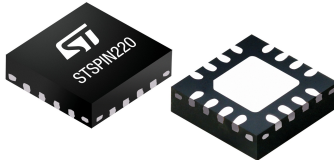


Low voltage stepper motor driver



VFQFPN 3 X 3 X 1.0 (16-pin)

Features

- Operating voltage: from 1.8 to 10 V
- Maximum output current: 1.3 A_{rms}
- R_{DS(ON)} HS + LS = 0.4 Ω typ.
- Microstepping up to 1/256th of a step
- 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 stepper motor applications such as:

- Pop-up camera control for smartphones
- Point of sale (POS) devices
- Portable printers
- PC peripherals and accessories
- Robotics
- Toys
- Reflex cameras

Description

The STSPIN220 is a stepper motor driver which integrates, in a small VFQFPN 3 x 3 x 1.0 mm package, both control logic and a low R_{DS(on)} power stage.

The integrated controller implements PWM current control with fixed OFF time and a microstepping resolution up to 1/256th of a step.

The device is designed to operate in battery-powered scenarios and can be forced into 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.

Product status link

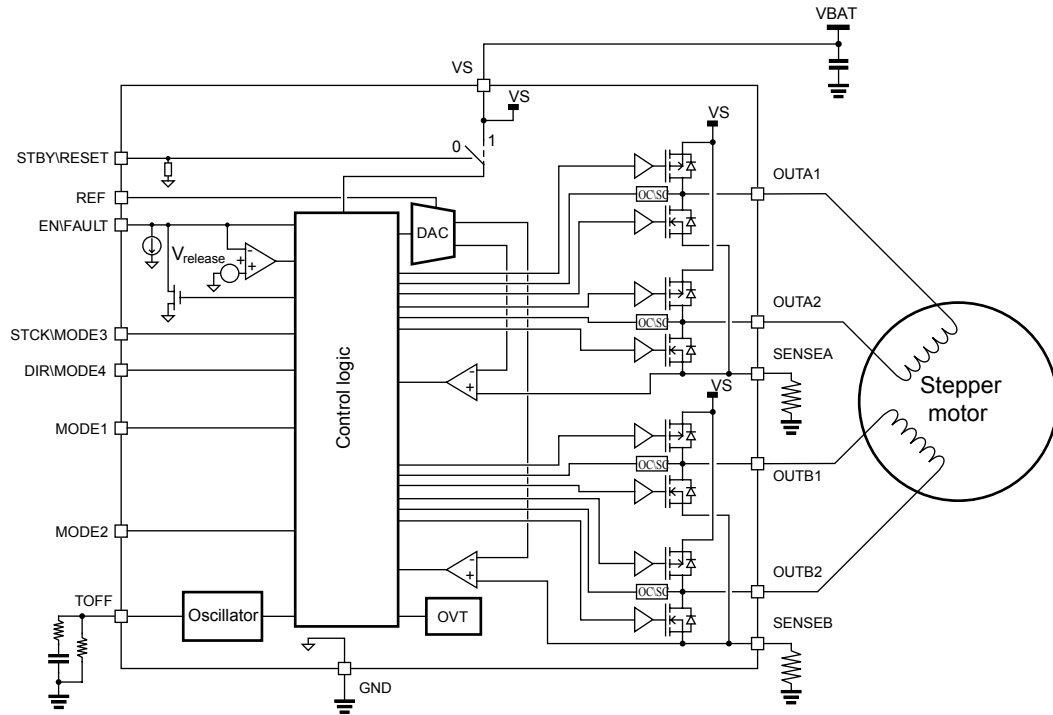
[STSPIN220](#)

Product summary

Order code	STSPIN220
Package	VFQFPN 3x3x1.0 16L
Packing	Tape & reel

1 Block diagram

Figure 2. Block diagram



AM040026

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 pin voltage		-1 to 1	V
V_{REF}	Reference voltage input		-0.3 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
t_{INW}	Logic inputs positive/negative pulse width		300			ns

2.3 Thermal data

Table 3. Thermal data

Symbol	Parameter	Conditions	Value	Unit
$R_{th(JA)}$	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
Ψ_{JT}	Junction to top characterization	According to JESD51-2a ⁽¹⁾	3.3	°C/W
Ψ_{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 μ m vias below exposed pad.

2.4 ESD protection

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-002-2014	C2a	500	V

3 Electrical characteristics

Test conditions: $V_S = 5\text{ V}$, $T_j = 25\text{ °C}$ unless otherwise specified.

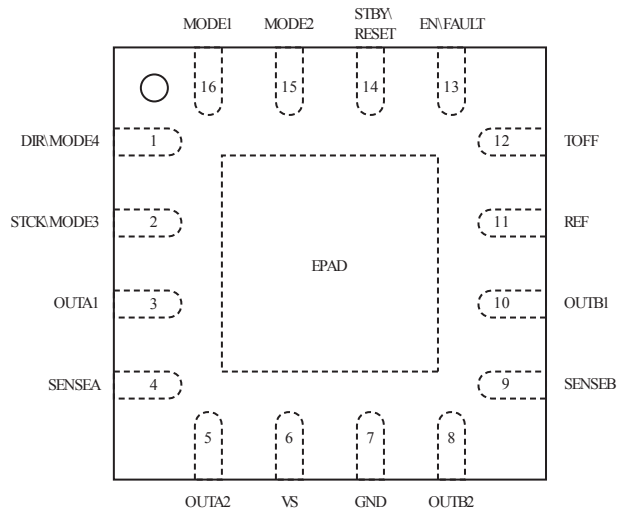
Table 5. Electrical characteristics

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 EN = '0' $R_{OFF} = 160\text{ k}\Omega$		960	1300	μA
		No commutations EN = '1' $R_{OFF} = 160\text{ k}\Omega$		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 high logic level input voltage		1.48			V
Power stage						
$R_{DS(ON)HS+LS}$	Total ON resistance HS + LS	$V_S = 10\text{ V}$, $I_{OUT} = 1.3\text{ A}$		0.4	0.65	Ω
		$V_S = 10\text{ V}$, $I_{OUT} = 1.3\text{ A}$, $T_j = 125\text{ °C}^{(1)}$		0.53	0.87	
		$V_S = 3\text{ V}$, $I_{OUT} = 0.4\text{ A}$		0.53	0.8	
I_{DSS}	Leakage current	OUTx = V_S			1	μA
		OUTx = GND	- 1			
V_{DF}	Freewheeling diode forward voltage	$I_D = 1.3\text{ A}$		0.9		V
t_{rise}	Rise time	$V_S = 10\text{ V}$; unloaded outputs		10		ns
t_{fall}	Fall time	$V_S = 10\text{ V}$; unloaded outputs		10		ns
t_{DT}	Dead time			50		ns
Current control						

