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VN5E160AS-E

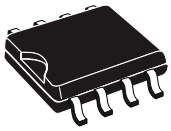
Single channel high side driver with analog for automotive applications

Features

Max supply voltage	V_{CC}	41 V
Operating voltage range	V_{CC}	4.5 V to 28 V
Max ON-state resistance (per ch.)	R_{ON}	160 mΩ
Current limitation (typ)	I_{LIMH}	10 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 standby current
  - 3.0 V CMOS compatible inputs
  - Optimized electromagnetic emission
  - 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-precision current sense for wide-range currents
  - Current sense disable
  - OFF-state open-load detection
  - Output short to V_{CC} detection
  - Overload and short to ground (power limitation) 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}
  - Overtemperature shutdown with autorestart (thermal shutdown)



  - Reverse battery protected
  - Electrostatic discharge protection

Application

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

Description

The VN5E160AS-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 VN5E160AS-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, overtemperature shut-off with auto-restart and overvoltage 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, overtemperature indication, short-circuit to V_{CC} diagnosis and ON & 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

List of tables

List of figures

1 Block diagram and pin configuration

Figure 1. Block diagram

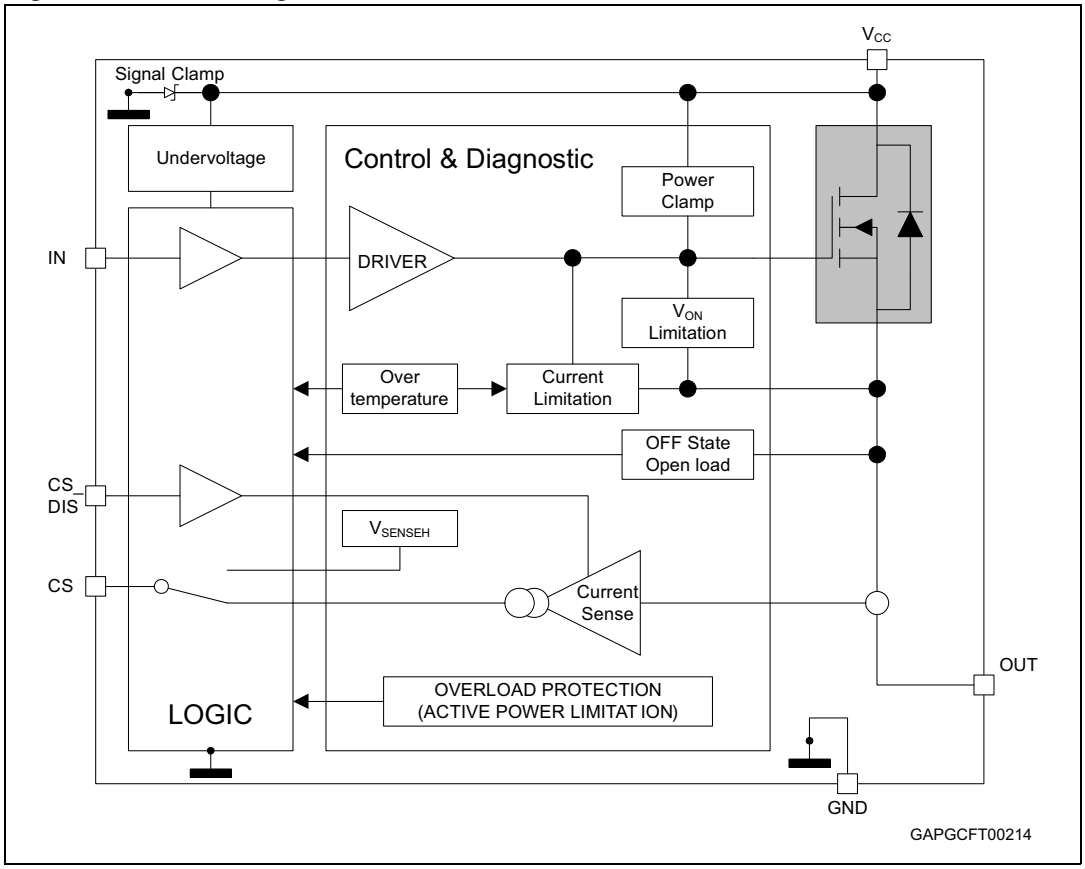


Table 1. Pin function

Name	Function
V_{CC}	Battery connection.
OUT	Power output.
GND	Ground connection. Must be reverse battery protected by an external diode/resistor network.
IN	Voltage-controlled input pin with hysteresis, CMOS compatible. Controls output switch state.
CS	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)

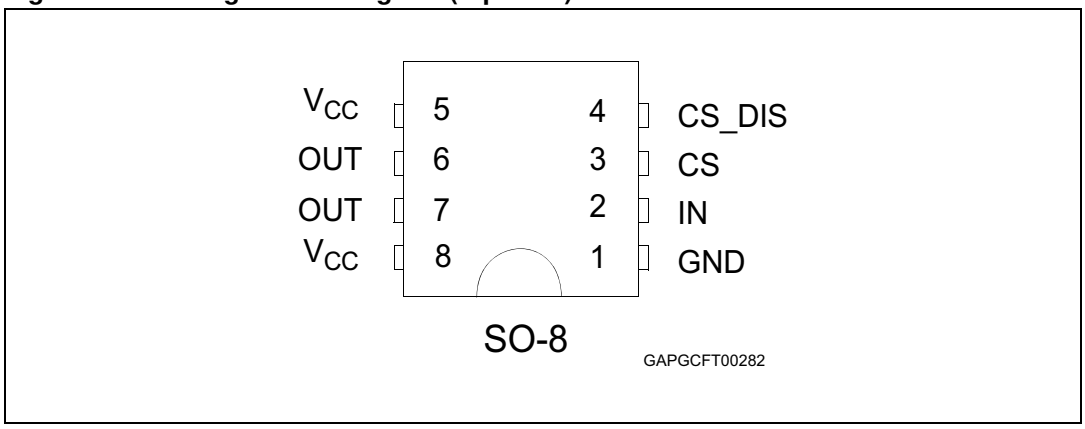
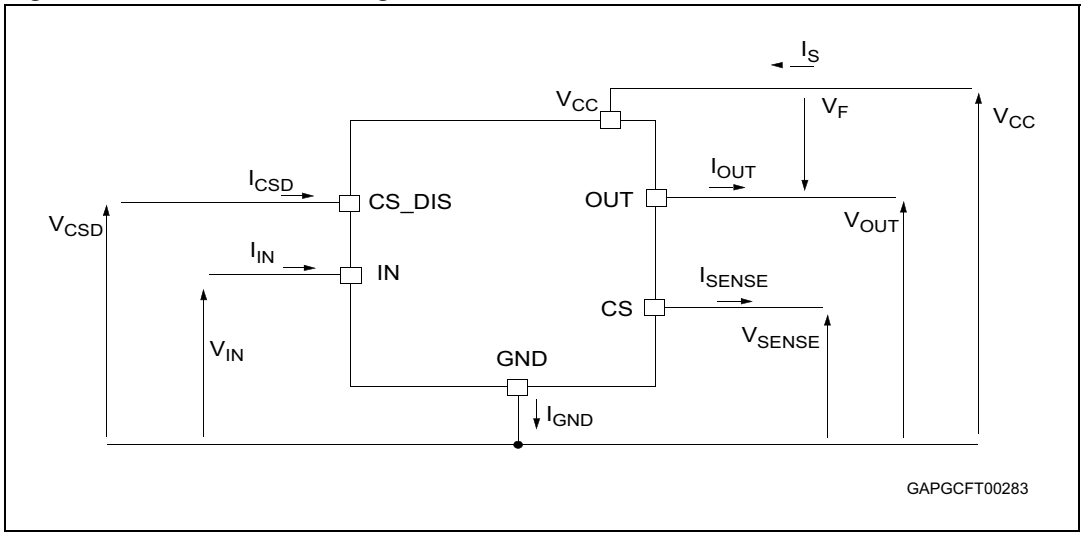


