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VN5E025AJ-E

Single channel high-side driver with analog current sense for automotive applications

Features

Max supply voltage	V_{CC}	41 V
Operating voltage range	V_{CC}	4.5 to 28 V
Max On-State resistance	R_{ON}	25 mΩ
Current limitation (typ)	I_{LIMH}	60 A
Off state supply current	I_S	2 µA(1)

1. Typical value with all loads connected.

- General
  - Inrush current active management by power limitation
  - Very low stand-by current
  - 3.0 V CMOS compatible inputs
  - Optimized electromagnetic emissions
  - Very low electromagnetic susceptibility
  - In compliance with the 2002/95/EC european directive
  - Very low current sense leakage
- Diagnostic functions
  - Proportional load current sense
  - High current sense precision for wide currents range
  - Current sense disable
  - Off state openload detection
  - Output short to V_{CC} detection
  - Overload and short to ground (power limitation) indication
  - Thermal shutdown indication
- Protections
  - Undervoltage shutdown
  - Overvoltage clamp
  - Load current limitation
  - Self limiting of fast thermal transients
  - Protection against loss of ground and loss of V_{CC}
  - Over-temperature shutdown with autorestart (thermal shutdown)

PowerSSO-12

  - Reverse battery protected
  - Electrostatic discharge protection

Application

- All types of resistive, inductive and capacitive loads
- Suitable as LED driver

Description

The VN5E025AJ-E is a single channel high-side driver manufactured in the ST proprietary VIPower M0-5 technology and housed in the tiny PowerSSO-12 package. The VN5E025AJ-E is designed to drive 12 V automotive grounded loads delivering protection, diagnostics and easy 3 V and 5 V 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 analog current sense pin is associated with every output channel in order to provide *Ehnanced* diagnostic functions including fast detection of overload and short-circuit to ground through power limitation indication, over-temperature indication, short-circuit to V_{CC} diagnosis and ON-state and OFF-state open load detection.

The current sensing and diagnostic feedback of the whole device can be disabled by pulling the CS_DIS pin high to allow sharing of the external sense resistor with other similar devices

Contents

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List of figures

1 Block diagram and pin description

Figure 1. Block diagram

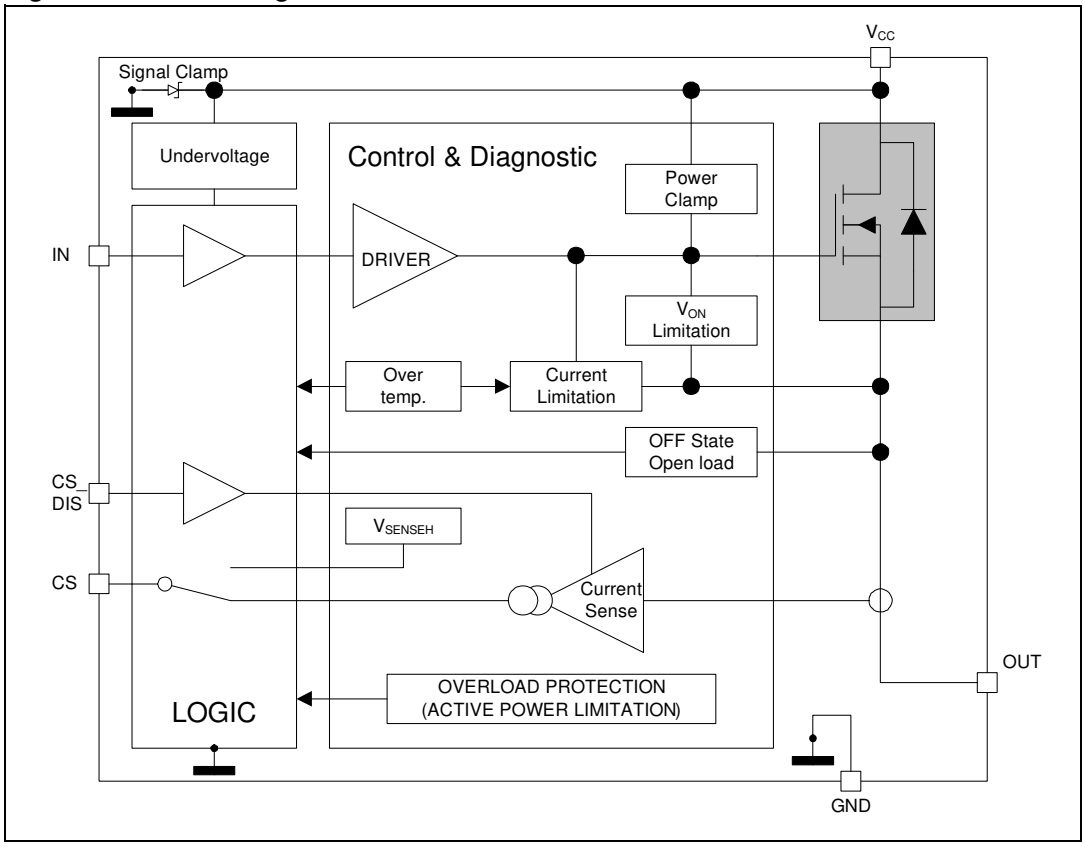


Table 1. Pin function

Name	Function
V_{CC}	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.
CURRENT SENSE	Analog current sense pin, delivers a current proportional to the load current.
CS_DIS	Active high CMOS compatible pin, to disable the current sense pin.

Figure 2. Configuration diagram (top view)

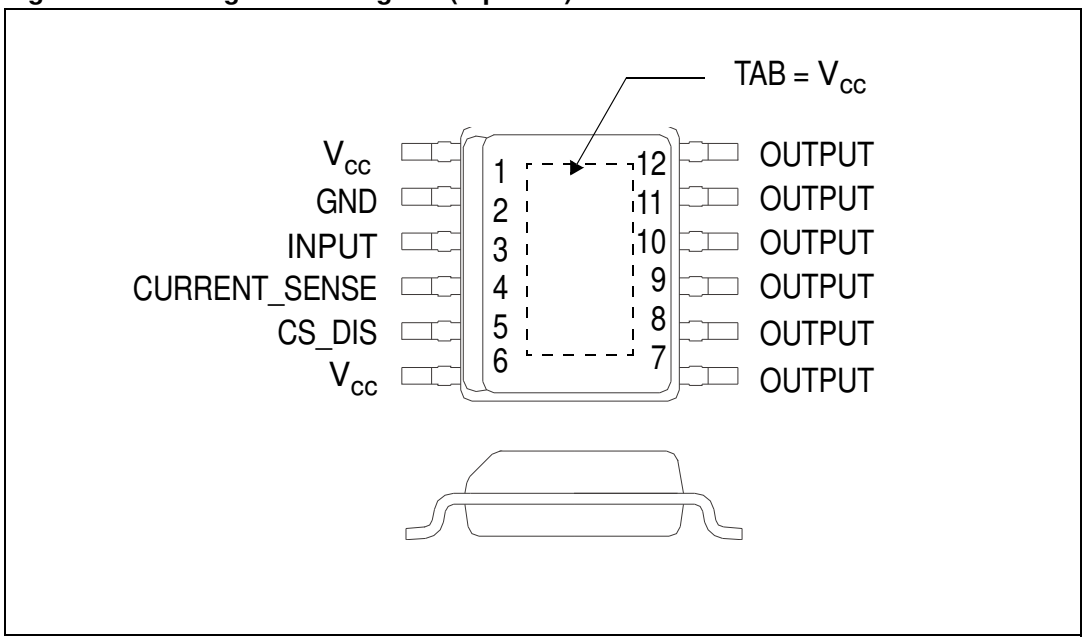
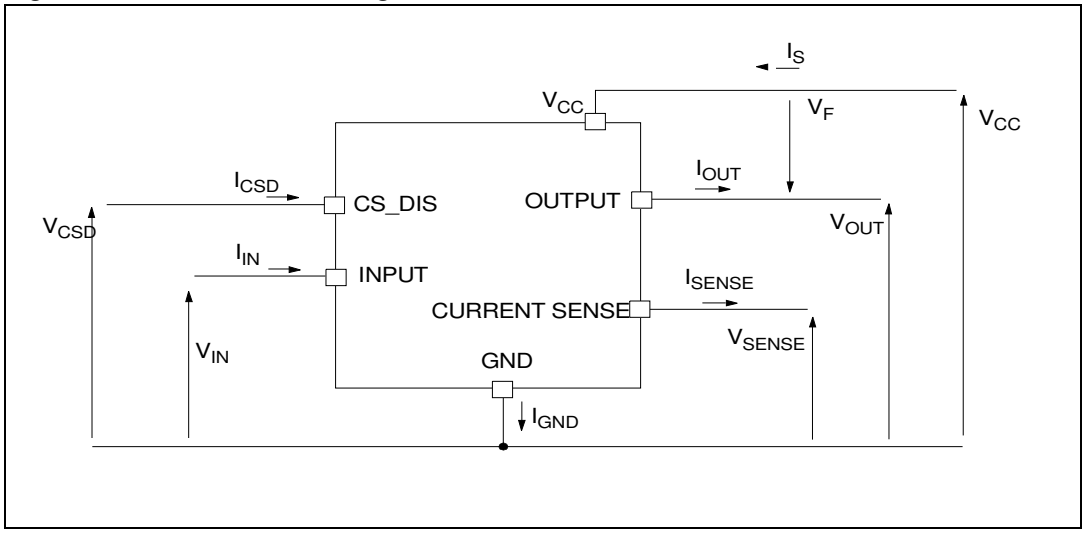


