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1 Block diagram and pin description

Figure 1. Block diagram

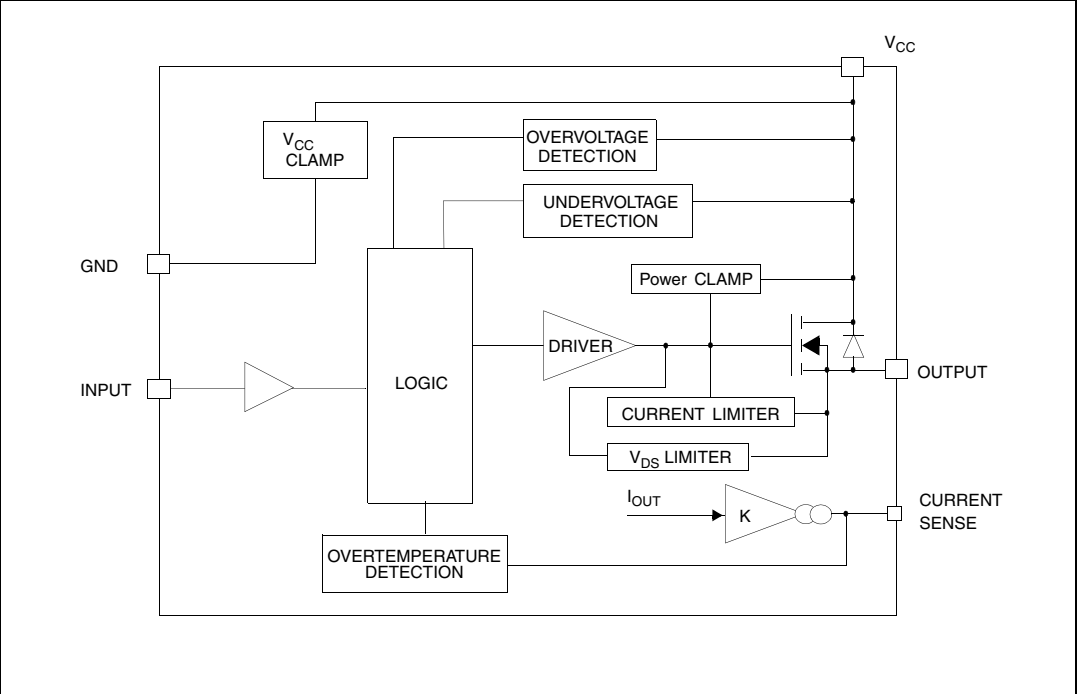


Figure 2. Configuration diagram (top view)

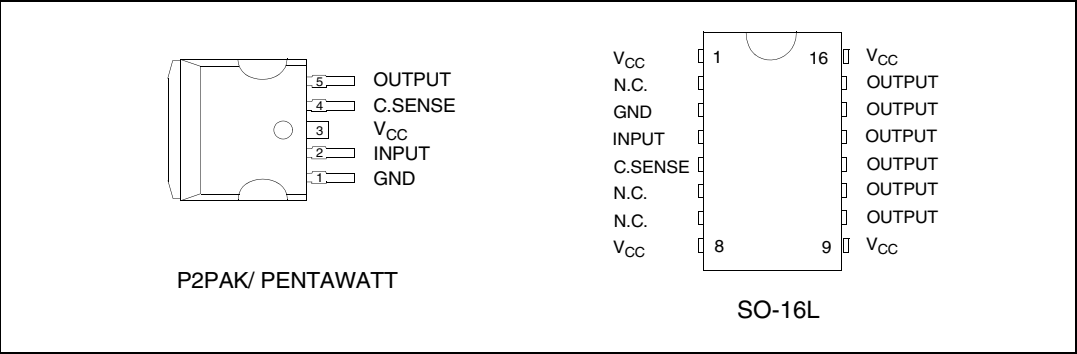
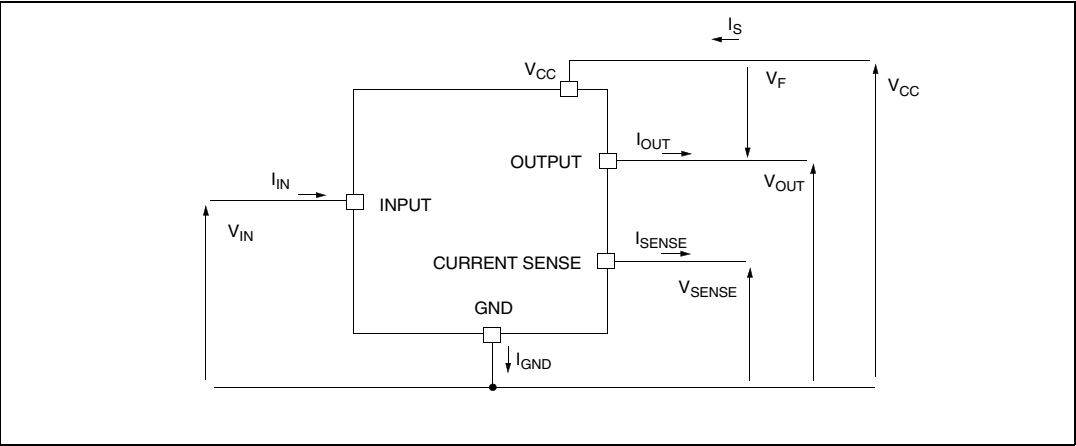


Table 2. Suggested connections for unused and not connected pins

Connection / pin	Current Sense	N.C.	Output	Input
Floating		X	X	X
To ground	Through 1KΩ resistor	X		Through 10KΩ resistor

2 Electrical specifications

Figure 3. Current and voltage conventions



2.1 Absolute maximum ratings

Stressing the device above the rating listed in the “Absolute maximum ratings” table may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to 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
		SO-16L	PENTAWATT	P ² PAK	
V _{CC}	DC supply voltage	41			V
- V _{CC}	Reverse DC supply voltage	- 0.3			V
- I _{gnd}	DC reverse ground pin current	- 200			mA
I _{OUT}	DC output current	Internally limited			A
- I _{OUT}	Reverse DC output current	- 21			A
I _{IN}	DC input current	+/- 10			mA
V _{CSENSE}	Current sense maximum voltage	- 3 + 15			V V
V _{ESD}	Electrostatic discharge (human body model: R = 1.5KΩ; C = 100pF)				
	INPUT	4000			V
	CURRENT SENSE	2000			V
	OUTPUT	5000			V
	V _{CC}	5000			V

Table 3. Absolute maximum ratings (continued)

Symbol	Parameter	Value			Unit
		SO-16L	PENTAWATT	P ² PAK	
E_{MAX}	Maximum switching energy ($L = 0.25\text{mH}$; $R_L = 0\Omega$; $V_{bat} = 13.5\text{V}$; $T_{jstart} = 150^\circ\text{C}$; $I_L = 45\text{A}$)	352		364	mJ
P_{tot}	Power dissipation $T_C \leq 25^\circ\text{C}$	8.3	96.1	96.1	W
T_j	Junction operating temperature	Internally limited			$^\circ\text{C}$
T_C	Case operating temperature	- 40 to 150			$^\circ\text{C}$
T_{stg}	Storage temperature	- 55 to 150			$^\circ\text{C}$

2.2 Thermal data

Table 4. Thermal data

Symbol	Parameter	Max. value			Unit
		SO-16L	PENTAWATT	P ² PAK	
$R_{thj-case}$	Thermalresistance junction-case	-	1.3	1.3	$^\circ\text{C/W}$
$R_{thj-lead}$	Thermalresistance junction-lead	15	-		$^\circ\text{C/W}$
$R_{thj-amb}$	Thermalresistance junction-ambient	65 ⁽¹⁾	61.3	51.3 ⁽²⁾	$^\circ\text{C/W}$
		48 ⁽³⁾		37 ⁽⁴⁾	$^\circ\text{C/W}$

1. When mounted on a standard single-sided FR-4 board with 0.5cm² of Cu (at least 35μm thick) connected to all VCC pins.
2. When mounted on a standard single-sided FR-4 board with 0.5cm² of Cu (at least 35μm thick).
3. When mounted on a standard single-sided FR-4 board with 6cm² of Cu (at least 35μm thick) connected to all VCC pins.
4. When mounted on a standard single-sided FR-4 board with 6cm² of Cu (at least 35μm thick).

2.3 Electrical characteristics

Values specified in this section are for $8V < V_{CC} < 36V$; $-40^{\circ}C < T_j < 150^{\circ}C$, 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}	Under-voltage shutdown		3	4	5.5	V
V_{OV}	Over-voltage shutdown		36			V
R_{ON}	On-state resistance	$I_{OUT} = 10A$; $T_j = 25^{\circ}C$; $I_{OUT} = 10A$; $I_{OUT} = 3A$; $V_{CC} = 6V$			16 32 55	$m\Omega$ $m\Omega$ $m\Omega$
V_{CLAMP}	Clamp voltage	$I_{CC} = 20mA$	41	48	55	V
I_S	Supply current	Off-state; $V_{CC} = 13V$; $V_{IN} = V_{OUT} = 0V$		10	25	μA
		Off-state; $V_{CC} = 13V$; $V_{IN} = V_{OUT} = 0V$; $T_j = 25^{\circ}C$		10	20	μA
		On-state; $V_{CC} = 13V$; $V_{IN} = 5V$; $I_{OUT} = 0A$; $R_{SENSE} = 3.9 k\Omega$			5	mA
$I_{L(off1)}$	Off-state output current	$V_{IN} = V_{OUT} = 0V$	0		50	μA
$I_{L(off2)}$	Off-state output current	$V_{IN} = 0V$; $V_{OUT} = 3.5V$	-75		0	μA
$I_{L(off3)}$	Off-state output current	$V_{IN} = V_{OUT} = 0V$; $V_{CC} = 13V$; $T_j = 125^{\circ}C$			5	μA
$I_{L(off4)}$	Off-state output current	$V_{IN} = V_{OUT} = 0V$; $V_{CC} = 13V$; $T_j = 25^{\circ}C$			3	μA

Note: V_{CLAMP} and V_{OV} are correlated. Typical difference is 5V.

