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1 Block diagram and pin configuration

Figure 1. Block diagram

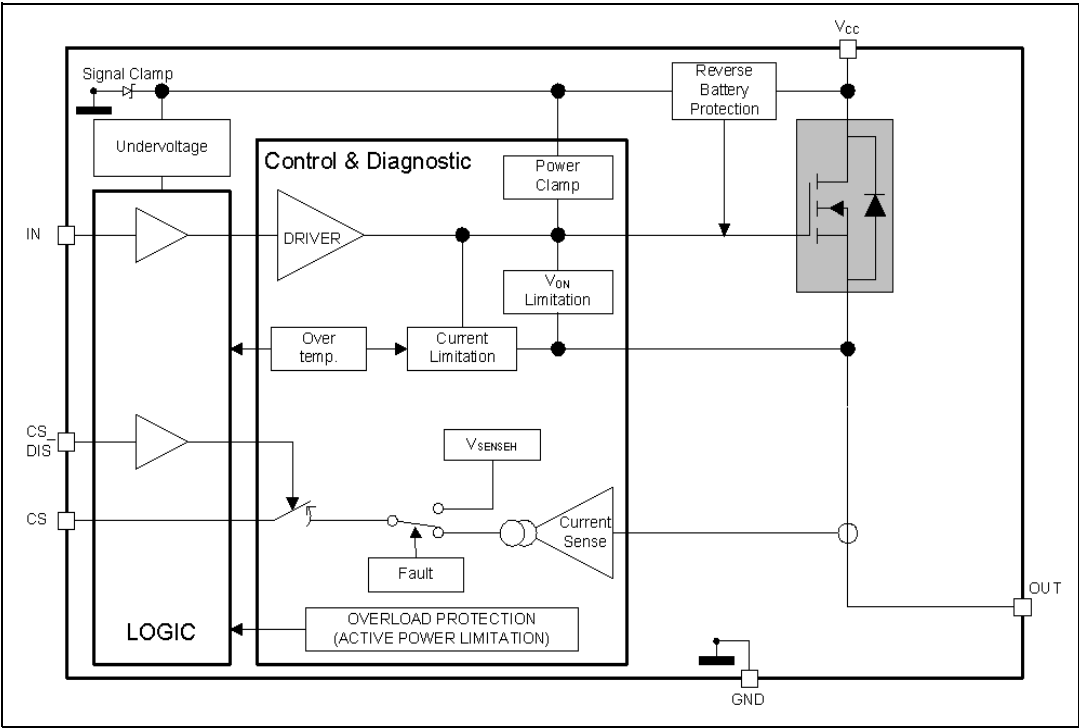


Table 1. Pin functions

Name	Function
V _{CC}	Battery connection
OUT	Power output ⁽¹⁾
GND	Ground connection
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

1. Pins 1 and 7 must be externally tied together.

Figure 2. Configuration diagram (top view) not in scale

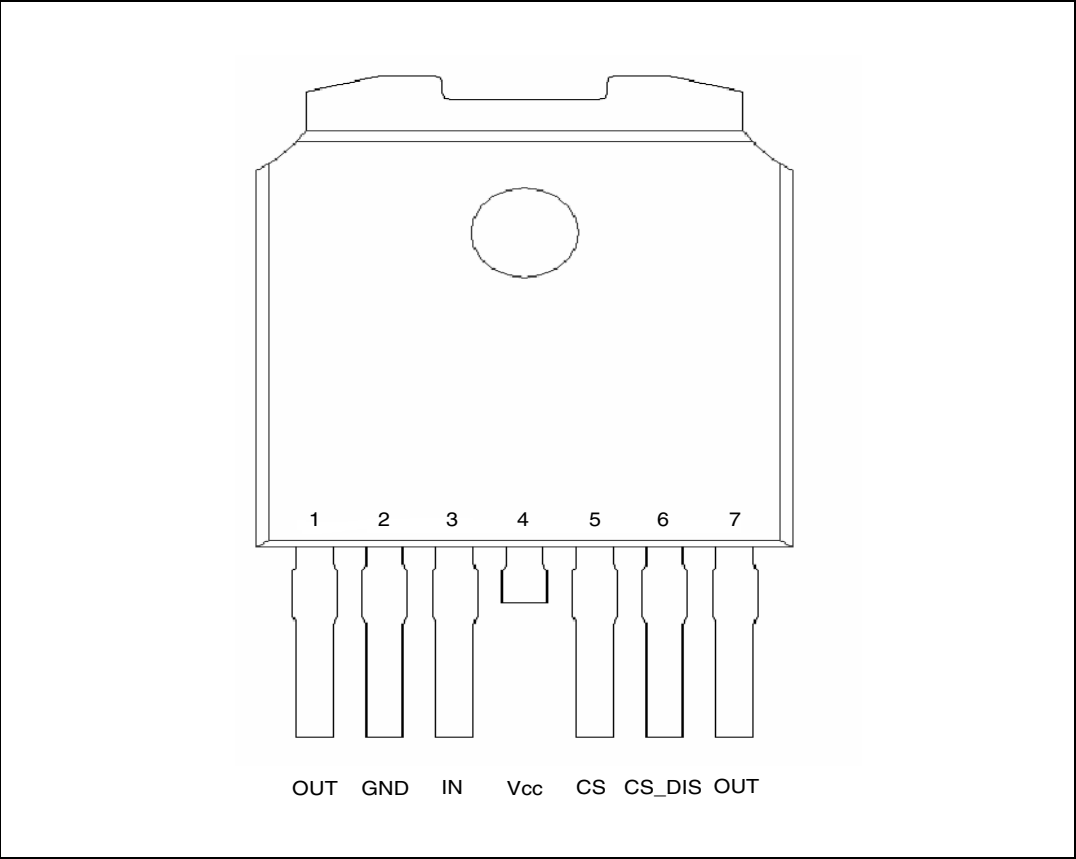
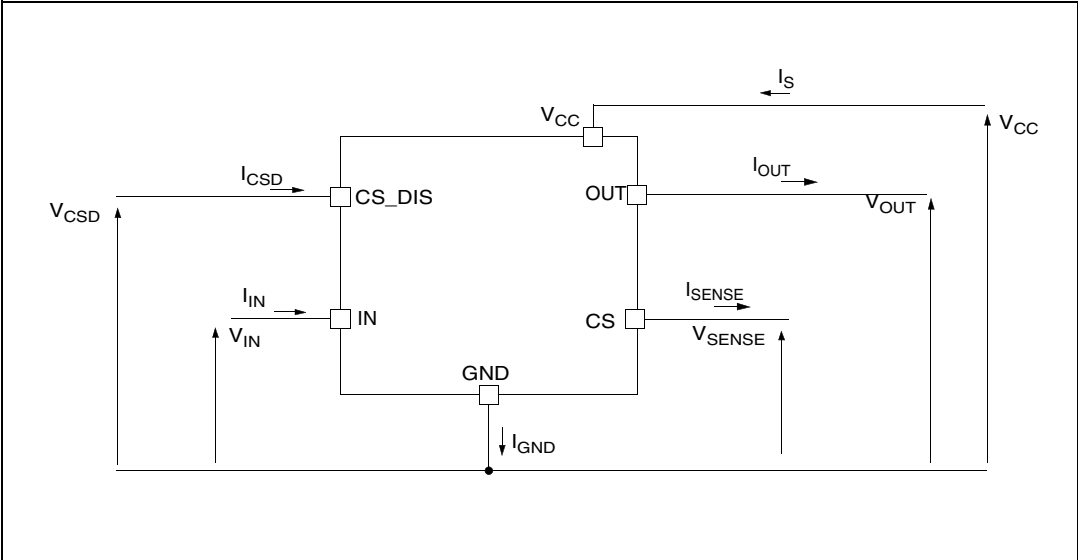


Table 2. Suggested connections for unused and not connected pins

Connection / pin	CS	OUT	IN	CS_DIS
Floating	Not allowed	X	X	X
To ground	Through 1kΩ resistor	Through 22 kΩ resistor	Through 10 kΩ resistor	Through 10 kΩ resistor

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Stressing the device above the rating listed in the [Table 3: Absolute maximum ratings](#) 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	16	V
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
V_{CSENSE}	Current sense maximum voltage ($V_{CC} > 0$)	$V_{CC} - 41$ $+V_{CC}$	V V
E_{MAX}	Maximum switching energy (single pulse) ($L = 2.2 \text{ mH}$; $R_L = 0 \Omega$; $V_{BAT} = 13.5 \text{ V}$; $T_{jstart} = 150 \text{ }^\circ\text{C}$; $I_{OUT} = I_{limL}(Typ.)$)	645	mJ

Table 3. Absolute maximum ratings (continued)

Symbol	Parameter	Value	Unit
V_{ESD}	Electrostatic discharge (human body model: $R = 1.5\text{ K}\Omega$; $C = 100\text{ pF}$)		
	– IN	4000	V
	– CS	2000	V
	– CS_DIS	4000	V
	– OUT	5000	V
	– V_{CC}	5000	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
$R_{thj-case}$	Thermal resistance junction-case	0.55	°C/W
$R_{thj-amb}$	Thermal resistance junction-ambient	67.7	°C/W

2.3 Electrical characteristics

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

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	$I_{OUT} = 6\text{ A}$; $T_j = 25\text{ °C}$		10		mΩ
		$I_{OUT} = 6\text{ A}$; $T_j = 150\text{ °C}$			20	
		$I_{OUT} = 6\text{ A}$; $V_{CC} = 5\text{ V}$; $T_j = 25\text{ °C}$			13	
R_{ON-Rev}	$R_{DS(on)}$ in reverse battery condition	$V_{CC} = -13\text{ V}$; $I_{OUT} = -6\text{ A}$; $T_j = 25\text{ °C}$		10		mΩ
V_{clamp}	Clamp voltage	$I_{CC} = 20\text{ mA}$; $I_{OUT} = 0\text{ A}$	41	46	52	V
I_S	Supply current	OFF-state: $V_{CC} = 13\text{ V}$; $T_j = 25\text{ °C}$; $V_{IN} = V_{OUT} = V_{SENSE} = 0\text{ V}$		2	5	μA
		ON-state: $V_{CC} = 13\text{ V}$; $V_{IN} = 5\text{ V}$; $I_{OUT} = 0\text{ A}$		1.5	3	mA
$I_{L(off)}$	OFF-state output current	$V_{IN} = V_{OUT} = 0\text{ V}$; $V_{CC} = 13\text{ V}$; $T_j = 25\text{ °C}$	0	0.01	3	μA
		$V_{IN} = V_{OUT} = 0\text{ V}$; $V_{CC} = 13\text{ V}$; $T_j = 125\text{ °C}$	0		5	

