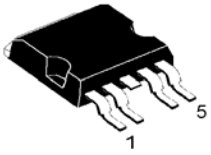
VN920B5-E

Single channel high-side solid state relay

Features

Type	$R_{DS(on)}$	I_{OUT}	V_{CC}
VN920B5-E	16 mΩ	30 A	36 V

- ECOPACK®: lead free and RoHS compliant
- Automotive Grade: compliance with AEC Guidelines
- Very low standby current
- CMOS compatible input
- Proportional load current sense
- Current sense disable
- Thermal shutdown protection and diagnosis
- Undervoltage shutdown
- Overvoltage clamp
- Load current limitation



P^2PAK

Description

The VN920B5-E is a monolithic device designed in STMicroelectronics™ VIPower™ M0-3 technology. The VN920B5-E is intended for driving any type of load with one side connected to ground.

The active V_{CC} pin voltage clamp protects the device against low energy spikes (see ISO7637 transient compatibility table).

Active current limitation combined with thermal shutdown and automatic restart protect the device against overload.

The device integrates an analog current sense output which delivers a current proportional to the load current. The device automatically turns off in the case where the ground pin becomes disconnected.

Table 1. Device summary

Package	Order codes	
	Tube	Tape and reel
P^2PAK	VN920B5-E	VN920B5TR-E

Contents

List of tables

List of figures

1 Block diagram and pin description

Figure 1. Block diagram

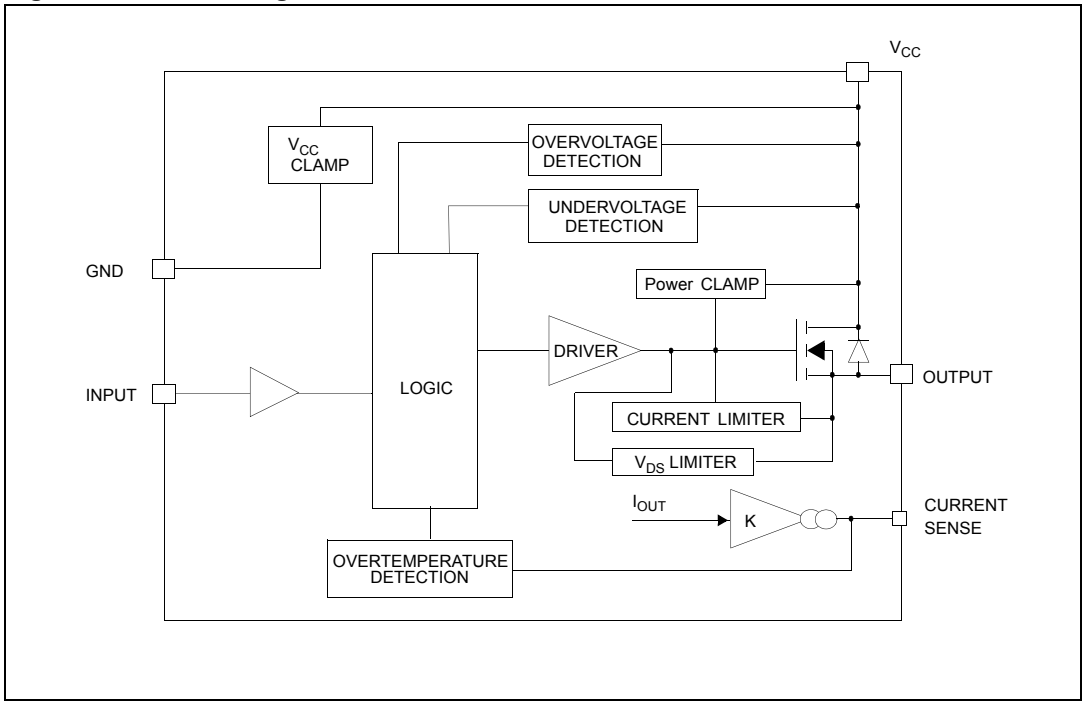
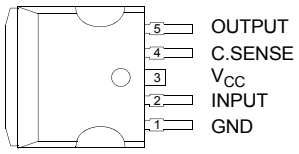


Figure 2. Configuration diagram (top view)



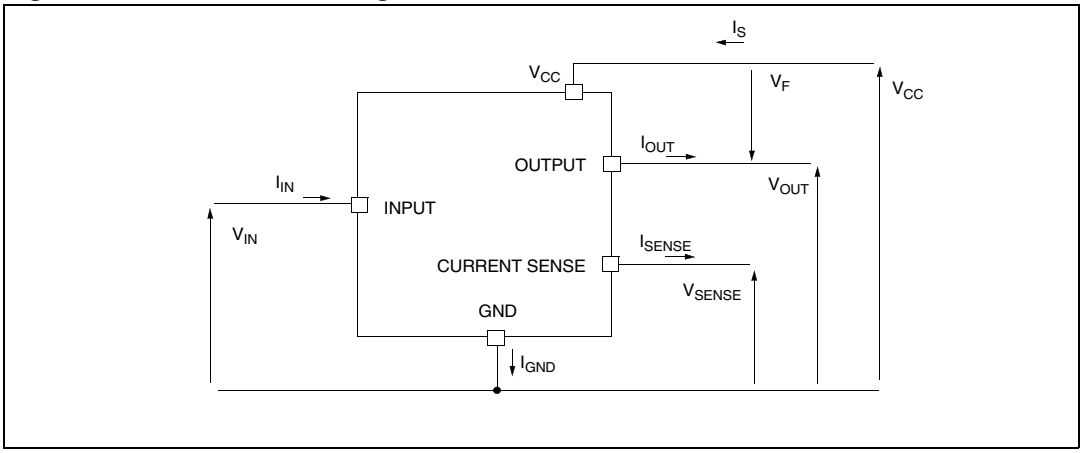
P²PAK

Table 2. Suggested connections for unused and not connected pins

Connection / pin	Current Sense	N.C.	Output	Input
Floating		X	X	X
To ground	Through 1KΩ resistor	X		Through 10KΩ resistor

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Stressing the device above the rating listed in the “Absolute maximum ratings” table 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 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CC}	DC supply voltage	41	V
- V_{CC}	Reverse DC supply voltage	- 0.3	V
- I_{gnd}	DC reverse ground pin current	- 200	mA
I_{OUT}	DC output current	Internally limited	A
- I_{OUT}	Reverse DC output current	- 21	A
I_{IN}	DC input current	+/- 10	mA
V_{CSENSE}	Current sense maximum voltage	- 3 + 15	V V
V_{ESD}	Electrostatic discharge (human body model: R = 1.5 KΩ; C = 100 pF) – INPUT – CURRENT SENSE – OUTPUT – V_{CC}	 4000 2000 5000 5000	 V V V V
E_{MAX}	Maximum switching energy (L = 0.25 mH; R_L = 0 Ω; V_{bat} = 13.5 V; T_{jstart} = 150 °C; I_L = 45 A)	364	mJ

Table 3. Absolute maximum ratings (continued)

Symbol	Parameter	Value	Unit
P_{tot}	Power dissipation $T_C \leq 25$ °C	96.1	W
T_j	Junction operating temperature	Internally limited	°C
T_c	Case operating temperature	- 40 to 150	°C
T_{stg}	Storage temperature	- 55 to 150	°C

2.2 Thermal data

Table 4. Thermal data

Symbol	Parameter	Max. value	Unit
$R_{thj\text{-}case}$	Thermal resistance junction-case	1.3	°C/W
$R_{thj\text{-}lead}$	Thermal resistance junction-lead		°C/W
$R_{thj\text{-}amb}$	Thermal resistance junction-ambient	51.3(1)	°C/W
		37(2)	°C/W

1. When mounted on a standard single-sided FR-4 board with 0.5cm2 of Cu (at least 35µm thick).
2. When mounted on a standard single-sided FR-4 board with 6cm2 of Cu (at least 35µm thick).

2.3 Electrical characteristics

Values specified in this section are for 8 V < V_{CC} < 36 V; -40 °C < T_j < 150 °C, unless otherwise stated.