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

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$R_L = 1.3\Omega$ (see Figure 4.)		50		μs
$t_{d(off)}$	Turn-off delay time	$R_L = 1.3\Omega$ (see Figure 4.)		50		μs
$dV_{OUT}/dt_{(on)}$	Turn-on voltage slope	$R_L = 1.3\Omega$ (see Figure 4.)	See Figure 10.			V/ μs
$dV_{OUT}/dt_{(off)}$	Turn-off voltage slope	$R_L = 1.3\Omega$ (see Figure 4.)	See Figure 12.			V/ μs

Table 7. Logic inputs

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

Table 8. Current sense ($9V \leq V_{CC} \leq 16V$)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
K_1	I_{OUT}/I_{SENSE}	$I_{OUT} = 1A$; $V_{SENSE} = 0.5V$; $T_j = -40^\circ C \dots 150^\circ C$	3300	4400	6000	
dK_1/K_1	Current sense ratio drift	$I_{OUT} = 1A$; $V_{SENSE} = 0.5V$; $T_j = -40^\circ C \dots 150^\circ C$	-10		+10	%
K_2	I_{OUT}/I_{SENSE}	$I_{OUT} = 10A$; $V_{SENSE} = 4V$; $T_j = -40^\circ C$ $T_j = 25^\circ C \dots 150^\circ C$	4200 4400	4900 4900	6000 5750	
dK_2/K_2	Current sense ratio drift	$I_{OUT} = 10A$; $V_{SENSE} = 4V$; $T_j = -40^\circ C \dots 150^\circ C$	-8		+8	%
K_3	I_{OUT}/I_{SENSE}	$I_{OUT} = 30A$; $V_{SENSE} = 4V$; $T_j = -40^\circ C$ $T_j = 25^\circ C \dots 150^\circ C$	4200 4400	4900 4900	5500 5250	
dK_3/K_3	Current sense ratio drift	$I_{OUT} = 30A$; $V_{SENSE} = 4V$; $T_j = -40^\circ C \dots 150^\circ C$	-6		+6	%
I_{SENSE0}	Analog sense current	$V_{CC} = 6 \dots 16V$; $I_{OUT} = 0A$; $V_{SENSE} = 0V$; $T_j = -40^\circ C \dots 150^\circ C$	0		10	μA
V_{SENSE}	Max analog sense output voltage	$V_{CC} = 5.5V$; $I_{OUT} = 5A$; $R_{SENSE} = 10k\Omega$ $V_{CC} > 8V$, $I_{OUT} = 10A$; $R_{SENSE} = 10k\Omega$	2 4			V V
V_{SENSEH}	Sense voltage in over-temperature condition	$V_{CC} = 13V$; $R_{SENSE} = 3.9k\Omega$		5.5		V

Table 8. Current sense ($9V \leq V_{CC} \leq 16V$) (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$R_{VSENSEH}$	Analog sense output impedance in over-temperature condition	$V_{CC} = 13V$; $T_j > T_{TSD}$; output open		400		Ω
t_{DSENSE}	Current sense delay response	To 90% $I_{SENSE}^{(1)}$			500	μs

1. Current sense signal delay after positive input slope.

Table 9. V_{CC} output diode

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_F	Forward on voltage	- $I_{OUT} = 5A$; $T_j = 150^\circ C$			0.6	V

Table 10. Protections⁽¹⁾

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
T_{TSD}	Shutdown temperature		150	175	200	$^\circ C$
T_R	Reset temperature		135			$^\circ C$
T_{hyst}	Thermal hysteresis		7	15		$^\circ C$
I_{lim}	Current limitation	$V_{CC} = 13V$ $5V < V_{CC} < 36V$	30	45	75 75	A A
V_{demag}	Turn-off output clamp voltage	$I_{OUT} = 2 A$; $V_{IN} = 0V$; $L = 6mH$	$V_{CC} - 41$	$V_{CC} - 48$	$V_{CC} - 55$	V
V_{ON}	Output voltage drop limitation	$I_{OUT} = 1 A$; $T_j = -40^\circ C \dots 150^\circ C$		50		mV

1. To ensure long term reliability under heavy over-load 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. Truth table

Conditions	Input	Output	Sense
Normal operation	L H	L H	0 Nominal
Over-temperature	L H	L L	0 V_{SENSEH}
Under-voltage	L H	L L	0 0
Over-voltage	L H	L L	0 0
Short circuit to GND	L H H	L L L	0 ($T_j < T_{TSD}$) 0 ($T_j > T_{TSD}$) V_{SENSEH}
Short circuit to V_{CC}	L H	H H	0 < Nominal
Negative output voltage clamp	L	L	0

Table 12. Electrical transient requirements

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

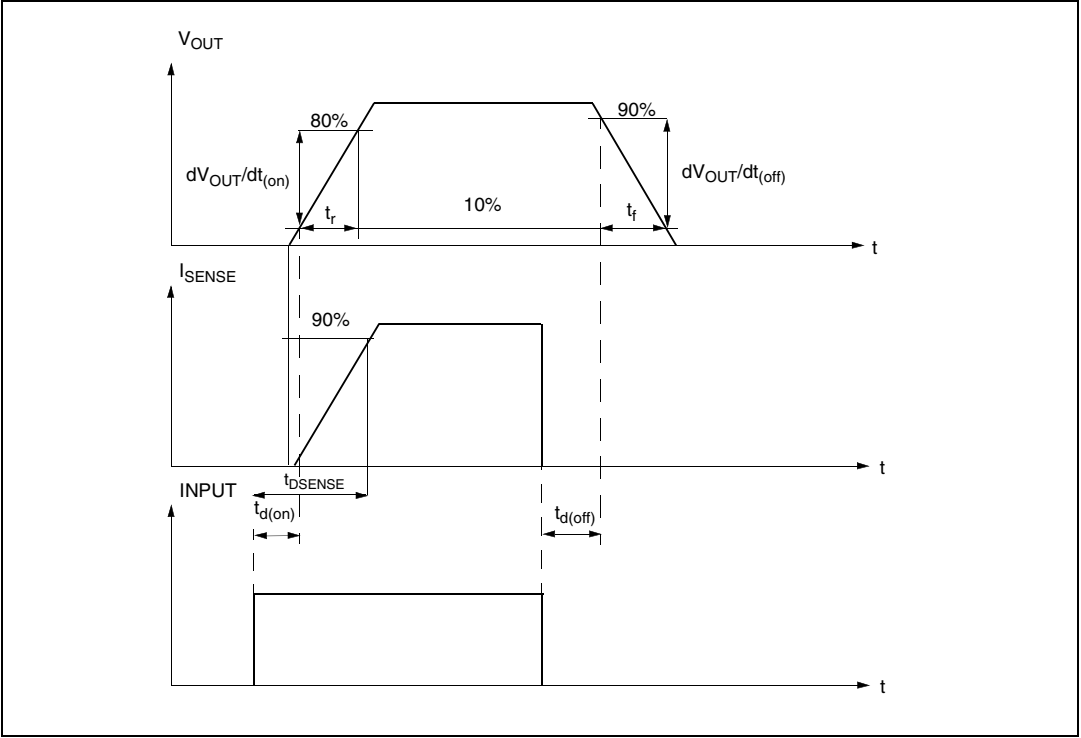


Figure 5. I_{OUT}/I_{SENSE} versus I_{OUT}

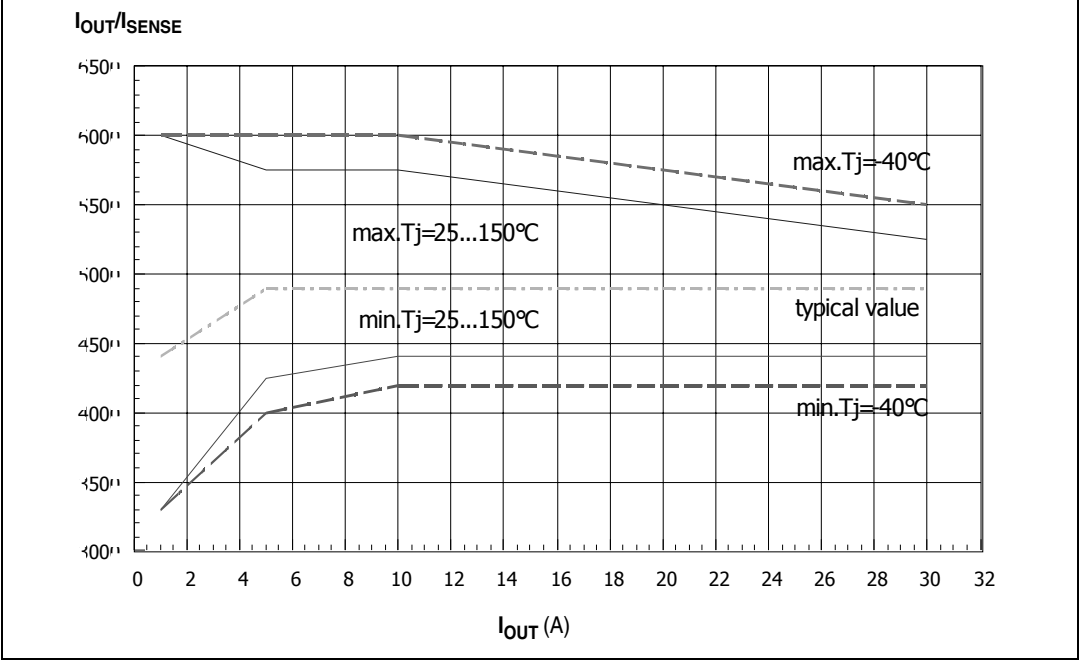
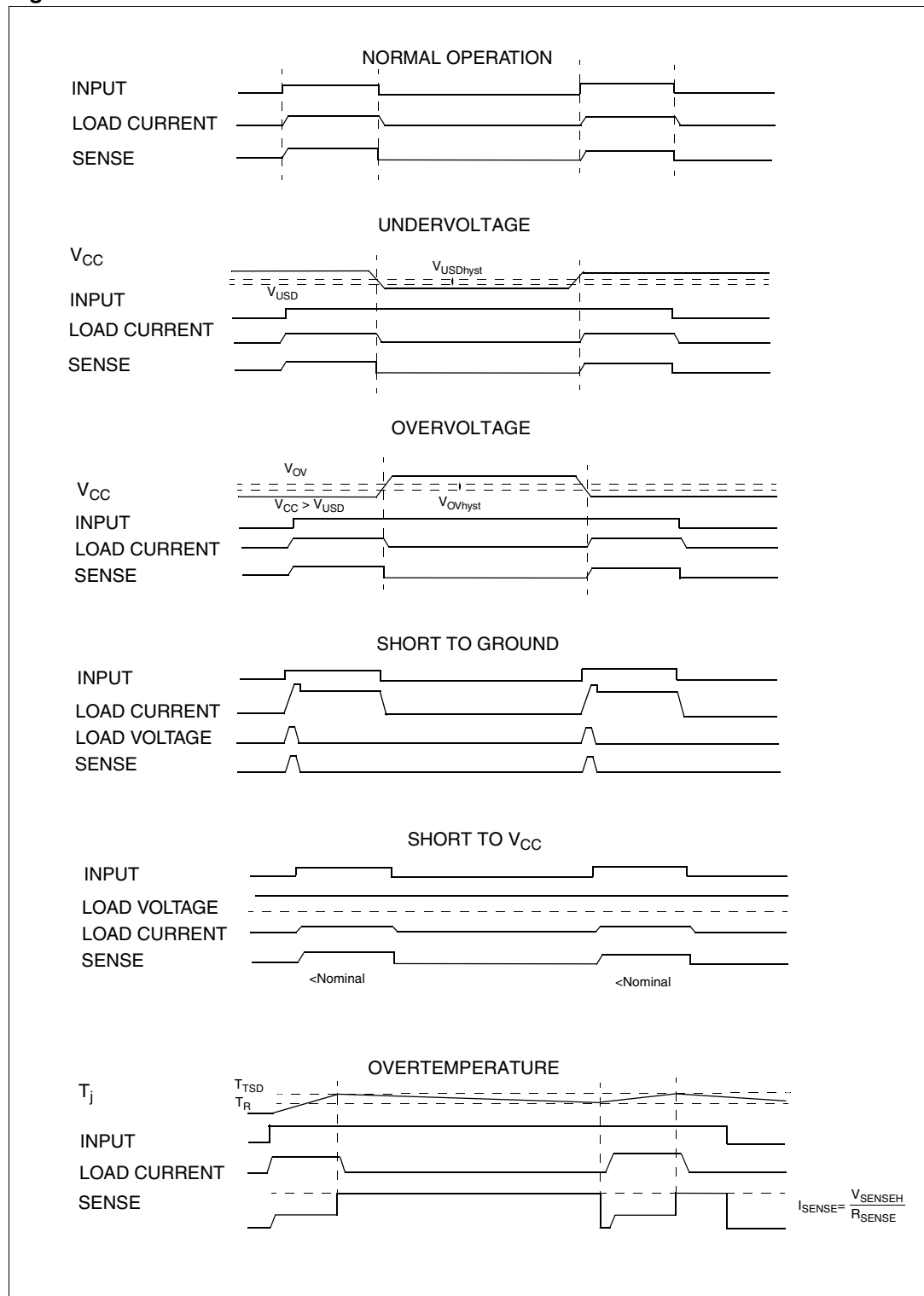


