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## Single channel high side driver for automotive applications

### Features

Max transient supply voltage	$V_{CC}$	41V
Operating voltage range	$V_{CC}$	4.5 to 28V
Max On-state resistance (per ch.)	$R_{ON}$	160 m $\Omega$
Current limitation (typ)	$I_{LIMH}$	10A
Off state supply current	$I_S$	2 $\mu$ A <sup>(1)</sup>

1. Typical value with all loads connected.

#### ■ General

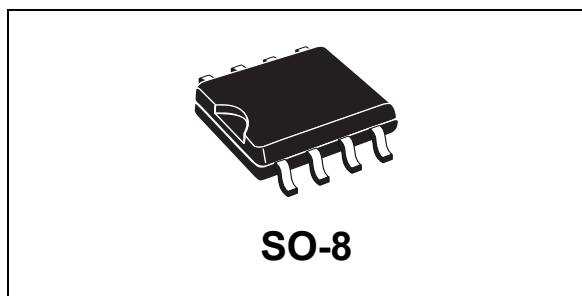
- Inrush current active management by power limitation
- Very low stand-by current
- 3.0V CMOS compatible inputs
- Optimized electromagnetic emissions
- Very low electromagnetic susceptibility
- In compliance with the 2002/95/EC european directive

#### ■ Diagnostic functions

- Open Drain status output
- On-state open load detection
- Off-state open load detection
- Output short to  $V_{CC}$  detection
- Overload and short to ground (power limitation) indication
- Thermal shut-down indication

#### ■ Protections

- Undervoltage shut-down
- Overvoltage clamp
- Load current limitation
- Self limiting of fast thermal transients
- Protection against loss of ground and loss of  $V_{CC}$
- Over-temperature shut-down with autorestart (thermal shut-down)
- Reverse battery protected <sup>(a)</sup>
- Electrostatic discharge protection



### Application

- All types of resistive, inductive and capacitive loads

### Description

The VN5E160S-E is a single channel high-side driver manufactured in the ST proprietary VIPower M0-5 technology and housed in the tiny SO-8 package.

The VN5E160S-E is designed to drive automotive grounded loads delivering protection, diagnostics and easy 3V and 5V CMOS-compatible interface with any microcontroller.

The device integrates advanced protective functions such as load current limitation, inrush and overload active management by power limitation, over-temperature shut-off with auto-restart and over-voltage active clamp.

A dedicated active low digital status pin is associated with every output channel in order to provide *Enhanced* diagnostic functions including fast detection of overload and short-circuit to ground, over-temperature indication, short-circuit to  $V_{CC}$  diagnosis and ON & OFF state open-load detection.

The diagnostic feedback of the whole device can be disabled by pulling the STAT\_DIS pin up, thus allowing wired-ORing with other similar devices.

a. See [Figure 32: Application schematic](#).

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# 1 Block diagram and pin configuration

Figure 1. Block diagram

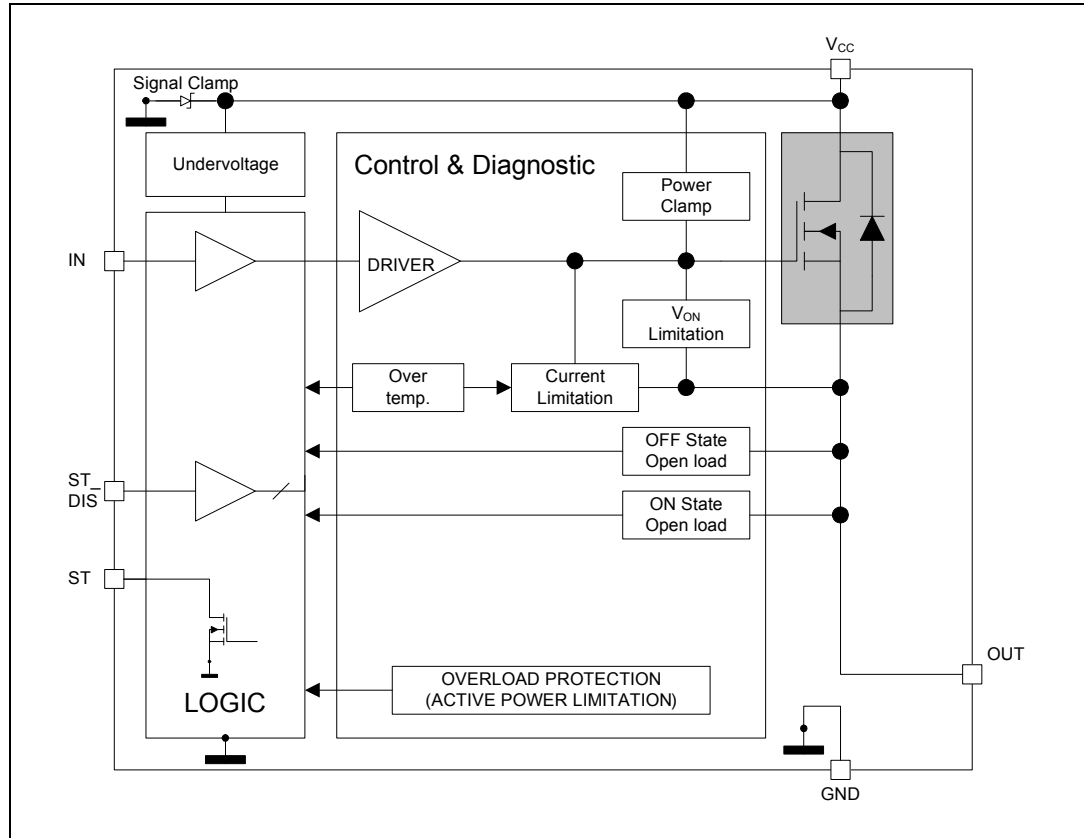


Table 1. Pin function

Name	Function
V <sub>CC</sub>	Battery connection.
OUTPUT	Power output.
GND	Ground connection. Must be reverse battery protected by an external diode/ resistor network.
INPUT	Voltage controlled input pin with hysteresis, CMOS compatible. Controls output switch state.
STATUS	Open Drain digital diagnostic pin.
STAT_DIS	Active high CMOS compatible pin, to disable the STATUS pin.

Figure 2. Configuration diagram (top view)

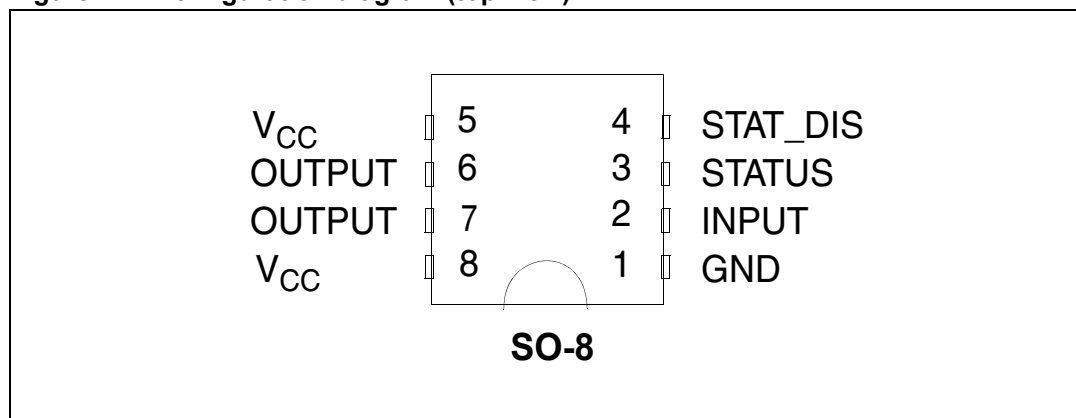
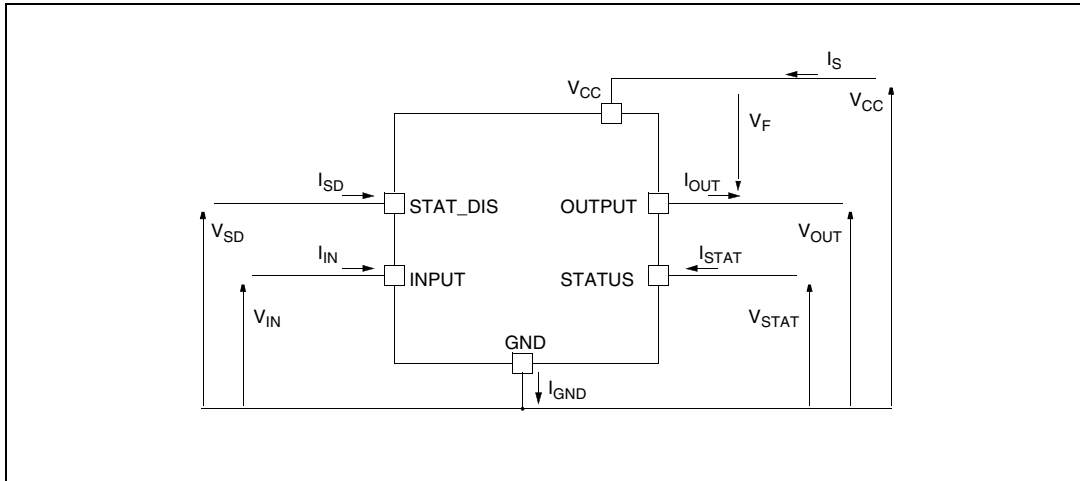


Table 2. Suggested connections for unused and not connected pins

Connection / pin	Status	N.C.	Output	Input	STAT_DIS
Floating	X	X	X	X	X
To ground	Not allowed	X	Not allowed	Through 10K $\Omega$ resistor	Through 10K $\Omega$ resistor

## 2 Electrical specifications

Figure 3. Current and voltage conventions



Note:  $V_F = V_{OUT} - V_{CC}$  during reverse battery condition.