Table 2. Suggested connections for unused and not connected pins

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

2 Electrical specifications

Figure 3. Current and voltage conventions(1)



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

2.1 Absolute maximum ratings

Stressing the device above the ratings listed in the “absolute maximum ratings” 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 the “absolute maximum ratings” table for extended periods may affect device reliability. Refer also to the STMicroelectronics SURE program and other 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	-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

Table 3. Absolute maximum ratings (continued)

Symbol	Parameter	Value	Unit
E_{MAX}	Maximum switching energy (single pulse) (L = 8 mH; R_L = 0 Ω; V_{bat} = 13.5 V; T_{jstart} = 150 °C; I_{OUT} = I_{limL}*(Typ.)*)	36	mJ
V_{ESD}	Electrostatic discharge (human body model: R = 1.5 KΩ; C = 100 pF) – IN – CS – CS_DIS – OUT – 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
$R_{thj\text{-}pins}$	Thermal resistance junction-pins	30	°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 8 V < V_{CC} < 28 V; -40 °C < Tj < 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 shut-down			3.5	4.5	V
$V_{USDhyst}$	Undervoltage shut-down hysteresis			0.5		V
R_{ON}	ON-state resistance	I_{OUT} = 1 A, T_j = 25 °C			160	mΩ
		I_{OUT} = 1 A, T_j = 150 °C			320	
		I_{OUT} = 1 A, V_{CC} = 5 V, T_j = 25 °C			210	
V_{clamp}	Voltage clamp	I_S = 20 mA	41	46	52	V
I_S	Supply current	OFF-state: V_{CC} = 13 V, V_{IN} = V_{OUT} = 0 V, T_j = 25 °C		2(1)	5(1)	µA
		ON-state: V_{IN} = 5 V, V_{CC} = 13 V, I_{OUT} = 0 A		1.9	3.5	mA
$I_{L(off1)}$	OFF-state output current	V_{IN} = V_{OUT} = 0 V, V_{CC} = 13 V, T_j = 25 °C	0	0.01	3	µA
		V_{IN} = V_{OUT} = 0 V, V_{CC} = 13 V, T_j = 125 °C	0		5	
V_F	Output - V_{CC} diode voltage	-I_{OUT} = 1 A, T_j = 150 °C			0.7	V

1. PowerMOS leakage included.

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

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	R_L = 13 Ω (see *Figure 6*)	—	10	—	µs
$t_{d(off)}$	Turn-off delay time	R_L = 13 Ω (see *Figure 6*)	—	10	—	µs
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	R_L = 13 Ω	—	See *Figure 26*	—	V/µs
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	R_L = 13 Ω	—	See *Figure 28*	—	V/µs
W_{ON}	Switching energy losses during t_{won}	R_L = 13 Ω (see *Figure 6*)	—	0.05	—	mJ
W_{OFF}	Switching energy losses during t_{woff}	R_L = 13 Ω (see *Figure 6*)	—	0.03	—	mJ

Table 7. Logic inputs

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

Table 8. Protection and diagnostics(1)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{limH}	DC short-circuit current	V_{CC} = 13 V	7	10	14	A
		5 V < V_{CC} < 28 V			14	A
I_{limL}	Short-circuit current during thermal cycling	V_{CC} = 13 V $T_R < T_j < T_{TSD}$		2.5		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} = 1 A, V_{IN} = 0, L = 20 mH	V_{CC} - 41	V_{CC} - 46	V_{CC} - 52	V
V_{ON}	Output voltage drop limitation	I_{OUT} = 0.03 A (see *Figure 8*) T_j = -40 °C to +150 °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. Current sense (8 V < V_{CC} < 18 V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
K_0	I_{OUT}/I_{SENSE}	I_{OUT} = 0.025 A, V_{SENSE} = 0.5 V T_j = -40 °C to 150 °C	265	490	715	
K_1	I_{OUT}/I_{SENSE}	I_{OUT} = 0.35 A, V_{SENSE} = 0.5 V T_j = -40 °C to 150 °C T_j = 25 °C to 150 °C	355 385	465 465	575 545	
dK_1/K_1 (1)	Current sense ratio drift	I_{OUT} =0.35 A, V_{SENSE} = 0.5 V T_j = -40 °C to 150 °C	-11		+11	%
K_2	I_{OUT}/I_{SENSE}	I_{OUT} = 0.5 A, V_{SENSE} = 4 V T_j = -40 °C to 150 °C T_j = 25 °C to 150 °C	380 400	455 455	530 510	
dK_2/K_2 (1)	Current sense ratio drift	I_{OUT} = 0.5 A; T_j = -40 °C to 150 °C	-8		+8	%
K_3	I_{OUT}/I_{SENSE}	I_{OUT} = 1.5 A, V_{SENSE} = 4 V T_j = -40 °C to 150 °C T_j = 25 °C to 150 °C	420 420	455 455	490 480	
dK_3/K_3 (1)	Current sense ratio drift	I_{OUT} = 1.5 A; T_j = -40 °C to 150 °C	-4		+4	%
I_{SENSE0}	Analog sense leakage current	I_{OUT} = 0 A, V_{SENSE} = 0 V, V_{CSD} = 5 V, V_{IN} = 0 V, T_j = -40 °C to 150 °C	0		1	µA
		I_{OUT} = 0 A, V_{SENSE} = 0 V, V_{CSD} = 0 V, V_{IN} = 5 V, T_j = -40 °C to 150 °C	0		2	
		I_{OUT} = 1 A, V_{SENSE} = 0 V, V_{CSD} = 5 V, V_{IN} = 5 V, T_j = -40 °C to 150 °C	0		1	
V_{SENSE}	Max analog sense output voltage	R_{SENSE} = 10 KΩ I_{OUT} = 1 A;	5			V
V_{SENSEH} (2)	Analog sense output voltage in fault condition	V_{CC} = 13 V, R_{SENSE} = 3.9 KΩ		8		V
I_{SENSEH} (2)	Analog sense output current in fault condition	V_{CC} = 13 V, V_{SENSE} = 5 V		9		mA
$t_{DSENSE1H}$	Delay response time from falling edge of CS_DIS pin	V_{SENSE} < 4 V, 0.025 A < I_{OUT} < 1.5 A 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} < 4 V, 0.025 A < I_{OUT} < 1.5 A I_{SENSE} = 10% of $I_{SENSE\ max}$ (see *Figure 4*)		5	20	µs

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

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{DSENSE2H}$	Delay response time from rising edge of IN pin	V_{SENSE} < 4 V, 0.025 A < I_{OUT} < 1.5 A I_{SENSE}=90% of $I_{SENSE\ max}$ (see *Figure 4*)		30	160	µs
$\Delta t_{DSENSE2H}$	Delay response time between rising edge of output current and rising edge of current sense	V_{SENSE} < 4 V, I_{SENSE} = 90% of $I_{SENSEMAX}$, I_{OUT} = 90% of I_{OUTMAX} I_{OUTMAX}=1.5A (see *Figure 7*)			110	µs
$t_{DSENSE2L}$	Delay response time from falling edge of IN pin	V_{SENSE} < 4 V, 0.025 A < I_{OUT} < 1.5 A I_{SENSE}=10% of $I_{SENSE\ max}$ (see *Figure 4*)		80	250	µs

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 (8 V < V_{CC} < 18 V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{OL}	OFF-state open-load voltage detection threshold	V_{IN} = 0 V, 8 V < V_{CC} < 18 V	2		4	V
I_{OL}	ON-state open-load current detection threshold	V_{IN} = 5V, 8 V < V_{CC} < 18 V I_{SENSE} = 5 µA	0.5		5	mA
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} = 4 V	V_{IN} = 0 V, V_{SENSE} = 0 V V_{OUT} rising from 0 V to 4 V	-120		0	µA
$I_{L(off2)f}$	OFF-state output current at V_{OUT} = 2 V	V_{IN} = 0 V, V_{SENSE} = V_{SENSEH} V_{OUT} falling from V_{CC} to 2 V	-50		90	
td_vol	Delay response from output rising edge to V_{SENSE} rising edge in open-load	V_{OUT} = 4 V, V_{IN} = 0 V V_{SENSE}= 90% of V_{SENSEH}			20	µs

