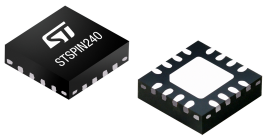
# STSPIN240

Datasheet

## Low voltage dual brush DC motor driver



VFQFPN 3 X 3 X 1.0 (16-pin)

## Features

- Operating voltage from 1.8 to 10 V
- Maximum output current 1.3 Arms
- $R_{DS(ON)}$ HS + LS = 0.4 Ω typ.
- Current control with adjustable 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

## Application

- Battery-powered DC motor applications such as:
  - Toys
  - Portable printers
  - Robotics
  - Point of sale (POS) devices
  - Portable medical equipment
  - Healthcare and wellness devices (shavers and toothbrushes)

**Product status link**

STSPIN240

**Product label**

## Description

The STSPIN240 is a dual brush DC motor driver integrating a low $R_{DS(ON)}$ power stage in a small QFN 3 x 3 mm package.

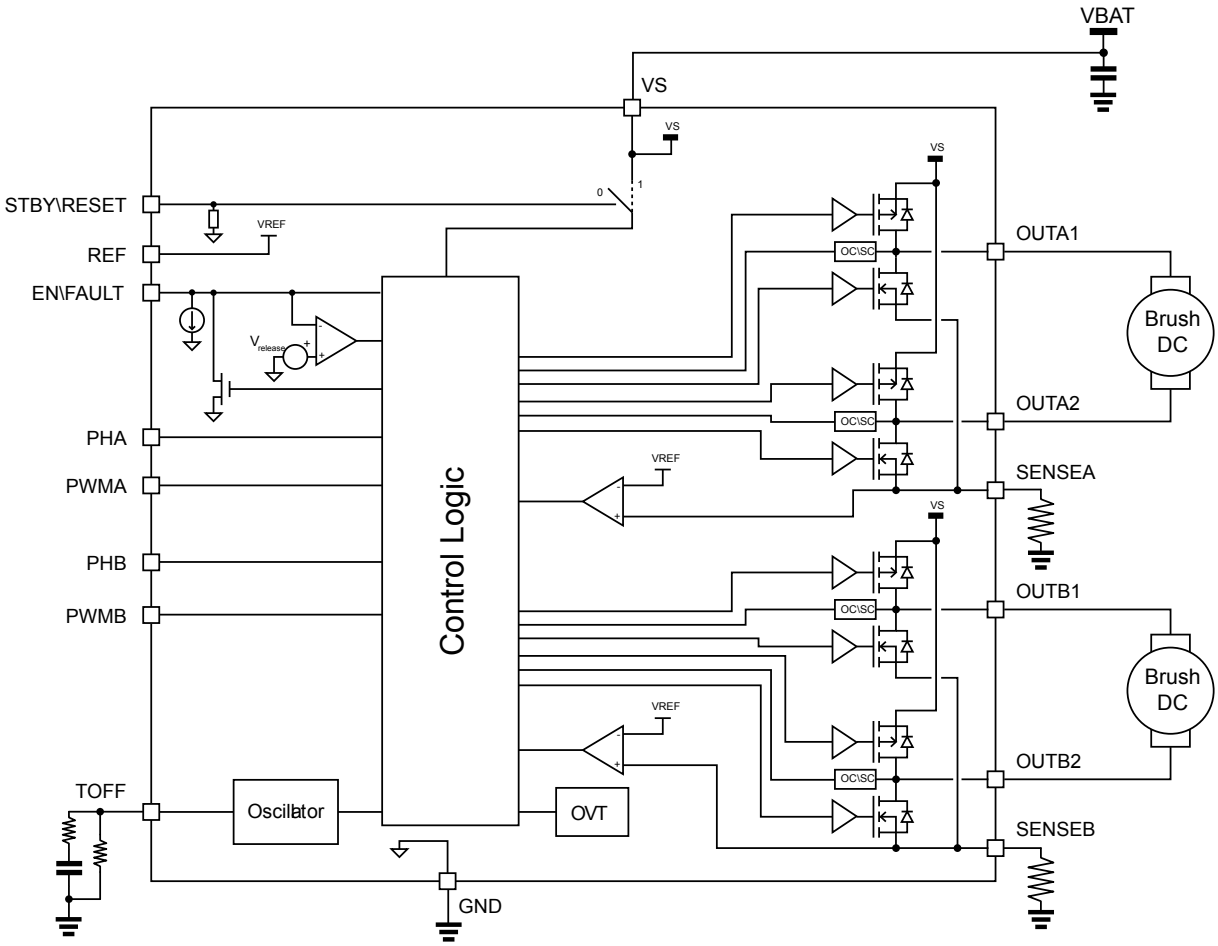
Both the full-bridges implement an independent PWM current controller with fixed OFF time.

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 STSPIN240 offers a complete set of protection including overcurrent, overtemperature and short-circuit protection.

# 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 |
| $I_{OUT,RMS}$ | Continuous power stage output current (each bridge) | | 1.3 | $A_{rms}$ |
| $T_{j,OP}$ | 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 |

## 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 21.2x21.2 mm board, 2s2p 1 Oz copper and four 300 µm vias below exposed pad*

## 2.4 ESD protection ratings

Table 4. **ESD protection ratings**

| Symbol | Parameter | Conditions | 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