Figure 6. Waveforms



2.4 Electrical characteristics curves

Figure 7. Off-state output current

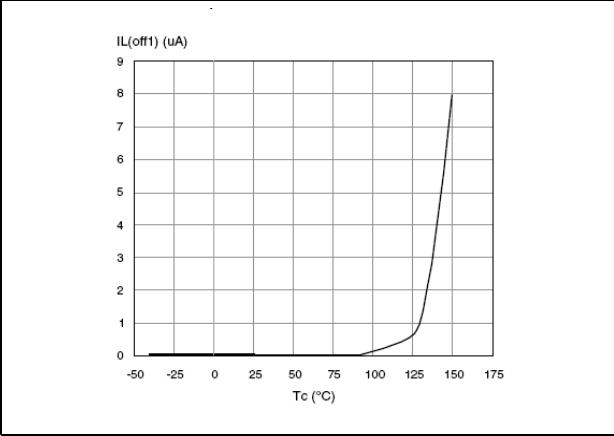


Figure 8. High-level input current

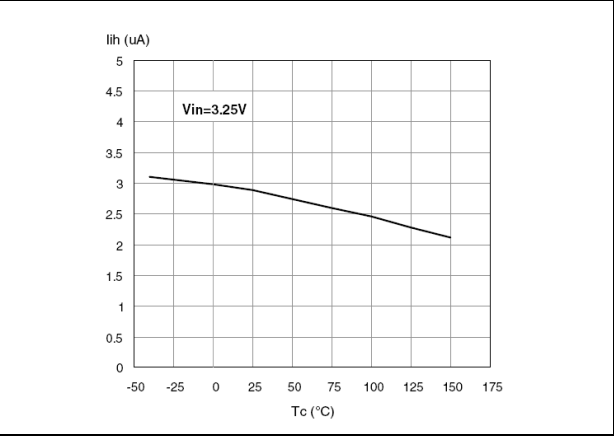


Figure 9. Input clamp voltage

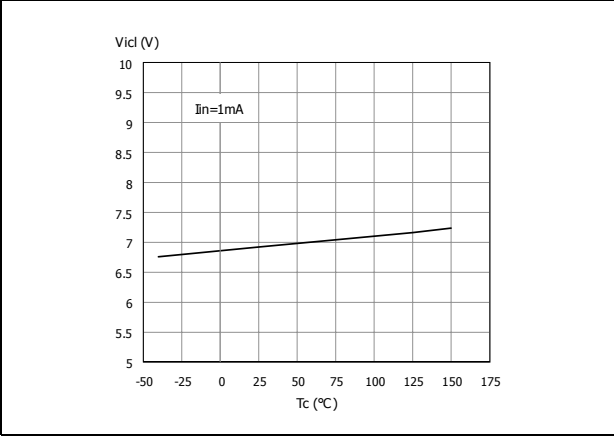


Figure 10. Turn-on voltage slope

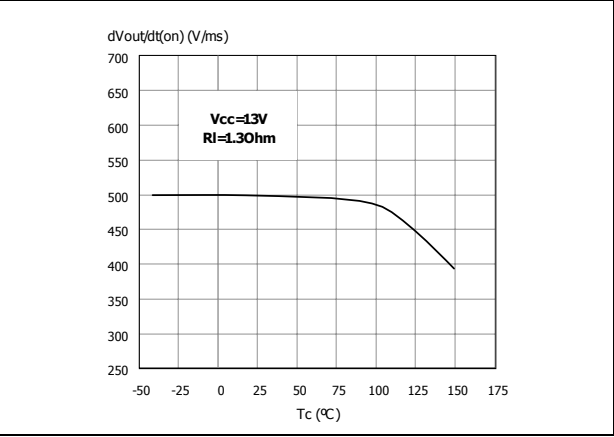


Figure 11. Over-voltage shutdown

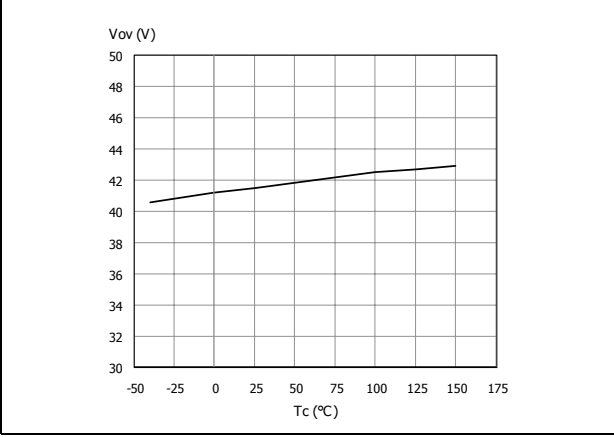


Figure 12. Turn-off voltage slope

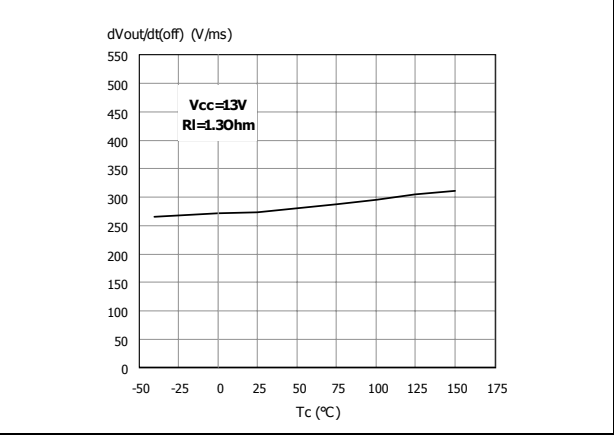


Figure 13. I_{LIM} vs T_{case}

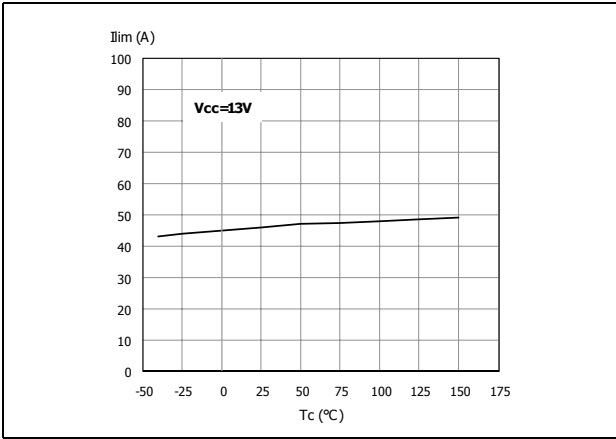


Figure 14. On-state resistance vs V_{CC}

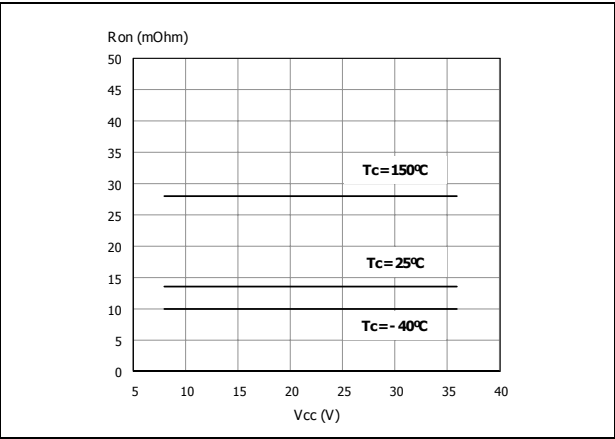


Figure 15. Input high-level

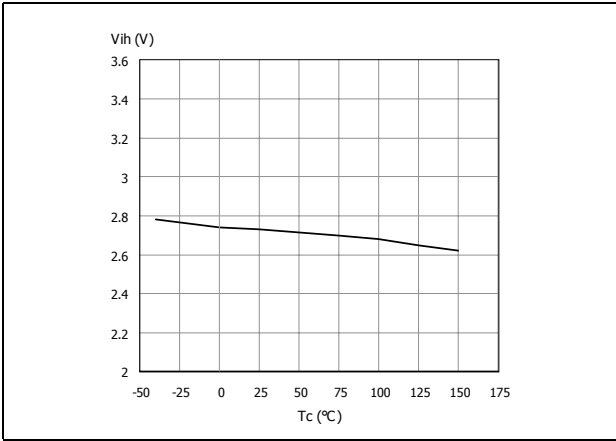


Figure 16. Input hysteresis voltage

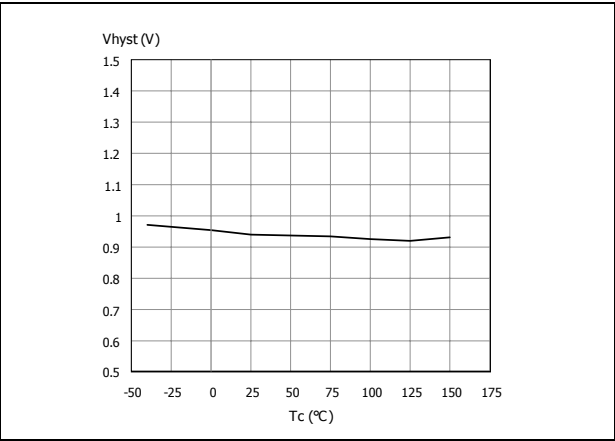


Figure 17. On-state resistance vs T_{case}

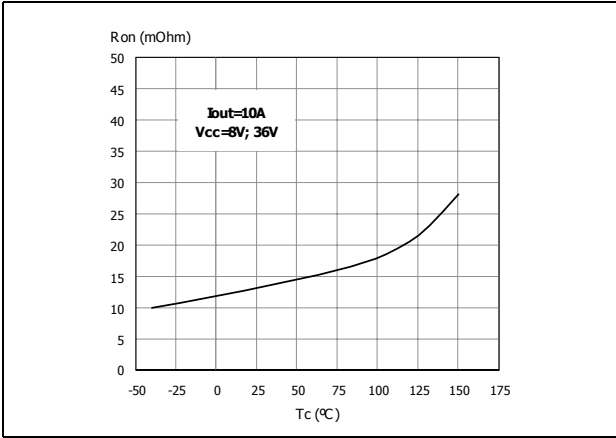
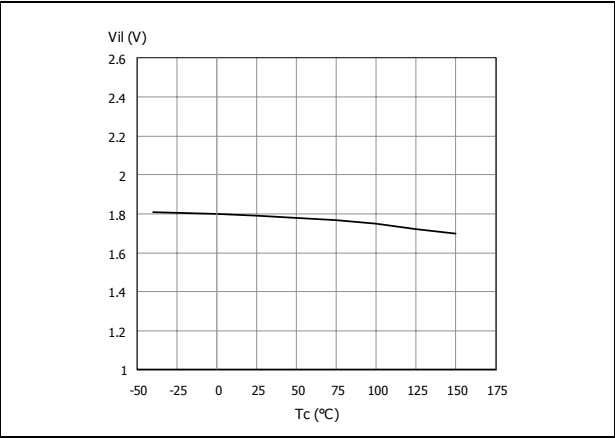
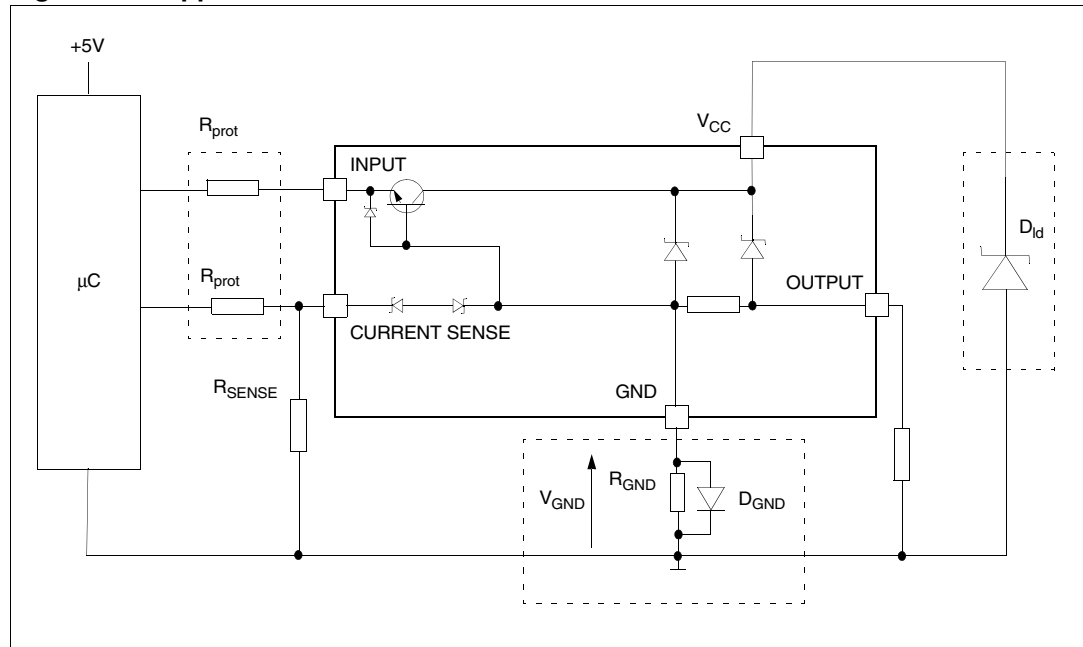


Figure 18. Input low level



3 Application information

Figure 19. Application schematic



3.1 GND protection network against reverse battery

3.1.1 Solution 1: resistor in the ground line (R_{GND} only)

This can be used with any type of load.

The following is an indication on how to dimension the R_{GND} resistor.

1. $R_{GND} \leq 600\text{mV} / (I_{S(on)max})$.
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_{GND} (when $V_{CC} < 0$: during reverse battery situations) is:

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

