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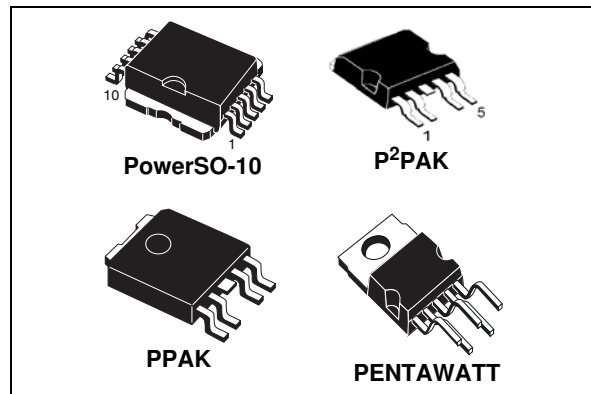
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### Features

Type	R <sub>DS(on)</sub>	I <sub>OUT</sub>	V <sub>CC</sub>
VN820-E VN820SP-E VN820B5-E VN820PT-E VN820-12-E VN820-11-E	40 mΩ	9 A	36 V

- ECOPACK®: lead free and RoHS compliant
- Automotive Grade: compliance with AEC guidelines
- Very low steady current
- CMOS compatible input
- On-state open-load detection
- Off-state open-load detection
- Thermal shutdown protection and diagnosis
- Undervoltage shutdown
- Overvoltage clamp
- Output stuck to V<sub>CC</sub> detection
- Load current limitation
- Reverse battery protection
- Electrostatic discharge protection



### Description

The VN820-E is a monolithic device designed in STMicroelectronics' VIPower® M0-3 technology. The VN820-E is intended for driving any type of load with one side connected to ground. The active V<sub>CC</sub> pin voltage clamp protects the device against low energy spikes.

Active current limitation combined with thermal shutdown and automatic restart protect the device against overload. The device detects the open-load condition in both on- and off-state mode. In the off-state the device detects if the output is shorted to V<sub>CC</sub>. The device automatically turns off where the ground pin becomes disconnected.

**Table 1. Device summary**

Package	Order codes	
	Tube	Tape and reel
PENTAWATT	VN820-E VN820-12-E VN820-11-E	-
PowerSO-10	VN820SP-E	VN820SPTR-E
P <sup>2</sup> PAK	VN820B5-E	VN820B5TR-E
PPAK	VN820PT-E	VN820PTTR-E

# Contents

<b>1</b>	<b>Block diagram and pin description</b>	<b>7</b>
<b>2</b>	<b>Electrical specifications</b>	<b>8</b>
2.1	Absolute maximum ratings	8
2.2	Thermal data	9
2.3	Electrical characteristics	10
2.4	Electrical characteristics curves	15
<b>3</b>	<b>Application information</b>	<b>18</b>
3.1	GND protection network against reverse battery	18
3.1.1	Solution 1: resistor in the ground line (RGND only)	18
3.1.2	Solution 2: diode (DGND) in the ground line	19
3.2	Load dump protection	19
3.3	MCU I/Os protection	19
3.4	Open-load detection in off-state	19
3.5	PowerSO-10, P <sup>2</sup> PAK, PPAK, PENTAWATT maximum demagnetization energy ( $V_{CC} = 13.5V$ )	21
<b>4</b>	<b>Package and PCB thermal data</b>	<b>22</b>
4.1	P <sup>2</sup> PAK thermal data	22
4.2	PPAK thermal data	25
4.3	PowerSO-10 thermal data	28
<b>5</b>	<b>Package and packing information</b>	<b>31</b>
5.1	ECOPACK <sup>®</sup> packages	31
5.2	PENTAWATT mechanical data	31
5.3	P <sup>2</sup> PAK mechanical data	33
5.4	PPAK mechanical data	35
5.5	PowerSO-10 mechanical data	37
5.6	PENTAWATT packing information	39
5.7	P <sup>2</sup> PAK packing information	39
5.8	PPAK packing information	40

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5.9	PowerSO-10 packing information .....	42
<b>6</b>	<b>Revision history .....</b>	<b>43</b>

## List of tables

Table 1.	Device summary . . . . .	1
Table 2.	Suggested connections for unused and not connected pins . . . . .	7
Table 3.	Absolute maximum ratings . . . . .	8
Table 4.	Thermal data . . . . .	9
Table 5.	Power . . . . .	10
Table 6.	Switching ( $V_{CC} = 13\text{ V}$ ) . . . . .	10
Table 7.	Input pin . . . . .	11
Table 8.	$V_{CC}$ output diode . . . . .	11
Table 9.	Status pin . . . . .	11
Table 10.	Protections . . . . .	11
Table 11.	Open-load detection . . . . .	12
Table 12.	Truth table . . . . .	13
Table 13.	Electrical transient requirements . . . . .	13
Table 14.	P <sup>2</sup> PAK thermal parameters . . . . .	24
Table 15.	PPAK thermal parameters . . . . .	27
Table 16.	PowerSO-10 thermal parameters . . . . .	30
Table 17.	PENTAWATT mechanical data . . . . .	32
Table 18.	P <sup>2</sup> PAK mechanical data . . . . .	34
Table 19.	PPAK mechanical data . . . . .	36
Table 20.	PowerSO-10 mechanical data . . . . .	38
Table 21.	Document revision history . . . . .	43

## List of figures

Figure 1.	Block diagram . . . . .	7
Figure 2.	Configuration diagram (top view) . . . . .	7
Figure 3.	Current and voltage conventions . . . . .	8
Figure 4.	Status timings . . . . .	12
Figure 5.	Switching time waveforms . . . . .	12
Figure 6.	Waveforms . . . . .	14
Figure 7.	Off-state output current. . . . .	15
Figure 8.	High-level input current. . . . .	15
Figure 9.	Input clamp voltage. . . . .	15
Figure 10.	Status leakage current . . . . .	15
Figure 11.	Status low output voltage . . . . .	15
Figure 12.	Status clamp voltage . . . . .	15
Figure 13.	On-state resistance vs $T_{case}$ . . . . .	16
Figure 14.	On-state resistance vs $V_{CC}$ . . . . .	16
Figure 15.	Open-load on-state detection threshold . . . . .	16
Figure 16.	Input high-level . . . . .	16
Figure 17.	Input low-level. . . . .	16
Figure 18.	Input hysteresis voltage . . . . .	16
Figure 19.	Overshoot shutdown . . . . .	17
Figure 20.	Open-load off-state voltage detection threshold . . . . .	17
Figure 21.	Turn-on voltage slope . . . . .	17
Figure 22.	Turn-off voltage slope . . . . .	17
Figure 23.	$I_{lim}$ vs $T_{case}$ . . . . .	17
Figure 24.	Application schematic . . . . .	18
Figure 25.	Open-load detection in off-state . . . . .	20
Figure 26.	PowerSO-10, P <sup>2</sup> PAK, PPAK, PENTAWATT maximum turn-off current versus inductance . . . . .	21
Figure 27.	P <sup>2</sup> PAK PC board . . . . .	22
Figure 28.	P <sup>2</sup> PAK $R_{thj-amb}$ vs PCB copper area in open box free air conditions . . . . .	22
Figure 29.	P <sup>2</sup> PAK thermal impedance junction ambient single pulse . . . . .	23
Figure 30.	Thermal fitting model of a single channel HSD in P <sup>2</sup> PAK. . . . .	23
Figure 31.	PPAK PC board . . . . .	25
Figure 32.	PPAK $R_{thj-amb}$ vs PCB copper area in open box free air conditions . . . . .	25
Figure 33.	PPAK thermal impedance junction ambient single pulse . . . . .	26
Figure 34.	Thermal fitting model of a single channel HSD in PPAK . . . . .	26
Figure 35.	PowerSO-10 PC board. . . . .	28
Figure 36.	PowerSO-10 $R_{thj-amb}$ vs PCB copper area in open box free air conditions . . . . .	28
Figure 37.	PowerSO-10 thermal impedance junction ambient single pulse . . . . .	29
Figure 38.	Thermal fitting model of a single channel HSD in PowerSO-10 . . . . .	29
Figure 39.	PENTAWATT package dimensions . . . . .	31
Figure 40.	P <sup>2</sup> PAK package dimensions. . . . .	33
Figure 41.	PPAK package dimensions . . . . .	35
Figure 42.	PowerSO-10 package dimensions . . . . .	37
Figure 43.	PENTAWATT tube shipment (no suffix) . . . . .	39
Figure 44.	P <sup>2</sup> PAK tube shipment (no suffix) . . . . .	39
Figure 45.	P <sup>2</sup> PAK tape and reel (suffix "TR"). . . . .	40
Figure 46.	PPAK suggested pad layout . . . . .	40
Figure 47.	PPAK tube shipment (no suffix) . . . . .	41