**Table 5. Electrical characteristics**

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

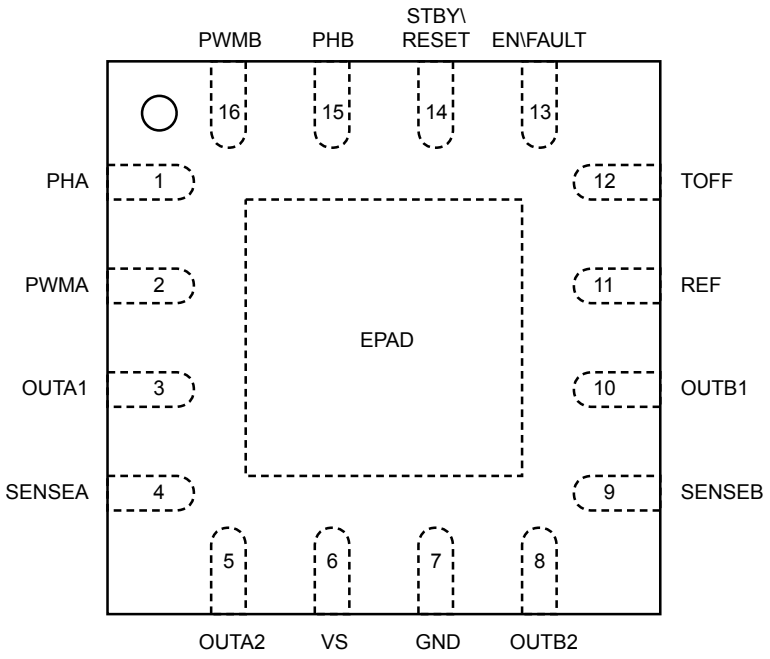
| Symbol | Parameter | Test condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Supply** | | | | | | |
| $V_{Sth(ON)}$ | $V_S$ turn-on voltage | $V_S$ rising from 0 V | 1.45 | 1.65 | 1.79 | V |
| $V_{Sth(OFF)}$ | $V_S$ turn-off voltage | $V_S$ falling from 5 V | 1.3 | 1.45 | 1.65 | V |
| $V_{Sth(HYS)}$ | $V_S$ hysteresis voltage | | | 180 | | mV |
| $I_S$ | $V_S$ supply current | No commutations, EN\FAULT = 0<br>$R_{OFF}$ = 160 kΩ | | 960 | 1300 | µA |
| | | No commutations, EN\FAULT = 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 voltage | | | | 0.9 | V |
| $V_{STBYH}$ | Standby high voltage | | 1.48 | | | V |
| **Power stage** | | | | | | |
| $R_{DS(ON)HS+LS}$ | Total on resistance HS + LS | $V_S$ = 10 V, $I_{OUT}$ = 1.3 A | | 0.4 | 0.65 | Ω |
| | | $V_S$ = 10 V, $I_{OUT}$ = 1.3 A<br>$T_j$ = 125 °C (1) | | 0.53 | 0.87 | |
| | | $V_S$ = 3 V, $I_{OUT}$ = 0.4 A | | 0.53 | 0.8 | |
| $I_{DSS}$ | 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;<br>unloaded outputs | | 10 | | ns |
| $t_{fall}$ | Fall time | $V_S$ = 10 V;<br>unloaded outputs | | 10 | | ns |
| $t_{DT}$ | Integrated dead time | | | 50 | | ns |
| **PWM current controller** | | | | | | |
| $V_{SNS,OFFSET}$ | Sensing offset | $V_{REF}$ = 0.1 V | -15 | | +15 | mV |
| $t_{OFF}$ | Total OFF time | $R_{OFF}$ = 10 kΩ | | 9 | | µs |
| | | $R_{OFF}$ = 160 kΩ | | 125 | | µs |
| $\Delta f_{OSC}$ | Internal oscillator precision ($f_{OSC}/f_{OSC,\ ID}$) | $R_{OFF}$ = 20 kΩ | -20% | | +20% | - |
| $t_{OFF,jitter}$ | Total OFF time jitter | $R_{OFF}$ = 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 |
| $V_{RELEASE}$ | EN\FAULT open drain release voltage | | | | 0.4 | V |
| $V_{OL}$ | EN\FAULT Low logic level output voltage | $I_{EN}$ = 4 mA | | | 0.4 | V |
| $R_{STBY}$ | STBY pull-down resistance | | | 36 | | kΩ |

| Symbol | Parameter | Test condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $I_{PDEN}$ | EN\FAULT pull-down current | | | 10.5 | | µA |
| $t_{ENd}$ | EN\FAULT input propagation delay | From EN\FAULT falling edge to OUT high impedance | | 55 | | ns |
| $t_{PWM,d(ON)}$ | PWMx turn-on propagation delay | Refer to Figure 4 | | 125 | | ns |
| $t_{PWM,d(OFF)}$ | PWMx turn-off propagation delay | Refer to Figure 4 | | 140 | | ns |
| $t_{PH,d}$ | PHx propagation delay | Refer to Figure 4 | | 125 | | ns |
| **Protections** | | | | | | |
| $T_{jSD}$ | Thermal shutdown threshold | | | 160 | | °C |
| $T_{jSD,Hyst}$ | Thermal shutdown hysteresis | | | 40 | | °C |
| $I_{OC}$ | Over-current threshold | See Figure 14 | | 2 | | A |

1. *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 must be connected to ground.*

Table 6. **Pin description**

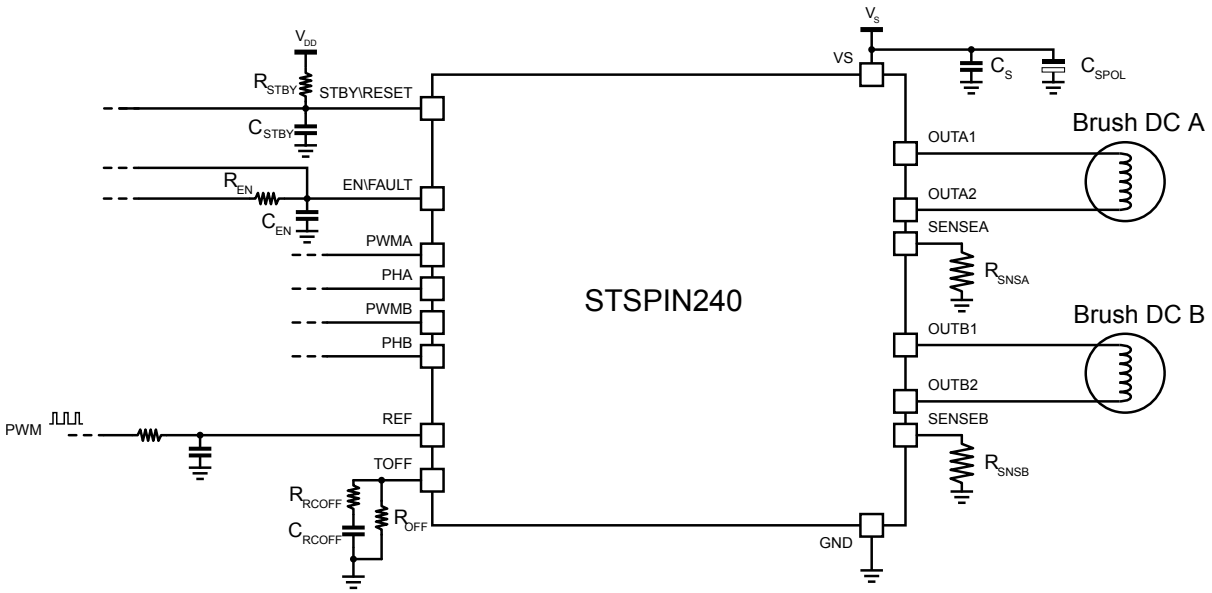
| No. | Name | Type | Function |
|---|---|---|---|
| 1 | PHA | Logic input | Phase input for bridge A |
| 2 | PWMA | Logic input | PWM input for bridge A |
| 3 | OUTA1 | Power output | Power bridge output side A1 |
| 4 | SENSEA | Power output | Sense output of the bridge A |
| 5 | OUTA2 | Power output | Power bridge output side A2 |
| 6 | VS | Supply | Device supply voltage |
| 7, EPAD | GND | Ground | Device ground |
| 8 | OUTB2 | Power output | Power bridge output side B2 |
| 9 | SENSEB | Power output | Sense output of the bridge B |
| 10 | OUTB1 | Power output | Power bridge output side B1 |
| 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 and open drain output.<br>This is the enable of the power stage (when low the power stage is turned off) and it is forced low by the integrated open-drain MOSFET when a failure occurs. |
| 14 | STBY\RESET | Logic input | Logic input 5 V compliant.<br>When forced low the device is forced in low consumption mode. |
| 15 | PHB | Logic input | Phase input for bridge B |
| 16 | PWMB | Logic input | PWM input for bridge B |