### 2.1 Absolute maximum ratings

Stressing the device above the ratings listed in the “Absolute maximum ratings” tables 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 the conditions in the “Absolute maximum ratings” tables for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE Program and others relevant quality documents.

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	6	A
$I_{IN}$	DC input current	+10 / -1	mA
$I_{STAT}$	DC status current	+10 / -1	mA
$I_{STAT\_DIS}$	DC status disable current	+10 / -1	mA
$E_{MAX}$	Maximum switching energy (single pulse) ( $L=8\text{ mH}$ ; $R_L=0\Omega$ ; $V_{bat}=13.5\text{V}$ ; $T_{jstart}=150^\circ\text{C}$ ; $I_{OUT} = I_{limL}(Typ.)$ )	36	mJ



**Table 3. Absolute maximum ratings (continued)**

Symbol	Parameter	Value	Unit
V <sub>ESD</sub>	Electrostatic discharge (Human body model: R=1.5KΩ; C=100pF)		
	– INPUT	4000	V
	– STATUS	4000	V
	– STAT_DIS	4000	V
	– OUTPUT	5000	V
	– V <sub>CC</sub>	5000	V
V <sub>ESD</sub>	Charge device model (CDM-AEC-Q100-011)	750	V
T <sub>j</sub>	Junction operating temperature	-40 to 150	°C
T <sub>stg</sub>	Storage temperature	- 55 to 150	°C

**Table 4. Thermal data**

Symbol	Parameter	Max. value	Unit
R <sub>thj-pins</sub>	Thermal resistance junction-pins	30	°C/W
R <sub>thj-amb</sub>	Thermal resistance junction-ambient	See <a href="#">Figure 36</a> .	°C/W

## 2.2 Electrical characteristics

Values specified in this section are for  $8V < V_{CC} < 28V$ ;  $-40^{\circ}C < T_j < 150^{\circ}C$ , unless otherwise stated.

**Table 5. Power section**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{CC}$	Operating supply voltage		4.5	13	28	V
$V_{USD}$	Undervoltage shut-down			3.5	4.5	V
$V_{USDhyst}$	Undervoltage shut-down hysteresis			0.5		V
$R_{ON}$	On state resistance	$I_{OUT}=1A$ ; $T_j=25^{\circ}C$			160	m $\Omega$
		$I_{OUT}=1A$ ; $T_j=150^{\circ}C$			320	m $\Omega$
		$I_{OUT}=1A$ ; $V_{CC}=5V$ ; $T_j=25^{\circ}C$			210	m $\Omega$
$V_{clamp}$	Clamp voltage	$I_S=20$ mA	41	46	52	V
$I_S$	Supply current	Off State; $V_{CC}=13V$ ; $V_{IN}=V_{OUT}=0V$ ; $T_j=25^{\circ}C$		2 <sup>(1)</sup>	5 <sup>(1)</sup>	$\mu A$
		On State; $V_{IN}=5V$ ; $V_{CC}=13V$ ; $I_{OUT}=0A$		1.9	3.5	mA
$I_{L(off1)}$	Off state output current	$V_{IN}=V_{OUT}=0V$ ; $V_{CC}=13V$ ; $T_j=25^{\circ}C$	0	0.01	3	$\mu A$
		$V_{IN}=V_{OUT}=0V$ ; $V_{CC}=13V$ ; $T_j=125^{\circ}C$	0		5	$\mu A$
$V_F$	Output - $V_{CC}$ diode voltage	$-I_{OUT}=0.6A$ ; $T_j=150^{\circ}C$			0.7	V

1. PowerMOS leakage included.

**Table 6. Switching ( $V_{CC} = 13V$ ;  $T_j = 25^{\circ}C$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-On delay time	$R_L=13\Omega$ (see <a href="#">Figure 6.</a> )		10		$\mu s$
$t_{d(off)}$	Turn-Off delay time	$R_L=13\Omega$ (see <a href="#">Figure 6.</a> )		15		$\mu s$
$dV_{OUT}/dt_{(on)}$	Turn-On voltage slope	$R_L=13\Omega$		See <a href="#">Figure 26.</a>		V/ $\mu s$
$dV_{OUT}/dt_{(off)}$	Turn-Off voltage slope	$R_L=13\Omega$		See <a href="#">Figure 28.</a>		V/ $\mu s$
$W_{ON}$	Switching energy losses during $t_{won}$	$R_L=13\Omega$ (see <a href="#">Figure 6.</a> )		70		$\mu J$
$W_{OFF}$	Switching energy losses during $t_{woff}$	$R_L=13\Omega$ (see <a href="#">Figure 6.</a> )		40		$\mu J$

**Table 7. Status pin ( $V_{SD}=0$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{STAT}$	Status low output voltage	$I_{STAT}= 1.6 \text{ mA}$ , $V_{SD}=0V$			0.5	V
$I_{LSTAT}$	Status leakage current	Normal operation or $V_{SD}=5V$ , $V_{STAT}= 5V$			10	$\mu\text{A}$
$C_{STAT}$	Status pin input capacitance	Normal operation or $V_{SD}=5V$ , $V_{STAT}= 5V$			100	pF
$V_{SCL}$	Status clamp voltage	$I_{STAT}= 1\text{mA}$ $I_{STAT}= - 1\text{mA}$	5.5	-0.7	7	V V

**Table 8. Protection (1)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{limH}$	DC short circuit current	$V_{CC}=13V$ ; $5V < V_{CC} < 28V$	7	10	14 14	A A
$I_{limL}$	Short circuit current during thermal cycling	$V_{CC}=13V$ ; $T_R < T_j < T_{TSD}$		2.5		A
$T_{TSD}$	Shutdown temperature		150	175	200	$^{\circ}\text{C}$
$T_R$	Reset temperature		$T_{RS} + 1$	$T_{RS} + 5$		$^{\circ}\text{C}$
$T_{RS}$	Thermal reset of STATUS		135			$^{\circ}\text{C}$
$T_{HYST}$	Thermal hysteresis ( $T_{TSD}-T_R$ )			7		$^{\circ}\text{C}$
$t_{SDL}$	Status delay in overload conditions	$T_j > T_{TSD}$ (see <a href="#">Figure 4</a> )			20	$\mu\text{s}$
$V_{DEMAG}$	Turn-off output voltage clamp	$I_{OUT}=1A$ ; $V_{IN}=0$ ; $L=20\text{mH}$	$V_{CC}-41$	$V_{CC}-46$	$V_{CC}-52$	V
$V_{ON}$	Output voltage drop limitation	$I_{OUT}=0.03A$ (see <a href="#">Figure 5.</a> ) $T_j = -40^{\circ}\text{C} \dots +150^{\circ}\text{C}$		25		mV

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

**Table 9. Open load detection ( $8V < V_{CC} < 18V$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{OL}$	Open load ON state detection threshold	$V_{IN} = 5V$	10		40	mA
$t_{DOL(on)}$	Open load ON state detection delay	$I_{OUT} = 0A, V_{CC} = 13V$ (see <a href="#">Figure 4</a> )			200	$\mu s$
$t_{POL}$	Delay between INPUT falling edge and STATUS rising edge in open load condition	$I_{OUT} = 0A$ (see <a href="#">Figure 4</a> )	200	500	1200	$\mu s$
$V_{OL}$	Open load OFF state voltage detection threshold	$V_{IN} = 0V$	2		4	V
$t_{DSTKON}$	Output short circuit to $V_{CC}$ detection delay at turn-off	See <a href="#">Figure 4</a>	180		$t_{POL}$	$\mu s$
$I_{L(off2)}$	Off state output current	$V_{IN} = 0V; V_{OUT} = 4V$ (see <a href="#">Section 3.4: Open load detection in Off state</a> )	-75		0	$\mu A$
td_vol	Delay response from output rising edge to STATUS falling edge in open load	$V_{IN} = 0V; V_{OUT} = 4V$			20	$\mu s$

**Table 10. Logic input**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{IL}$	Input low level				0.9	V
$I_{IL}$	Low level input current	$V_{IN} = 0.9V$	1			$\mu A$
$V_{IH}$	Input high level		2.1			V
$I_{IH}$	High level input current	$V_{IN} = 2.1V$			10	$\mu A$
$V_{I(hyst)}$	Input hysteresis voltage		0.25			V
$V_{ICL}$	Input clamp voltage	$I_{IN} = 1mA$ $I_{IN} = -1mA$	5.5	-0.7	7	V V
$V_{SDL}$	STAT_DIS low level voltage				0.9	V
$I_{SDL}$	Low level STAT_DIS current	$V_{SD} = 0.9V$	1			$\mu A$
$V_{SDH}$	STAT_DIS high level voltage		2.1			V
$I_{SDH}$	High level STAT_DIS current	$V_{SD} = 2.1V$			10	$\mu A$
$V_{SD(hyst)}$	STAT_DIS hysteresis voltage		0.25			V
$V_{SDCL}$	STAT_DIS clamp voltage	$I_{SD} = 1mA$ $I_{SD} = -1mA$	5.5	-0.7	7	V V