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Figure 48.	PPAK tape and reel (suffix "TR") . . . . .	41
Figure 49.	PowerSO-10 suggested pad layout . . . . .	42
Figure 50.	PowerSO-10 tube shipment (no suffix) . . . . .	42
Figure 51.	PowerSO-10 tape and reel shipment (suffix "TR") . . . . .	42

# 1 Block diagram and pin description

Figure 1. Block diagram

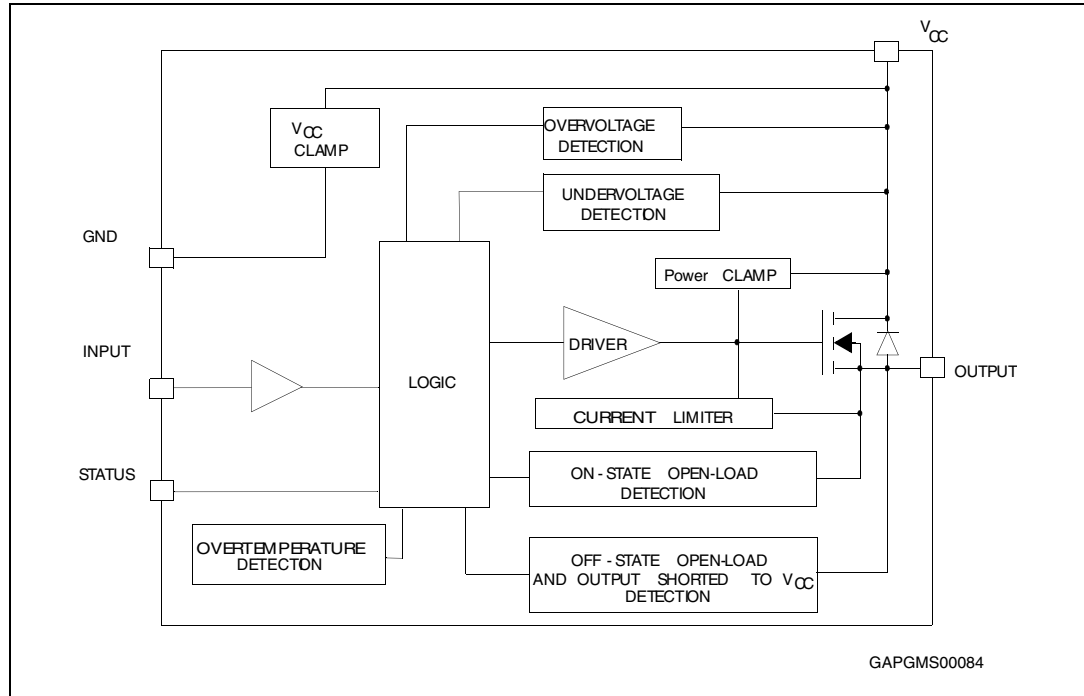


Figure 2. Configuration diagram (top view)

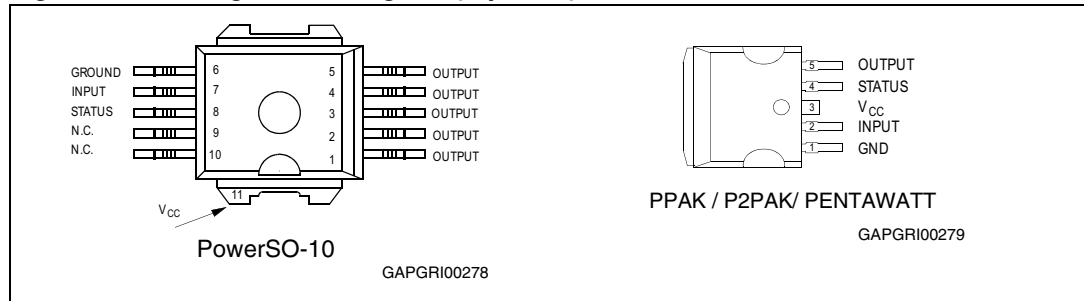


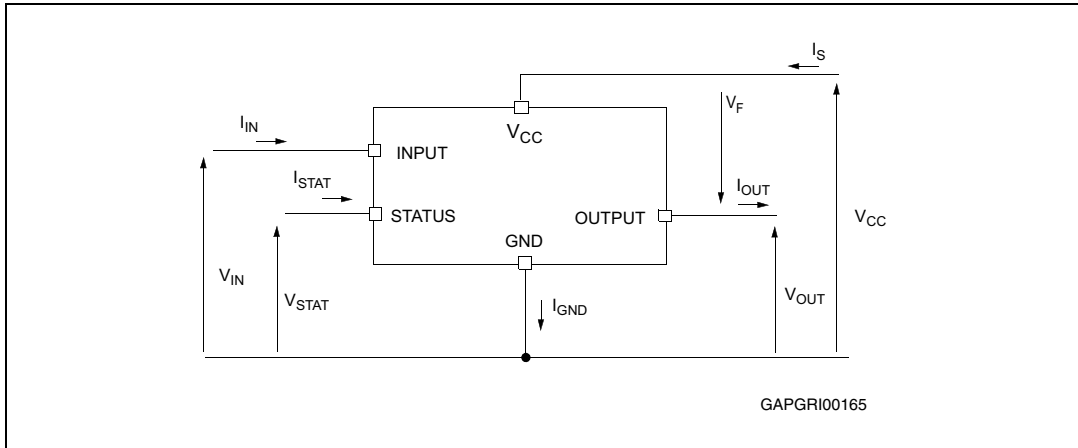
Table 2. Suggested connections for unused and not connected pins

Connection / pin	Status	N.C.	Output	Input
Floating	X	X	X	X
To ground		X		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](#) 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.

Table 3. Absolute maximum ratings

Symbol	Parameter	Value				Unit
		PowerSO-10	PENTAWATT	P <sup>2</sup> PAK	PPAK	
V <sub>CC</sub>	DC supply voltage	41				V
-V <sub>CC</sub>	Reverse DC supply voltage	- 0.3				V
-I <sub>gnd</sub>	DC reverse ground pin current	- 200				mA
I <sub>OUT</sub>	DC output current	Internally limited				A
-I <sub>OUT</sub>	Reverse DC output current	- 9				A
I <sub>IN</sub>	DC input current	+/- 10				mA
I <sub>STAT</sub>	DC Status current	+/- 10				mA
V <sub>ESD</sub>	Electrostatic discharge (human body model: R = 1.5 KΩ; C = 100 pF)					
	- INPUT	4000				V
	- STATUS	4000				V
	- OUTPUT	5000				V
	- V <sub>CC</sub>	5000				V

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

Symbol	Parameter	Value				Unit
		PowerSO-10	PENTAWATT	P <sup>2</sup> PAK	PPAK	
$E_{MAX}$	Maximum switching energy ( $L = 1.4$ mH; $R_L = 0$ $\Omega$ ; $V_{bat} = 13.5$ V; $T_{jstart} = 150$ °C; $I_L = 13$ A)	156				mJ
$P_{tot}$	Power dissipation $T_C = 25$ °C	65.8				W
$T_j$	Junction operating temperature	Internally limited				°C
$T_C$	Case 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
		PowerSO-10	PENTAWATT	P <sup>2</sup> PAK	PPAK	
$R_{thj-case}$	Thermalresistance junction-case	1.9	1.9	1.9	1.9	°C/W
$R_{thj-lead}$	Thermalresistance junction-lead	-	-	-	-	°C/W
$R_{thj-amb}$	Thermalresistance junction-ambient	51.9 <sup>(1)</sup>	61.9 <sup>(2)</sup>	51.9 <sup>(2)</sup>	76.9 <sup>(2)</sup>	°C/W
		37 <sup>(2)</sup>	-	37 <sup>(4)</sup>	45 <sup>(4)</sup>	°C/W

1. When mounted on a standard single-sided FR-4 board with 0.5cm<sup>2</sup> of Cu (at least 35 $\mu$ m thick).
2. When mounted on a standard single-sided FR-4 board with 6cm<sup>2</sup> of Cu (at least 35 $\mu$ m thick).

## 2.3 Electrical characteristics

Values specified in this section are for  $8\text{ V} < V_{CC} < 36\text{ V}$ ;  $-40\text{ °C} < T_j < 150\text{ °C}$ , unless otherwise stated.