# 5 Typical applications

**Table 7. Typical application value**

| Name | Value |
|---|---|
| $C_S$ | 2.2 µF / 16 V |
| $C_{SPOL}$ | 22 µF / 16 V |
| $R_{SNSA}$, $R_{SNSB}$ | 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 ($t_{OFF}$ ≅ 37 µs) |

**Figure 3. Typical application schematic**



# 6 Description

The STSPIN240 is a dual brush DC motor driver integrating two PWM current controllers and a power stage composed by two fully-protected full-bridges.

## 6.1 Standby and power-up

The device provides a low consumption mode, which is set 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. When the device leaves the standby status, all the control circuitry is reset at power-up condition.

At power-up, power-down and when leaving the standby condition, the EN\FAULT pin is forced low until the internal circuitry stabilize.

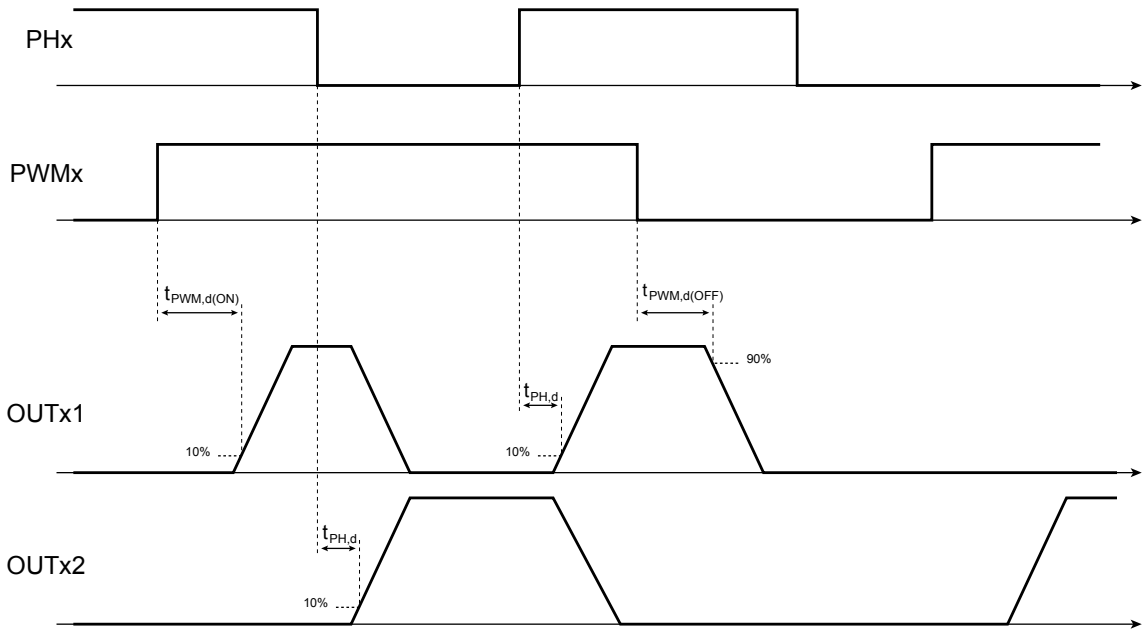
## 6.2 Motor driving

The outputs of each half-bridge is controlled by the respective PWMx and PHx inputs as listed in Table 8.

**Table 8. STSPIN240 truth table**

| EN\FAULT | PHx | PWMx | OUTx1 | OUTx2 | Full-bridge condition |
|---|---|---|---|---|---|
| 0 | X | X | HiZ | HiZ | Disabled |
| 1 | 0 | 0 | GND | GND | Both LS on |
| 1 | 0 | 1 | GND | VS | HS2 and LS1 on (current X1 ← X2) |
| 1 | 1 | 0 | GND | GND | Both LS on |
| 1 | 1 | 1 | VS | GND | HS1 and LS2 on (current X1 → X2) |

**Figure 4. Timing diagram**



## 6.3 PWM current control

The device implements two independent PWM current controllers, one for each full bridge.

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

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

The decay sequence turns on both the low sides of the full bridge for the entire duration of the OFF time.

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

| PHx | PWMx | ON | Decay (1) |
|---|---|---|---|
| 0 | 0 | HSx1 = OFF<br>**LSx1 = ON**<br>HSx2 = OFF<br>**LSx2 = ON** | N.A. |
| 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 | **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 inputs values are ignored until the system returns to ON condition (decay time expired).*