Table 2. Suggested connections for unused and not connected pins

Connection / pin	Current sense	N.C.	Output	Input	CS_DIS
Floating	Not allowed	X	X	X	X
To ground	Through 1kΩ resistor	X	Through 22kΩ resistor	Through 10kΩ resistor	Through 10kΩ resistor

2 Electrical specifications

Figure 3. Current and voltage conventions



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

2.1 Absolue 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 the conditions in table below 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	20	A
I_{IN}	DC input current	-1 to 10	mA
I_{CSD}	DC current sense disable input current	-1 to 10	mA
$-I_{CSENSE}$	DC reverse CS pin current	200	mA
V_{CSENSE}	Current sense maximum voltage	V_{CC}-41 +V_{CC}	V V
E_{MAX}	Maximum switching energy (single pulse) (L=0.8mH; R_L=0Ω; V_{bat}=13.5V; T_{jstart}=150ºC; I_{OUT} = I_{limL}*(Typ.)*)	140	mJ

Table 3. Absolute maximum ratings (continued)

Symbol	Parameter	Value	Unit
V_{ESD}	Electrostatic discharge (Human Body Model: R=1.5KΩ; C=100pF) - INPUT - CURRENT SENSE - CS_DIS - OUTPUT - V_{CC}	 4000 2000 4000 5000 5000	 V V V V V
V_{ESD}	Charge device model (CDM-AEC-Q100-011)	750	V
T_j	Junction 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	1.4	°C/W
$R_{thj\text{-}amb}$	Thermal resistance junction-ambient	See *Figure 36*	°C/W

2.3 Electrical characteristics

Values specified in this section are for 8V<V_{CC}<28V; -40°C<T_j<150°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 shutdown			3.5	4.5	V
$V_{USDhyst}$	Undervoltage shutdown hysteresis			0.5		V
R_{ON}	On state resistance	I_{OUT}= 3A; T_j=25°C I_{OUT}= 3A; T_j=150°C I_{OUT}= 3A; V_{CC}=5V; T_j=25°C			25 50 35	mΩ mΩ mΩ
V_{clamp}	Clamp voltage	I_S= 20 mA	41	46	52	V
I_S	Supply current	Off State; V_{CC}=13V; T_j=25°C; V_{IN}=V_{OUT}=V_{SENSE}=V_{CSD}=0V On State; V_{CC}=13V; V_{IN}=5V; I_{OUT}= 0A		2(1) 1.5	5(1) 3	µA mA
$I_{L(off1)}$	Off state output current	V_{IN}=V_{OUT}=0V; V_{CC}=13V; T_j=25°C V_{IN}=V_{OUT}=0V; V_{CC}=13V; T_j=125°C	0 0	0.01	3 5	µA
V_F	Output - V_{CC} diode voltage	-I_{OUT}= 2A; T_j= 150°C			0.7	V

1. PowerMOS leakage included.

Table 6. Switching characteristics (V_{CC}=13V, T_j=25°C)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-On delay time	R_L= 4.3Ω (see *Figure 6.*)		15		µs
$t_{d(off)}$	Turn-Off delay time	R_L= 4.3Ω (see *Figure 6.*)		40		µs
$(dV_{OUT}/dt)_{on}$	Turn-On voltage slope	R_L= 4.3Ω		See *Figure 26*		V/µs
$(dV_{OUT}/dt)_{off}$	Turn-Off voltage slope	R_L= 4.3Ω		See *Figure 28*		V/µs
W_{ON}	Switching energy losses during t_{won}	R_L= 4.3Ω (see *Figure 6.*)		0.4		mJ
W_{OFF}	Switching energy losses during t_{woff}	R_L= 4.3Ω (see *Figure 6.*)		0.5		mJ

Table 7. Logic inputs

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IL}	Input low level voltage				0.9	V
I_{IL}	Low level input current	V_{IN}= 0.9V	1			µA
V_{IH}	Input high level voltage		2.1			V
I_{IH}	High level input current	V_{IN}= 2.1V			10	µA
$V_{I(hyst)}$	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_{CSDL}	CS_DIS low level voltage				0.9	V
I_{CSDL}	Low level CS_DIS current	V_{CSD}= 0.9V	1			µA
V_{CSDH}	CS_DIS high level voltage		2.1			V
I_{CSDH}	High level CS_DIS current	V_{CSD}= 2.1V			10	µA
$V_{CSD(hyst)}$	CS_DIS hysteresis voltage		0.25			V
V_{CSCL}	CS_DIS clamp voltage	I_{CSD}=1mA I_{CSD}= -1mA	5.5	 -0.7	7	V V

Table 8. Protection and diagnostics (1)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{limH}	DC short circuit current	V_{CC}= 13V 5V<V_{CC}<28V	43	60	85 85	A A
I_{limL}	Short circuit current during thermal cycling	V_{CC}= 13V; T_R<T_j<T_{TSD}		15		A
T_{TSD}	Shutdown temperature		150	175	200	°C
T_R	Reset temperature		T_{RS} + 1	T_{RS} + 5		°C
T_{RS}	Thermal reset of status		135			°C
T_{HYST}	Thermal hysteresis (T_{TSD}-T_R)			7		°C
V_{DEMAG}	Turn-Off output voltage clamp	I_{OUT}= 2A; V_{IN}=0; L= 6mH	V_{CC}-41	V_{CC}-46	V_{CC}-52	V
V_{ON}	Output voltage drop limitation	I_{OUT}= 0.1A T_j= -40°C...150°C (see *Figure 8*)		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 operates under abnormal conditions this software must limit the duration and number of activation cycles.

Table 9. Current sense (8V<V_{CC}<18V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
K_{LED}	I_{OUT}/I_{SENSE}	I_{OUT}= 0.05A, V_{SENSE}=0.5V, V_{CSD}=0V T_j= -40°C...150°C	1370	3180	4930	
K_0	I_{OUT}/I_{SENSE}	I_{OUT}= 0.5A; V_{SENSE}=0.5V; V_{CSD}=0V; T_j= -40°C...150°C	1990	3050	4120	
K_1	I_{OUT}/I_{SENSE}	I_{OUT}= 2A; V_{SENSE}=4V; V_{CSD}=0V; T_j= -40°C...150°C T_j= 25°C...150°C	2100 2220	2860 2860	3840 3500	
dK_1/K_1 (1)	Current sense ratio drift	I_{OUT}=2A; V_{SENSE}= 4V; V_{CSD}=0V; T_J= -40 °C to 150 °C	-10		10	%
K_2	I_{OUT}/I_{SENSE}	I_{OUT}= 3A; V_{SENSE}=4V; V_{CSD}=0V; T_j= -40°C...150°C T_j=25°C...150°C	2300 2420	2850 2850	3520 3300	
dK_2/K_2 (1)	Current sense ratio drift	I_{OUT}=3 A; V_{SENSE}= 4 V; V_{CSD}=0V; T_J= -40 °C to 150 °C	-7		7	%
K_3	I_{OUT}/I_{SENSE}	I_{OUT}= 10A; V_{SENSE}=4V; V_{CSD}=0V; T_j= -40°C...150°C T_j=25°C...150°C	2690 2700	2830 2830	3060 3020	
dK_3/K_3 (1)	Current sense ratio drift	I_{OUT}= 10 A; V_{SENSE}= 4 V; V_{CSD}=0V; T_J= -40 °C to 150 °C	-4		4	%
I_{SENSE0}	Analog sense leakage current	I_{OUT}=0A; V_{SENSE}=0V; V_{CSD}=5V; V_{IN}=0V; T_j=-40°C...150°C V_{CSD}=0V; V_{IN}=5V; T_j=-40°C...150°C I_{OUT}=2A; V_{SENSE}=0V; V_{CSD}=5V; V_{IN}=5V; T_j=-40°C...150°C	0 0 0		1 2 1	µA µA µA
I_{OL}	Open load ON state current detection threshold	V_{IN} = 5V, 8V<V_{CC}<18V I_{SENSE}= 5 µA	5		30	mA
V_{SENSE}	Max analog sense output voltage	I_{OUT}= 3A; V_{CSD}= 0V	5			V
V_{SENSEH} (2)	Analog sense output voltage in fault condition	V_{CC}= 13V; R_{SENSE}= 3.9KΩ		8		
I_{SENSEH} (2)	Analog sense output current in fault condition	V_{CC}= 13V; V_{SENSE}= 5V		9		mA

Table 9. Current sense (8V<V_{CC}<18V) (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{DSENSE1H}$	Delay response time from falling edge of CS_DIS pin	V_{SENSE}<4V, 0.5<Iout<10A I_{SENSE}=90% of $I_{SENSE\ max}$ (see *Figure 4*)		40	100	µs
$t_{DSENSE1L}$	Delay response time from rising edge of CS_DIS pin	V_{SENSE}<4V, 0.5<Iout<10A I_{SENSE}=10% of $I_{SENSE\ max}$ (see *Figure 4*)		5	20	
$t_{DSENSE2H}$	Delay response time from rising edge of INPUT pin	V_{SENSE}<4V, 0.5<Iout<10A I_{SENSE}=90% of $I_{SENSE\ max}$ (see *Figure 4*)		80	300	
$\Delta t_{DSENSE2H}$	Delay response time between rising edge of output current and rising edge of current sense	V_{SENSE} < 4V, I_{SENSE} = 90% of $I_{SENSEMAX}$, I_{OUT} = 90% of I_{OUTMAX} I_{OUTMAX}= 3A (see *Figure 7*)			110	
$t_{DSENSE2L}$	Delay response time from falling edge of INPUT pin	V_{SENSE}<4V, 0.5<Iout<10A I_{SENSE}=10% of $I_{SENSE\ max}$ (see *Figure 4*)		80	250	

1. Parameter guaranteed by design, it is not tested.
2. Fault condition includes: power limitation, overtemperature and open load OFF state detection.