**Table 5. Power**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{CC}$	Operating supply voltage		5.5	13	36	V
$V_{USD}$	Undervoltage shutdown		3	4	5.5	V
$V_{USDhyst}$	Undervoltage shutdown hysteresis			0.5		V
$V_{OV}$	Overvoltage shutdown		36			V
$R_{ON}$	On-state resistance	$I_{OUT} = 3\text{ A}$ ; $T_j = 25\text{ °C}$ ; $V_{CC} > 8\text{ V}$ $I_{OUT} = 3\text{ A}$ ; $V_{CC} > 8\text{ V}$			40 80	mΩ mΩ
$I_S$	Supply current	Off-state; $V_{CC} = 13\text{ V}$ ; $V_{IN} = V_{OUT} = 0\text{ V}$		10	25	μA
		Off-state; $V_{CC} = 13\text{ V}$ ; $V_{IN} = V_{OUT} = 0\text{ V}$ ; $T_j = 25\text{ °C}$		10	20	μA
		On-state; $V_{CC} = 13\text{ V}$ ; $V_{IN} = 5\text{ V}$ ; $I_{OUT} = 0\text{ A}$		2	3.5	mA
$I_{L(off1)}$	Off-state output current	$V_{IN} = V_{OUT} = 0\text{ V}$	0		50	μA
$I_{L(off2)}$	Off-state output current	$V_{IN} = 0\text{ V}$ ; $V_{OUT} = 3.5\text{ V}$	-75		0	μA
$I_{L(off3)}$	Off-state output current	$V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ ; $T_j = 125\text{ °C}$			5	μA
$I_{L(off4)}$	Off-state output current	$V_{IN} = V_{OUT} = 0\text{ V}$ ; $V_{CC} = 13\text{ V}$ ; $T_j = 25\text{ °C}$			3	μA

**Table 6. Switching ( $V_{CC} = 13\text{ V}$ )**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$R_L = 4.3\text{ Ω}$ from $V_{IN}$ rising edge to $V_{OUT} = 1.3\text{ V}$		30		μs
$t_{d(off)}$	Turn-off delay time	$R_L = 4.3\text{ Ω}$ from $V_{IN}$ falling edge to $V_{OUT} = 11.7\text{ V}$		30		μs
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	$R_L = 4.3\text{ Ω}$ from $V_{OUT} = 1.3\text{ V}$ to $V_{OUT} = 10.4\text{ V}$	See <a href="#">Figure 21</a>			V/μs
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	$R_L = 4.3\text{ Ω}$ from $V_{OUT} = 11.7\text{ V}$ to $V_{OUT} = 1.3\text{ V}$	See <a href="#">Figure 22</a>			V/μs

Table 7. Input pin

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{IL}$	Input low-level				1.25	V
$I_{IL}$	Low-level input current	$V_{IN} = 1.25\text{ V}$	1			$\mu\text{A}$
$V_{IH}$	Input high-level		3.25			V
$I_{IH}$	High-level input current	$V_{IN} = 3.25\text{ V}$			10	$\mu\text{A}$
$V_{hyst}$	Input hysteresis voltage		0.5			V
$V_{ICL}$	Input clamp voltage	$I_{IN} = 1\text{ m A}$ $I_{IN} = -1\text{ m A}$	6	6.8 - 0.7	8	V V

Table 8.  $V_{CC}$  output diode

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_F$	Forward on voltage	$-I_{OUT} = 2\text{ A}; T_j = 150\text{ }^\circ\text{C}$	-	-	0.6	V

Table 9. Status pin

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{STAT}$	Status low output voltage	$I_{STAT} = 1.6\text{ mA}$			0.5	V
$I_{LSTAT}$	Status leakage current	Normal operation; $V_{STAT} = 5\text{ V}$			10	$\mu\text{A}$
$C_{STAT}$	Status pin input capacitance	Normal operation; $V_{STAT} = 5\text{ V}$			100	pF
$V_{SCL}$	Status clamp voltage	$I_{STAT} = 1\text{ m A}$ $I_{STAT} = -1\text{ m A}$	6	6.8 - 0.7	8	V V

Table 10. Protections<sup>(1)</sup>

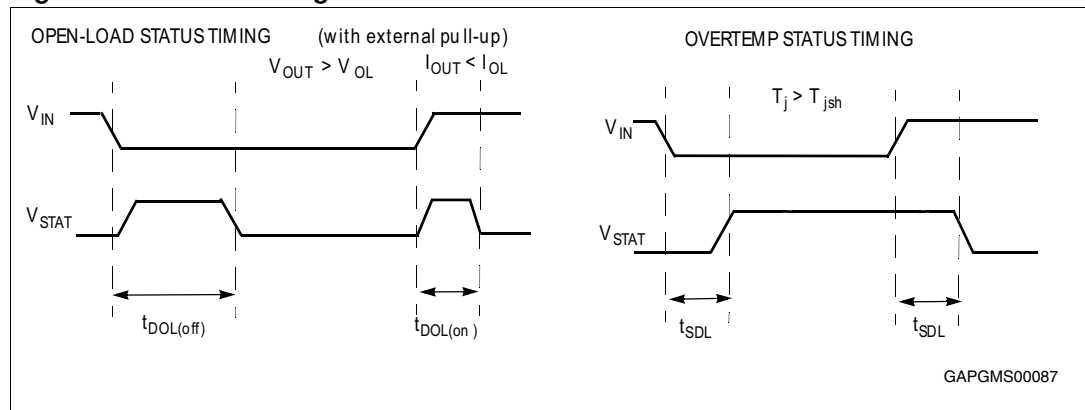
Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$T_{TSD}$	Shutdown temperature		150	175	200	$^\circ\text{C}$
$T_R$	Reset temperature		135			$^\circ\text{C}$
$T_{hyst}$	Thermal hysteresis		7	15		$^\circ\text{C}$
$t_{SDL}$	Status delay in overload condition	$T_j > T_{jsh}$			20	ms
$I_{lim}$	Current limitation	$9\text{ V} < V_{CC} < 36\text{ V}$ $5.5\text{ V} < V_{CC} < 36\text{ V}$	9	13	20 20	A A
$V_{demag}$	Turn-off output clamp voltage	$I_{OUT} = 3\text{ A};$ $V_{IN} = 0\text{ V};$ $L = 6\text{ mH}$	$V_{CC} - 41$	$V_{CC} - 48$	$V_{CC} - 55$	V

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

**Table 11. Open-load detection**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{OL}$	Open-load on-state detection threshold	$V_{IN} = 5\text{ V}$	70	150	300	mA
$t_{DOL(on)}$	Open-load on-state detection delay	$I_{OUT} = 0\text{ A}$			200	$\mu\text{s}$
$V_{OL}$	Open-load off-state voltage detection threshold	$V_{IN} = 0\text{ V}$	1.5	2.5	3.5	V
$t_{DOL(off)}$	Open-load detection delay at turn-off				1000	$\mu\text{s}$

