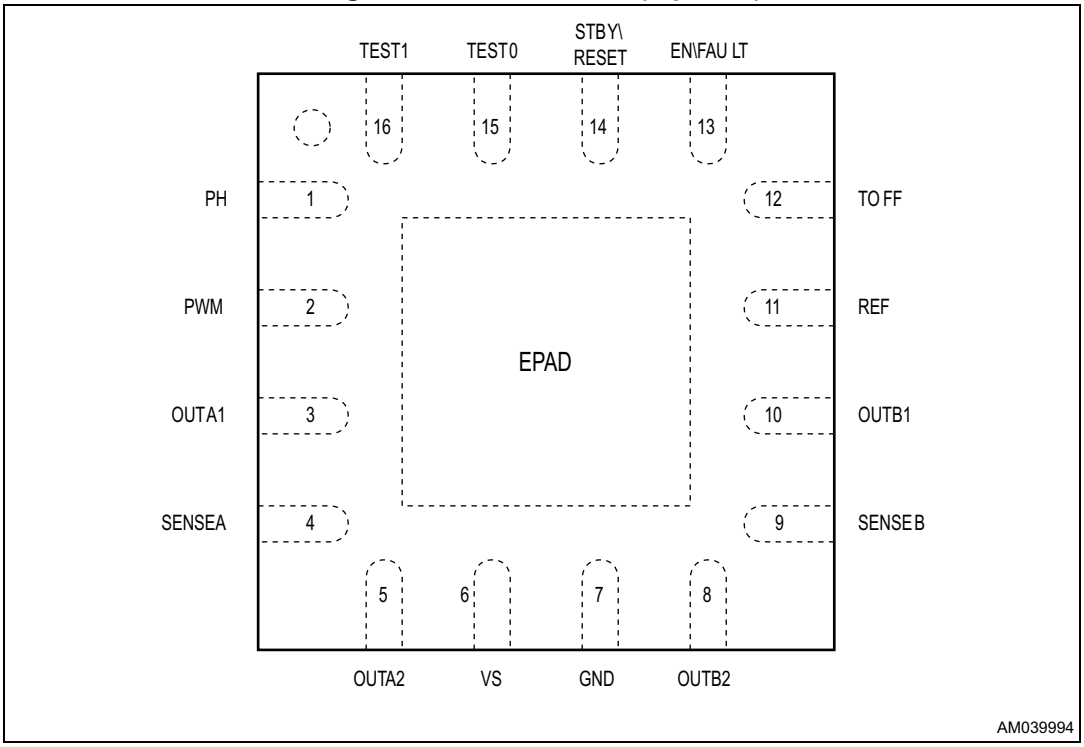
**Table 5. Electrical characteristics (continued)**

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $\Delta f_{OSC}$ | Oscillator precision | $f_{OSC}/f_{OSC,ID}$ | -20% | - | +20% | - |
| $t_{OFF,jitter}$ | Total OFF time jittering | $R_{OFF}$ = 10 kΩ | - | - | 2% | - |
| **Logic IOs** | | | | | | |
| $V_{IH}$ | High logic level input voltage | - | 1.6 | - | - | V |
| $V_{IL}$ | Low logic level input voltage | - | - | - | 0.6 | V |
| $V_{RELEASE}$ | FAULT open drain release voltage | - | - | - | 0.4 | V |
| $V_{OL}$ | Low logic level output voltage | $I_{OL}$ = 4 mA | - | - | 0.4 | V |
| $R_{STBY}$ | STBY pull-down resistance | - | - | 36 | - | kΩ |
| $I_{PDEN}$ | EN pull-down current | - | - | 10.5 | - | µA |
| $t_{ENd}$ | EN input propagation delay | From EN falling edge to OUT high impedance | - | 55 | - | ns |
| $t_{PWM,d(ON)}$ | PWM turn-on propagation delay | See *Figure 4 on page 14* | - | 125 | - | ns |
| $t_{PWM,d(OFF)}$ | PWM turn-off propagation delay | See *Figure 4* | - | 140 | - | ns |
| $t_{PH,d}$ | PH propagation delay | See *Figure 4* | - | 125 | - | ns |
| **Protections** | | | | | | |
| $T_{jSD}$ | Thermal shutdown threshold | - | - | 160 | - | °C |
| $T_{jSD,Hyst}$ | Thermal shutdown hysteresis | - | - | 40 | - | °C |
| $I_{OC}$ | Overcurrent threshold | Single OUT | - | 2 | - | A |
| | | OUTAx // OUTBx | - | 4 | - | |

1. Production test made on single outputs.
2. Based on characterization data on a limited number of samples, not tested during production.

# 4 Pin description

**Figure 2. Pin connection (top view)**




*Note: The exposed pad, TEST0 and TEST1 pins must be connected to ground.*
*OUTA1 and OUTB1 must be connected together.*
*OUTA2 and OUTB2 must be connected together.*
*SENSEA and SENSEB must be connected together.*

**Table 6. Pin description**

| No. | Name | Type | Function |
|---|---|---|---|
| 1 | PH | Logic input | Phase input |
| 2 | PWM | Logic input | PWM input |
| 3 | OUTA1 | Power output | Power bridge output side A1, must be connected to OUTB1. |
| 4 | SENSEA | Power output | Sense output A, must be connected to SENSEB. |
| 5 | OUTA2 | Power output | Power bridge output side A2, must be connected to OUTB2. |
| 6 | VS | Supply | Device supply voltage. |
| 7, EPAD | GND | Ground | Device ground. |
| 8 | OUTB2 | Power output | Power bridge output side B2, must be connected to OUTA2. |
| 9 | SENSEB | Power output | Sense output B, must be connected to SENSEA. |