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

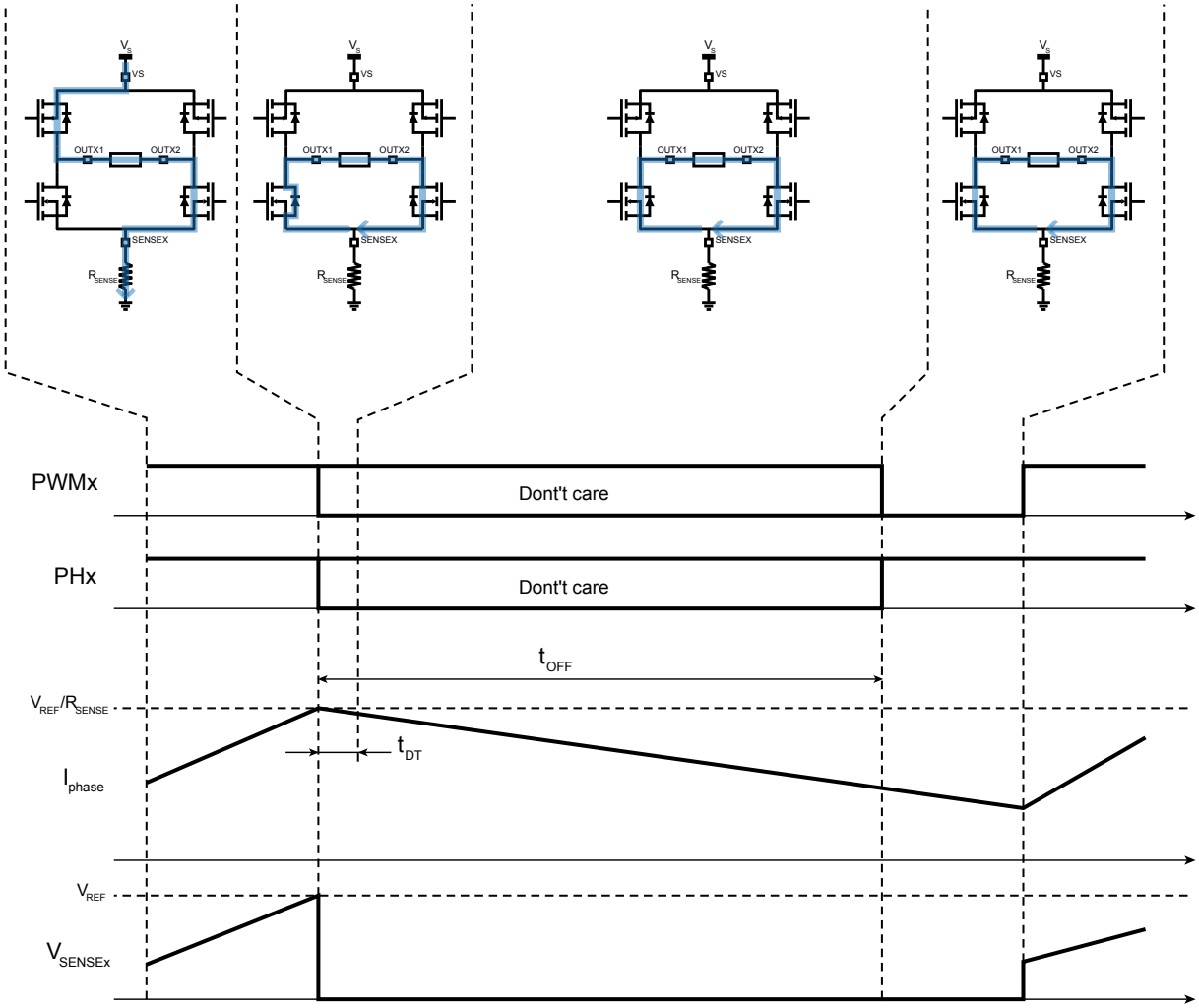
**Equation 1**

$$V_{REF} = R_{SNSx} \cdot I_{LOAD,peak} \quad (1)$$

When choosing the sense resistor value, two main issues must be taken into account:

- The sense resistor dissipates energy; for this reason the resistance of this component should be kept low.
- The lower the $R_{SNSx}$ value, the higher the peak current error due to noise on the $V_{REF}$ pin and the input offset of the current sense comparator. Values of $R_{SNSx}$ that are too low must be avoided.

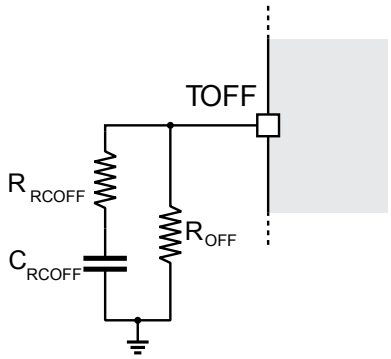
Figure 5. **PWM current control sequence**



### 6.3.1 OFF time adjustment

The total OFF 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 to indications listed in Table 10 .

**Figure 6. OFF time regulation circuit**

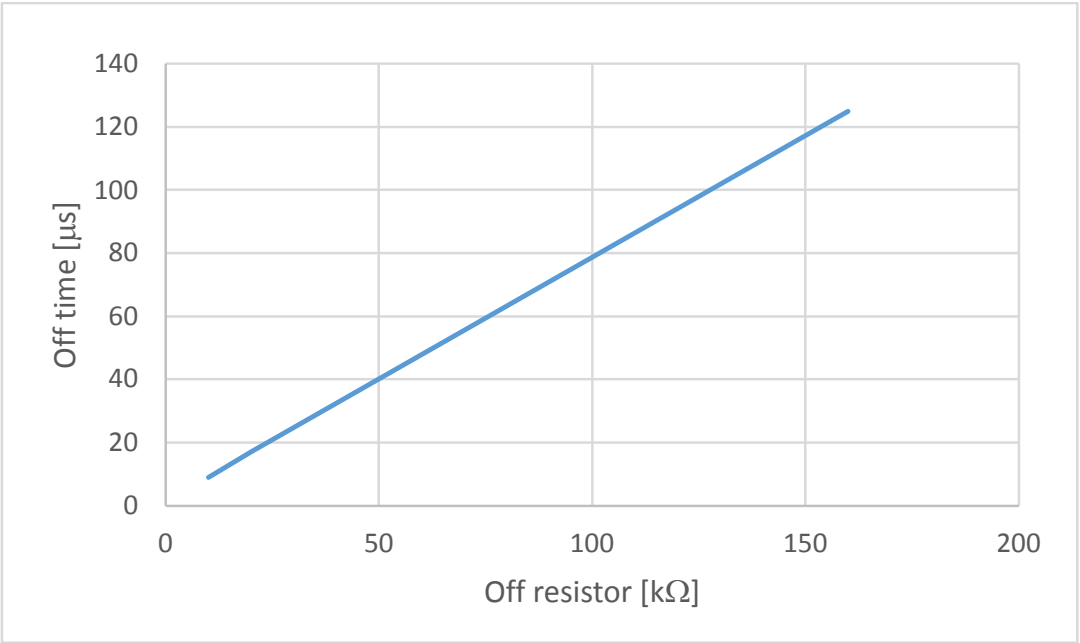



The relationship between the OFF time and the external resistor value is shown in Figure 7. The value typically ranges from 10 µs to 150 µs.

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

| $R_{OFF}$ | $R_{RCOFF}$ | $C_{RCOFF}$ |
|---|---|---|
| 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**