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
$V_{SNS,OF}$ F_{SET}	Sensing offset	$V_{REF} = 0.5\text{ V}$; Internal reference 20% V_{REF}	-15		+15	mV
t_{OFF}	Total OFF time	$R_{OFF} = 10\text{ k}\Omega$		9		μs
		$R_{OFF} = 160\text{ k}\Omega$		125		μs
Δf_{OSC}	Internal oscillator precision ($f_{OSC}/f_{OSC,ID}$)	$R_{OFF} = 20\text{ k}\Omega$	-20%		+20%	
$t_{OFF,jitter}$	Total OFF time jittering	$R_{OFF} = 10\text{ k}\Omega$			2%	
$t_{OFF,SLOW}$	Slow decay time			$5/8 \times t_{OFF}$		μs
$t_{OFF,FAST}$	Fast decay time			$3/8 \times t_{OFF}$		μs
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}	EN Low logic level output voltage	$I_{EN} = 4\text{ mA}$			0.4	V
R_{STBY}	STBY pull-down resistance			36		k Ω
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_{MODEHo}	MODEx input hold time	From STBY edge, see Figure 6	100			μs
t_{MODESu}	MODEx input setup time	From STBY edge, see Figure 6	1			μs
t_{DIRh}	DIR input hold time	From STCK rising edge, see Figure 5	100			ns
t_{DIRsu}	DIR input setup time	From STCK rising edge, see Figure 5	100			ns
t_{STCKH}	STCK high time	See Figure 5	100			ns
t_{STCKL}	STCK low time	See Figure 5	100			ns
f_{STCK}	STCK inputs frequency	See Figure 5			1	MHz
Protections						
T_{jSD}	Thermal shutdown threshold			160		$^{\circ}\text{C}$
$T_{jSD,Hyst}$	Thermal shutdown hysteresis			40		$^{\circ}\text{C}$
I_{OC}	Overcurrent threshold	See Figure 15. Power stage resistance versus temperature		2		A

1. Based on characterization data on a limited number of samples, not tested during production.

4 Pin description

Figure 3. Pin connection (top view)


Note: The exposed pad must be connected to ground.

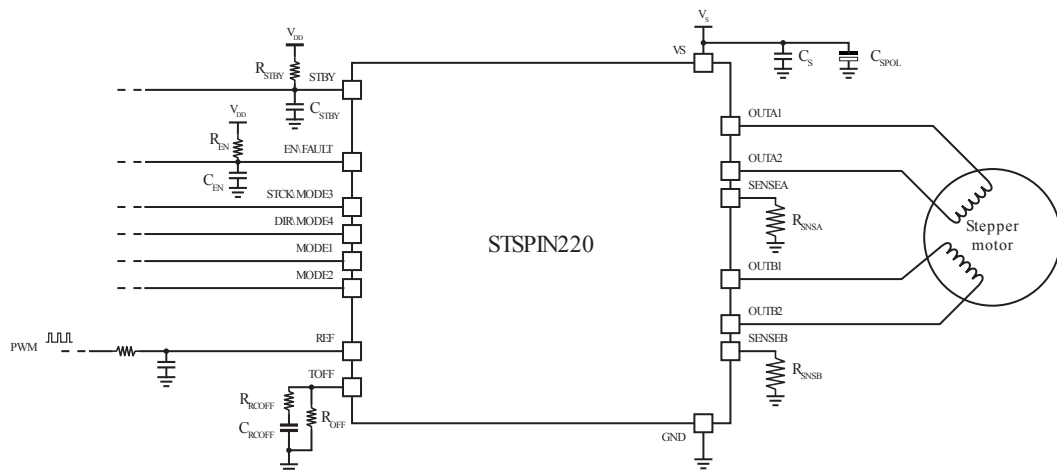
Table 6. Pin description

N.	Name	Type	Function
1	DIR\MODE4	Logic input	Direction input, Step mode selection input 4.
2	STCK\MODE3	Logic input	Step clock input, Step mode selection input 3.
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 PWM current control circuitry.
12	TOFF	Analog input	Internal oscillator frequency adjustment.
13	EN\FAULT	Logic input/Open drain output	This is the power stage enable (when low, the power stage is turned off) and is forced low through the integrated open-drain MOSFET when a failure occurs.
14	STBY\RESET	Logic input	When forced low, the device is forced into low consumption mode.
15	MODE2	Logic input	Step mode selection input 2.
16	MODE1	Logic input	Step mode selection input 1.

5 Typical application

Table 7. Typical application values

Name	Value
C_S	2.2 μF / 16V
C_{SPOL}	22 μF / 16V
$R_{\text{SNSA}}, R_{\text{SNSB}}$	330 $\text{m}\Omega$ / 1W
C_{EN}	10 nF / 6.3V
R_{EN}	18 $\text{k}\Omega$
C_{STBY}	1 nF / 6.3V
R_{STBY}	18 $\text{k}\Omega$
C_{OFF}	22 nF
R_{COFF}	1 $\text{k}\Omega$
R_{OFF}	47 $\text{k}\Omega$ ($t_{\text{OFF}} \cong 37 \mu\text{s}$)

Figure 4. Typical application schematic


6 Functional description

The STSPIN220 is a stepper motor driver integrating a microstepping sequencer (up to 1/256th of a step), two PWM current controllers and a power stage composed of 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 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 exits the standby status, all of the control circuitry is reset to 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 Microstepping sequencer

The value of the MODE_x inputs is latched at power-up and when the device exits the STBY condition. After this, the input value is unimportant and the MODE3 and MODE4 inputs start operating as step-clock and direction input.

The only exception is the MODE1 = MODE2 = LOW condition; in this case the system is forced into full-step mode. The previous condition is restored as soon as the MODE1 and MODE2 inputs switch to a different combination.

An example of mode selection is shown in [Figure 5. STCK and DIR timing](#).

At each STCK rising edge, the sequencer of the device is increased (DIR input high) or decreased (DIR input low) of a module selected through the MODE_x inputs as listed in [Table 8. Step mode selection through MODE_x inputs](#).

The sequencer is a 10-bit counter that sets the reference value of the PWM current controller and the direction of the current for both of the H bridges.

