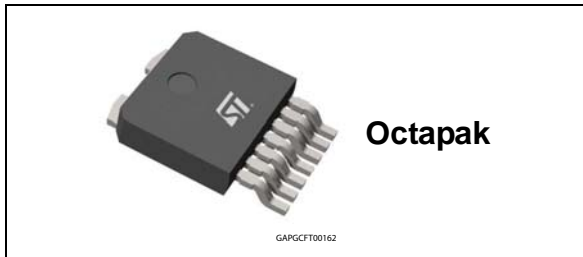


## High-side driver with CurrentSense analog feedback for automotive applications

Datasheet - production data



- Protections
  - Undervoltage shutdown
  - Overvoltage clamp
  - Load current limitation
  - Self limiting of fast thermal transients
  - Loss of ground and loss of  $V_{CC}$
  - Reverse battery
  - Electrostatic discharge protection

### Features

Max transient supply voltage	$V_{CC}$	40 V
Operating voltage range	$V_{CC}$	4 to 28 V
Typ. on-state resistance (per Ch)	$R_{ON}$	4.9 m $\Omega$
Current limitation (typ)	$I_{LIMH}$	150 A
Stand-by current (max)	$I_{STBY}$	0.5 $\mu$ A

- Automotive qualified
- General
  - Single channel smart high-side driver with CurrentSense analog feedback
  - Very low standby current
  - Compatible with 3.0 V and 5 V CMOS outputs
- Diagnostic functions
  - Overload and short to ground (power limitation) indication
  - Thermal shutdown indication
  - OFF-state open-load detection
  - Output short to  $V_{CC}$  detection
  - Sense enable/ disable

### Applications

- All types of Automotive resistive, inductive and capacitive loads
- Specially intended for Automotive Headlamps

### Description

The VN7004AH-E is a single channel high-side driver manufactured using ST proprietary VIpower® technology and housed in the Octapak package. The device is designed to drive 12 V automotive grounded loads through a 3 V and 5 V CMOS-compatible interface, providing protection and diagnostics.

The device integrates advanced protective functions such as load current limitation, overload active management by power limitation and overtemperature shutdown.

A sense enable pin allows OFF-state diagnosis to be disabled during the module low-power mode as well as external sense resistor sharing among similar devices.

**Table 1. Device summary**

Package	Order codes	
	Tube	Tape and reel
Octapak	VN7004AH-E	VN7004AHTR-E

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# 1 Block diagram and pin description

Figure 1. Block diagram

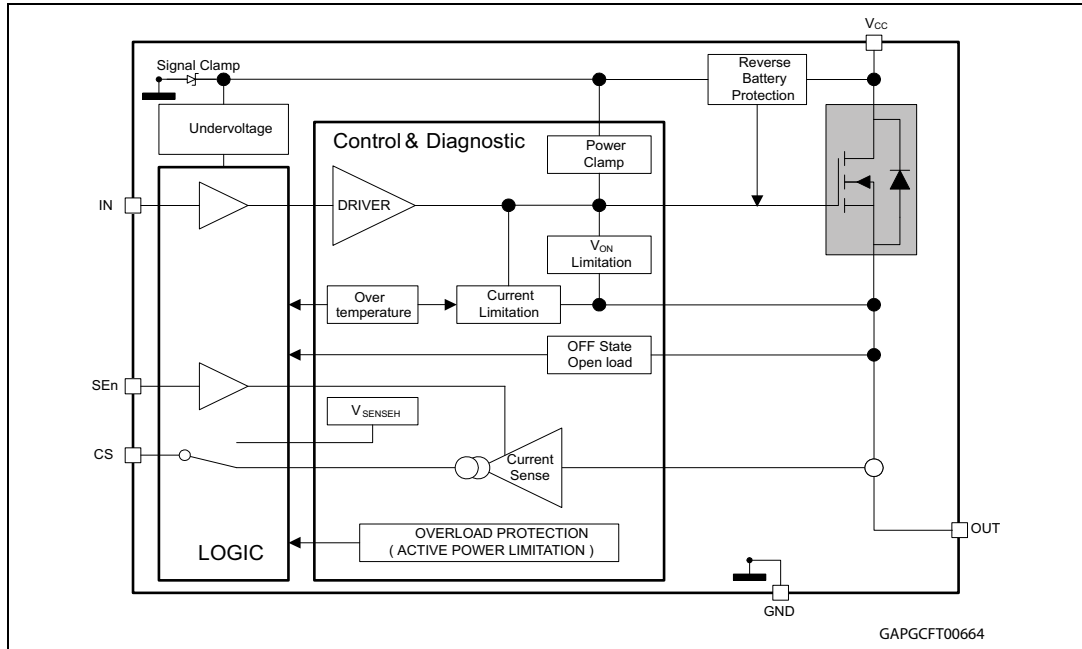


Table 2. Pin functions

Name	Function
V <sub>CC</sub>	Battery connection.
OUTPUT	Power outputs. All the pins must be connected together.
GND	Ground connection.
INPUT	Voltage controlled input pin with hysteresis. Compatible with 3 V and 5 V CMOS outputs. It controls output switch state.
CS	Analog current sense output pin delivers a current proportional to the load current.
SEn	Active high compatible with 3 V and 5 V CMOS outputs pin; it enables the CurrentSense diagnostic pin.

Figure 2. Configuration diagram (top view)

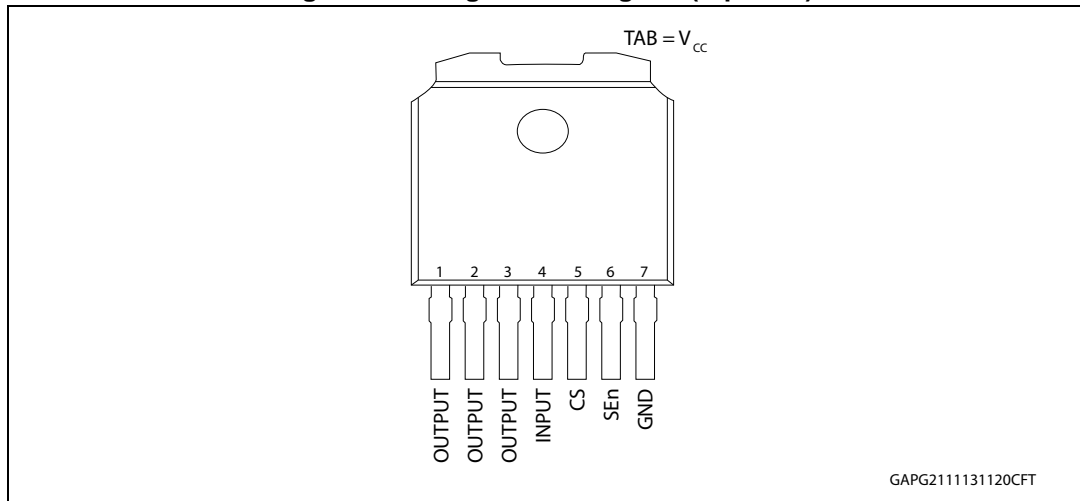


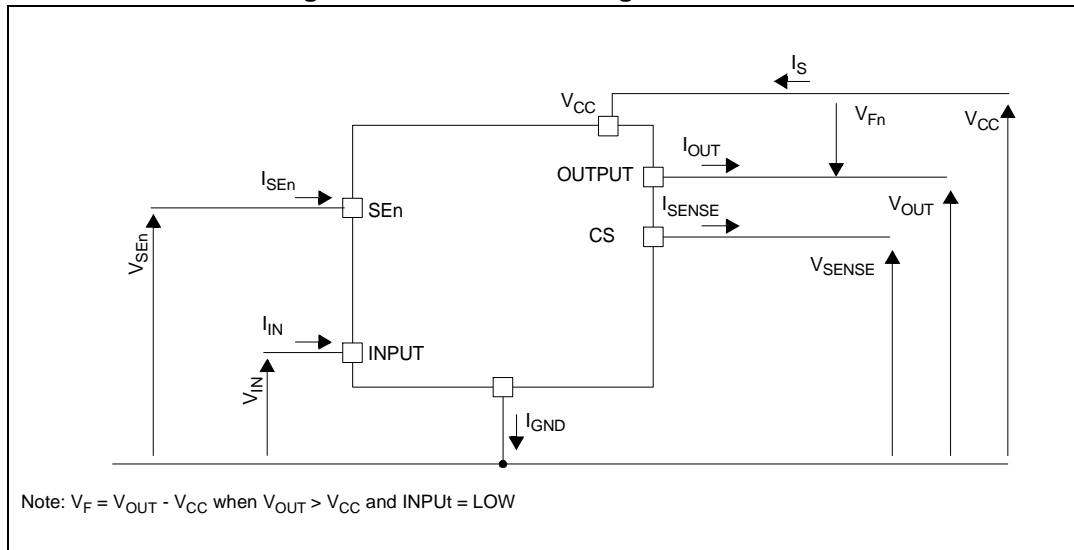
Table 3. Suggested connections for unused and not connected pins

Connection / pin	CurrentSense	N.C.	Output	Input	SEn
Floating	Not allowed	X <sup>(1)</sup>	X	X	X
To ground	Through 1 kΩ resistor	X	Not allowed	Through 15 kΩ resistor	Through 15 kΩ resistor

1. X: do not care.

## 2 Electrical specification

Figure 3. Current and voltage conventions



### 2.1 Absolute maximum ratings

Stressing the device above the rating listed in [Table 4](#) 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.

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
$V_{CC}$	DC supply voltage	38	V
$V_{CC\_LSC}$	Maximum supply voltage for single pulse short circuit protection ( $L \leq 5 \mu H$ ; $R_L \geq 100 m\Omega$ )	18	
$V_{CCPK}$	Maximum transient supply voltage (ISO7637-2:2004 Pulse 5b level IV clamped to 40 V; $R_L = 4\Omega$ )	40	
$-V_{CC}$	Reverse DC supply voltage	16	
$-I_{GND}$	DC reverse ground pin current	200	mA
$I_{OUT}$	OUTPUT DC output current	Internally limited	A
$-I_{OUT}$	Reverse DC output current	65	
$I_{IN}$	INPUT DC input current	-1 to 10	mA
$I_{SEn}$	SEn DC input current		
$I_{SENSE}$	CS pin DC output current ( $V_{GND} = V_{CC}$ and $V_{SENSE} < 0 V$ )	10	mA
	CS pin DC output current in reverse ( $V_{CC} < 0 V$ )	-20	

Table 4. Absolute maximum ratings (continued)

Symbol	Parameter	Value	Unit
$E_{MAX}$	Maximum switching energy (single pulse) $T_{DEMAG} = 0.4 \text{ ms}$ ; $I_{OUT} = 19 \text{ A}$ ; $T_{jstart} = 150^\circ\text{C}$	165	mJ
$V_{ESD}$	Electrostatic discharge (JEDEC 22A-114F)		
	– INPUT	4000	V
	– CurrentSense	2000	V
	– SEn	4000	V
	– OUTPUT	4000	V
	– $V_{CC}$	4000	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	

## 2.2 Thermal data

Table 5. Thermal data

Symbol	Parameter	Typ. value	Unit
$R_{thj-board}$	Thermal resistance junction-board <sup>(1)</sup>	2.1	°C/W
$R_{thj-amb}$	Thermal resistance junction-ambient (JEDEC JESD 51-5) <sup>(2)</sup>	57.9	
$R_{thj-amb}$	Thermal resistance junction-ambient (JEDEC JESD 51-7) <sup>(1)</sup>	15.4	

1. Device mounted on four-layers 2s2p PCB
2. Device mounted on two-layers 2s0p PCB with 2 cm<sup>2</sup> heatsink copper trace



## 2.3 Electrical characteristics

$7\text{ V} < V_{CC} < 28\text{ V}$ ;  $-40^\circ\text{C} < T_j < 150^\circ\text{C}$ , unless otherwise specified.

All typical values refer to  $V_{CC} = 13\text{ V}$ ;  $T_j = 25^\circ\text{C}$ , unless otherwise specified.