Figure 4. Current sense delay characteristics

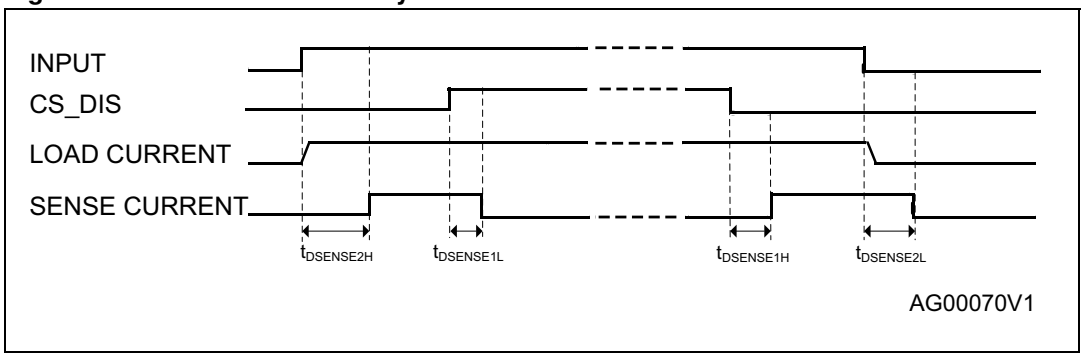


Figure 5. OFF-state open-load delay timing

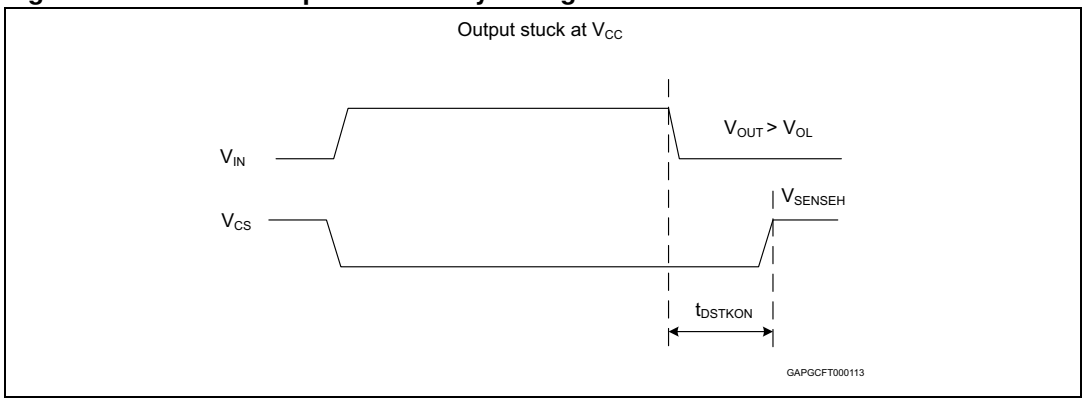


Figure 6. Switching characteristics

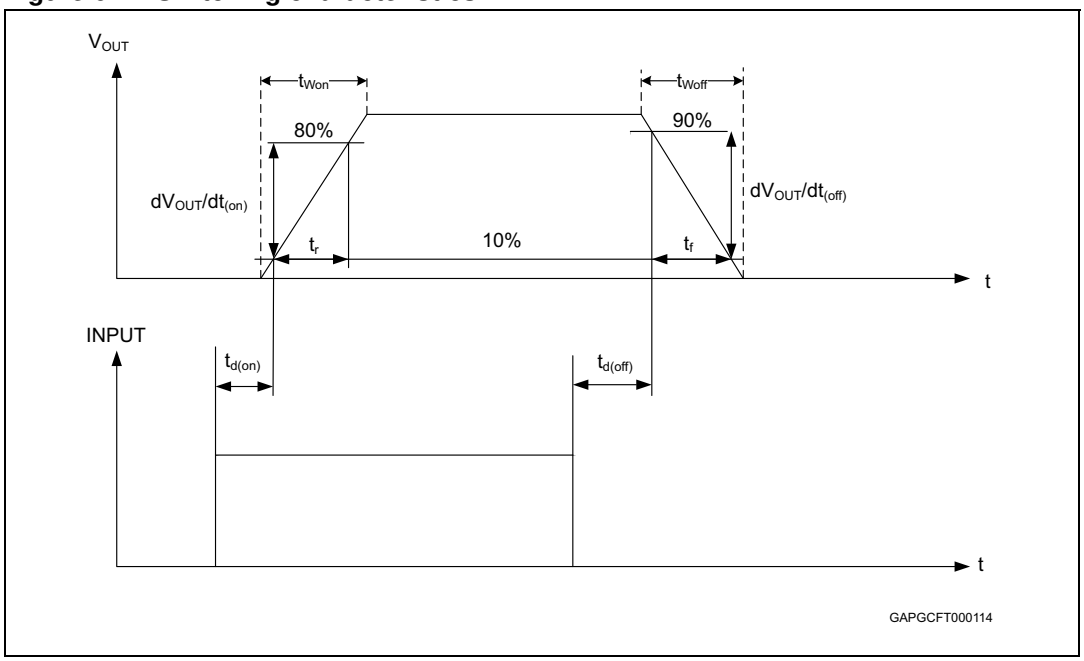


Figure 7. Delay response time between rising edge of ouput current and rising edge of current sense (CS enabled)