Table 8. Step mode selection through MODE_x inputs

MODE3 (STCK)	MODE4 (DIR)	MODE1	MODE2	Step mode
0	0	0	0	Full-step
0	0	0	1	1/32 nd step
0	0	1	0	1/128 th step
0	0	1	1	1/256 th step
0	1	0	0	Full-step - 1/32 nd step ⁽¹⁾
0	1	0	1	1/4 th step
0	1	1	0	1/256 th step
0	1	1	1	1/64 th step
1	0	0	0	Full-step - 1/128 nd step ⁽¹⁾
1	0	0	1	1/256 th step
1	0	1	0	1/2 step
1	0	1	1	1/8 th step
1	1	0	0	Full-step - 1/256 th step ⁽¹⁾
1	1	0	1	1/64 th step

MODE3 (STCK)	MODE4 (DIR)	MODE1	MODE2	Step mode
1	1	1	0	1/8 th step
1	1	1	1	1/16 th step

1. This driving mode is automatically bypassed by the $MODE1 = MODE2 = 0$ if it is kept after the device quit the standby condition.

Figure 5. STCK and DIR timing

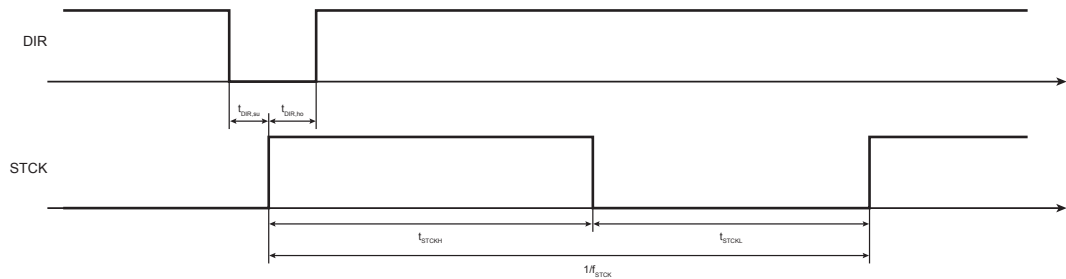
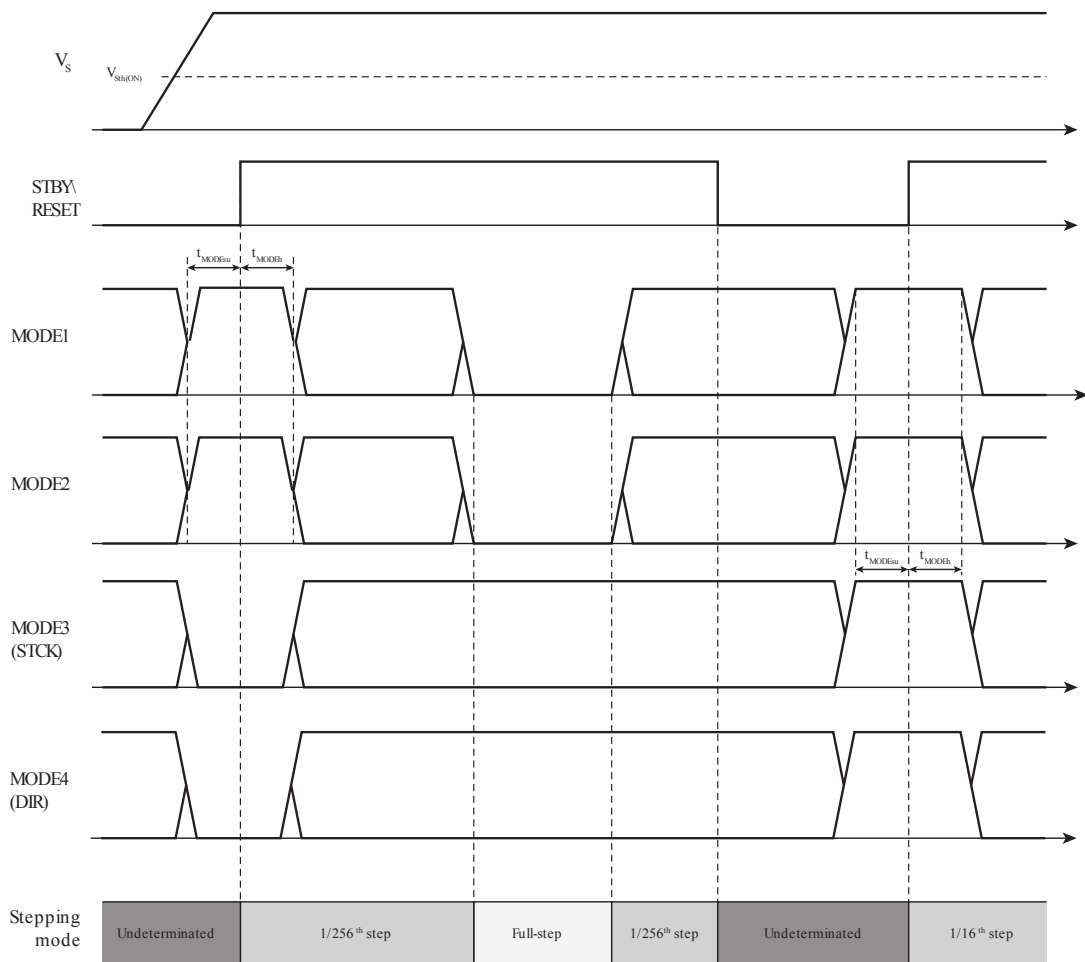


Figure 6. Mode selection example



When the full-step mode is set, the reference value of the PWM current controller and the direction of the current for both H bridges as listed in Table 8. Step mode selection through MODEx inputs.

Table 9. Target reference and current direction according to sequencer value (full-step mode)

Sequencer value											Phase A		Phase B	
											Reference voltage	Current direction	Reference voltage	Current direction
0	0	X	X	X	X	X	X	X	X	X	$100\% \times V_{REF}$	A1 → A2	$100\% \times V_{REF}$	B1 → B2
0	1	X	X	X	X	X	X	X	X	X	$100\% \times V_{REF}$	A1 → A2	$100\% \times V_{REF}$	B1 ← B2
1	0	X	X	X	X	X	X	X	X	X	$100\% \times V_{REF}$	A1 ← A2	$100\% \times V_{REF}$	B1 ← B2
1	1	X	X	X	X	X	X	X	X	X	$100\% \times V_{REF}$	A1 ← A2	$100\% \times V_{REF}$	B1 → B2

When the step mode is different from the full-step mode the values listed in [Table 10. Target reference and current direction according to sequencer value \(not full-step mode\)](#) are used.