Table 5. Power

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{CC}	Operating supply voltage		5.5	13	36	V
V_{USD}	Undervoltage shutdown		3	4	5.5	V
V_{OV}	Overvoltage shutdown		36			V
R_{ON}	On-state resistance	I_{OUT} = 10 A; T_j = 25 °C			16	mΩ
		I_{OUT} = 10 A			32	mΩ
		I_{OUT} = 3 A; V_{CC} = 6 V			55	mΩ
V_{CLAMP}	Clamp voltage	I_{CC} = 20 mA	41	48	55	V
I_S	Supply current	Off-state; V_{CC} = 13 V; V_{IN} = V_{OUT} = 0 V		10	25	µA
		Off-state; V_{CC} = 13 V; V_{IN} = V_{OUT} = 0 V; T_j = 25 °C		10	20	µA
		On-state; V_{CC} = 13 V; V_{IN} = 5 V; I_{OUT} = 0 A; R_{SENSE} = 3.9 kΩ			5	mA
$I_{L(off1)}$	Off-state output current	V_{IN} = V_{OUT} = 0 V	0		50	µA
$I_{L(off2)}$	Off-state output current	V_{IN} = 0 V; V_{OUT} = 3.5 V	-75		0	µA
$I_{L(off3)}$	Off-state output current	V_{IN} = V_{OUT} = 0V; V_{CC} = 13 V; T_j = 125 °C			5	µA
$I_{L(off4)}$	Off-state output current	V_{IN} = V_{OUT} = 0 V; V_{CC} = 13 V; T_j = 25 °C			3	µA

Note: V_{CLAMP} and V_{OV} are correlated. Typical difference is 5V.

Table 6. Switching (V_{CC} = 13 V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	R_L = 1.3 Ω (see *Figure 4*)		50		µs
$t_{d(off)}$	Turn-off delay time	R_L = 1.3 Ω (see *Figure 4*)		50		µs
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	R_L = 1.3 Ω (see *Figure 4*)	See *Figure 10*			V/µs
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	R_L = 1.3 Ω (see *Figure 4*)	See *Figure 12*			V/µs

Table 7. Logic inputs

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IL}	Input low level voltage				1.25	V
I_{IL}	Low level input current	V_{IN} = 1.25 V	1			µA
V_{IH}	Input high-level voltage		3.25			V
I_{IH}	High-level input current	V_{IN} = 3.25 V			10	µA
$V_{I(hyst)}$	Input hysteresis voltage		0.5			V
V_{ICL}	Input clamp voltage	I_{IN} = 1 mA	6	6.8	8	V
		I_{IN} = - 1 mA		-0.7		V

Table 8. Current sense (9 V ≤ V_{CC} ≤ 16 V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
K_1	I_{OUT}/I_{SENSE}	I_{OUT} = 1 A; V_{SENSE} = 0.5 V; T_j = -40 °C...150 °C	3300	4400	6000	
dK_1/K_1	Current sense ratio drift	I_{OUT} = 1 A; V_{SENSE} = 0.5 V; T_j= - 40 °C...150 °C	-10		+10	%
K_2	I_{OUT}/I_{SENSE}	I_{OUT} = 10 A; V_{SENSE} = 4 V; T_j = - 40 °C T_j= 25 °C...150 °C	4200 4400	4900 4900	6000 5750	
dK_2/K_2	Current sense ratio drift	I_{OUT} = 10 A; V_{SENSE} = 4 V; T_j = -40 °C...150 °C	-8		+8	%
K_3	I_{OUT}/I_{SENSE}	I_{OUT} = 30 A; V_{SENSE} = 4 V; T_j = -40 °C T_j = 25 °C...150 °C	4200 4400	4900 4900	5500 5250	
dK_3/K_3	Current sense ratio drift	I_{OUT} = 30 A; V_{SENSE} = 4 V; T_j = -40 °C...150 °C	-6		+6	%
I_{SENSE0}	Analog sense current	V_{CC} = 6...16 V; I_{OUT} = 0 A; V_{SENSE} = 0 V; T_j = -40 °C...150 °C	0		10	µA
V_{SENSE}	Max analog sense output voltage	V_{CC} = 5.5 V; I_{OUT} = 5 A; R_{SENSE} = 10 kΩ	2			V
		V_{CC} > 8 V, I_{OUT} = 10 A; R_{SENSE} = 10 kΩ	4			V
V_{SENSEH}	Sense voltage in overtemperature condition	V_{CC} = 13 V; R_{SENSE} = 3.9 kΩ		5.5		V
$R_{VSENSEH}$	Analog sense output impedance in overtemperature condition	V_{CC} = 13 V; T_j > T_{TSD}; output open		400		Ω
t_{DSENSE}	Current sense delay response	To 90 % I_{SENSE}(1)			500	µs

1. Current sense signal delay after positive input slope.

Table 9. V_{CC} output diode

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_F	Forward on voltage	$-I_{OUT}$ = 5 A; T_j = 150 °C	—	—	0.6	V

Table 10. Protections(1)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
T_{TSD}	Shutdown temperature		150	175	200	°C
T_R	Reset temperature		135			°C
T_{hyst}	Thermal hysteresis		7	15		°C
I_{lim}	Current limitation	V_{CC} = 13 V	30	45	75	A
		5 V < V_{CC} < 36 V			75	A
V_{demag}	Turn-off output clamp voltage	I_{OUT} = 2 A; V_{IN} = 0 V; L = 6 mH	V_{CC} - 41	V_{CC} - 48	V_{CC} - 55	V
V_{ON}	Output voltage drop limitation	I_{OUT} = 1 A; T_j = -40 °C...150 °C		50		mV

1. To ensure long term reliability under heavy over-load or short circuit conditions, protection and related diagnostic signals must be used together with a proper software strategy. If the device operates under abnormal conditions this software must limit the duration and number of activation cycles.

Table 11. Truth table

Conditions	Input	Output	Sense
Normal operation	L H	L H	0 Nominal
Overtemperature	L H	L L	0 V_{SENSEH}
Undervoltage	L H	L L	0 0
Overvoltage	L H	L L	0 0
Short circuit to GND	L H H	L L L	0 (T_j<T_{TSD}) 0 (T_j>T_{TSD}) V_{SENSEH}
Short circuit to V_{CC}	L H	H H	0 < Nominal
Negative output voltage clamp	L	L	0

Table 12. Electrical transient requirements

ISO T/R 7637/1 Test pulse	Test level				
	I	II	III	IV	Delays and impedance
1	- 25V(1)	- 50V(1)	- 75V(1)	- 100V(1)	2ms, 10Ω
2	+ 25V(1)	+ 50V(1)	+ 75V(1)	+ 100V(1)	0.2ms, 10Ω
3a	- 25V(1)	- 50V(1)	- 100V(1)	- 150V(1)	0.1µs, 50Ω
3b	+ 25V(1)	+ 50V(1)	+ 75V(1)	+ 100V(1)	0.1µs, 50Ω
4	- 4V(1)	- 5V(1)	- 6V(1)	- 7V(1)	100ms, 0.01Ω
5	+ 26.5V(1)	+ 46.5V(2)	+ 66.5V(2)	+ 86.5V(2)	400ms, 2Ω

1. All functions of the device are performed as designed after exposure to disturbance.
2. One or more functions of the device is not performed as designed after exposure and cannot be returned to proper operation without replacing the device.