**Table 6. Power section**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{CC}$	Operating supply voltage		4	13	28	V
$V_{USD}$	Undervoltage shutdown				4	
$V_{USDReset}$	Undervoltage shutdown reset				5	
$V_{USDhyst}$	Undervoltage shutdown hysteresis			0.3		
$R_{ON}$	On-state resistance	$I_{OUT} = 15\text{ A}$ ; $T_j = 25^\circ\text{C}$		4.9		m $\Omega$
		$I_{OUT} = 15\text{ A}$ ; $T_j = 150^\circ\text{C}$			9	
		$I_{OUT} = 15\text{ A}$ ; $V_{CC} = 4\text{ V}$ ; $T_j = 25^\circ\text{C}$			6	
$R_{ON\_Rev}$	$R_{DSON}$ in reverse battery condition	$V_{CC} = -13\text{ V}$ ; $I_{OUT} = -15\text{ A}$ ; $T_j = 25^\circ\text{C}$		4.9		m $\Omega$
$V_{clamp}$	Clamp voltage	$I_S = 20\text{ mA}$ ; $T_j = -40^\circ\text{C}$	38			V
		$I_S = 20\text{ mA}$ ; $25^\circ\text{C} < T_j < 150^\circ\text{C}$	41	46	52	
$I_{STBY}$	Supply current in standby at $V_{CC} = 13\text{ V}$ (1)	$V_{CC} = 13\text{ V}$ ; $V_{IN} = V_{OUT} = V_{SEn} = 0\text{ V}$ ; $T_j = 25^\circ\text{C}$			0.5	$\mu\text{A}$
		$V_{CC} = 13\text{ V}$ ; $V_{IN} = V_{OUT} = V_{SEn} = 0\text{ V}$ ; $T_j = 85^\circ\text{C}$ (2)			0.5	$\mu\text{A}$
		$V_{CC} = 13\text{ V}$ ; $V_{IN} = V_{OUT} = V_{SEn} = 0\text{ V}$ ; $T_j = 125^\circ\text{C}$			3	$\mu\text{A}$
$t_{D\_STBY}$	Standby mode blanking time	$V_{CC} = 13\text{ V}$ ; $V_{IN} = 5\text{ V}$ ; $V_{SEn} = 0\text{ V}$ ; $I_{OUT} = 0\text{ A}$	60	300	550	$\mu\text{s}$
$I_{S(ON)}$	Supply current	$V_{CC} = 13\text{ V}$ ; $V_{SEn} = 0\text{ V}$ ; $V_{IN} = 5\text{ V}$ ; $I_{OUT} = 0\text{ A}$		4	6.5	mA
$I_{GND(ON)}$	Control stage current consumption in ON-state. All channels active.	$V_{CC} = 13\text{ V}$ ; $V_{SEn} = 5\text{ V}$ ; $V_{IN} = 5\text{ V}$ ; $I_{OUT} = 15\text{ A}$			9	mA
$I_{L(off)}$	Off-state output current at $V_{CC} = 13\text{ V}$	$V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ ; $T_j = 25^\circ\text{C}$	0	0.01	0.5	$\mu\text{A}$
		$V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ ; $T_j = 125^\circ\text{C}$	0		3	
$V_F$	Output - $V_{CC}$ diode voltage	$I_{OUT} = -15\text{ A}$ ; $T_j = 150^\circ\text{C}$			0.7	V

1. PowerMOS leakage included.

2. Parameter specified by design; not subject to production test.

**Table 7. Switching ( $V_{CC} = 13\text{ V}$ ;  $-40\text{ °C} < T_j < 150\text{ °C}$ , unless otherwise specified)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}^{(1)}$	Turn-on delay time at $T_j = 25\text{ °C}$	$R_L = 0.87\ \Omega$	10	70	120	$\mu\text{s}$
$t_{d(off)}^{(1)}$	Turn-off delay time at $T_j = 25\text{ °C}$		10	44	100	
$(dV_{OUT}/dt)_{on}^{(1)}$	Turn-on voltage slope at $T_j = 25\text{ °C}$	$R_L = 0.87\ \Omega$	0.1	0.47	0.8	$\text{V}/\mu\text{s}$
$(dV_{OUT}/dt)_{off}^{(1)}$	Turn-off voltage slope at $T_j = 25\text{ °C}$		0.1	0.49	0.8	
$W_{ON}$	Switching energy losses at turn-on ( $t_{won}$ )	$R_L = 0.87\ \Omega$	—	1.6	2.7 <sup>(2)</sup>	mJ
$W_{OFF}$	Switching energy losses at turn-off ( $t_{woff}$ )	$R_L = 0.87\ \Omega$	—	1.7	2.7 <sup>(2)</sup>	mJ
$t_{SKEW}^{(1)}$	Differential Pulse skew ( $t_{PHL} - t_{PLH}$ )	$R_L = 0.87\ \Omega$	-30	20	70	$\mu\text{s}$

1. See [Figure 6: Switching times and Pulse skew](#).

2. Parameter guaranteed by design and characterization; not subject to production test.

**Table 8. Logic Inputs ( $7\text{ V} < V_{CC} < 28\text{ V}$ ;  $-40\text{ °C} < T_j < 150\text{ °C}$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
<b>INPUT characteristics</b>						
$V_{IL}$	Input low level voltage				0.9	V
$I_{IL}$	Low level input current	$V_{IN} = 0.9\text{ V}$	1			$\mu\text{A}$
$V_{IH}$	Input high level voltage		2.1			V
$I_{IH}$	High level input current	$V_{IN} = 2.1\text{ V}$			10	$\mu\text{A}$
$V_{I(hyst)}$	Input hysteresis voltage		0.2			V
$V_{ICL}$	Input clamp voltage	$I_{IN} = 1\text{ mA}$	5.3		7.5	V
		$I_{IN} = -1\text{ mA}$		-0.7		
<b>SEn characteristics (<math>7\text{ V} &lt; V_{CC} &lt; 18\text{ V}</math>)</b>						
$V_{SEnL}$	Input low level voltage				0.9	V
$I_{SEnL}$	Low level input current	$V_{IN} = 0.9\text{ V}$	1			$\mu\text{A}$
$V_{SEnH}$	Input high level voltage		2.1			V
$I_{SEnH}$	High level input current	$V_{IN} = 2.1\text{ V}$			10	$\mu\text{A}$
$V_{SEn(hyst)}$	Input hysteresis voltage		0.2			V
$V_{SEnCL}$	Input clamp voltage	$I_{IN} = 1\text{ mA}$	5.3		7.5	V
		$I_{IN} = -1\text{ mA}$		-0.7		

Table 9. Protections (7 V < V<sub>CC</sub> < 18 V; -40 °C < T<sub>j</sub> < 150 °C)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I <sub>LIMH</sub> <sup>(1)</sup>	DC short circuit current	V <sub>CC</sub> = 13 V; V <sub>DS</sub> = 5 V	70	150	230	A
		4 V < V <sub>CC</sub> < 18 V; V <sub>DS</sub> = 5 V <sup>(2)</sup>			230	
I <sub>LIML</sub>	Short circuit current during thermal cycling	V <sub>CC</sub> = 13 V; T <sub>R</sub> < T <sub>j</sub> < T <sub>TSD</sub>		38		
T <sub>TSD</sub>	Shutdown temperature		150	175	200	°C
T <sub>R</sub>	Reset temperature <sup>(2)</sup>		T <sub>RS</sub> + 1	T <sub>RS</sub> + 7		
T <sub>RS</sub>	Thermal reset of fault diagnostic indication	V <sub>SEn</sub> = 5 V;	135			
T <sub>HYST</sub>	Thermal hysteresis (T <sub>TSD</sub> - T <sub>R</sub> ) <sup>(2)</sup>			7		
ΔT <sub>J_SD</sub>	Dynamic temperature	T <sub>j</sub> = -40°C; V <sub>CC</sub> = 13 V		60		K
V <sub>DEMAG</sub>	Turn-off output voltage clamp	I <sub>OUT</sub> = 2 A; L = 6 mH; T <sub>j</sub> = -40°C	V <sub>CC</sub> - 38			V
		I <sub>OUT</sub> = 2 A; L = 6 mH; T <sub>j</sub> = 25°C to 150°C	V <sub>CC</sub> - 41	V <sub>CC</sub> - 46	V <sub>CC</sub> - 52	V
V <sub>ON</sub>	Output voltage drop limitation	I <sub>OUT</sub> = 2.5 A		20		mV

1. Parameter guaranteed by an indirect test sequence.

2. Parameter guaranteed by design and characterization; not subject to production test.

Table 10. CurrentSense (7 V < V<sub>CC</sub> < 18 V; -40 °C < T<sub>j</sub> < 150 °C)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V <sub>SENSE_CL</sub>	CurrentSense clamp voltage	V <sub>SEn</sub> = 0 V; I <sub>SENSE</sub> = 1 mA	-17		-12	V
		V <sub>SEn</sub> = 0 V; I <sub>SENSE</sub> = -1 mA		7		V
<b>Current Sense characteristics</b>						
K <sub>1</sub>	I <sub>OUT</sub> /I <sub>SENSE</sub>	I <sub>OUT</sub> = 10 A; V <sub>SENSE</sub> = 4 V; V <sub>SEn</sub> = 5 V	6640	16300	28000	
dK <sub>1</sub> /K <sub>1</sub> <sup>(1)(2)</sup>	Current sense ratio drift	I <sub>OUT</sub> = 10 A; V <sub>SENSE</sub> = 4 V; V <sub>SEn</sub> = 5 V	-25		25	%
K <sub>2</sub>	I <sub>OUT</sub> /I <sub>SENSE</sub>	I <sub>OUT</sub> = 15 A; V <sub>SENSE</sub> = 4 V; V <sub>SEn</sub> = 5 V	10600	15650	21050	
dK <sub>2</sub> /K <sub>2</sub> <sup>(1)(2)</sup>	Current sense ratio drift	I <sub>OUT</sub> = 15 A; V <sub>SENSE</sub> = 4 V; V <sub>SEn</sub> = 5 V	-11		11	%
K <sub>3</sub>	I <sub>OUT</sub> /I <sub>SENSE</sub>	I <sub>OUT</sub> = 45 A; V <sub>SENSE</sub> = 4 V; V <sub>SEn</sub> = 5 V	10500	15500	20500	
dK <sub>3</sub> /K <sub>3</sub> <sup>(1)(2)</sup>	Current sense ratio drift	I <sub>OUT</sub> = 45 A; V <sub>SENSE</sub> = 4 V; V <sub>SEn</sub> = 5 V	-7		7	%

Table 10. CurrentSense (7 V < V<sub>CC</sub> < 18 V; -40 °C < T<sub>j</sub> < 150 °C) (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I <sub>SENSE0</sub>	CurrentSense leakage current	CurrentSense disabled: V <sub>SEn</sub> = 0 V;	0		0.5	μA
		CurrentSense disabled; -1 V < V <sub>SENSE</sub> < 5 V <sup>(1)</sup>	-0.5		0.5	μA
		CurrentSense enabled: V <sub>SEn</sub> = 5 V; V <sub>IN</sub> = 5 V; I <sub>OUT</sub> = 0 A;	0		2	μA
V <sub>OUT_CSD</sub> <sup>(1)</sup>	Output voltage for CurrentSense shutdown	V <sub>SEn</sub> = 5 V; R <sub>SENSE</sub> = 2.7 kΩ; V <sub>IN</sub> = 5 V; I <sub>OUT</sub> = 15 A		5		V
V <sub>SENSE_SAT</sub>	CurrentSense saturation voltage	V <sub>CC</sub> = 7 V; R <sub>SENSE</sub> = 2.7 kΩ; V <sub>SEn</sub> = 5 V; V <sub>IN</sub> = 5 V; I <sub>OUT</sub> = 45 A; T <sub>j</sub> = 150°C	5			V
I <sub>SENSE_SAT</sub> <sup>(1)</sup>	CS saturation current	V <sub>CC</sub> = 7 V; V <sub>SENSE</sub> = 4 V; V <sub>IN</sub> = 5 V; V <sub>SEn</sub> = 5 V; T <sub>j</sub> = 150°C	4			mA
I <sub>OUT_SAT</sub> <sup>(1)</sup>	Output saturation current	V <sub>CC</sub> = 7 V; V <sub>SENSE</sub> = 4 V; V <sub>IN</sub> = 5 V; V <sub>SEn</sub> = 5 V; T <sub>j</sub> = 150°C	80			A
<b>OFF-state diagnostic</b>						
V <sub>OL</sub>	OFF-state open-load voltage detection threshold	V <sub>IN</sub> = 0 V; V <sub>SEn</sub> = 5 V;	2	3	4	V
I <sub>L(off2)</sub>	OFF-state output sink current	V <sub>IN</sub> = 0 V; V <sub>OUT</sub> = V <sub>OL</sub> ; T <sub>j</sub> = -40°C to 125°C	-100		-15	μA
t <sub>DSTKON</sub>	OFF-state diagnostic delay time from falling edge of INPUT (see Figure 7)	V <sub>IN</sub> = 5 V to 0 V; V <sub>SEn</sub> = 5 V; I <sub>OUT</sub> = 0 A; V <sub>OUT</sub> = 4 V	100	350	700	μs
t <sub>D_OL_V</sub>	Settling time for valid OFF-state open load diagnostic indication from rising edge of SEN	V <sub>IN</sub> = 0 V; V <sub>OUT</sub> = 4 V; V <sub>SEn</sub> = 0 V to 5 V			60	μs
t <sub>D_VOL</sub>	OFF-state diagnostic delay time from rising edge of V <sub>OUT</sub>	V <sub>IN</sub> = 0 V; V <sub>SEn</sub> = 5 V; V <sub>OUT</sub> = 0 V to 4 V		5	30	μs
<b>Fault diagnostic feedback (see Table 11)</b>						
V <sub>SENSEH</sub>	CurrentSense output voltage in fault condition	V <sub>CC</sub> = 13 V; V <sub>IN</sub> = 0 V; V <sub>SEn</sub> = 5 V; I <sub>OUT</sub> = 0 A; V <sub>OUT</sub> = 4 V; R <sub>SENSE</sub> = 1 kΩ	5		6.6	V