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

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$R_L = 2.2\text{ Ω}$ (see Figure 5)	-	40	-	μs
$t_{d(off)}$	Turn-off delay time	$R_L = 2.2\text{ Ω}$ (see Figure 5)	-	28	-	μs
$(dV_{OUT}/dt)_{on}$	Turn-on voltage slope	$R_L = 2.2\text{ Ω}$	-	(see Figure 23)	-	V/μs
$(dV_{OUT}/dt)_{off}$	Turn-off voltage slope	$R_L = 2.2\text{ Ω}$	-	(see Figure 25)	-	V/μs
W_{ON}	Switching energy losses at turn-on (t_{won})	$R_L = 2.2\text{ Ω}$ (see Figure 5)	-	2	-	mJ
W_{OFF}	Switching energy losses at turn-off (t_{woff})	$R_L = 2.2\text{ Ω}$ (see Figure 5)	-	0.6	-	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	$V_{IN} = 0.9\text{ V}$	1			μA
V_{IH}	High-level input voltage		2.1			V
I_{IH}	High-level input current	$V_{IN} = 2.1\text{ V}$			10	μA
$V_{I(hyst)}$	Input hysteresis voltage		0.25			V
V_{ICL}	Input clamp voltage	$I_{IN} = 1\text{ mA}$	5.5		7	V
		$I_{IN} = -1\text{ mA}$		-0.7		
V_{CSDL}	Low-level CS_DIS voltage				0.9	V
I_{CSDL}	Low-level CS_DIS current	$V_{CSD} = 0.9\text{ V}$	1			μA
V_{CSDH}	High-level CS_DIS voltage		2.1			V
I_{CSDH}	High-level CS_DIS current	$V_{CSD} = 2.1\text{ V}$			10	μA
$V_{CSD(hyst)}$	CS_DIS hysteresis voltage		0.25			V
V_{CSCL}	CS_DIS clamp voltage	$I_{CSD} = 1\text{ mA}$	5.5		7	V
		$I_{CSD} = -1\text{ mA}$		-0.7		

Table 8. Protection and diagnostics⁽¹⁾

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{limH}	Short-circuit current	$V_{CC} = 13\text{ V}$	60	85	120	A
		$5\text{ V} < V_{CC} < 28\text{ V}$			120	
I_{limL}	Short-circuit current during thermal cycling	$V_{CC} = 13\text{ V}; T_R < T_J < T_{TSD}$		21		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		$^{\circ}\text{C}$
V_{DEMAG}	Turn-off output voltage clamp	$I_{OUT} = 2\text{ A}; V_{IN} = 0;$ $L = 6\text{ mH}$	$V_{CC} - 41$	$V_{CC} - 46$	$V_{CC} - 52$	V
V_{ON}	Output voltage drop limitation	$I_{OUT} = 0.5\text{ A};$ $T_J = -40\text{ }^{\circ}\text{C}$ to $150\text{ }^{\circ}\text{C}$		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. Current sense (8 V < V_{CC} < 18 V)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
K ₀	I _{OUT} /I _{SENSE}	I _{OUT} = 0.25 A; V _{SENSE} = 0.5 V T _j = -40 °C to 150 °C T _j = 25 °C to 150 °C	3000 3000	7410 7410	12000 11600	
K ₁	I _{OUT} /I _{SENSE}	I _{OUT} = 6 A; V _{SENSE} = 0.5 V T _j = -40 °C to 150 °C T _j = 25 °C to 150 °C	5350 5510	6740 6740	8500 7745	
dK ₁ /K ₁ ⁽¹⁾	Current sense ratio drift	I _{OUT} = 6 A; V _{SENSE} = 0.5 V; V _{CSD} = 0 V; T _j = -40 °C to 150 °C	-15		15	%
K ₂	I _{OUT} /I _{SENSE}	I _{OUT} = 10 A; V _{SENSE} = 4 V T _j = -40 °C to 150 °C T _j = 25 °C to 150 °C	5850 5800	6570 6570	7690 7195	
dK ₂ /K ₂ ⁽¹⁾	Current sense ratio drift	I _{OUT} = 10 A; V _{SENSE} = 4 V; V _{CSD} = 0 V; T _j = -40 °C to 150 °C	-11		11	%
K ₃	I _{OUT} /I _{SENSE}	I _{OUT} = 25 A; V _{SENSE} = 4 V T _j = -40 °C to 150 °C T _j = 25 °C to 150 °C	5915 5850	6420 6420	7000 6755	
dK ₃ /K ₃ ⁽¹⁾	Current sense ratio drift	I _{OUT} = 25 A; V _{SENSE} = 4 V; V _{CSD} = 0 V; T _j = -40 °C to 150 °C	-8		8	%
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} = 2 A; V _{SENSE} = 0 V; V _{CSD} = 5 V; V _{IN} = 5 V; T _j = -40 °C to 150 °C			1	
I _{OL}	Open load ON-state current detection threshold	V _{IN} = 5 V, 8 V < V _{CC} < 18 V I _{SENSE} = 5 μA	5		80	mA
V _{SENSE}	Max analog sense output voltage	I _{OUT} = 18 A; R _{SENSE} = 3.9 kΩ	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

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

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
t _{DSENSE1H}	Delay response time from falling edge of CS_DIS pin	V _{SENSE} < 4 V, 1.5 A < I _{OUT} < 25 A I _{SENSE} = 90% of I _{SENSE MAX} (see Figure 4)		50	100	μs
t _{DSENSE1L}	Delay response time from rising edge of CS_DIS pin	V _{SENSE} < 4 V, 1.5 A < I _{OUT} < 25 A I _{SENSE} = 10% of I _{SENSE MAX} (see Figure 4)		5	20	μs
t _{DSENSE2H}	Delay response time from rising edge of IN pin	V _{SENSE} < 4 V, 1.5 A < I _{OUT} < 25 A I _{SENSE} = 90% of I _{SENSE max} (see Figure 4)		270	600	μs
Δt _{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} = 3 A (see Figure 6)			310	μs
t _{DSENSE2L}	Delay response time from falling edge of IN pin	V _{SENSE} < 4 V, 1.5 A < I _{OUT} < 25 A I _{SENSE} = 10% of I _{SENSE max} (see fig Figure 4)		100	250	μs

- 1. Parameter guaranteed by design, it is not tested.
- 2. Fault condition includes: power limitation and overtemperature.

Figure 4. Current sense delay characteristics

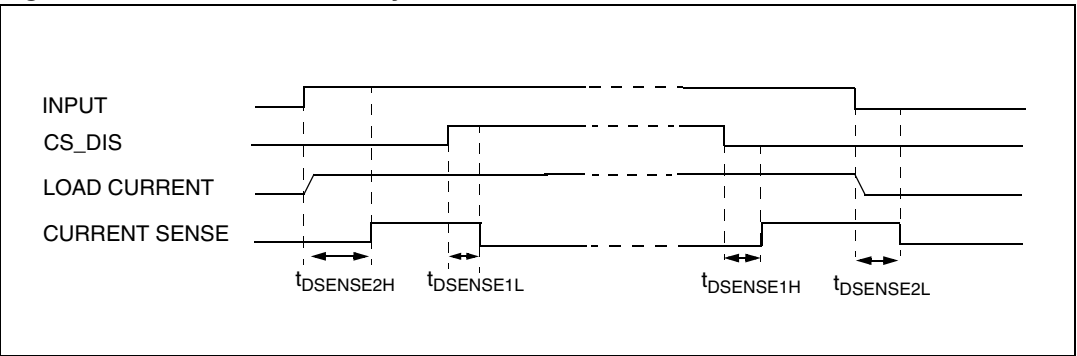


Figure 5. Switching characteristics

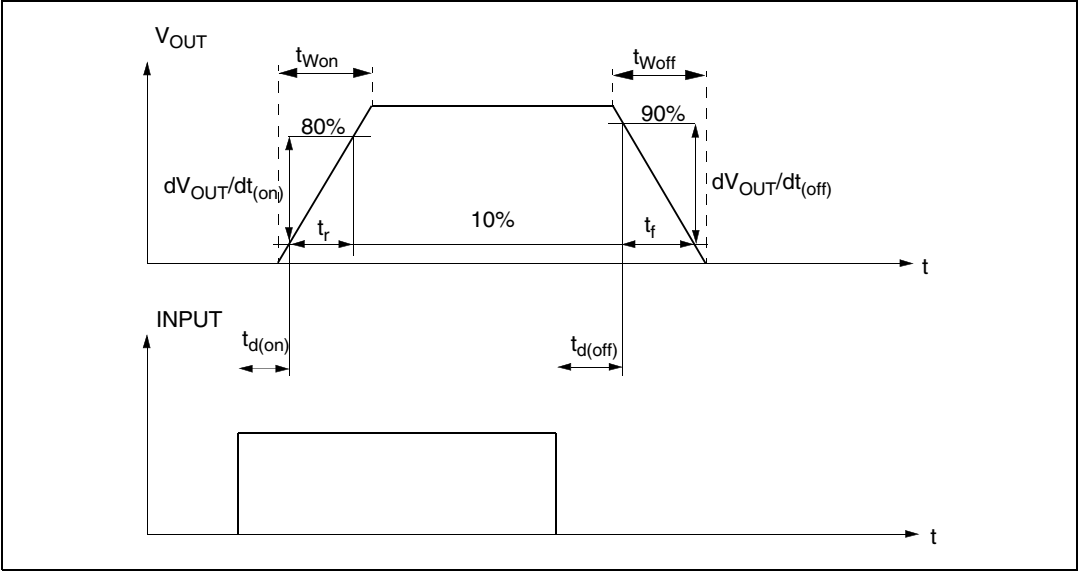


Figure 6. Delay response time between rising edge of output current and rising edge of current sense (CS enabled)