**Table 6. Pin description (continued)**

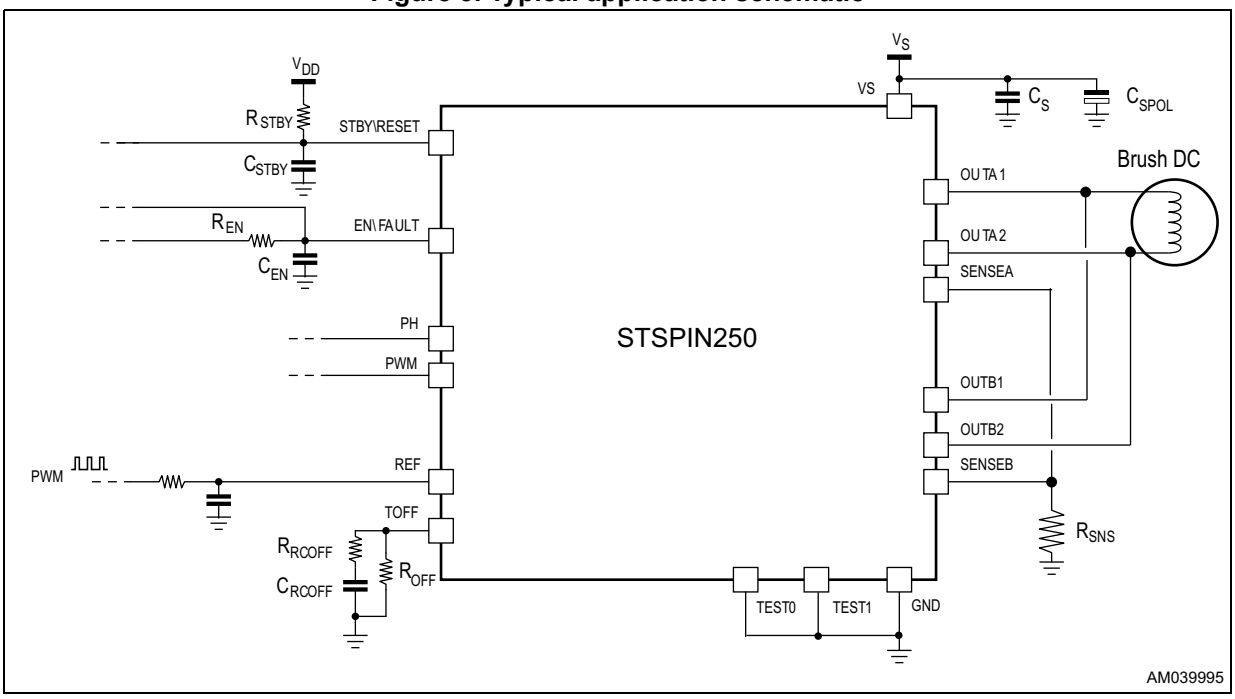
| No. | Name | Type | Function |
|---|---|---|---|
| 10 | OUTB1 | Power output | Power bridge output side B1, must be connected to OUTA1. |
| 11 | REF | Analog input | Reference voltage for the current limiter circuitry. |
| 12 | TOFF | Analog input | Internal oscillator frequency adjustment. |
| 13 | EN\FAULT | Logic input\ open drain output | Logic input 5 V compliant whit and open drain output. This is the power stage enable (when low the power stage is turned off) and it is forced low through the integrated open-drain MOSFET when a failure occurs. |
| 14 | STBY\RESET | Logic input | Logic input 5 V compliant. When forced low the device is forced into the low consumption mode. |
| 15 | TEST0 | - | Reserved pin. This pin must be connected to ground. |
| 16 | TEST1 | - | Reserved pin. This pin must be connected to ground. |

# 5 Typical applications

**Table 7. Typical application values**

| Name | Value |
|---|---|
| $C_S$ | 2.2 µF / 16 V |
| $C_{SPOL}$ | 22 µF / 16 V |
| $R_{SNS}$ | 330 mΩ / 1 W |
| $C_{EN}$ | 10 nF / 6.3 V |
| $R_{EN}$ | 18 kΩ |
| $C_{STBY}$ | 1 nF / 6.3 V |
| $R_{STBY}$ | 18 kΩ |
| $C_{RCOFF}$ | 22 nF |
| $R_{RCOFF}$ | 1 kΩ |
| $R_{OFF}$ | 47 kΩ ($t_{OFF} \cong$ 37 µs) |

**Figure 3. Typical application schematic**



# 6 Device description

The STSPIN250 is a single brush DC motor driver integrating a PWM current controller and a power stage composed by a fully-protected full-bridge.

## 6.1 Standby and power-up

The device provides a low settable consumption mode forcing the STBY\RESET input below the $V_{STBYL}$ threshold.

When the device is in the standby status, the power stage is disabled (outputs are in high impedance) and the supply to the integrated control circuitry is cut-off.

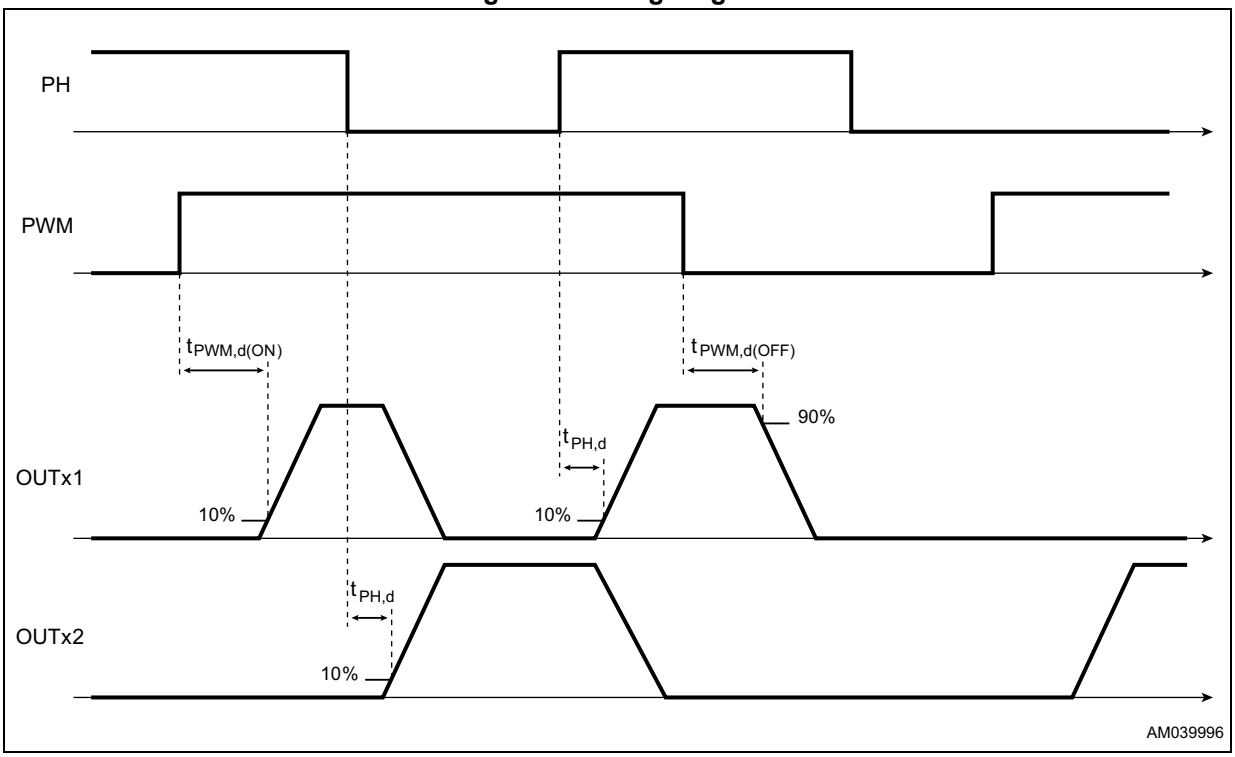
## 6.2 Motor driving

The outputs of the full-bridge are controlled by the PWM and PH inputs as listed in *Table 8*.