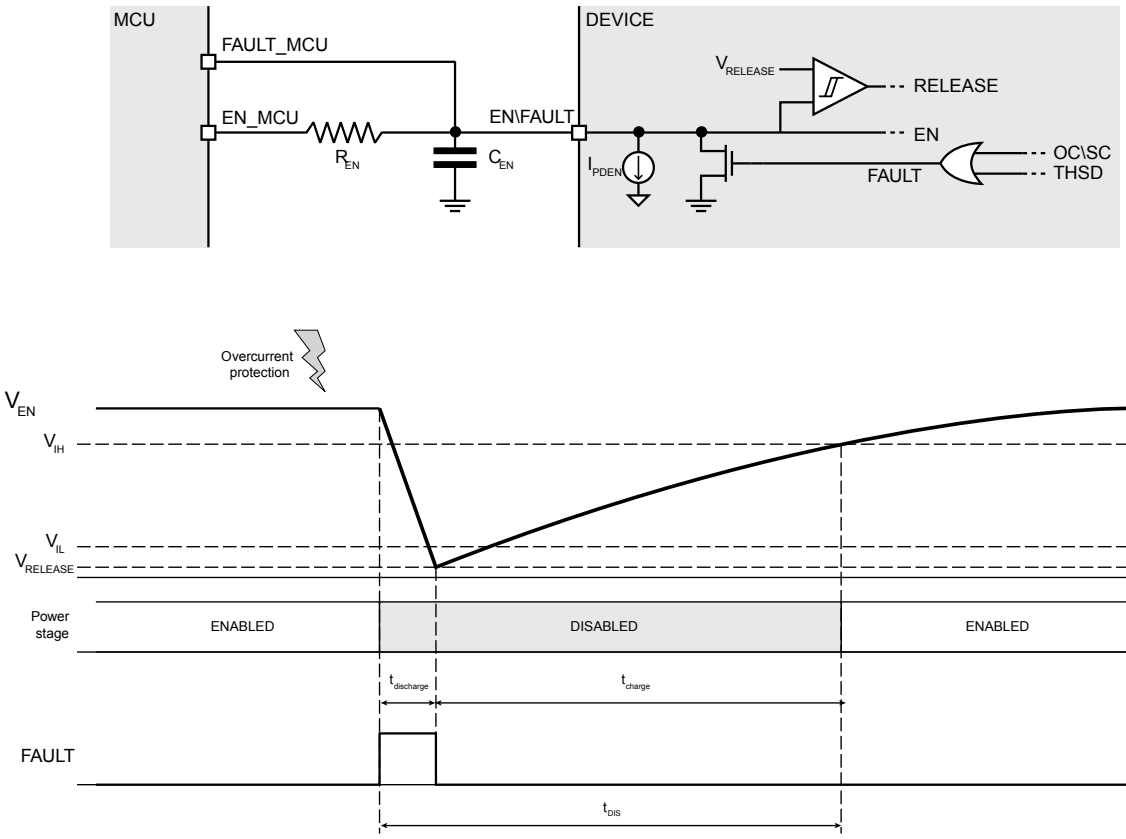
## 6.4 Overcurrent and short circuit protections

The device embeds a circuitry protecting each power output against the over load and short circuit conditions (short to ground, short to $V_S$ and short 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 by 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 sizing properly the external network connected to the EN\FAULT pin (refer to Figure 9 and Figure 10).

**Equation 2**

(2)

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

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

**Equation 3**

(3)

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

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

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

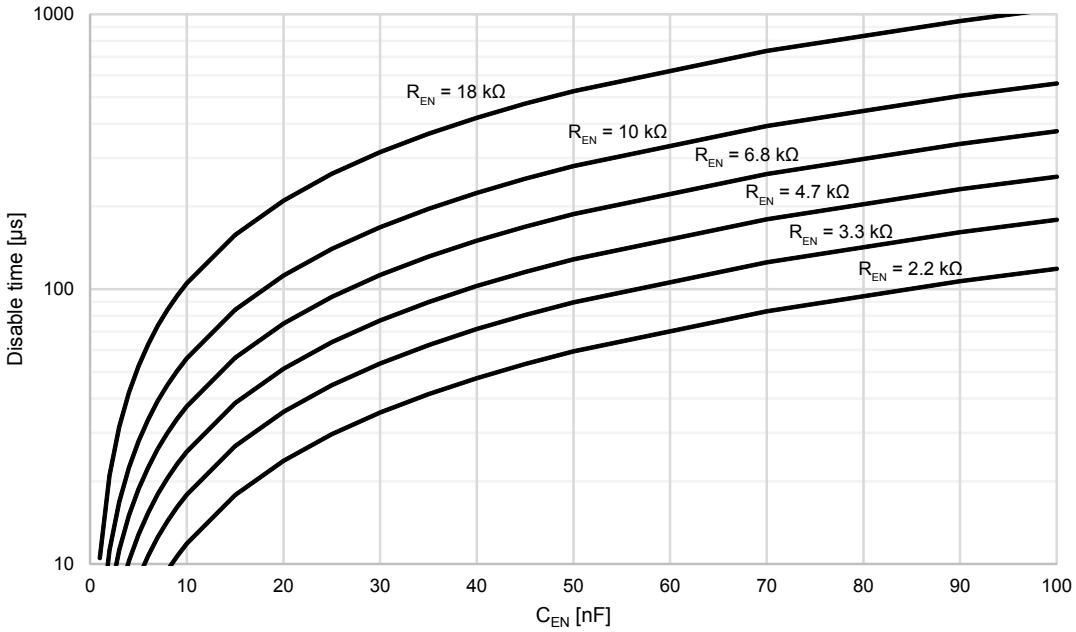
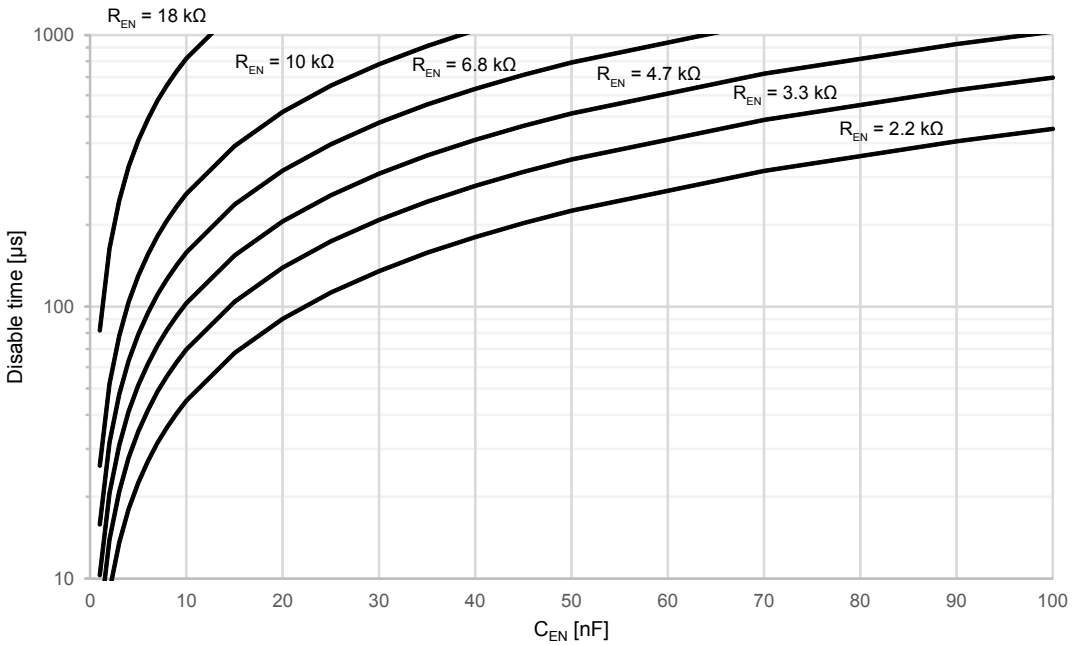