Table 10. Openload detection (8V<V_{CC}<18V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{OL}	Openload 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 *Figure 5.*	180		1200	µs
$I_{L(off2)r}$	Off state output current at V_{OUT} = 4V	V_{IN}=0V; V_{SENSE}=0V V_{OUT} rising from 0V to 4V	-120		0	µA
$I_{L(off2)f}$	Off state output current at V_{OUT} = 2V	V_{IN}=0V; V_{SENSE}=V_{SENSEH} V_{OUT} falling from V_{CC} to 2V	-50		90	µA
td_vol	Delay response from output rising edge to V_{SENSE} rising edge in open load	V_{OUT}= 4 V; V_{IN}= 0V V_{SENSE}= 90% of V_{SENSEH}			20	µs

Figure 4. Current sense delay characteristics

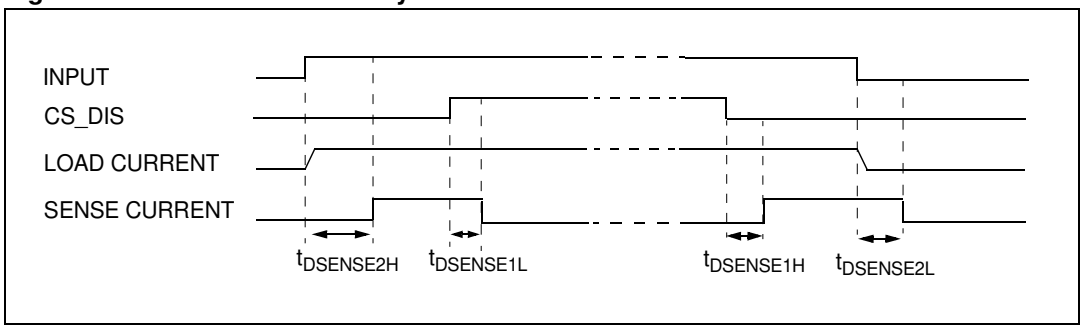


Figure 5. Openload Off-state delay timing

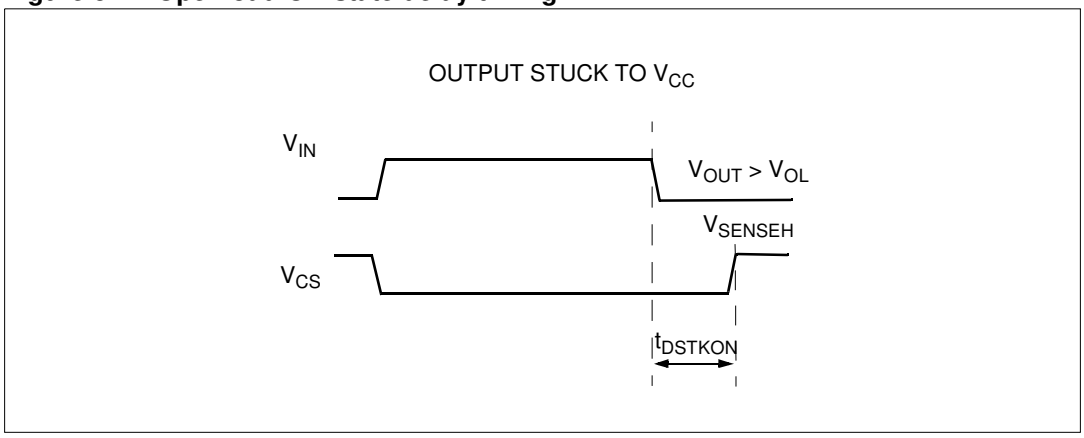


Figure 6. Switching characteristics

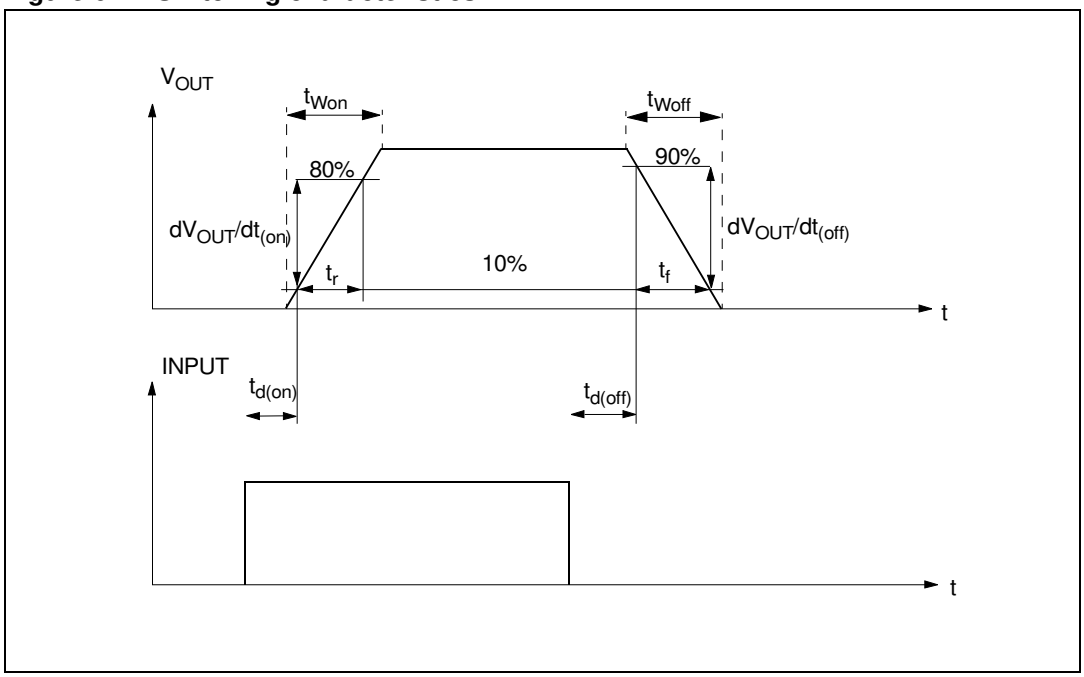


Figure 7. Delay response time between rising edge of ouput current and rising edge of current sense (CS enabled)