**Table 10. CurrentSense (7 V < V<sub>CC</sub> < 18 V; -40 °C < T<sub>j</sub> < 150 °C) (continued)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I <sub>SENSEH</sub>	CurrentSense output current in fault condition	V <sub>CC</sub> = 13 V; V <sub>SENSE</sub> = 5 V	7	20	30	mA
<b>CurrentSense timings (current sense mode)</b>						
t <sub>DSENSE1H</sub>	Current sense settling time from rising edge of SEn	V <sub>IN</sub> = 5 V; V <sub>SEn</sub> = 0 V to 5 V; R <sub>SENSE</sub> = 1 kΩ; R <sub>L</sub> = 0.87 kΩ			60	μs
t <sub>DSENSE1L</sub>	Current sense disable delay time from falling edge of SEn	V <sub>IN</sub> = 5 V; V <sub>SEn</sub> = 5 V to 0 V; R <sub>SENSE</sub> = 1 kΩ; R <sub>L</sub> = 0.87 kΩ		5	20	μs
t <sub>DSENSE2H</sub>	Current sense settling time from rising edge of INPUT	V <sub>IN</sub> = 0 V to 5 V; V <sub>SEn</sub> = 5 V; R <sub>SENSE</sub> = 1 kΩ; R <sub>L</sub> = 0.87 kΩ		100	300	μs
Δt <sub>DSENSE2H</sub>	Current sense settling time from rising edge of I <sub>OUT</sub> (dynamic response to a step change of I <sub>OUT</sub> )	V <sub>IN</sub> = 5 V; V <sub>SEn</sub> = 5 V; R <sub>SENSE</sub> = 1 kΩ; I <sub>SENSE</sub> = 90% of I <sub>SENSEMAX</sub> ; R <sub>L</sub> = 0.87 kΩ			200	μs
t <sub>DSENSE2L</sub>	Current sense turn-off delay time from falling edge of INPUT	V <sub>IN</sub> = 5 V to 0 V; V <sub>SEn</sub> = 5 V; R <sub>SENSE</sub> = 1 kΩ; R <sub>L</sub> = 0.87 kΩ		50	250	μs

1. Parameter guaranteed by design and characterization; not subject to production test.
2. All values refer to V<sub>CC</sub> = 13 V; T<sub>j</sub> = 25°C, unless otherwise specified.

**Figure 4. I<sub>OUT</sub>/I<sub>SENSE</sub> versus I<sub>OUT</sub>**

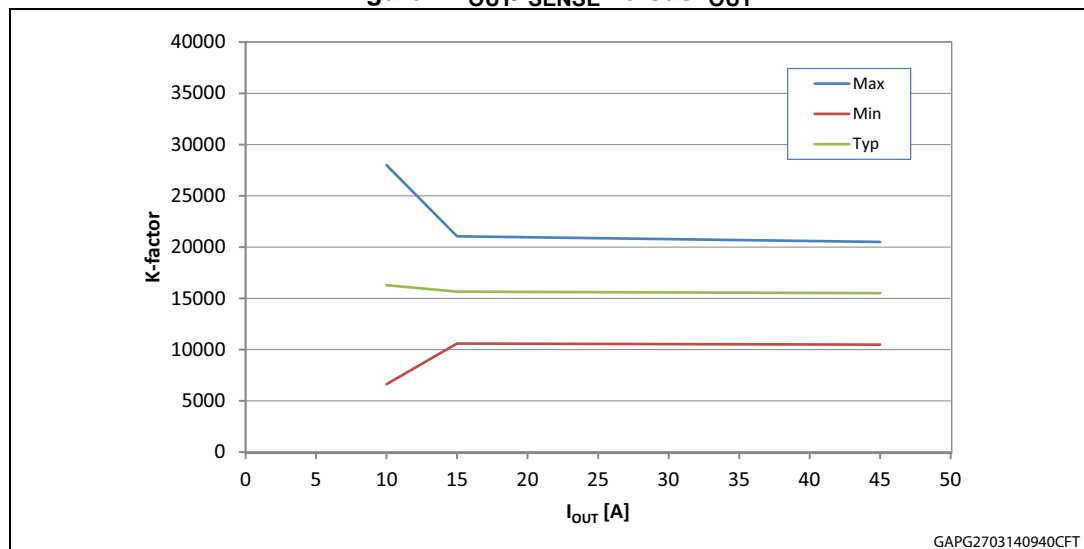


Figure 5. Current sense precision vs.  $I_{OUT}$

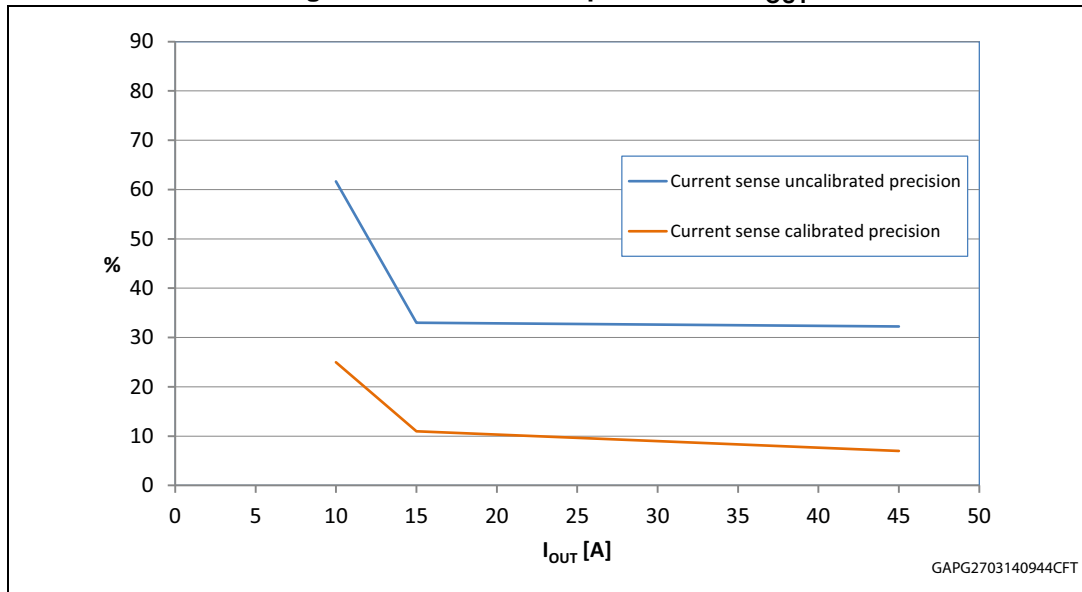


Figure 6. Switching times and Pulse skew

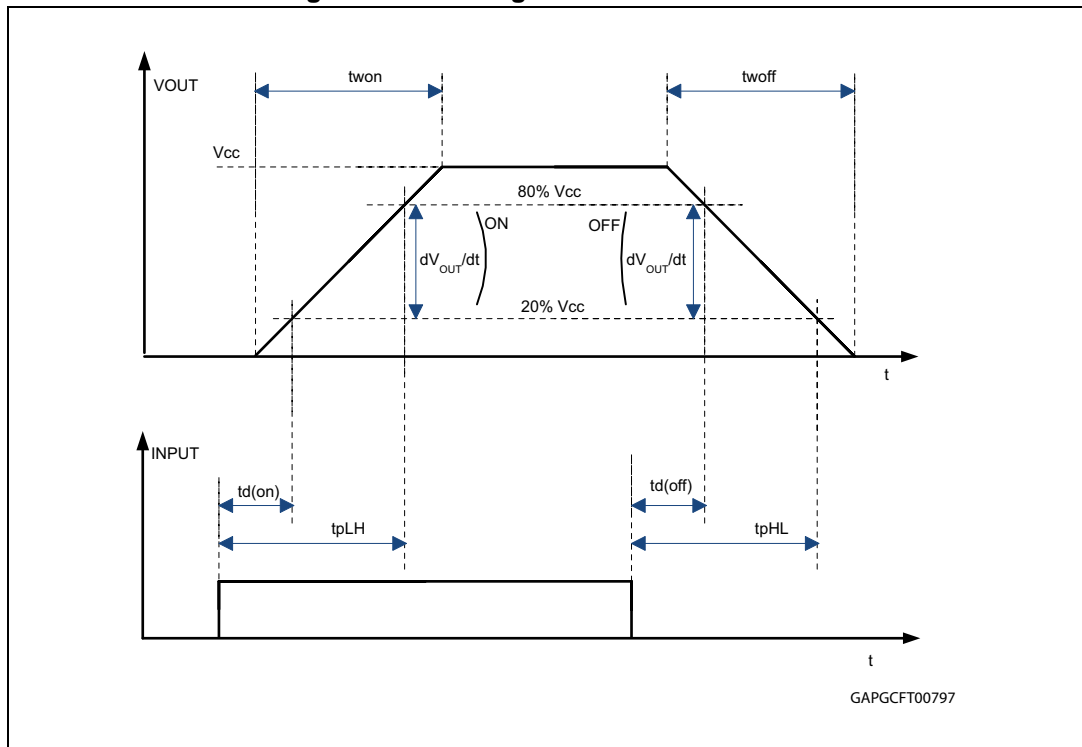


Figure 7.  $T_{DSTKON}$

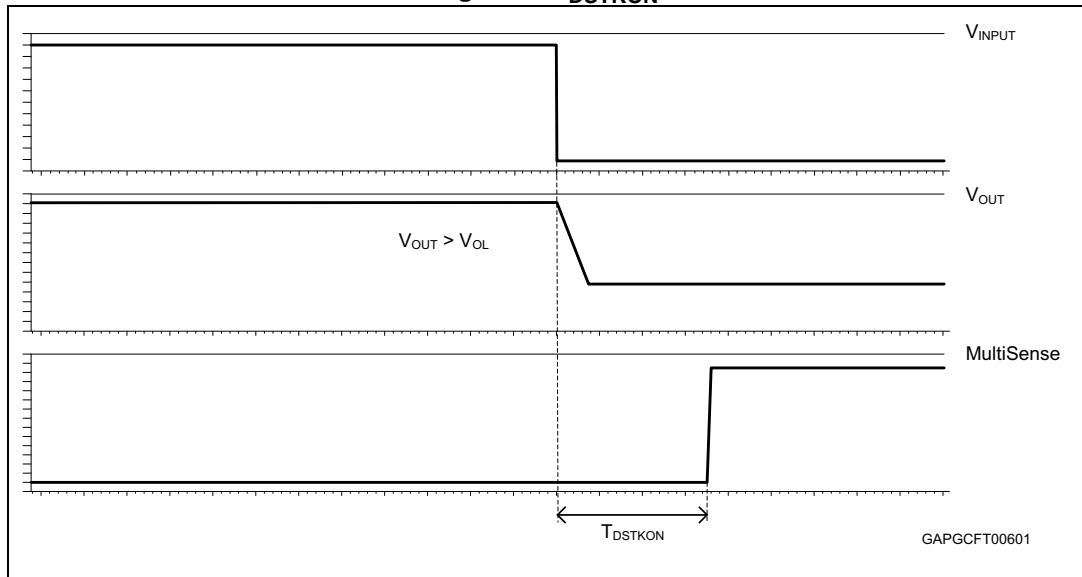


Table 11. Truth table

Mode	Conditions	$IN_x$	SEn	$OUT_x$	Current Sense	Comments
Stand by	All logic inputs low	L	L	L	Hi-Z	Low quiescent current consumption
Normal	Nominal load connected; $T_j < 150^\circ\text{C}$	L	H	L	0	
		H	L	H	Hi-Z	
		H	H	H	$I_{SENSE} = 1/K * I_{OUT}$	
Overload	Overload or short to GND causing: $T_j > T_{TSD}$ or $\Delta T_j > \Delta T_{j\_SD}$	H	L	H	Hi-Z	Output cycles with temperature hysteresis
		H	H	H	$V_{SENSEH}$	
Under-voltage	$V_{CC} < V_{USD}$ (falling)	X	X	L L	Hi-Z Hi-Z	Re-start when $V_{CC} > V_{USD} + V_{USDphys\_t}$ (rising)
OFF-state diagnostics	Short to $V_{CC}$	L	H	H	$V_{SENSEH}$	
	Open-load	L	H	H		External pull-up
Negative output voltage	Inductive loads turn-off	L	X	$< 0\text{ V}$	0	