**Figure 4. Status timings**



**Figure 5. Switching time waveforms**

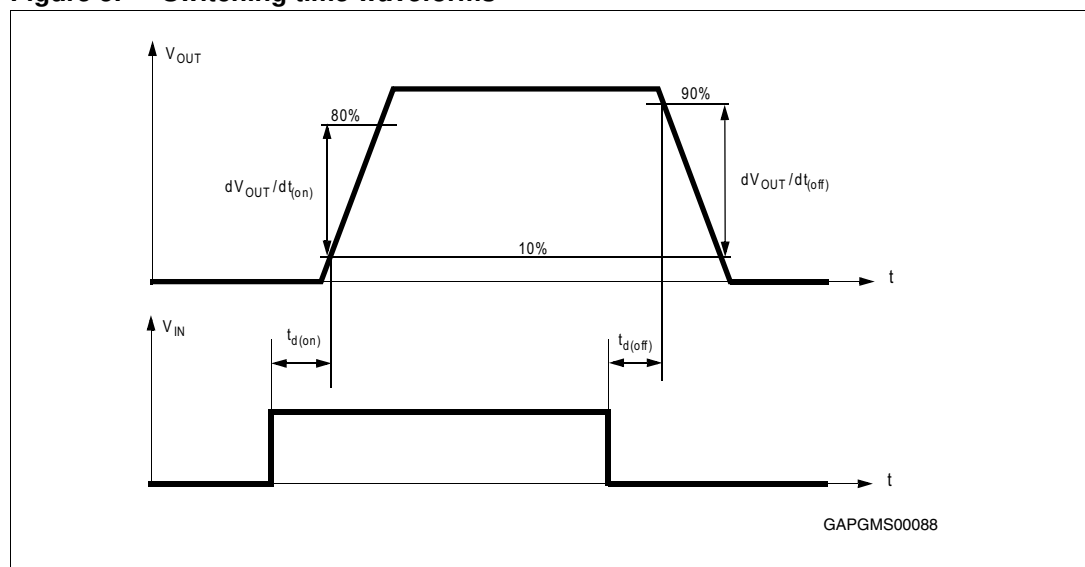


Table 12. Truth table

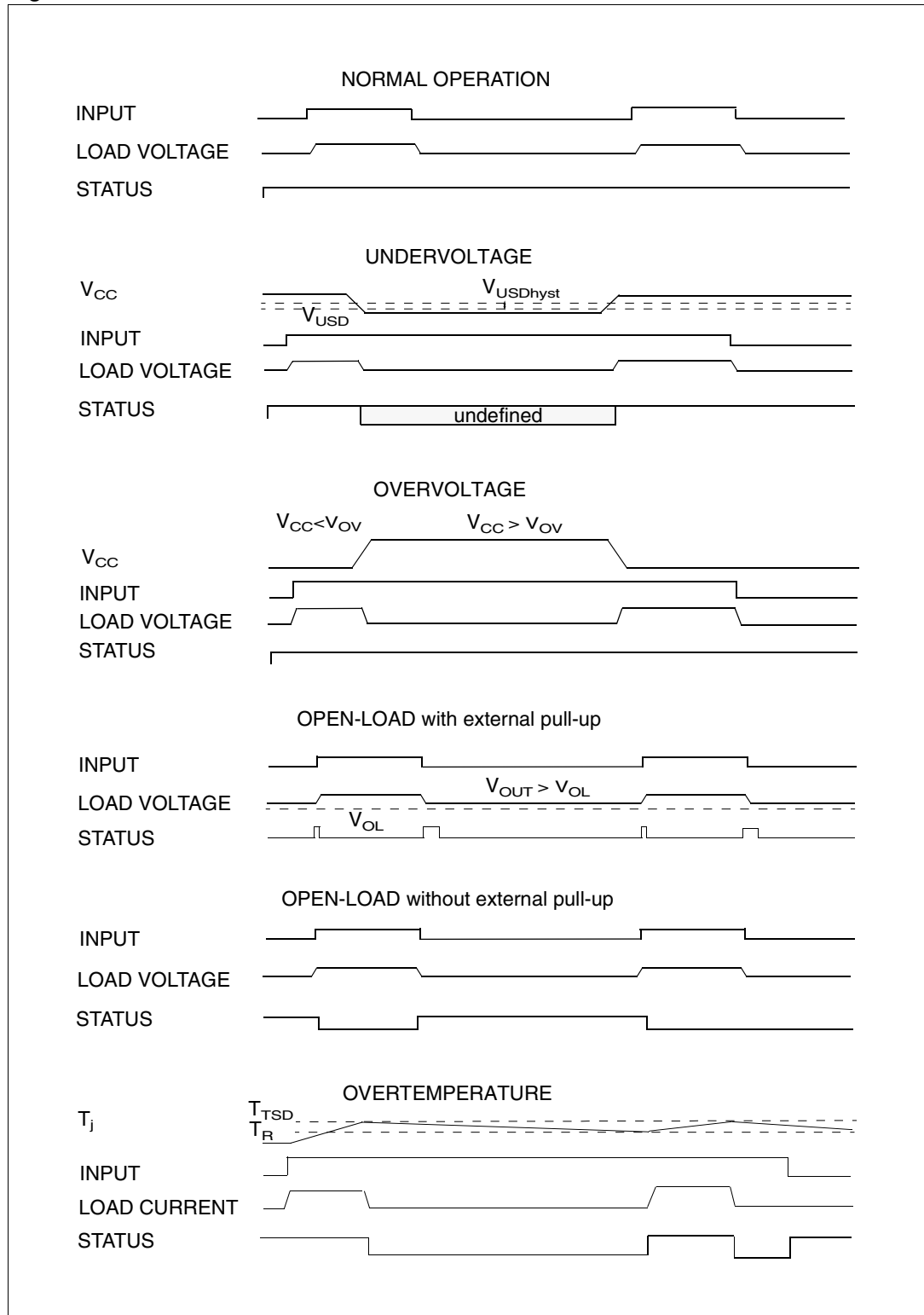
Conditions	Input	Output	Status
Normal operation	L	L	H
	H	H	H
Current limitation	L	L	H
	H	X	$(T_j < T_{TSD})$ H
	H	X	$(T_j > T_{TSD})$ L
Overtemperature	L	L	H
	H	L	L
Undervoltage	L	L	X
	H	L	X
Overvoltage	L	L	H
	H	L	H
Output voltage $> V_{OL}$	L	H	L
	H	H	H
Output current $< I_{OL}$	L	L	H
	H	H	L

Table 13. Electrical transient requirements

ISO T/R 7637/1 Test pulse	Test level				Delays and impedance
	I	II	III	IV	
1	- 25V <sup>(1)</sup>	- 50V <sup>(1)</sup>	- 75V <sup>(1)</sup>	- 100V <sup>(1)</sup>	2ms, 10Ω
2	+ 25V <sup>(1)</sup>	+ 50V <sup>(1)</sup>	+ 75V <sup>(1)</sup>	+ 100V <sup>(1)</sup>	0.2ms, 10Ω
3a	- 25V <sup>(1)</sup>	- 50V <sup>(1)</sup>	- 100V <sup>(1)</sup>	- 150V <sup>(1)</sup>	0.1μs, 50Ω
3b	+ 25V <sup>(1)</sup>	+ 50V <sup>(1)</sup>	+ 75V <sup>(1)</sup>	+ 100V <sup>(1)</sup>	0.1μs, 50Ω
4	- 4V <sup>(1)</sup>	- 5V <sup>(1)</sup>	- 6V <sup>(1)</sup>	- 7V <sup>(1)</sup>	100ms, 0.01Ω
5	+ 26.5V <sup>(1)</sup>	+ 46.5V <sup>(2)</sup>	+ 66.5V <sup>(2)</sup>	+ 86.5V <sup>(2)</sup>	400ms, 2Ω

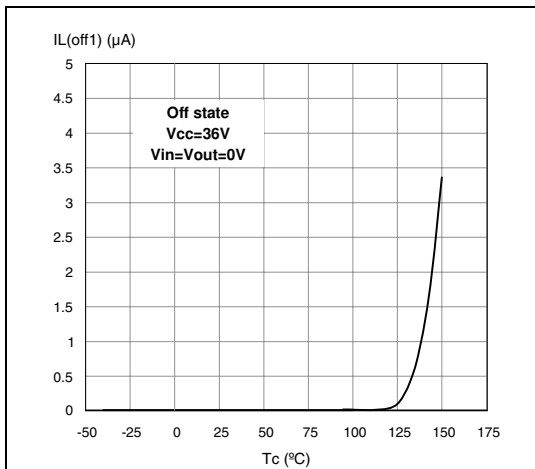
1. All functions of the device are performed as designed after exposure to disturbance.
2. One or more functions of the device is not performed as designed after exposure and cannot be returned to proper operation without replacing the device.