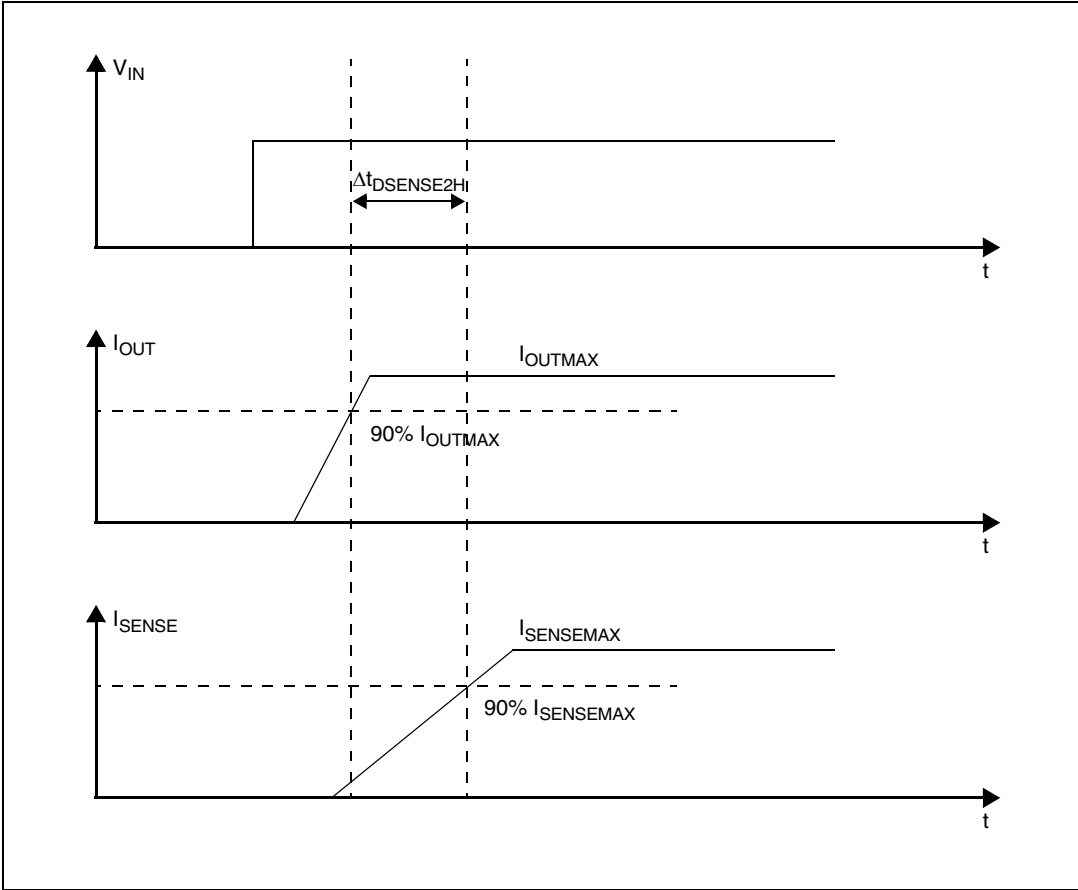


Figure 7. Output voltage drop limitation

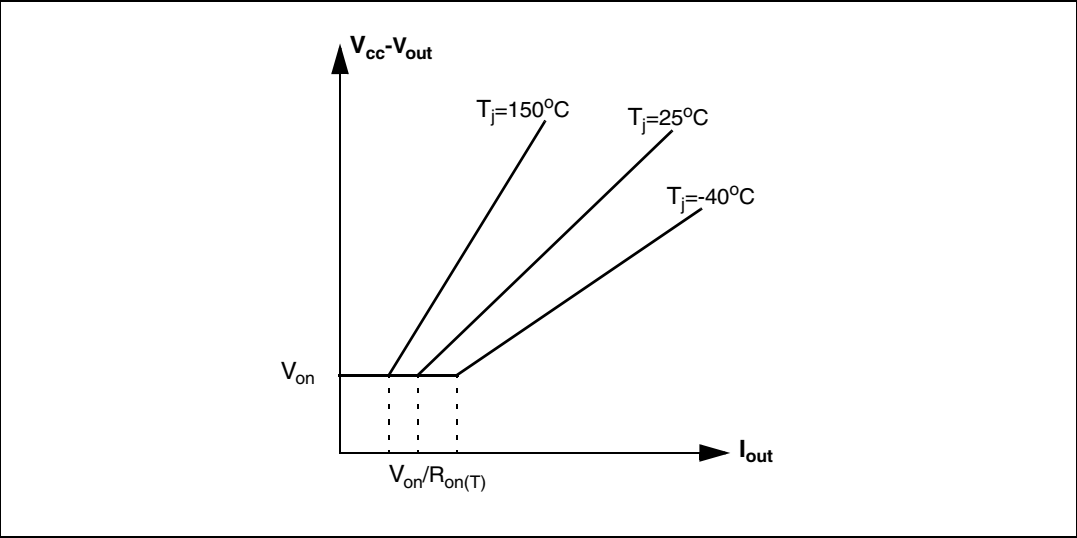


Figure 8. I_{OUT}/I_{SENSE} vs. I_{OUT}

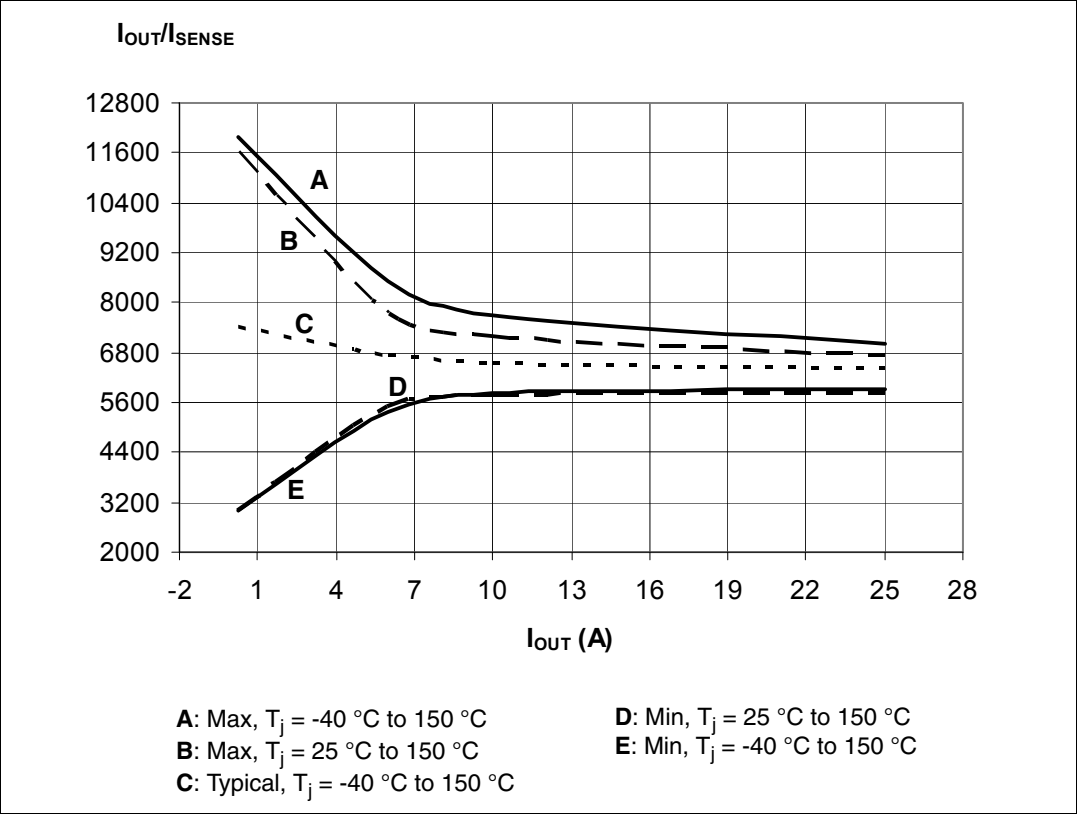
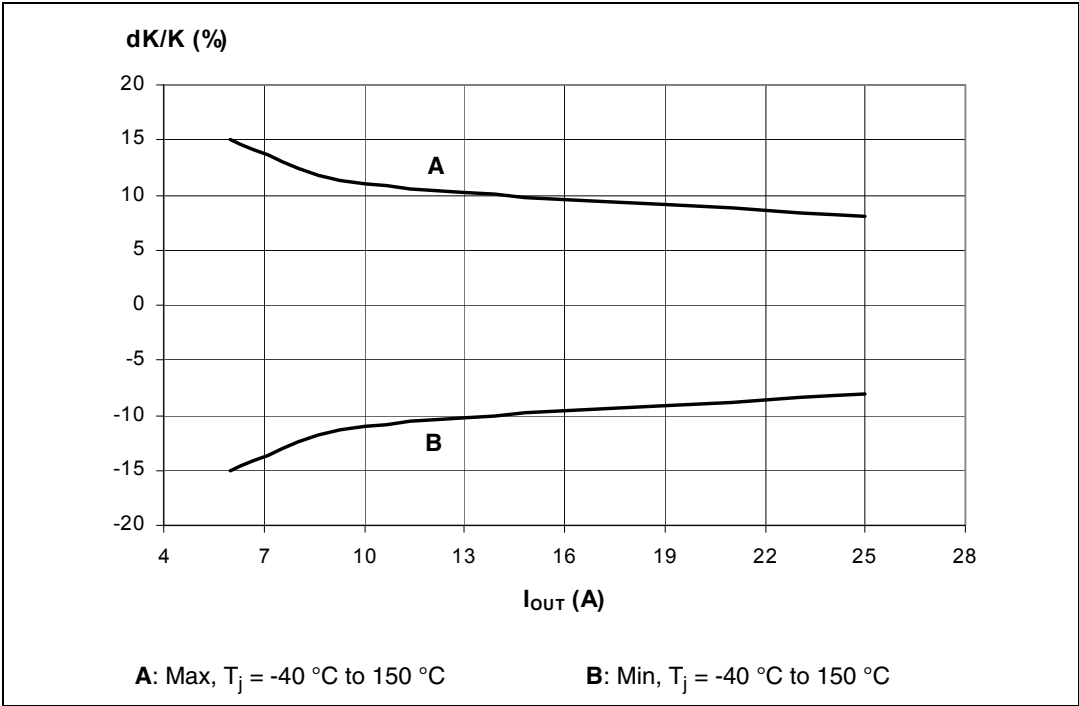


Figure 9. Maximum current sense ratio drift vs. load current⁽¹⁾



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

Table 10. Truth table

Conditions	Input	Output	SENSE ($V_{CSD} = 0\text{ V}$) ⁽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}
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 11. 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		Min.	Max.	
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 μ s, 2 Ω
3a	-100 V	-150 V	1 h	90 ms	100 ms	0.1 μ s, 50 Ω
3b	+75 V	+100 V	1 h	90 ms	100 ms	0.1 μ s, 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

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 12. Electrical transient requirements (part 2)

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

1. Valid in case of external load dump clamp: 40 V maximum referred to ground.

Table 13. 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 10. Normal operation