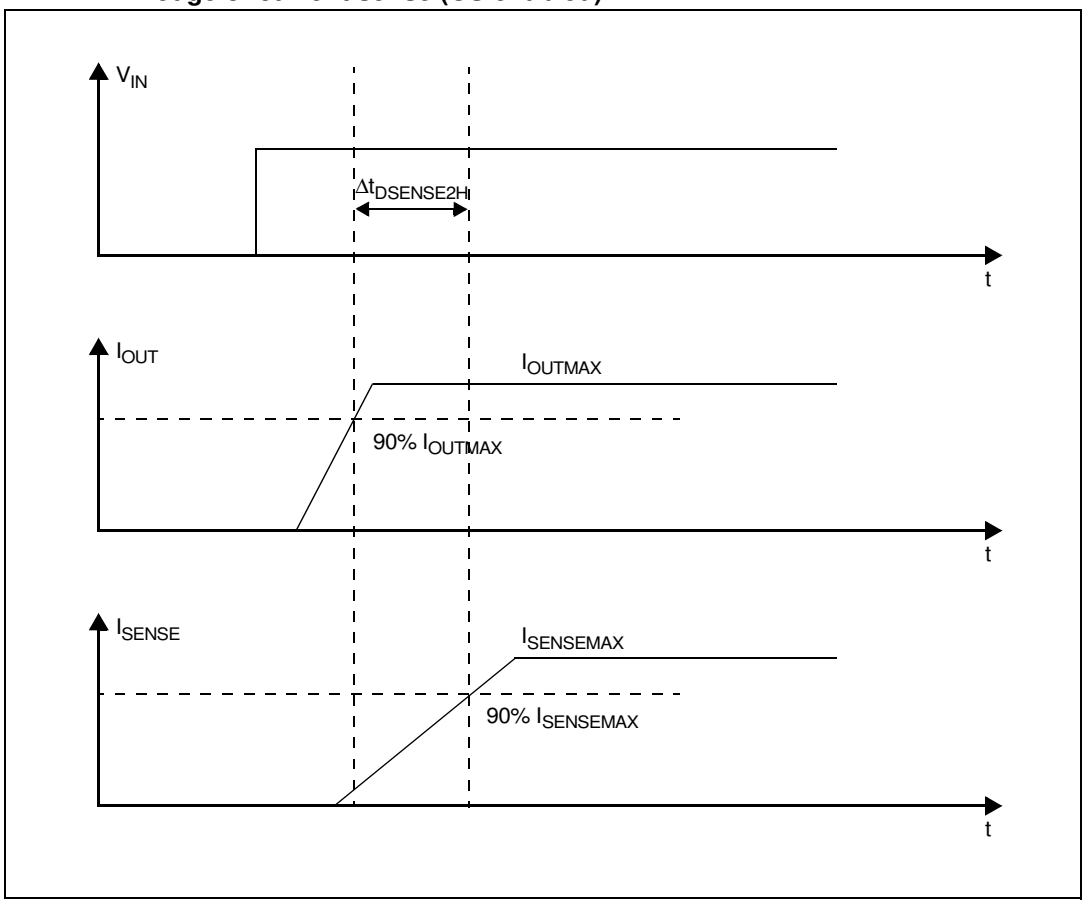


Figure 8. Output voltage drop limitation

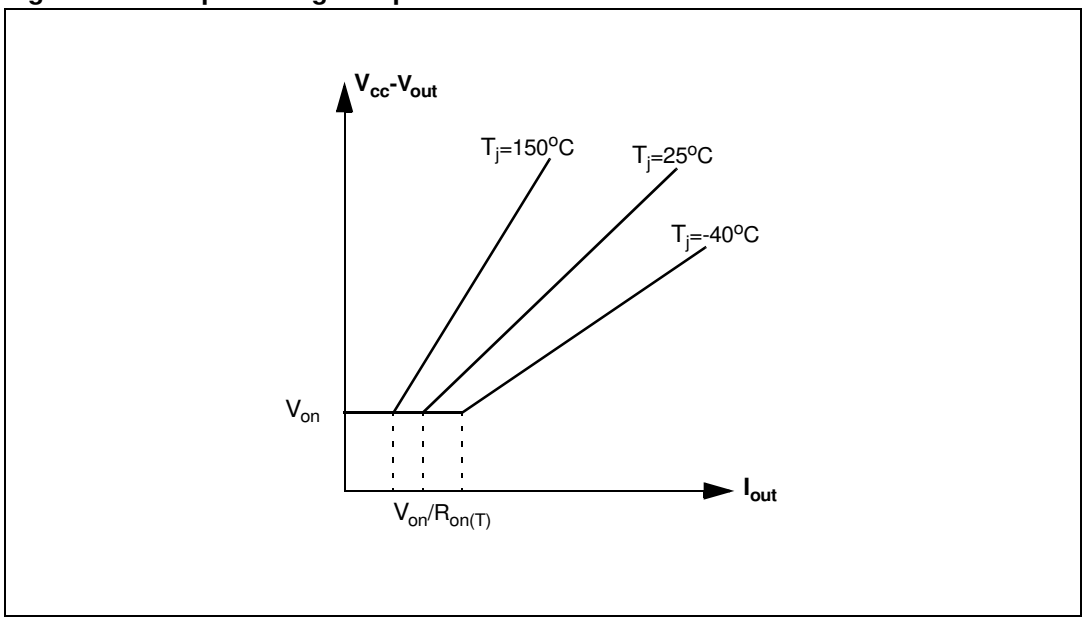


Figure 9. I_{OUT} / I_{SENSE} vs I_{OUT}

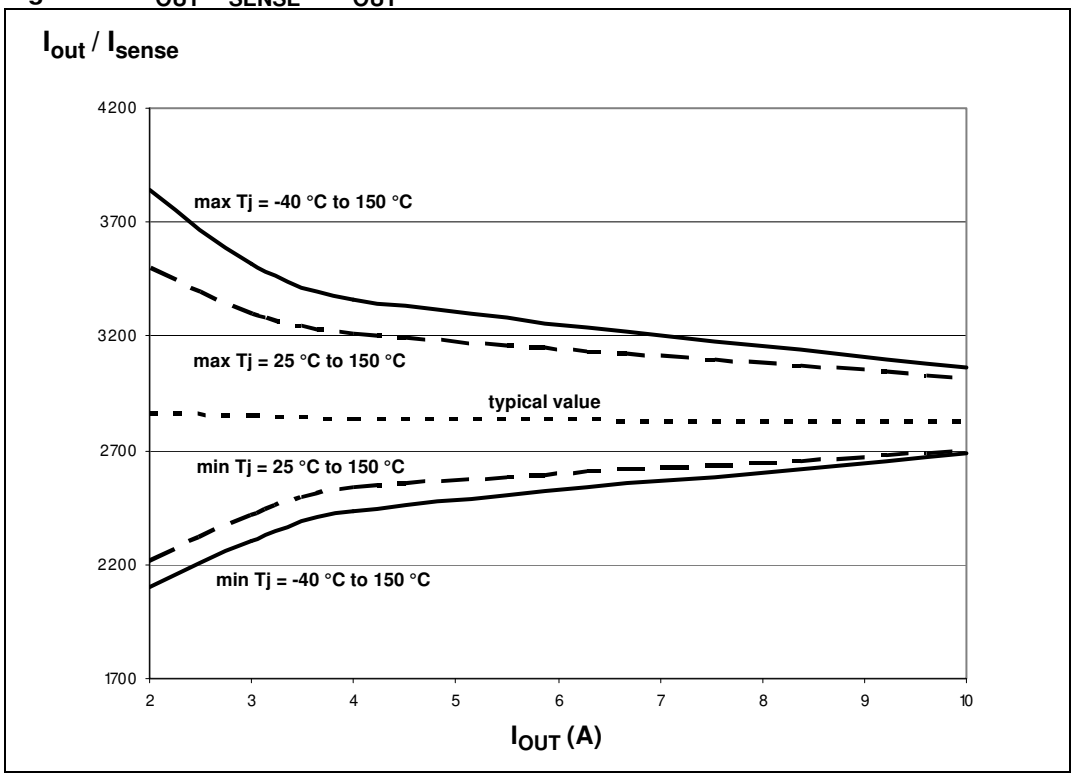
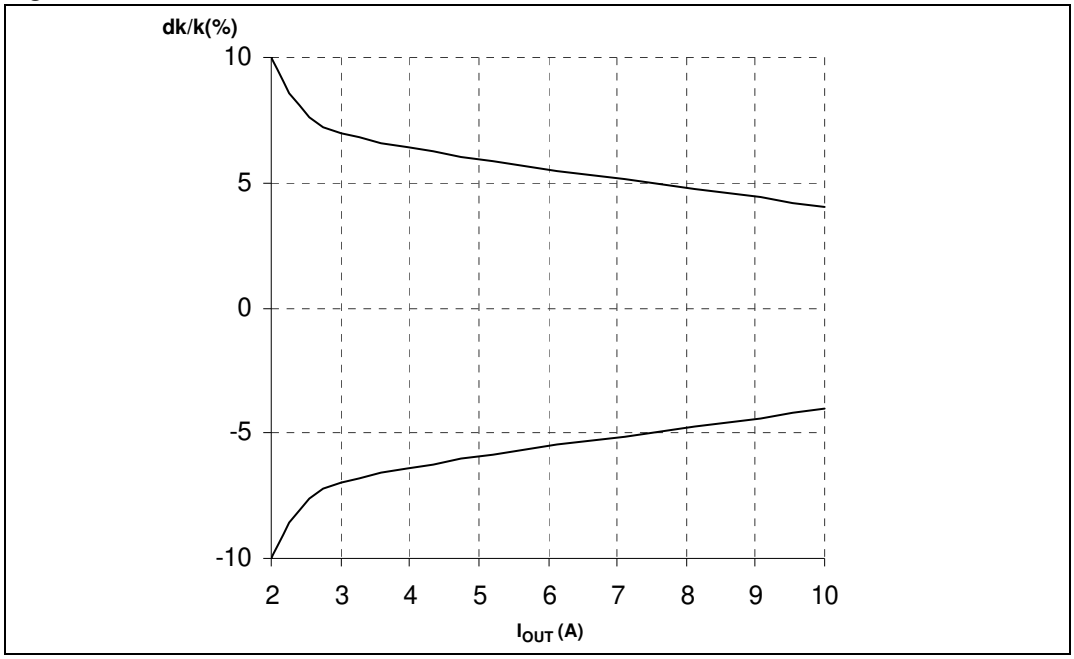


Figure 10. Maximum current sense ratio drift vs load current



Note: Parameter guaranteed by design; it is not tested.