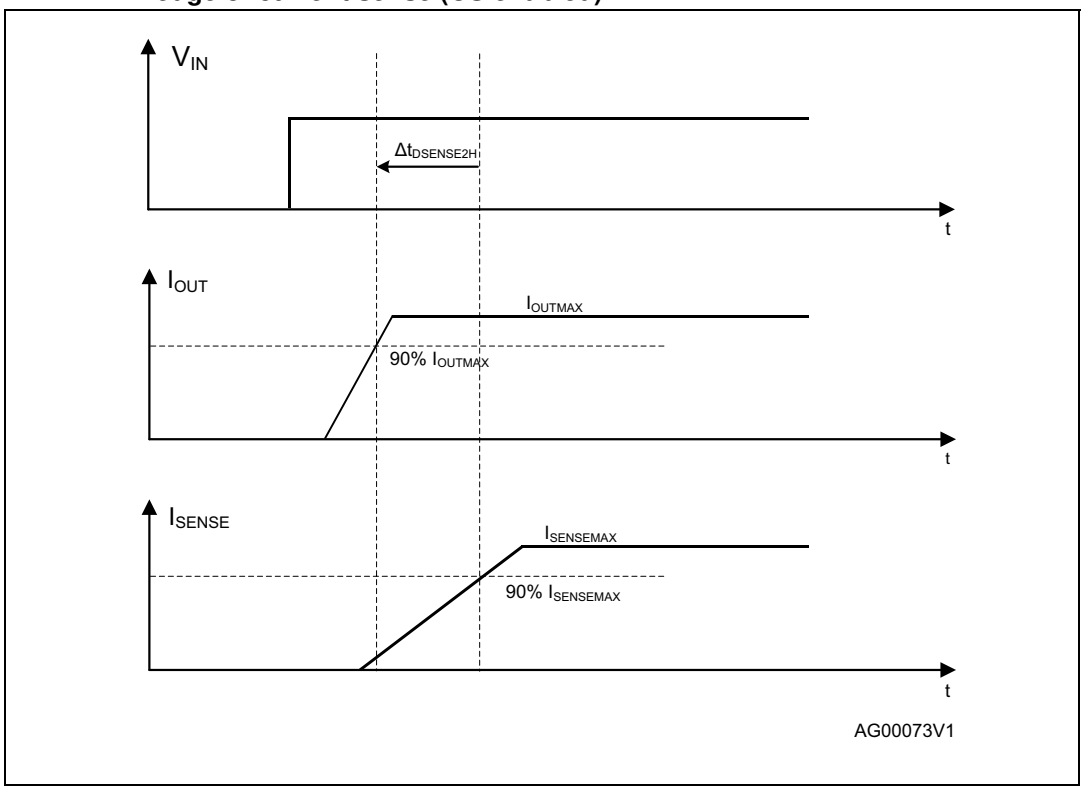


Figure 8. Output voltage drop limitation

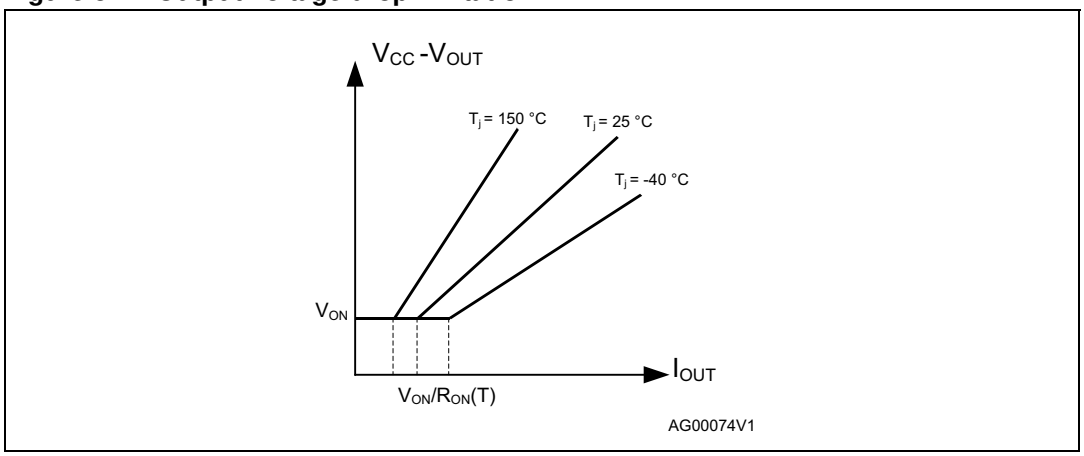
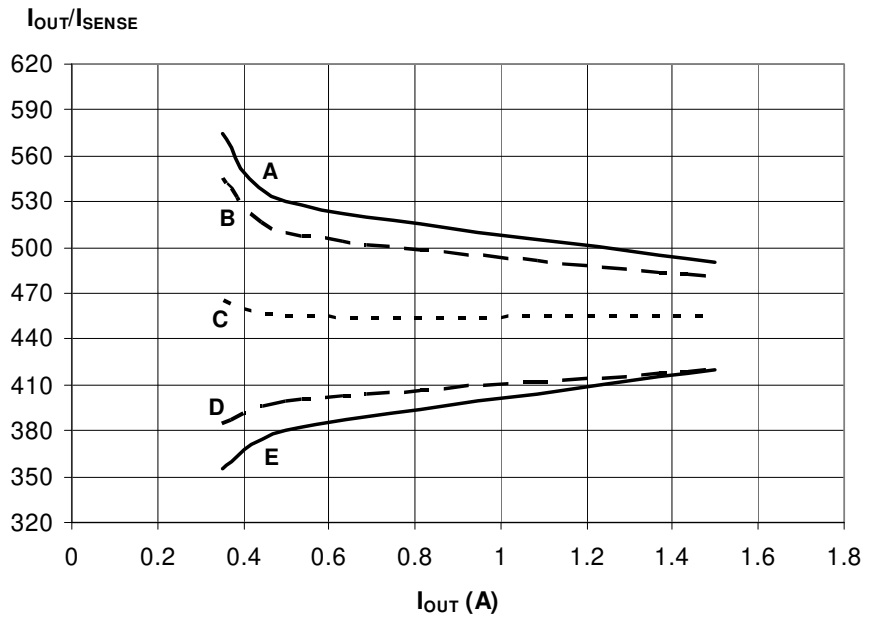
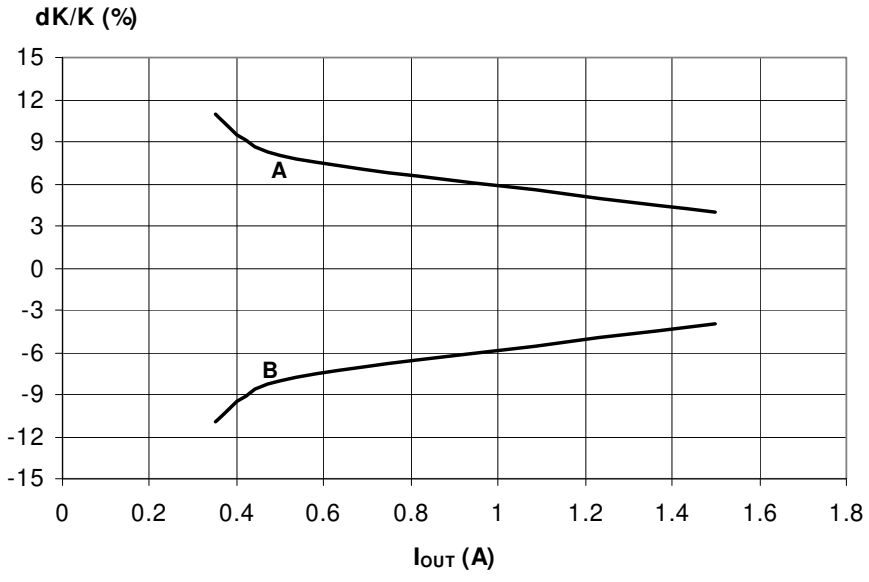


Figure 9. I_{OUT}/I_{SENSE} vs I_{OUT}



A: Max, T_j = -40 °C to 150 °C
B: Max, T_j = 25 °C to 150 °C
C: Typical, T_j = -40 °C to 150 °C
D: Min, T_j = 25 °C to 150 °C
E: Min, T_j = -40 °C to 150 °C

Figure 10. Maximum current sense ratio drift vs load current(1)



A: Max, T_j = -40 °C to 150 °C
B: Min, T_j = 25 °C to 150 °C

1. Parameter guaranteed by design; it is not tested.

Table 11. Truth table

Conditions	IN	OUT	SENSE (V_{CSD} = 0 V)(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}
OFF-state open-load (with external pull-up)	L	H	V_{SENSEH}

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 (part 1)

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				
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(2)	+65 V	+87 V	1 pulse			400 ms, 2 Ω

Table 13. Electrical transient requirements (part 2)

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

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

Table 14. Electrical transient requirements (part 3)

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.