Figure 4. Status timings

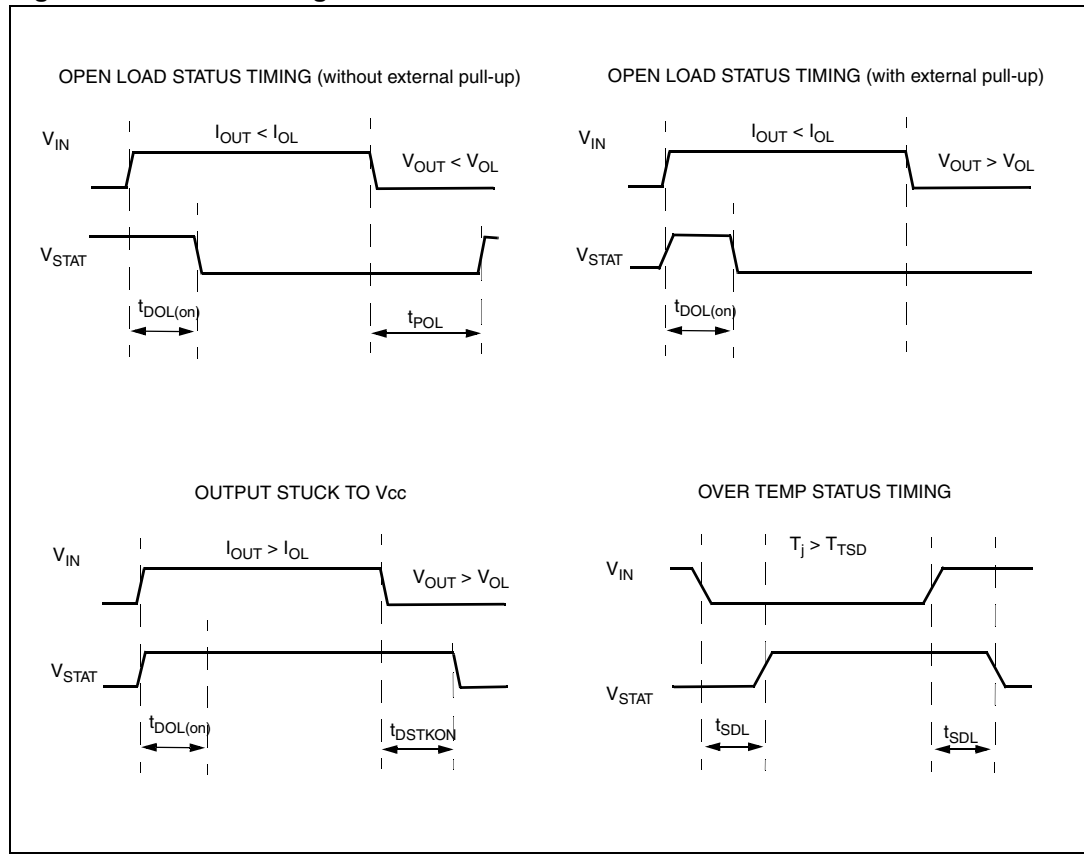


Figure 5. Output voltage drop limitation

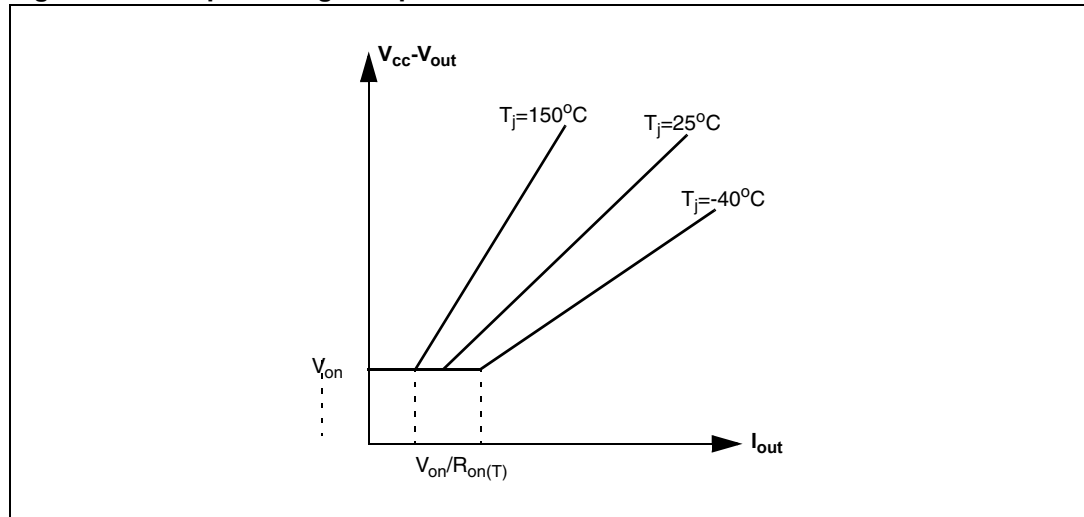


Figure 6. Switching characteristics

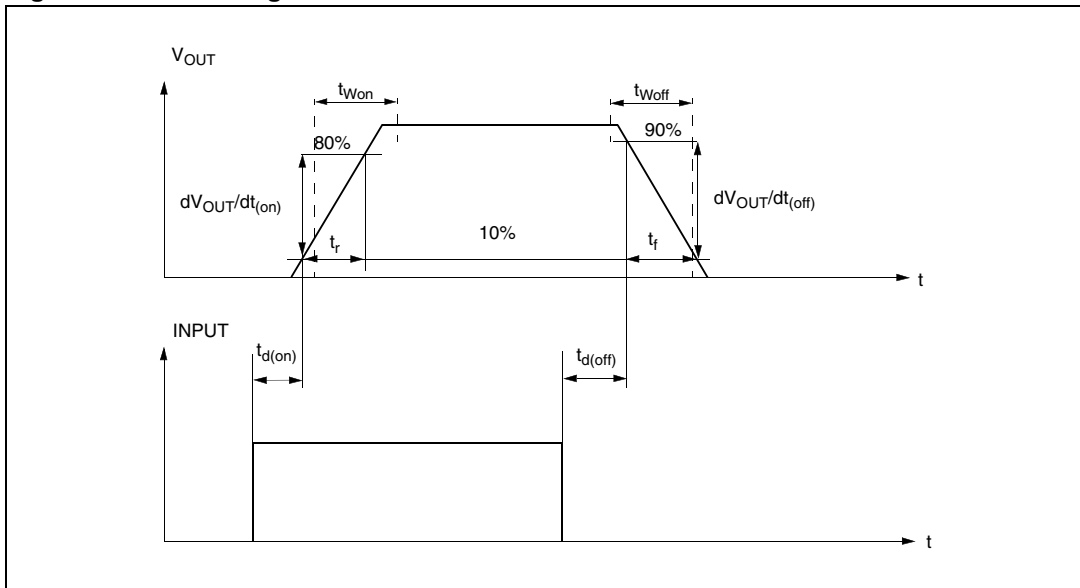


Table 11. Truth table

Conditions	INPUT	OUTPUT	STATUS ( $V_{SD}=0V$ ) <sup>(1)</sup>
Normal operation	L	L	H
	H	H	H
Overtemperature	L	L	H
	H	L	L
Undervoltage	L	L	X
	H	L	X
Overload & Short circuit to GND	H	X	H
	H	(no power limitation) Cycling (power limitation)	L
Output voltage > $V_{OL}$	L	H	L <sup>(2)</sup>
	H	H	H
Output current < $I_{OL}$	L	L	H <sup>(3)</sup>
	H	H	L

1. If the  $V_{SD}$  is high, the STATUS pin is in a high impedance.
2. The STATUS pin is low with a delay equal to  $t_{DSTKON}$  after INPUT falling edge.
3. The STATUS pin becomes high with a delay equal to  $t_{POL}$  after INPUT falling edge.



**Table 12. Electrical transient requirements**

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

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

1. The above test levels must be considered referred to V<sub>CC</sub> = 13.5V except for pulse 5b.
2. Valid in case of external load dump clamp: 40V maximum referred to ground.