**Table 8. Truth table**

| EN\FAULT | PH | PWM | OUTx1 | OUTx2 | Full-bridge condition |
|---|---|---|---|---|---|
| 0 | X | X | HiZ | HiZ | Disabled |
| 1 | 0 | 0 | GND | GND | Both LS on |
| 1 | 0 | 1 | GND | VS | HSx2 and LSx1 on (current X1 ← X2) |
| 1 | 1 | 0 | GND | GND | Both LS on |
| 1 | 1 | 1 | VS | GND | HSx1 and LSx2 on (current X1 → X2) |

**Figure 4. Timing diagram**



## 6.3 PWM current control

The device implements a current controller.

The voltage on the sense pins ($V_{SENSE}$) is compared to the reference voltage applied on the REF pin ($V_{REF}$).

When $V_{SENSE} > V_{REF}$, the current limiter is triggered, the OFF time counter is started, and the decay sequence is performed.

The decay sequence starts turning on all the low sides of the full-bridge. After the programmed OFF time the system returns to the ON state.

**Table 9. ON and slow decay states**

| PH | PWM | ON | Decay |
|---|---|---|---|
| 0 | 0 | HSx1 = OFF<br>**LSx1 = ON**<br>HSx2 = OFF<br>**LSx2 = ON** | N.A.(1) |
| 0 | 1 | HSx1 = OFF<br>**LSx1 = ON**<br>**HSx2 = ON**<br>LSx2 = OFF | HSx1 = OFF<br>**LSx1 = ON**<br>HSx2 = OFF<br>**LSx2 = ON** |
| 1 | 0 | HSx1 = OFF<br>**LSx1 = ON**<br>HSx2 = OFF<br>**LSx2 = ON** | N.A.(1) |
| 1 | 1 | **HSx1 = ON**<br>LSx1 = OFF<br>HSx2 = OFF<br>**LSx2 = ON** | HSx1 = OFF<br>**LSx1 = ON**<br>HSx2 = OFF<br>**LSx2 = ON** |

1. During decays the input values are ignored until the system returns to ON condition (decay time expired).

The reference voltage value, $V_{REF}$, has to be selected according to the load current target value (peak value) and sense resistors value.

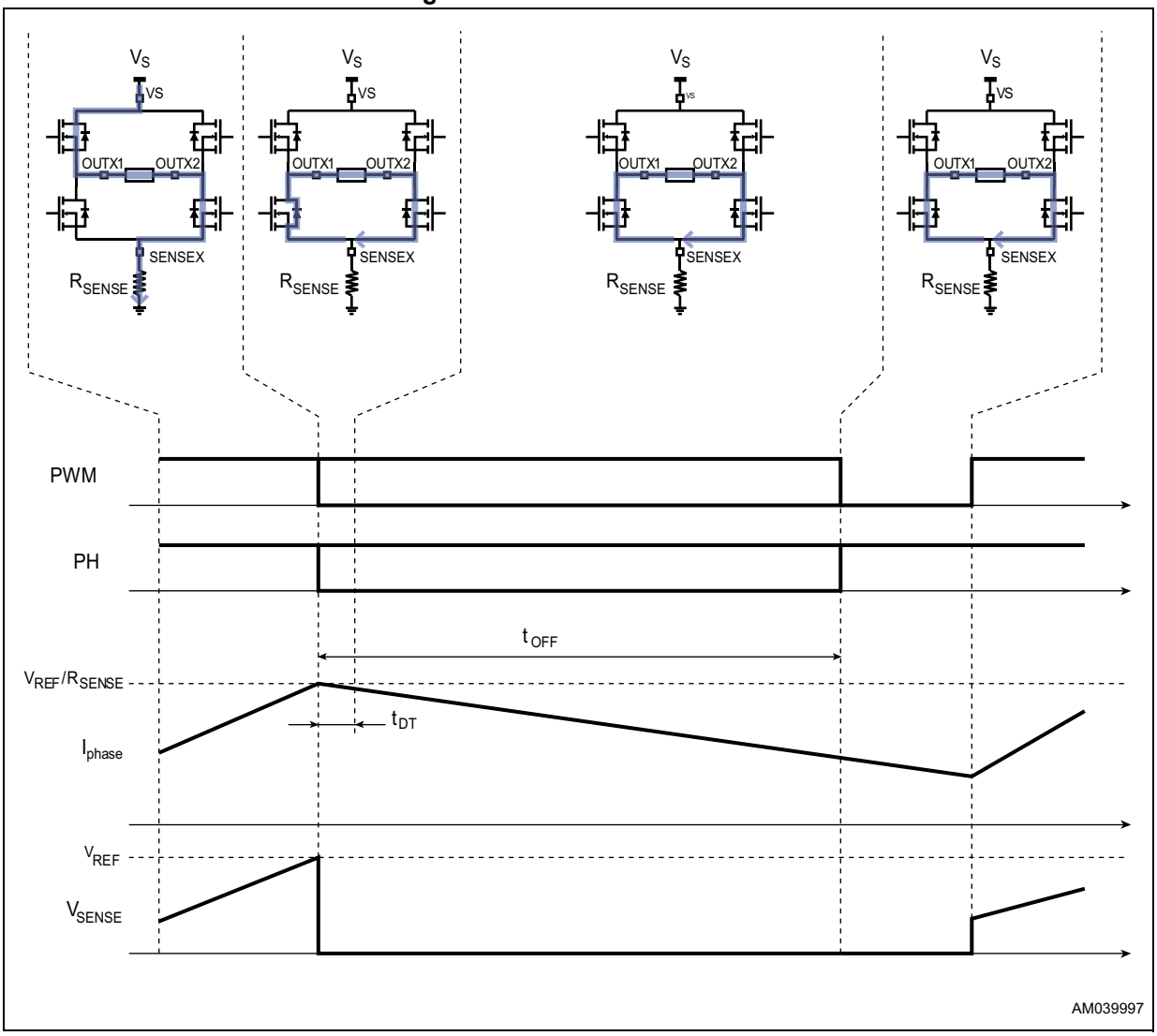
**Equation 1**

$$V_{REF} = R_{SNSx} \bullet I_{LOAD,peak}$$

In choosing the sense resistors value, two main issues must be taken into account:

- The sensing resistor dissipates energy and provides dangerous negative voltages on the SENSE pins during the current recirculation. For this reason the resistance of this component should be kept low (using multiple resistors in parallel will help obtaining the required power rating with standard resistors).
- The lower is the $R_{SNSx}$ value, the higher is the peak current error due to noise on the $V_{REF}$ pin and to the input offset of the current sense comparator: too low values of $R_{SNSx}$ must be avoided.