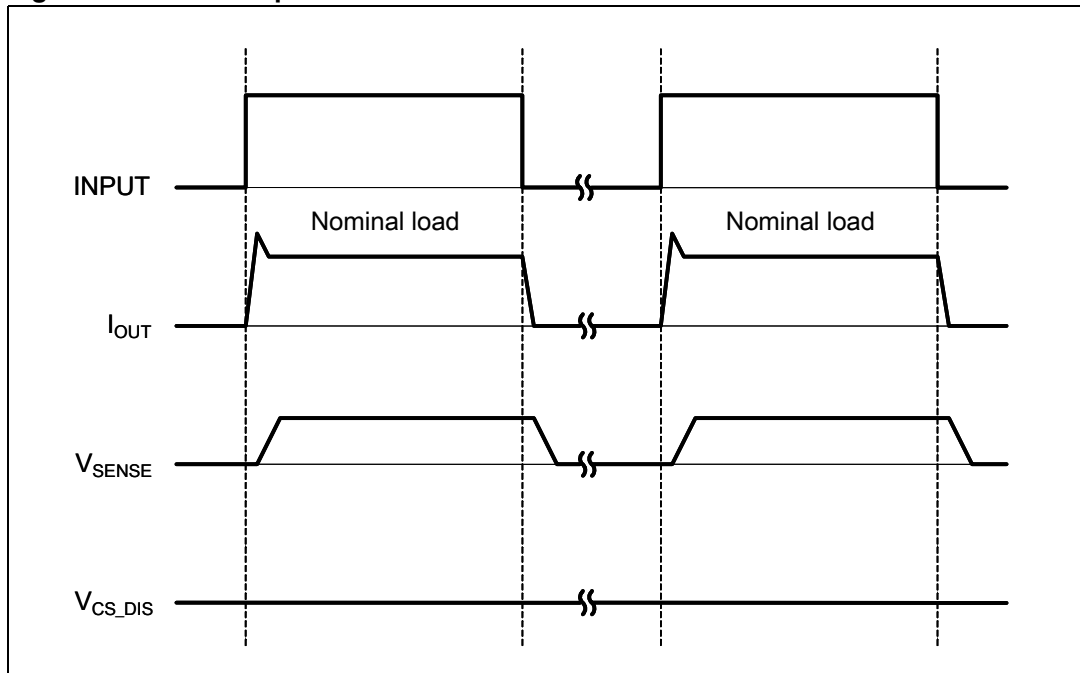


Figure 11. Overload or short to GND

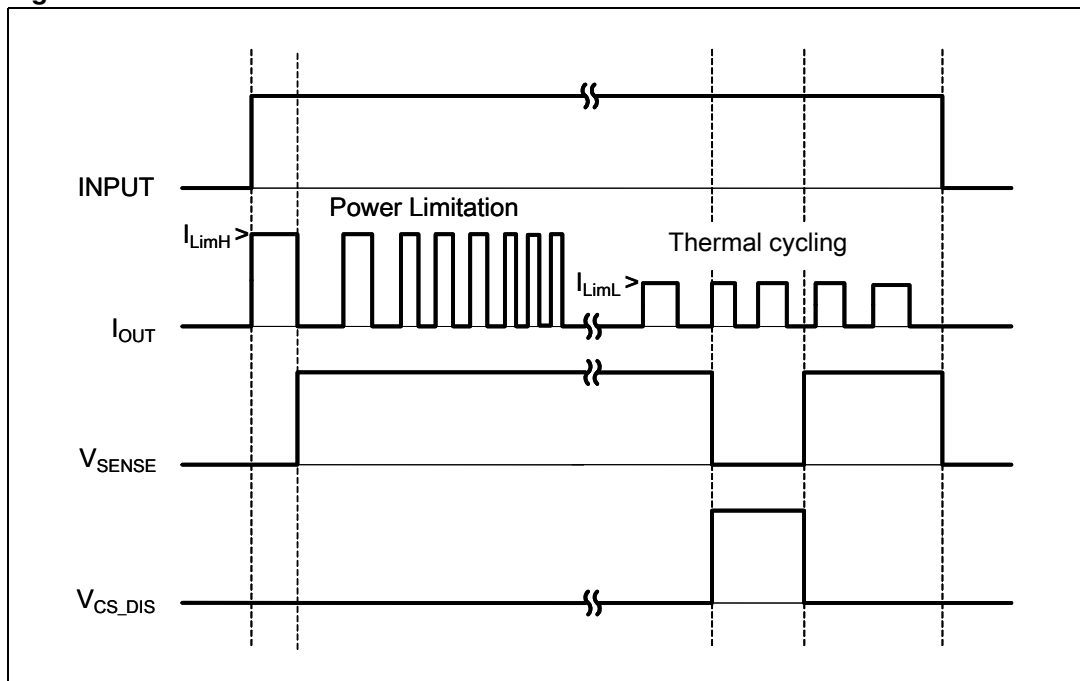


Figure 12. Intermittent overload

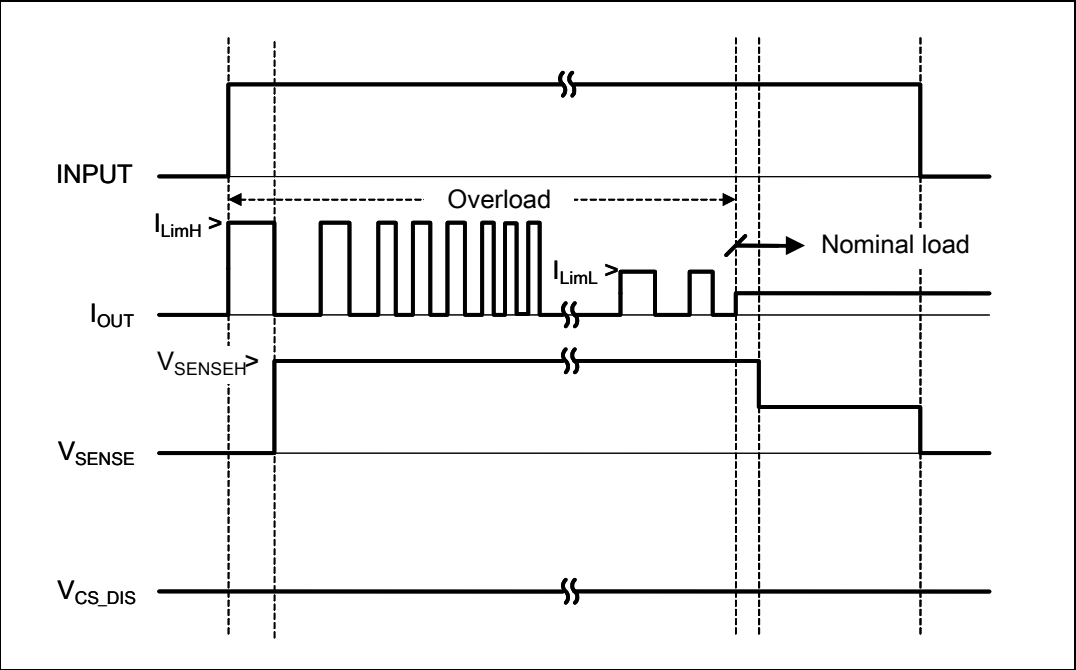
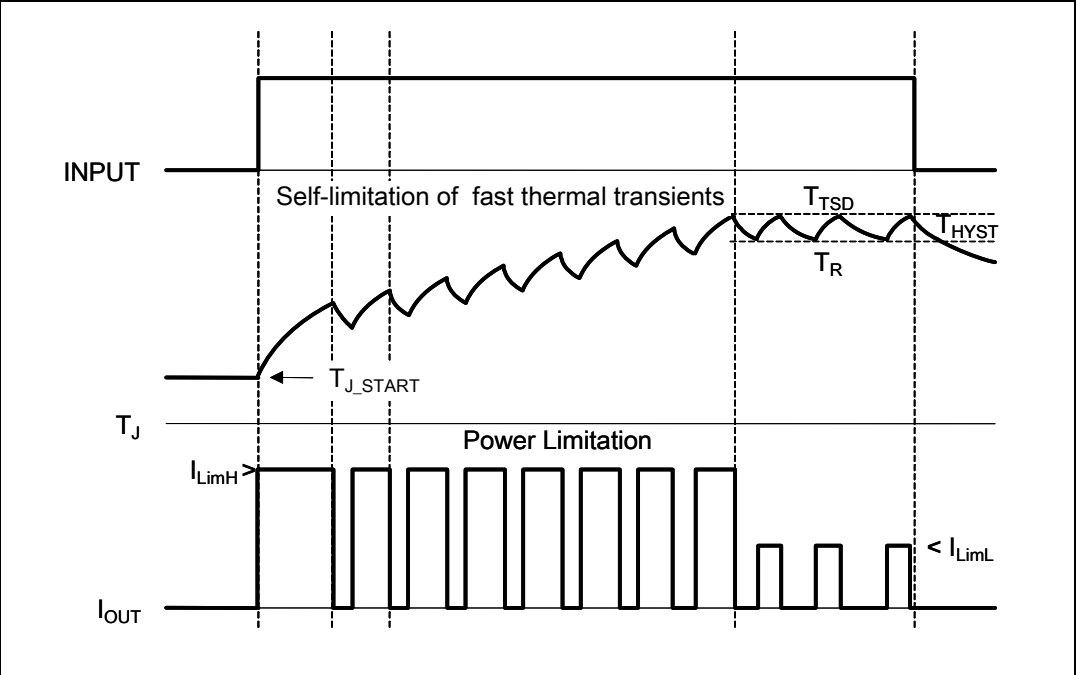