Figure 10. Disable time versus $R_{EN}$ and $C_{EN}$ values ($V_{DD}$ = 1.8 V)



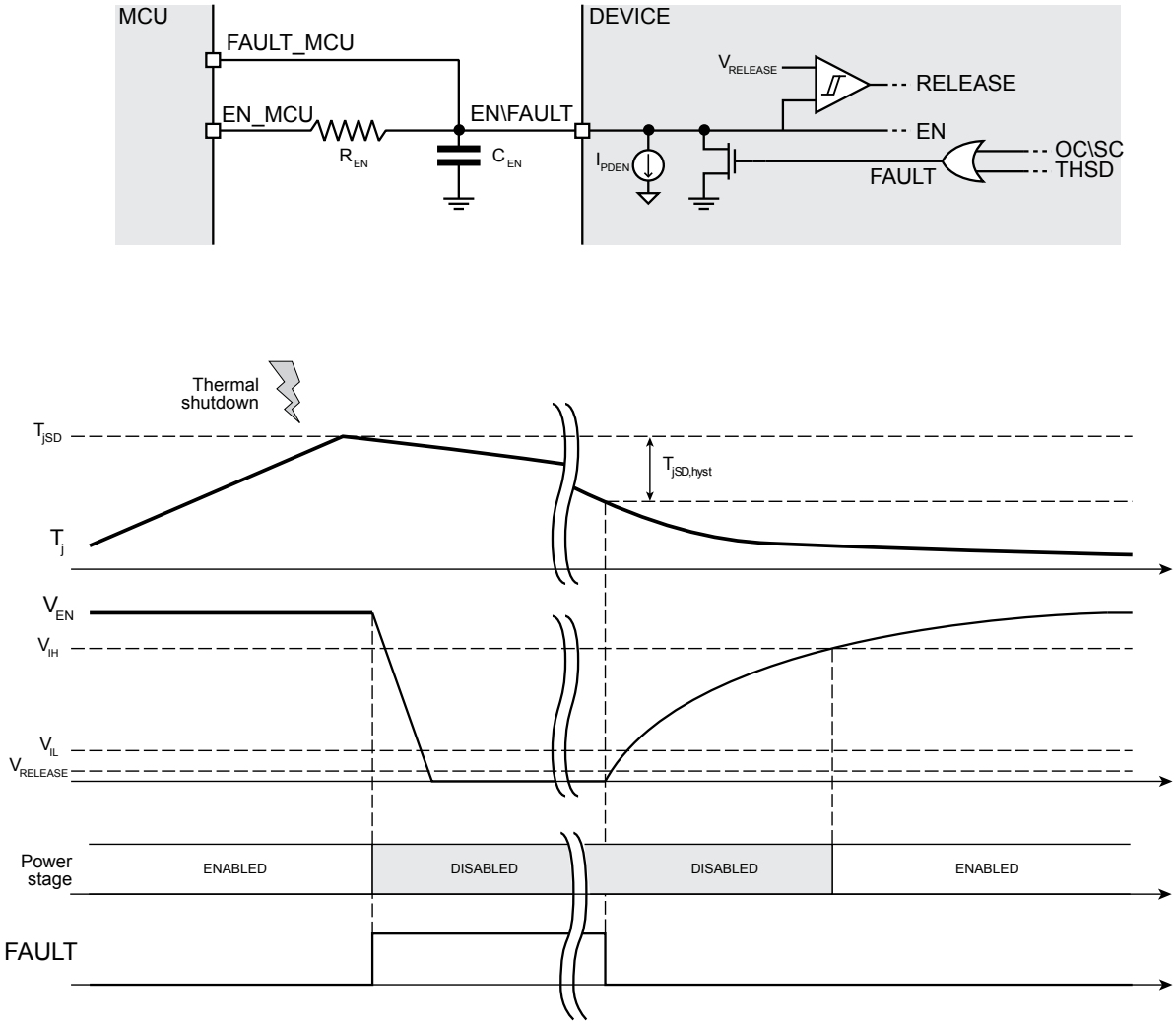
## 6.5 Thermal shutdown

The device embeds a circuitry protecting it from the over-temperature conditions.

When the thermal shutdown temperature is reached the power stage is disabled and the EN\FAULT input is forced low by the integrated open-drain MOSFET (refer to Figure 11).