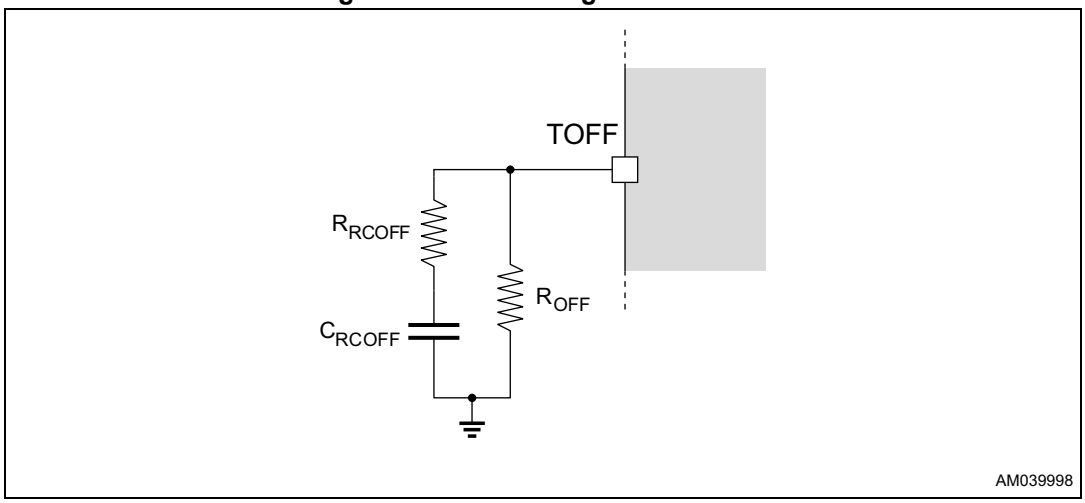
**Figure 5. PWM current control**



## TOFF adjustment

The decay time is adjusted through an external resistor connected between the TOFF pin and ground as shown in *Figure 6*. A small RC series must be inserted in parallel with the regulator resistor in order to increase the stability of the regulation circuit according indications listed in *Table 10*.

**Figure 6. OFF time regulation circuit**

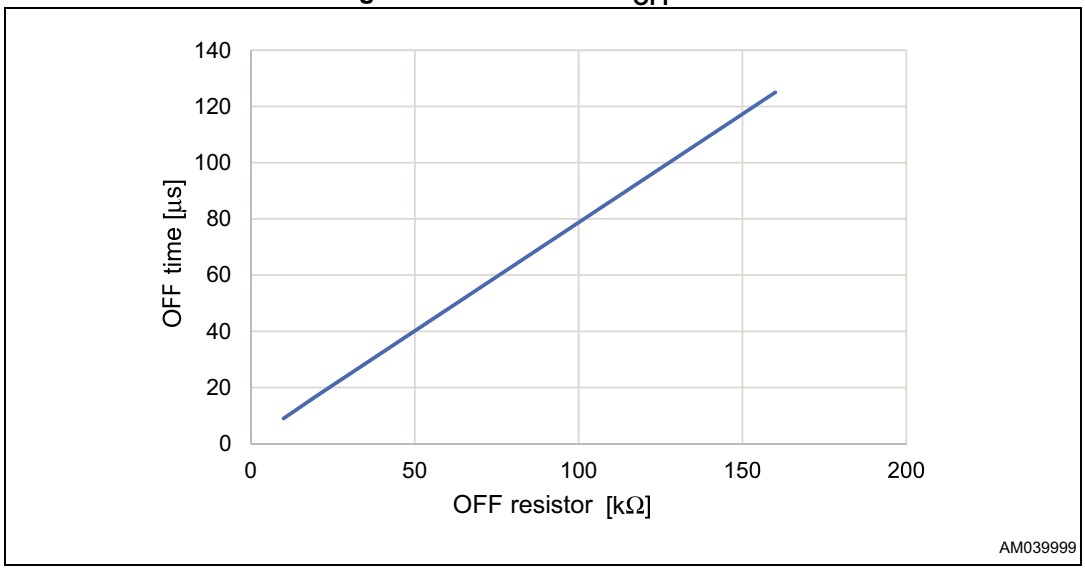



The relation between the OFF time and the external resistor value is shown in the graph of *Figure 7*. The value typically ranges from 10 µs to 150 µs.

**Table 10. Recommended $R_{RCOFF}$ and $C_{RCOFF}$ values according to $R_{OFF}$**

| ROFF | RRCOFF | CRCOFF |
|---|---|---|
| 10 kΩ ≤ $R_{OFF}$ < 82 kΩ | 1 kΩ | 22 nF |
| 82 kΩ ≤ $R_{OFF}$ ≤ 160 kΩ | 2.2 kΩ | 22 nF |

**Figure 7. OFF time vs $R_{OFF}$ value**



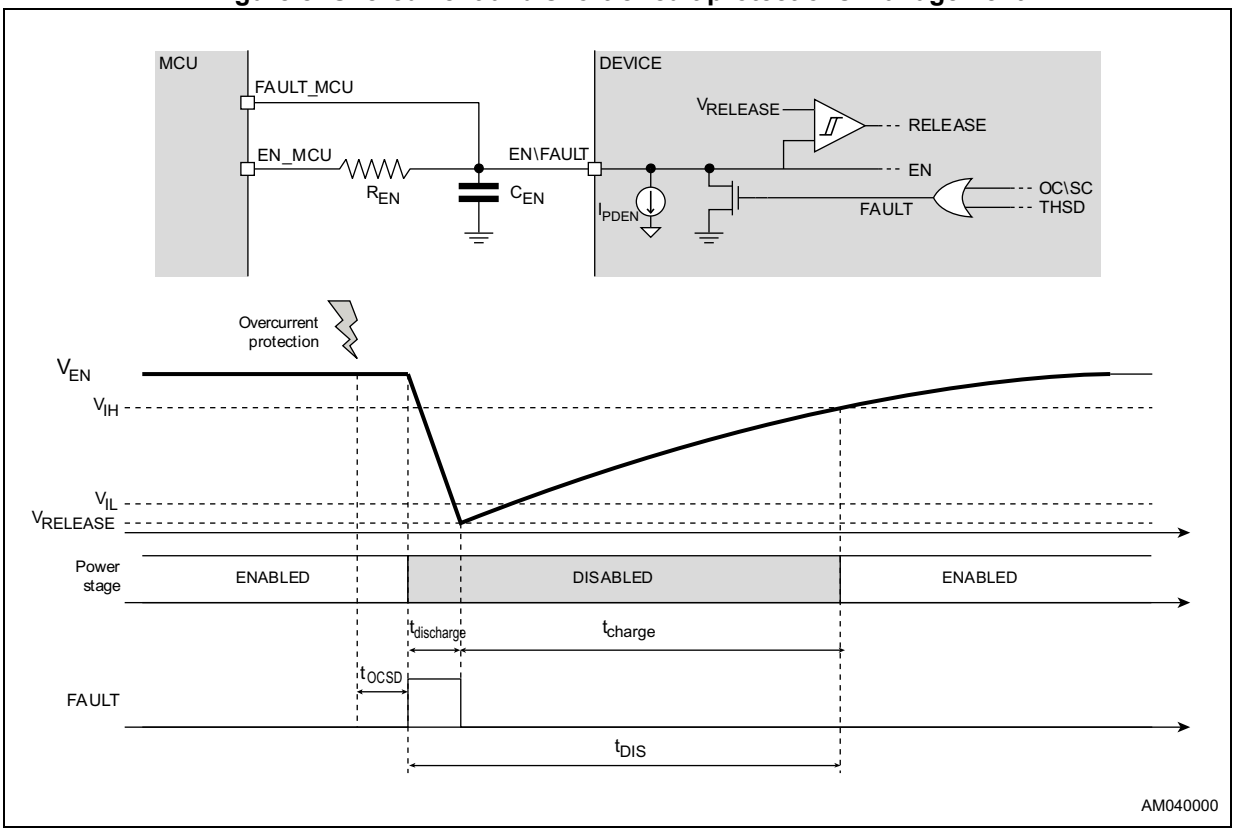
## 6.4 Overcurrent and short-circuit protections

The device embeds circuitry protecting each power output against the overload and short-circuit conditions (short-circuit to ground, short-circuit to VS and short-circuit between outputs).