This resistor can be shared amongst several different HSDs. Please note that the value of this resistor should be calculated with formula (1) where $I_{S(on)max}$ becomes the sum of the maximum on-state currents of the different devices.

Please note that if the microprocessor ground is not shared by the device ground then the R_{GND} will produce a shift ($I_{S(on)max} * R_{GND}$) in the input thresholds and the status output values. This shift will vary depending on how many devices are ON in the case of several high-side drivers sharing the same R_{GND} .

If the calculated power dissipation leads to a large resistor or several devices have to share the same resistor then ST suggests to utilize Solution 2 (see 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 will produce a shift ($\approx 600mV$) in the input threshold and in the status output values if the microprocessor ground is not common to the device ground. This shift will not vary 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.

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 transient are present on the V_{CC} line, the control pins will be pulled negative. ST suggests to insert a resistor (R_{prot}) in line to prevent the μC I/Os pins to latch-up.

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

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

Calculation example:

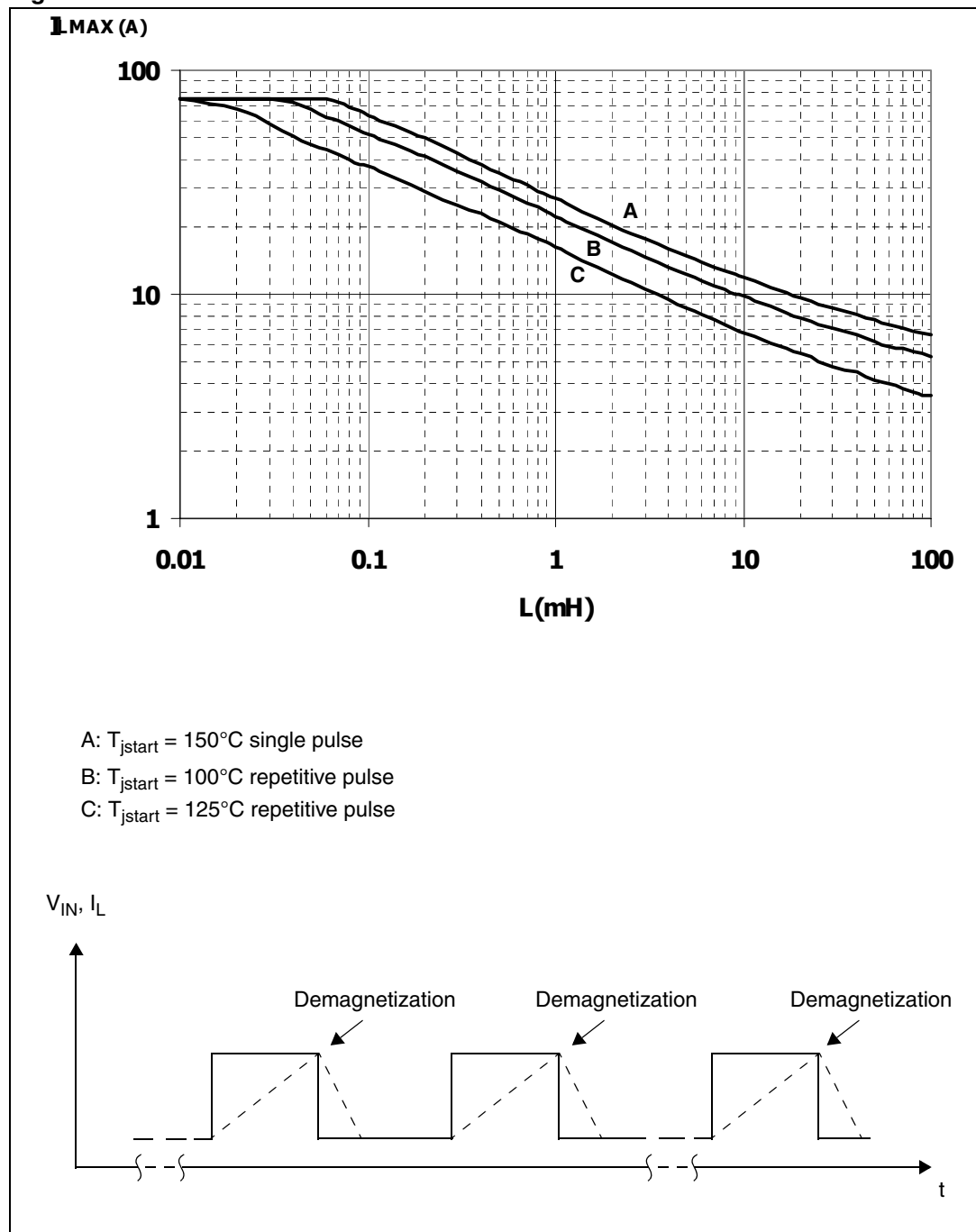
For $V_{CCpeak} = -100V$ and $I_{latchup} \geq 20mA$; $V_{OH\mu C} \geq 4.5V$

