

N-channel 600 V, 0.135  $\Omega$  typ., 22 A MDmesh™ M2  
Power MOSFETs in D<sup>2</sup>PAK, I<sup>2</sup>PAK, TO-220 and TO-247

Datasheet - production data

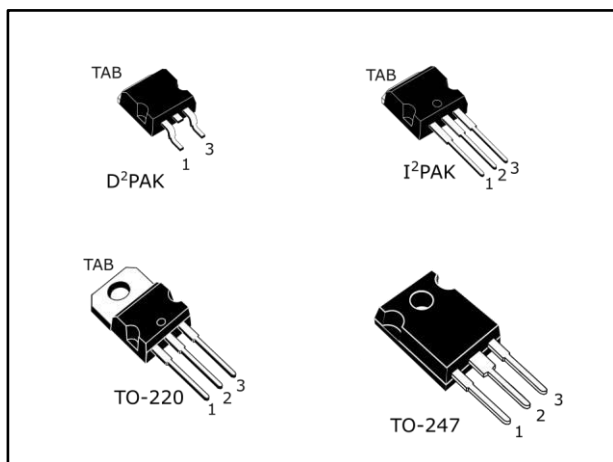
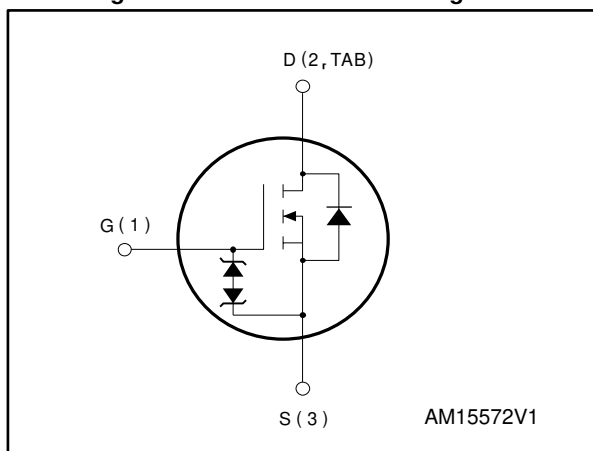


Figure 1: Internal schematic diagram



## Features

Order code	V <sub>DS</sub> @ T <sub>Jmax</sub>	R <sub>DS(on)</sub> max.	I <sub>D</sub>
STB28N60M2	650 V	0.150 $\Omega$	22 A
STI28N60M2			
STP28N60M2			
STW28N60M2			

- Extremely low gate charge
- Excellent output capacitance (C<sub>oss</sub>) profile
- 100% avalanche tested
- Zener-protected

## Applications

- Switching applications
- LCC converters, resonant converters

## Description

These devices are N-channel Power MOSFETs developed using MDmesh™ M2 technology. Thanks to their strip layout and improved vertical structure, these devices exhibit low on-resistance and optimized switching characteristics, rendering them suitable for the most demanding high efficiency converters.

Table 1: Device summary

Order code	Marking	Package	Packing
STB28N60M2	28N60M2	D <sup>2</sup> PAK	Tape and reel
STI28N60M2		I <sup>2</sup> PAK	Tube
STP28N60M2		TO-220	
STW28N60M2		TO-247	

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# 1 Electrical ratings

**Table 2: Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V <sub>GS</sub>	Gate-source voltage	±25	V
I <sub>D</sub>	Drain current (continuous) at T <sub>C</sub> = 25 °C	22	A
I <sub>D</sub>	Drain current (continuous) at T <sub>C</sub> = 100 °C	14	A
I <sub>DM</sub> <sup>(1)</sup>	Drain current (pulsed)	88	A
P <sub>TOT</sub>	Total dissipation at T <sub>C</sub> = 25 °C	170	W
dv/dt <sup>(2)</sup>	Peak diode recovery voltage slope	15	V/ns
dv/dt <sup>(3)</sup>	MOSFET dv/dt ruggedness	50	V/ns
T <sub>stg</sub>	Storage temperature range	-55 to 150	°C
T <sub>j</sub>	Operating junction temperature range		

**Notes:**

<sup>(1)</sup>Pulse width limited by safe operating area.

<sup>(2)</sup>I<sub>SD</sub> ≤ 22 A, di/dt ≤ 400 A/μs; V<sub>DS(peak)</sub> < V<sub>(BR)DSS</sub>, V<sub>DD</sub> = 400 V.

<sup>(3)</sup>V<sub>DS</sub> ≤ 480 V

**Table 3: Thermal data**

Symbol	Parameter	Value				Unit
		D <sup>2</sup> PAK	I <sup>2</sup> PAK	TO-220	TO-247	
R <sub>thj-case</sub>	Thermal resistance junction-case max	0.74				°C/W
R <sub>thj-pcb</sub>	Thermal resistance junction-pcb max <sup>(1)</sup>	30				°C/W
R <sub>thj-amb</sub>	Thermal resistance junction-ambient max		62.5	62.5	50	°C/W

**Notes:**

<sup>(1)</sup>When mounted on 1 inch<sup>2</sup> FR-4, 2 Oz copper board.

**Table 4: Avalanche characteristics**

Symbol	Parameter	Value	Unit
I <sub>AR</sub>	Avalanche current, repetitive or not repetitive (pulse width limited by T <sub>jmax</sub> )	3.6	A
E <sub>AS</sub>	Single pulse avalanche energy (starting T <sub>j</sub> = 25 °C, I <sub>D</sub> = I <sub>AR</sub> ; V <sub>DD</sub> = 50 V)	350	mJ

## 2 Electrical characteristics

$T_C = 25\text{ °C}$  unless otherwise specified.

**Table 5: On/off states**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	$V_{GS} = 0\text{ V}$ , $I_D = 1\text{ mA}$	600			V
$I_{DSS}$	Zero gate voltage drain current	$V_{GS} = 0\text{ V}$ , $V_{DS} = 600\text{ V}$			1	$\mu\text{A}$
		$V_{GS} = 0\text{ V}$ , $V_{DS} = 600\text{ V}$ , $T_C = 125\text{ °C}^{(1)}$			100	$\mu\text{A}$
$I_{GSS}$	Gate-body leakage current	$V_{DS} = 0\text{ V}$ , $V_{GS} = \pm 25\text{ V}$			$\pm 10$	$\mu\text{A}$
$V_{GS(th)}$	Gate threshold voltage	$V_{DS} = V_{GS}$ , $I_D = 250\text{ }\mu\text{A}$	2	3	4	V
$R_{DS(on)}$	Static drain-source on-resistance	$V_{GS} = 10\text{ V}$ , $I_D = 11\text{ A}$		0.135	0.150	$\Omega$

**Notes:**

<sup>(1)</sup> Defined by design, not subject to production test.