Figure 4. Switching characteristics

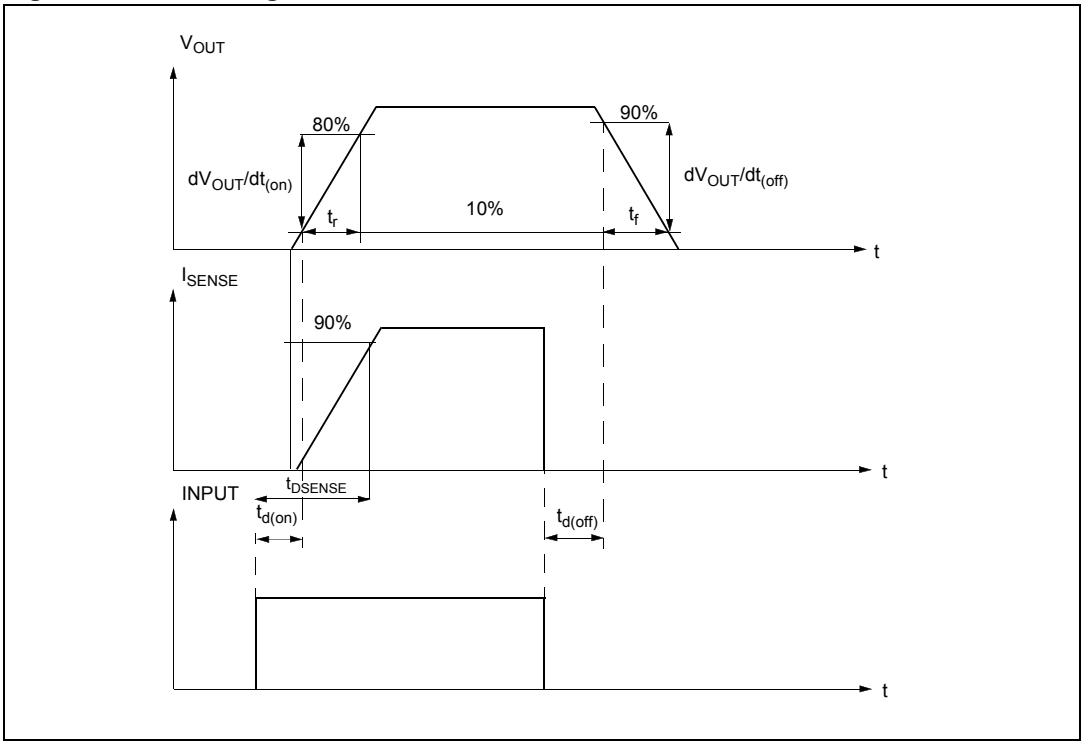


Figure 5. I_{OUT}/I_{SENSE} versus I_{OUT}

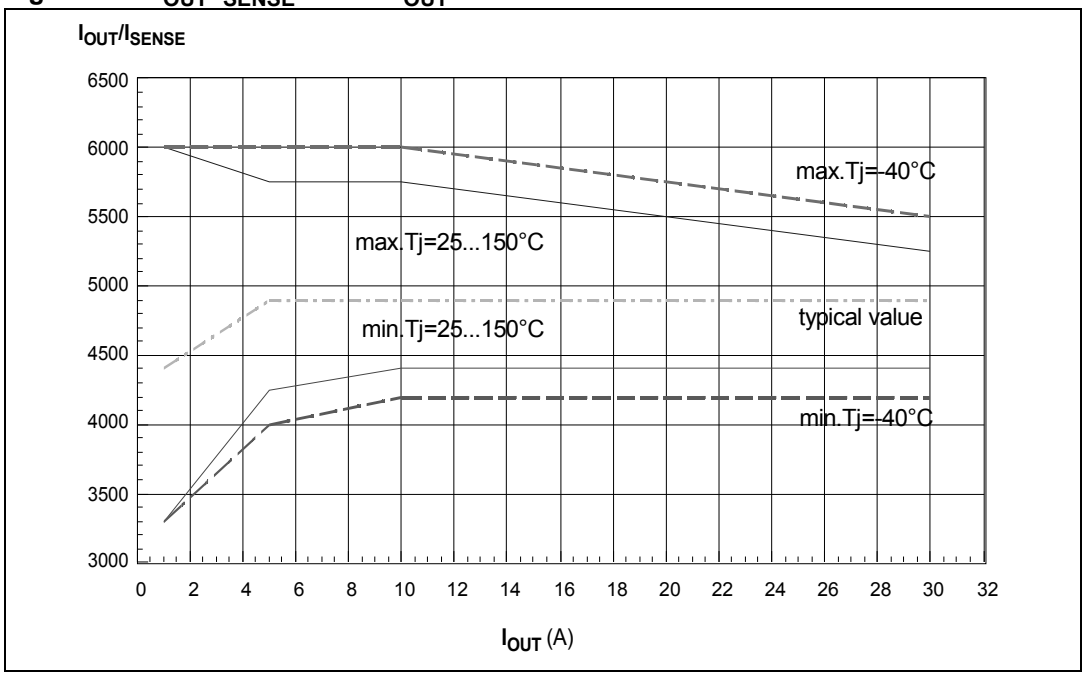
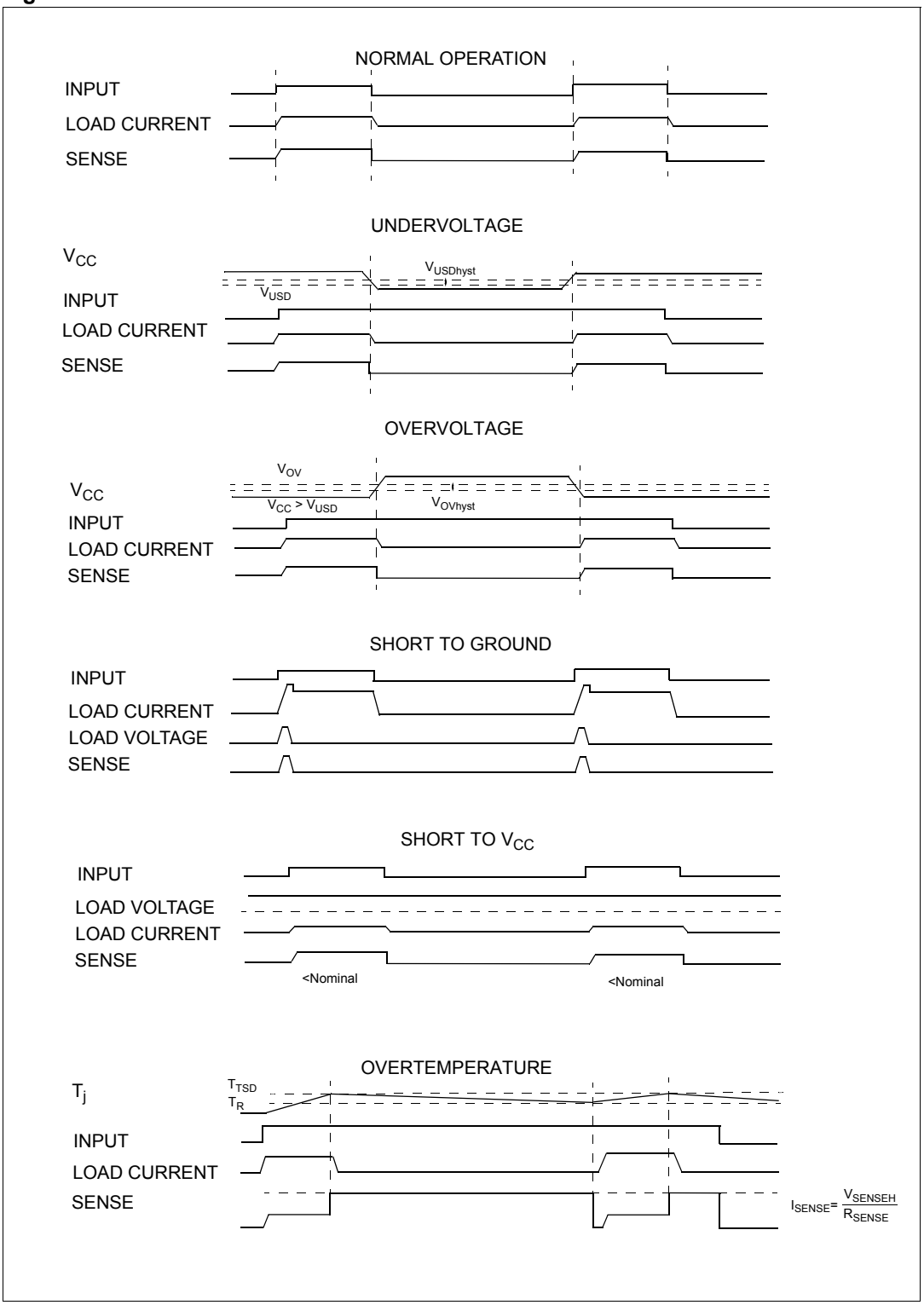