Table 10. Target reference and current direction according to sequencer value (not full-step mode)

Sequencer value											Phase A		Phase B	
											Reference voltage	Current direction	Reference voltage	Current direction
0	0	0	0	0	0	0	0	0	0	0	Zero (power bridge disabled)	-	$100\% \times V_{REF}$	B1 → B2
0	0	N									$\sin(N/256 \times \pi/2) \times V_{REF}$	A1 → A2	$\cos(N/256 \times \pi/2) \times V_{REF}$	B1 → B2
0	1	0	0	0	0	0	0	0	0	0	$100\% \times V_{REF}$	A1 → A2	Zero (power bridge disabled)	-
0	1	N									$\sin(\pi/2 + N/256 \times \pi/2) \times V_{REF}$	A1 → A2	$\cos(\pi/2 + N/256 \times \pi/2) \times V_{REF}$	B1 ← B2
1	0	0	0	0	0	0	0	0	0	0	Zero (power bridge disabled)	-	$100\% \times V_{REF}$	B1 ← B2
1	0	N									$\sin(N/256 \times \pi/2) \times V_{REF}$	A1 ← A2	$\cos(N/256 \times \pi/2) \times V_{REF}$	B1 ← B2
1	1	0	0	0	0	0	0	0	0	0	$100\% \times V_{REF}$	A1 ← A2	Zero (power bridge disabled)	-
1	1	N									$\sin(\pi/2 + N/256 \times \pi/2) \times V_{REF}$	A1 ← A2	$\cos(\pi/2 + N/256 \times \pi/2) \times V_{REF}$	B1 → B2

The following table shows the target reference and sequencer values for 1/2-, 1/4- and 1/8-step operation. Higher microstepping resolutions follow the same pattern. The reset state (home state) for all stepping mode is entered at power-up or when the device exits the standby status.

Table 11. Example

1/2 step	1/4 step	1/8 step	VREF phase A	VREF phase B	Sequencer value
1	1	1	0%	100%	000000000 home state
		2	19.509%	98.079%	0000100000
	2	3	38.268%	92.388%	0001000000
		4	55.557%	83.147%	0001100000

1/2 step	1/4 step	1/8 step	VREF phase A	VREF phase B	Sequencer value
2	3	5	70.711%	70.711%	001000000
		6	83.147%	55.557%	001010000
	4	7	92.388%	19.509%	001110000
		8	98.079%	19.509%	001110000
3	5	9	100%	0%	010000000
		10	98.079%	-19.509%	010010000
	6	11	92.388%	-38.268%	010100000
		12	83.147%	-55.557%	010110000
4	7	13	70.711%	-70.711%	011000000
		14	55.557%	-83.147%	011010000
	8	15	38.268%	-92.388%	011100000
		16	19.509%	-98.079%	100010000
5	9	17	0%	100%	100000000
		18	-19.509%	-98.079%	100010000
	10	19	-38.268%	-92.388%	100100000
		20	-55.557%	-83.147%	100110000
6	11	21	-70.711%	-70.711%	101000000
		22	-83.147%	-55.557%	101010000
	12	23	-92.388%	-38.268%	101100000
		24	-98.079%	-19.509%	101110000
7	13	25	-100%	0%	110000000
		26	-98.079%	19.509%	110010000
	14	27	-92.388%	38.268%	110100000
		28	-83.147%	55.557%	110110000
8	15	29	-70.711%	70.711%	111000000
		30	-55.557%	83.147%	111010000
	16	31	-38.268%	92.388%	111100000
		32	-19.509%	98.079%	111110000

Note: The positive number means that the output current is flowing from OUTx1 to OUTx2, vice versa for a negative value.

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 respective internal reference generated based on the sequencer value (see [Table 9. Target reference and current direction according to sequencer value \(full-step mode\)](#) and [Table 10. Target reference and current direction according to sequencer value \(not full-step mode\)](#)).

When $V_{SENSEX} > V_{REFX}$, the integrated comparator is triggered, the OFF time counter is started and the decay sequence is performed.

The decay sequence starts turning on both the low sides of the full bridge. When 5/8^{ths} of the programmed OFF time ($t_{OFF,SLOW}$) has expired, the decay sequence performs a quasi-synchronous fast decay.

Table 12. ON, slow decay and fast decay states

Current direction ⁽¹⁾	ON	Slow decay	Fast decay (quasi-synch)
Zero (power bridge disabled)	HSX1 = OFF LSX1 = OFF HSX2 = OFF LSX2 = OFF	HSX1 = OFF LSX1 = OFF HSX2 = OFF LSX2 = OFF	HSX1 = OFF LSX1 = OFF HSX2 = OFF LSX2 = OFF
X1 → X2	HSX1 = ON LSX1 = OFF HSX2 = OFF LSX2 = ON	HSX1 = OFF LSX1 = ON HSX2 = OFF LSX2 = ON	HSX1 = OFF LSX1 = ON HSX2 = OFF LSX2 = OFF
X1 ← X2	HSX1 = OFF LSX1 = ON HSX2 = ON LSX2 = OFF	HSX1 = OFF LSX1 = ON HSX2 = OFF LSX2 = ON	HSX1 = OFF LSX1 = OFF HSX2 = OFF LSX2 = ON

1. The current direction is set according to Table 9. Table 9 and Table 9. Target reference and current direction according to sequencer value (full-step mode) Table 10. Target reference and current direction according to sequencer value (not full-step mode).