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

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

3.4 P²PAK maximum demagnetization energy ($V_{CC} = 13.5V$)

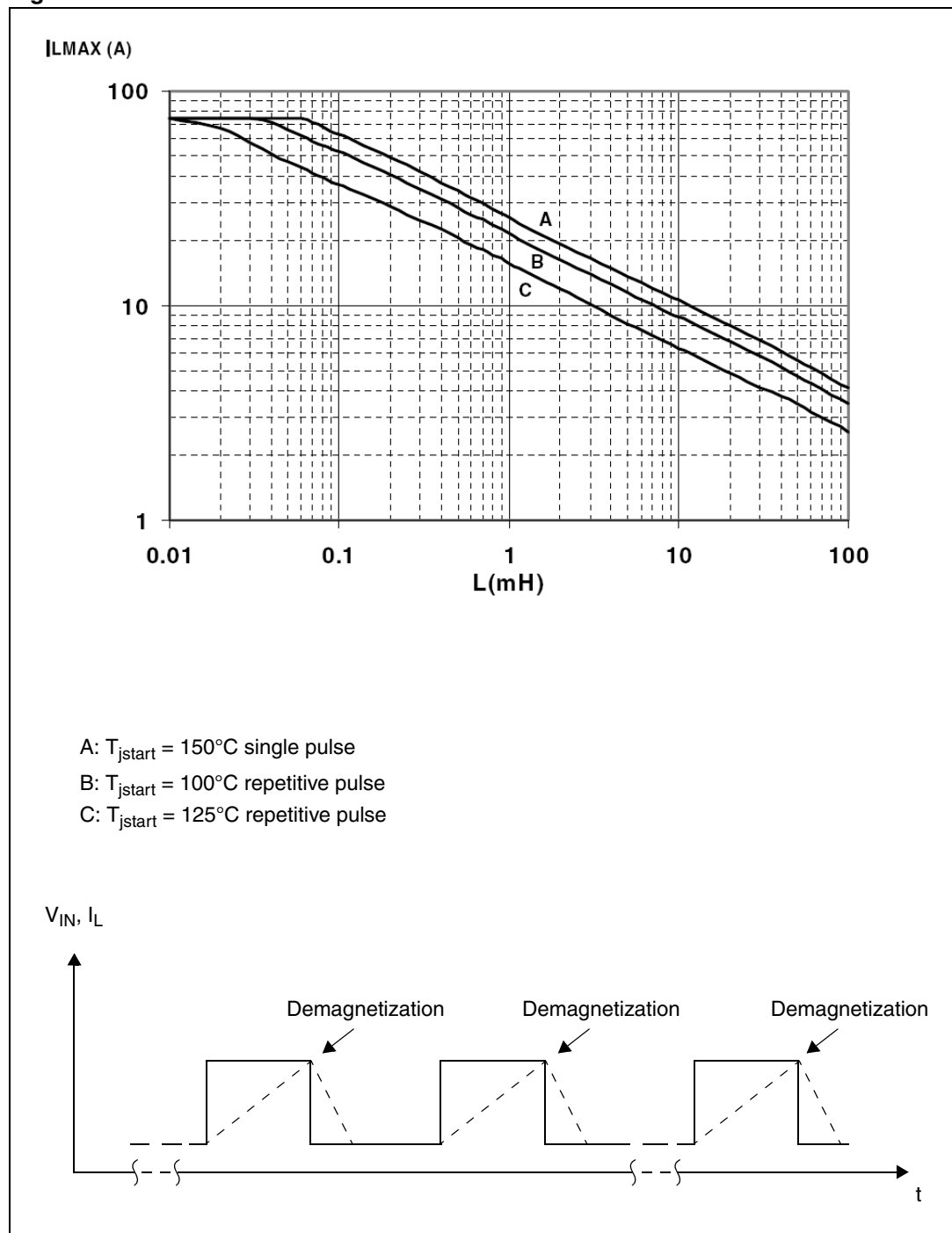
Figure 20. P²PAK maximum turn-off current versus inductance



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.

3.5 SO-16L maximum demagnetization energy ($V_{CC} = 13.5V$)

Figure 21. SO-16L maximum turn-off current versus inductance

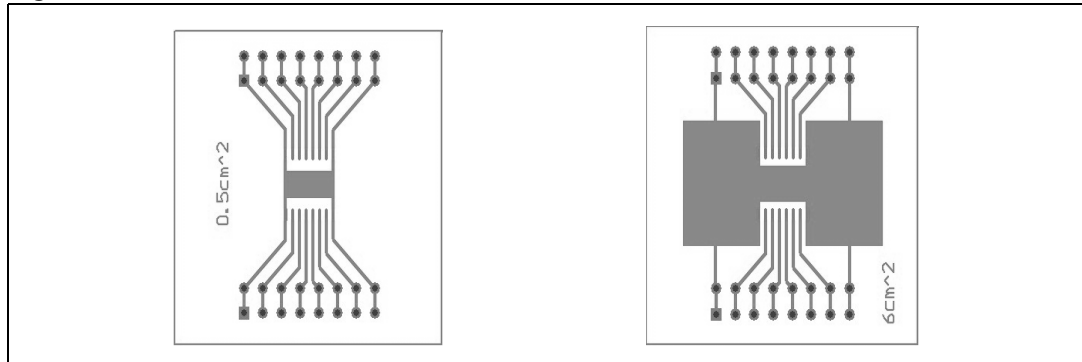


Note: Values are generated with $R_L = 0 \Omega$. In case of repetitive pulses, T_{jstart} (at beginning of each demagnetization) of every pulse must not exceed the temperature specified above for curves A and B.

4 Package and PCB thermal data

4.1 SO-16L thermal data

Figure 22. SO-16L PC board



Note: Layout condition of R_{th} and Z_{th} measurements (PCB FR4 area = 41mm x 48mm, PCB thickness = 2mm, Cu thickness = 35 μ m, Copper areas: 0.5cm², 6cm²).

Figure 23. SO-16L $R_{thj-amb}$ Vs PCB copper area in open box free air condition

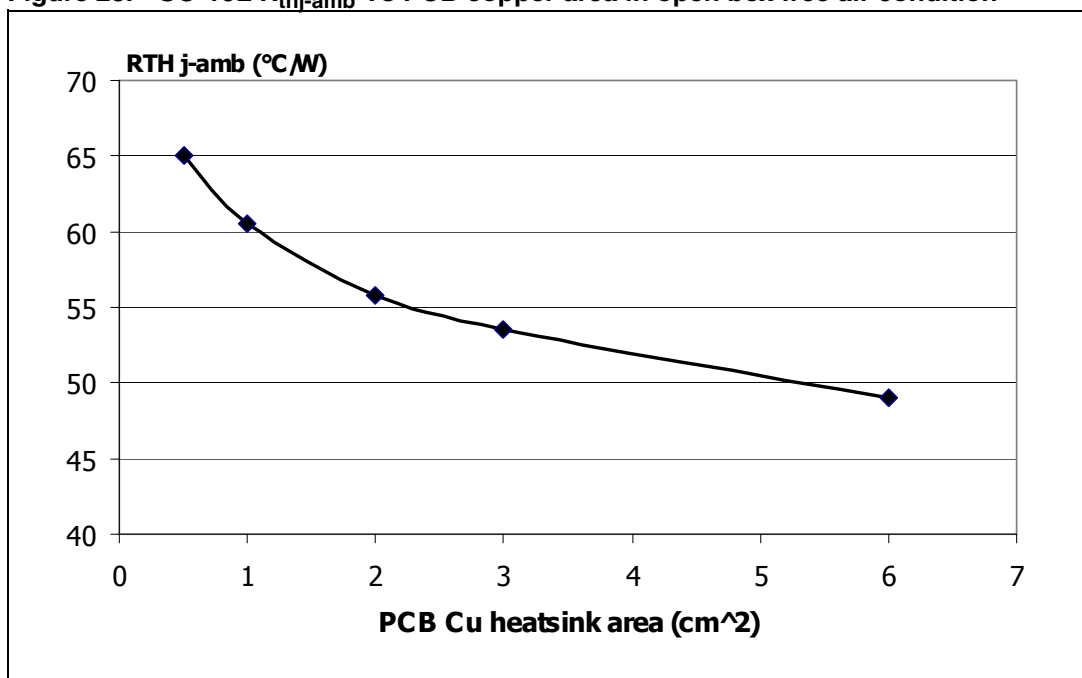
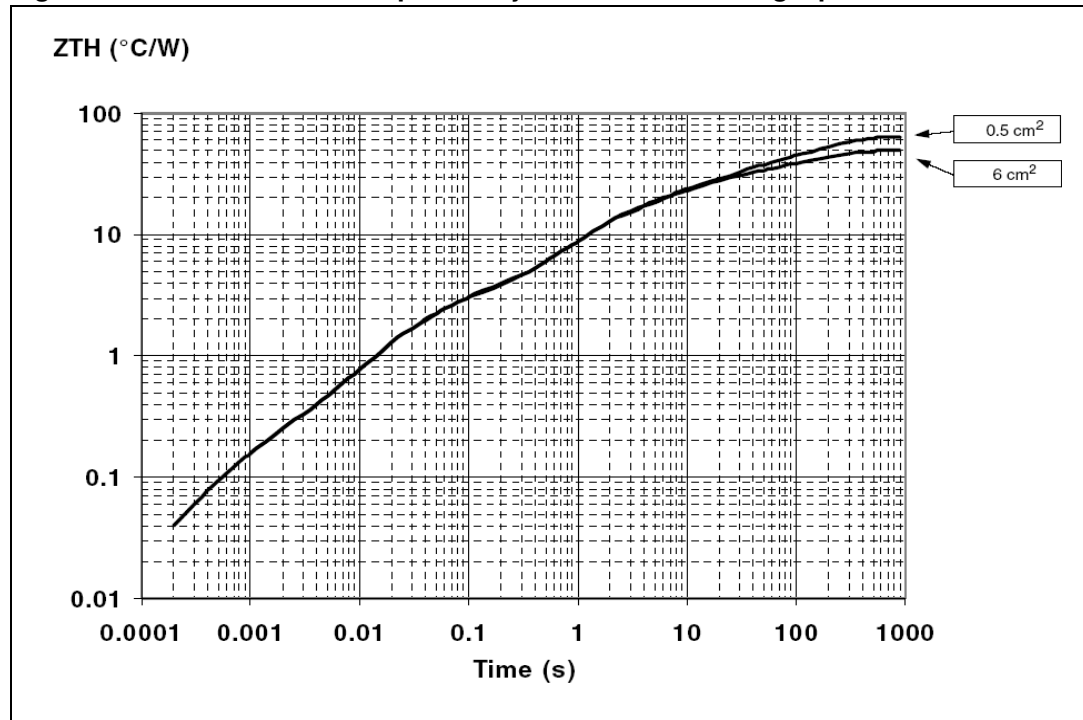


Figure 24. SO-16L thermal impedance junction ambient single pulse



Equation 1: pulse calculation formula

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

$$\text{where } \delta = t_p / T$$

Figure 25. Thermal fitting model of a single channel HSD in SO-16L

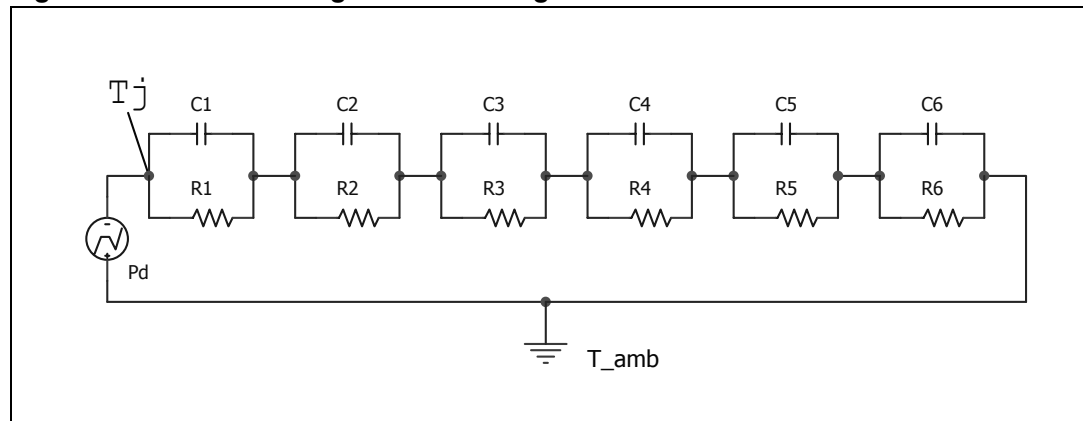
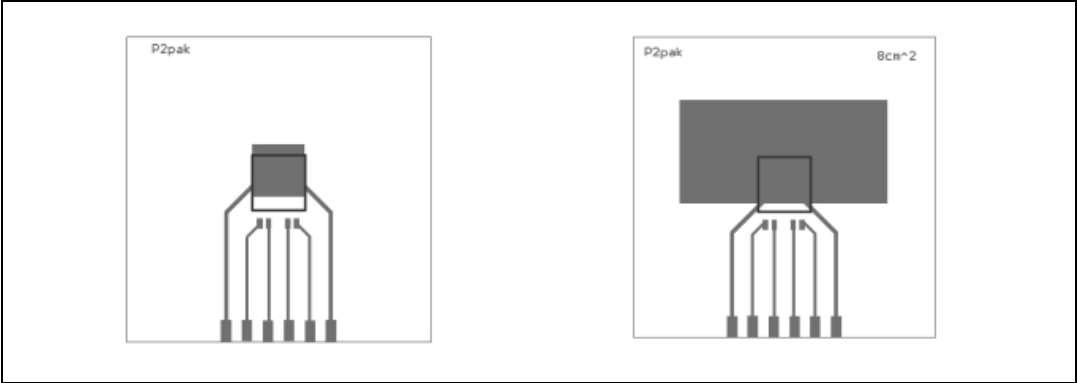