When the overcurrent or the short-circuit protection is triggered, the power stage is disabled and the EN\FAULT input is forced low through the integrated open-drain MOSFET discharging the external $C_{EN}$ capacitor.

The power stage is kept disabled and the open-drain MOSFET is kept ON until the EN\FAULT input falls below the $V_{RELEASE}$ threshold, then the $C_{EN}$ capacitor is charged through the $R_{EN}$ resistor.

**Figure 8. Overcurrent and short-circuit protections management**




The total disable time after an overcurrent event can be set by properly sizing the external network connected to the EN\FAULT pin (refer to *Figure 9* and *Figure 10*):

**Equation 2**

$$t_{DIS} = t_{discharge} + t_{charge}$$

But $t_{charge}$ is normally very higher than $t_{discharge}$ we can consider only the second one contribution:

$$t_{DIS} \cong R_{EN} \cdot C_{EN} \cdot ln \frac{(V_{DD} - R_{EN} \cdot I_{PD}) - V_{RELEASE}}{(V_{DD} - R_{EN} \cdot I_{PD}) - V_{IH}}$$

Where $V_{DD}$ is the pull-up voltage of the $R_{EN}$ resistor.

**Figure 9. Disable time versus $R_{EN}$ and $C_{EN}$ values ($V_{DD}$ = 3.3 V)**

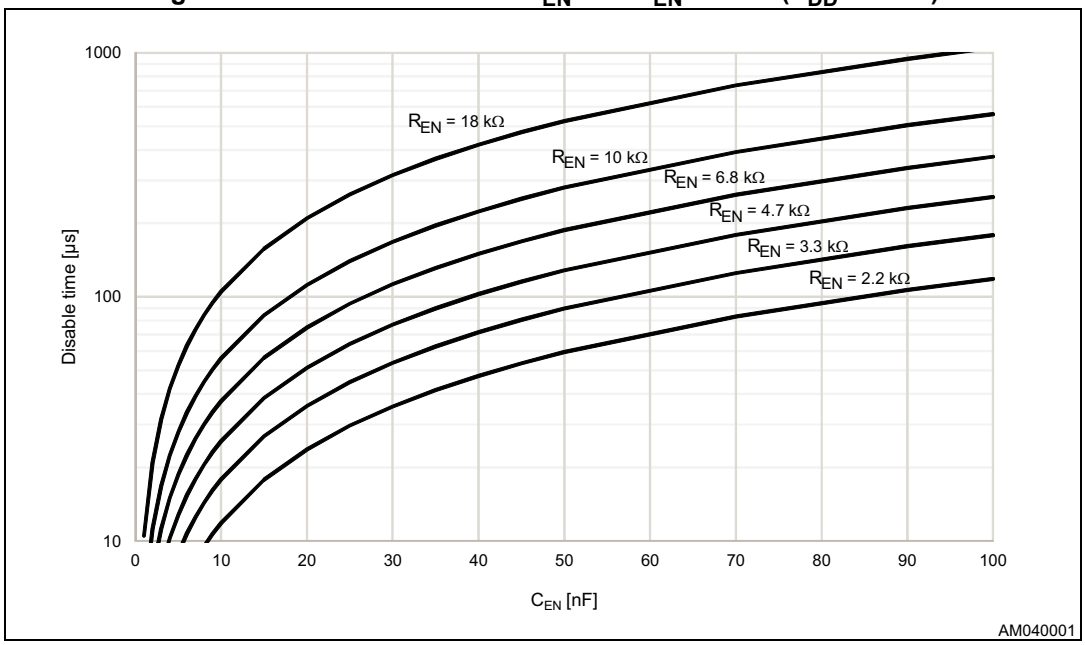
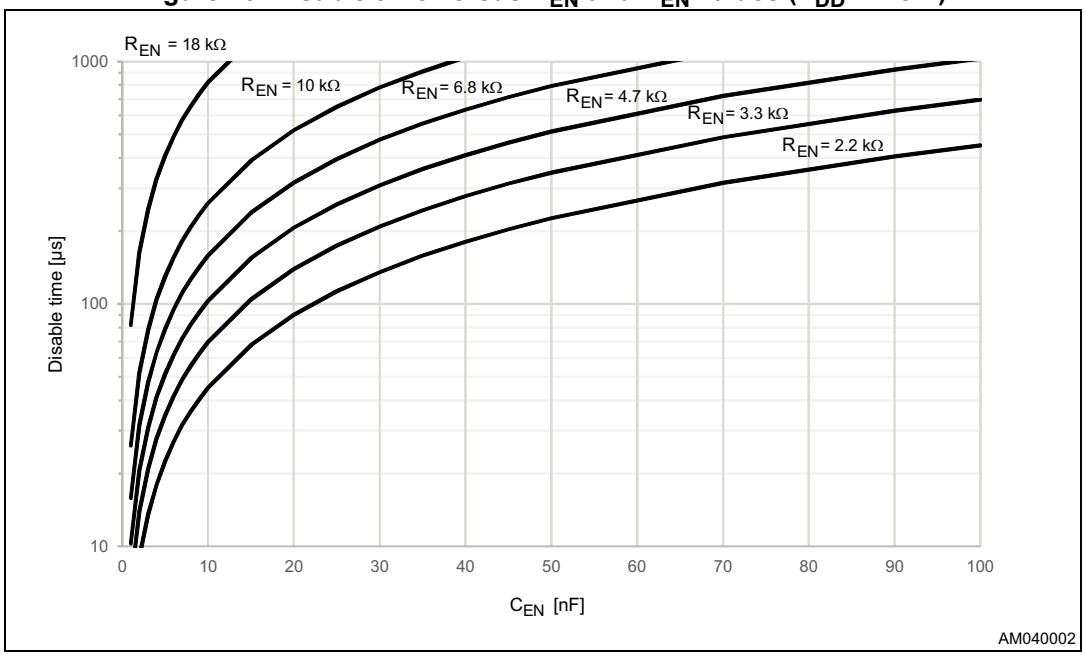