**Table 6: Dynamic**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$C_{iss}$	Input capacitance	$V_{DS} = 100\text{ V}$ , $f = 1\text{ MHz}$ , $V_{GS} = 0\text{ V}$	-	1440	-	pF
$C_{oss}$	Output capacitance		-	70	-	pF
$C_{rss}$	Reverse transfer capacitance		-	2	-	pF
$C_{oss\text{ eq.}}^{(1)}$	Equivalent output capacitance	$V_{DS} = 0\text{ to }480\text{ V}$ , $V_{GS} = 0\text{ V}$	-	104	-	pF
$R_G$	Intrinsic gate resistance	$f = 1\text{ MHz}$ open drain	-	5.5	-	$\Omega$
$Q_g$	Total gate charge	$V_{DD} = 480\text{ V}$ , $I_D = 22\text{ A}$ ,	-	36	-	nC
$Q_{gs}$	Gate-source charge	$V_{GS} = 0\text{ to }10\text{ V}$ (see <a href="#">Figure 17: "Test circuit for gate charge behavior"</a> )	-	7.2	-	nC
$Q_{gd}$	Gate-drain charge		-	16	-	nC

**Notes:**

<sup>(1)</sup> $C_{oss\text{ eq.}}$  is defined as a constant equivalent capacitance giving the same charging time as  $C_{oss}$  when  $V_{DS}$  increases from 0 to 80 %  $V_{DSS}$ .

**Table 7: Switching times**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	$V_{DD} = 300\text{ V}$ , $I_D = 11\text{ A}$ , $R_G = 4.7\text{ }\Omega$ , $V_{GS} = 10\text{ V}$ (see <a href="#">Figure 16: "Test circuit for resistive load switching times"</a> and <a href="#">Figure 21: "Switching time waveform"</a> )	-	14.5	-	ns
$t_r$	Rise time		-	7.2	-	ns
$t_{d(off)}$	Turn-off-delay time		-	100	-	ns
$t_f$	Fall time		-	8	-	ns

Table 8: Source drain diode

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{SD}$	Source-drain current		-		22	A
$I_{SDM}^{(1)}$	Source-drain current (pulsed)		-		88	A
$V_{SD}^{(2)}$	Forward on voltage	$V_{GS} = 0\text{ V}$ , $I_{SD} = 22\text{ A}$	-		1.6	V
$t_{rr}$	Reverse recovery time	$I_{SD} = 22\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$ , $V_{DD} = 60\text{ V}$ (see <a href="#">Figure 21</a> : "Switching time waveform")	-	350		ns
$Q_{rr}$	Reverse recovery charge		-	4.7		$\mu\text{C}$
$I_{RRM}$	Reverse recovery current		-	27		A
$t_{rr}$	Reverse recovery time	$I_{SD} = 22\text{ A}$ , $di/dt = 100\text{ A}/\mu\text{s}$ , $V_{DD} = 60\text{ V}$ , $T_j = 150\text{ }^\circ\text{C}$ (see <a href="#">Figure 21</a> : "Switching time waveform")	-	451		ns
$Q_{rr}$	Reverse recovery charge		-	6.5		$\mu\text{C}$
$I_{RRM}$	Reverse recovery current		-	29		A

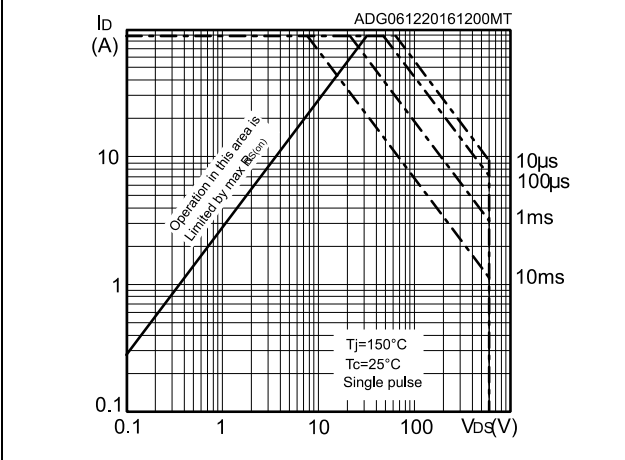
**Notes:**

(1) Pulse width is limited by safe operating area.

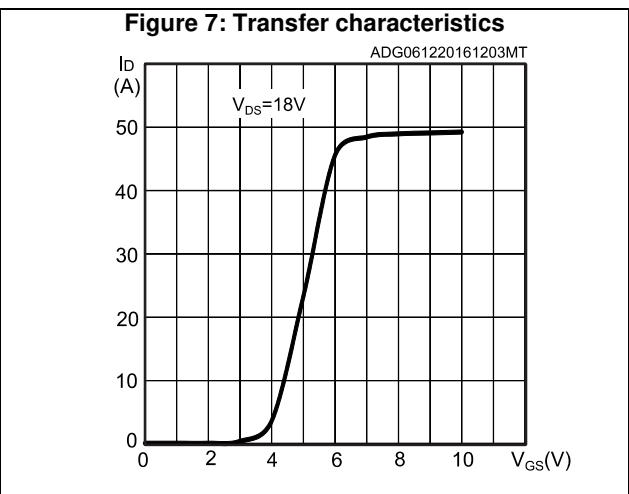
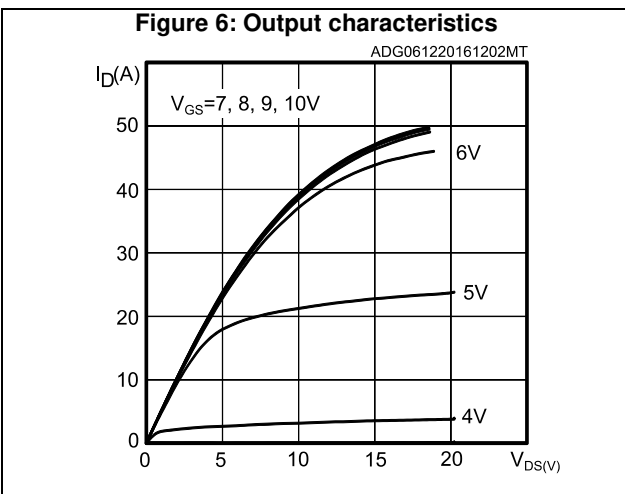
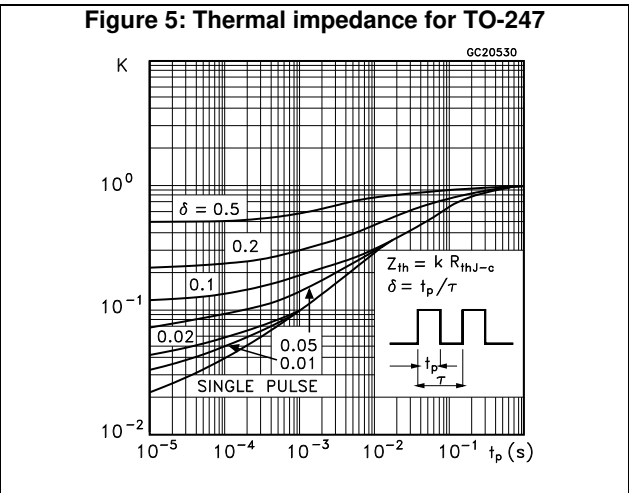
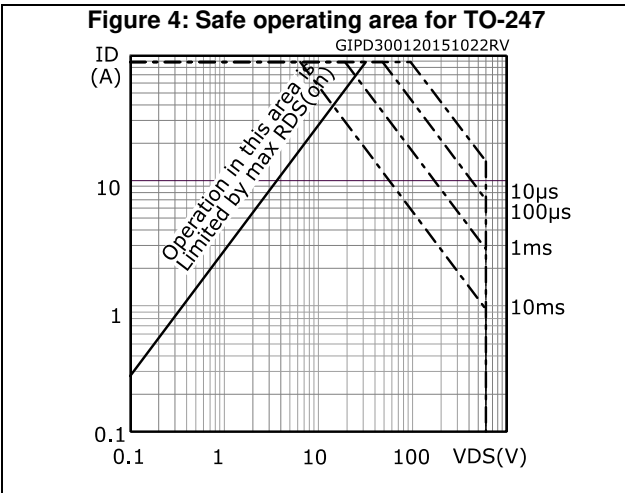
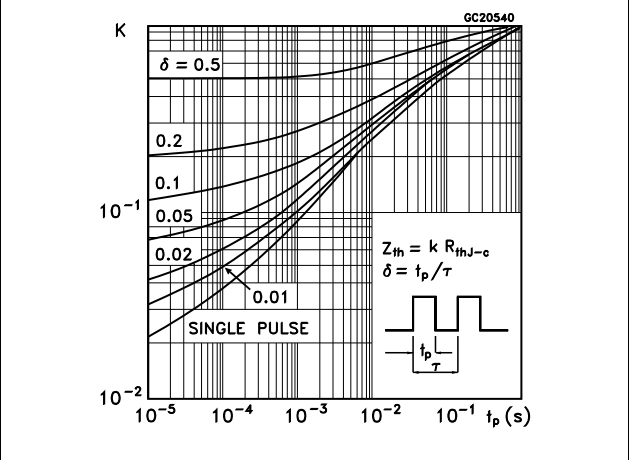
(2) Pulsed: pulse duration = 300  $\mu\text{s}$ , duty cycle 1.5 %.