Figure 6. Waveforms

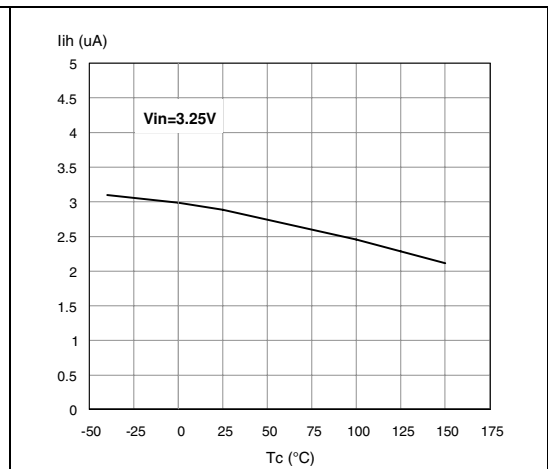


## 2.4 Electrical characteristics curves

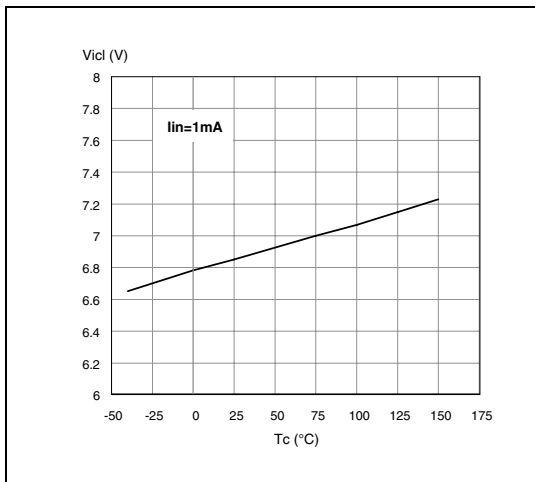
**Figure 7. Off-state output current**



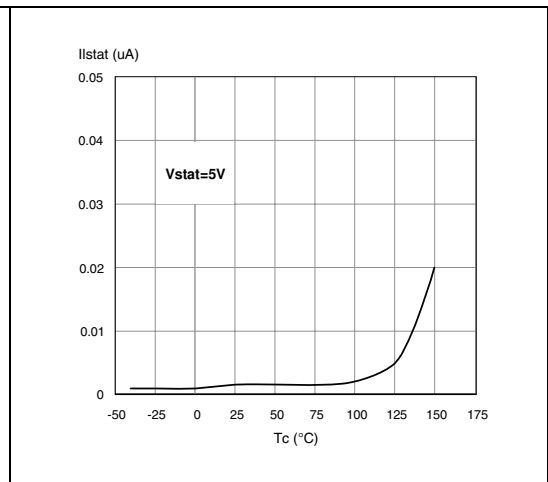
**Figure 8. High-level input current**



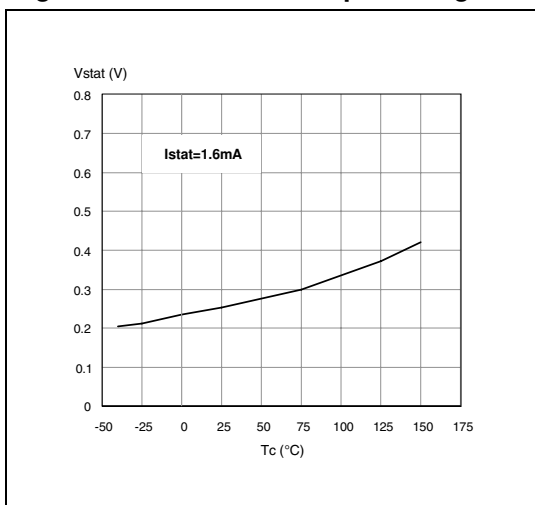
**Figure 9. Input clamp voltage**



**Figure 10. Status leakage current**



**Figure 11. Status low output voltage**



**Figure 12. Status clamp voltage**

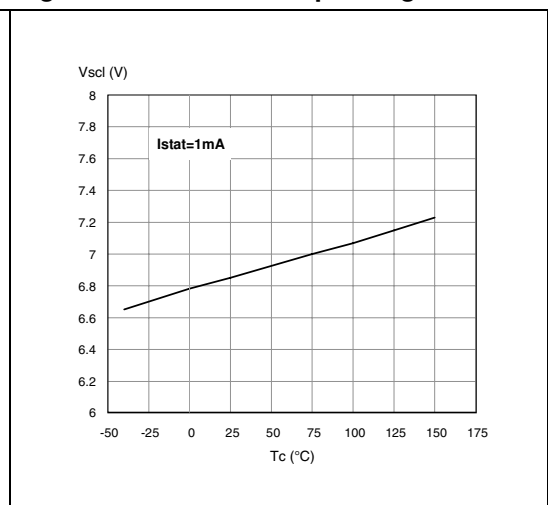




Figure 13. On-state resistance vs  $T_{case}$

Figure 14. On-state resistance vs  $V_{CC}$

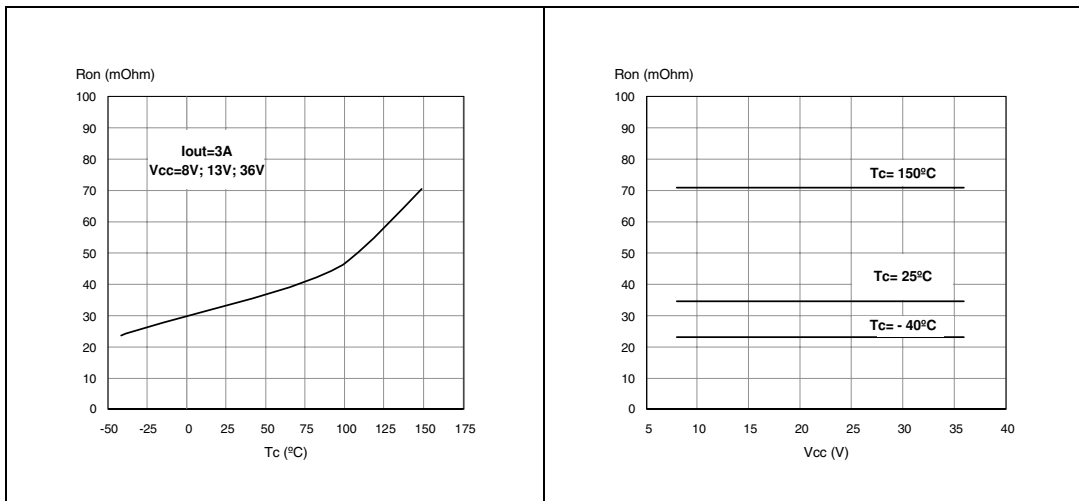


Figure 15. Open-load on-state detection

Figure 16. Input high-level threshold

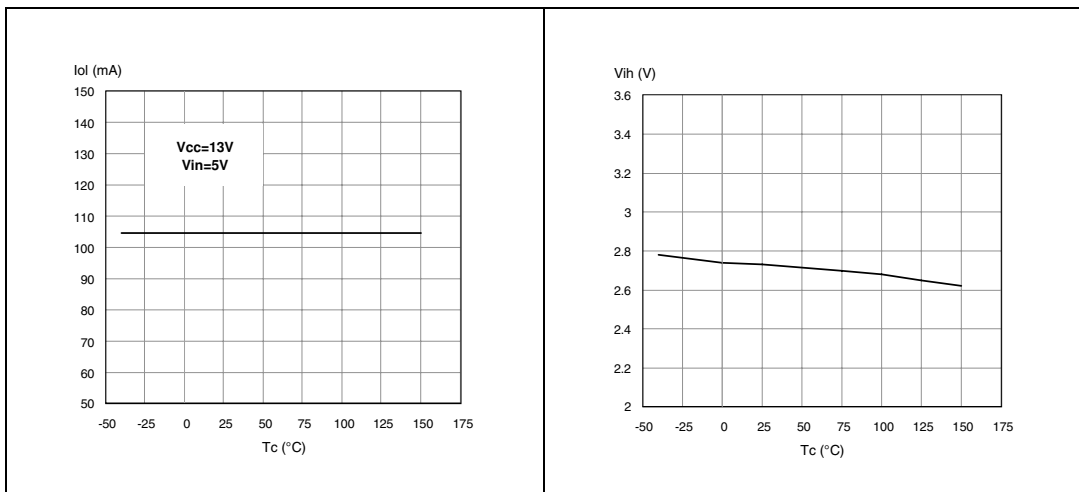


Figure 17. Input low-level

Figure 18. Input hysteresis voltage

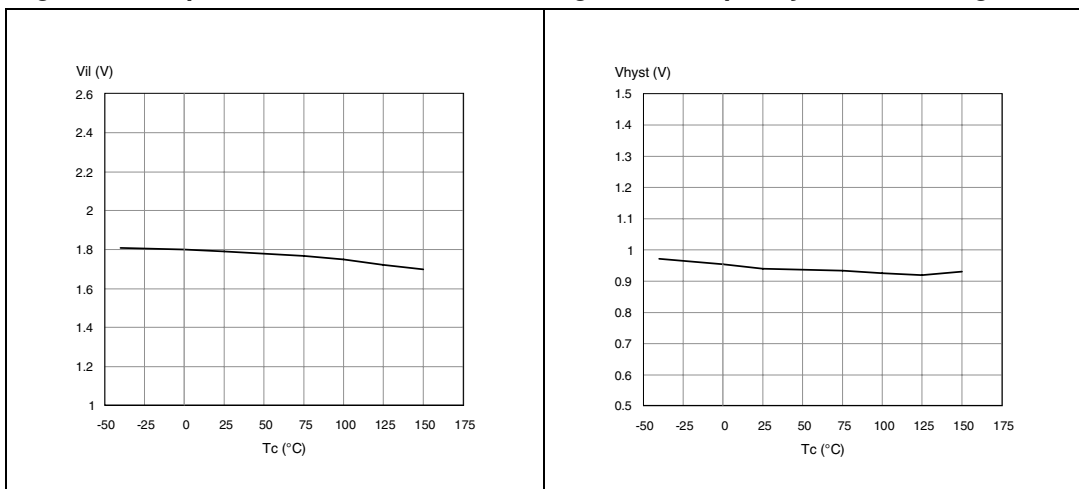


Figure 19. Overvoltage shutdown

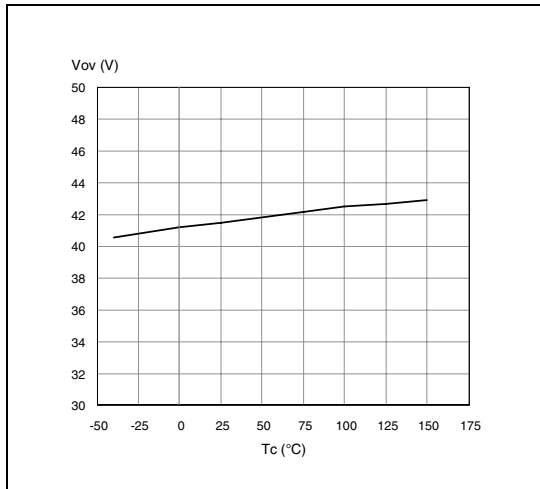


Figure 20. Open-load off-state voltage detection threshold

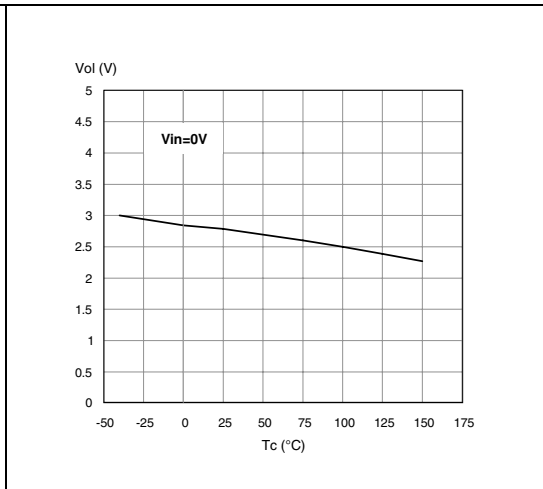


Figure 21. Turn-on voltage slope

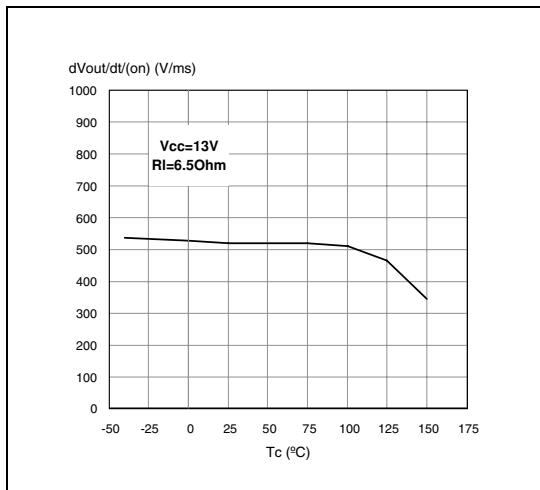


Figure 22. Turn-off voltage slope

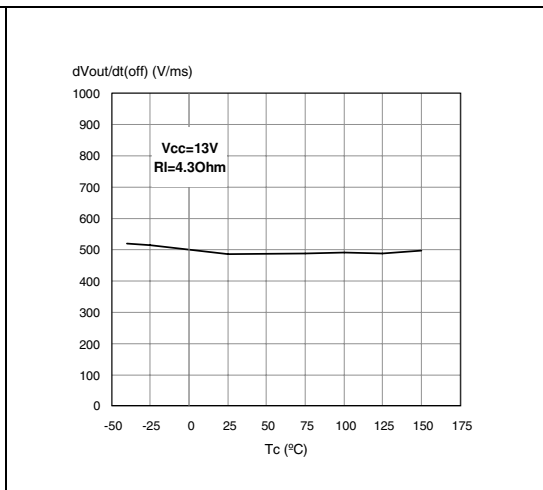
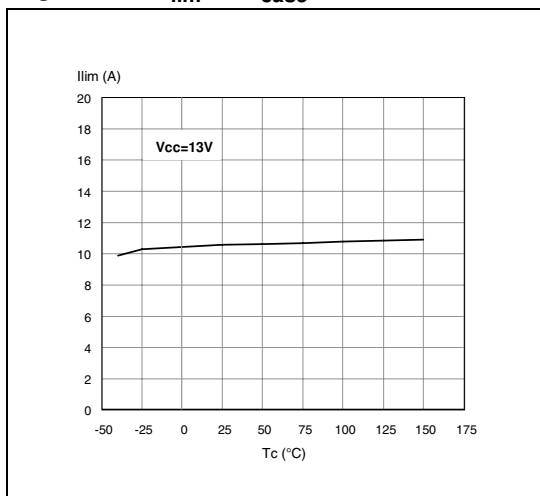
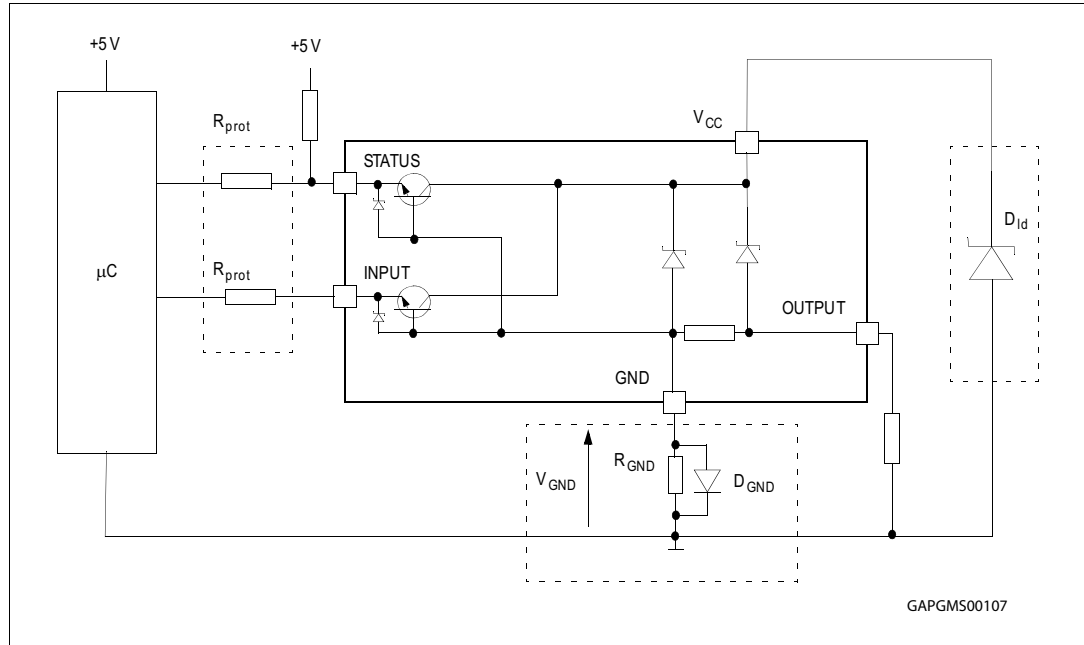


Figure 23. Ilim vs Tcase



### 3 Application information

Figure 24. Application schematic



#### 3.1 GND protection network against reverse battery

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

This can be used with any type of load.

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

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

where  $-I_{GND}$  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<sub>GND</sub> (when V<sub>CC</sub> < 0: during reverse battery situations) is:

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