**Figure 10. Disable time versus $R_{EN}$ and $C_{EN}$ values ($V_{DD}$ = 1.8 V)**



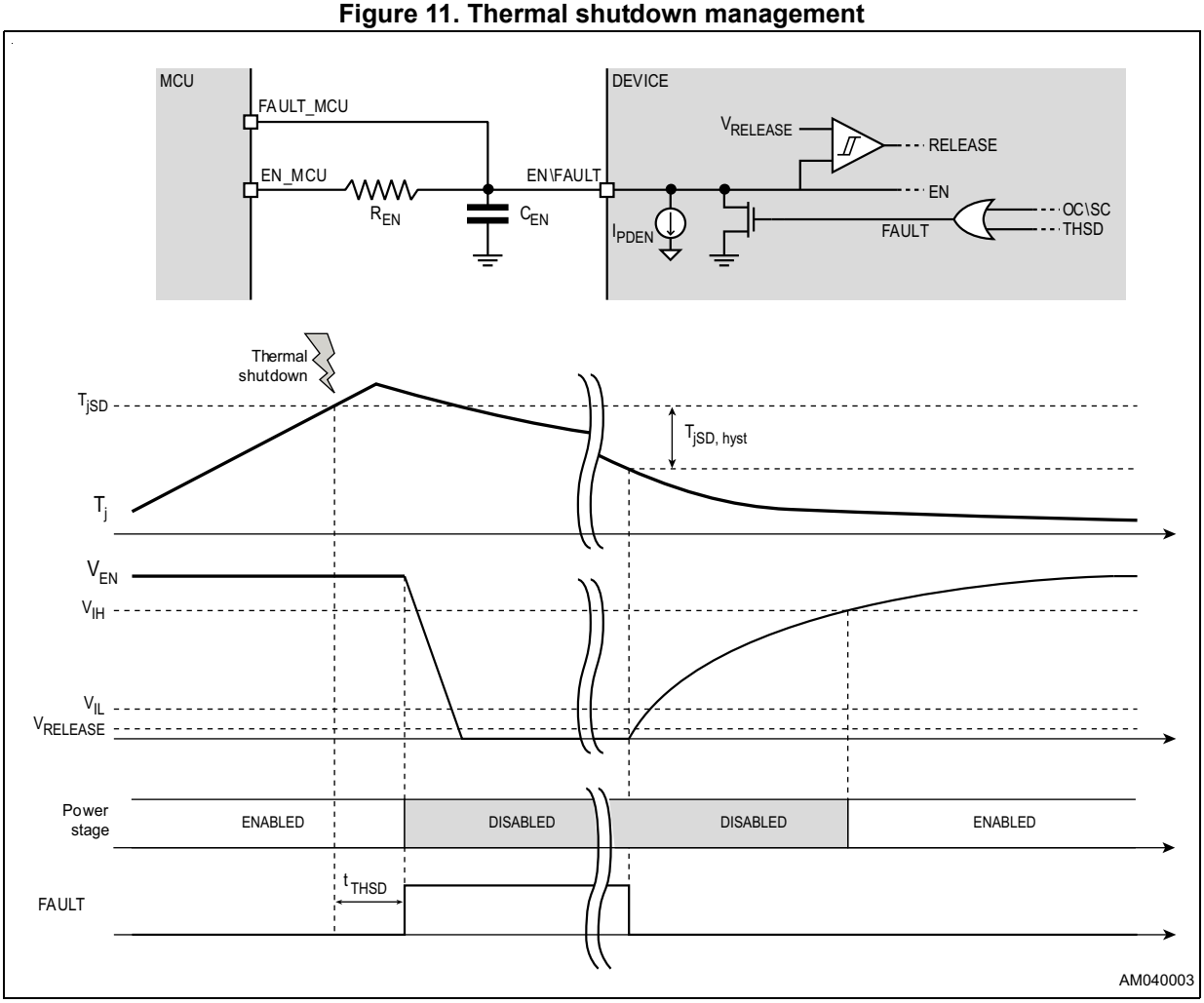
## 6.5 Thermal shutdown

The device embeds circuitry protecting it from the overtemperature condition.

When the thermal shutdown temperature is reached the power stage is disabled and the EN\FAULT input is forced low through the integrated open-drain MOSFET.

The protection and the EN\FAULT output are released when the IC temperature returns below a safe operating value ($T_{jSD}$ - $T_{jSD,Hyst}$).