## 2.1 Electrical characteristics (curves)

**Figure 2: Safe operating area for D<sup>2</sup>PAK, TO-220 and I<sup>2</sup>PAK**



**Figure 3: Thermal impedance for D<sup>2</sup>PAK, TO-220 and I<sup>2</sup>PAK**



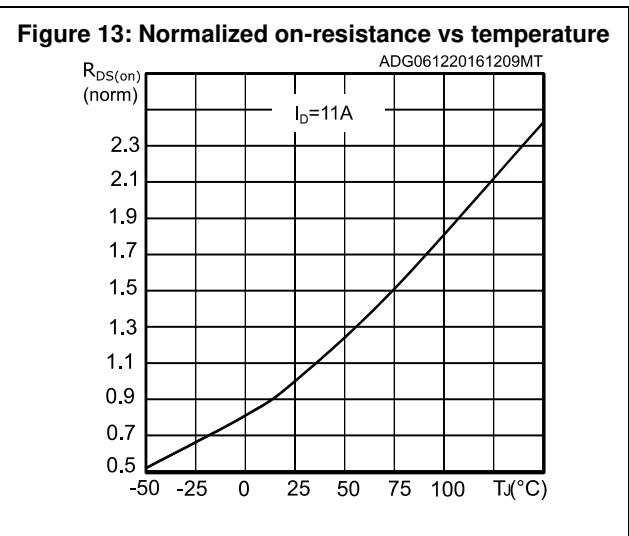
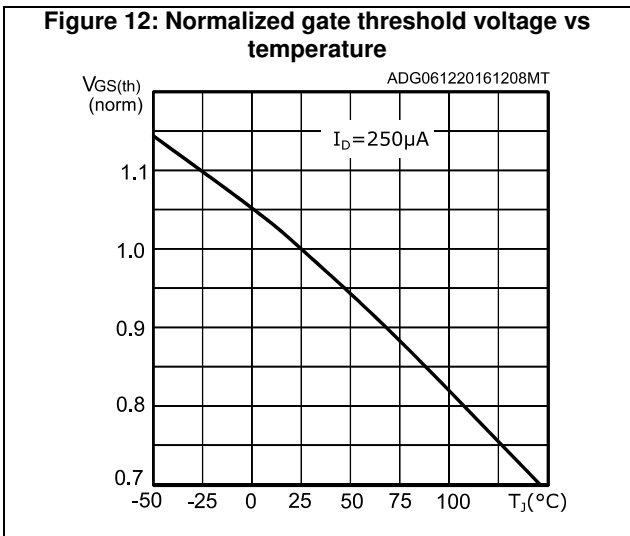
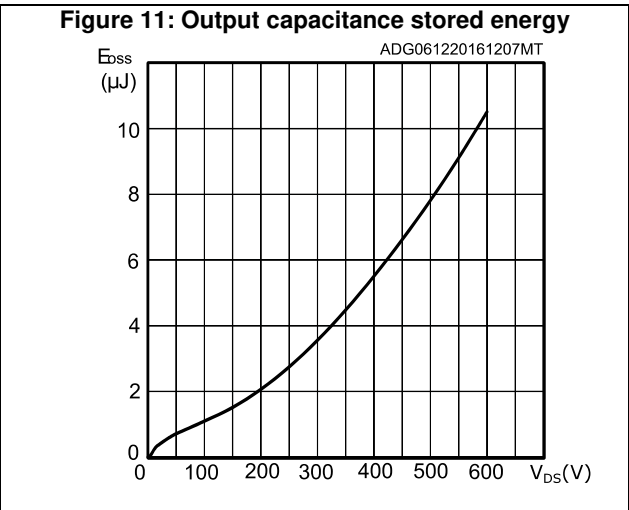
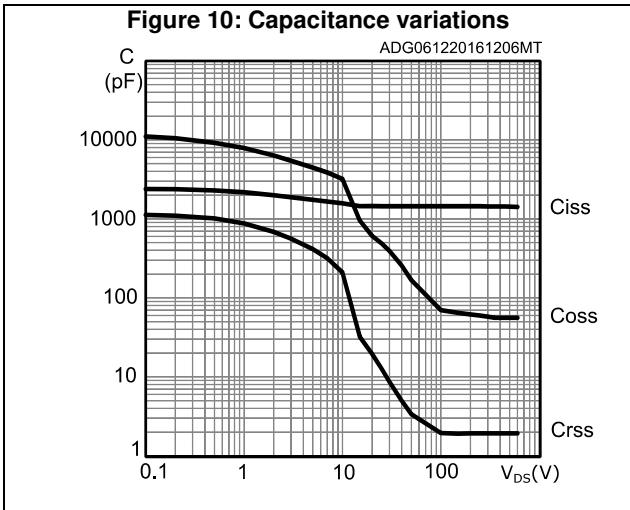
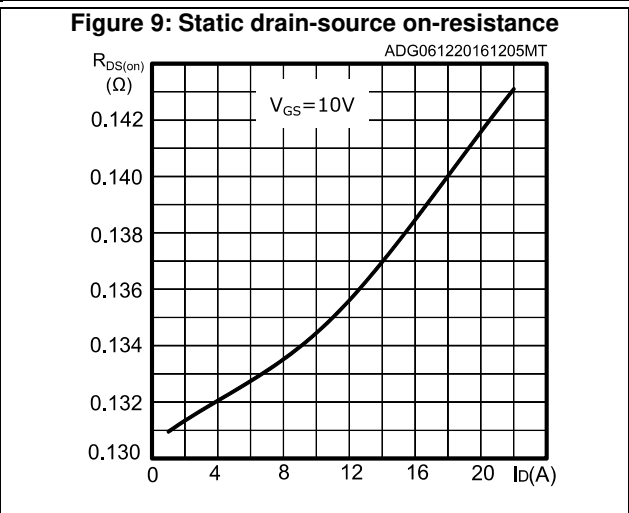
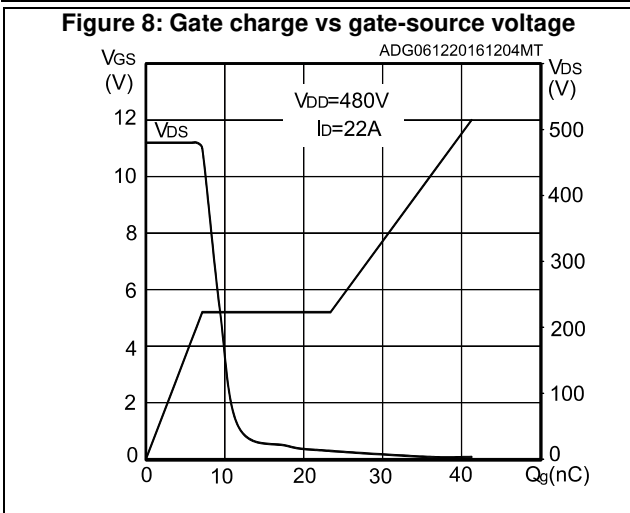