2.4 Waveforms

Figure 11. Normal operation

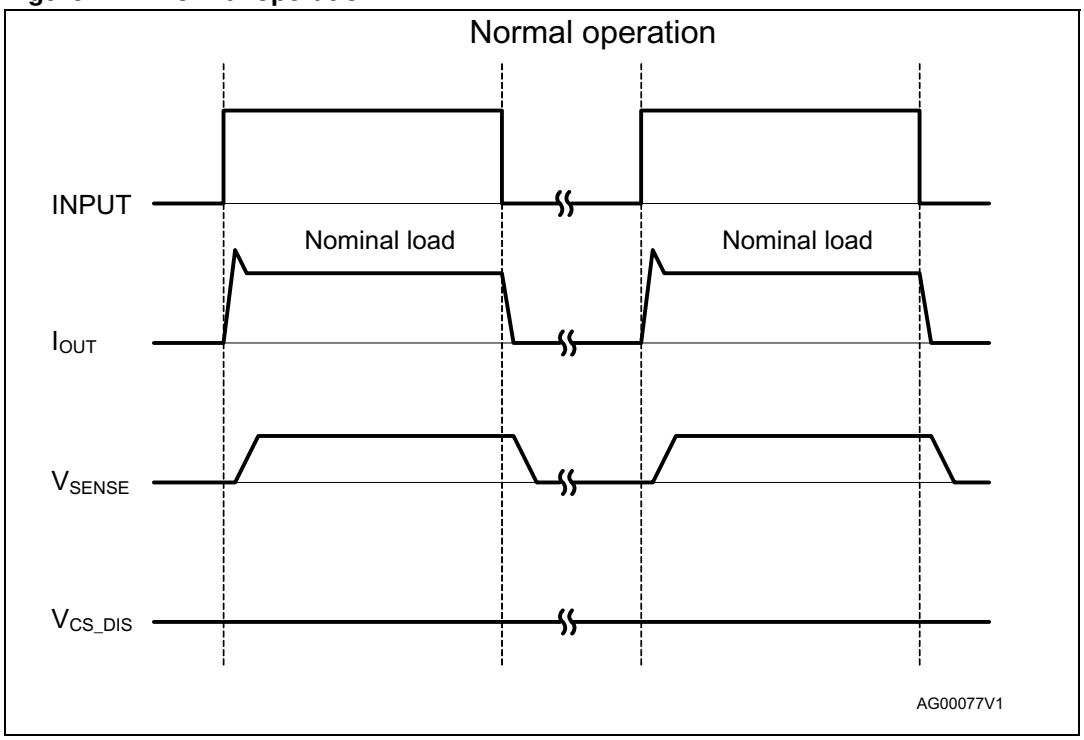


Figure 12. Overload or short to GND

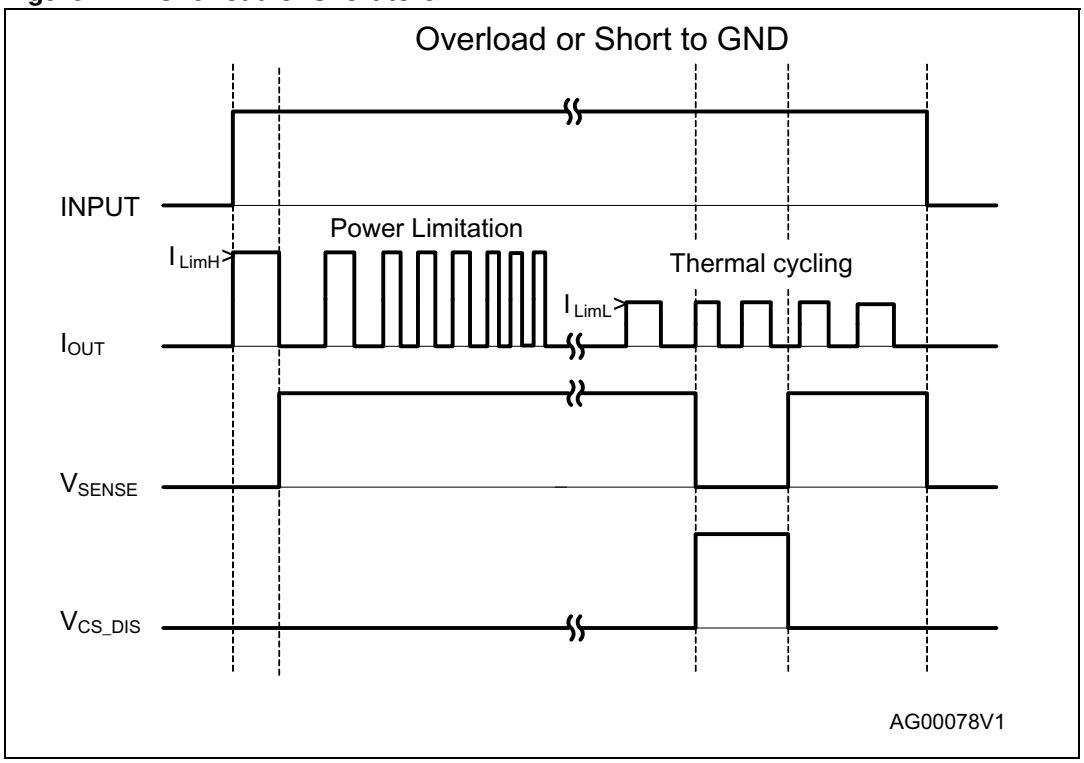


Figure 13. Intermittent overload

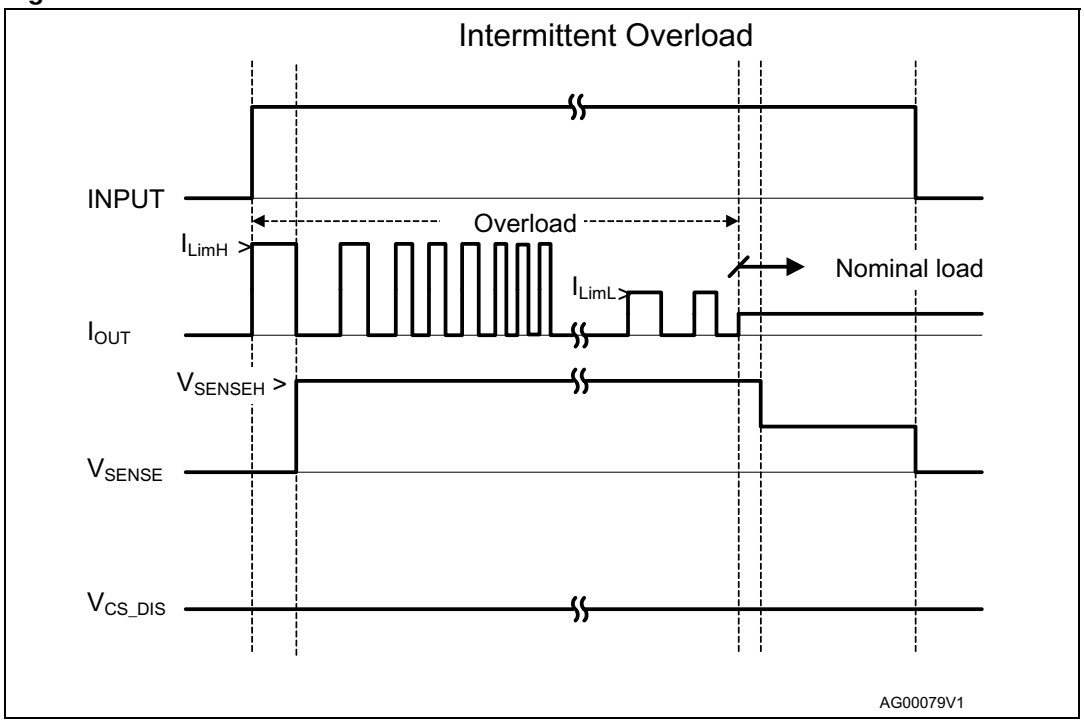