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

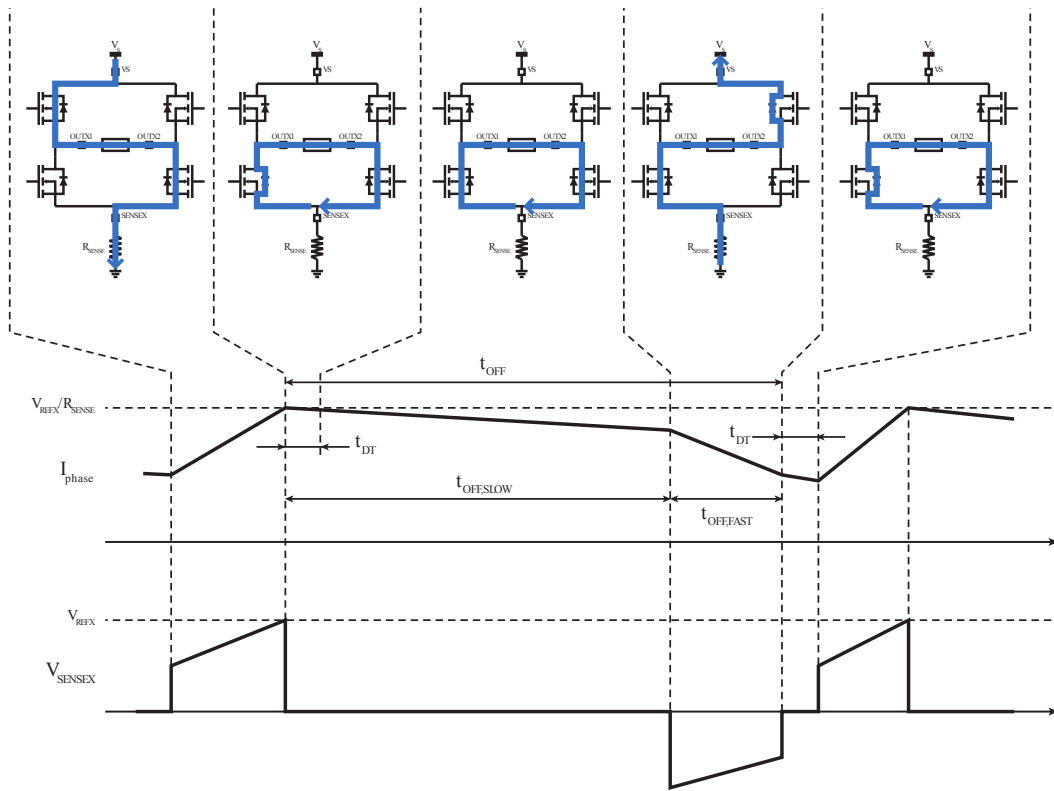
Equation 1

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

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

- The sense resistor dissipates energy and provides dangerous negative voltages on the SENSE pins during current recirculation. For this reason the resistance of this component should be kept low (using multiple resistors in parallel will help to obtain the required power rating with standard resistors).
- 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.

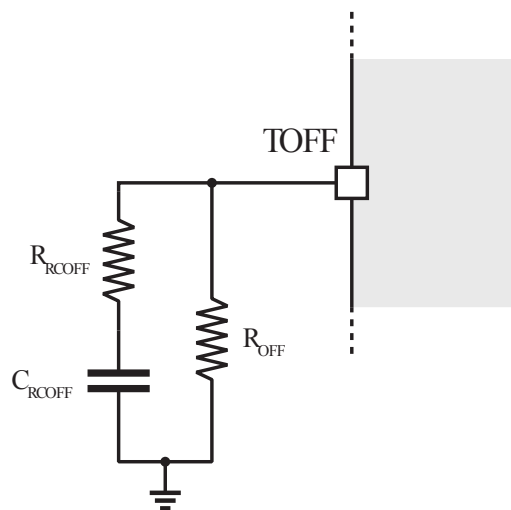
Figure 7. PWM current control sequence



6.3.1 OFF time adjustment

The total OFF time (slow decay + fast decay) is adjusted through an external resistor connected between the TOFF pin and ground, as shown in Figure 8. PWM current control sequence. 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 Table 12. ON, slow decay and fast decay states indications.

Figure 8. OFF time regulation circuit

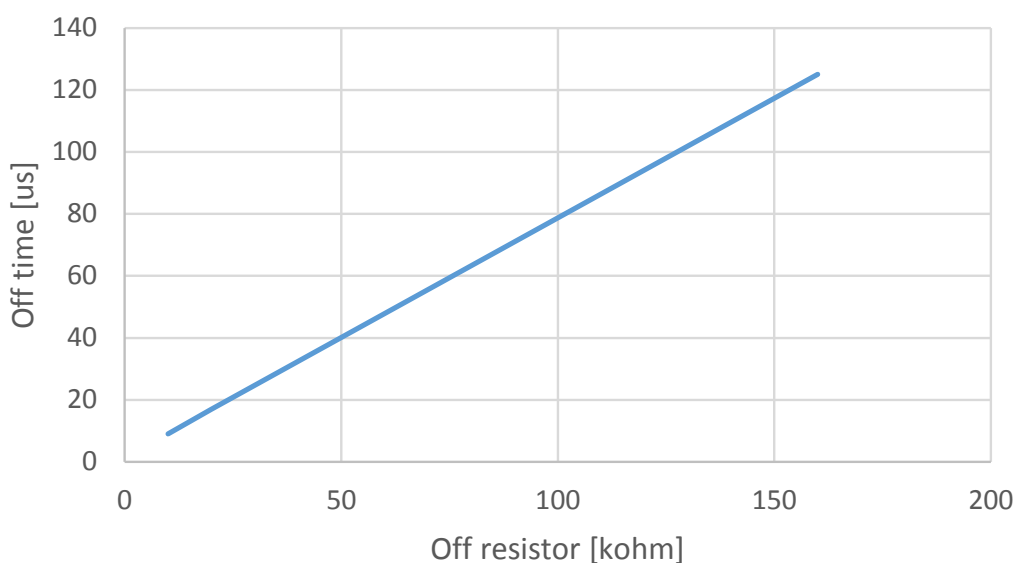


The relationship between the OFF time and the external resistor value is shown in [Figure 8. OFF time regulation circuit](#). The value typically ranges from 10 μ s to 150 μ s.

Table 13. Recommended R_{RCOFF} and C_{RCOFF} values according to R_{OFF}

R_{OFF}	R_{RCOFF}	C_{RCOFF}
$10\text{ k}\Omega \leq R_{OFF} < 82\text{ k}\Omega$	1 k Ω	22 nF
$82\text{ k}\Omega \leq R_{OFF} \leq 160\text{ k}\Omega$	2.2 k Ω	22 nF

Figure 9. OFF time vs. R_{OFF} value



6.4 Overcurrent and short-circuit protection

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 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 (refer to [Figure 10. Overcurrent and short-circuit protection management](#)).

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 external R_{EN} resistor.