**Figure 11. Thermal shutdown management**



# 7 Graphs

Figure 12. Power stage resistance versus supply voltage

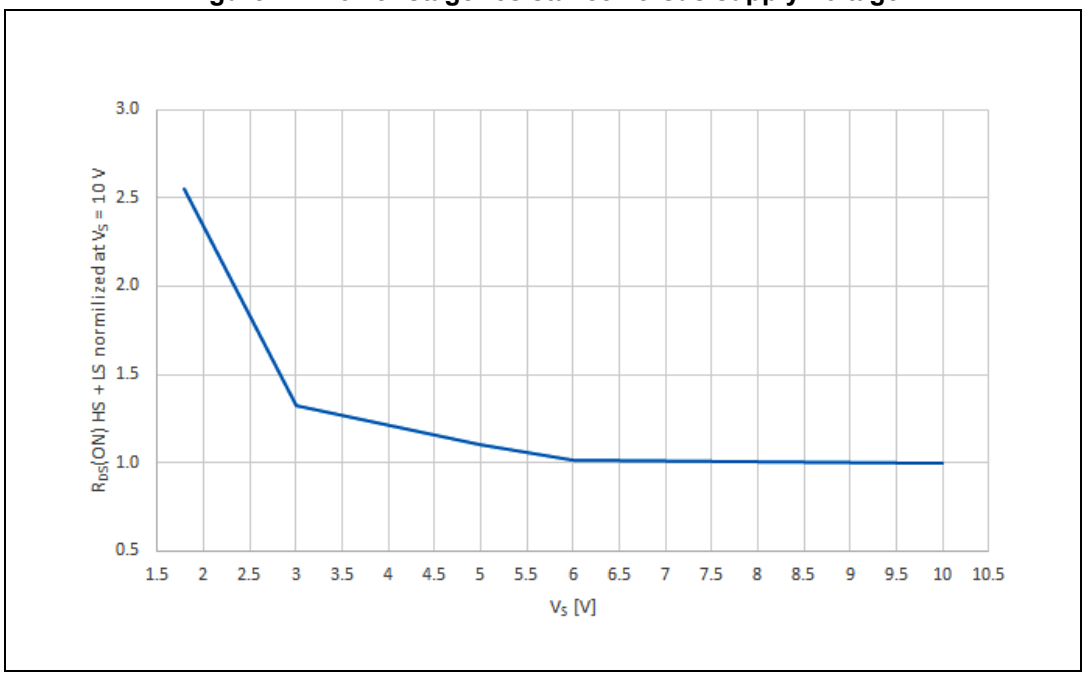



Figure 13. Power stage resistance versus temperature

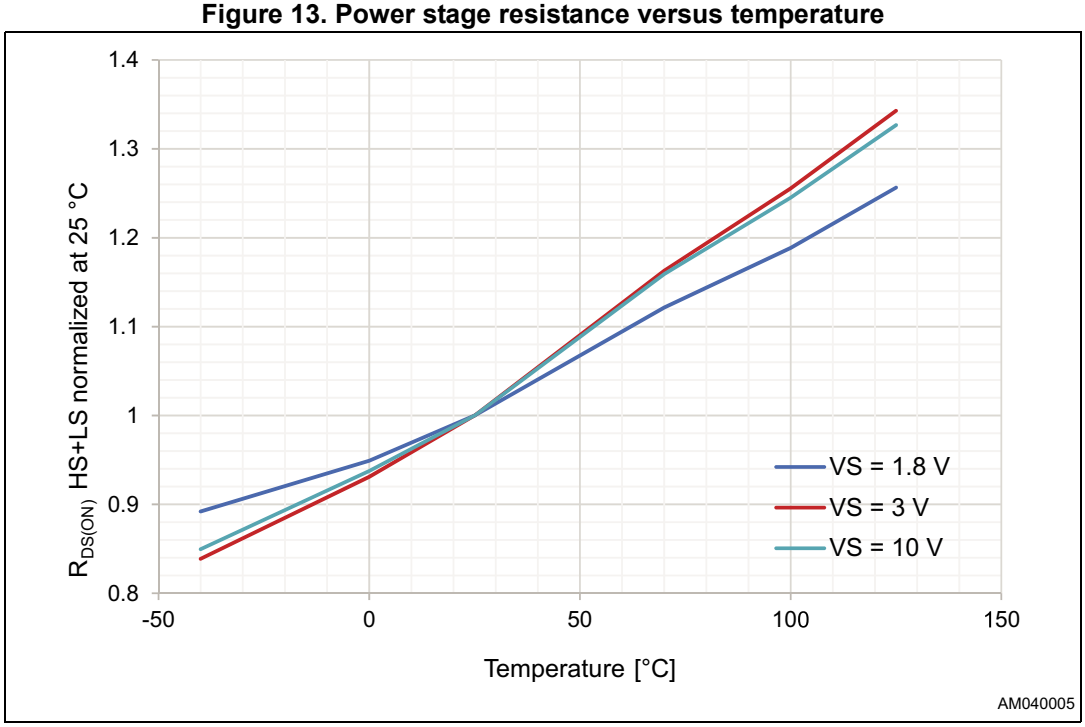
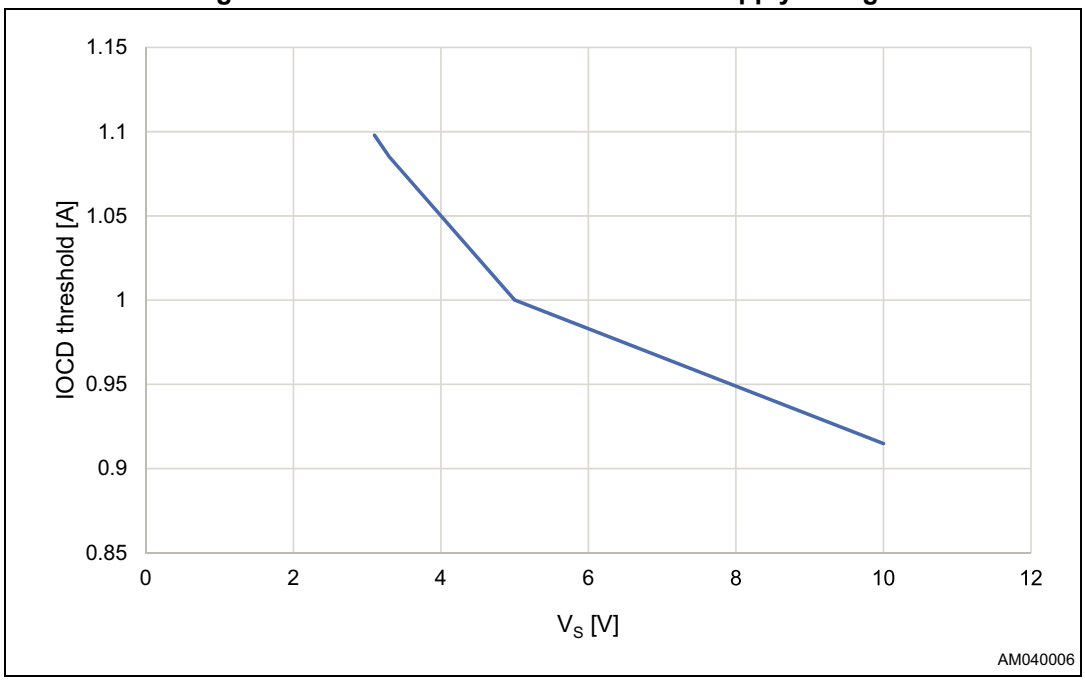


**Figure 14. Overcurrent threshold versus supply voltage**



# 8 Package information

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*. ECOPACK® is an ST trademark.