## 2.4 Electrical characteristics curves

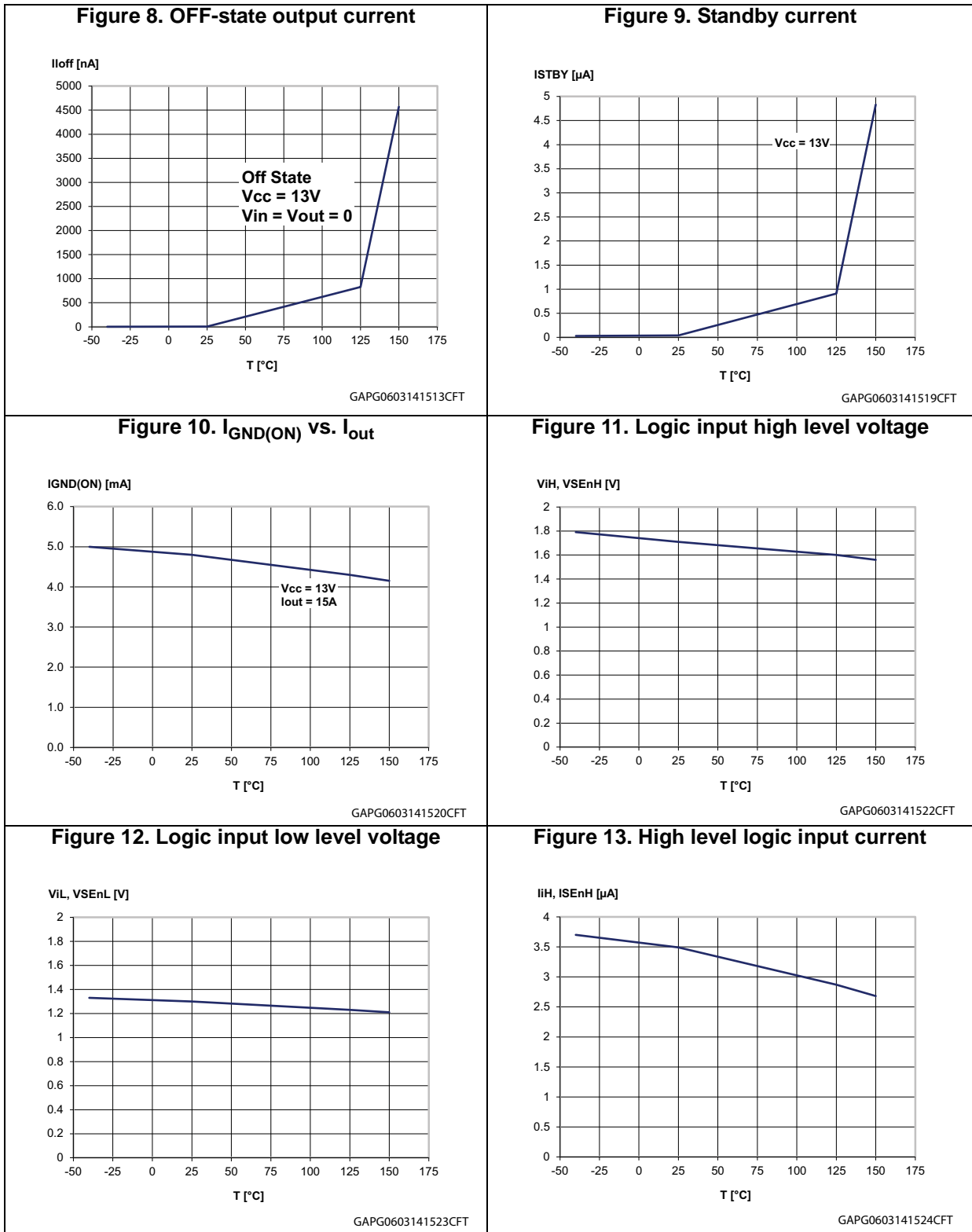
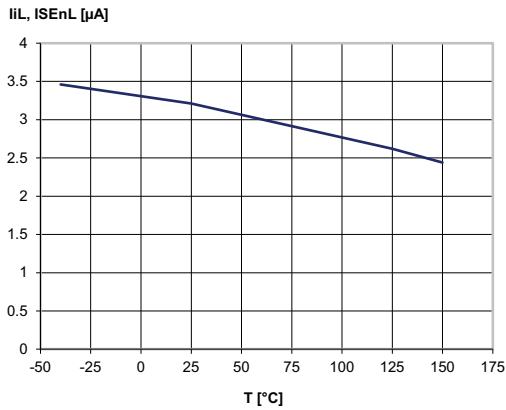


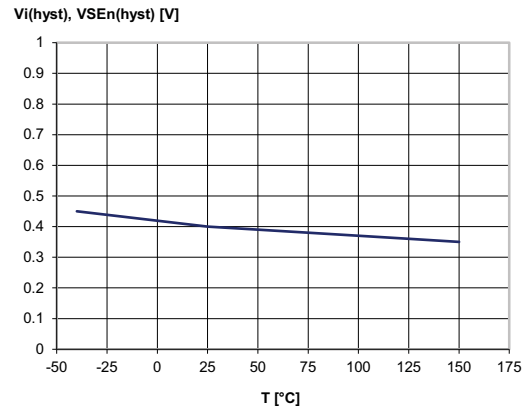


Figure 14. Low level logic input current



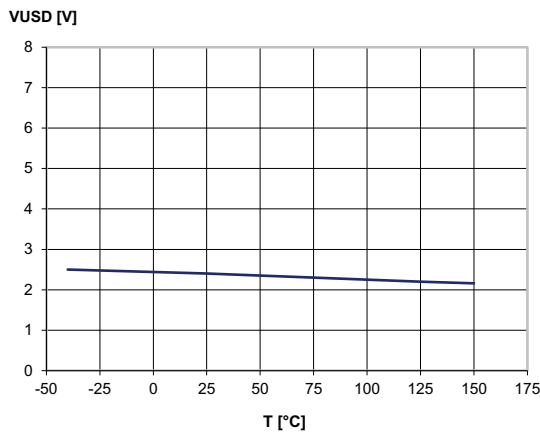
GAPG0603141526CFT

Figure 15. Logic Input hysteresis voltage



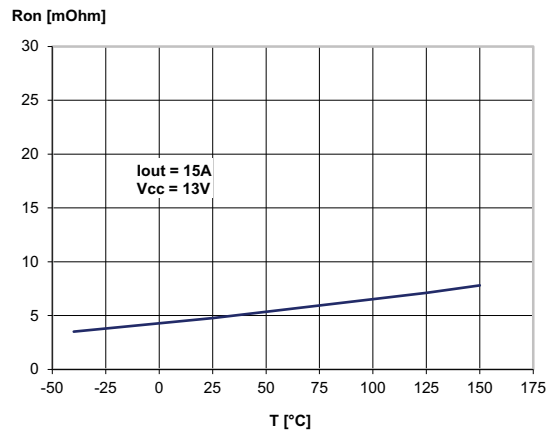
GAPG0603141520CFT

Figure 16. Undervoltage shutdown



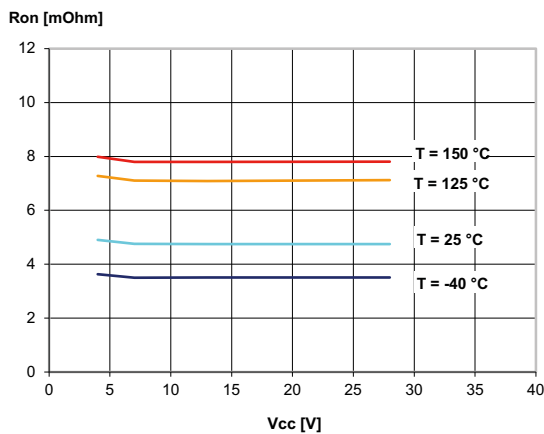
GAPG0603141541CFT

Figure 17. On-state resistance vs. T<sub>case</sub>



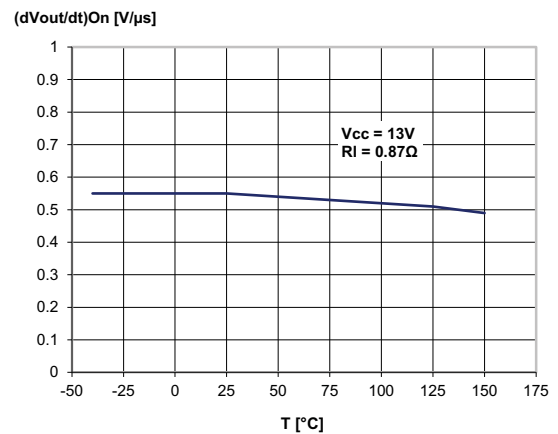
GAPG0603141542CFT

Figure 18. On-state resistance vs. V<sub>CC</sub>

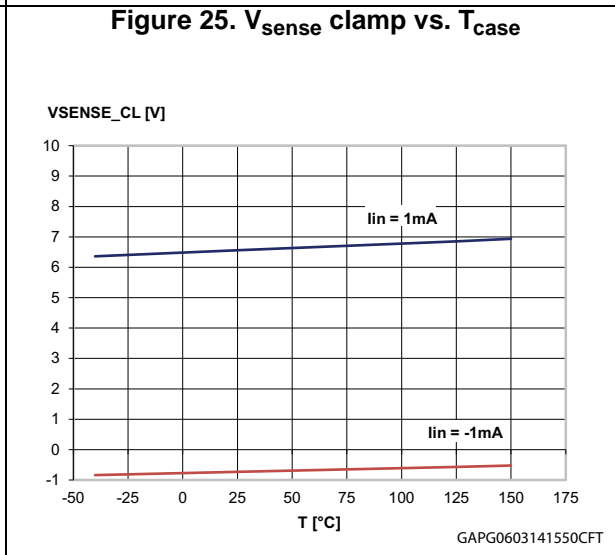
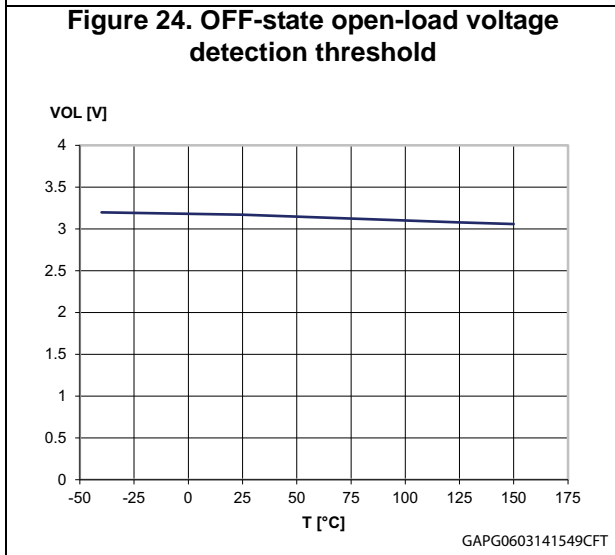
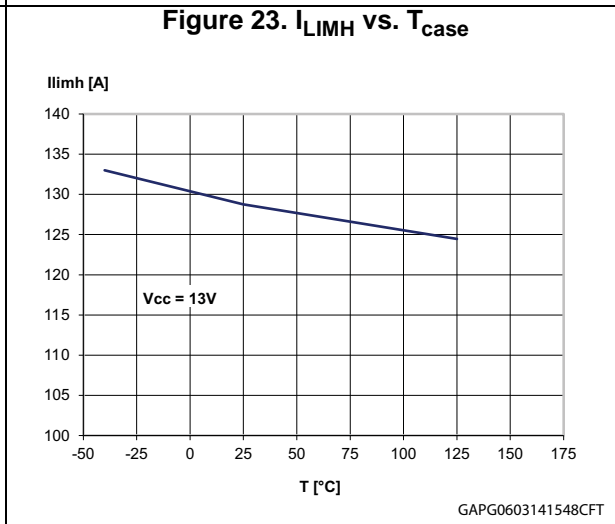
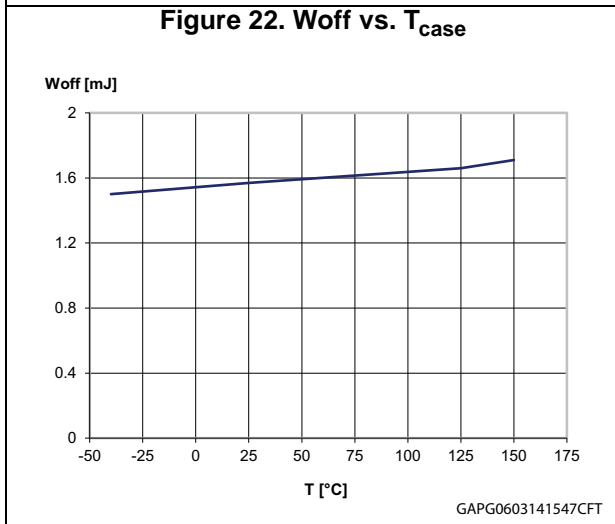
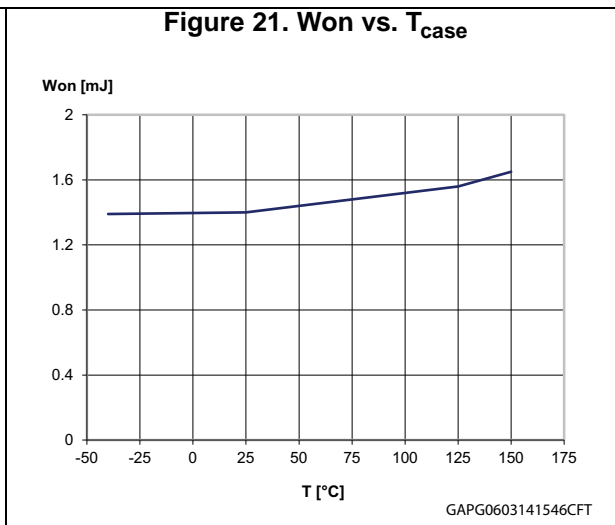
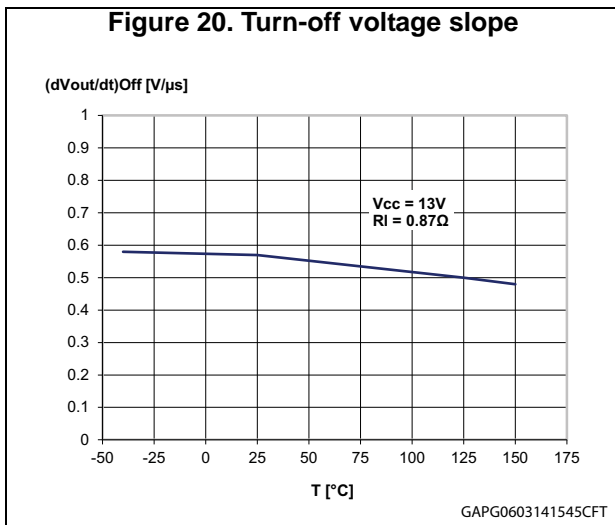