Figure 11. Disable time versus R_{EN} and C_{EN} values ($V_{DD} = 3.3\text{ V}$)

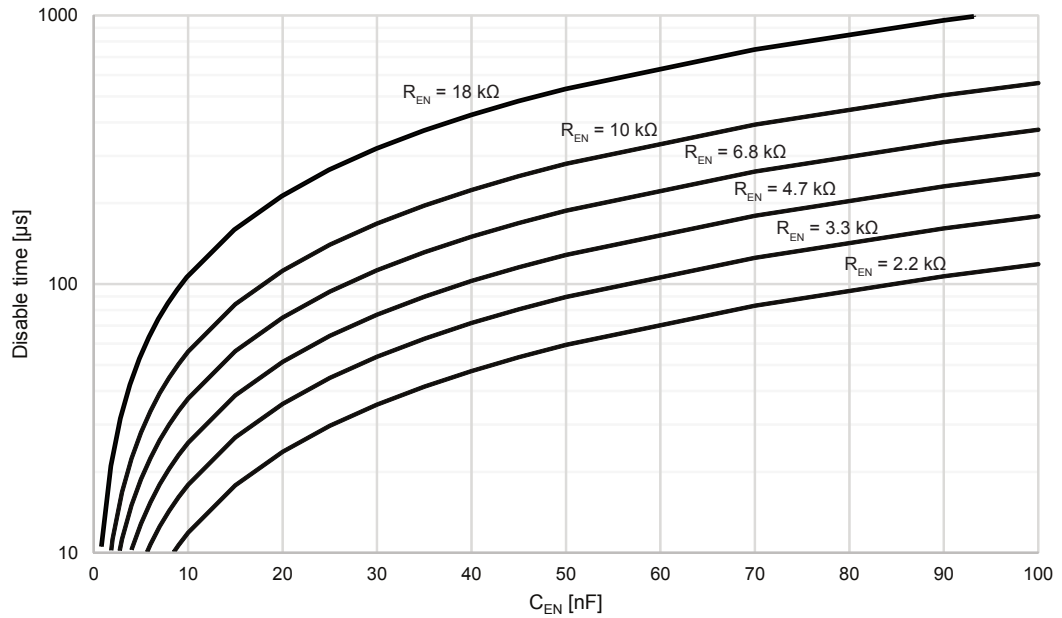
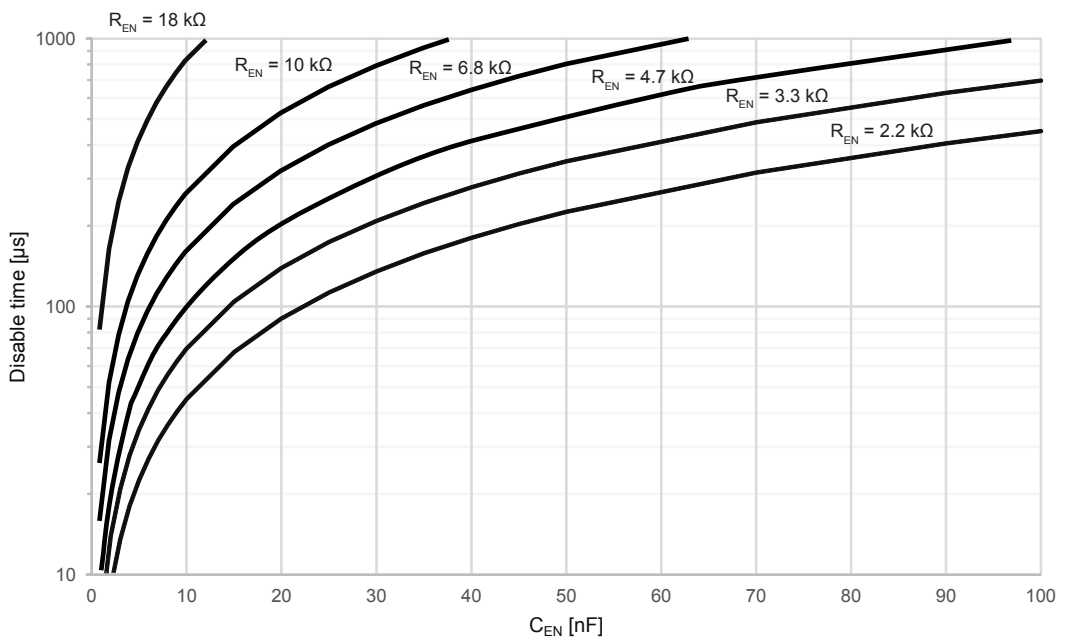


Figure 12. Disable time versus R_{EN} and C_{EN} values ($V_{DD} = 1.8\text{ V}$)

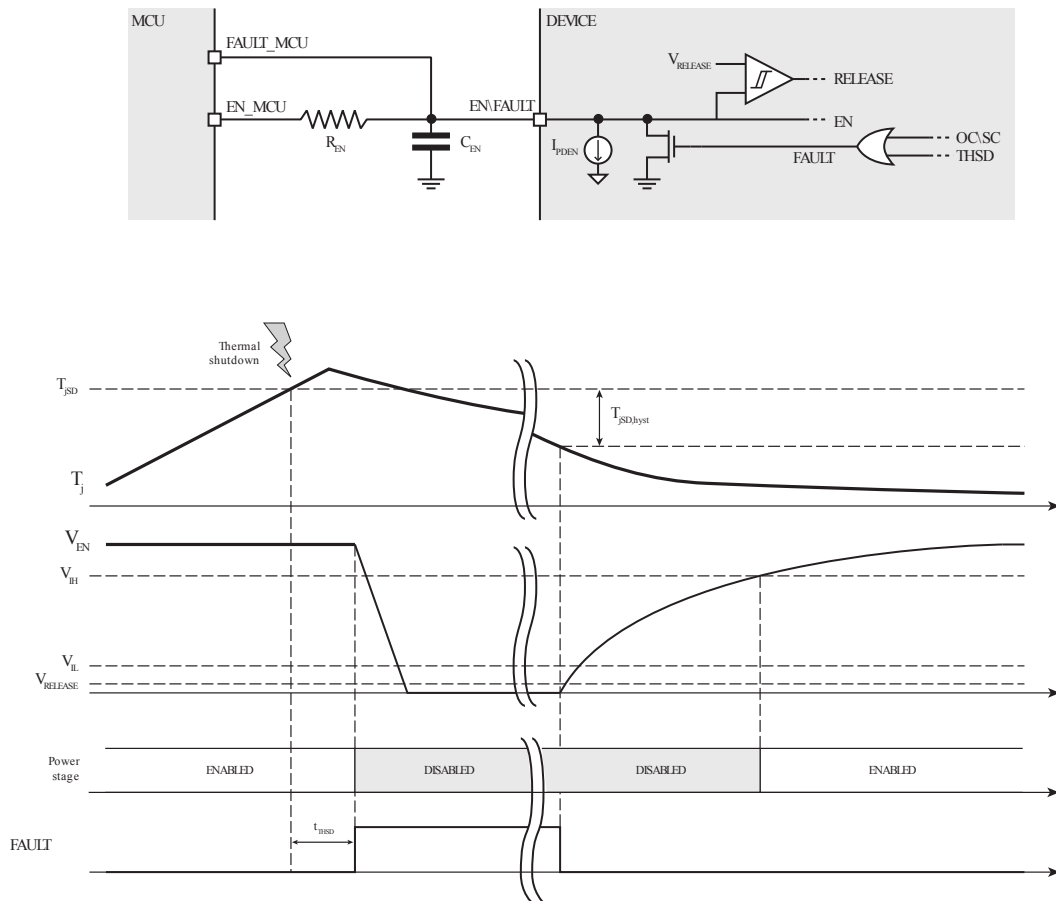


6.5 Thermal shutdown

The device embeds circuitry protecting it from the overtemperature conditions.