Figure 13. T_J evolution in overload or short to GND



2.5 Electrical characteristics curves

Figure 14. OFF-state output current

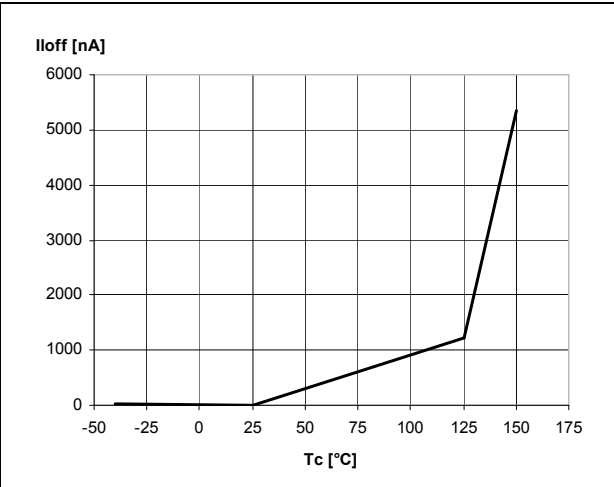


Figure 15. High-level input current

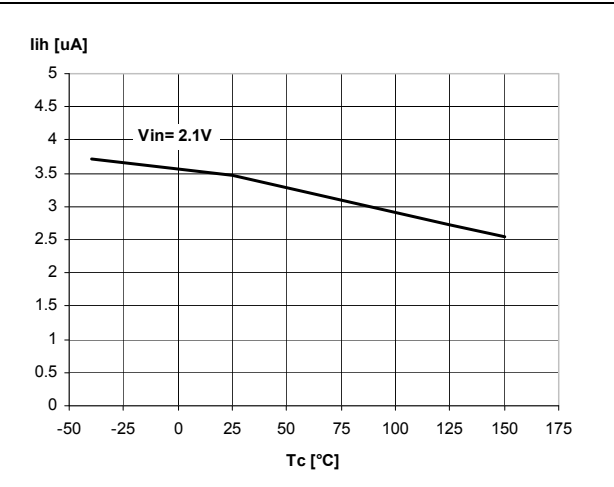


Figure 16. Input clamp voltage

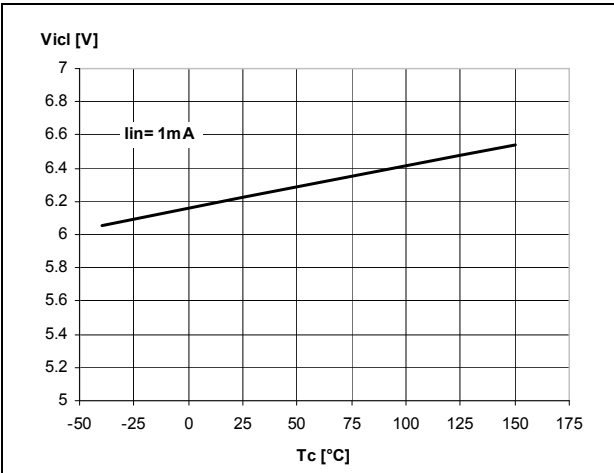


Figure 17. Low-level input voltage

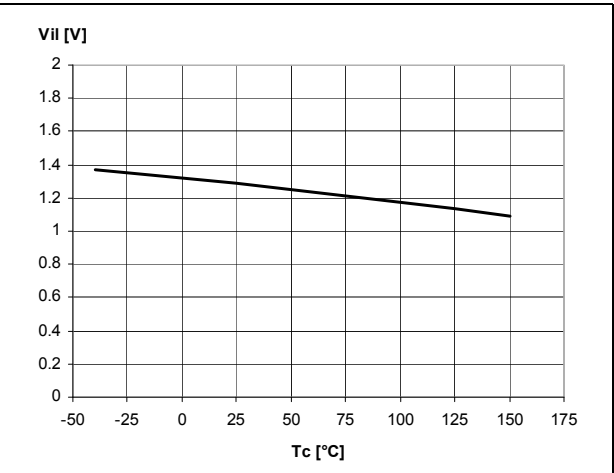


Figure 18. High-level input voltage

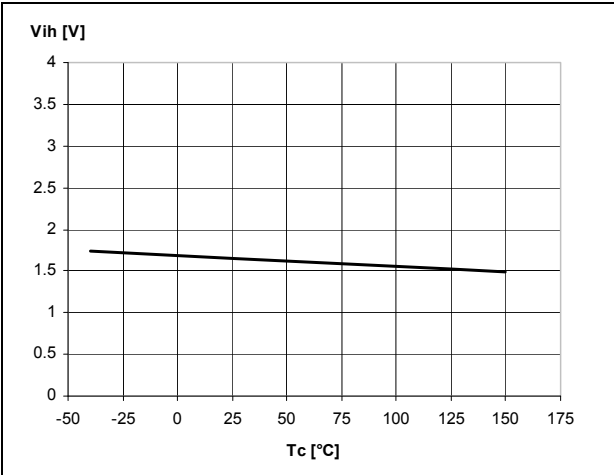


Figure 19. Input hysteresis voltage

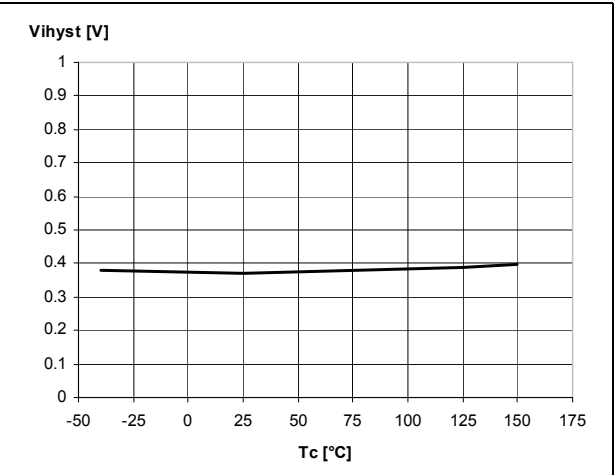


Figure 20. ON-state resistance vs. T_{case}

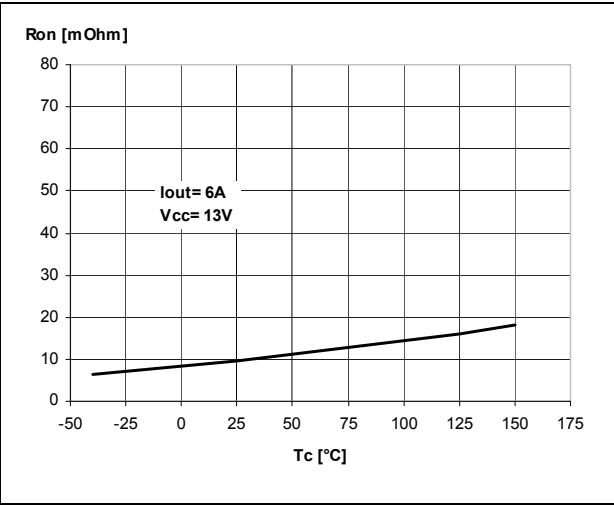


Figure 21. ON-state resistance vs. V_{CC}

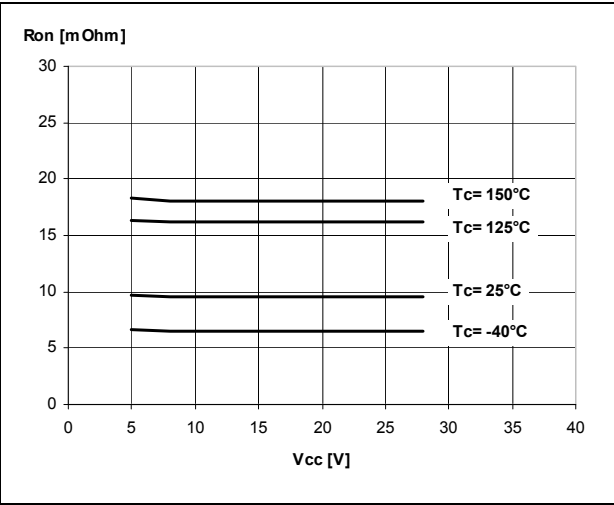


Figure 22. Undervoltage shutdown

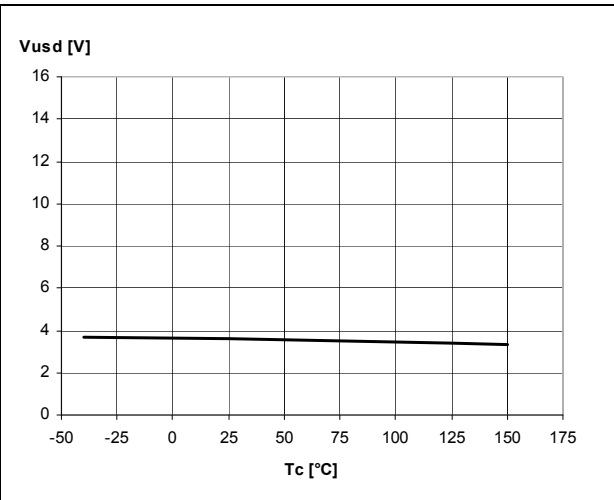


Figure 23. Turn-on voltage slope

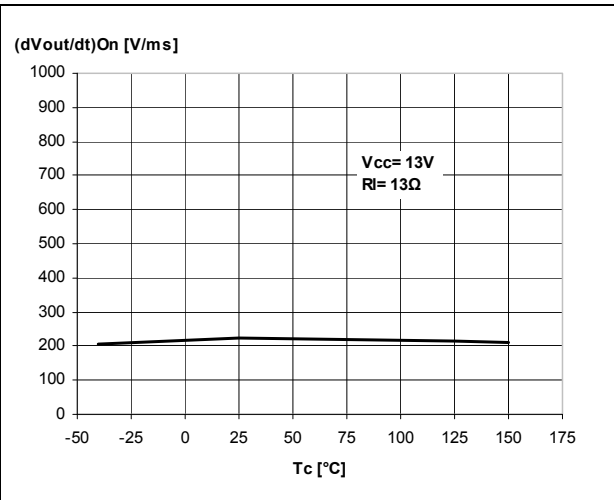


Figure 24. I_{LIMH} vs. T_{case}

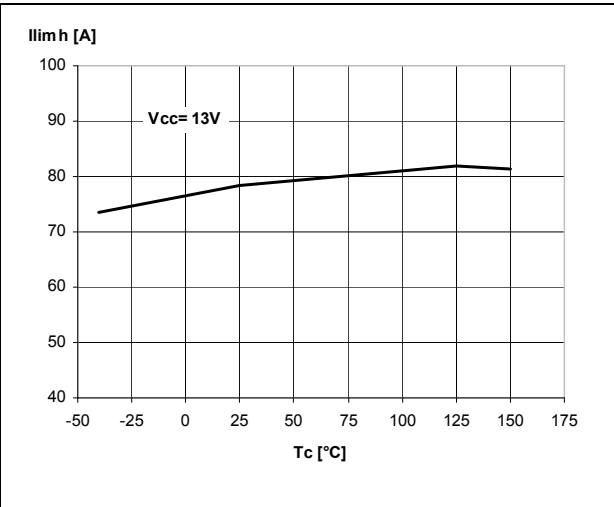


Figure 25. Turn-off voltage slope

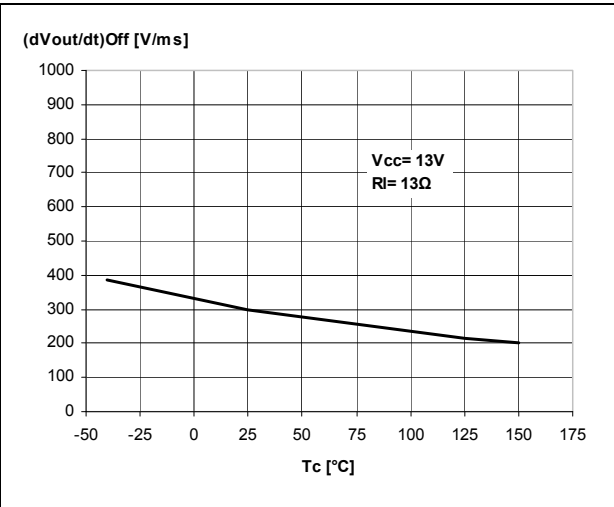


Figure 26. High-level CS_DIS voltage

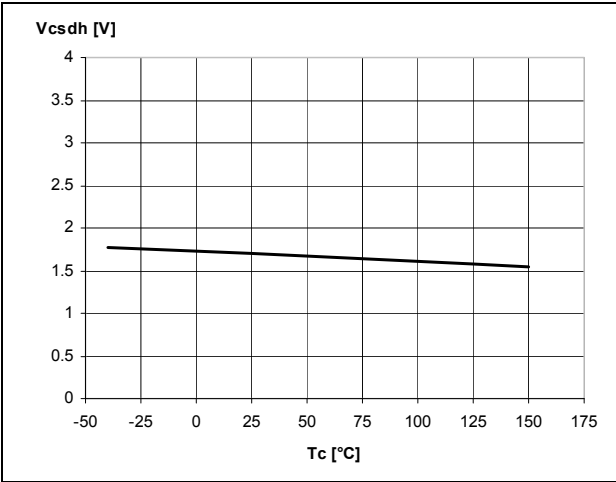


Figure 27. CS_DIS clamp voltage

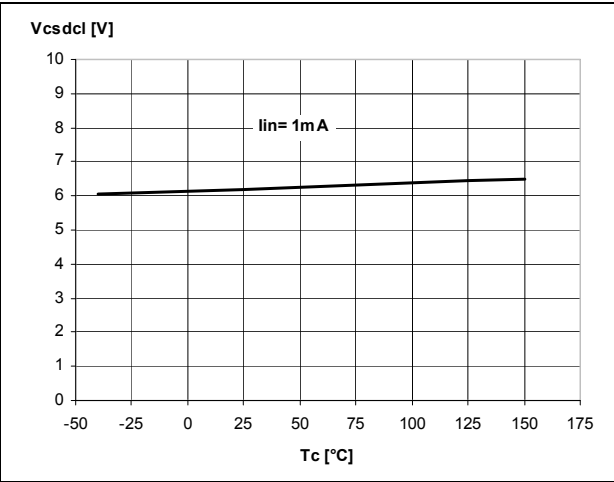
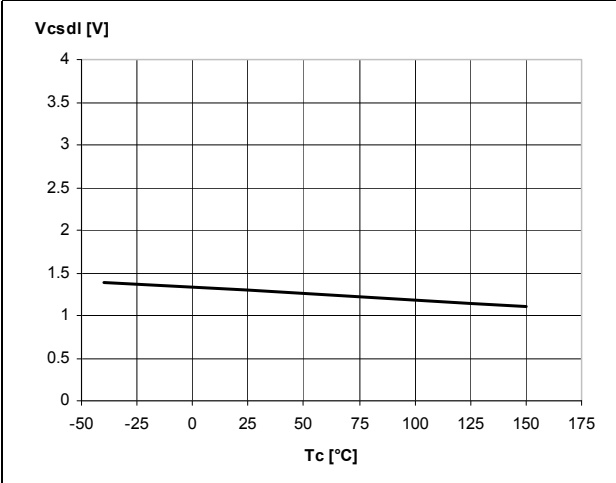
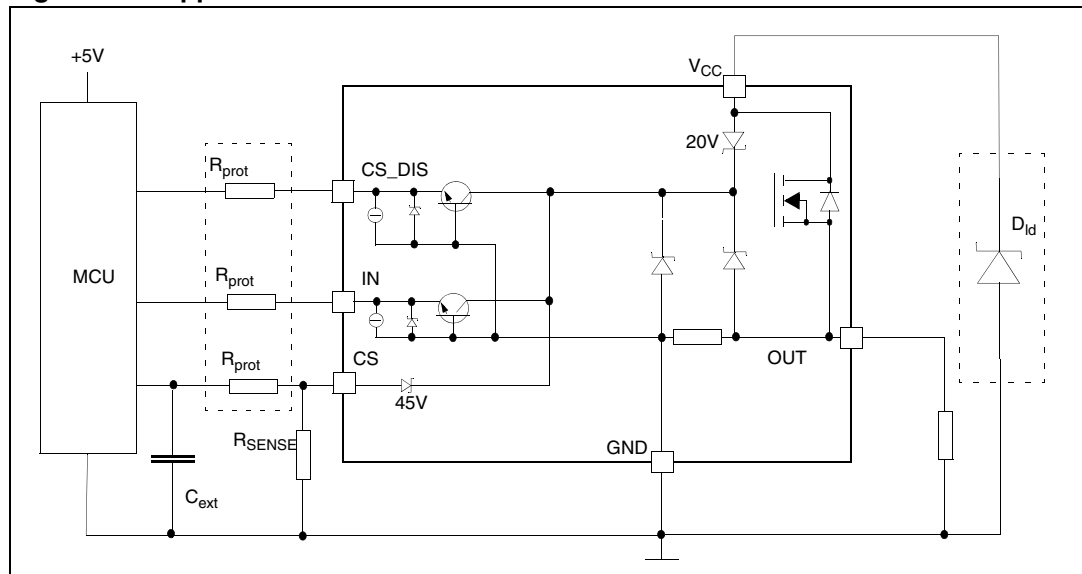