Figure 6. Waveforms



2.4 Electrical characteristics curves

Figure 7. Off-state output current

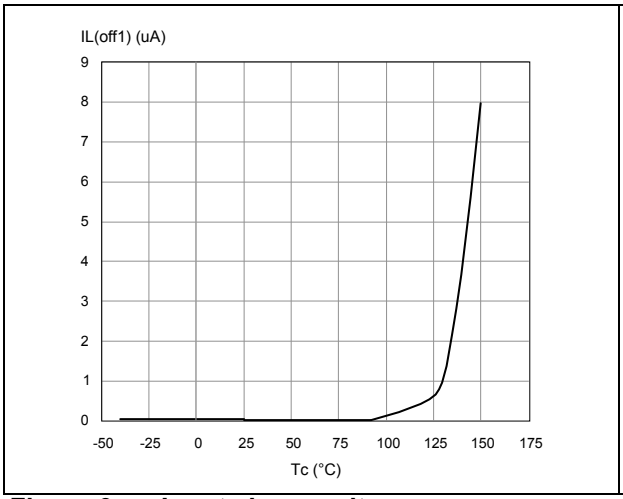


Figure 8. High-level input current

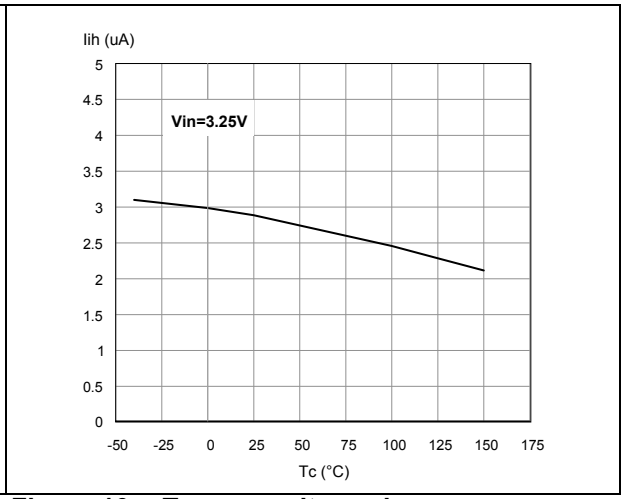


Figure 9. Input clamp voltage

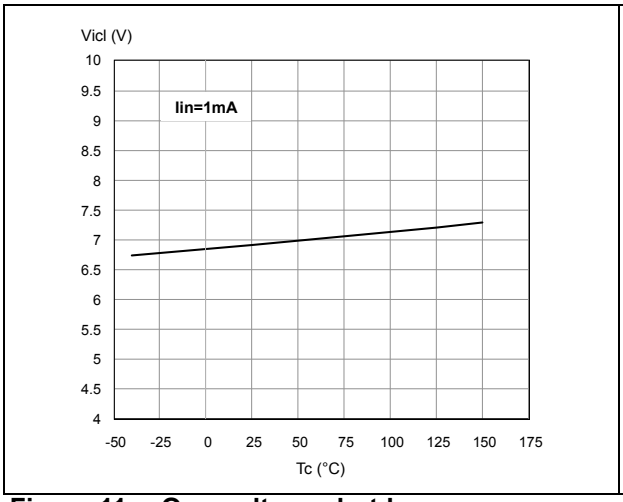


Figure 10. Turn-on voltage slope

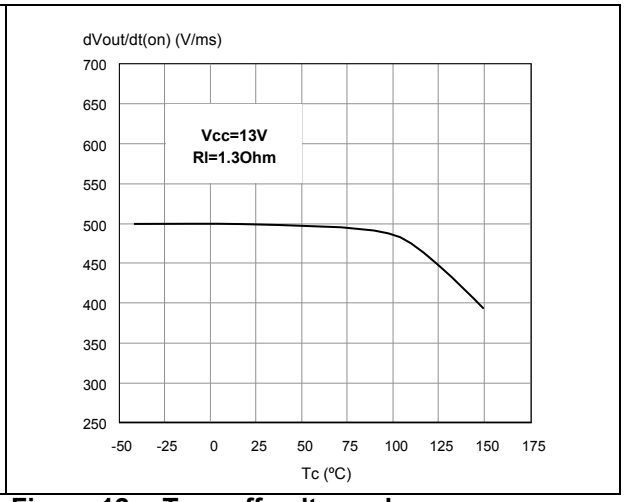


Figure 11. Overvoltage shutdown

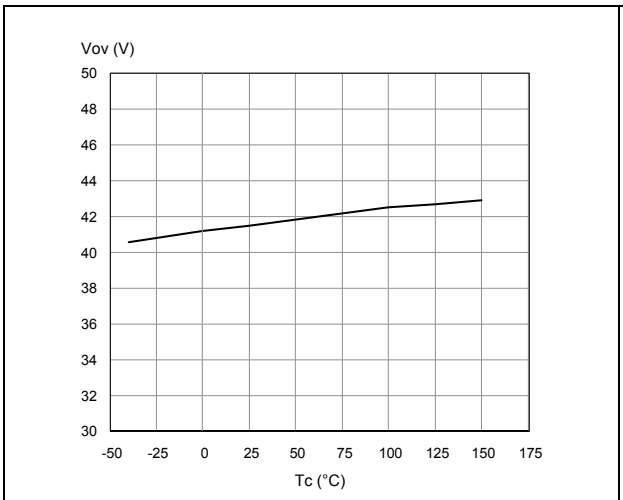


Figure 12. Turn-off voltage slope

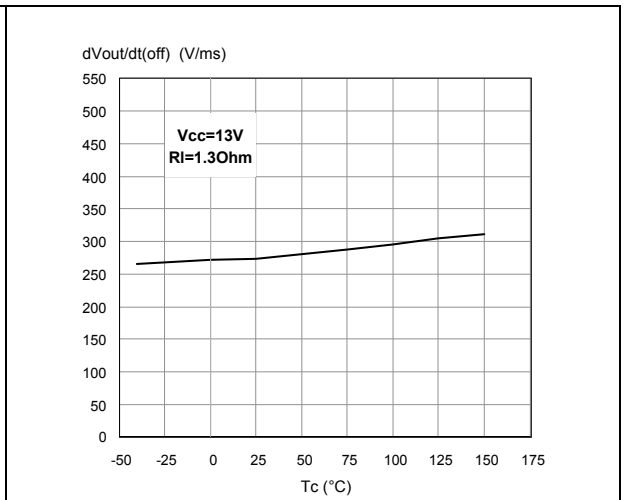


Figure 13. I_{LIM} vs T_{case}

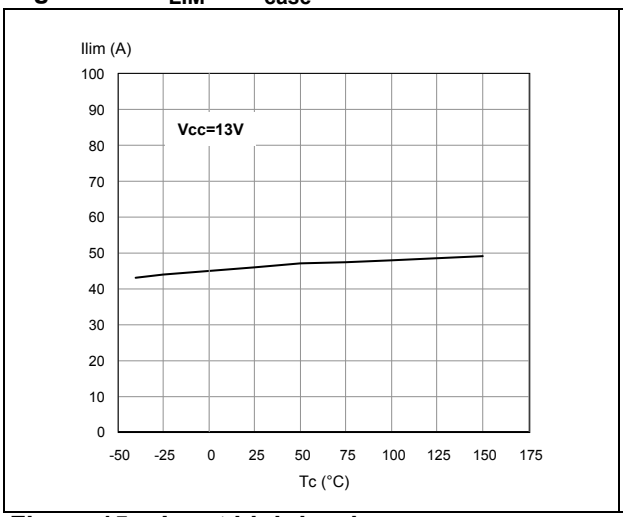


Figure 14. On-state resistance vs V_{CC}

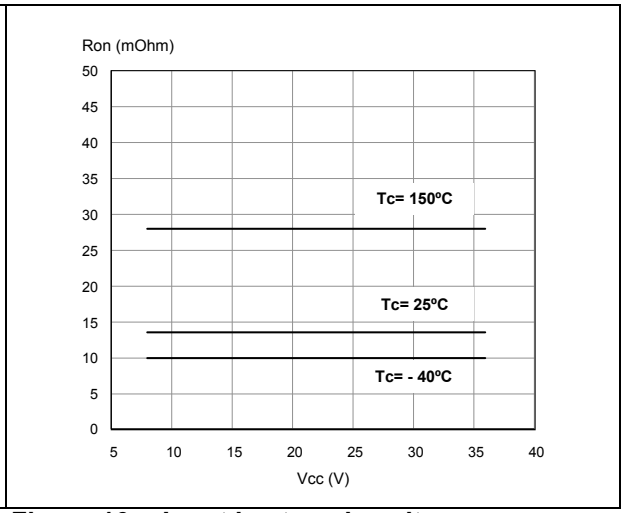


Figure 15. Input high-level

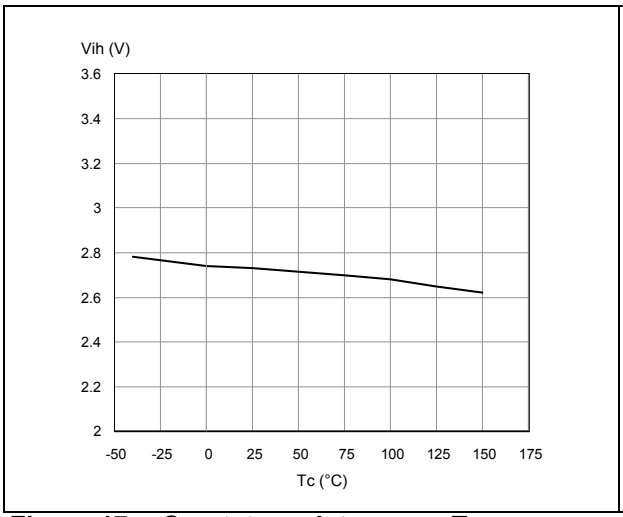


Figure 16. Input hysteresis voltage

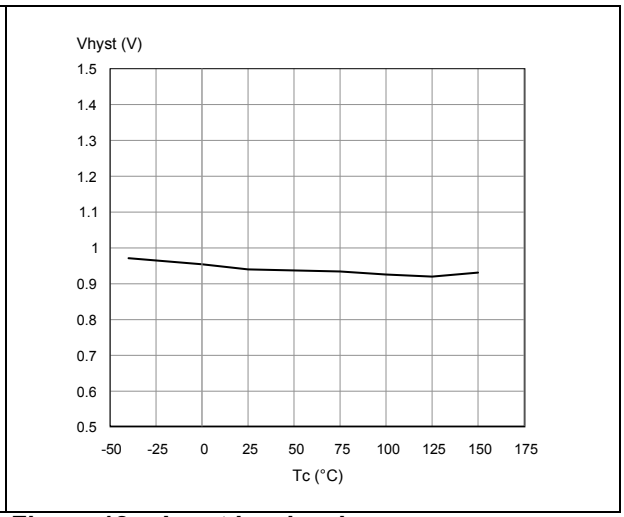


Figure 17. On-state resistance vs T_{case}

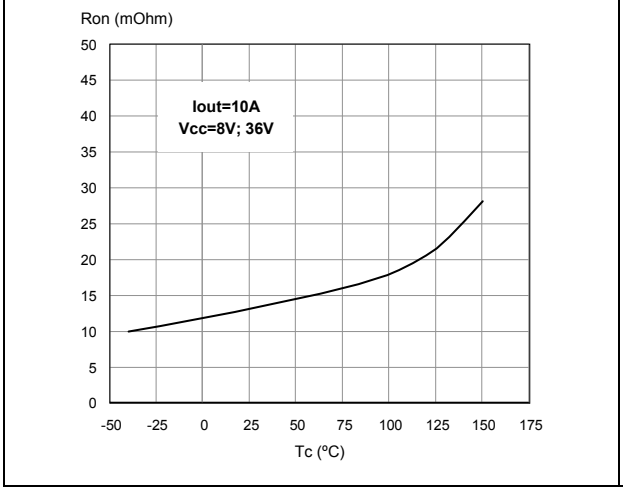
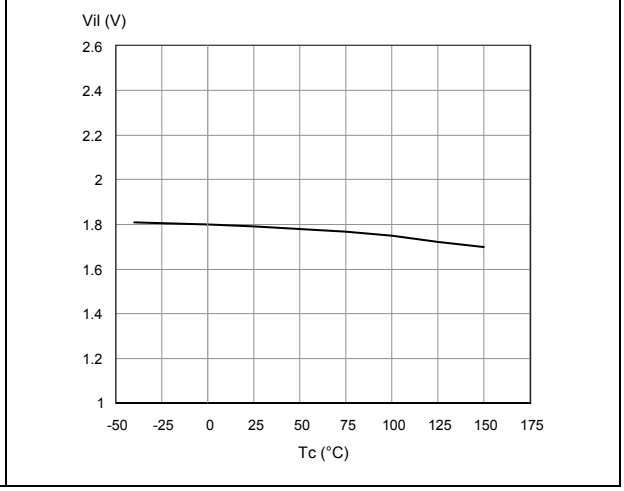
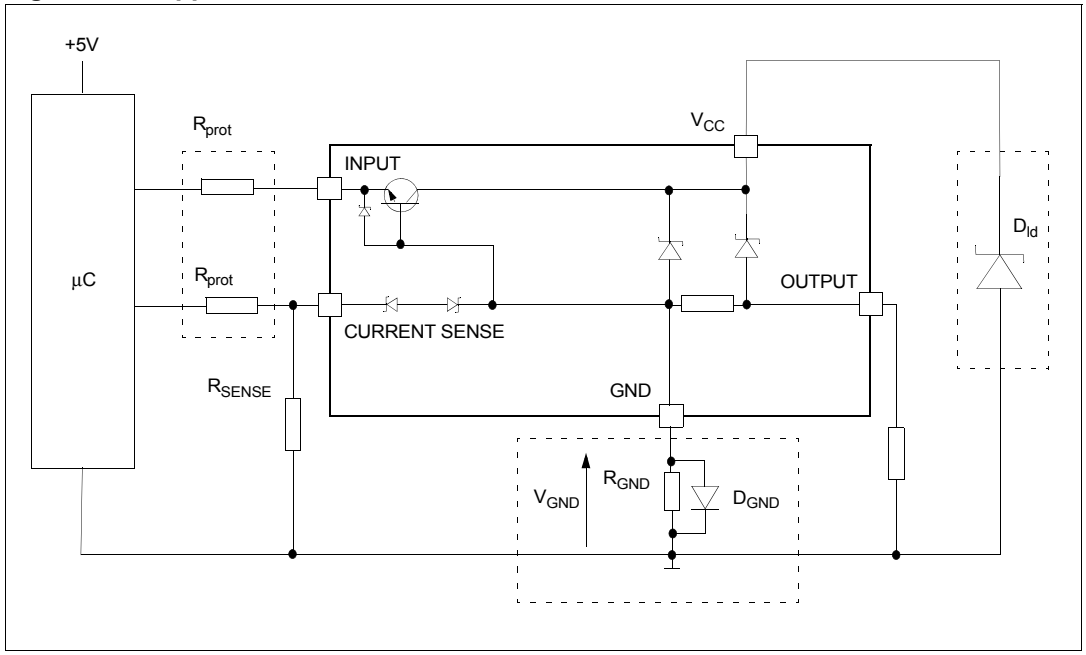


Figure 18. Input low level



3 Application information

Figure 19. Application schematic



3.1 GND protection network against reverse battery

3.1.1 Solution 1: resistor in the ground line (R_{GND} only)

This can be used with any type of load.

The following is an indication on how to dimension the R_{GND} resistor.

1. $R_{GND} \leq 600\ mV / (I_{S(on)max})$
2. $R_{GND} \geq (-V_{CC}) / (-I_{GND})$

where $-I_{GND}$ is the DC reverse ground pin current and can be found in the absolute maximum rating section of the device datasheet.

Power Dissipation in R_{GND} (when $V_{CC} < 0$: during reverse battery situations) is:

$P_D = (-V_{CC})^2 / R_{GND}$

This resistor can be shared amongst several different HSDs. Please note that the value of this resistor should be calculated with formula (1) where $I_{S(on)max}$ becomes the sum of the maximum on-state currents of the different devices.

Please note that if the microprocessor ground is not shared by the device ground then the R_{GND} produces a shift ($I_{S(on)max} * R_{GND}$) in the input thresholds and the status output values. This shift varies depending on how many devices are ON in the case of several high-side drivers sharing the same R_{GND}.

If the calculated power dissipation leads to a large resistor or several devices have to share the same resistor then ST suggests to utilize Solution 2 (see below).

3.1.2 Solution 2: diode (D_{GND}) in the ground line

A resistor (R_{GND} = 1 kΩ) should be inserted in parallel to D_{GND} if the device drives an inductive load.