Figure 14. OFF-state open-load with external circuitry

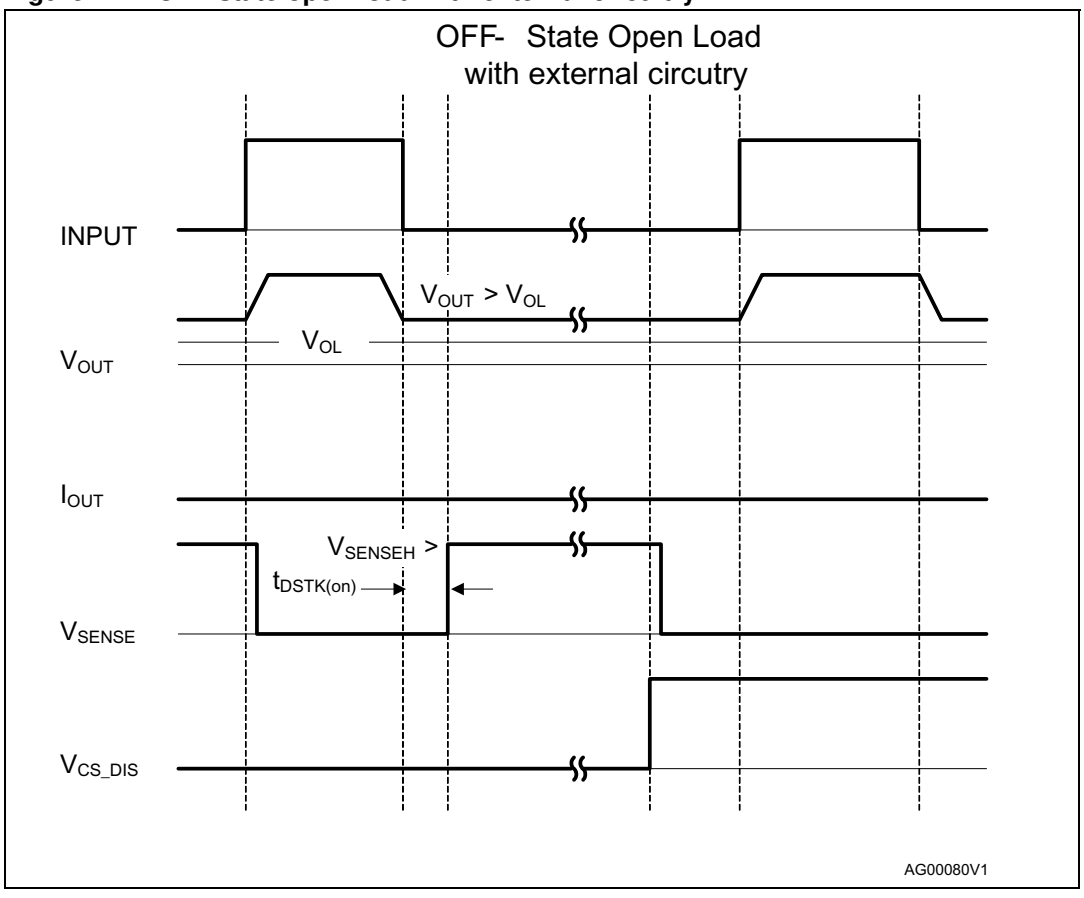


Figure 15. Short to V_{CC}

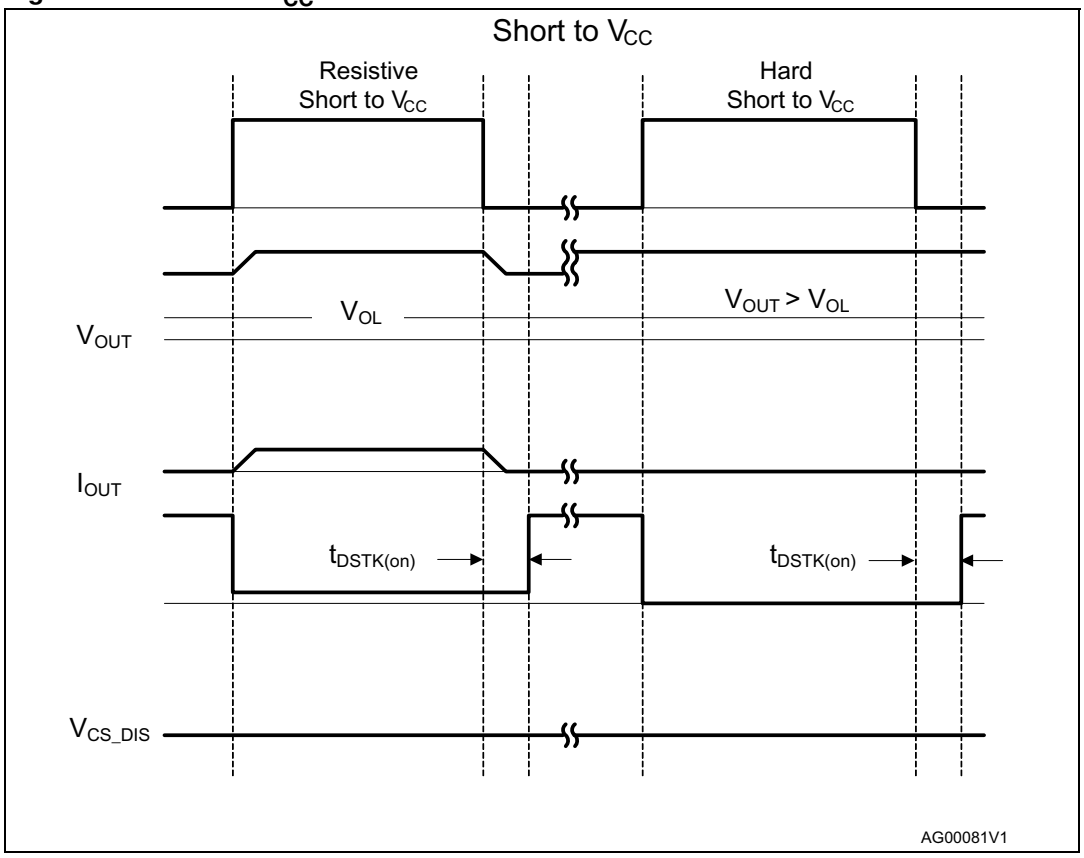
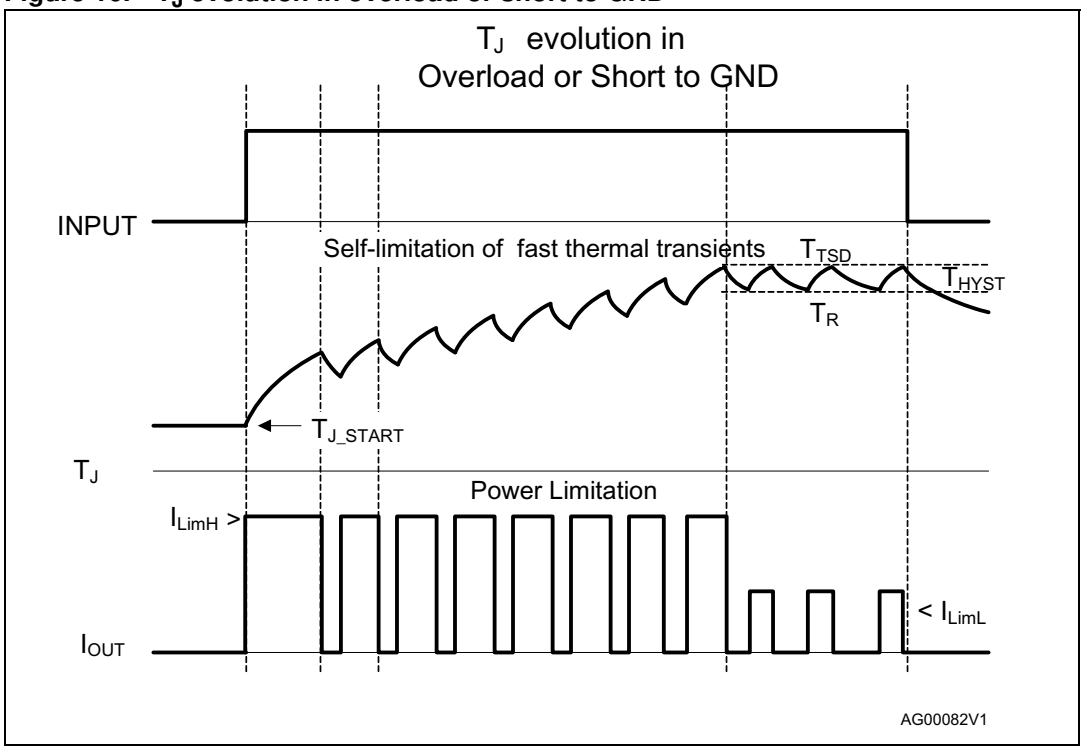