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

### 2.3 Waveforms

Figure 7. Normal operation

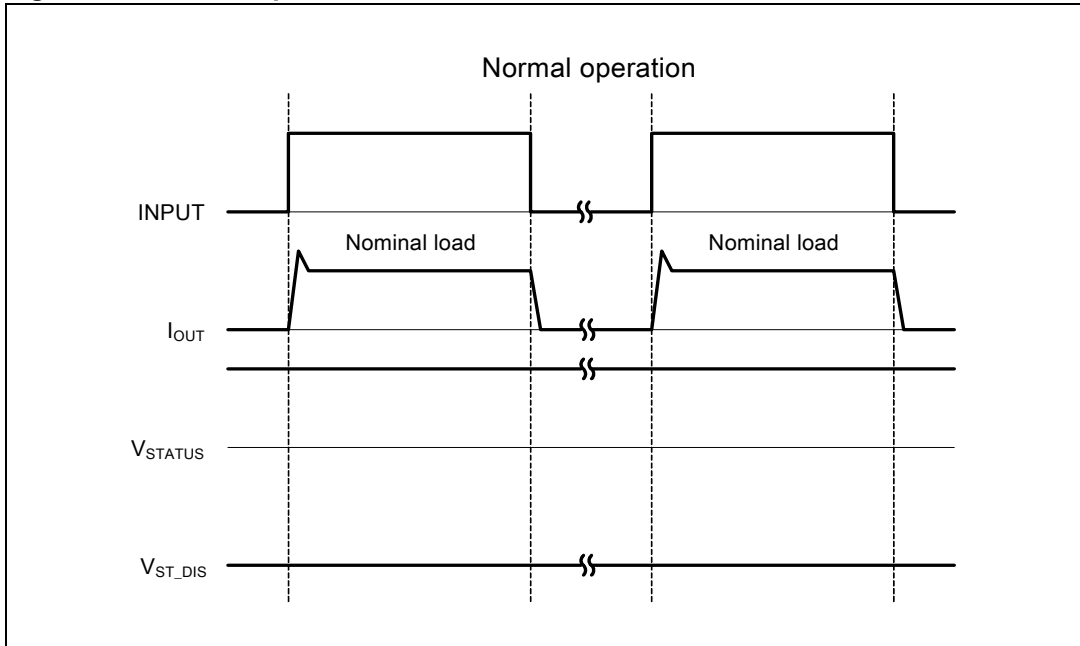


Figure 8. Undervoltage shut-down

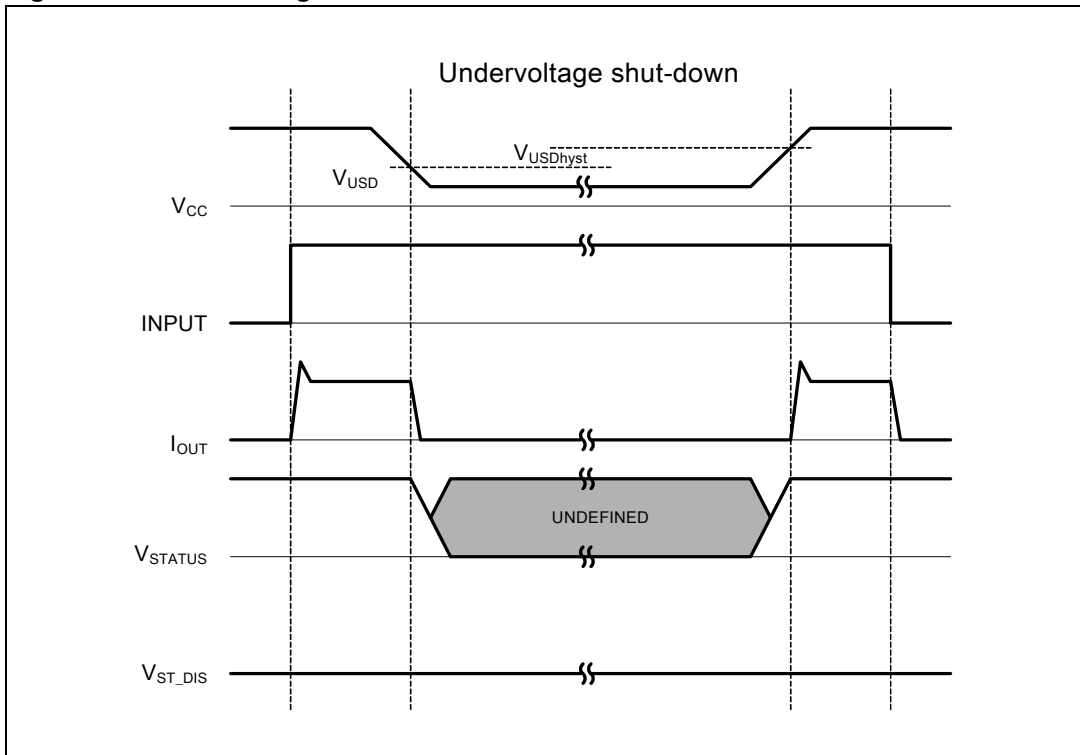


Figure 9. Overload or Short to GND

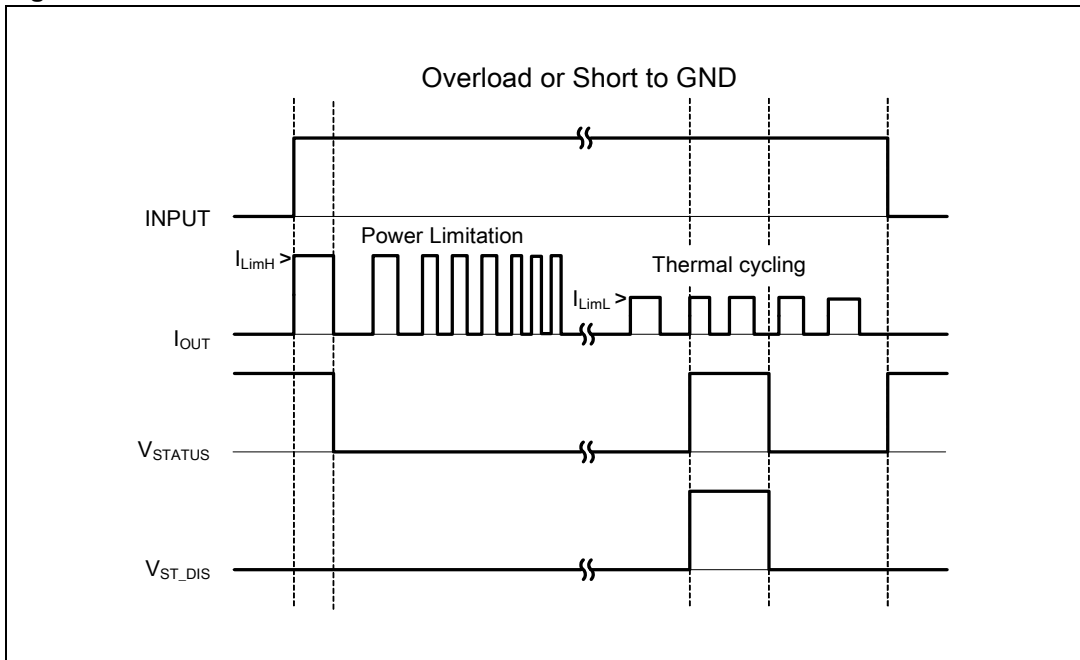


Figure 10. Intermittent Overload