Figure 14: Normalized VDS vs temperature

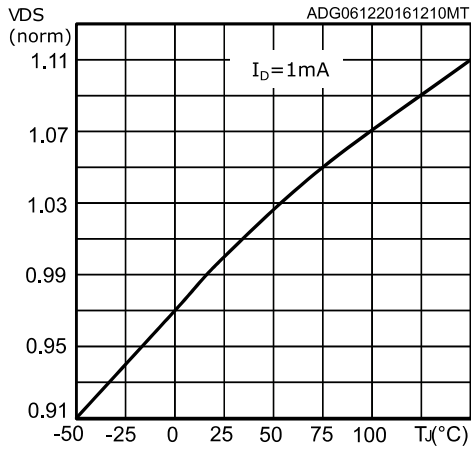
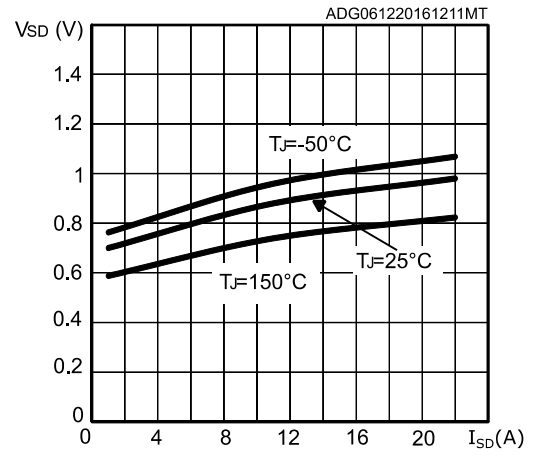


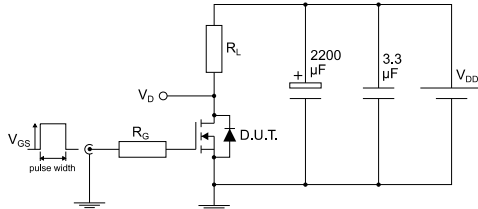
Figure 15: Source-drain diode forward characteristics





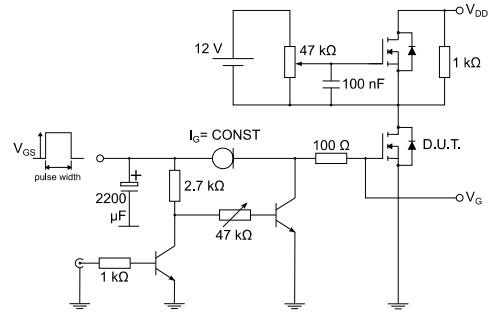
### 3 Test circuits

**Figure 16: Test circuit for resistive load switching times**



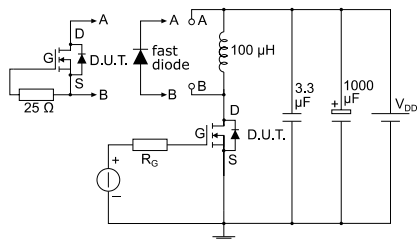
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**Figure 17: Test circuit for gate charge behavior**



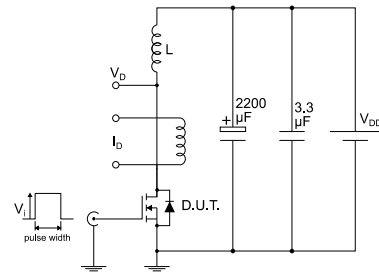
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**Figure 18: Test circuit for inductive load switching and diode recovery times**



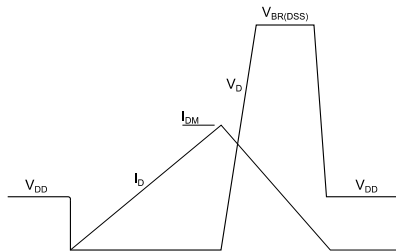
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**Figure 19: Unclamped inductive load test circuit**



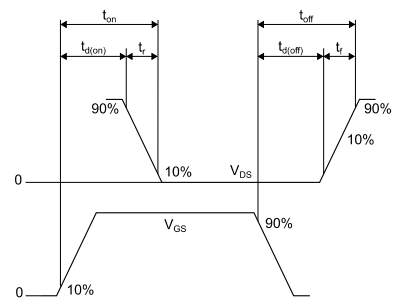
AM01471v1

**Figure 20: Unclamped inductive waveform**



AM01472v1

**Figure 21: Switching time waveform**



AM01473v1

## 4 Package information

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.