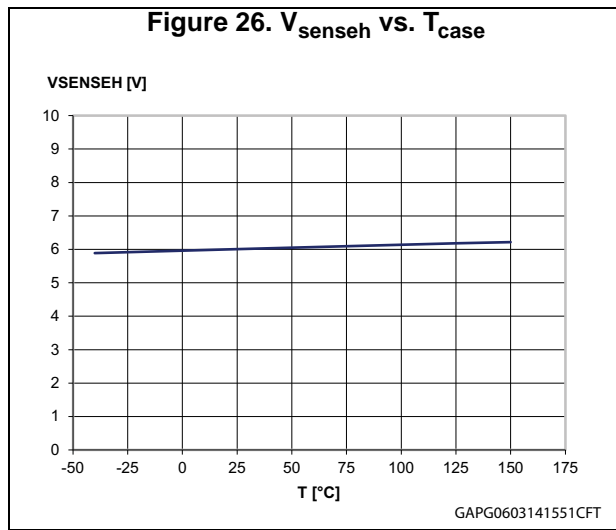
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Figure 19. Turn-on voltage slope



GAPG0603141544CFT





## 3 Protections

### 3.1 Power limitation

The basic working principle of this protection consists of an indirect measurement of the junction temperature swing  $\Delta T_j$  through the direct measurement of the spatial temperature gradient on the device surface in order to automatically shut off the output MOSFET as soon as  $\Delta T_j$  exceeds the safety level of  $\Delta T_{j\_SD}$ . The protection prevents fast thermal transient effects and, consequently, reduces thermo-mechanical fatigue.

### 3.2 Thermal shutdown

In case the junction temperature of the device exceeds the maximum allowed threshold (typically 175°C), it automatically switches off and the diagnostic indication is triggered. The device switches on again as soon as its junction temperature drops to  $T_R$  (see [Table 9](#)).

### 3.3 Current limitation

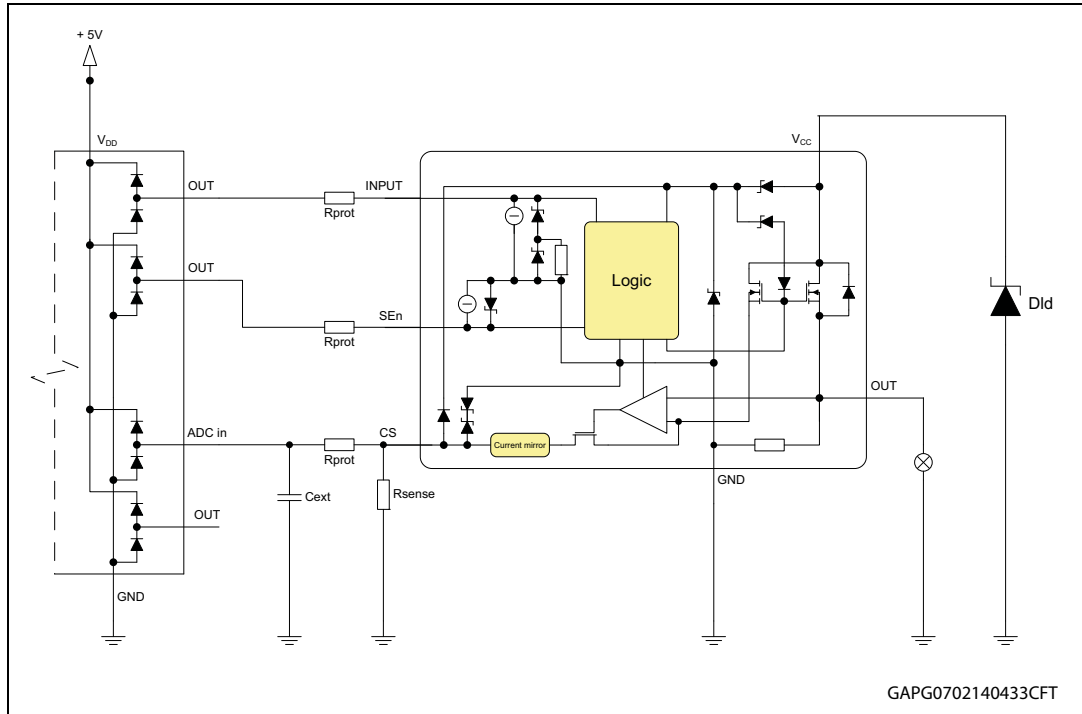
The device is equipped with an output current limiter in order to protect the silicon as well as the other components of the system (e.g. bonding wires, wiring harness, connectors, loads, etc.) from excessive current flow. Consequently, in case of short circuit, overload or during load power-up, the output current is clamped to a safety level,  $I_{LIMH}$ , by operating the output power MOSFET in the active region.

### 3.4 Negative voltage clamp

In case the device drives inductive load, the output voltage reaches negative value during turn off. A negative voltage clamp structure limits the maximum negative voltage to a certain value,  $V_{DEMAG}$  (see [Table 9](#)), allowing the inductor energy to be dissipated without damaging the device.

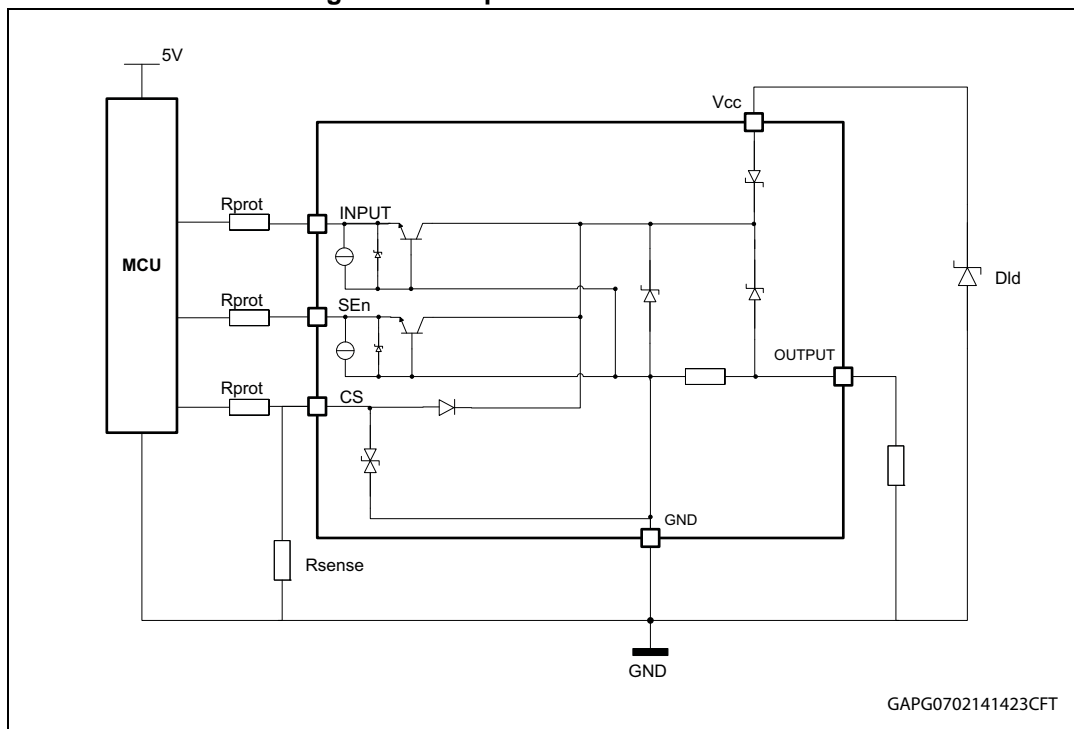
## 4 Application information

Figure 27. Application diagram



## 4.1 Protection against reverse battery

Figure 28. Simplified internal structure



The device does not need any external components to protect the internal logic in case of a reverse battery condition. The protection is provided by internal structures.

In addition, due to the fact that the output MOSFET turns on even in reverse battery mode, thus providing the same low ohmic path as in regular operating conditions, no additional power dissipation has to be considered.

## 4.2 Immunity against transient electrical disturbances

The immunity of the device against transient electrical emissions, conducted along the supply lines and injected into the  $V_{CC}$  pin, is tested in accordance with ISO7637-2:2011 (E) and ISO 16750-2:2010.

The related function performance status classification is shown in [Table 12](#).

Test pulses are applied directly to DUT (Device Under Test) both in ON and OFF-state and in accordance to ISO 7637-2:2011(E), chapter 4. The DUT is intended as the present device only, without components and accessed through  $V_{CC}$  and GND terminals.

Status II is defined in ISO 7637-1 Function Performance Status Classification (FPSC) as follows: "The function does not perform as designed during the test but returns automatically to normal operation after the test".

Table 12. ISO 7637-2 - electrical transient conduction along supply line

Test Pulse 2011(E)	Test pulse severity level with Status II functional performance status		Minimum number of pulses or test time	Burst cycle / pulse repetition time		Pulse duration and pulse generator internal impedance
	Level	$U_S^{(1)}$		min	max	
1	III	-112V	500 pulses	0,5 s		2ms, 10 $\Omega$
2a	III	+55V	500 pulses	0,2 s	5 s	50 $\mu$ s, 2 $\Omega$
3a	IV	-220V	1h	90 ms	100 ms	0.1 $\mu$ s, 50 $\Omega$
3b	IV	+150V	1h	90 ms	100 ms	0.1 $\mu$ s, 50 $\Omega$
4 <sup>(2)</sup>	IV	-7V	1 pulse			100ms, 0.01 $\Omega$
<b>Load dump according to ISO 16750-2:2010</b>						
Test B <sup>(3)</sup>		40V	5 pulse	1 min		400ms, 2 $\Omega$

1.  $U_S$  is the peak amplitude as defined for each test pulse in ISO 7637-2:2011(E), chapter 5.6.
2. Test pulse from ISO 7637-2:2004(E).
3. With 40 V external suppressor referred to ground ( $-40^\circ\text{C} < T_j < 150^\circ\text{C}$ ).

### 4.3 MCU I/Os protection

If a ground protection network is used and negative transients are present on the  $V_{CC}$  line, the control pins will be pulled negative. ST suggests to insert a resistor ( $R_{prot}$ ) in line both to prevent the microcontroller I/O pins from latch-up and to protect the HSD inputs.