This resistor can be shared amongst several different HSDs. Please note that the value of this resistor should be calculated with formula (1) where I<sub>S(on)max</sub> becomes the sum of the maximum on-state currents of the different devices.

Please note that if the microprocessor ground is not shared by the device ground then the R<sub>GND</sub> produces a shift (I<sub>S(on)max</sub> \* R<sub>GND</sub>) in the input thresholds and the status output values. This shift does not vary depending on how many devices are ON in case of several high-side drivers sharing the same R<sub>GND</sub>.

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

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

A resistor ( $R_{GND} = 1k\Omega$ ) should be inserted in parallel to  $D_{GND}$  if the device drives an inductive load.

This small signal diode can be safely shared amongst several different HSDs. Also in this case, the presence of the ground network produces a shift ( $\approx 600$  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.

Series resistor in INPUT and STATUS lines are also required to prevent that, during battery voltage transient, the current exceeds the absolute maximum rating.

The safest configuration for unused INPUT and STATUS pin is to leave them unconnected.

## 3.2 Load dump protection

$D_{ld}$  is necessary (Voltage Transient Suppressor) if the load dump peak voltage exceeds the  $V_{CC}$  max DC rating. The same applies if the device is subject to transients on the  $V_{CC}$  line that are greater than the ones shown in the ISO 7637-2: 2004(E) table.

## 3.3 MCU I/Os protection

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

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

Calculation example:

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

$$5 \text{ k}\Omega \leq R_{prot} \leq 65 \text{ k}\Omega$$

Recommended values:  $R_{prot} = 10 \text{ k}\Omega$ .