Figure 16. T_J evolution in overload or short to GND



2.5 Electrical characteristics curves

Figure 17. OFF-state output current

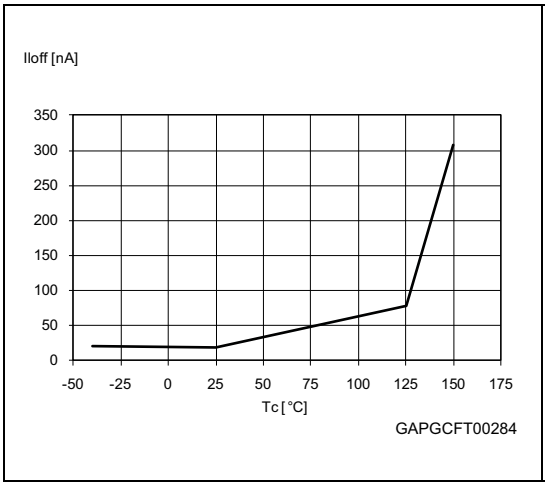


Figure 18. High-level input current

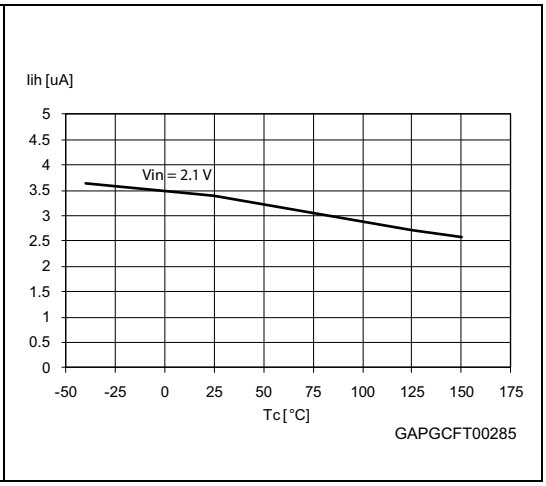


Figure 19. Input voltage clamp

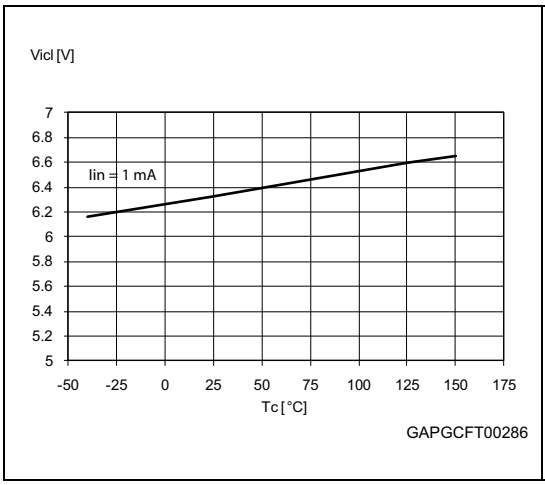


Figure 20. Low-level input voltage

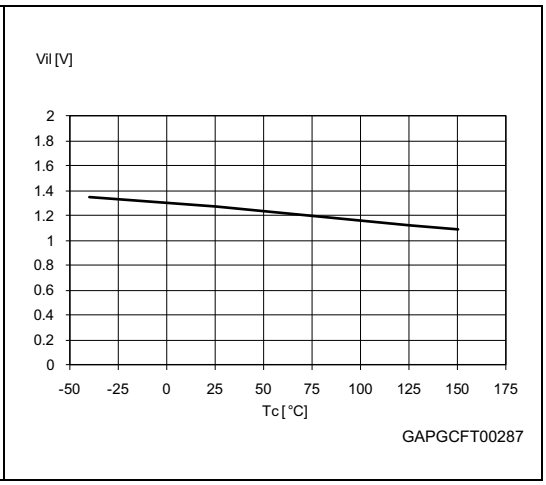


Figure 21. High-level input voltage

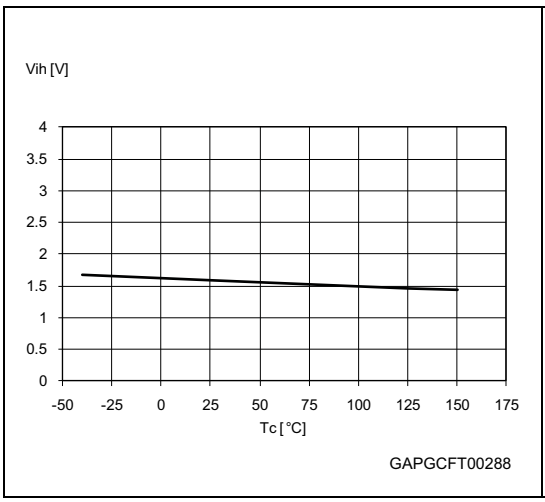


Figure 22. Hysteresis input voltage

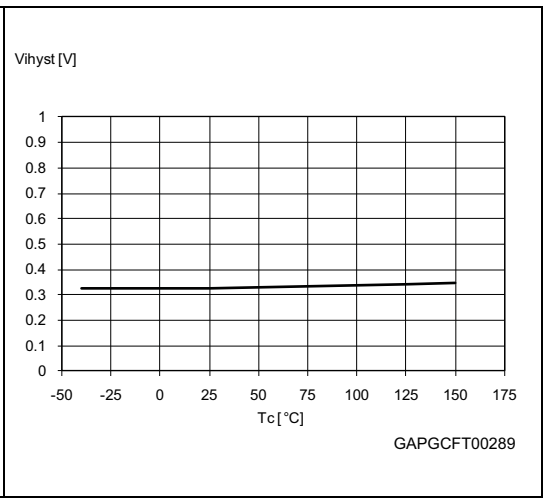


Figure 23. ON-state resistance vs. T_{case}

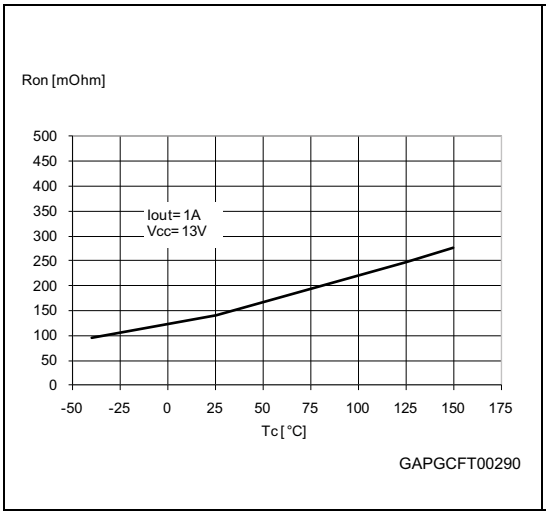


Figure 24. ON-state resistance vs. V_{CC}

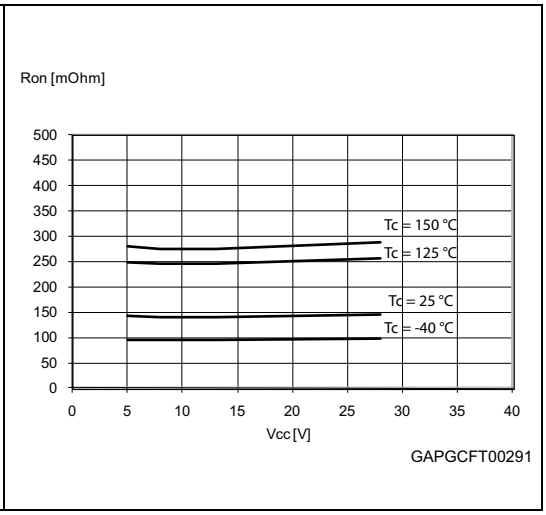


Figure 25. Undervoltage shutdown

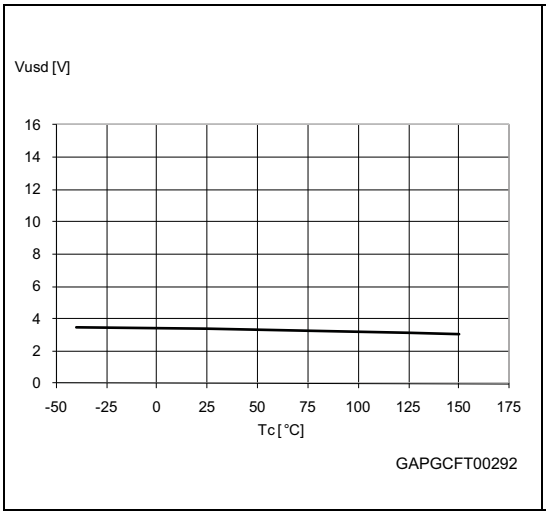


Figure 26. Turn-on voltage slope

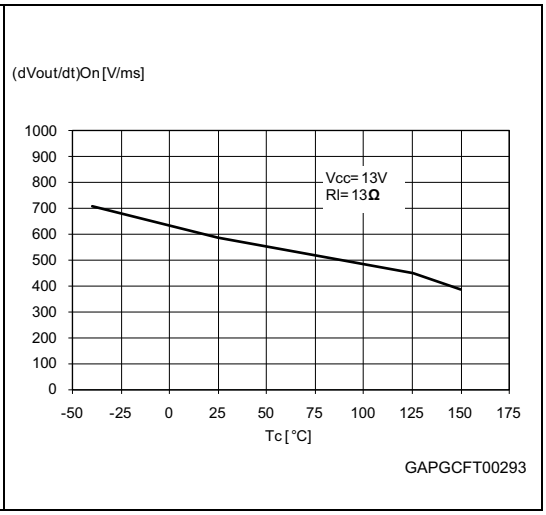


Figure 27. I_{LIMH} vs. T_{case}

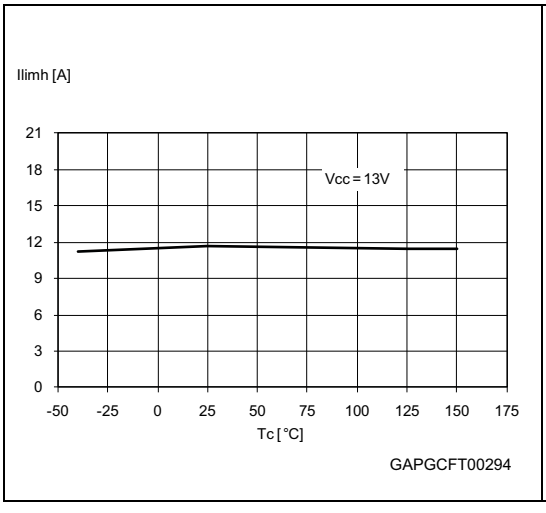


Figure 28. Turn-off voltage slope

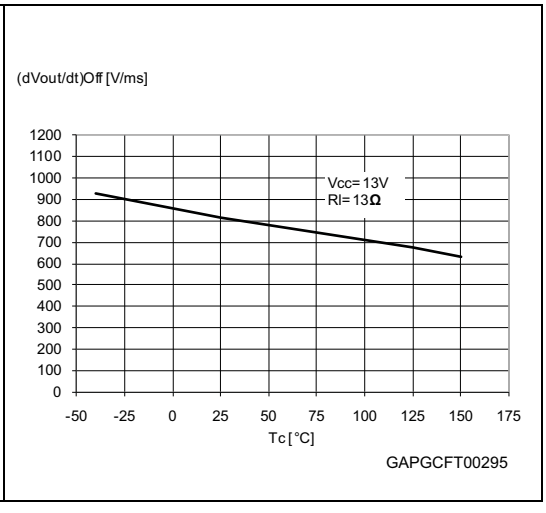