This small signal diode can be safely shared amongst several different HSDs. Also in this case, the presence of the ground network produces a shift (≈600mV) in the input threshold and in the status output values if the microprocessor ground is not common to the device ground. This shift not varies if more than one HSD shares the same diode/resistor network.

Series resistor in INPUT and STATUS lines are also required to prevent that, during battery voltage transient, the current exceeds the absolute maximum rating.

Safest configuration for unused INPUT and STATUS pin is to leave them unconnected.

3.2 Load dump protection

D_{ld} is necessary (Voltage Transient Suppressor) if the load dump peak voltage exceeds the V_{CC} max DC rating. The same applies if the device is subject to transients on the V_{CC} line that are greater than the ones shown in the ISO 7637-2: 2004(E) table.

3.3 MCU I/Os protection

If a ground protection network is used and negative transient are present on the V_{CC} line, the control pins are pulled negative. ST suggests to insert a resistor (R_{prot}) in line to prevent the microcontroller I/Os pins to latch-up.

The value of these resistors is a compromise between the leakage current of microcontroller and the current required by the HSD I/Os (Input levels compatibility) with the latch-up limit of microcontroller I/Os.

$-V_{CCpeak}/I_{latchup} \leq R_{prot} \leq (V_{OH\mu C} - V_{IH} - V_{GND}) / I_{IHmax}$

Calculation example:

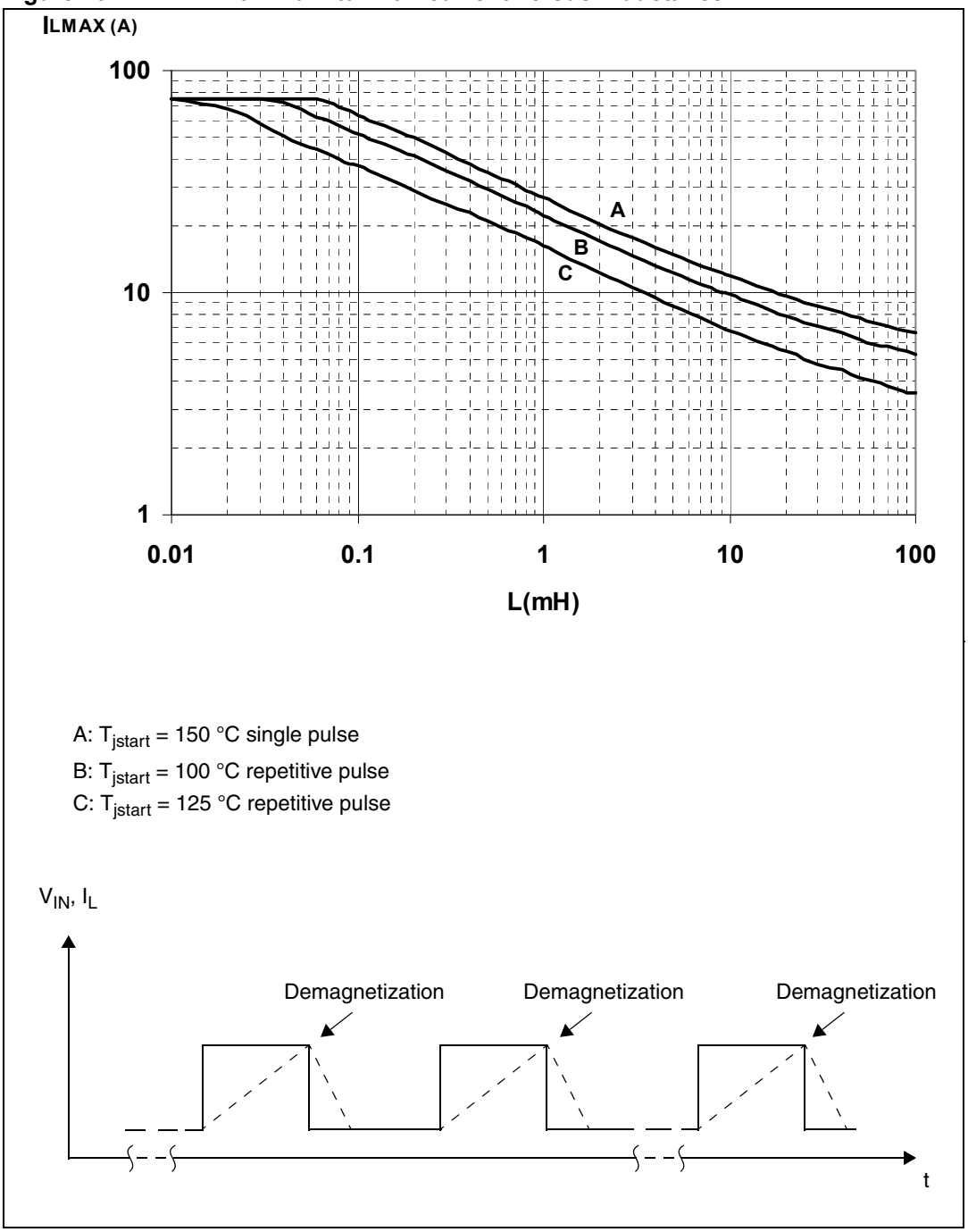
For V_{CCpeak}= -100 V and $I_{latchup} \geq$ 20 mA; $V_{OH\mu C} \geq$ 4.5 V

5 kΩ ≤ R_{prot} ≤ 65 kΩ.

Recommended values: R_{prot} =10 kΩ.

3.4 P²PAK maximum demagnetization energy (V_{CC} = 13.5V)

Figure 20. P²PAK maximum turn-off current versus inductance(1)

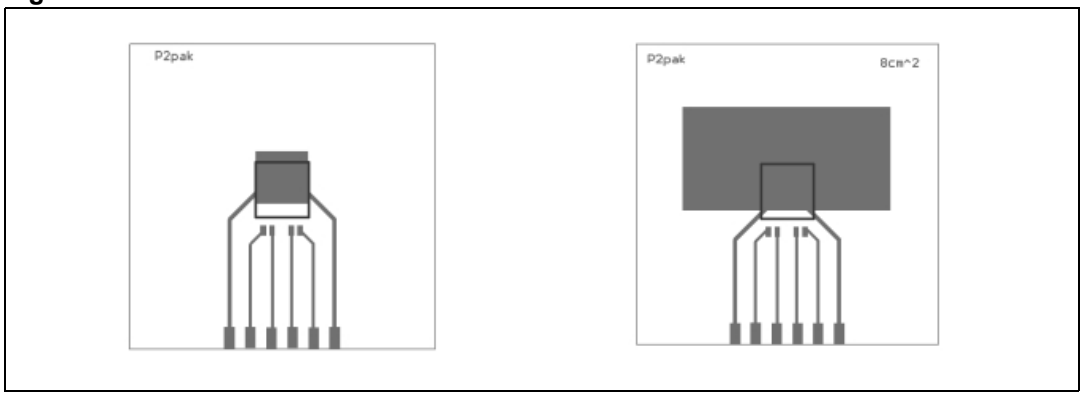


1. Values are generated with R_L =0 Ω.
In case of repetitive pulses, T_{jstart} (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

4 Package and PCB thermal data

4.1 P²PAK thermal data

Figure 21. P²PAK PC board(1)



1. Layout condition of R_{th} and Z_{th} measurements (PCB FR4 area = 60 mm x 60 mm, PCB thickness = 2 mm, Cu thickness = 35 µm , Copper areas: 0.97 cm^2, 8 cm^2).