### 4.1 D<sup>2</sup>PAK package information

Figure 22: D<sup>2</sup>PAK (TO-263) type A package outline

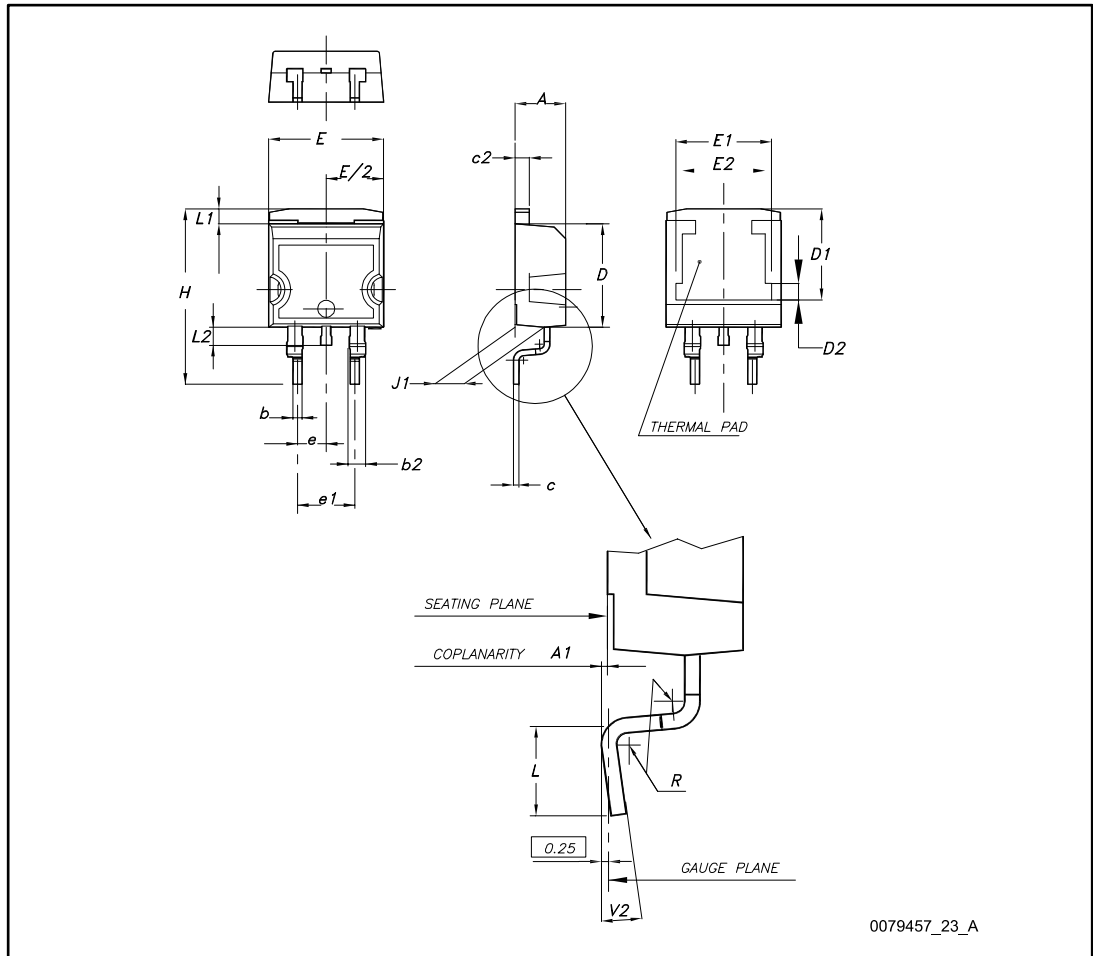
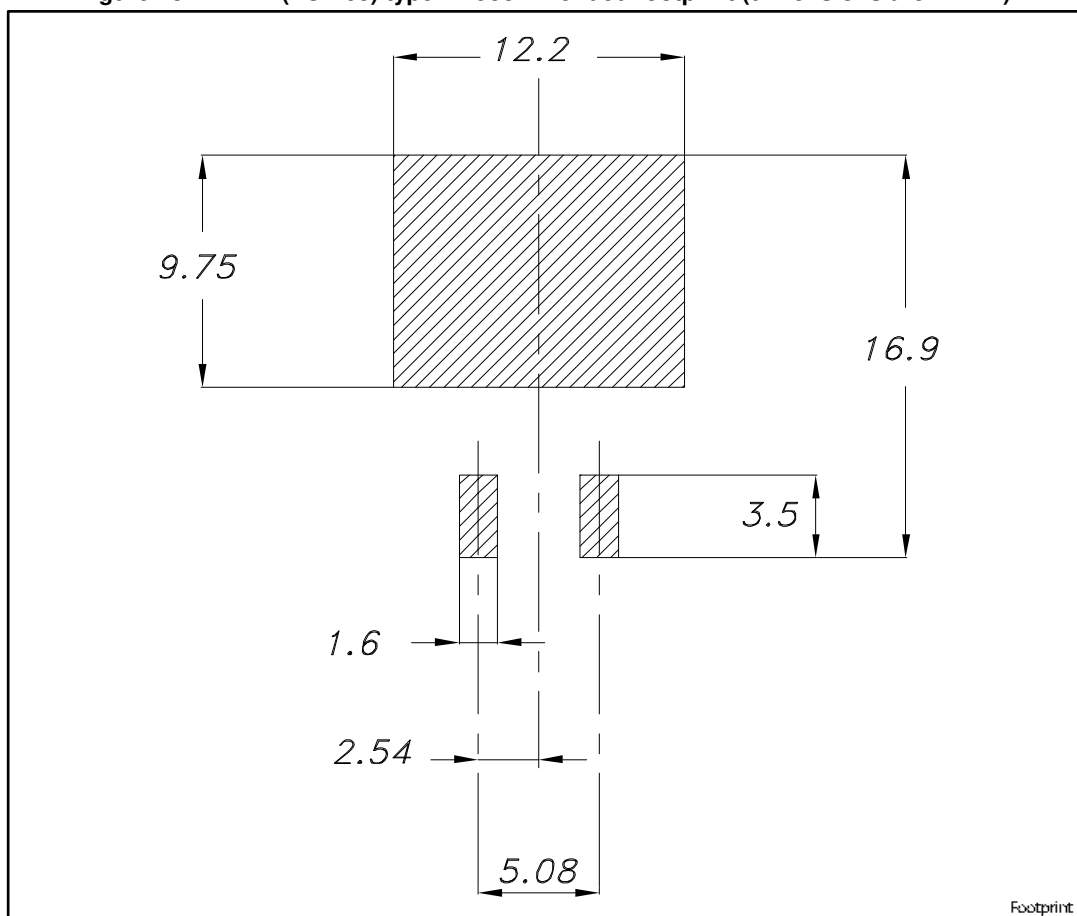


Table 9: D<sup>2</sup>PAK (TO-263) type A package mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.40		4.60
A1	0.03		0.23
b	0.70		0.93
b2	1.14		1.70
c	0.45		0.60
c2	1.23		1.36
D	8.95		9.35
D1	7.50	7.75	8.00
D2	1.10	1.30	1.50
E	10.00		10.40
E1	8.50	8.70	8.90
E2	6.85	7.05	7.25
e		2.54	
e1	4.88		5.28
H	15.00		15.85
J1	2.49		2.69
L	2.29		2.79
L1	1.27		1.40
L2	1.30		1.75
R		0.40	
V2	0°		8°