## 3.4 Open-load detection in off-state

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

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

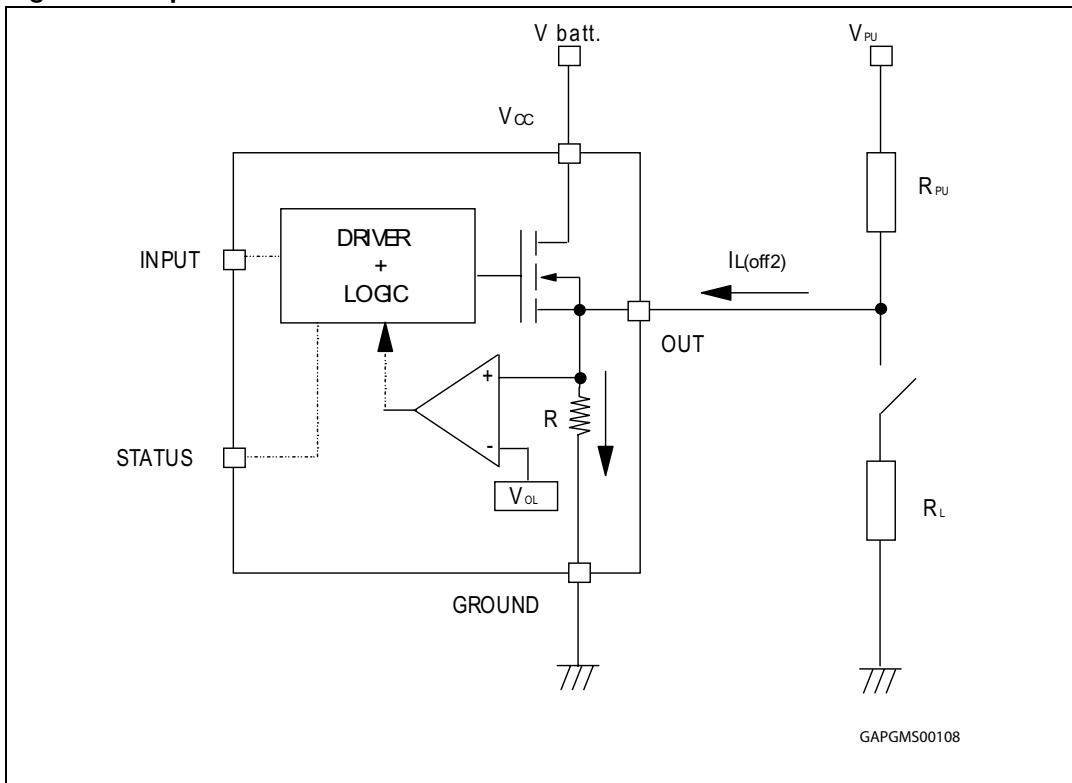
- no false open-load indication when load is connected: in this case we have to avoid  $V_{OUT}$  to be higher than  $V_{OLmin}$ ; this results in the following condition  

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

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

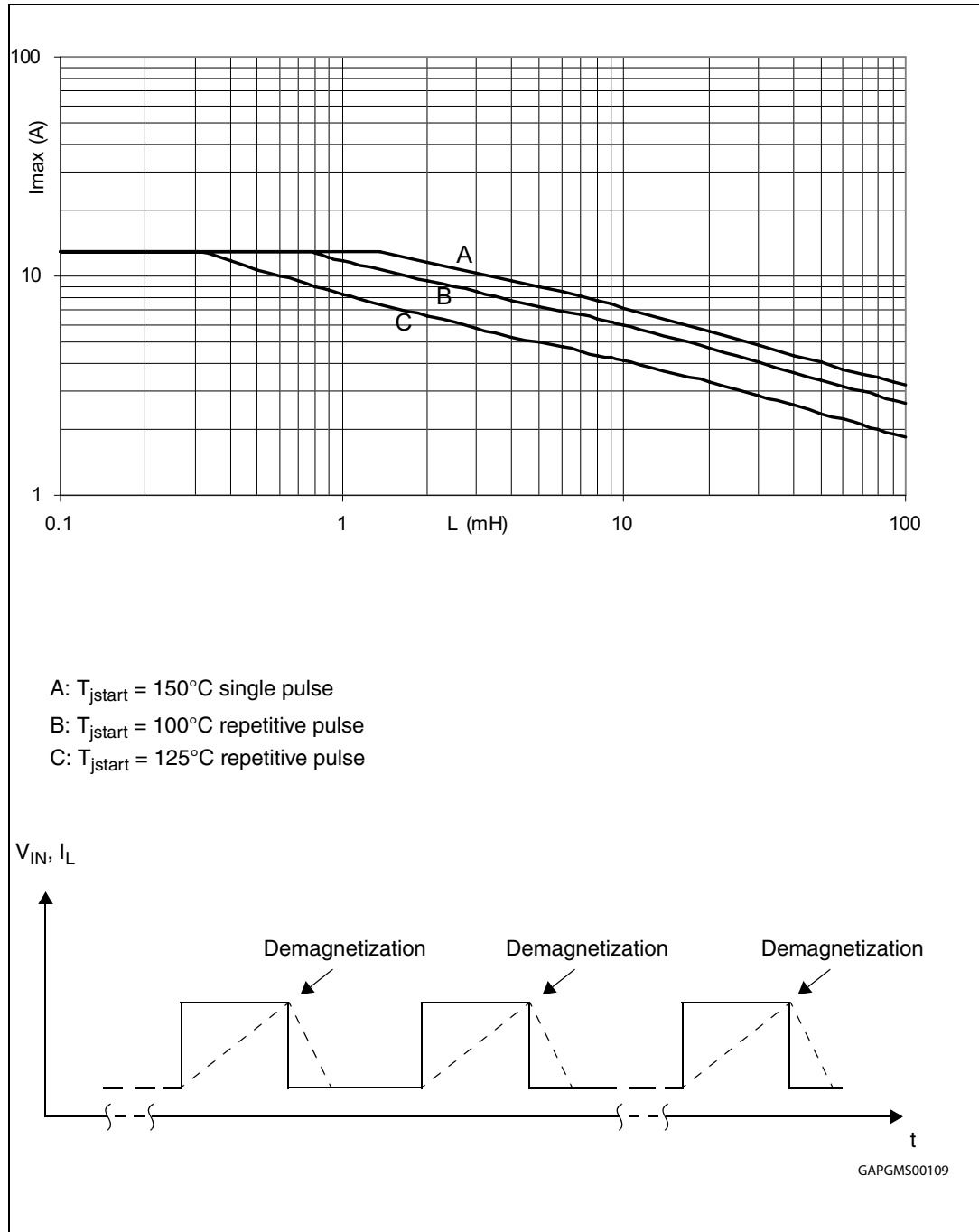
The values of  $V_{OLmin}$ ,  $V_{OLmax}$  and  $I_{L(off2)}$  are available in the electrical characteristics section.

Figure 25. Open-load detection in off-state



### 3.5 PowerSO-10, P<sup>2</sup>PAK, PPAK, PENTAWATT maximum demagnetization energy ( $V_{CC} = 13.5V$ )

Figure 26. PowerSO-10, P<sup>2</sup>PAK, PPAK, PENTAWATT maximum turn-off current versus inductance

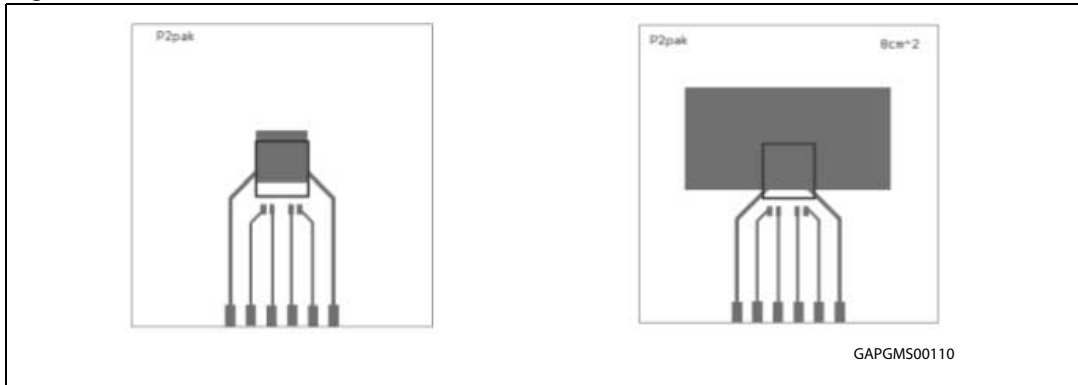


Note: Values are generated with  $R_L = 0 \Omega$ . In case of repetitive pulses,  $T_{jstart}$  (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

## 4 Package and PCB thermal data

### 4.1 P<sup>2</sup>PAK thermal data

Figure 27. P<sup>2</sup>PAK PC board



Note: Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area = 60 mm x 60 mm, PCB thickness = 2 mm, Cu thickness = 35  $\mu$ m, Copper areas: 0.97 cm<sup>2</sup>, 8 cm<sup>2</sup>).