Figure 22. P²PAK $R_{thj\text{-}amb}$ vs PCB copper area in open box free air condition

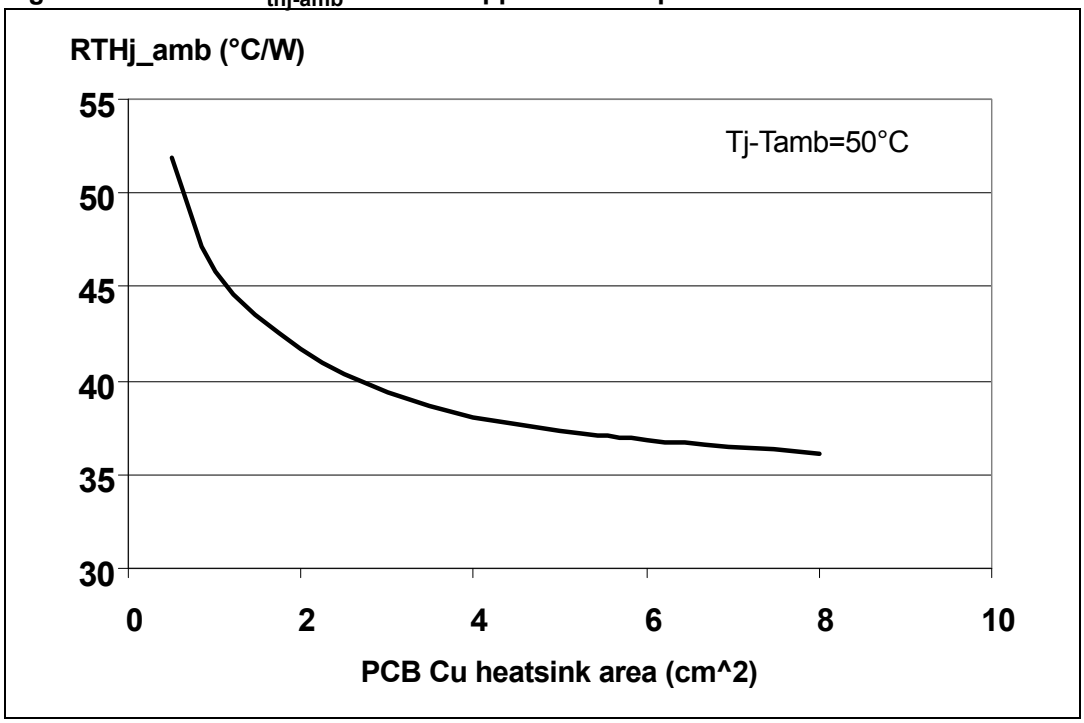
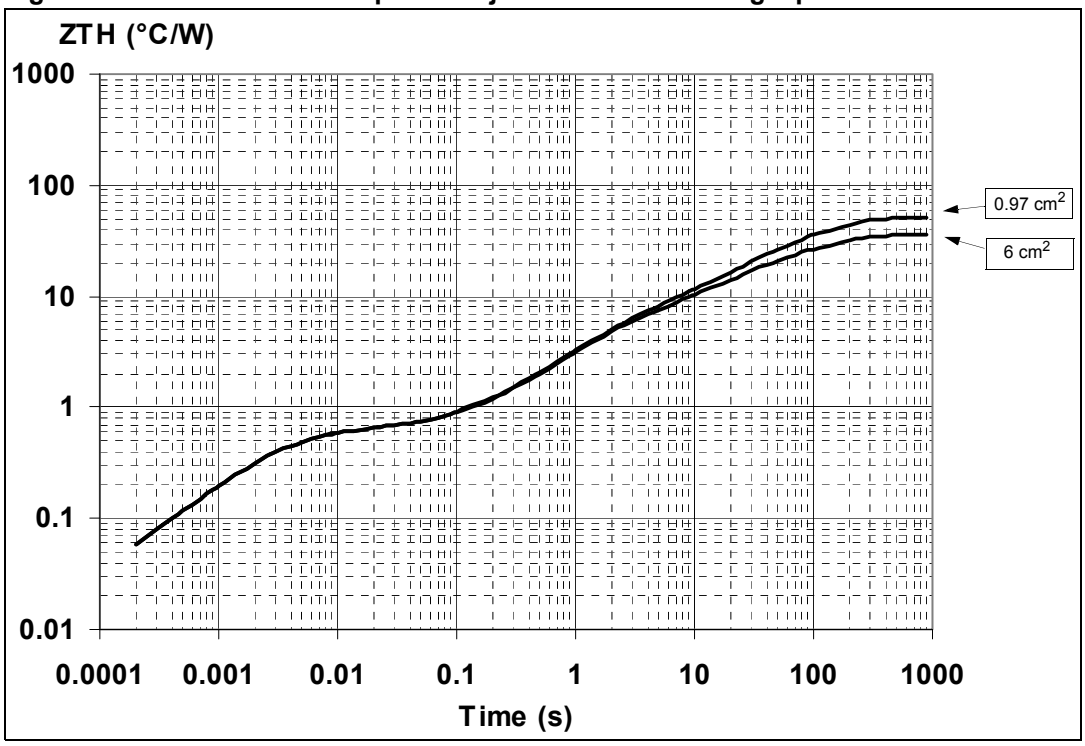


Figure 23. P²PAK thermal impedance junction ambient single pulse



Equation 1: pulse calculation formula

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

where $\delta = t_P/T$

Figure 24. Thermal fitting model of a single channel HSD in P²PAK

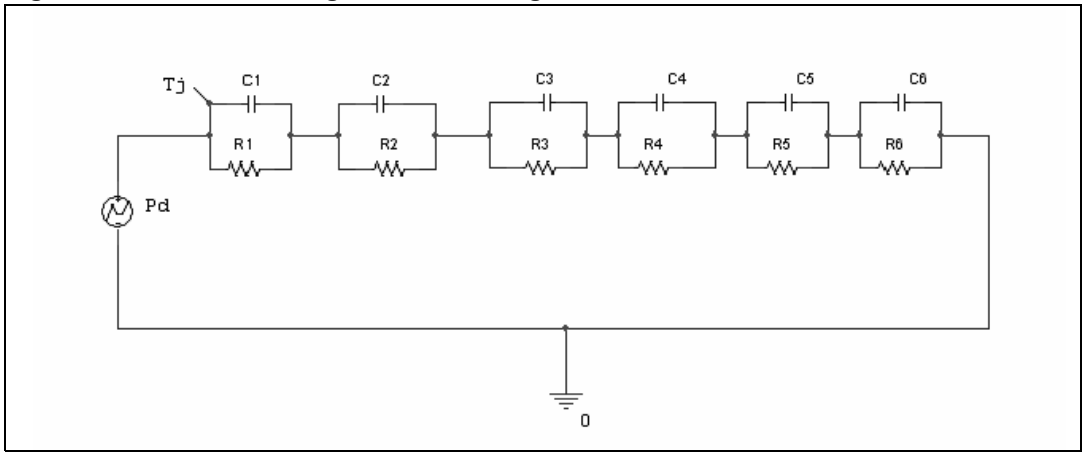


Table 13. P^2PAK thermal parameter

Area/island (cm^2)	0.97	6
R1 (°C/W)	0.02	
R2 (°C/W)	0.1	
R3 (°C/W)	0.22	
R4 (°C/W)	4	
R5 (°C/W)	9	
R6 (°C/W)	37	22
C1 (W·s/°C)	0.0015	
C2 (W·s/°C)	0.007	
C3 (W·s/°C)	0.015	
C4 (W·s/°C)	0.4	
C5 (W·s/°C)	2	
C6 (W·s/°C)	3	5

5 Package and packing information

5.1 ECOPACK® packages

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.