Figure 29. High-level CS_DIS voltage

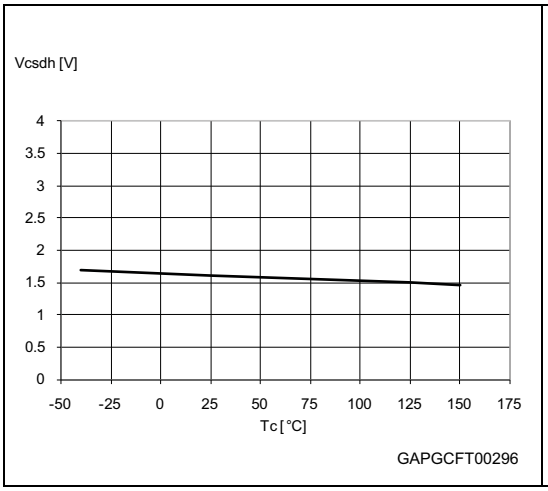


Figure 30. CS_DIS voltage clamp

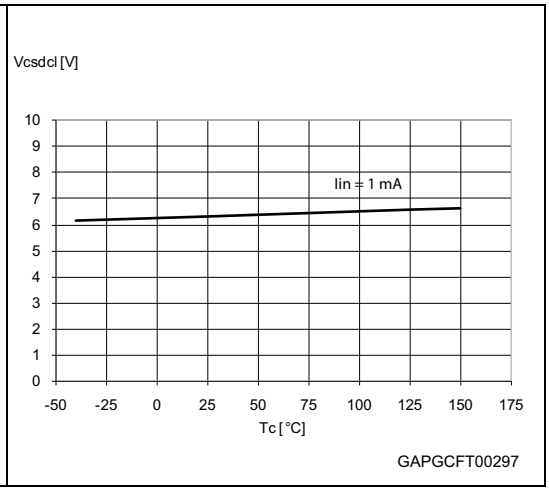
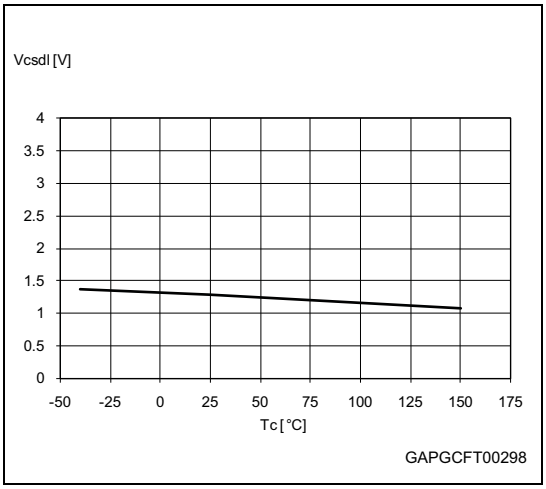
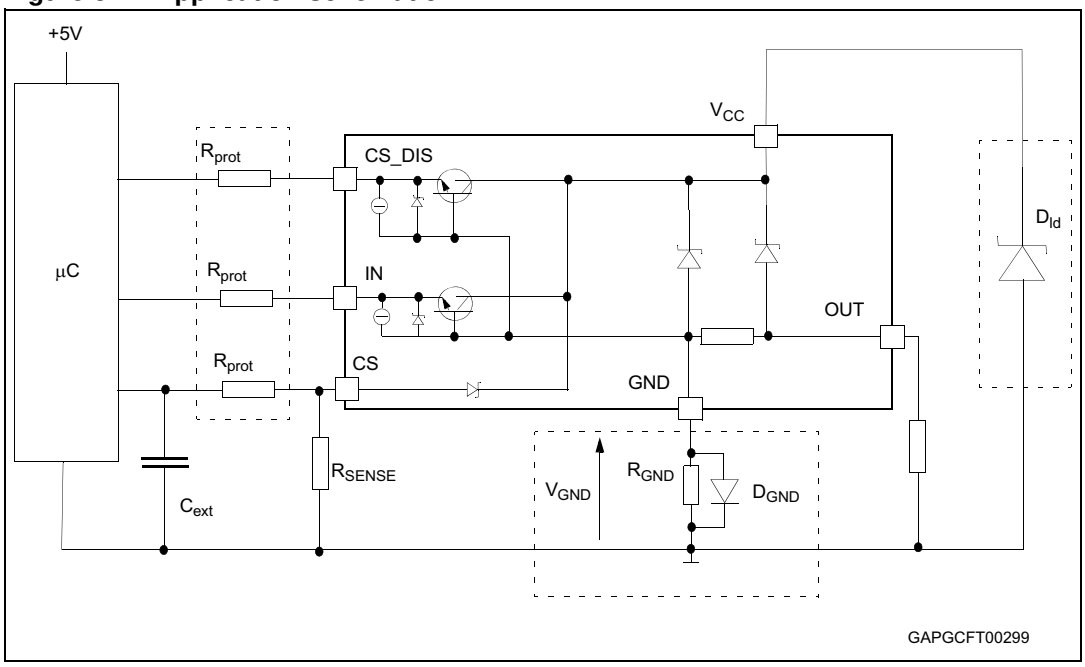


Figure 31. Low-level CS_DIS voltage



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_{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:

Equation 1

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

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 *Section 3.1.2: Solution 2: a diode (DGND) in the ground line*).

3.1.2 Solution 2: a 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 (≈600 mV) 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 T/R 7637/1 table.

3.3 MCU I/Os protection

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

Equation 2

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

Calculation example:

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

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

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