Table 13. SO-16L thermal parameters

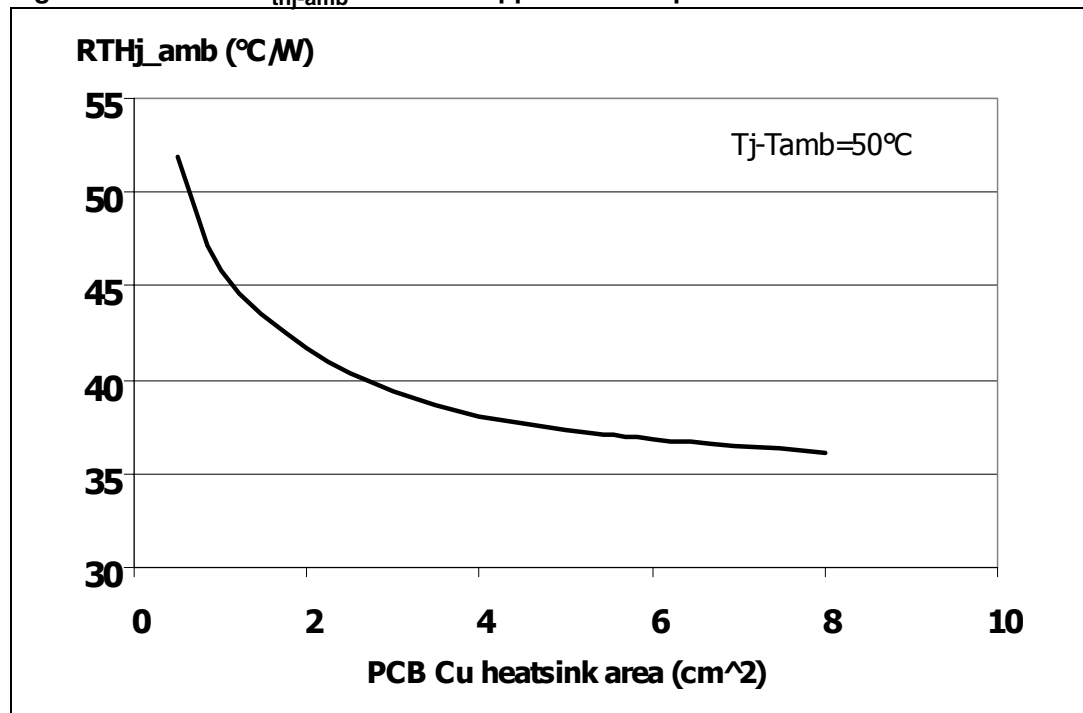
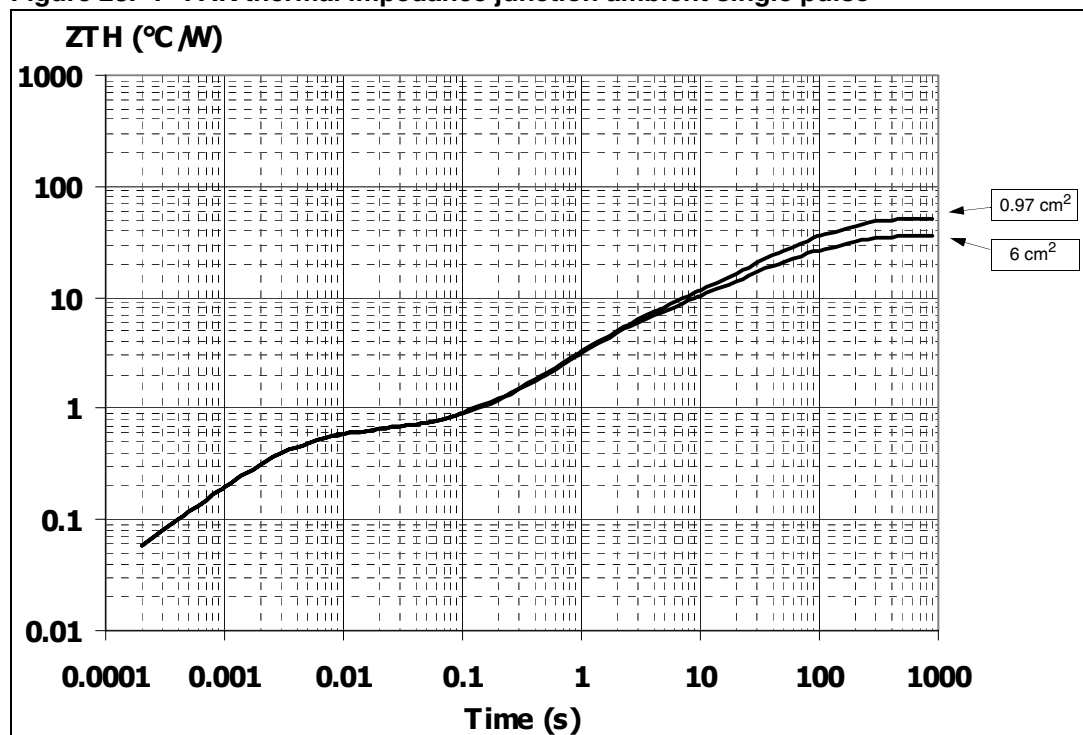
Area / island (cm ²)	Footprint	6
R1 (°C/W)	0.02	
R2 (°C/W)	0.1	
R3 (°C/W)	2.2	
R4 (°C/W)	12	
R5 (°C/W)	15	
R6 (°C/W)	35	20
C1 (W.s/°C)	0.0015	
C2 (W.s/°C)	7E-03	
C3 (W.s/°C)	1.5E-02	
C4 (W.s/°C)	0.14	
C5 (W.s/°C)	1	
C6 (W.s/°C)	5	8

4.2 P²PAK thermal data

Figure 26. P²PAK PC board



Note: Layout condition of R_{th} and Z_{th} measurements (PCB FR4 area = 60mm x 60mm, PCB thickness = 2 mm, Cu thickness = 35 μ m , Copper areas: 0.97cm², 8cm²).

Figure 27. P²PAK R_{thj-amb} Vs. PCB copper area in open box free air conditionFigure 28. P²PAK thermal impedance junction ambient single pulse

Equation 2: pulse calculation formula

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

where $\delta = t_p/T$

Figure 29. Thermal fitting model of a single channel HSD in P²PAK

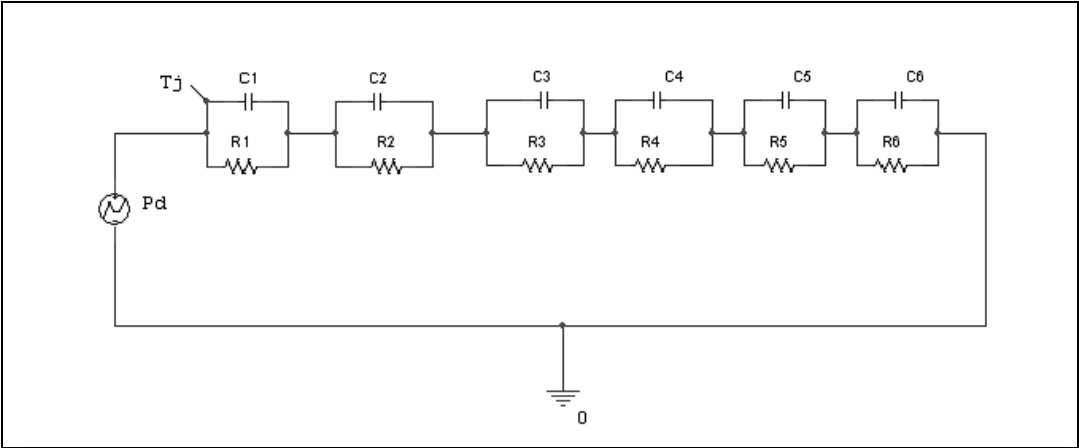


Table 14. P²PAK thermal parameter

Area/island (cm ²)	0.97	6
R1 (°C/W)	0.02	
R2 (°C/W)	0.1	
R3 (°C/W)	0.22	
R4 (°C/W)	4	
R5 (°C/W)	9	
R6 (°C/W)	37	22
C1 (W·s/°C)	0.0015	
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

5 Package and packing information

5.1 ECOPACK® packages

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.

Figure 30. SO-16L package dimensions

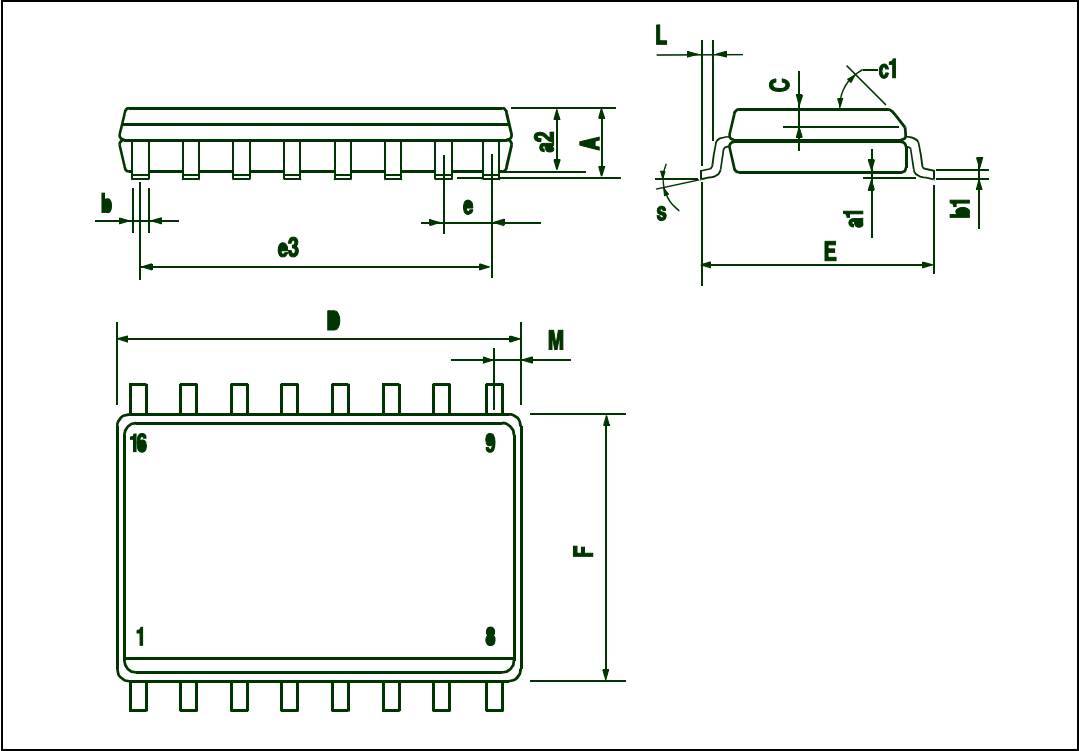


Table 15. SO-16L mechanical data

DIM.	mm.		
	Min.	Typ.	Max.
A			2.65
a1	0.1		0.2
a2			2.45
b	0.35		0.49
b1	0.23		0.32
C		0.5	
c1	45° (typ.)		