Figure 28. Low-level CS_DIS voltage



2.6 Application information

Figure 29. Application schematic



2.7 Load dump protection

D_{id} 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.

2.8 MCU I/Os protection

When negative transients are present on the V_{CC} line, the control pins are pulled negative to approximately -1.5 V. 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.

Equation 1

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

Calculation example:

For $V_{CCpeak} = -1.5$ V; $I_{latchup} \geq 20$ mA; $V_{OH\mu C} \geq 4.5$ V

$$75 \Omega \leq R_{prot} \leq 240 \text{ k}\Omega$$

Recommended values: $R_{prot} = 10 \text{ k}\Omega$, $C_{EXT} = 10 \text{ nF}$.

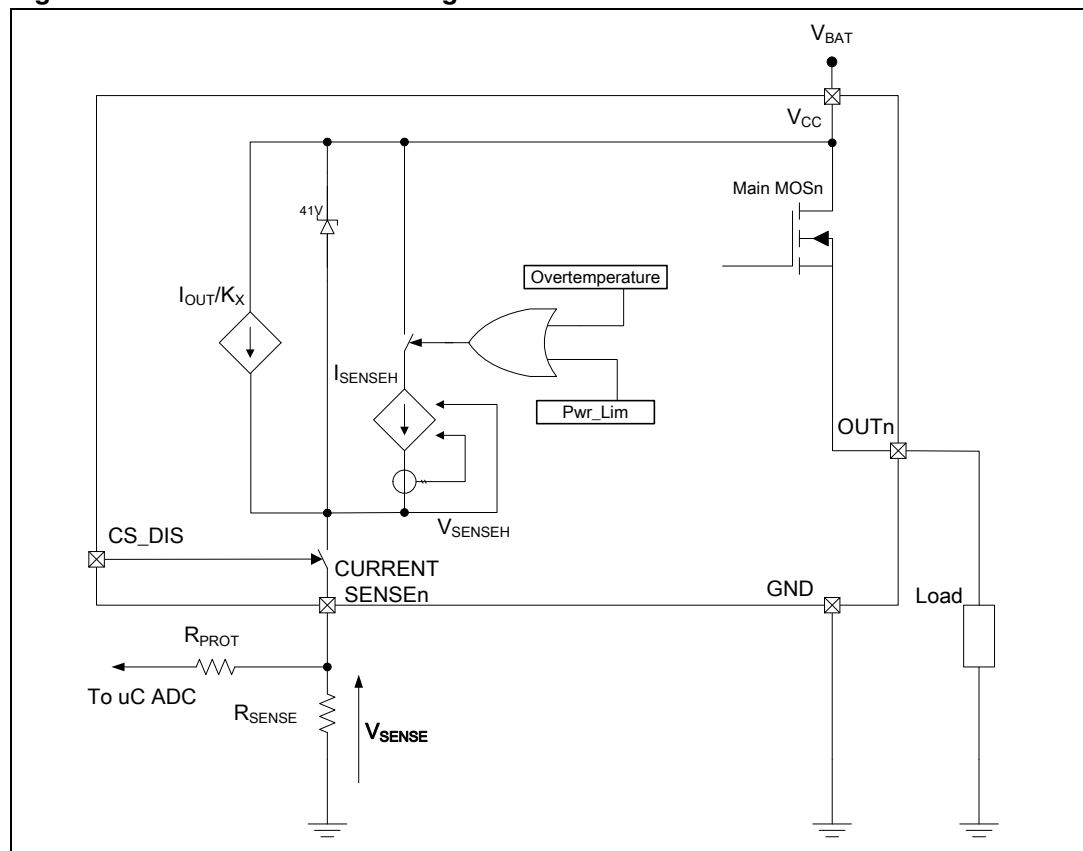
2.9 Current sense and diagnostic

The current sense pin performs a double function (see [Figure 30: Current sense and diagnostic](#)):

- **Current mirror of the load current in normal operation**, delivering a current proportional to the load one according to a known ratio K_X .
The current I_{SENSE} can be easily converted to a voltage V_{SENSE} by means of an external resistor R_{SENSE} . Linearity between I_{OUT} and V_{SENSE} is ensured up to 5 V minimum (see parameter V_{SENSE} in [Table 9: Current sense \(8 V < \$V_{CC}\$ < 18 V\)](#)). The current sense accuracy depends on the output current (refer to current sense electrical characteristics [Table 9: Current sense \(8 V < \$V_{CC}\$ < 18 V\)](#)).
- **Diagnostic flag in fault conditions**, delivering a fixed voltage V_{SENSEH} up to a maximum current I_{SENSEH} in case of the following fault conditions (refer to [Table 10: Truth table](#)):
 - Power limitation activation
 - Overtemperature

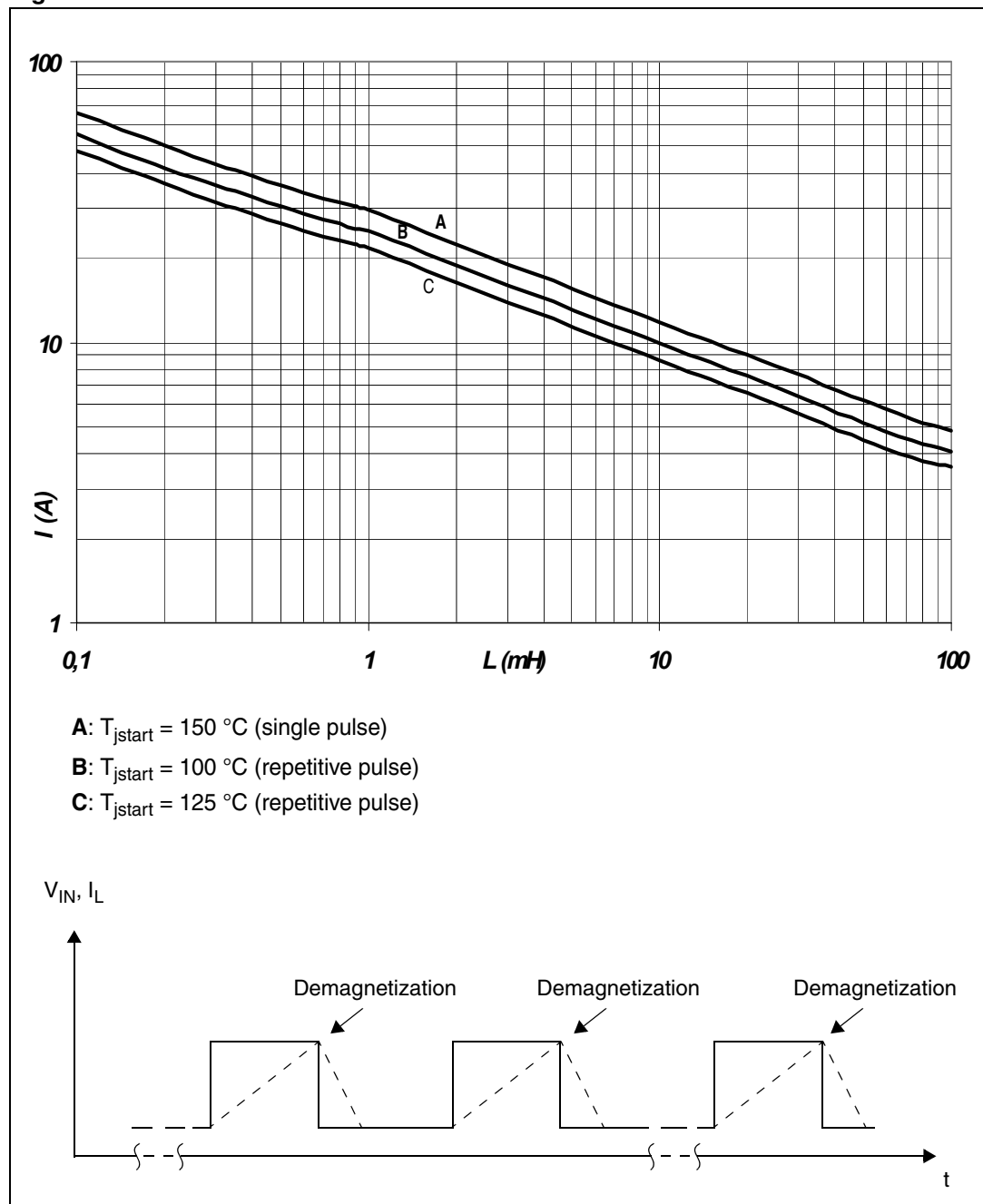
A logic level high on CS_DIS pin sets at the same time all the current sense pins of the device in a high-impedance state, thus disabling the current monitoring and diagnostic detection. This feature allows multiplexing of the microcontroller analog inputs by sharing of sense resistance and ADC line among different devices.