Table 11. Truth table

Conditions	Input	Output	Sense (V_{CSD}=0V)(1)
Normal operation	L H	L H	0 Nominal
Overtemperature	L H	L L	0 V_{SENSEH}
Undervoltage	L H	L L	0 0
Overload	H H	X (no power limitation) Cycling (power limitation)	Nominal V_{SENSEH}
Short circuit to GND (power limitation)	L H	L L	0 V_{SENSEH}
Open load OFF state (with external pull-up)	L	H	V_{SENSEH}
Short circuit to V_{CC} (external pull-up disconnected)	L H	H H	V_{SENSEH} < Nominal
Negative output voltage clamp	L	L	0

1. If the V_{CSD} is high, the SENSE output is at a high impedance, its potential depends on leakage currents and external circuit.

Table 12. Electrical transient requirements

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

ISO 7637-2: 2004E Test pulse	Test level results	
	III	VI
1	C	C
2a	C	C
3a	C	C
3b	C	C
4	C	C
5b(2)	C	C

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

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

2.4 Waveforms

Figure 11. Normal operation

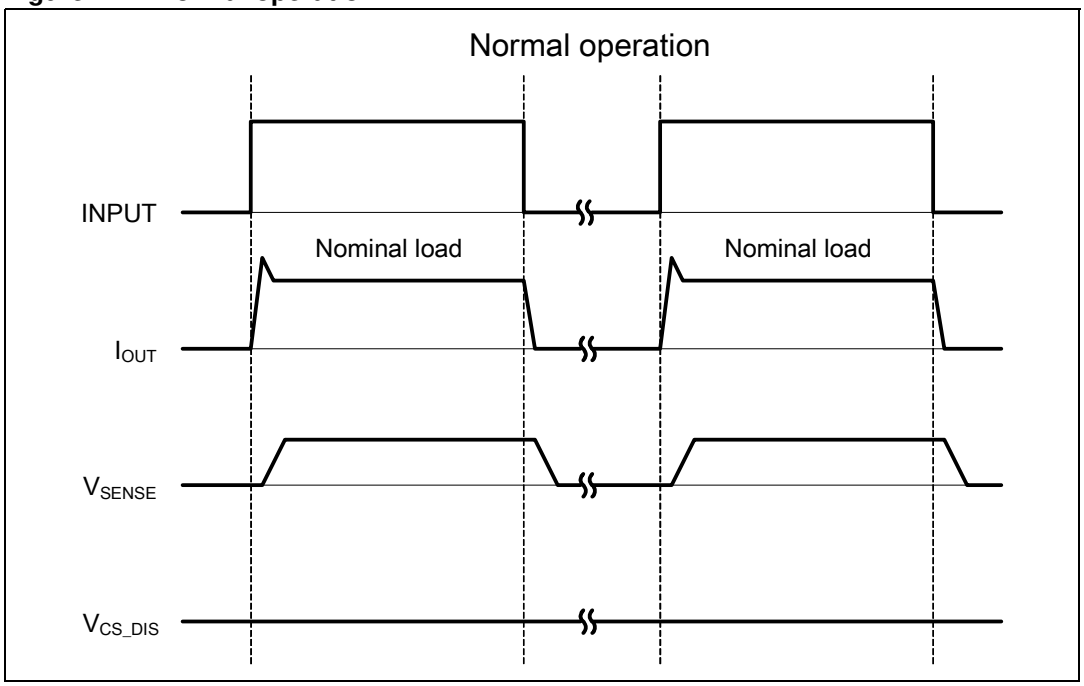


Figure 12. Overload or Short to GND

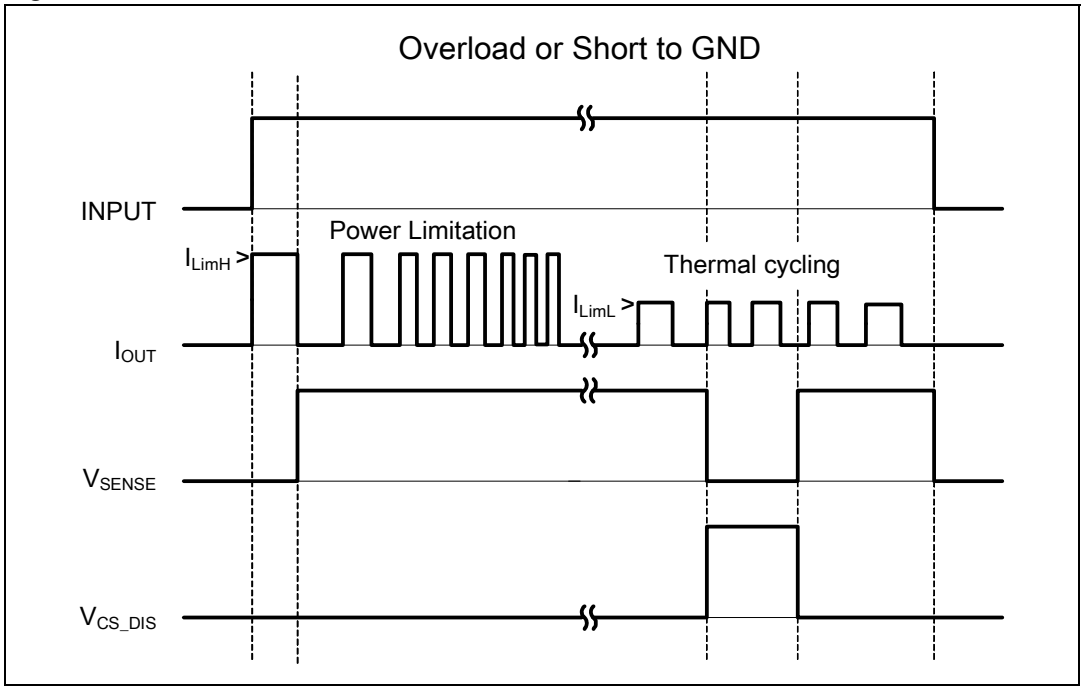


Figure 13. Intermittent Overload

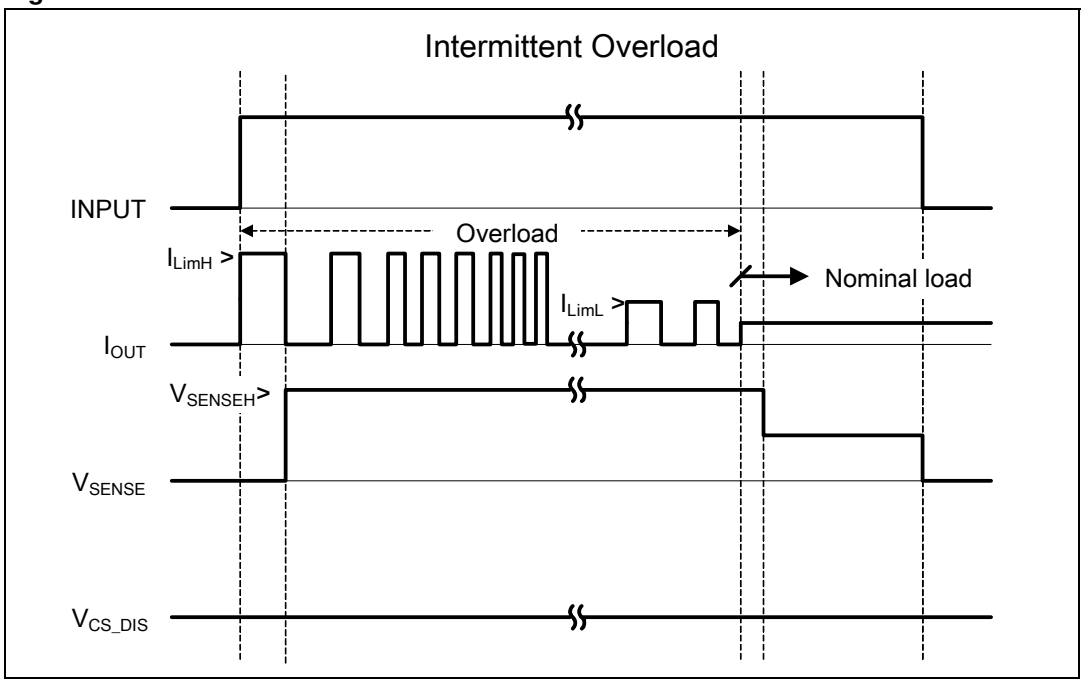


Figure 14. OFF-State Open Load with external circuitry

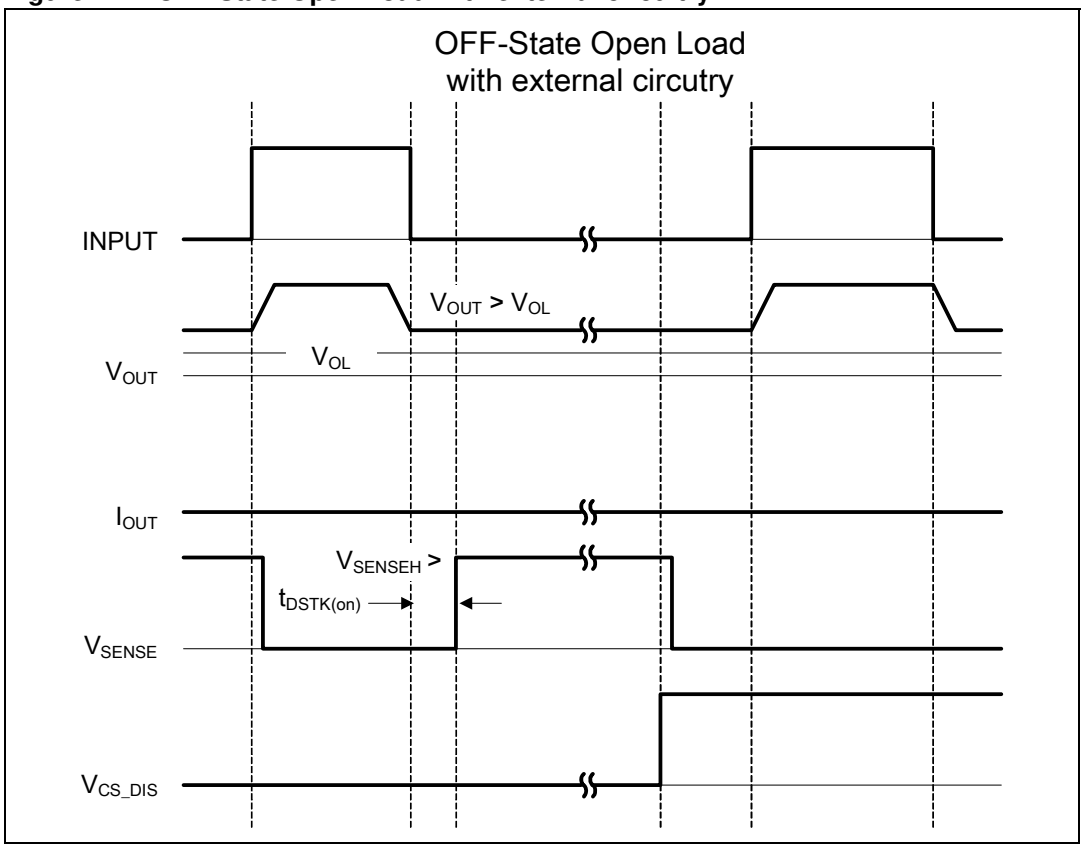


Figure 15. Short to V_{CC}

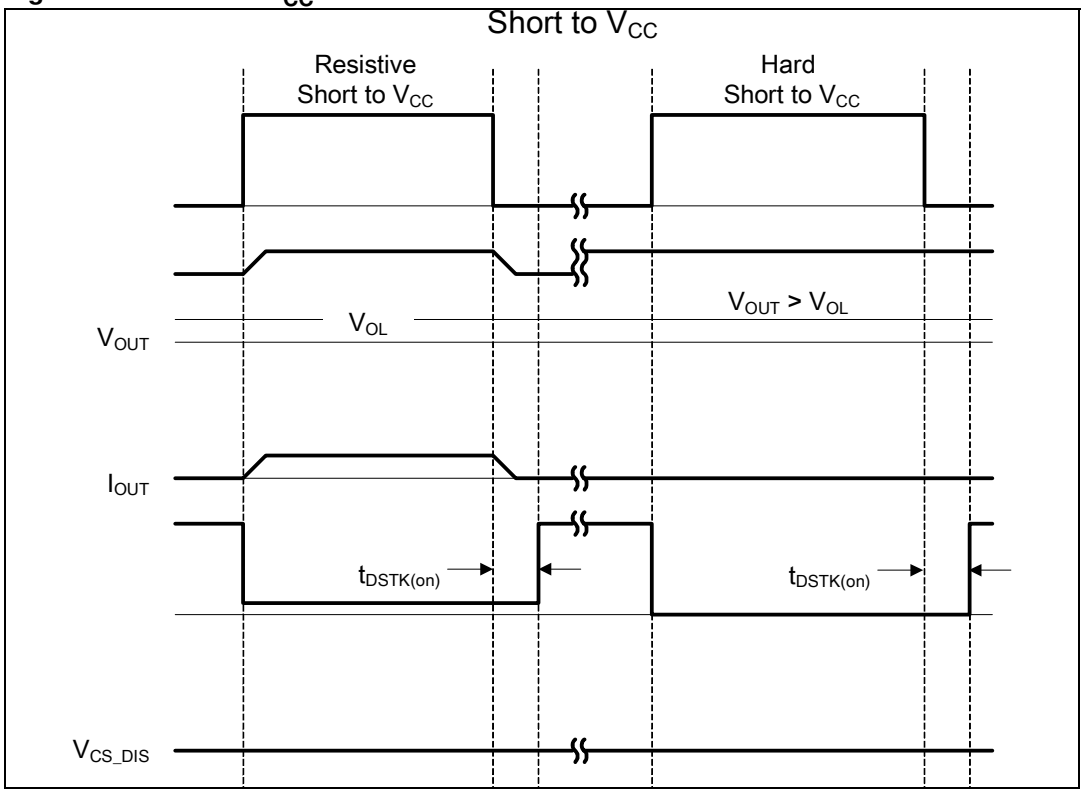
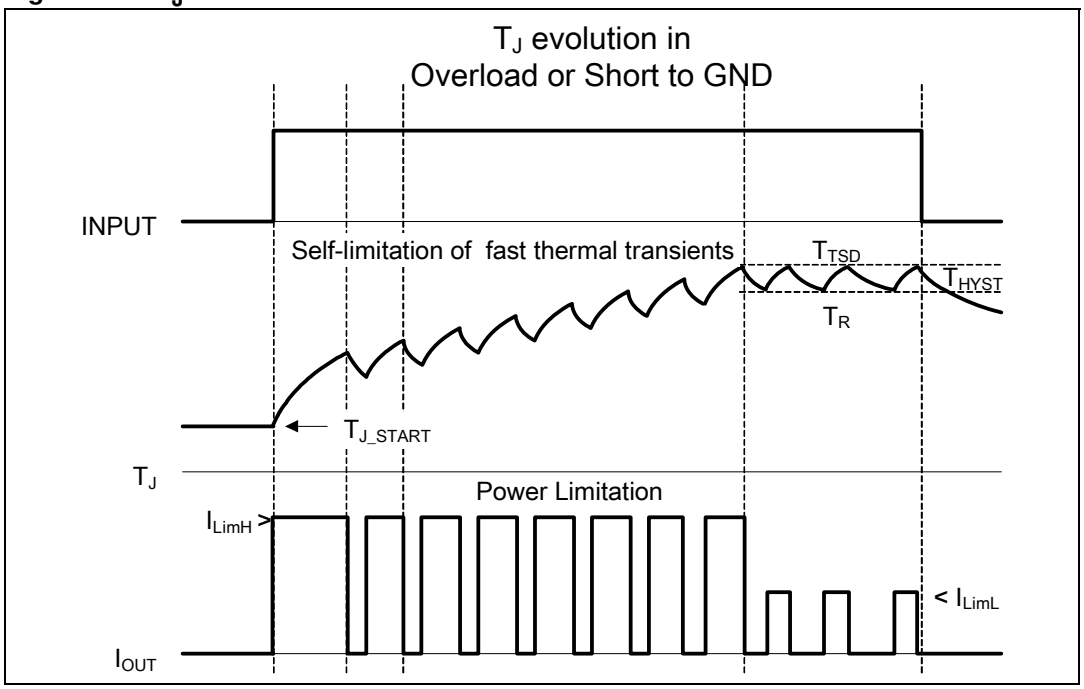


