英飞凌MOSFET

金属氧化物半导体场效应晶体管

CoolMOS™ P6

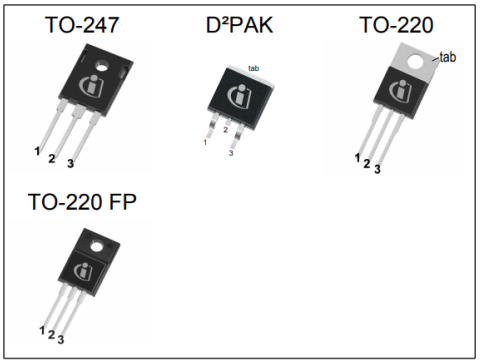
600V CoolMOS™ P6 功率管 IPx60R160P6

数据手册

Rev. 2.2
最终

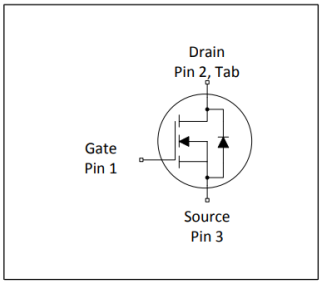
电源管理 & 多种市场

1 描述



CoolMOS™ 是高压功率 MOSFET 的革命性技术，根据超结（SJ）原理设计，由英飞凌科技率先推出。CoolMOS™ P6 系列将领先的 SJ MOSFET 供应商的经验与顶尖创新技术相结合。这些器件具有快速开关 SJ MOSFET 的全部优势，同时又不牺牲易用性。极低的开关损耗和传导损耗使开关应用更加高效、紧凑、轻便和低温。

特性



- 提高 MOSFET dv/dt 耐用性
- 极低损耗，因为 FOM RDS(on)*Qg 和 RDS(on)*Eoss 值低
- 出色的换向耐用性
- 易于使用或驱动
- 无铅电镀、无卤模塑料
- 符合 JEDEC（J-STD20 和 JESD22）标准，可用于工业级应用

应用

例如，PFC 级、硬开关 PWM 级和谐振开关级。PC Silverbox、适配器、LCD & PDP TV、照明、服务器、通信和 UPS。

请注意：对于 MOSFET 并联，通常建议在栅极上使用铁氧体磁珠或单独的图腾柱。

表 1 主要性能参数

Parameter	Value	Unit
V_{DS} @ $T_{j,max}$	650	V
$R_{DS(on),max}$	160	mΩ
$Q_{g,typ}$	44	nC
$I_{D,pulse}$	68	A
E_{oss}@400V	5.7	µJ
Body diode di/dt	500	A/µs

Type / Ordering Code	Package	Marking	Related Links
IPW60R160P6	PG-TO 247	6R160P6	see Appendix A
IPB60R160P6	PG-TO 263		
IPP60R160P6	PG-TO 220		
IPA60R160P6	PG-TO 220 FullPAK		

本数据手册的原文使用英文撰写。为方便起见，英飞凌提供了译文；由于翻译过程中可能使用了自动化工具，英飞凌不保证译文的准确性。为确认准确性，请务必访问 infineon.com 参考最新的英文版本（控制文档）。

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2 最大额定值

除非另有规定， T_j = 25 °C

表 2 最大额定值

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Continuous drain current[1]	I_D	- -	- -	23.8 15.0	A	T_C=25°C T_C=100°C
Pulsed drain current[2]	$I_{D,pulse}$	-	-	68	A	T_C=25°C
Avalanche energy, single pulse	E_{AS}	-	-	497	mJ	I_D=4.1A; V_{DD}=50V; see table 12
Avalanche energy, repetitive	E_{AR}	-	-	0.75	mJ	I_D=4.1A; V_{DD}=50V; see table 12
Avalanche current, repetitive	I_{AR}	-	-	4.1	A	-
MOSFET dv/dt ruggedness	dv/dt	-	-	100	V/ns	V_{DS}=0...400V
Gate source voltage (static)	V_{GS}	-20	-	20	V	static;
Gate source voltage (dynamic)	V_{GS}	-30	-	30	V	AC (f>1 Hz)
Power dissipation (Non FullPAK) TO-220, TO-263, TO-247	P_{tot}	-	-	176	W	T_C=25°C
Power dissipation (FullPAK) TO-220FP	P_{tot}	-	-	34	W	T_C=25°C
Storage temperature	T_{stg}	-55	-	150	°C	-
Operating junction temperature	T_j	-55	-	150	°C	-
Mounting torque (Non FullPAK) TO-220, TO-247	-	-	-	60	Ncm	M3 and M3.5 screws
Mounting torque (FullPAK) TO-220FP	-	-	-	50	Ncm	M2.5 screws
Continuous diode forward current	I_S	-	-	20.6	A	T_C=25°C
Diode pulse current[2]	$I_{S,pulse}$	-	-	68	A	T_C=25°C
Reverse diode dv/dt[3]	dv/dt	-	-	15	V/ns	V_{DS}=0...400V, I_{SD}<=I_S, T_j=25°C see table 10
Maximum diode commutation speed	di_f/dt	-	-	500	A/µs	V_{DS}=0...400V, I_{SD}<=I_S, T_j=25°C see table 10
Insulation withstand voltage for TO-220FP	V_{ISO}	-	-	2500	V	V_{rms}, T_C=25°C, t=1min