Figure 30. Current sense and diagnostic



2.10 Maximum demagnetization energy ($V_{CC} = 13.5\text{ V}$)

Figure 31. Maximum turn-off current versus inductance⁽¹⁾



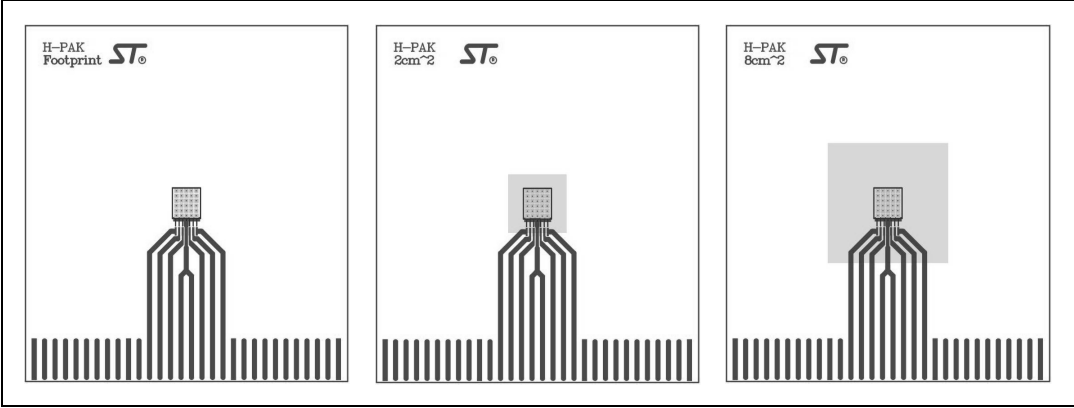
1. Values are generated with $R_L = 0\text{ }\Omega$.

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.

3 Package and PC board thermal data

3.1 HPAK thermal data

Figure 32. PC board⁽¹⁾



1. Layout condition of R_{th} and Z_{th} measurements (PCB FR4 area = 58 mm x 58 mm, PCB thickness = 1.8 mm, Cu thickness = 70 μ m, Copper areas: from minimum pad lay-out to 8 cm²).

Figure 33. R_{thj_amb} vs. PCB copper area in open box free air condition

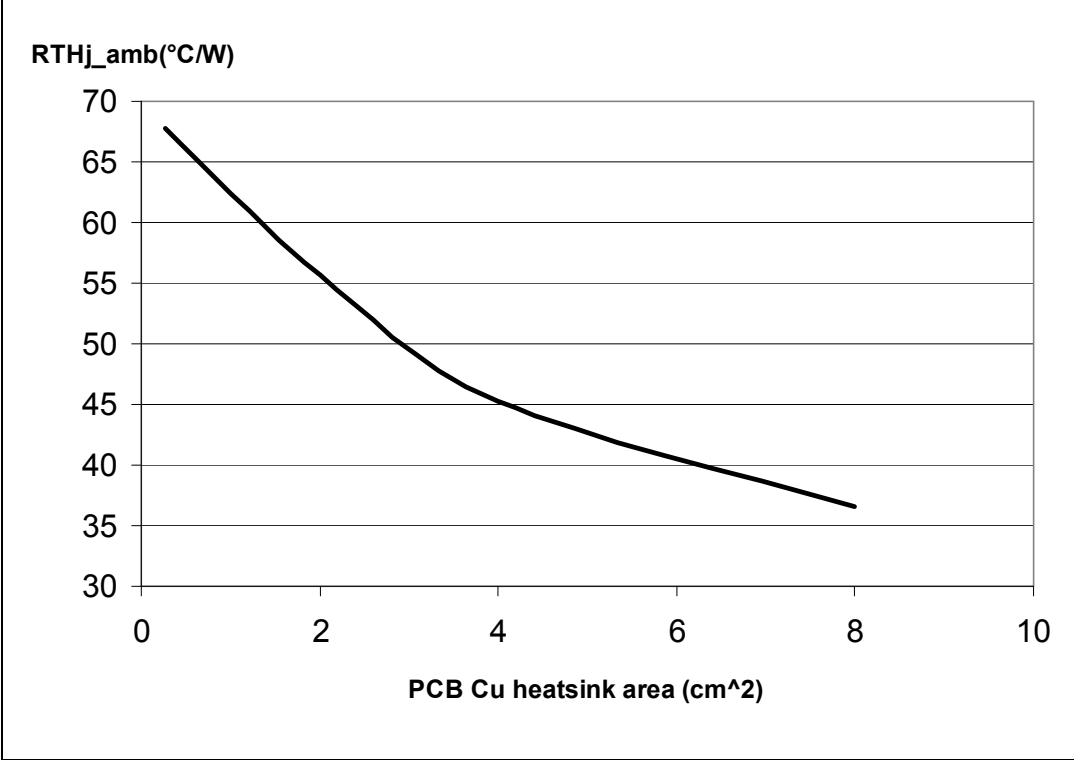
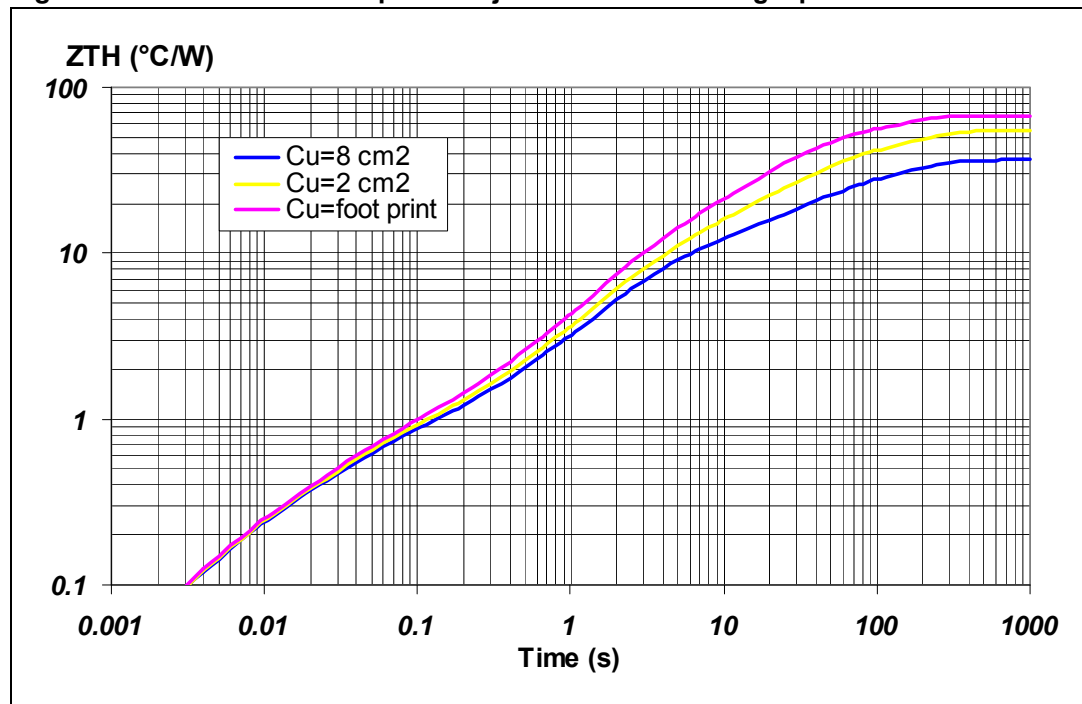
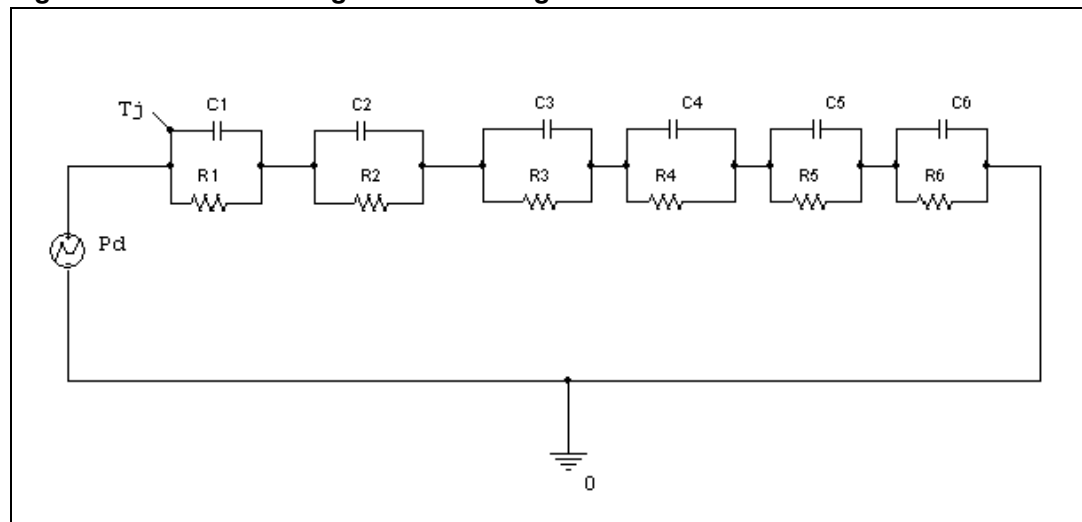


Figure 34. HPAK thermal impedance junction ambient single pulse**Figure 35. Thermal fitting model of a single-channel HSD in HPAK⁽¹⁾**

1. The fitting model is a simplified thermal tool and is valid for transient evolutions where the embedded protections (power limitation or thermal cycling during thermal shutdown) are not triggered.

Equation 2: pulse calculation formula

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

where $\delta = t_p/T$

Table 14. Thermal parameter

Area/island (cm ²)	Footprint	4	8
R1 (°C/W)	0.01		
R2 (°C/W)	0.15		
R3 (°C/W)	0.5		
R4 (°C/W)	8		
R5 (°C/W)	28	22	12
R6 (°C/W)	31	25	16
C1 (W.s/°C)	0.005		
C2 (W.s/°C)	0.05		
C3 (W.s/°C)	0.1		
C4 (W.s/°C)	0.4		
C5 (W.s/°C)	0.8	1.4	3
C6 (W.s/°C)	3	6	9

4 Package and packing information

4.1 ECOPACK®

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.