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

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

Calculation example:

$$\text{For } V_{CCpeak} = -150 \text{ V}; I_{latchup} \geq 20\text{mA}; V_{OH\mu C} \geq 4.5\text{V}$$

$$7.5 \text{ k}\Omega \leq R_{prot} \leq 140 \text{ k}\Omega$$

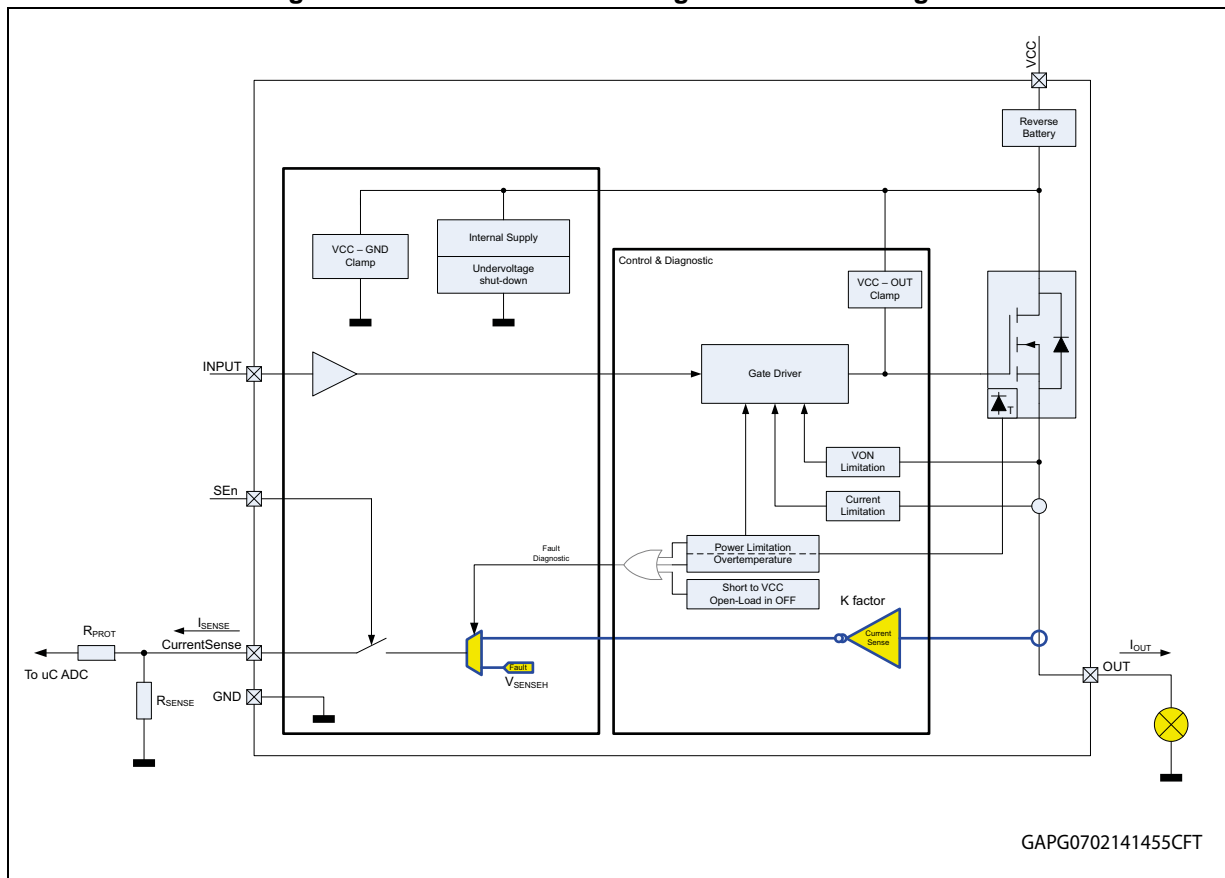
Recommended values:  $R_{prot} = 15 \text{ k}\Omega$

### 4.4 CS - analog current sense

Diagnostic information on device and load status are provided by an analog output pin (CS) delivering the following signal:

- Current monitor: current minitor of channel output current

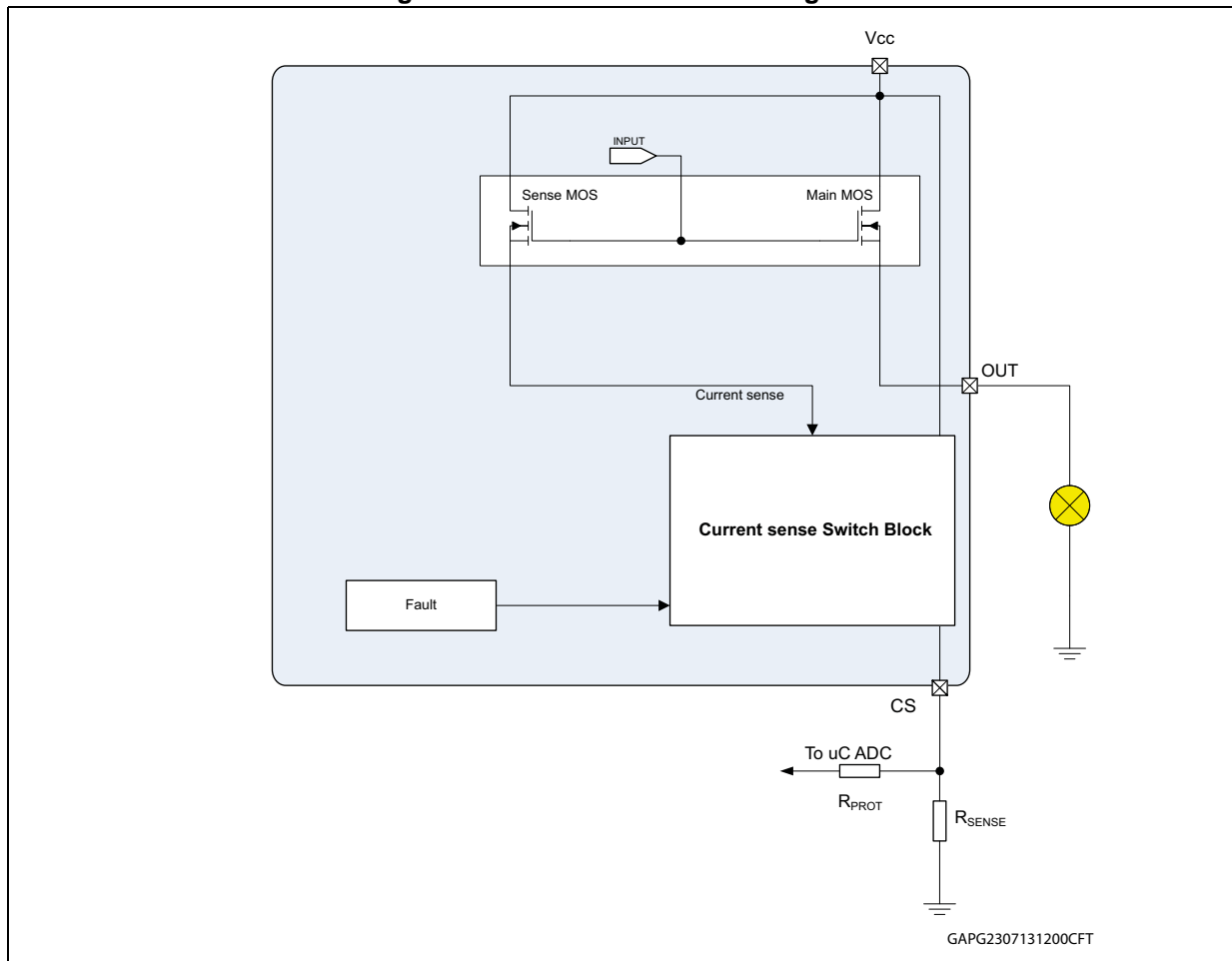
Figure 29. CurrentSense and diagnostic – block diagram





#### 4.4.1 Principle of CurrentSense signal generation

Figure 30. CurrentSense block diagram



##### Current sense

This output is capable of providing:

- **Current mirror proportional to the load current in normal operation**, delivering current proportional to the load according to known ratio named **K**
- **Diagnostics flag in fault conditions** delivering fixed voltage  $V_{SENSEH}$

The current delivered by the current sense circuit,  $I_{SENSE}$ , can be easily converted to a voltage  $V_{SENSE}$  by using an external sense resistor,  $R_{SENSE}$ , allowing continuous load monitoring and abnormal condition detection.

##### Normal operation (channel ON, no fault, SEn active)

While device is operating in normal conditions (no fault intervention),  $V_{SENSE}$  calculation can be done using simple equations

Current provided by CurrentSense output:  $I_{SENSE} = I_{OUT}/K$

Voltage on  $R_{SENSE}$ :  $V_{SENSE} = R_{SENSE} \cdot I_{SENSE} = R_{SENSE} \cdot I_{OUT}/K$



Figure 32. Open-load / short to  $V_{CC}$  condition

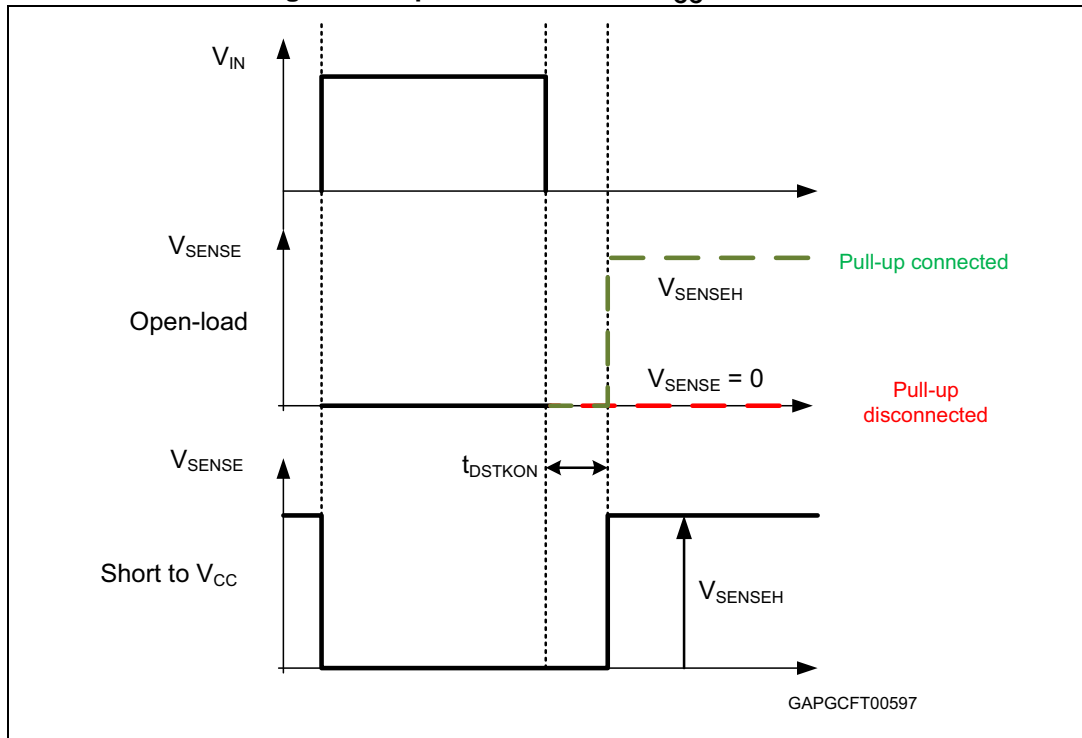


Table 13. CurrentSense pin levels in off-state

Condition	Output	CurrentSense	SEn
Open-load	$V_{OUT} > V_{OL}$	Hi-Z	L
		$V_{SENSEH}$	H
	$V_{OUT} < V_{OL}$	Hi-Z	L
		0	H
Short to $V_{CC}$	$V_{OUT} > V_{OL}$	Hi-Z	L
		$V_{SENSEH}$	H
Nominal	$V_{OUT} < V_{OL}$	Hi-Z	L
		0	H

#### 4.4.2 Short to $V_{CC}$ and OFF-state open-load detection

##### Short to $V_{CC}$

A short circuit between  $V_{CC}$  and output is indicated by the relevant current sense pin set to  $V_{SENSEH}$  during the device off-state. Small or no current is delivered by the current sense during the on-state depending on the nature of the short circuit.

##### OFF-state open-load with external circuitry

Detection of an open-load in off mode requires an external pull-up resistor  $R_{PU}$  connecting the output to a positive supply voltage  $V_{PU}$ .

It is preferable  $V_{PU}$  to be switched off during the module standby mode in order to avoid the overall standby current consumption to increase in normal conditions, i.e. when load is connected.