Figure 23: D<sup>2</sup>PAK (TO-263) type A recommended footprint (dimensions are in mm)



## 4.2 D<sup>2</sup>PAK packing information

Figure 24: D<sup>2</sup>PAK type A tape outline

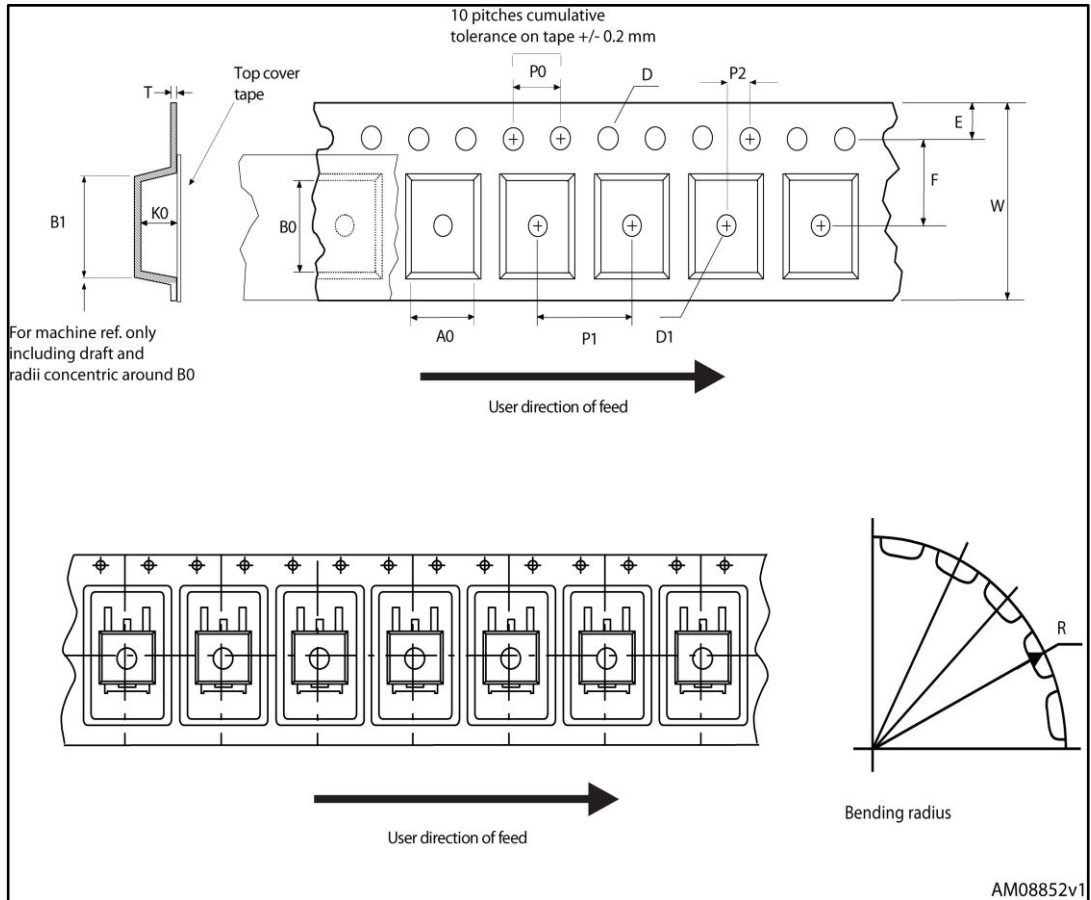


Figure 25: D2PAK type A reel outline

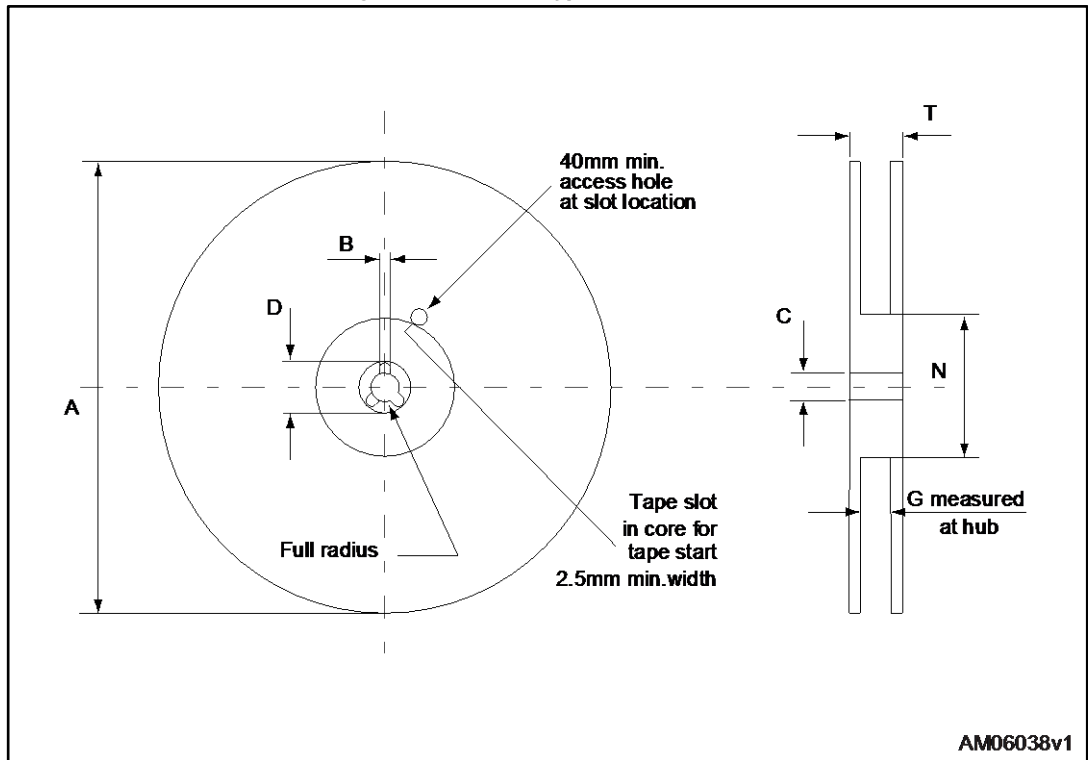


Table 10: D<sup>2</sup>PAK type A tape and reel mechanical data

Tape			Reel		
Dim.	mm		Dim.	mm	
	Min.	Max.		Min.	Max.
A0	10.5	10.7	A		330
B0	15.7	15.9	B	1.5	
D	1.5	1.6	C	12.8	13.2
D1	1.59	1.61	D	20.2	
E	1.65	1.85	G	24.4	26.4
F	11.4	11.6	N	100	
K0	4.8	5.0	T		30.4
P0	3.9	4.1			
P1	11.9	12.1	Base quantity		1000
P2	1.9	2.1	Bulk quantity		1000
R	50				
T	0.25	0.35			
W	23.7	24.3			