Table 15. SO-16L mechanical data (continued)

DIM.	mm.		
	Min.	Typ.	Max.
D	10.1		10.5
E	10.0		10.65
e		1.27	
e3		8.89	
F	7.4		7.6
L	0.5		1.27
M			0.75
S	8° (max.)		

5.2 PENTAWATT mechanical data

Figure 31. PENTAWATT package dimensions

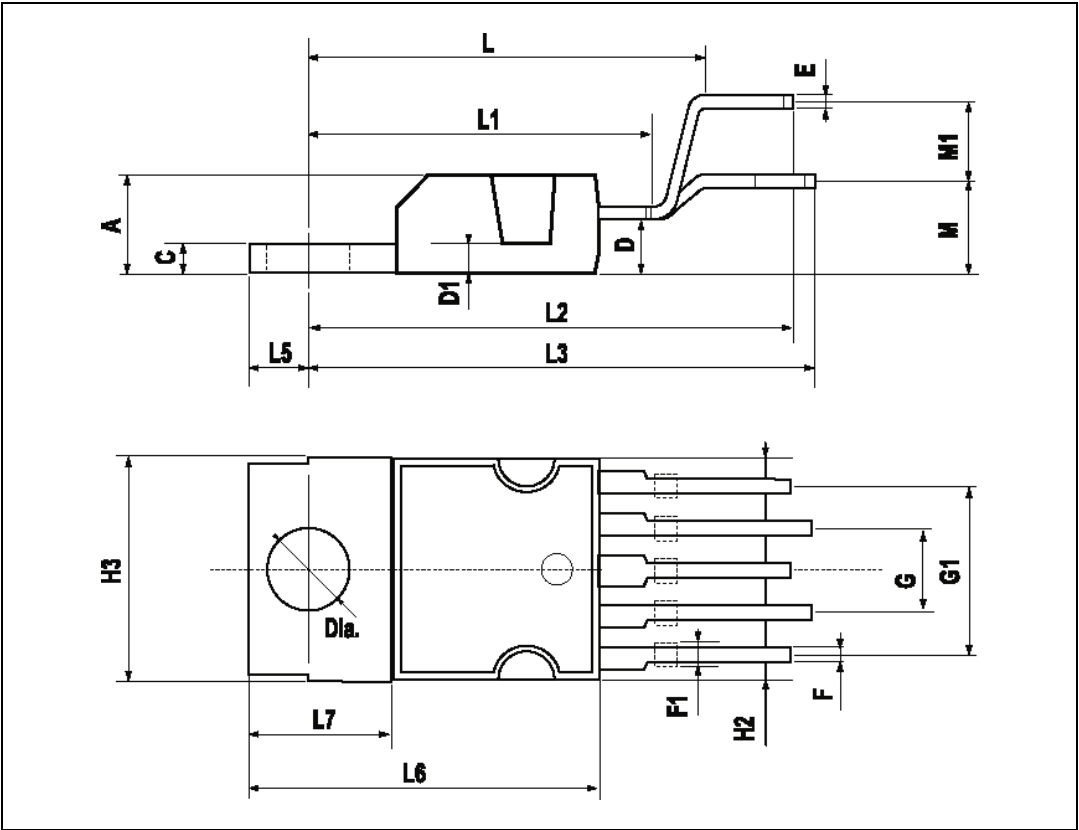


Table 16. PENTAWATT mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A			4.8
C			1.37
D	2.4		2.8
D1	1.2		1.35
E	0.35		0.55
F	0.8		1.05
F1	1		1.4
G	3.2	3.4	3.6
G1	6.6	6.8	7
H2			10.4
H3	10.05		10.4
L		17.85	
L1		15.75	
L2		21.4	
L3		22.5	
L5	2.6		3
L6	15.1		15.8
L7	6		6.6
M		4.5	
M1		4	
Diam.	3.65		3.85

5.3 P²PAK mechanical data

Figure 32. P²PAK package dimensions

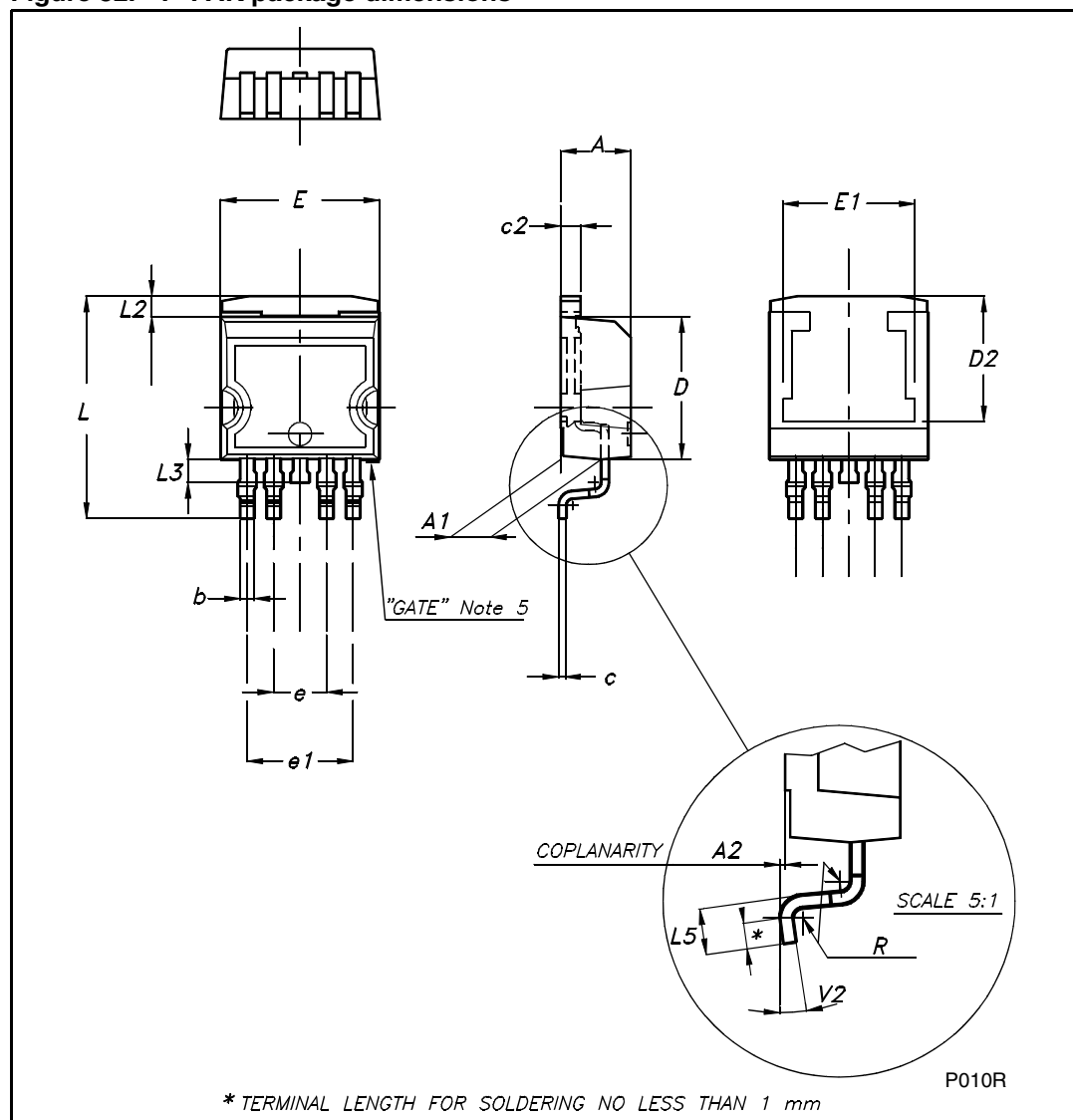


Table 17. P²PAK mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.30		4.80
A1	2.40		2.80
A2	0.03		0.23
b	0.80		1.05
c	0.45		0.60
c2	1.17		1.37
D	8.95		9.35
D2		8.00	
E	10.00		10.40
E1		8.50	
e	3.20		3.60
e1	6.60		7.00
L	13.70		14.50
L2	1.25		1.40
L3	0.90		1.70
L5	1.55		2.40
R		0.40	
V2	0°		8°
Package weight	1.40 Gr (typ)		

5.4 SO-16L packing information

Figure 33. SO-16L tube shipment (no suffix)