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**

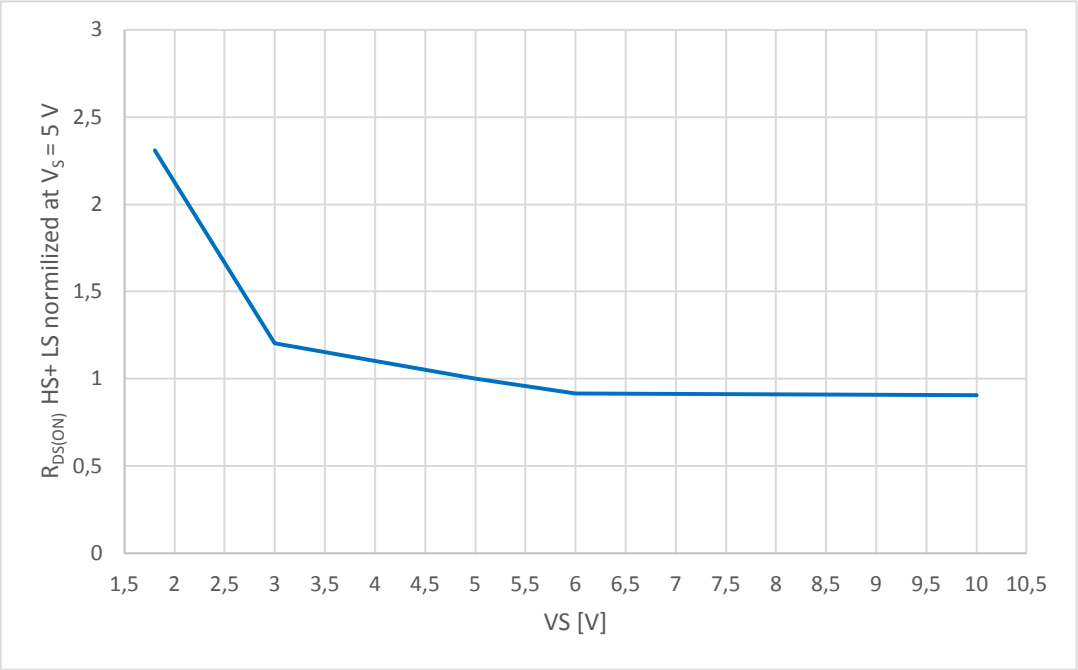



Figure 13. **Power stage resistance versus temperature**

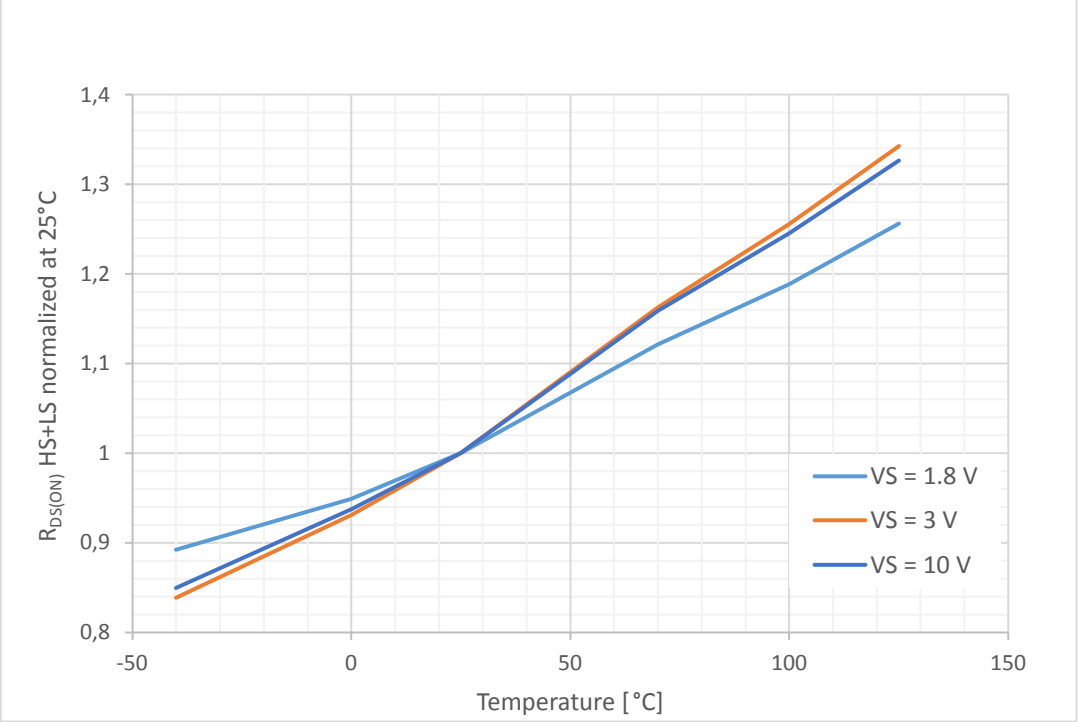
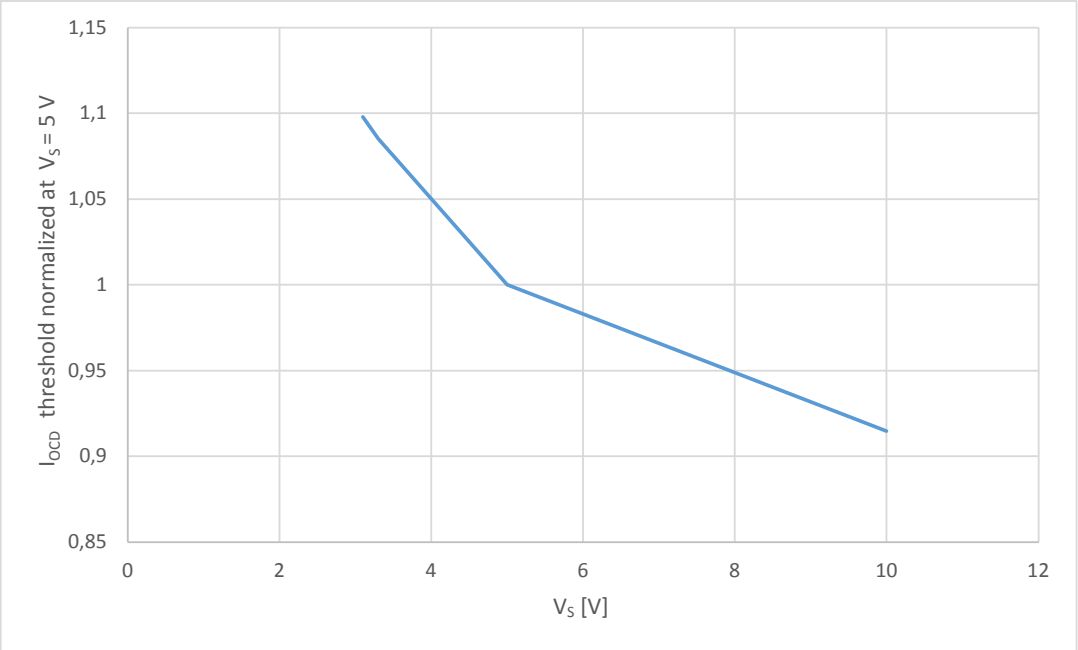


Figure 14. **Overcurrent threshold versus supply voltage**



# 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 3x3x1.0 16L package information

**Table 11. Package dimensions**

| Symbol | Dimensions [mm] | | |
|---|---|---|---|
| | Min. | Typ. | Max. |
| A | 0.80 | 0.90 | 1.00 |
| A1 | 0.00 | 0.02 | 0.05 |
| A3 | | 0.20 | |
| b | 0.20 | 0.25 | 0.30 |
| D | | 3.00 BSC | |
| D1 | | 1.50 BSC | |
| D2 | 1.60 | 1.70 | 1.80 |
| e | | 0.50 BSC | |
| E | | 3.00 BSC | |
| D2 | | 1.50 BSC | |
| E2 | 1.60 | 1.70 | 1.80 |
| L | 0.30 | 0.40 | 0.50 |
| k | 0.20 | | |
| N | | 16 | |
| aaa | | 0.15 | |
| bbb | | 0.10 | |
| ccc | | 0.10 | |
| ddd | | 0.05 | |
| eee | | 0.08 | |
| fff | | 0.10 | |