### 4.3 I<sup>2</sup>PAK package information

Figure 26: I<sup>2</sup>PAK package outline

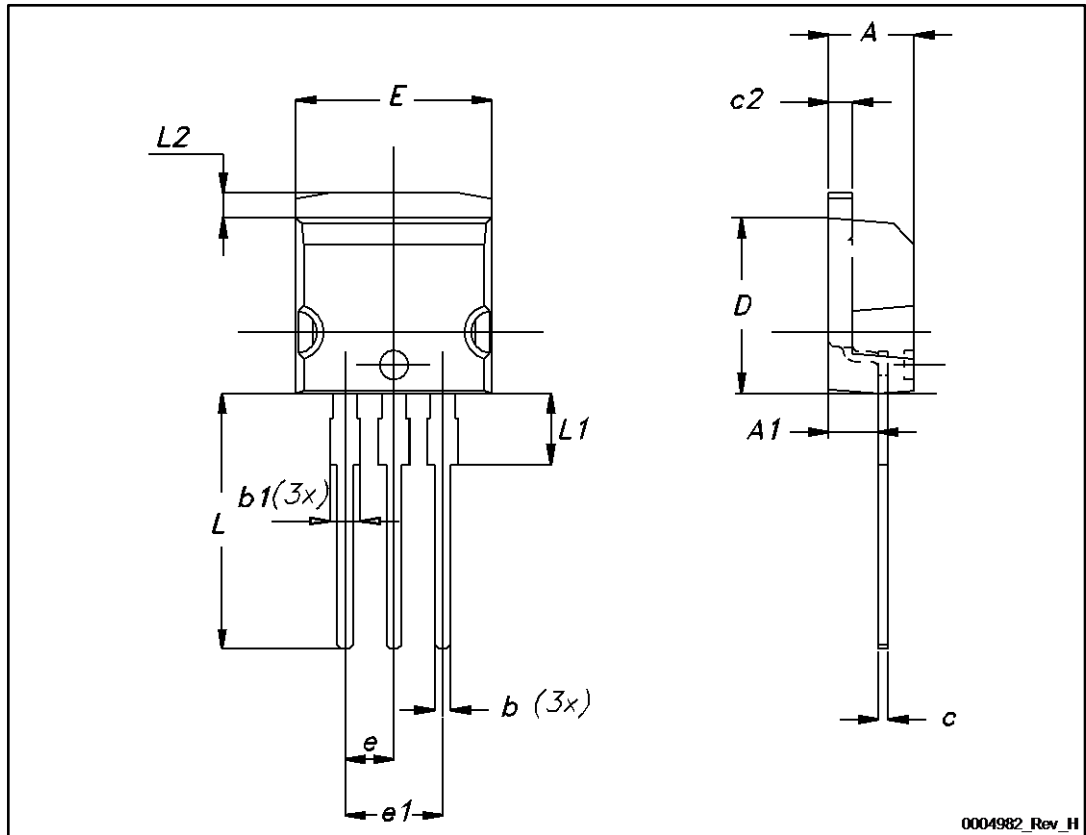
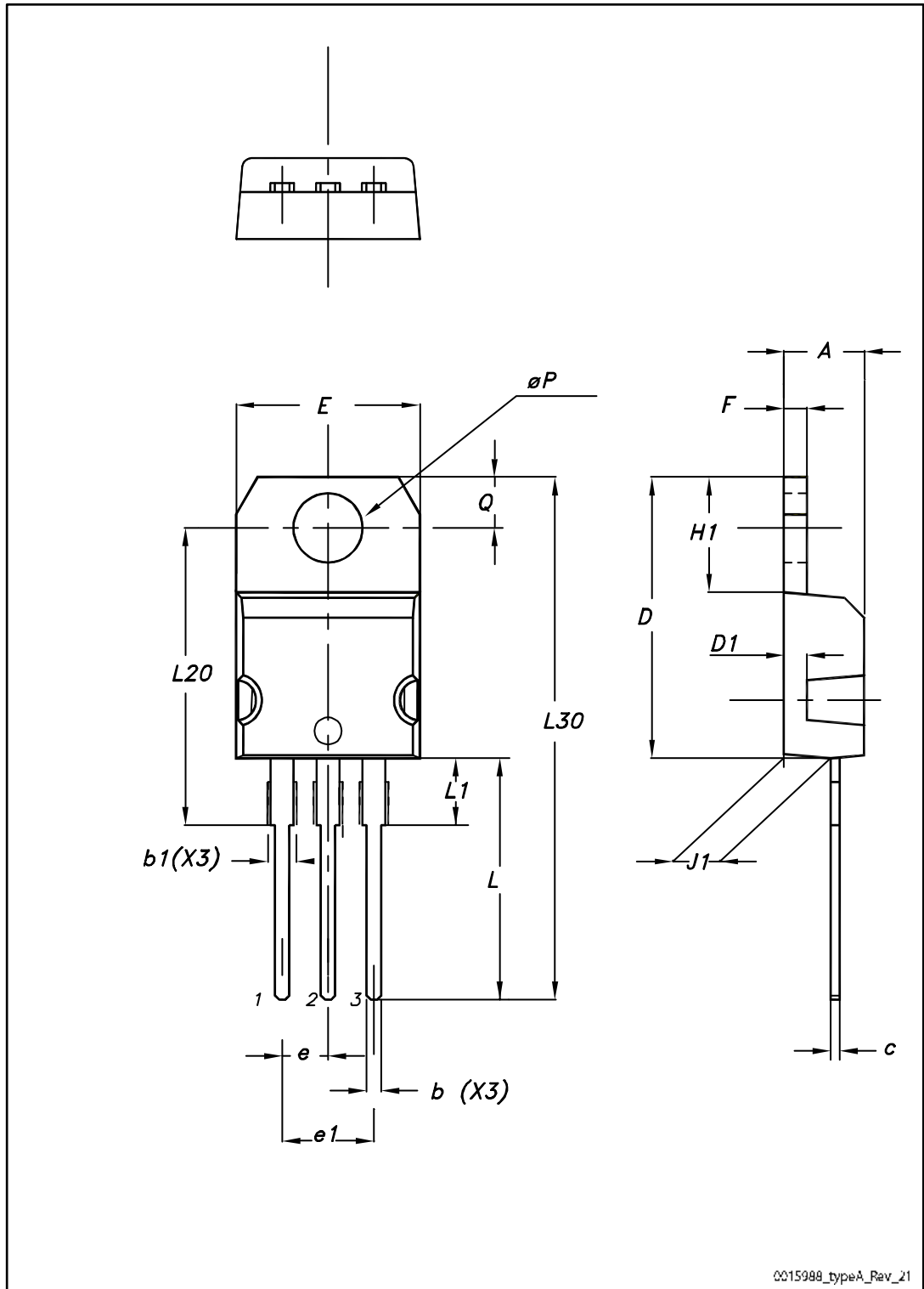