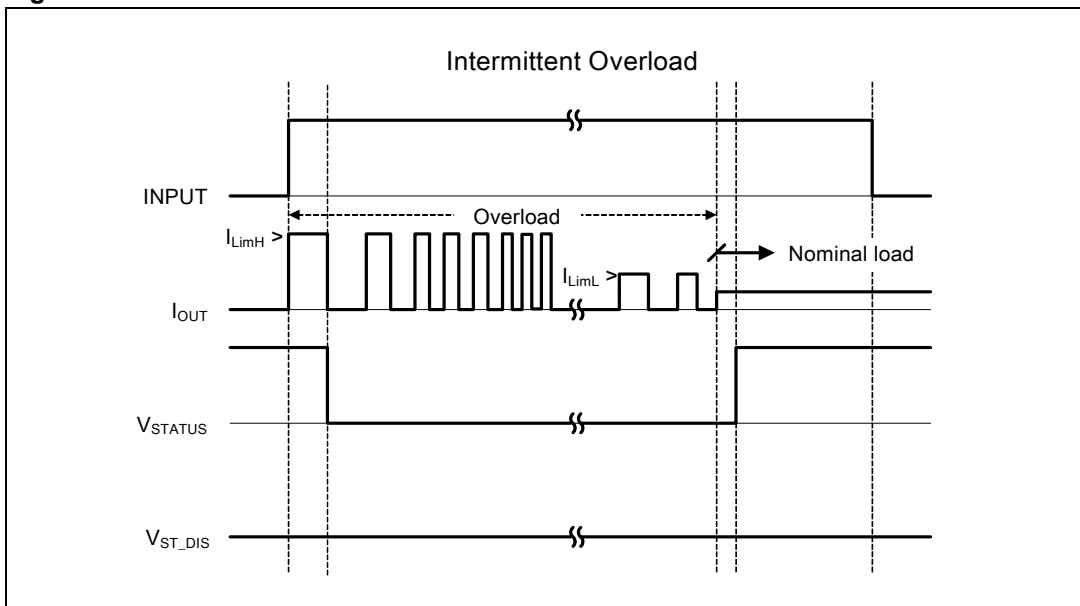


Figure 11. Open Load with external pull-up

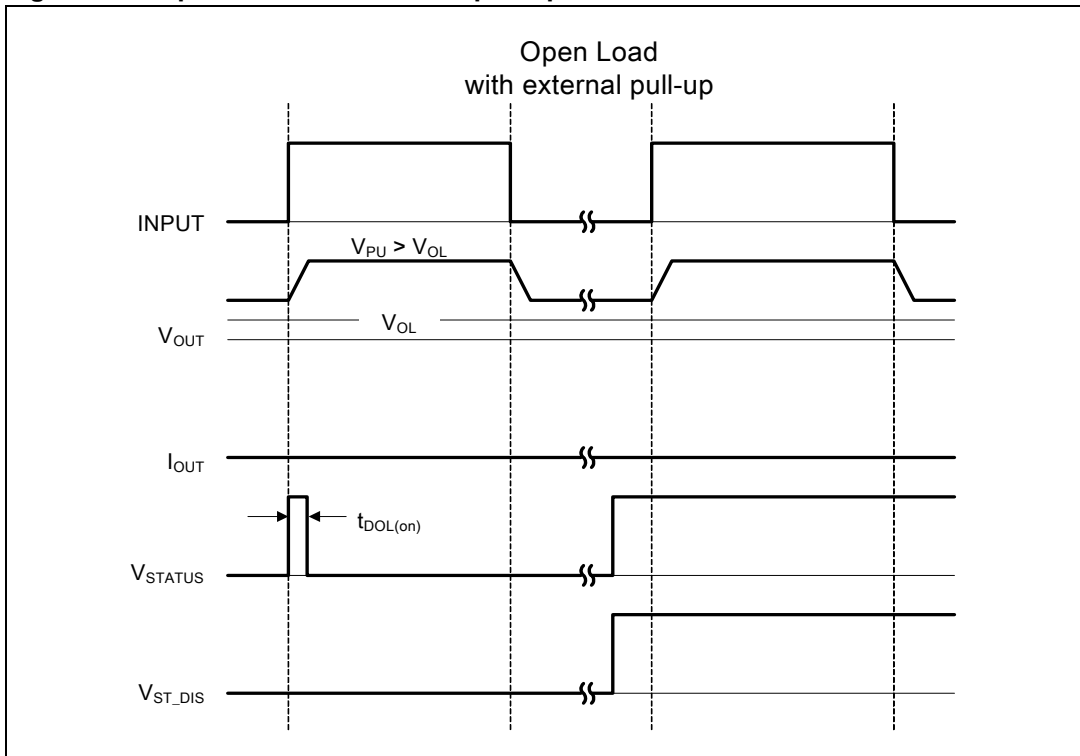


Figure 12. Open Load without external pull-up

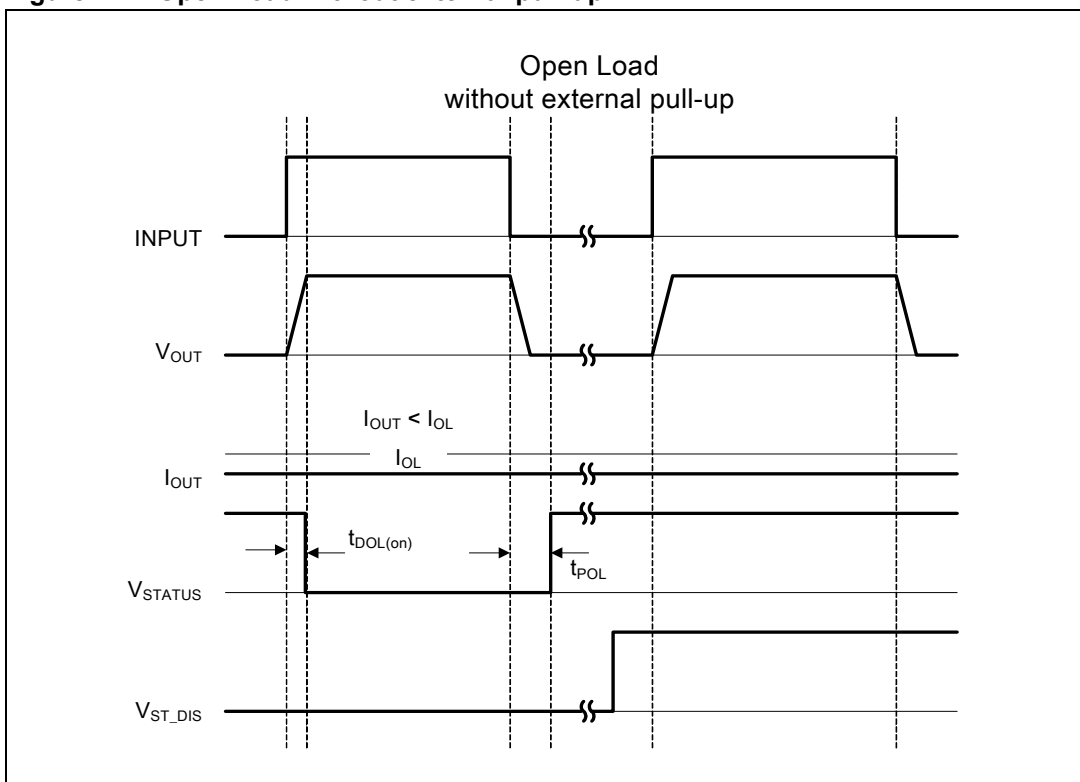


Figure 13. Short to  $V_{CC}$

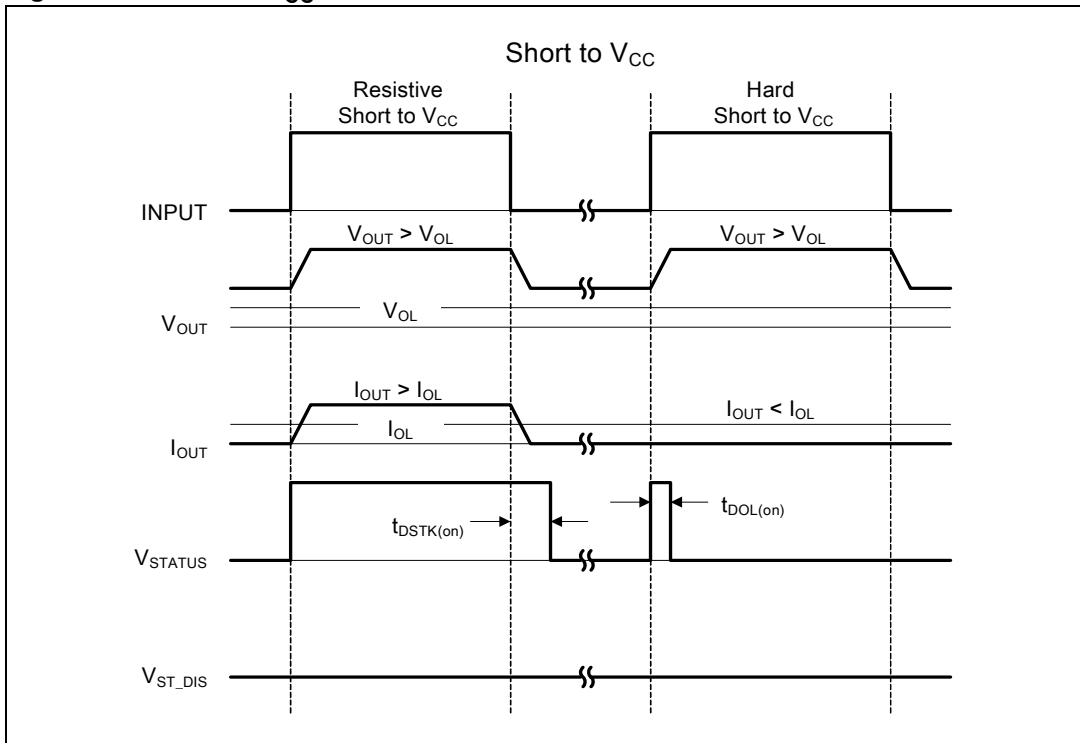
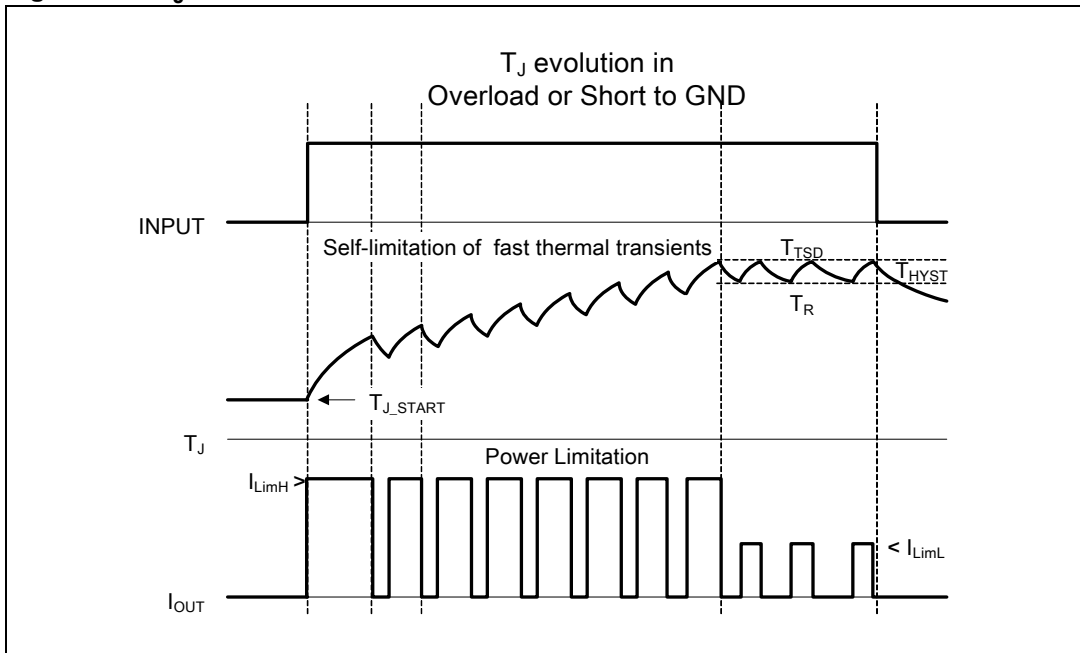