4.2 HPAK mechanical data

Figure 36. HPAK package dimension

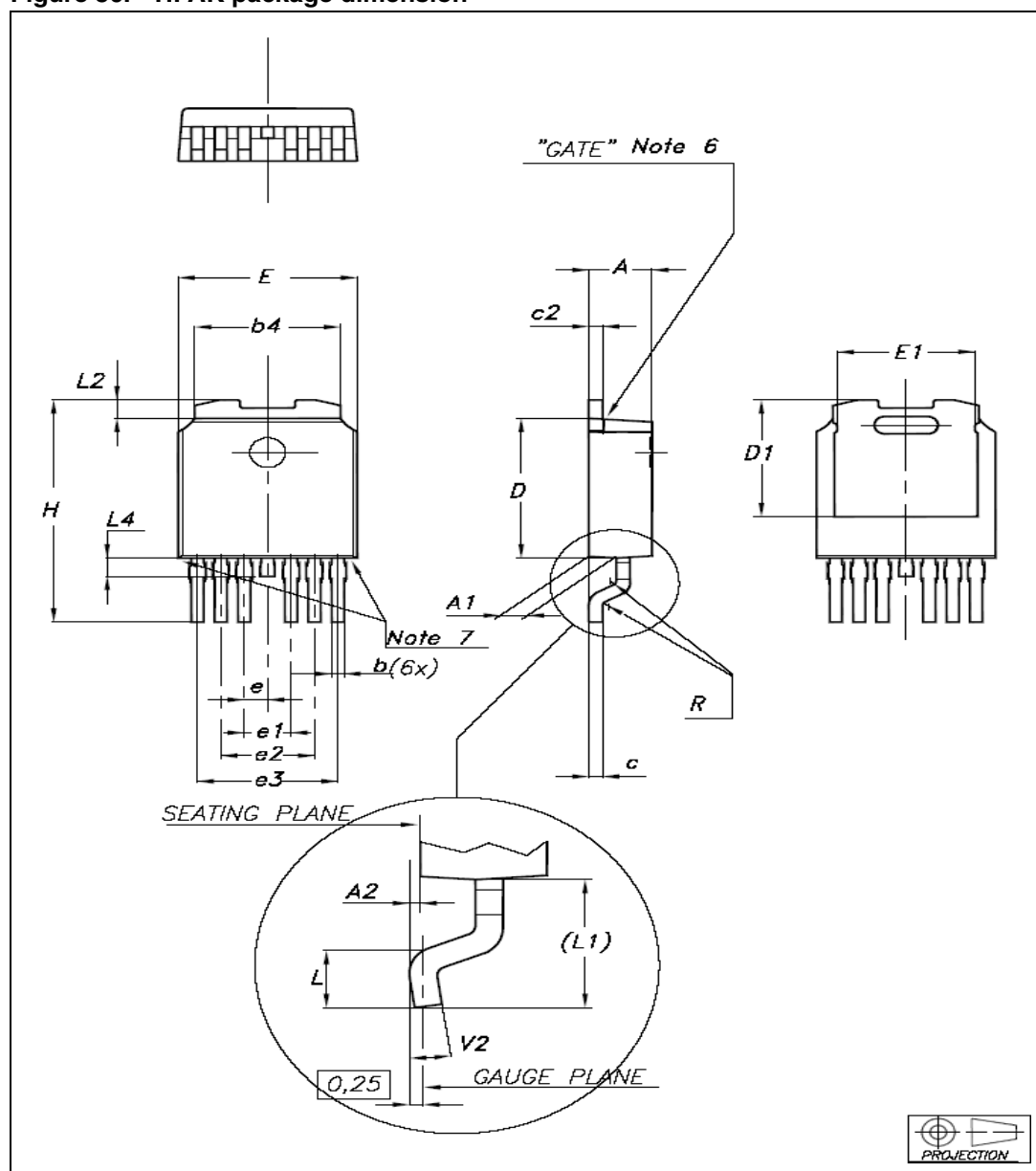
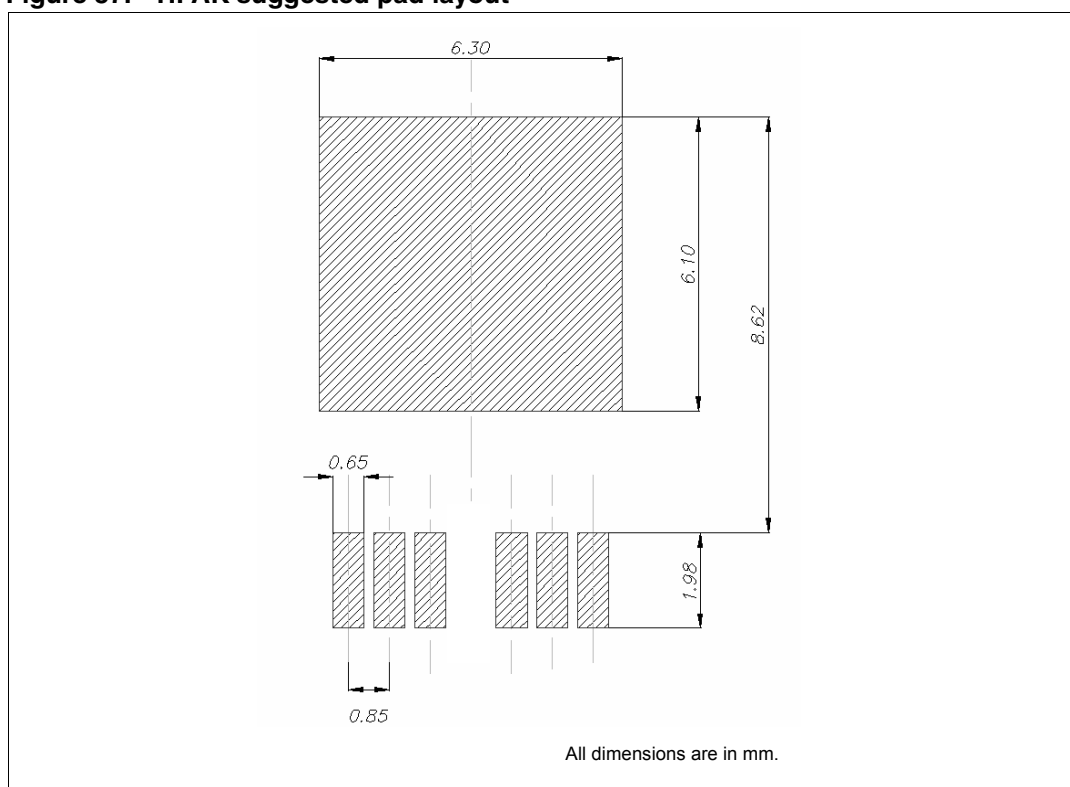


Table 15. HPAK mechanical data

Ref. dim	Data book mm		
	Nom.	Min.	Max.
A		2.20	2.40
A1		0.90	1.10
A2		0.03	0.23
b		0.45	0.60
b4		5.20	5.40
c		0.45	0.60
c2		0.48	0.60
D		6.00	6.20
D1	5.10		
E		6.40	6.60
E1	5.20		
e	0.85		
e1		1.60	1.80
e2		3.30	3.50
e3		5.00	5.20
H		9.35	10.10
L		1	
(L1)	2.80		
L2	0.80		
L4		0.60	1.00
R	0.20		
V2		0°	8°

4.3 HPAK suggested land pattern

Figure 37. HPAK suggested pad layout⁽¹⁾



1. The land pattern proposed is not intended to overrule User's PCB design, manufacturing and soldering process rules

4.4 Packing information

The devices can be packed in tube or tape and reel shipments (see [Table 16: Device summary](#)).

Figure 38. HPAK tube shipment (no suffix)

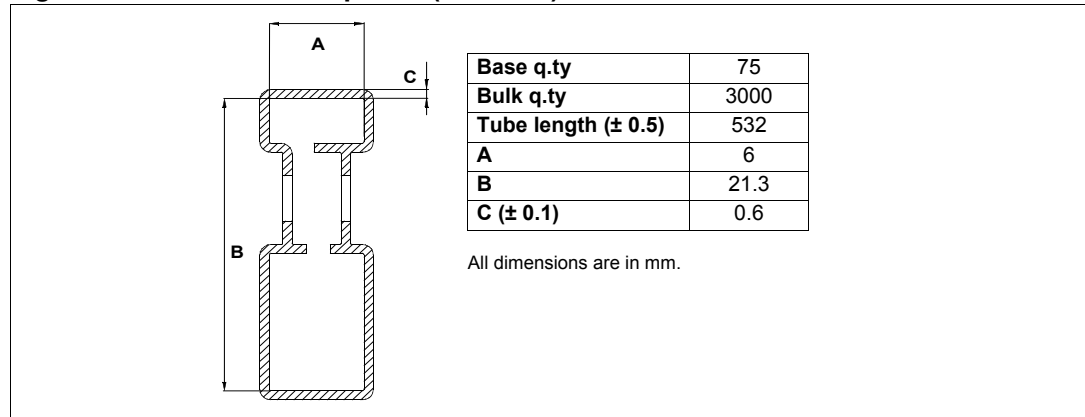
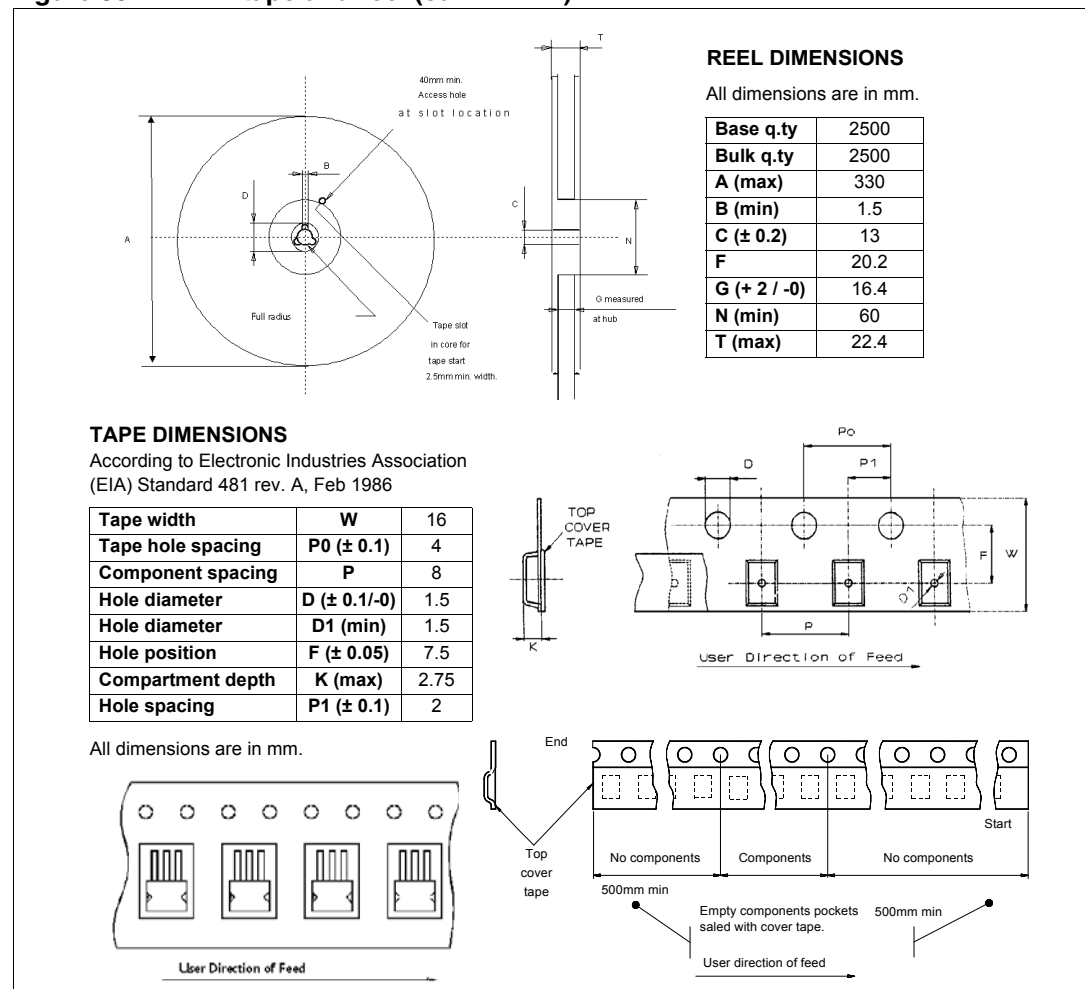


Figure 39. HPAK tape and reel (suffix “TR”)



5 Order codes

Table 16. Device summary

Package	Order codes	
	Tube	Tape and reel
6 pins HPAK	VN5E010MH-E	VN5E010MHTR-E

6 Revision history

Table 17. Document revision history

Date	Revision	Changes
28-May-2009	1	Initial release.
18-Jun-2009	2	Figure 32: PC board⁽¹⁾ – Changed footnote
15-Dec-2009	3	Updated Table 7: Logic inputs
25-Jan-2010	4	Updated Table 9: Current sense (8 V < V_{CC} < 18 V)
27-May-2010	5	Updated Table 15: HPAK mechanical data.
18-Sep-2013	6	Updated Disclaimer.

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