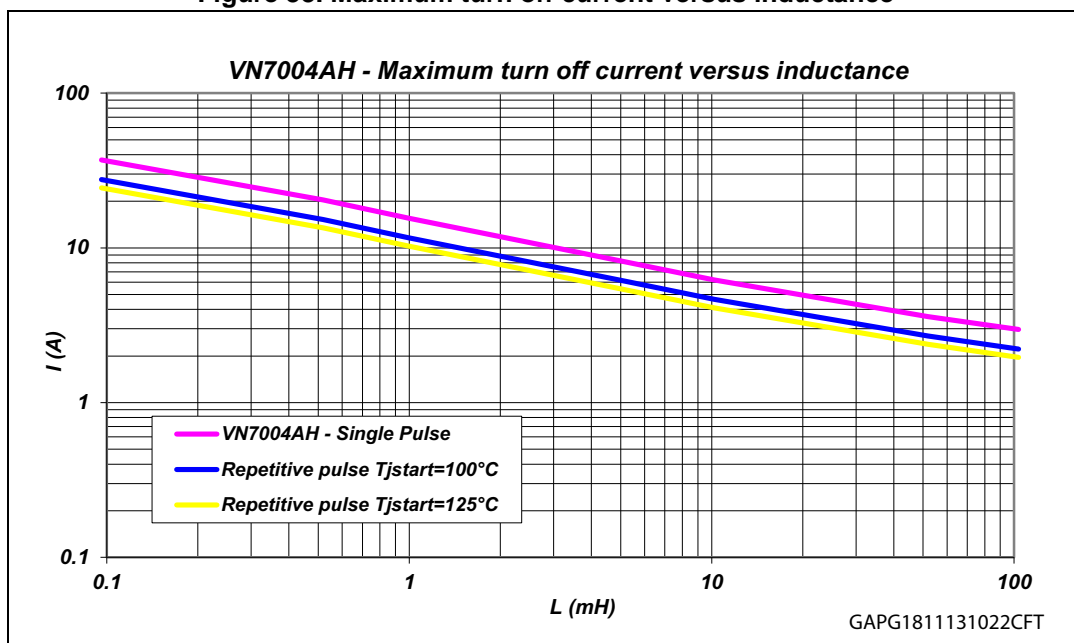
$R_{PU}$  must be selected in order to ensure  $V_{OUT} > V_{OLmax}$  in accordance with the following equation:

**Equation 2**

$$R_{PU} < \frac{V_{PU} - 4}{I_{L(off2)min @ 4V}}$$

**4.5 Maximum demagnetization energy ( $V_{CC} = 16 V$ )**

Figure 33. Maximum turn off current versus inductance



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

## 5 Package and PCB thermal data

### 5.1 Octapak thermal data

Figure 34. Octapak on two-layers PCB (2s0p to JEDEC JESD 51-5)

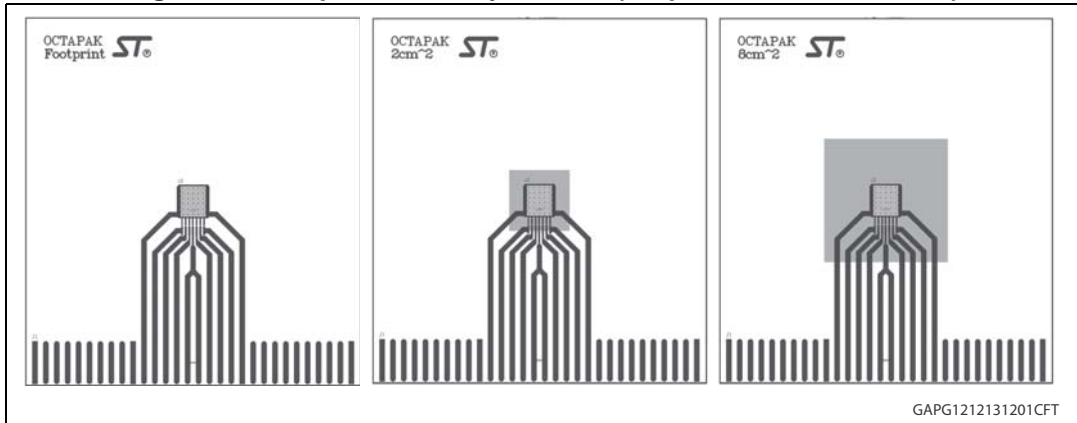


Figure 35. Octapak on four-layers PCB (2s2p to JEDEC JESD 51-7)

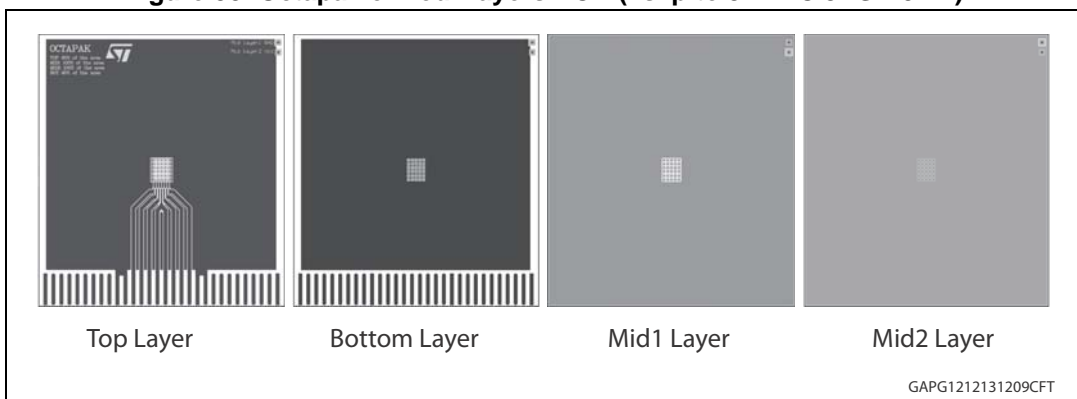


Table 14. PCB properties

Dimension	Value
Board finish thickness	1.6 mm +/- 10%
Board dimension	77 mm x 86 mm
Board Material	FR4
Copper thickness (top and bottom layers)	0.070 mm
Copper thickness (inner layers)	0.035 mm
Thermal via separation	1.2 mm
Thermal via diameter	0.3 mm +/- 0.08 mm
Copper thickness on vias	0.025 mm
Footprint dimension (top layer)	6.4 mm x 7mm
Heatsink copper area dimension (bottom layer)	Footprint, 2 cm <sup>2</sup> or 8 cm <sup>2</sup>

Figure 36.  $R_{thj-amb}$  vs PCB copper area in open box free air conditions

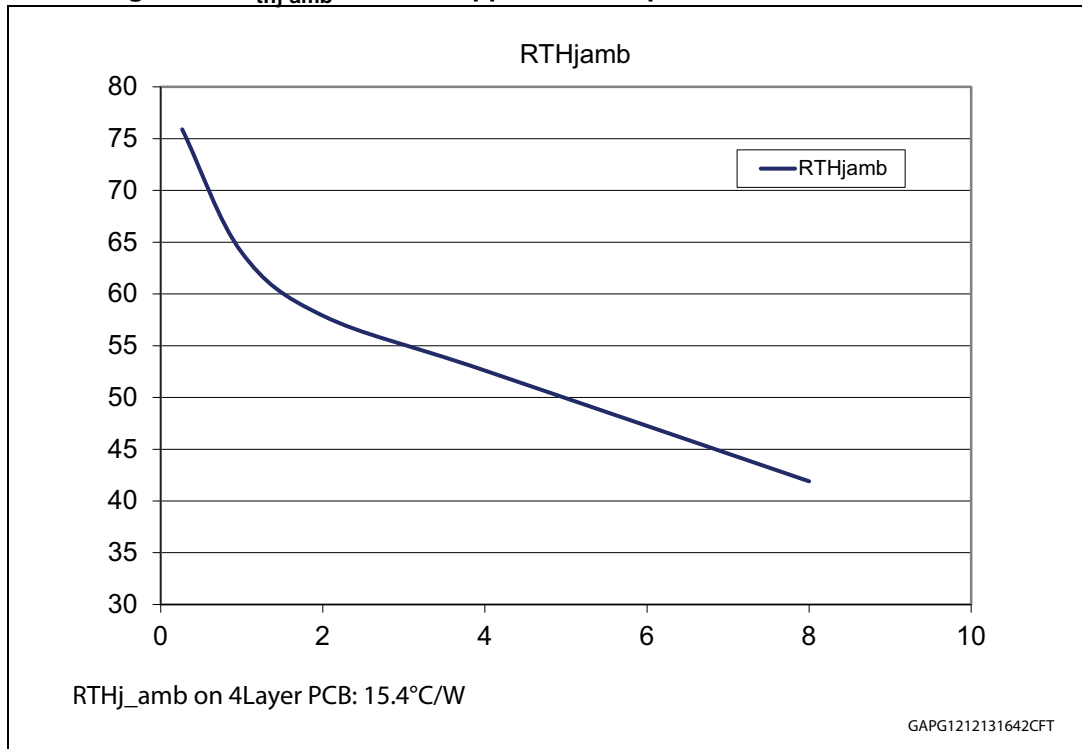
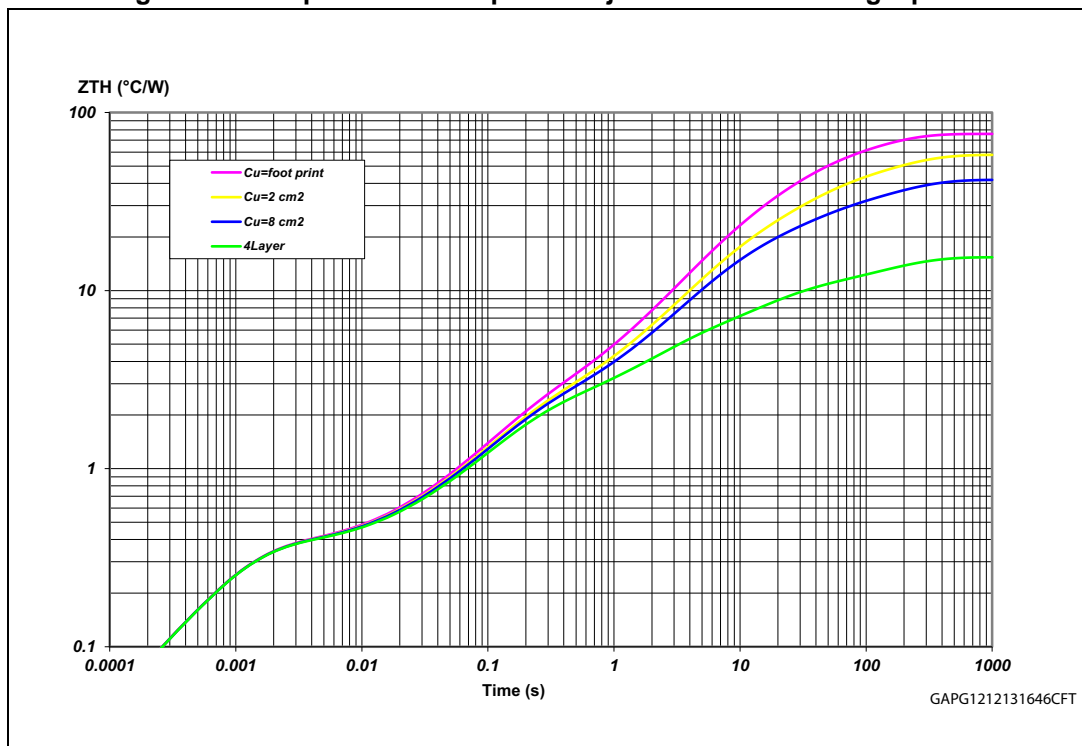


Figure 37. Octapak thermal impedance junction ambient single pulse

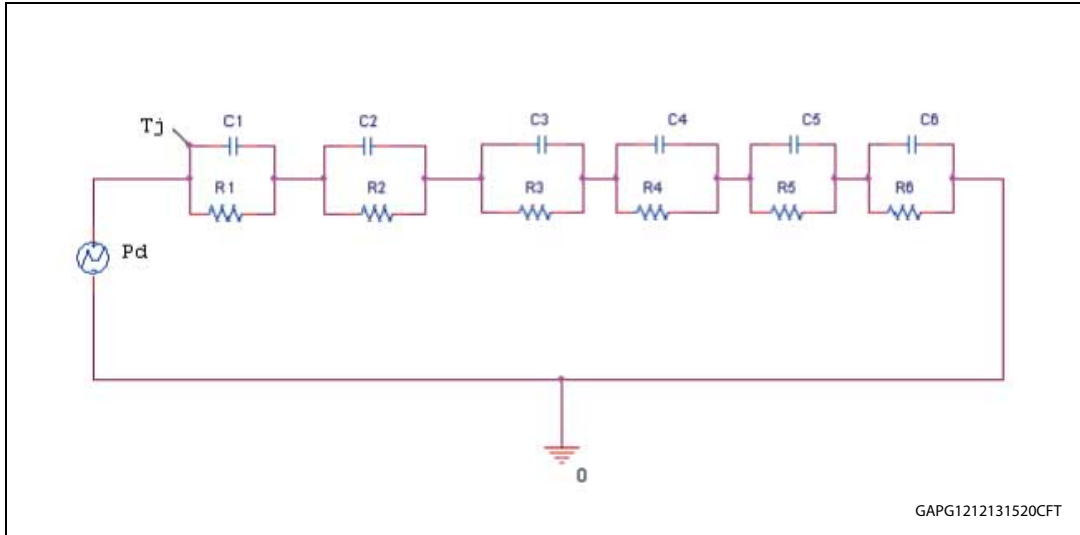


**Equation 3: pulse calculation formula**

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

where  $\delta = t_p/T$

**Figure 38. Thermal fitting model for Octapak**



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.

**Table 15. Thermal parameters**

Area/island (cm <sup>2</sup> )	Footprint	2	8	4L
R1 (°C/W)	0.005	0.005	0.005	0.005
R2 (°C/W)	0.35	0.35	0.35	0.35
R3 (°C/W)	1.54	1.54	1.54	1.54
R4 (°C/W)	10	10	10	2.5
R5 (°C/W)	28	20	12	5
R6 (°C/W)	36	26	18	6
C1 (W.s/°C)	0.002	0.002	0.002	0.002
C2 (W.s/°C)	0.0025	0.0025	0.0025	0.0025
C3 (W.s/°C)	0.1	0.1	0.1	0.1
C4 (W.s/°C)	0.6	0.6	0.6	0.8
C5 (W.s/°C)	0.8	1.4	2.2	3
C6 (W.s/°C)	3	6	9	25

## 6 Package information

### 6.1 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](http://www.st.com).

ECOPACK® is an ST trademark.