Figure 16. T_J evolution in Overload or Short to GND



2.5 Electrical characteristics curves

Figure 17. Off state output current

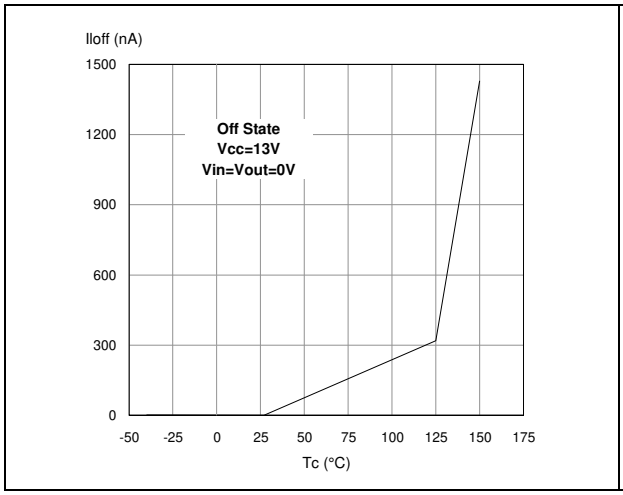


Figure 18. High level input current

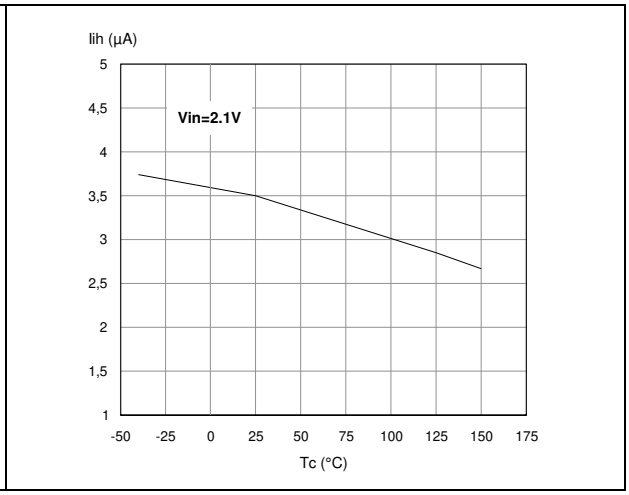


Figure 19. Input clamp level

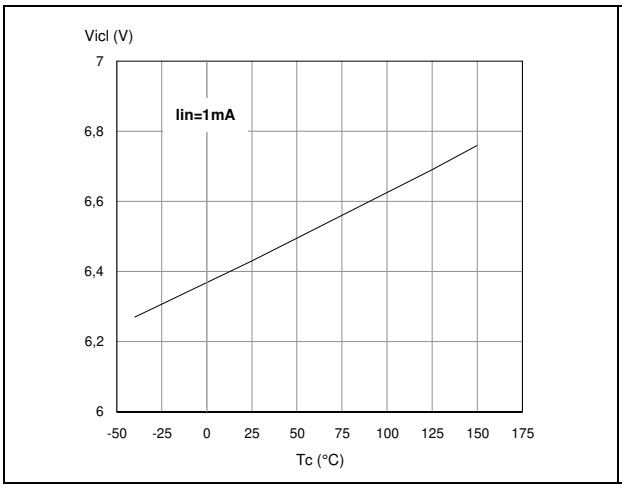


Figure 20. Input low level

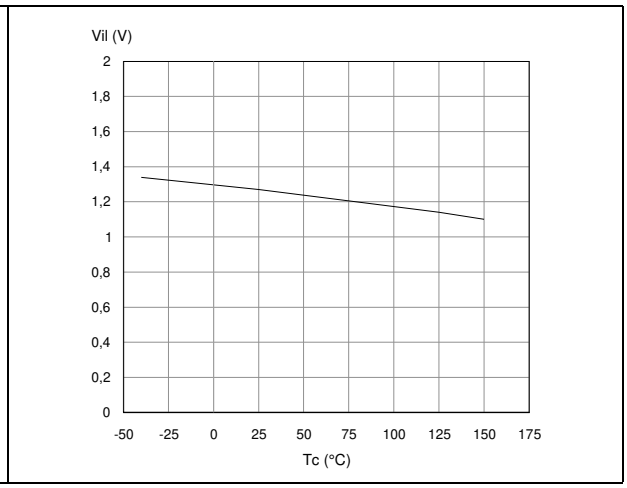


Figure 21. Input high level

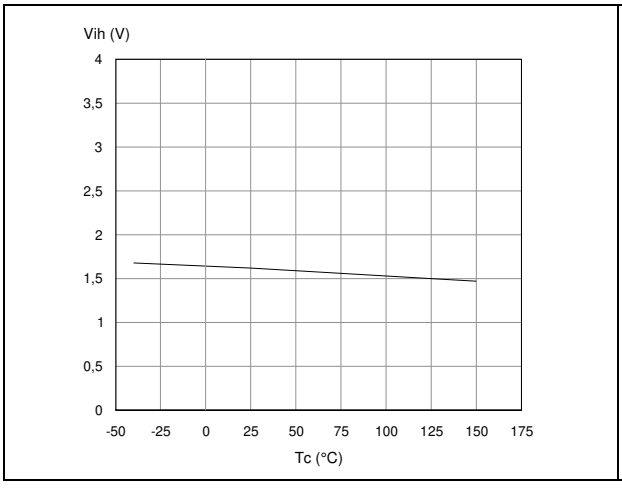


Figure 22. Input hysteresis voltage

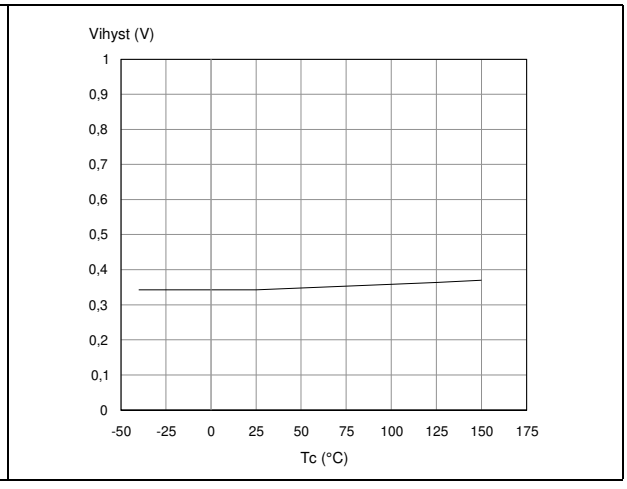


Figure 23. On state resistance vs T_{case}

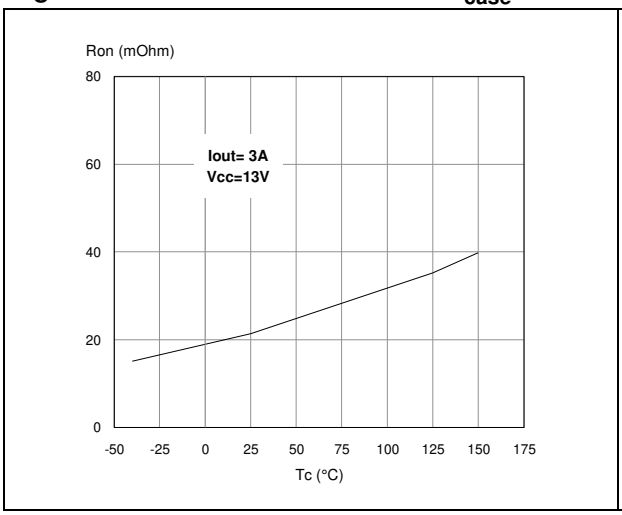


Figure 24. On state resistance vs V_{CC}

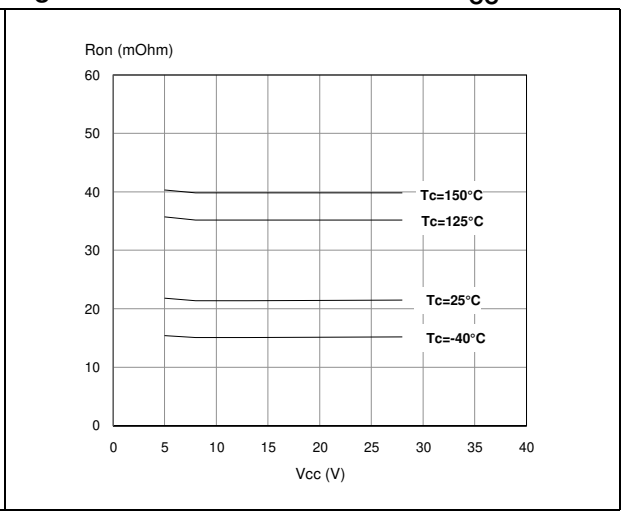


Figure 25. Undervoltage shutdown

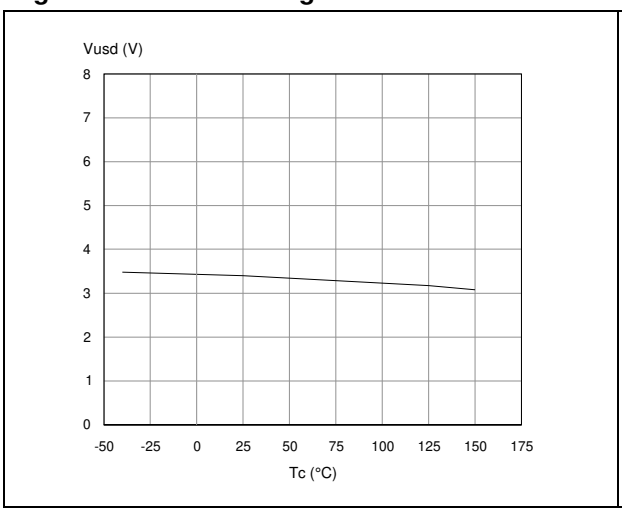


Figure 26. Turn-On voltage slope

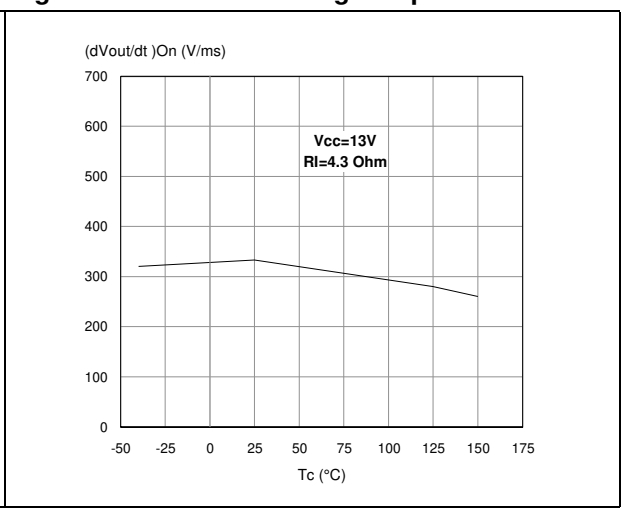


Figure 27. I_{LIMH} vs T_{case}

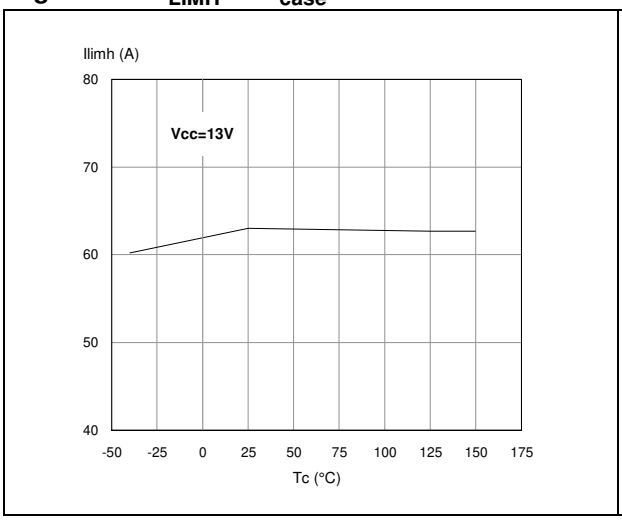


Figure 28. Turn-Off voltage slope

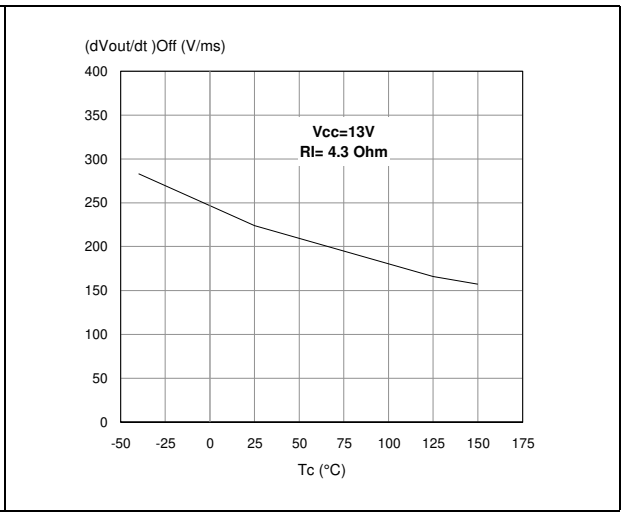


Figure 29. CS_DIS high level voltage

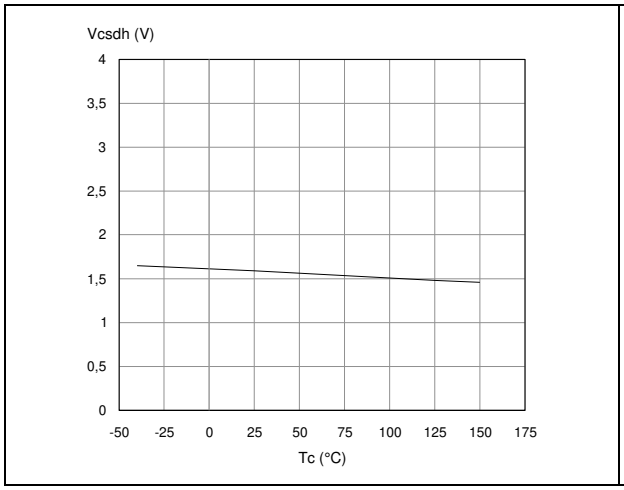


Figure 30. CS_DIS clamp voltage