Figure 28. P<sup>2</sup>PAK  $R_{thj-amb}$  vs PCB copper area in open box free air conditions

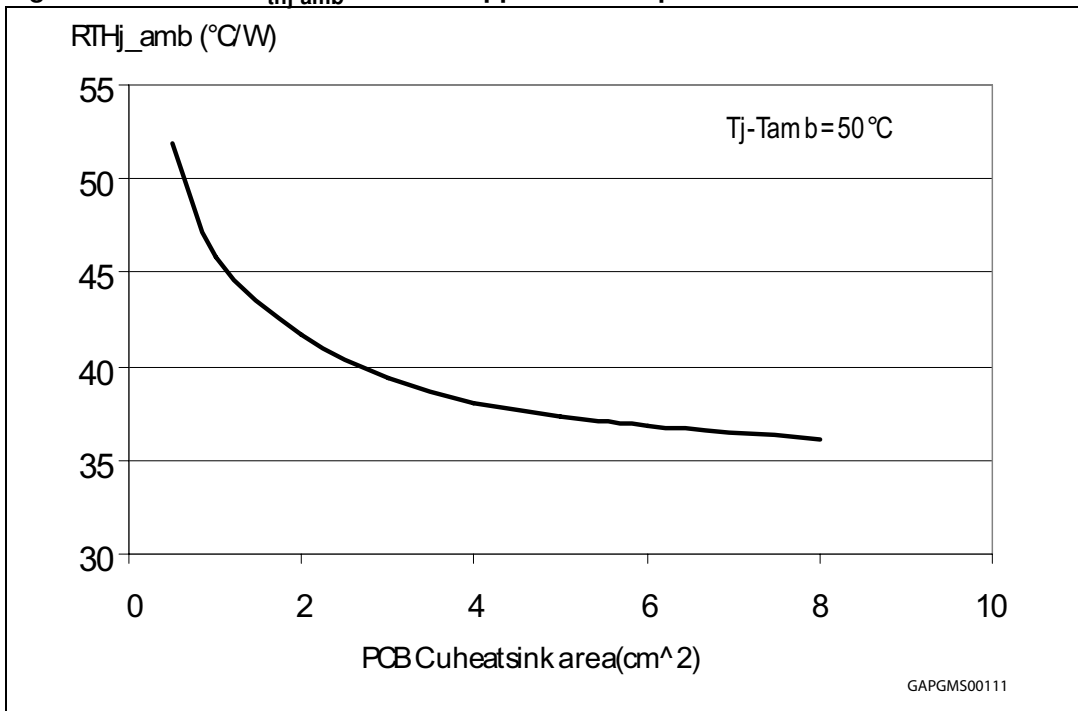
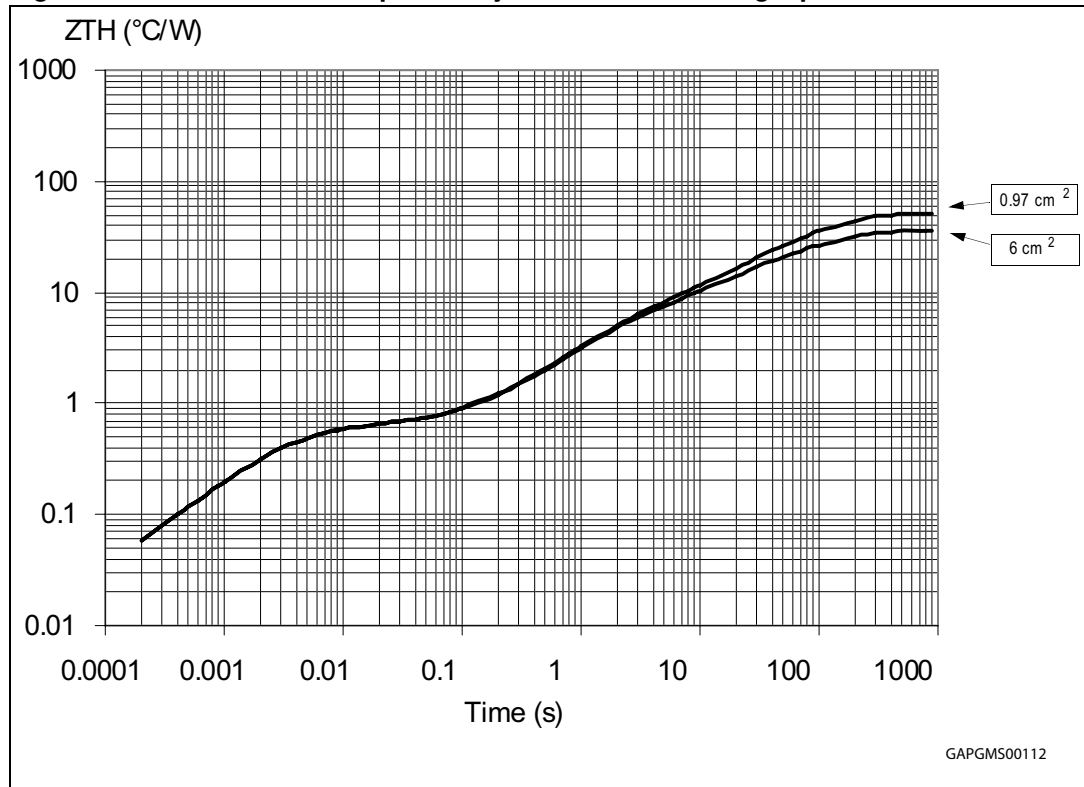


Figure 29. P<sup>2</sup>PAK thermal impedance junction ambient single pulse



Equation 1: pulse calculation formula

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

where  $\delta = t_p/T$

Figure 30. Thermal fitting model of a single channel HSD in P<sup>2</sup>PAK

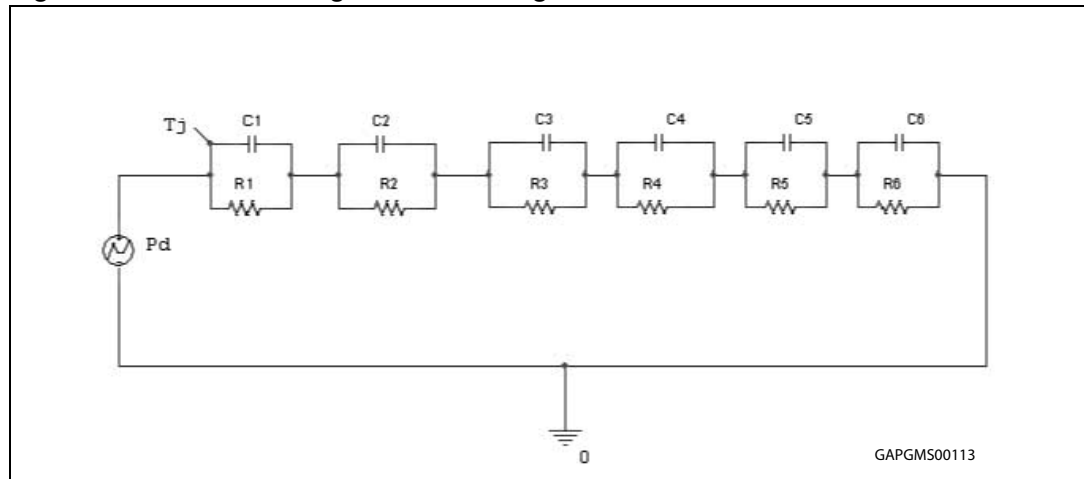


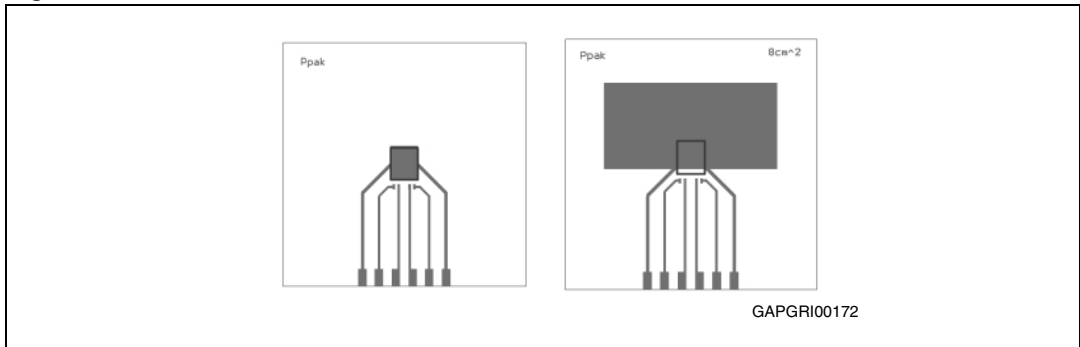


Table 14. P<sup>2</sup>PAK thermal parameters

Area/island (cm <sup>2</sup> )	0.97	6
R1 (°C/W)	0.04	
R2 (°C/W)	0.25	
R3 (°C/W)	0.3	
R4 (°C/W)	4	
R5 (°C/W)	9	
R6 (°C/W)	37	22
C1 (W·s/°C)	0.0008	
C2 (W·s/°C)	0.007	
C3 (W·s/°C)	0.015	
C4 (W·s/°C)	0.4	
C5 (W·s/°C)	2	
C6 (W·s/°C)	3	5

## 4.2 PPAK thermal data

Figure 31. PPAK PC board



Note: Layout condition of  $R_{th}$  and  $Z_{th}$  measurements (PCB FR4 area = 60 mm x 60 mm, PCB thickness = 2 mm, Cu thickness = 35  $\mu\text{m}$ , Copper areas: 0.44  $\text{cm}^2$ , 8  $\text{cm}^2$ ).

Figure 32. PPAK  $R_{thj-amb}$  vs PCB copper area in open box free air conditions