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 (refer to [Figure 13. Thermal shutdown management](#)). 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 13. Thermal shutdown management



7 Graphs

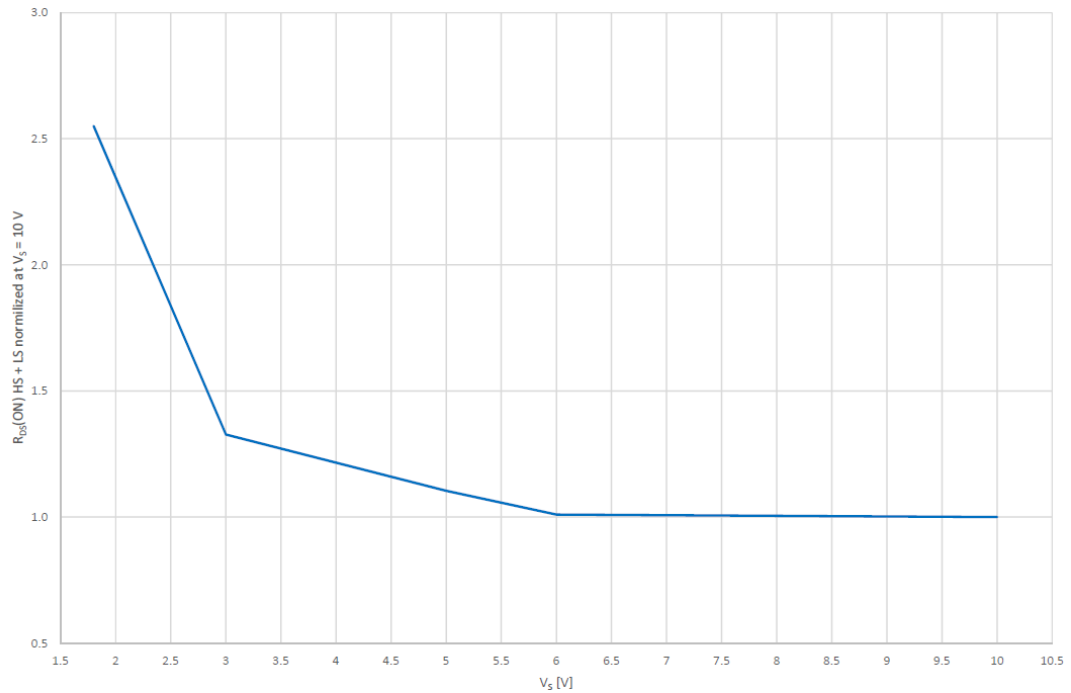
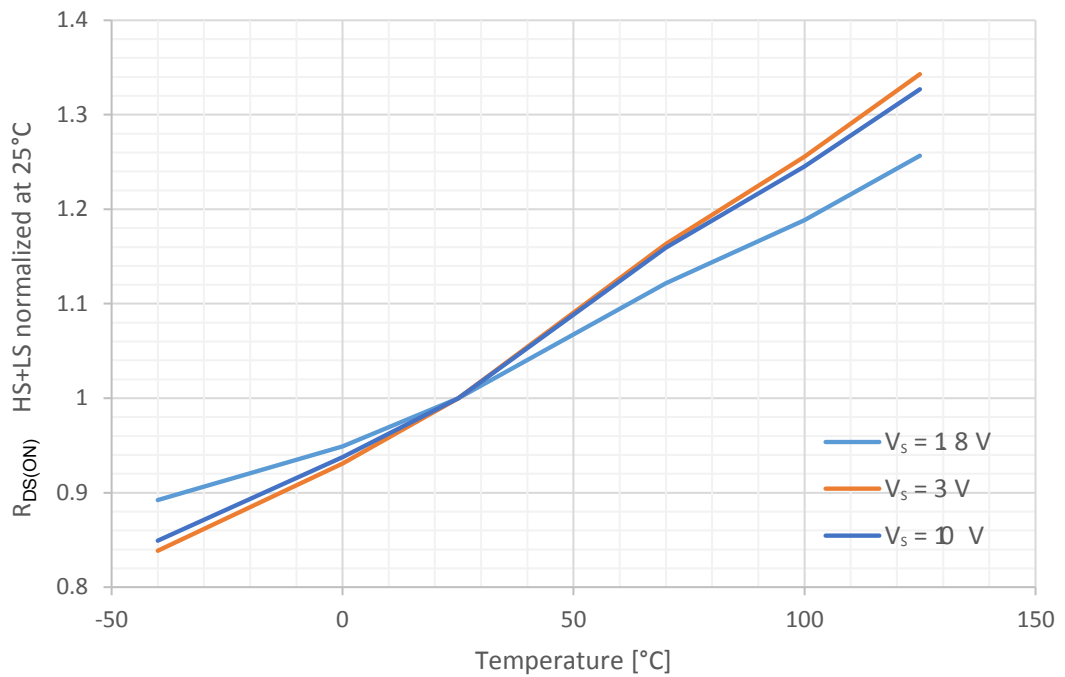
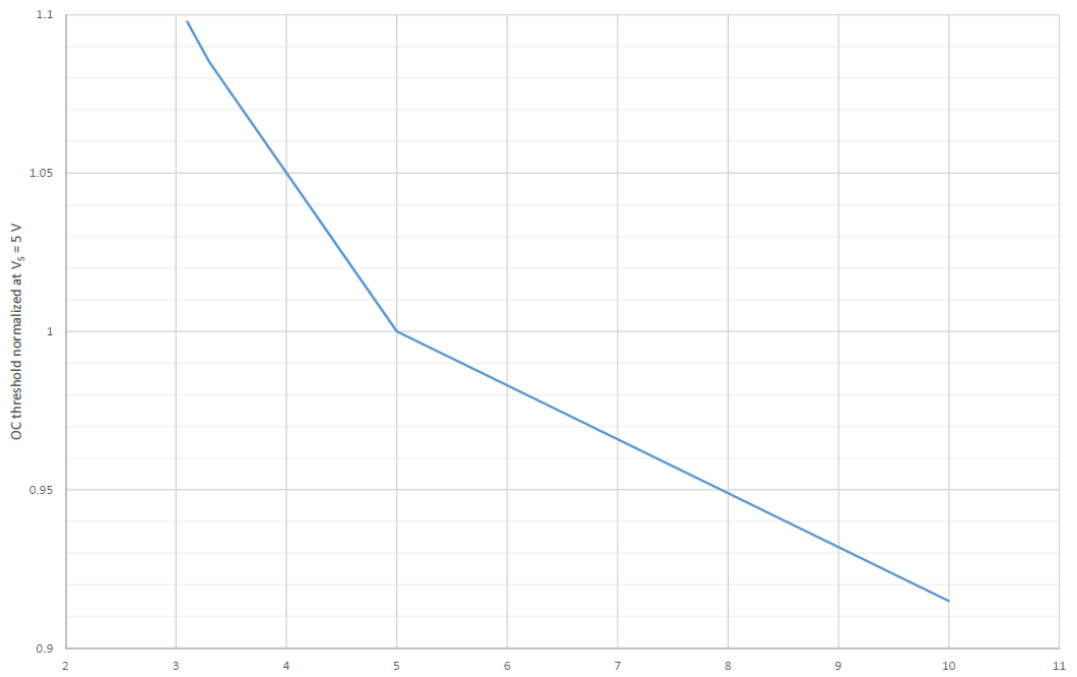
Figure 14. Power stage resistance versus supply voltage