## 8.1 VFQFPN 3 x 3 x 1.0- 16L package information

**Figure 15. VFQFPN 3 x 3 x 1.0 - 16L package outline**

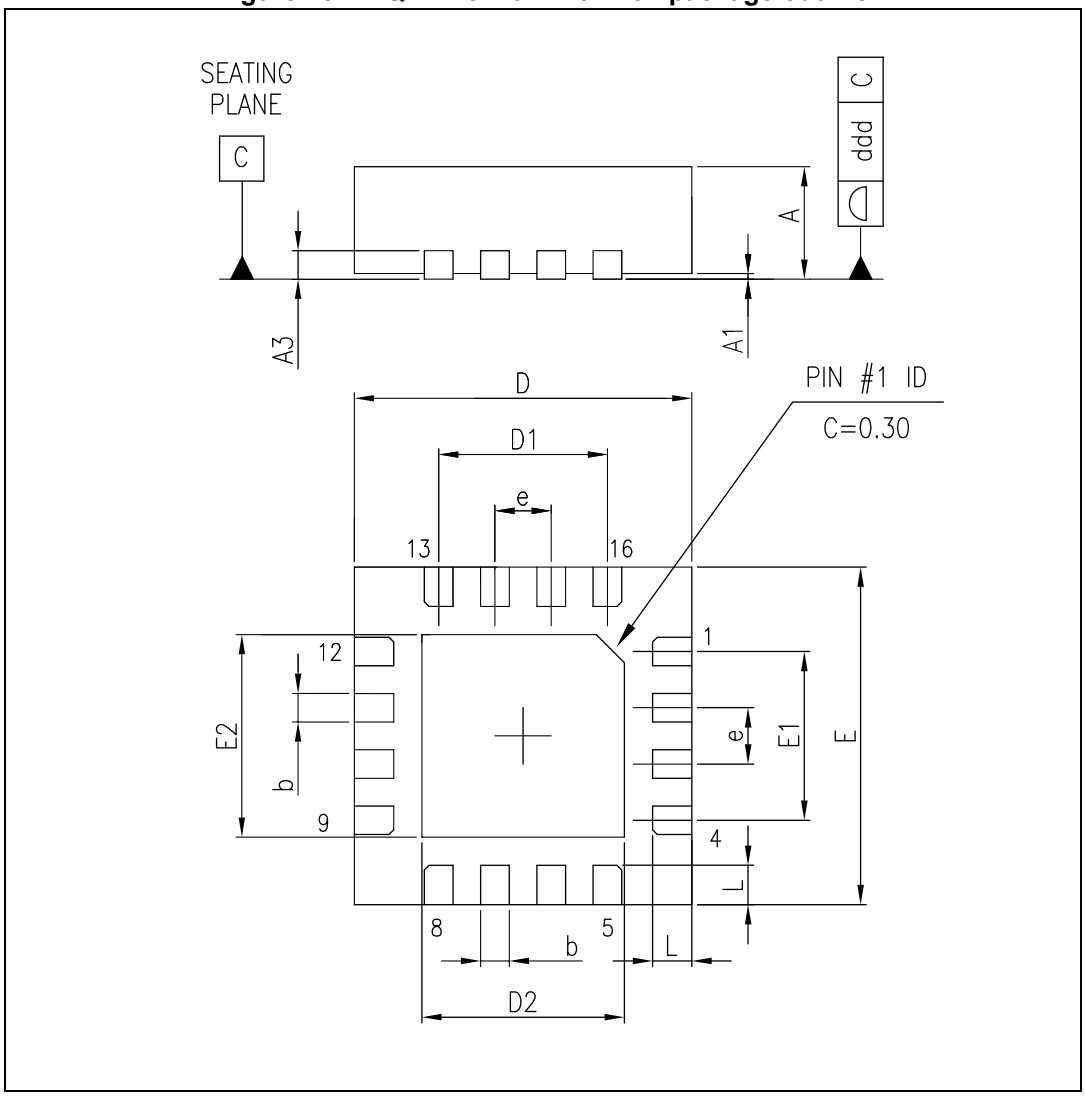
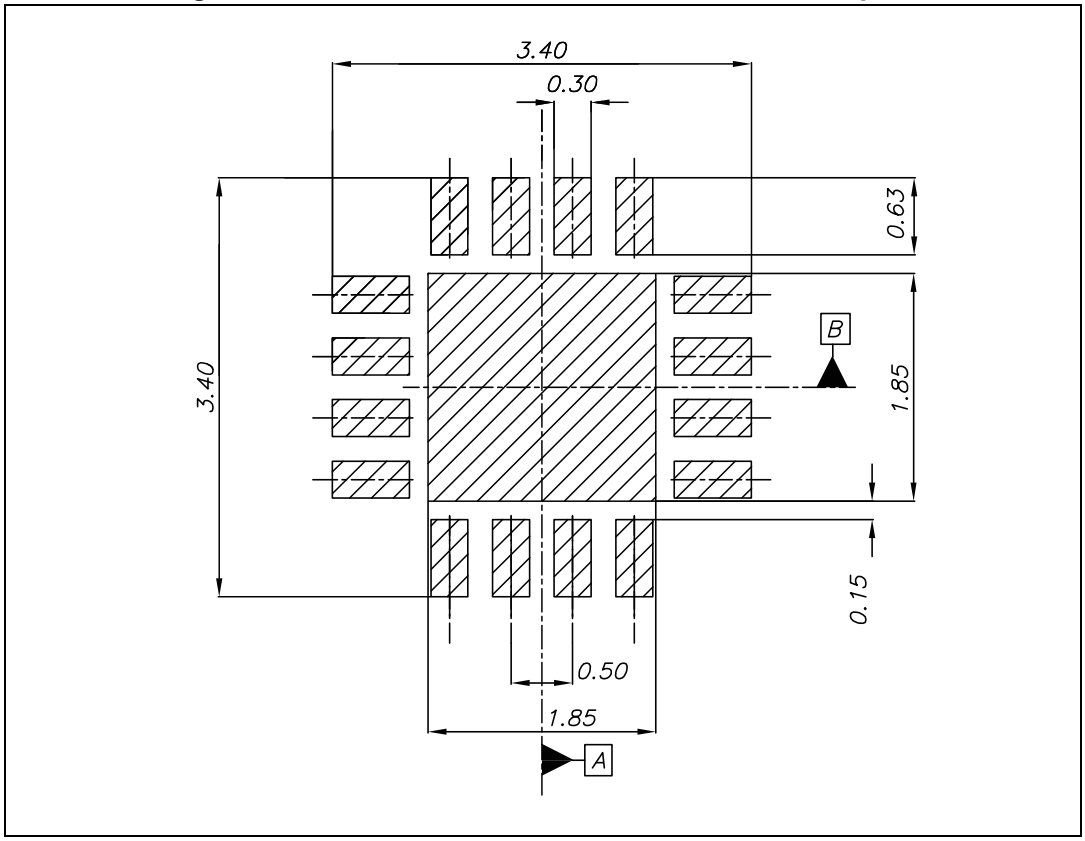


**Table 11. VFQFPN 3 x 3 x 1.0 - 16L package mechanical data(1)**

| Symbol | Dimensions (mm) | | |
|---|---|---|---|
| | Min. | Typ. | Max. |
| A | 0.80 | 0.90 | 1.00 |
| A1 | - | 0.02 | - |
| A3 | - | 0.20 | - |
| b | 0.18 | 0.25 | 0.30 |
| D | 2.85 | 3.00 | 3.15 |
| D2 | 1.70 | 1.80 | 1.90 |
| E | 2.85 | 3.00 | 3.15 |
| E2 | 1.70 | 1.80 | 1.90 |
| e | - | 0.50 | - |
| L | 0.45 | 0.50 | 0.55 |

1. VFQFPN stands for “Thermally Enhanced Very thin Fine pitch Quad Packages No lead”.
Very thin: 0.80 < A ≤ 1.00 mm / fine pitch: e < 1.00 mm.
The pin #1 identifier must exist on the top surface of the package by using indentation mark or other feature of the package body.

**Figure 16. VFQFPN 3 x 3 x 1.0 - 16L recommended footprint**



# 9 Ordering information

**Table 12. Device summary**

| Order code | Package | Packaging |
|---|---|---|
| STSPIN250 | VFQFPN 3 x 3 x1.0 - 16L | Tape and reel |

# 10 Revision history

**Table 13. Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 17-Oct-2016 | 1 | Initial release. |
| 04-Nov-2016 | 2 | Updated document status to*: Datasheet - production data* on page 1.<br>Updated *Figure 1 on page 5* and *Figure 12 on page 21* (replaced by new figures).<br>Updated *Table 2 on page 6* (added new parameter $t_{INw}$).<br>Minor modifications throughout document. |