Figure 15. **Package outline**

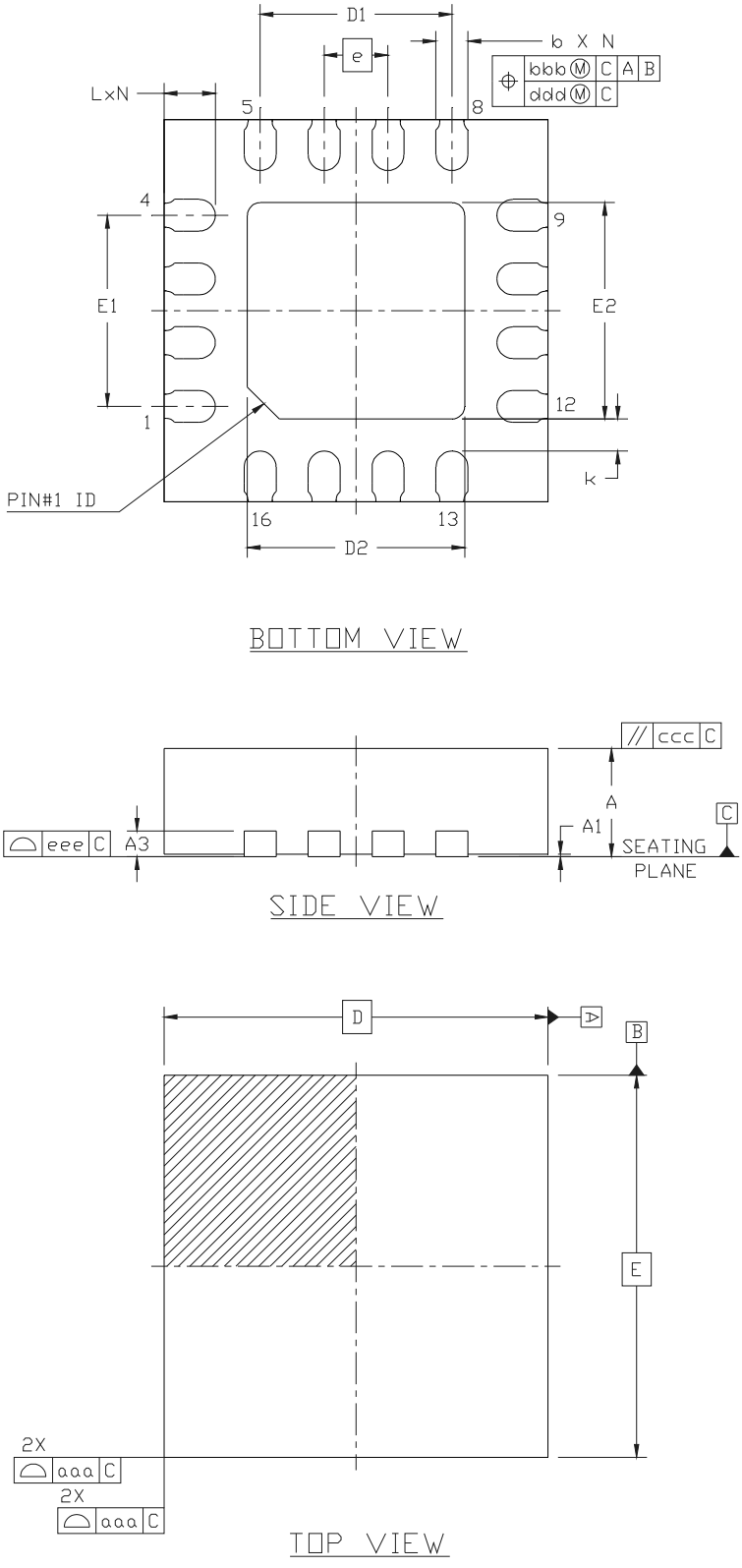
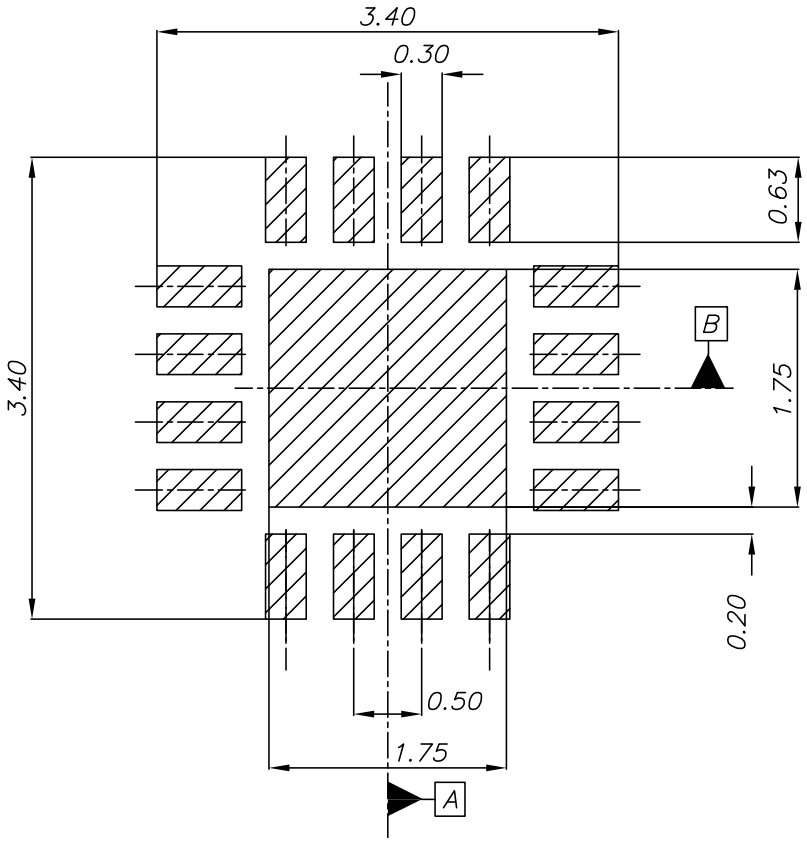


Figure 16. **Recommended footprint**



## Revision history

Table 12. **Document revision history**

| Date | Version | Changes |
|---|---|---|
| 06-May-2016 | 1 | Initial release. |
| 30-Jun-2016 | 2 | Updated document status to *Datasheet - production data* on cover page.<br>Updated Table 1 (changed Max. value of VS from 12 to 11).<br>Updated Table 7 (changed value of $t_{OFF}$ from 47 µs to 37 µs). |
| 04-Nov-2016 | 3 | Updated Figure 1 and Figure 12.<br>Updated Table 2 (added $t_{INw}$ parameter) and Table 3.<br>Minor modifications throughout document. |
| 11-Aug-2017 | 4 | Updated Table 2 (removed $t_{INw}$ parameter).<br>Updated title of Figure 12 and Figure 13.<br>Minor modifications throughout document. |
| 13-Sep-2023 | 5 | Updated Table 5 (modified test condition of $V_{SNS,OFFSET}$ parameter).<br>Updated Section 6.1 Standby and power-up.<br>Updated Figure 5, Figure 8 and Figure 11.<br>Updated all data in Section 8.1 VFQFPN 3x3x1.0 16L package information. |

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