Figure 14.  $T_J$  evolution in Overload or Short to GND



## 2.4 Electrical characteristics curves

Figure 15. Off state output current

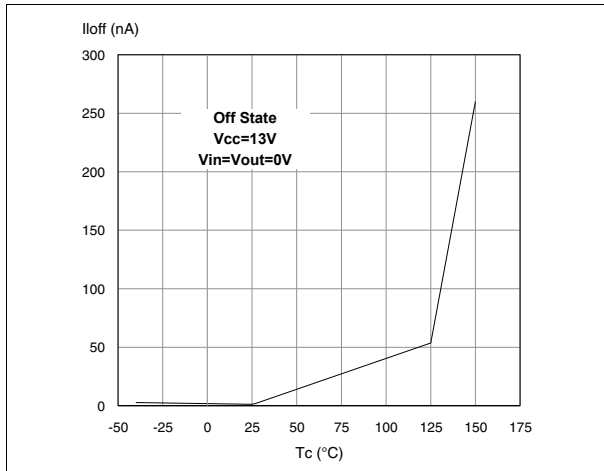


Figure 16. High level input current

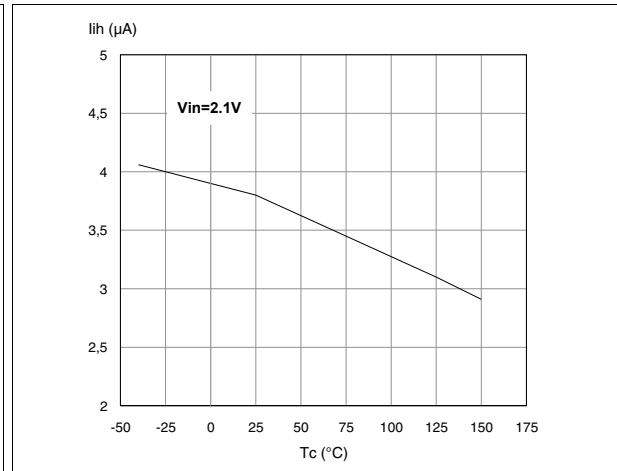


Figure 17. Input clamp voltage

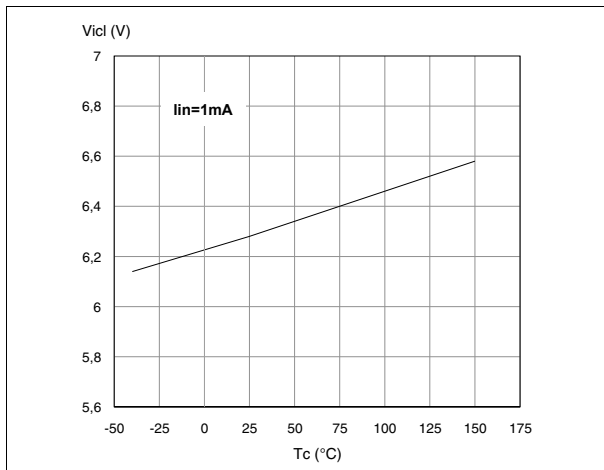


Figure 18. Input high level

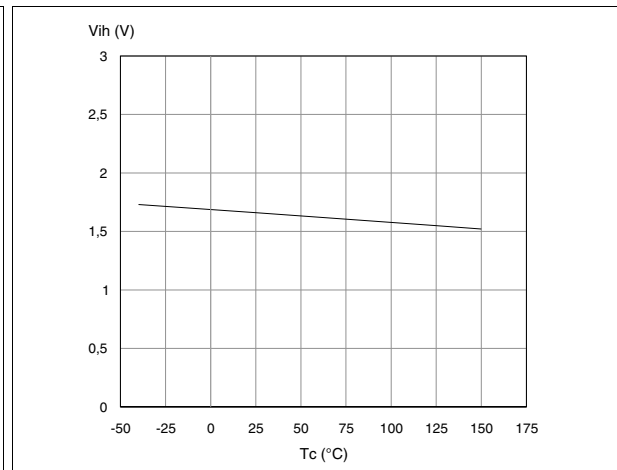


Figure 19. Input low level

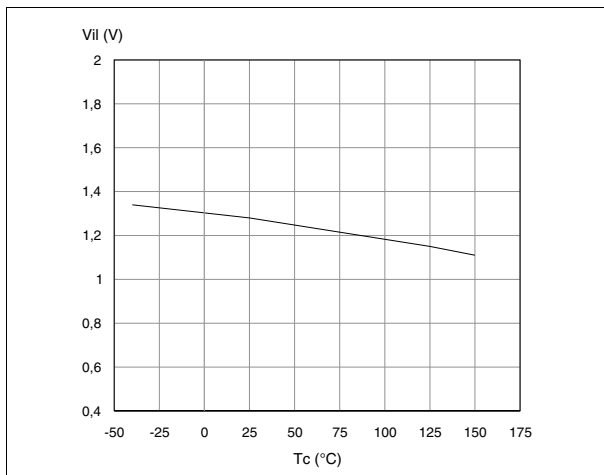


Figure 20. Low level STAT\_DIS current

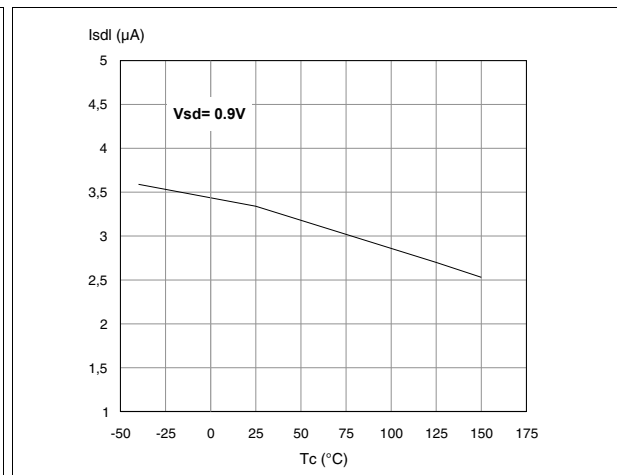




Figure 21. On state resistance vs  $T_{case}$

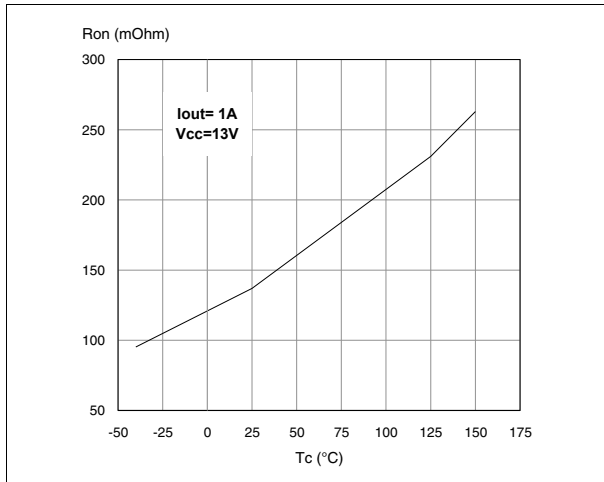


Figure 22. High level STAT\_DIS current

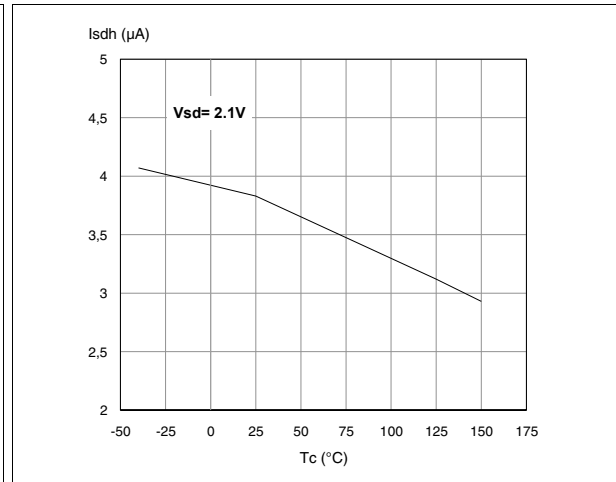


Figure 23. On state resistance vs  $V_{CC}$

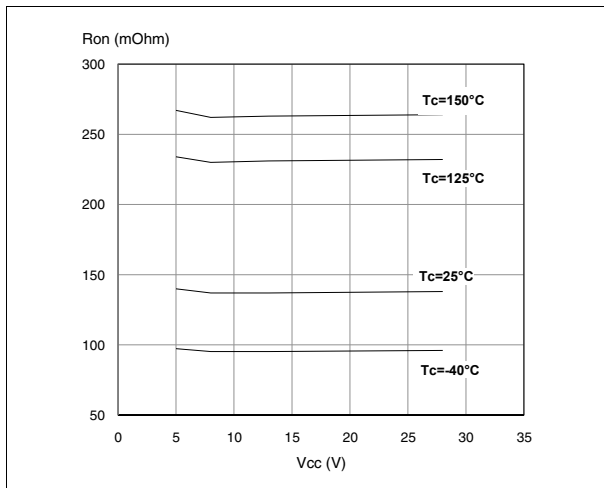


Figure 24. Low level input current