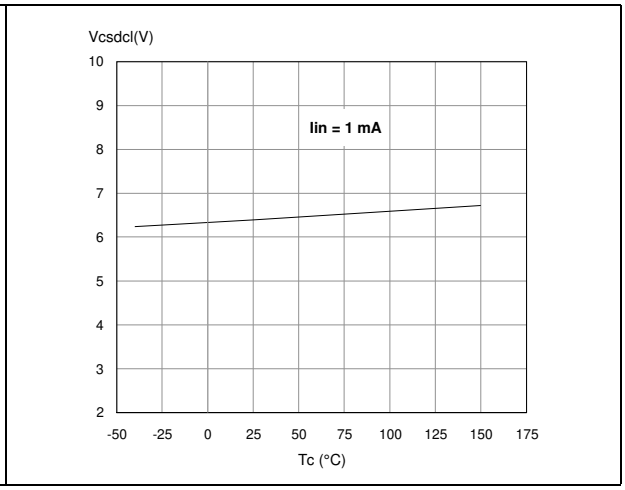
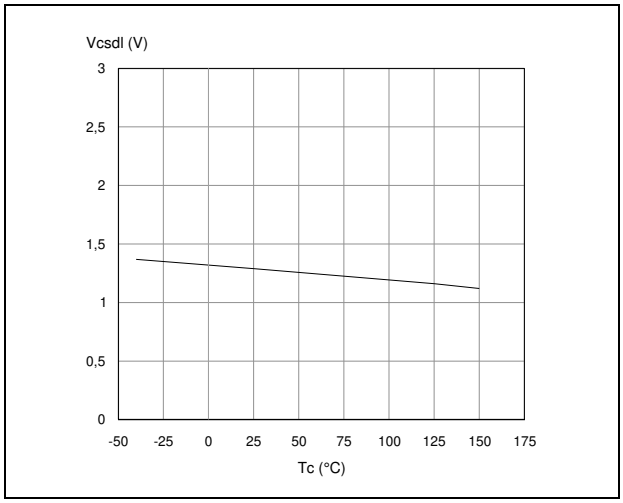
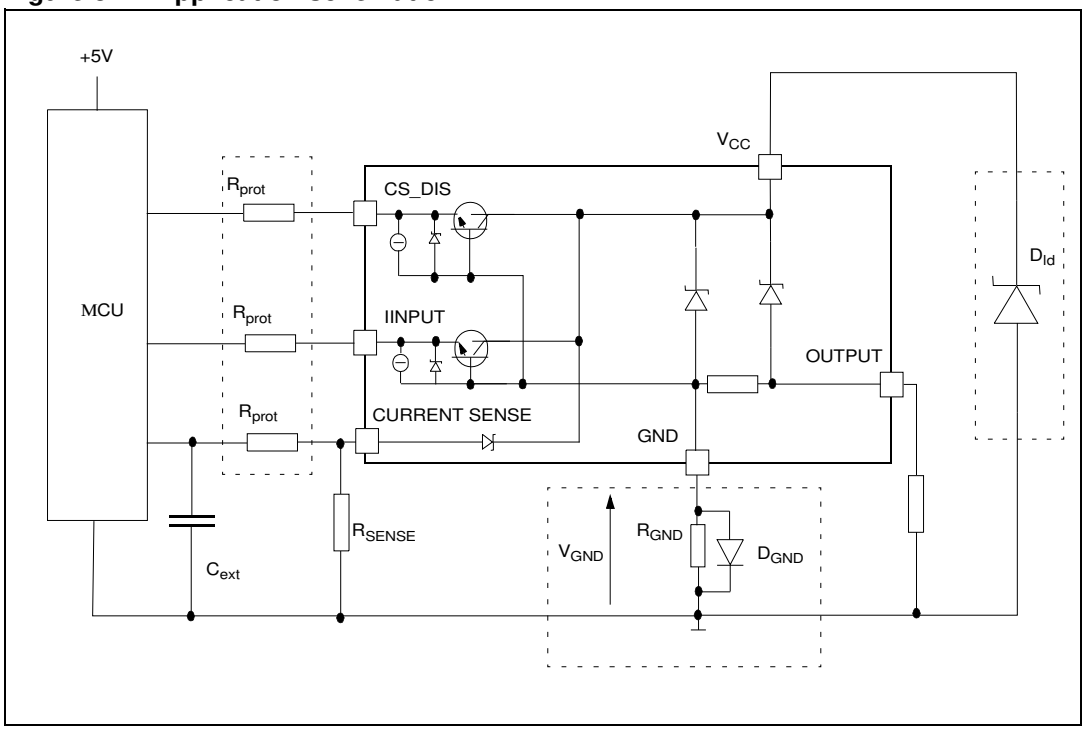


Figure 31. CS_DIS low level voltage



3 Application information

Figure 32. Application schematic



3.1 GND protection network against reverse battery

This section provides two solutions for implementing a ground 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 show how to dimension the R_{GND} resistor:

1. $R_{GND} \leq 600mV / (I_{S(on)max})$
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 requires the use of a large resistor, or several devices have to share the same resistor, then ST suggests using solution 2 below.

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

Note that a resistor (R_{GND}=1kΩ) 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.

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/O protection

If a ground protection network is used and negative transients 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 µC I/O pins from latching up.

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

5kΩ ≤ R_{prot} ≤ 180kΩ

Recommended values: R_{prot} =10kΩ, C_{EXT}=10nF.