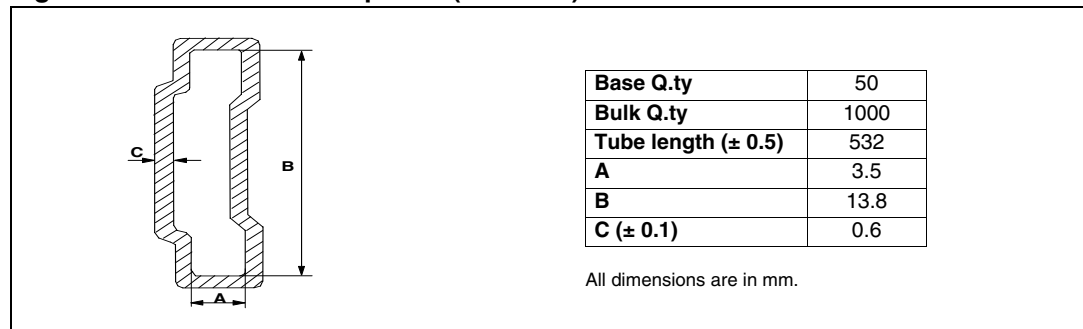
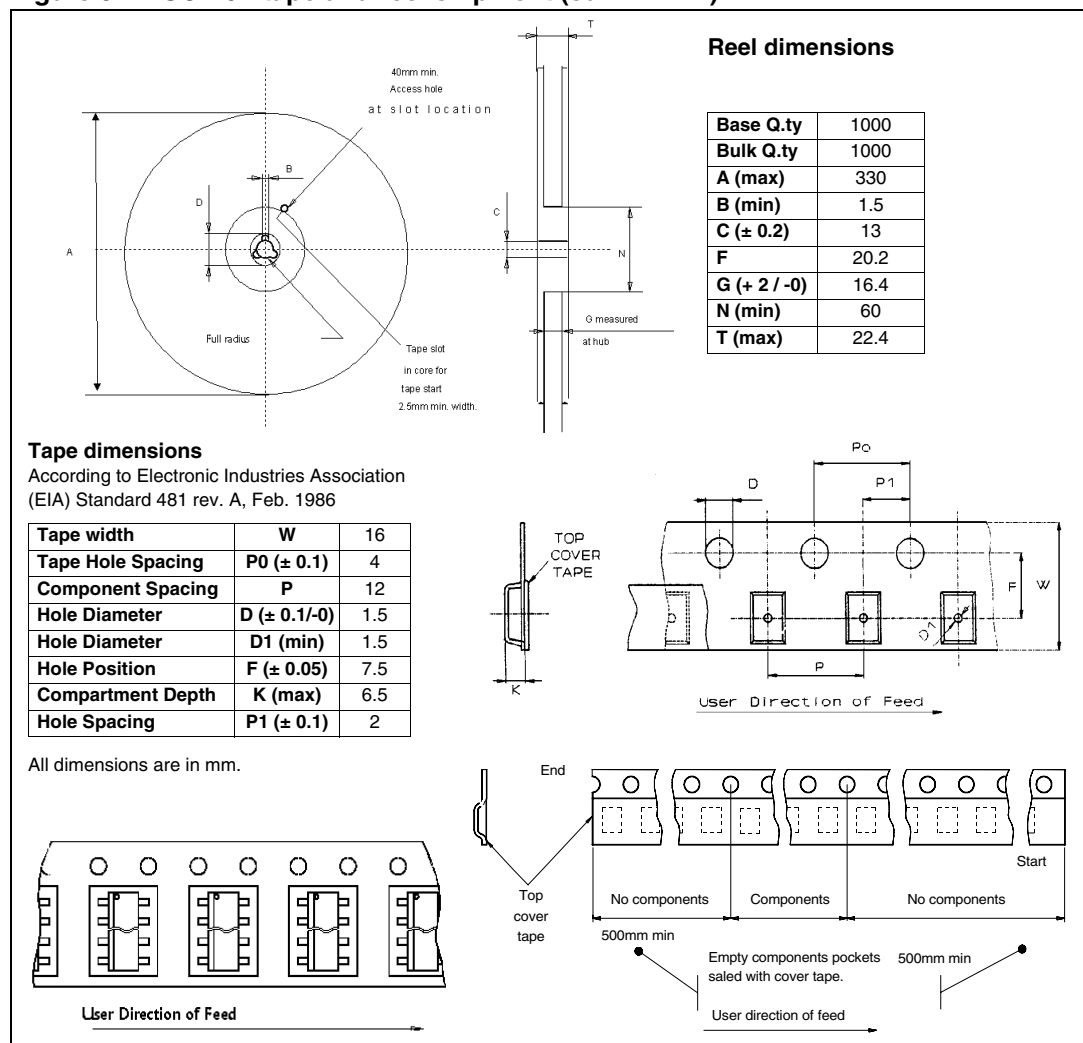
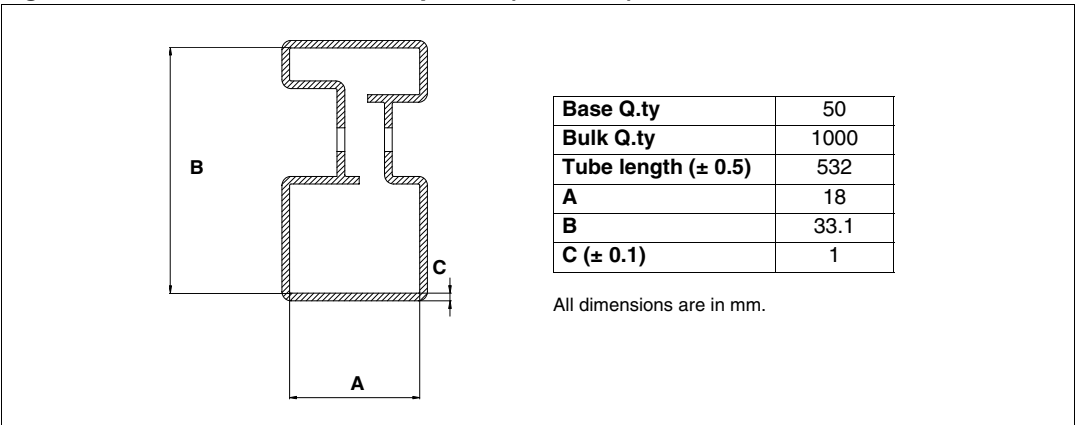


Figure 34. SO-16L tape and reel shipment (suffix "TR")



5.5 PENTAWATT packing information

Figure 35. PENTAWATT tube shipment (no suffix)



5.6 P²PAK packing information

Figure 36. P²PAK tube shipment (no suffix)

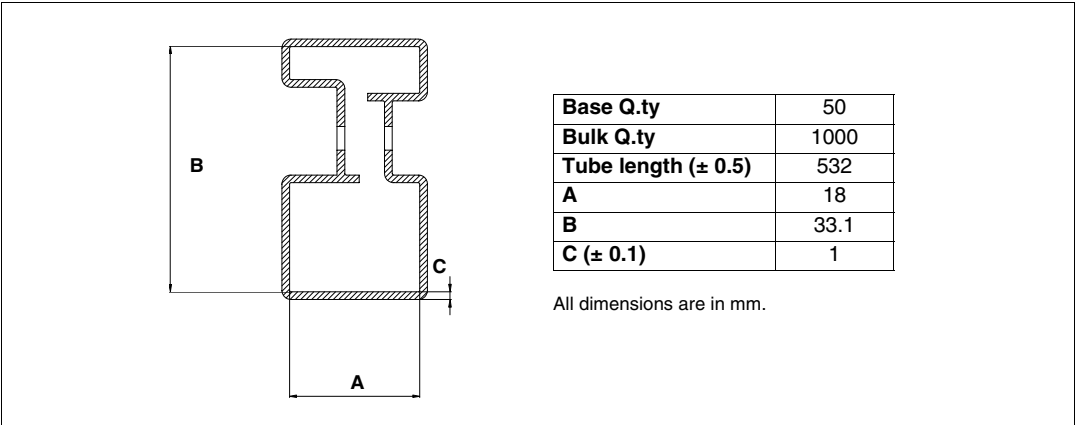
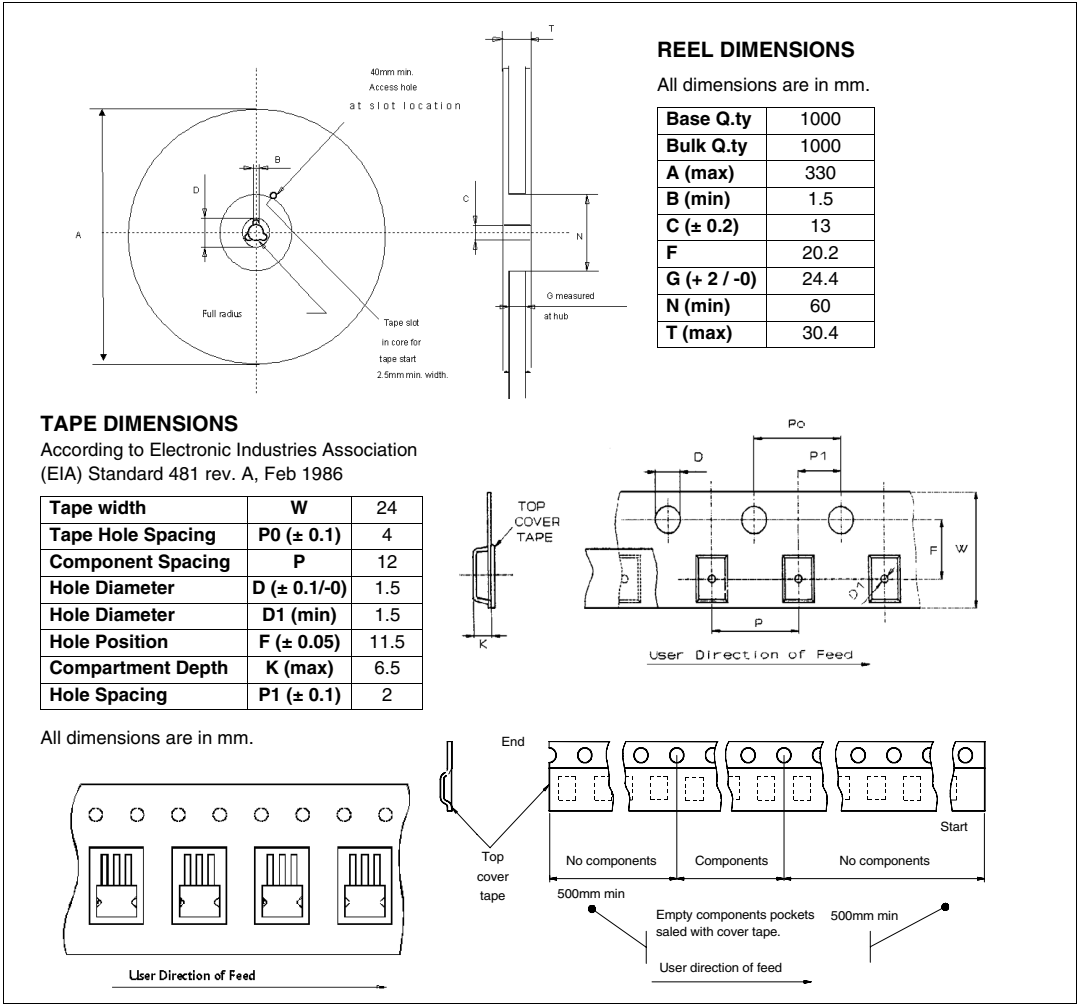


Figure 37. P²PAK tape and reel (suffix “13TR”)



6 Revision history

Table 18. Document revision history

Date	Revision	Changes
22-Jun-2004	1	Initial release.
07-Jul-2004	2	Current and voltage convention update (page 2). Configuration diagram (top view) & suggested connections for unused and n.c. pins insertion (page 2). 6cm2 Cu condition insertion in thermal data table (page 3).
09-Jul-2004	3	V _{CC} - output diode section update (page 5). Protections note insertion (page 5). Revision history table insertion (page 24). Disclaimers update (page 25).
03-May-2006	4	Suggested connections for unused and n.c.pins? correction (page 2).
17-Dec-2008	5	Document reformatted and restructured. Added content, list of figures and tables. Added ECOPACK® packages information. Updated Figure 37.: P²PAK tape and reel (suffix "13TR") : changed component spacing (P) in tape dimensions table from 16 mm to 12 mm.
24-Sep-2013	6	Updated Disclaimer.

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