### 6.2 Octapak package information

Figure 39. Octapak package dimensions

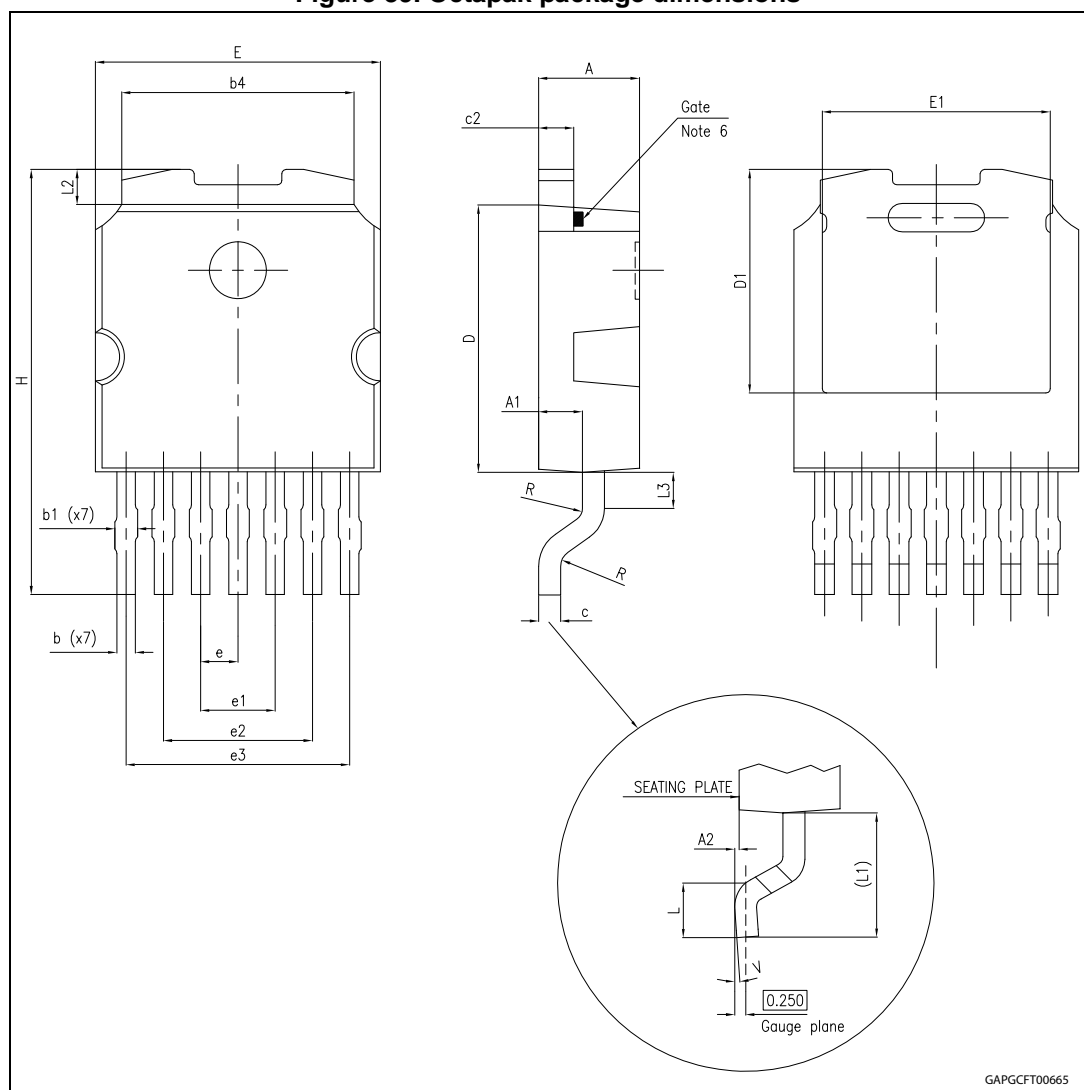




Table 16. Octapak mechanical data

Symbol	Millimeters		
	Min.	Typ.	Max.
A	2.20	2.30	2.40
A1	0.90	1.00	1.10
A2	0.03		0.15
b	0.38	0.45	0.52
b1			0.70
b4	5.20	5.30	5.40
c	0.45	0.50	0.60
c2	0.75	0.80	0.90
D	6.00	6.10	6.20
D1		5.15	
E	6.40	6.50	6.60
E1		5.30	
e		0.85 BSC	
e1	1.60	1.70	1.80
e2	3.30	3.40	3.50
e3	5.00	5.10	5.20
H	9.35	9.70	10.10
L	1.00		
(L1)		2.80	
L2		0.80	
L3		0.85	
R		0.40 BSC	
V2	0°		8°

## 7 Revision history

**Table 17. Document revision history**

Date	Revision	Changes
26-Jul-2012	1	Initial release
20-Mar-2013	2	<p>Updated <i>Features</i> list</p> <p><i>Table 2: Pin functions:</i></p> <ul style="list-style-type: none"> <li>– GND, INPUT, SEN: updated functions</li> </ul> <p>Updated <i>Table 3: Suggested connections for unused and not connected pins</i></p> <p><i>Table 4: Absolute maximum ratings:</i></p> <ul style="list-style-type: none"> <li>– <math>V_{CC}</math>, <math>-I_{OUT}</math>: updated value</li> <li>– <math>V_{CCJS}</math>: added row</li> <li>– <math>V_{CCPK}</math>, <math>I_{SENSE}</math>, <math>V_{ESD}</math>: updated parameter and value</li> <li>– <math>-V_{SENSE}</math>: removed row</li> </ul> <p><i>Table 5: Thermal data:</i></p> <ul style="list-style-type: none"> <li>– <math>R_{thj-case}</math>: removed row</li> <li>– <math>R_{thj-board}</math>: added row</li> </ul> <p><i>Table 6: Power section:</i></p> <ul style="list-style-type: none"> <li>– <math>V_{USDRreset}</math>, <math>R_{ON\_Rev}</math>, <math>I_{GND(ON)}</math>: added row</li> <li>– <math>V_{clamp}</math>: added test conditions and value</li> <li>– <math>I_{STBY}</math>, <math>I_{L(OFF)}</math>: updated parameter definition</li> <li>– <math>I_{S(ON)}</math>: updated values</li> </ul> <p>Updated <i>Table 7: Switching (<math>V_{CC} = 13\text{ V}</math>; <math>-40\text{ °C} &lt; T_j &lt; 150\text{ °C}</math>, unless otherwise specified)</i></p> <p><i>Table 8: Logic Inputs (<math>7\text{ V} &lt; V_{CC} &lt; 28\text{ V}</math>; <math>-40\text{ °C} &lt; T_j &lt; 150\text{ °C}</math>):</i></p> <ul style="list-style-type: none"> <li>– <math>V_{ICL}</math>, <math>V_{SENCL}</math>: updated values</li> </ul> <p><i>Table 9: Protections (<math>7\text{ V} &lt; V_{CC} &lt; 18\text{ V}</math>; <math>-40\text{ °C} &lt; T_j &lt; 150\text{ °C}</math>):</i></p> <ul style="list-style-type: none"> <li>– <math>I_{LIMH}</math>: updated test conditions and values</li> <li>– <math>I_{LIML}</math>: updated value</li> </ul> <p><i>Table 10: CurrentSense (<math>7\text{ V} &lt; V_{CC} &lt; 18\text{ V}</math>; <math>-40\text{ °C} &lt; T_j &lt; 150\text{ °C}</math>):</i></p> <ul style="list-style-type: none"> <li>– <math>V_{SENSE\_CL}</math>, <math>K_0</math>, <math>dK_0/K_0</math>, <math>K_1</math>, <math>dK_1/K_1</math>, <math>K_2</math>, <math>dK_2/K_2</math>, <math>K_3</math>, <math>dK_3/K_3</math>, <math>t_{DSENSE1L}</math>, <math>t_{DSENSE2H}</math>, <math>\Delta t_{DSENSE2H}</math>, <math>t_{DSENSE2L}</math>: updated test conditions</li> <li>– <math>I_{SENSE0}</math>: added test condition, updated values</li> <li>– <math>V_{OUT\_CSD}</math>, <math>V_{SENSE\_SAT}</math>, <math>I_{SENSE\_SAT}</math>, <math>I_{OUT\_SAT}</math>, <math>t_{D\_OL\_V}</math>: added rows</li> <li>– <math>I_{L(off2)}</math>, <math>V_{SENSEH}</math>, <math>t_{DSENSE1H}</math>: updated test conditions and values</li> <li>– <math>I_{SENSEH}</math>: updated value</li> </ul> <p>Removed <i>Figure: Switching times</i> and <i>Figure: Pulse skew</i></p> <p>Added <i>Figure 6: Switching times and Pulse skew</i> and <i>Figure 7: <math>T_{DSTKON}</math></i></p> <p><i>Table 11: Truth table:</i></p> <ul style="list-style-type: none"> <li>– Overload: updated conditions</li> </ul>
18-Sep-2013	3	Updated disclaimer.

Table 17. Document revision history (continued)

Date	Revision	Changes
27-Mar-2014	4	<p>Updated <i>Features</i> list.</p> <p>Updated <i>Figure 2: Configuration diagram (top view)</i></p> <p><i>Table 4: Absolute maximum ratings:</i></p> <ul style="list-style-type: none"> <li>– <math>E_{MAX}</math>: updated parameter and value</li> </ul> <p>Updated <i>Table 5: Thermal data</i></p> <p><i>Table 6: Power section:</i></p> <ul style="list-style-type: none"> <li>– <math>R_{ON}</math>, <math>R_{ON\_Rev}</math>: updated values</li> </ul> <p><i>Table 7: Switching (<math>V_{CC} = 13 V</math>; <math>-40\text{ }^{\circ}C &lt; T_j &lt; 150\text{ }^{\circ}C</math>, unless otherwise specified):</i></p> <ul style="list-style-type: none"> <li>– <math>W_{on}</math>, <math>W_{off}</math>, <math>(dV_{OUT}/dt)_{on}</math>, <math>(dV_{OUT}/dt)_{off}</math>: updated values</li> <li>– <math>t_{SKEW}</math>: updated values</li> </ul> <p><i>Table 9: Protections (<math>7 V &lt; V_{CC} &lt; 18 V</math>; <math>-40\text{ }^{\circ}C &lt; T_j &lt; 150\text{ }^{\circ}C</math>):</i></p> <ul style="list-style-type: none"> <li>– <math>I_{LIMH}</math>: updated values; added note</li> <li>– <math>T_{RS}</math>: updated test conditions</li> </ul> <p><i>Table 10: CurrentSense (<math>7 V &lt; V_{CC} &lt; 18 V</math>; <math>-40\text{ }^{\circ}C &lt; T_j &lt; 150\text{ }^{\circ}C</math>):</i></p> <ul style="list-style-type: none"> <li>– <math>K_0</math>, <math>dK_0/K_0</math>: removed rows</li> <li>– <math>K_1</math>, <math>dK_1/K_1</math>: updated test conditions and values</li> <li>– <math>K_2</math>, <math>dK_2/K_2</math>, <math>K_3</math>, <math>dK_3/K_3</math>, <math>t_{DSENSE2H}</math>, <math>\Delta t_{DSENSE2H}</math>: updated values</li> <li>– <math>t_{D\_OL\_V}</math>: updated test conditions</li> </ul> <p><i>Table 11: Truth table</i></p> <p>Removed <i>Table : Electrical transient requirements (part 1/3)</i>, <i>Table : Electrical transient requirements (part 2/3)</i> and <i>Table : Electrical transient requirements (part 3/3)</i></p> <p>Added <i>Figure 4: <math>I_{OUT}/I_{SENSE}</math> versus <math>I_{OUT}</math></i> and <i>Figure 5: Current sense precision vs. <math>I_{OUT}</math></i></p> <p>Added <i>Section 2.4: Electrical characteristics curves</i></p> <p>Added <i>Section 3: Protections</i>, <i>Chapter 4: Application information</i> and <i>Chapter 5: Package and PCB thermal data</i></p>
05-May-2014	5	<p>Updated <i>Figure 37: Octapak thermal impedance junction ambient single pulse</i></p> <p>Updated <i>Table 15: Thermal parameters</i></p>
26-Aug-2014	6	<p><i>Table 4: Absolute maximum ratings:</i></p> <ul style="list-style-type: none"> <li>– <math>V_{CCJS}</math>: removed parameter</li> <li>– <math>V_{CC\_LSC}</math>: added parameter</li> </ul> <p><i>Table 9: Protections (<math>7 V &lt; V_{CC} &lt; 18 V</math>; <math>-40\text{ }^{\circ}C &lt; T_j &lt; 150\text{ }^{\circ}C</math>):</i></p> <ul style="list-style-type: none"> <li>– <math>I_{LIMH}</math>: updated test conditions</li> </ul>
10-Sep-2014	7	<p><i>Table 9: Protections (<math>7 V &lt; V_{CC} &lt; 18 V</math>; <math>-40\text{ }^{\circ}C &lt; T_j &lt; 150\text{ }^{\circ}C</math>)</i></p> <ul style="list-style-type: none"> <li>– <math>V_{DS}</math>: updated test conditions</li> </ul>
17-Oct-2014	8	Updated <i>Table 16: Octapak mechanical data.</i>

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