Figure 15. Power stage resistance versus temperature


Figure 16. Overcurrent threshold versus supply voltage

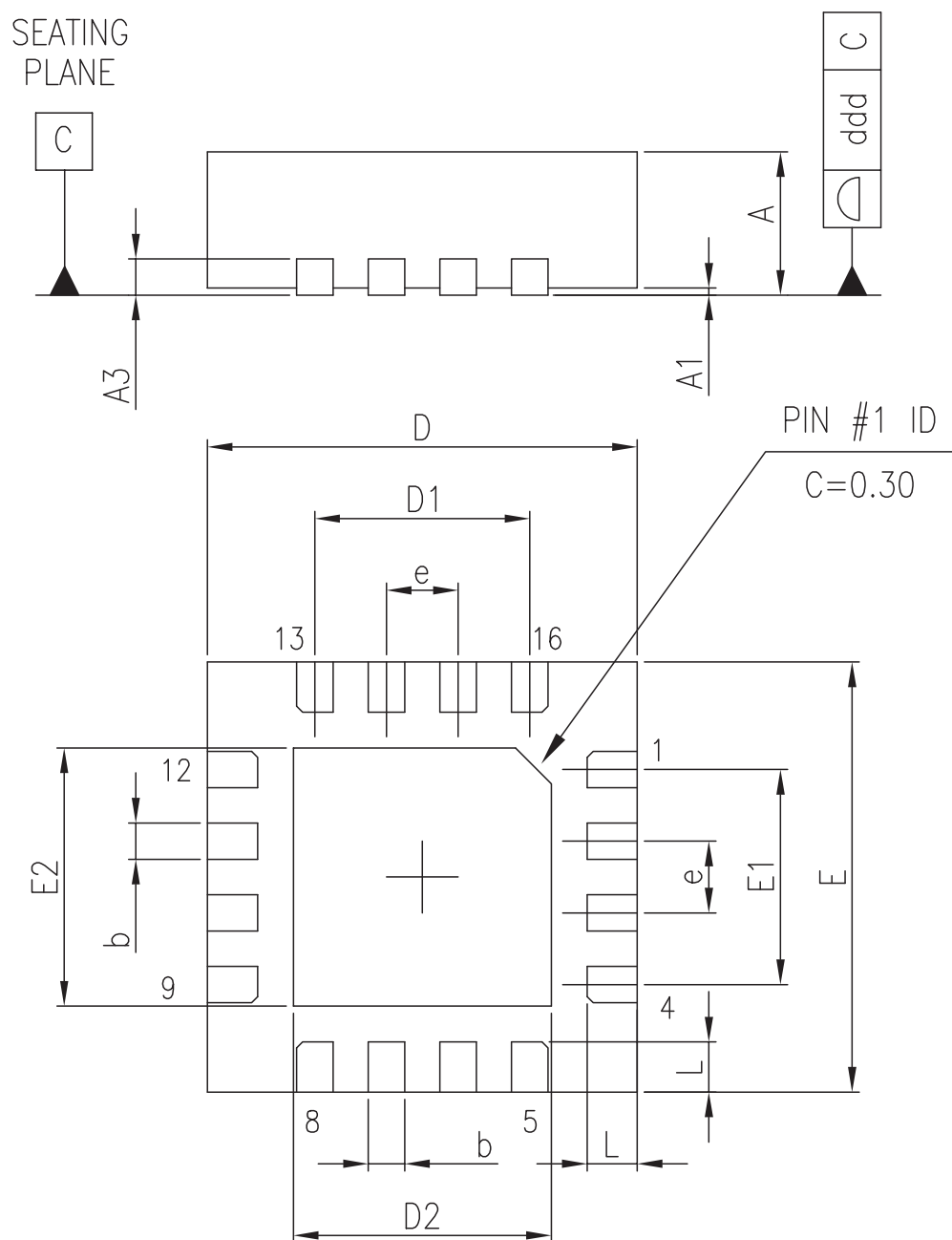


8 Package information

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

Figure 17. VFQFPN 3x3x1.0 16L package outline



Revision history

Table 15. Document revision history

Date	Version	Changes
06-May-2016	1	Initial release.
30-Jun-2016	2	<ul style="list-style-type: none"> - Updated document status to Datasheet - production data on page 1. - Updated Table 1 (changed Max. value of VS from 12 to 11) and Table 7 (changed t_{OFF} value from $\cong 47 \mu s$ to $\cong 37 \mu s$).
28-Nov-2016	3	<ul style="list-style-type: none"> - Updated Figure 1 in Section 1 Block diagram (replaced by new figure). - Updated Table 2 in Section 2.2 Recommended operating conditions (added t_{NW} symbol). - Updated Table 3 in Section 2.3 Thermal data(replaced by new table). - Updated Table 8 in Section 6.2 Microstepping sequencer [removed "Sequencer module (binary)" column]. - Added Table 11 in Section 6.2 Microstepping sequencer. - Updated Table 13 in (updated title). - Updated Figure 13 in (replaced by new figure). - Minor modifications throughout document.
21-Mar-2019	4	Updated Section 8.1 VFQFPN 3x3x1.0 16L package information

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