Table 11: I<sup>2</sup>PAK package mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.40	-	4.60
A1	2.40	-	2.72
b	0.61	-	0.88
b1	1.14	-	1.70
c	0.49	-	0.70
c2	1.23	-	1.32
D	8.95	-	9.35
e	2.40	-	2.70
e1	4.95	-	5.15
E	10	-	10.40
L	13	-	14
L1	3.50	-	3.93
L2	1.27	-	1.40

### 4.4 TO-220 type A package information

Figure 27: TO-220 type A package outline



0015988\_typeA\_Rev\_21



Table 12: TO-220 type A mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.40		4.60
b	0.61		0.88
b1	1.14		1.55
c	0.48		0.70
D	15.25		15.75
D1		1.27	
E	10.00		10.40
e	2.40		2.70
e1	4.95		5.15
F	1.23		1.32
H1	6.20		6.60
J1	2.40		2.72
L	13.00		14.00
L1	3.50		3.93
L20		16.40	
L30		28.90	
øP	3.75		3.85
Q	2.65		2.95

4.5 TO-247 package information

Figure 28: TO-247 package outline

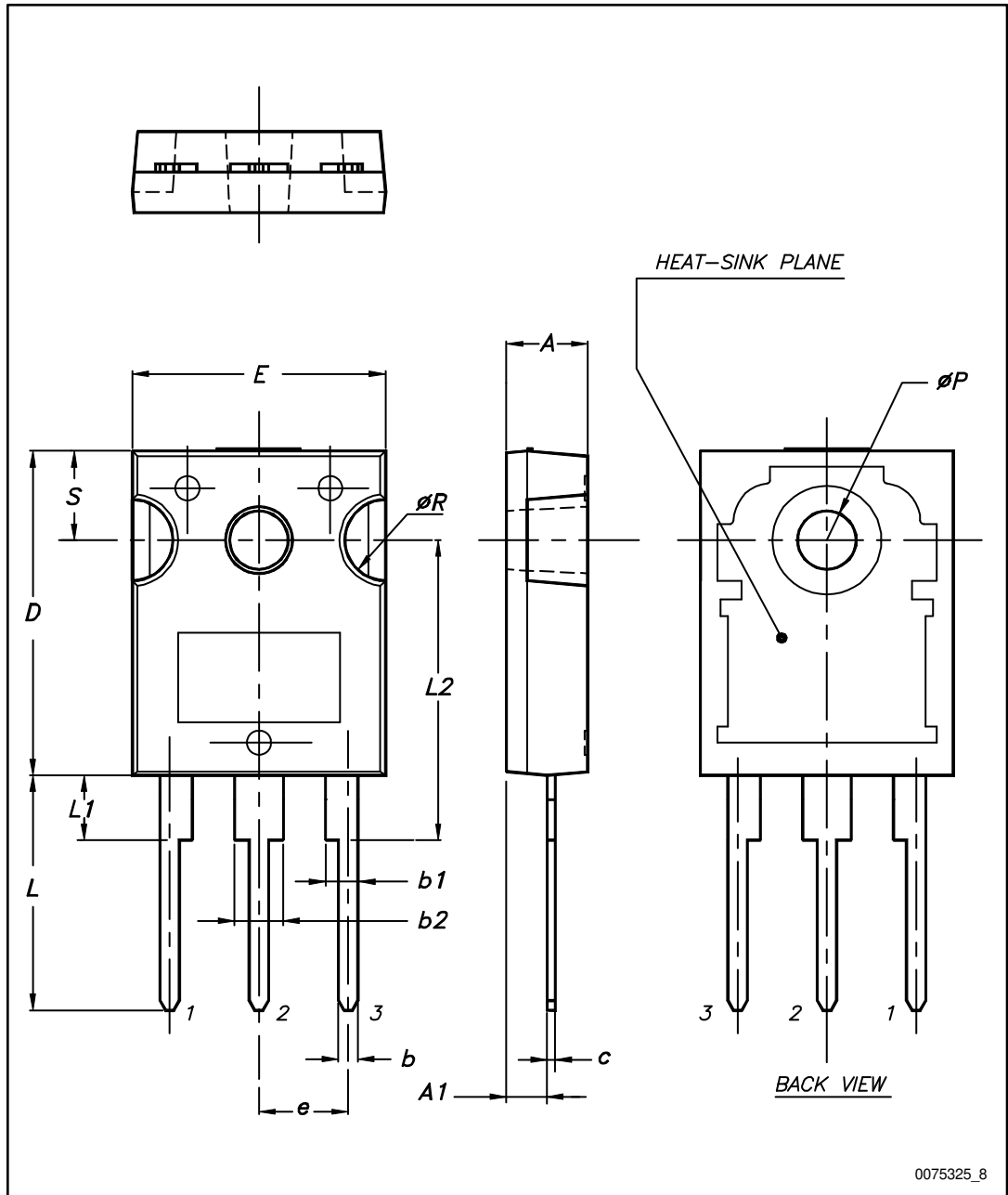


Table 13: TO-247 package mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	4.85		5.15
A1	2.20		2.60
b	1.0		1.40
b1	2.0		2.40
b2	3.0		3.40
c	0.40		0.80
D	19.85		20.15
E	15.45		15.75
e	5.30	5.45	5.60
L	14.20		14.80
L1	3.70		4.30
L2		18.50	
ØP	3.55		3.65
ØR	4.50		5.50
S	5.30	5.50	5.70

## 5 Revision history

Table 14: Document revision history

Date	Revision	Changes
13-Sep-2013	1	First release.
29-Jan-2014	2	<ul style="list-style-type: none"> <li>– Modified: title, ID value and features in cover page</li> <li>– Modified: ID, IDM and PTOT values in Table 2</li> <li>– Modified: note 2</li> <li>– Modified: Rthj-case value in Table 3</li> <li>– Modified: the entire typical values in Table 4, 6, 7 and 8</li> <li>– Modified: RDS(on) typical value in Table 5</li> <li>– Modified: Figure 9 and 10</li> <li>– Added: Section 4: Package information</li> <li>– Minor text changes</li> </ul>
09-Feb-2015	3	<ul style="list-style-type: none"> <li>– Updated title and description</li> <li>– Updated Table 2.: Absolute maximum ratings and Table 4.: Avalanche characteristics</li> <li>– Updated Figure 5.: Thermal impedance for TO-247 and Figure 6.: Output characteristics</li> <li>– Updated 4: Package information</li> <li>– Minor text changes.</li> </ul>
14-Mar-2017	4	<p>Added part number STI28N60M2.</p> <p>Updated title, silhouette, features and <a href="#">Table 1: "Device summary"</a> in cover page.</p> <p>Updated <a href="#">Table 3: "Thermal data"</a> and <a href="#">Section 4: "Package information"</a>.</p> <p>Minor text changes.</p>

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