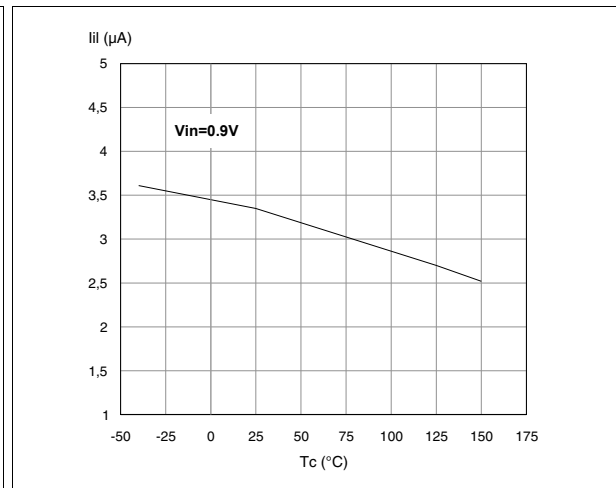


Figure 25.  $I_{LIM}$  vs  $T_{case}$

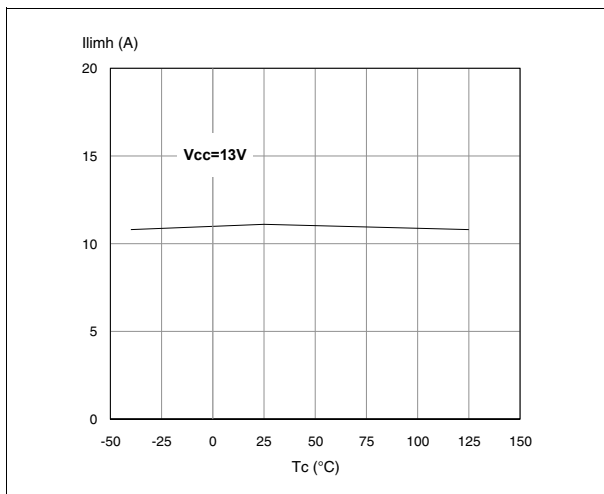


Figure 26. Turn-On voltage slope

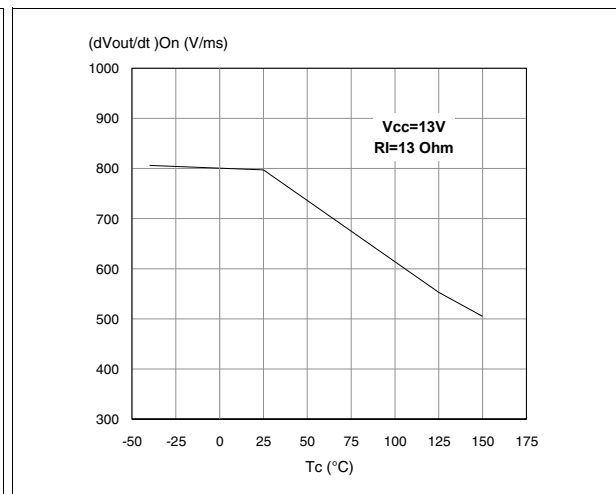


Figure 27. Undervoltage shutdown

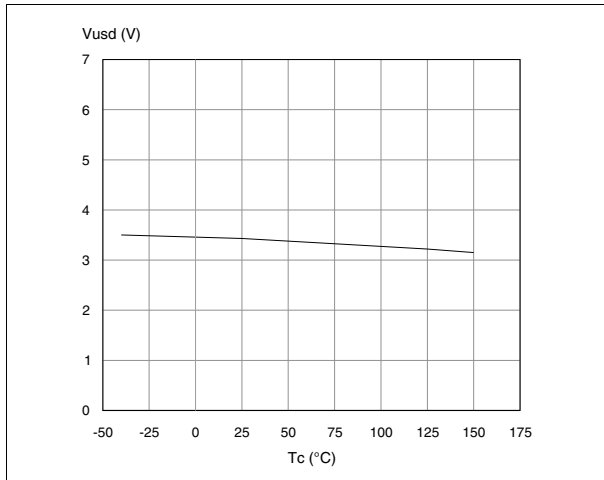


Figure 28. Turn-Off voltage slope

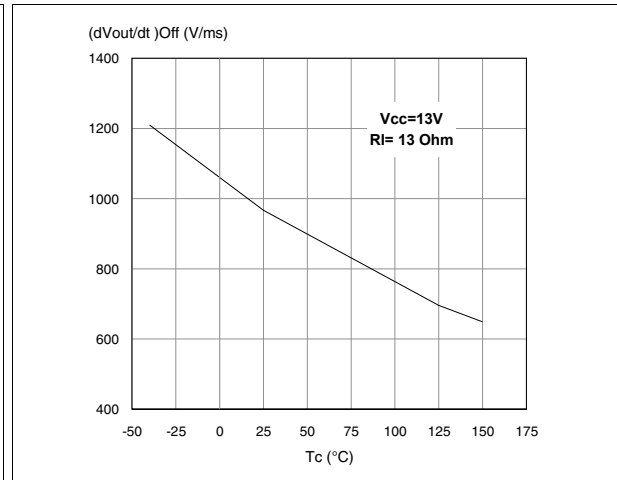


Figure 29. STAT\_DIS clamp voltage

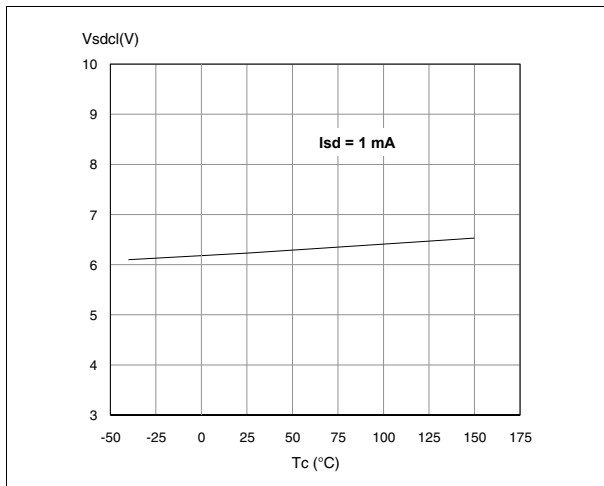


Figure 30. High level STAT\_DIS voltage

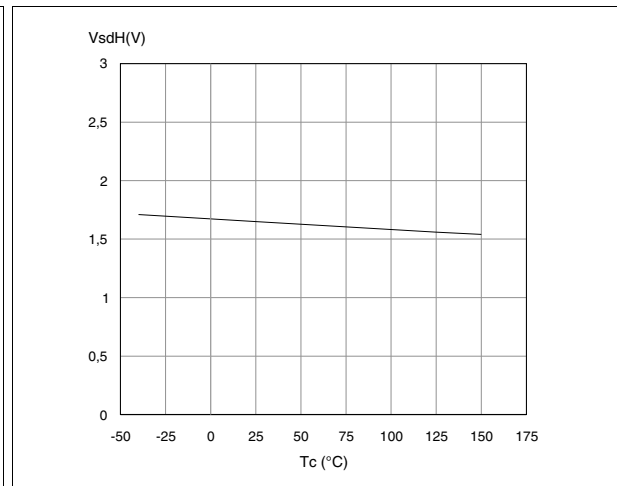
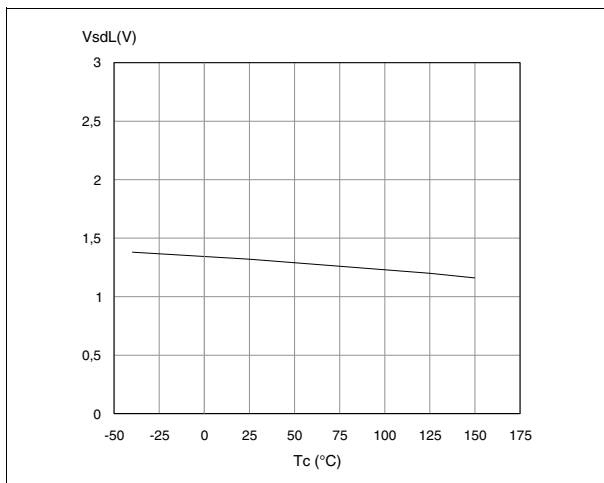
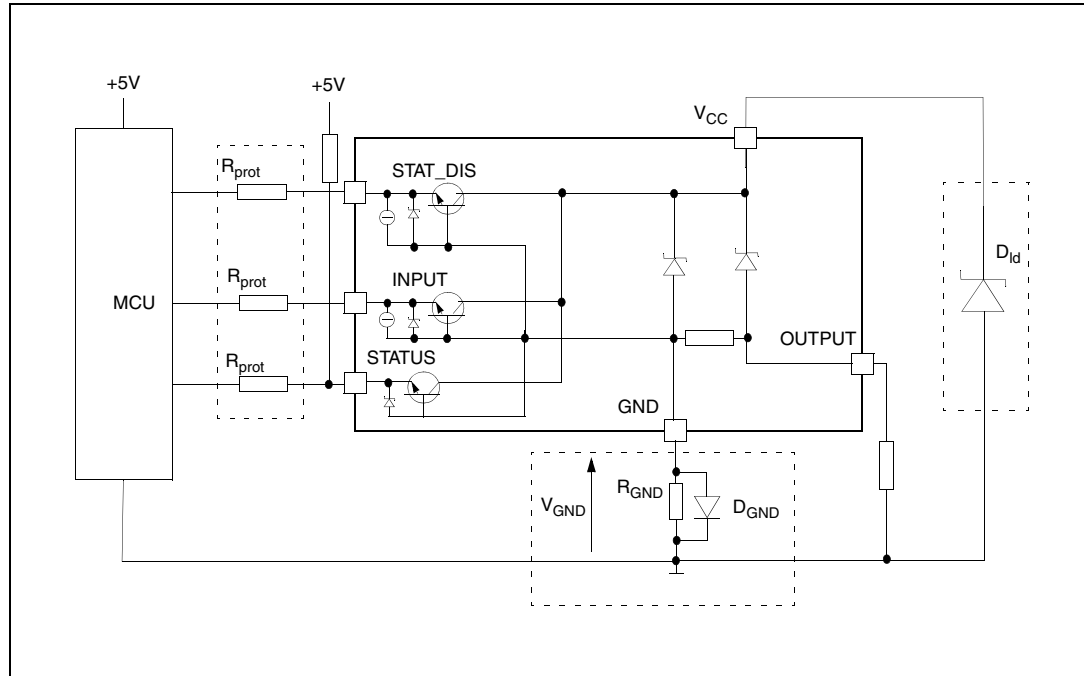


Figure 31. Low level STAT\_DIS voltage



### 3 Application information

Figure 32. Application schematic



#### 3.1 GND protection network against reverse battery

##### 3.1.1 Solution 1: resistor in the ground line (R<sub>GND</sub> only)

This solution can be used with any type of load.