5.2 P²PAK mechanical data

Figure 25. P²PAK package dimensions

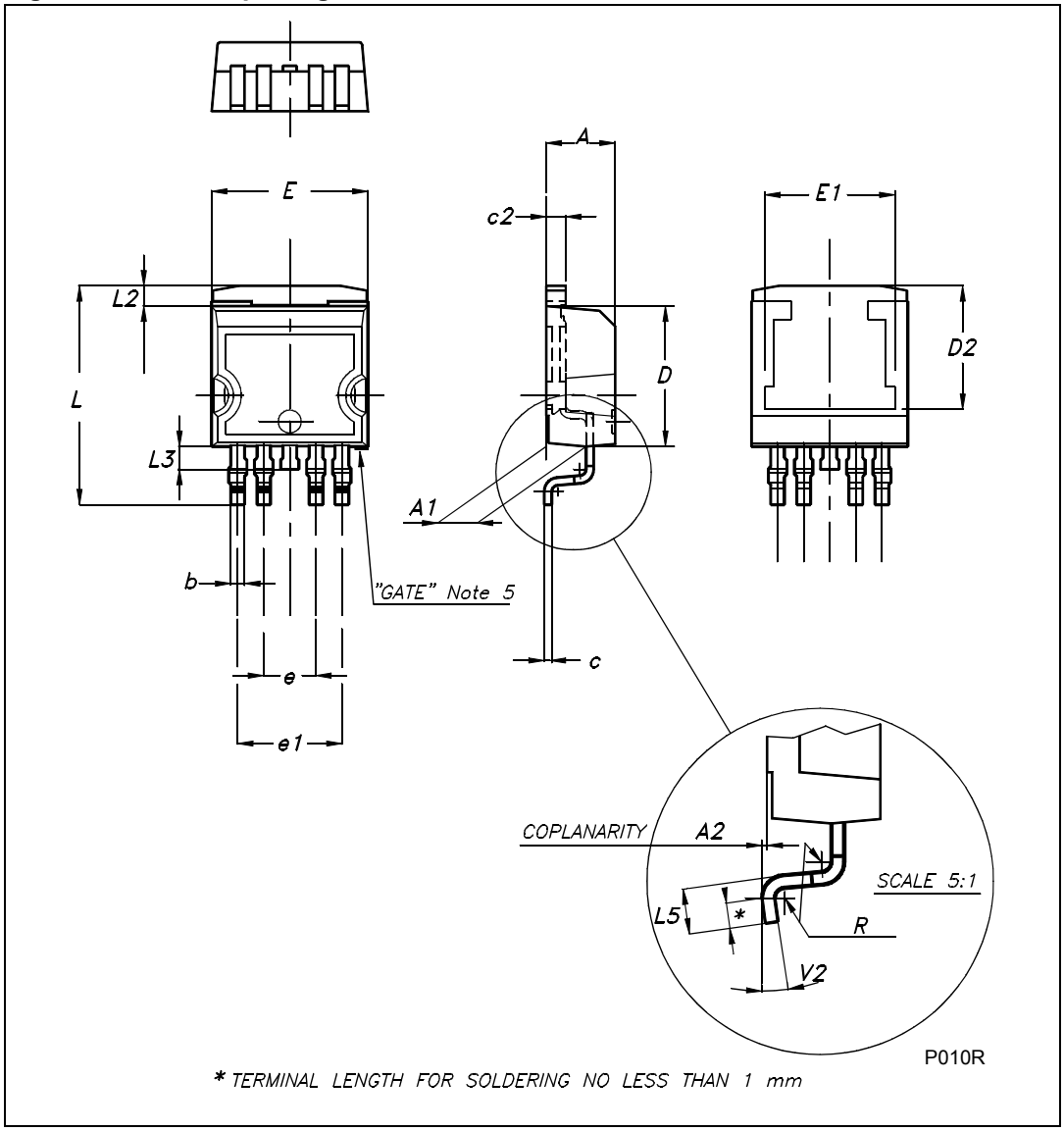
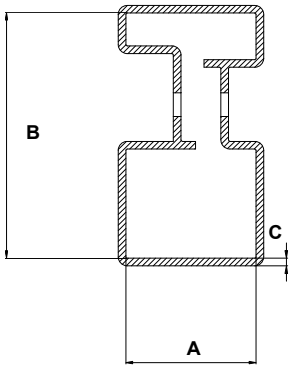


Table 14. P^2PAK mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.30		4.80
A1	2.40		2.80
A2	0.03		0.23
b	0.80		1.05
c	0.45		0.60
c2	1.17		1.37
D	8.95		9.35
D2		8.00	
E	10.00		10.40
E1		8.50	
e	3.20		3.60
e1	6.60		7.00
L	13.70		14.50
L2	1.25		1.40
L3	0.90		1.70
L5	1.55		2.40
R		0.40	
V2	0º		8º
Package weight	1.40 Gr (typ)		

5.3 P²PAK packing information

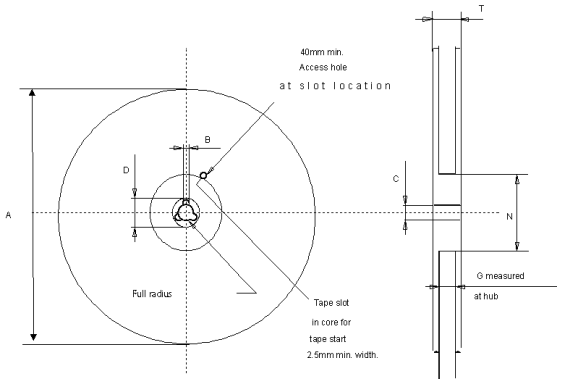
Figure 26. P²PAK tube shipment (no suffix)



Base Q.ty	50
Bulk Q.ty	1000
Tube length (± 0.5)	532
A	18
B	33.1
C (± 0.1)	1

All dimensions are in mm.

Figure 27. P²PAK tape and reel (suffix "TR")



REEL DIMENSIONS

All dimensions are in mm.

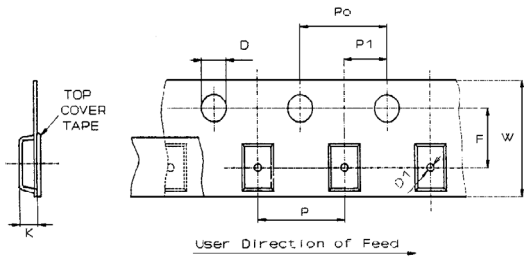
Base Q.ty	1000
Bulk Q.ty	1000
A (max)	330
B (min)	1.5
C (± 0.2)	13
F	20.2
G (+ 2 / -0)	24.4
N (min)	60
T (max)	30.4

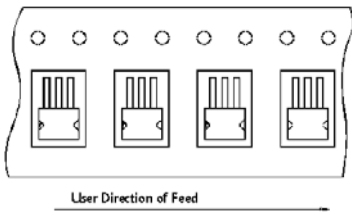
TAPE DIMENSIONS

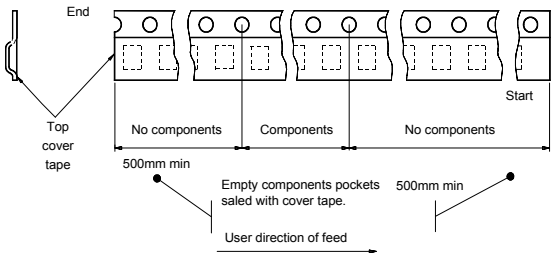
According to Electronic Industries Association (EIA) Standard 481 rev. A, Feb 1986

Tape width	**W**	24
Tape Hole Spacing	**P0 (± 0.1)**	4
Component Spacing	**P**	12
Hole Diameter	**D (± 0.1/-0)**	1.5
Hole Diameter	**D1 (min)**	1.5
Hole Position	**F (± 0.05)**	11.5
Compartment Depth	**K (max)**	6.5
Hole Spacing	**P1 (± 0.1)**	2

All dimensions are in mm.







6 Revision history

Table 15. Document revision history

Date	Revision	Changes
19-Jul-2010	1	Initial release.
19-Sep-2013	2	Updated Disclaimer

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST’s terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST’S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

ST PRODUCTS ARE NOT DESIGNED OR AUTHORIZED FOR USE IN: (A) SAFETY CRITICAL APPLICATIONS SUCH AS LIFE SUPPORTING, ACTIVE IMPLANTED DEVICES OR SYSTEMS WITH PRODUCT FUNCTIONAL SAFETY REQUIREMENTS; (B) AERONAUTIC APPLICATIONS; (C) AUTOMOTIVE APPLICATIONS OR ENVIRONMENTS, AND/OR (D) AEROSPACE APPLICATIONS OR ENVIRONMENTS. WHERE ST PRODUCTS ARE NOT DESIGNED FOR SUCH USE, THE PURCHASER SHALL USE PRODUCTS AT PURCHASER’S SOLE RISK, EVEN IF ST HAS BEEN INFORMED IN WRITING OF SUCH USAGE, UNLESS A PRODUCT IS EXPRESSLY DESIGNATED BY ST AS BEING INTENDED FOR “AUTOMOTIVE, AUTOMOTIVE SAFETY OR MEDICAL” INDUSTRY DOMAINS ACCORDING TO ST PRODUCT DESIGN SPECIFICATIONS. PRODUCTS FORMALLY ESCC, QML OR JAN QUALIFIED ARE DEEMED SUITABLE FOR USE IN AEROSPACE BY THE CORRESPONDING GOVERNMENTAL AGENCY.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.
Information in this document supersedes and replaces all information previously supplied.
The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com