The following is an indication on how to dimension the R<sub>GND</sub> resistor.

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

where -I<sub>GND</sub> 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<sub>GND</sub> (when V<sub>CC</sub><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<sub>S(on)max</sub> 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<sub>GND</sub> will produce a shift (I<sub>S(on)max</sub> \* R<sub>GND</sub>) in the input thresholds and the status output values. This shift will vary depending on how many devices are ON in the case of several high side drivers sharing the same R<sub>GND</sub>.

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

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

A resistor ( $R_{GND}=1k\Omega$ ) 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 will produce a shift ( $\sim 600mV$ ) in the input threshold and in the status output values, if the microprocessor ground is not common to the device ground. This shift will not vary if more than one HSD shares the same diode/resistor network.

## 3.2 Load dump protection

$D_{ld}$  is necessary (Voltage Transient Suppressor) if the load dump peak voltage exceeds to  $V_{CC}$  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 T/R 7637/2 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 will be pulled negative. ST suggests that a resistor ( $R_{prot}$ ) be inserted in line to prevent the  $\mu C$  I/Os pins to latch-up.

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

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

Calculation example:

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

$$5k\Omega \leq R_{prot} \leq 180k\Omega.$$

Recommended  $R_{prot}$  value is  $10k\Omega$ .

### 3.4 Open load detection in Off state

Off-state open-load detection requires an external pull-up resistor ( $R_{PU}$ ) connected between the OUTPUT pin and a positive supply voltage ( $V_{PU}$ ) like the +5V line used to supply the microprocessor.

The external resistor has to be selected according to the following requirements:

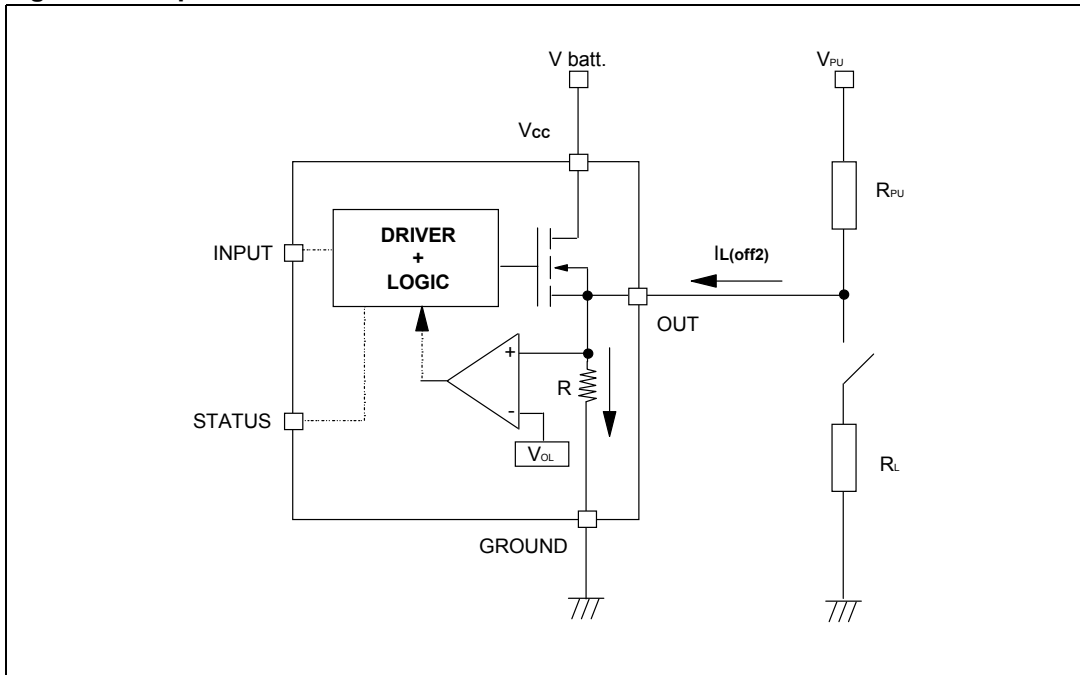
1. No false open load indication when load is connected: in this case we have to avoid  $V_{OUT}$  to be higher than  $V_{OLmin}$ ; this results in the following condition  

$$V_{OUT} = (V_{PU} / (R_L + R_{PU})) R_L < V_{OLmin}$$
2. No misdetection when load is disconnected: in this case the  $V_{OUT}$  has to be higher than  $V_{OLmax}$ ; this results in the following condition  $R_{PU} < (V_{PU} - V_{OLmax}) / I_{L(off2)}$ .

Because  $I_{s(OFF)}$  may significantly increase if  $V_{out}$  is pulled high (up to several mA), the pull-up resistor  $R_{PU}$  should be connected to a supply that is switched OFF when the module is in standby.

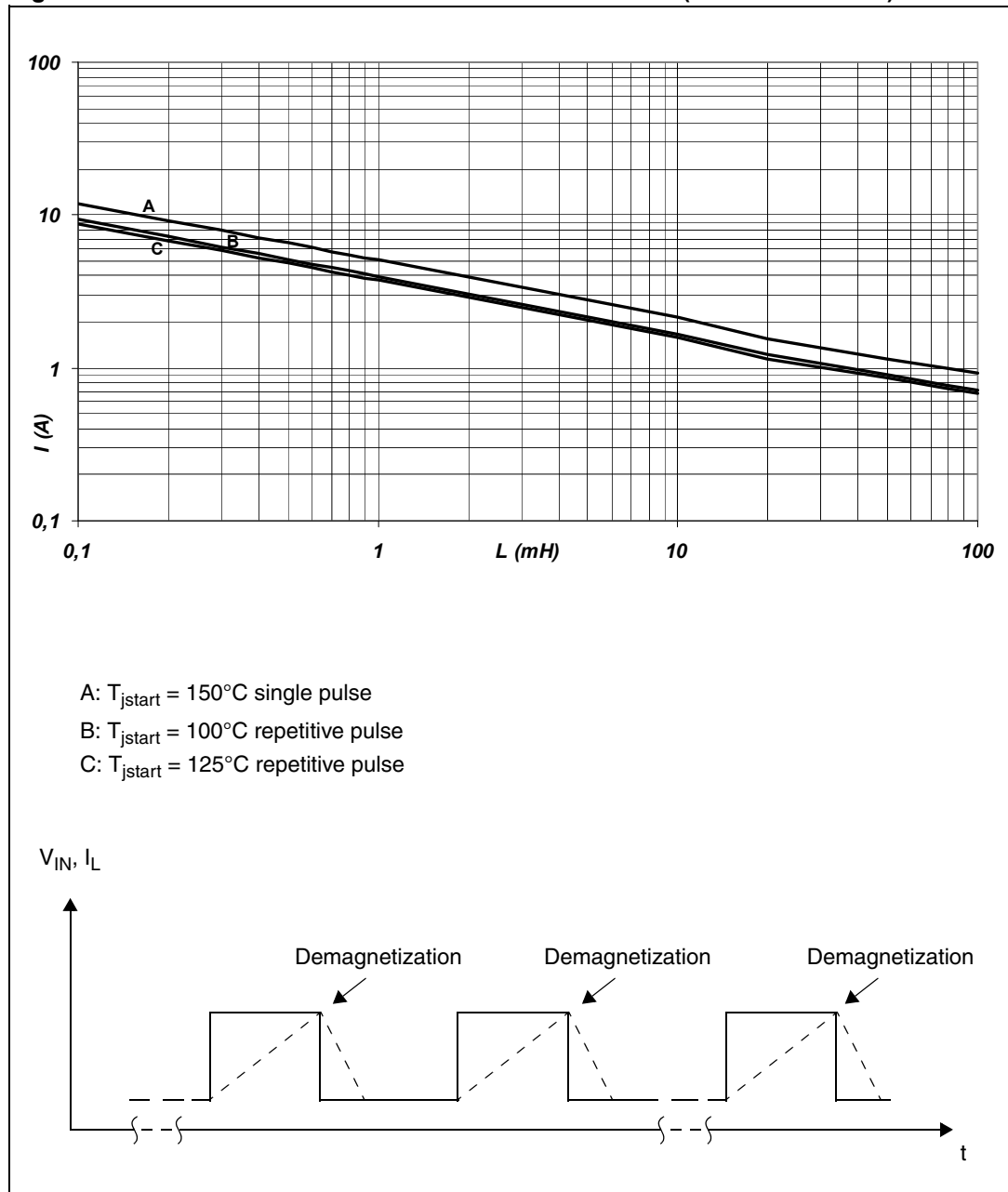
The values of  $V_{OLmin}$ ,  $V_{OLmax}$  and  $I_{L(off2)}$  are available in the Electrical characteristics section.

**Figure 33. Open load detection in Off state**



### 3.5 Maximum demagnetization energy ( $V_{CC} = 13.5V$ )

Figure 34. Maximum turn-off current versus inductance (for each channel)



Note: Values are generated with  $R_L = 0 \Omega$ .  
 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.