[1] 受限于 $T_{j\,max}$。最大空间占比 D=0.75

[2] 脉冲宽度 t_p 受 $T_{j,max}$ 限制

[3] 相同的低侧和高侧开关，具有相同的 R_G

3 热特性

表 3 热特性（Non FullPAK）TO-220, TO-247

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	R_{thJC}	-	-	0.71	°C/W	-
Thermal resistance, junction - ambient	R_{thJA}	-	-	62	°C/W	leaded
Soldering temperature, wavesoldering only allowed at leads	T_{sold}	-	-	260	°C	1.6mm (0.063 in.) from case for 10s

表 4 热特性（FullPAK）TO-220FP

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	R_{thJC}	-	-	3.67	°C/W	-
Thermal resistance, junction - ambient	R_{thJA}	-	-	80	°C/W	leaded
Soldering temperature, wavesoldering only allowed at leads	T_{sold}	-	-	260	°C	1.6mm (0.063 in.) from case for 10s

表 5 热特性 TO-263

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	R_{thJC}	-	-	0.71	°C/W	-
Thermal resistance, junction - ambient	R_{thJA}	-	-	62	°C/W	device on PCB, minimal footprint
Thermal resistance, junction - ambient for SMD version	R_{thJA}	-	35	45	°C/W	Device on 40mm*40mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70µm thickness) copper area for drain connection and cooling. PCB is vertical without air stream cooling.
Soldering temperature, wave & reflow soldering allowed	T_{sold}	-	-	260	°C	reflow MSL1

4 电气特性

除非另有规定， T_j = 25 °C

表 6 静态特性

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Drain-source breakdown voltage	$V_{(BR)DSS}$	600	-	-	V	V_{GS}=0V, I_D=1mA
Gate threshold voltage	$V_{(GS)th}$	3.5	4.0	4.5	V	V_{DS}=V_{GS}, I_D=0.75mA
Zero gate voltage drain current	I_{DSS}	- -	- 10	1 -	µA	V_{DS}=600, V_{GS}=0V, T_j=25°C V_{DS}=600, V_{GS}=0V, T_j=150°C
Gate-source leakage current	I_{GSS}	-	-	100	nA	V_{GS}=20V, V_{DS}=0V
Drain-source on-state resistance	$R_{DS(on)}$	- -	0.144 0.374	0.160 -	Ω	V_{GS}=10V, I_D=9A, T_j=25°C V_{GS}=10V, I_D=9A, T_j=150°C
Gate resistance	R_G	-	1.6	-	Ω	f=1MHz, open drain

表 7 动态特性

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input capacitance	C_{iss}	-	2080	-	pF	V_{GS}=0V, V_{DS}=100V, f=1MHz
Output capacitance	C_{oss}	-	89	-	pF	V_{GS}=0V, V_{DS}=100V, f=1MHz
Effective output capacitance, energy related[1)]	$C_{o(er)}$	-	72	-	pF	V_{GS}=0V, V_{DS}=0...400V
Effective output capacitance, time related[2)]	$C_{o(tr)}$	-	313	-	pF	I_D=constant, V_{GS}=0V, V_{DS}=0...400V
Turn-on delay time	$t_{d(on)}$	-	12.5	-	ns	V_{DD}=400V, V_{GS}=13V, I_D=11.3A, R_G=1.7Ω; see table 11
Rise time	t_r	-	7.6	-	ns	V_{DD}=400V, V_{GS}=13V, I_D=11.3A, R_G=1.7Ω; see table 11
Turn-off delay time	$t_{d(off)}$	-	40	-	ns	V_{DD}=400V, V_{GS}=13V, I_D=11.3A, R_G=1.7Ω; see table 11
Fall time	t_f	-	5.8	-	ns	V_{DD}=400V, V_{GS}=13 V, I_D=11.3A, R_G=1.7Ω; see table 11

表 8 栅极电荷特性

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Gate to source charge	Q_{gs}	-	13	-	nC	V_{DD}=400V, I_D=11.3A, V_{GS}=0 to 10V
Gate to drain charge	Q_{gd}	-	15	-	nC	V_{DD}=400V, I_D=11.3A, V_{GS}=0 to 10V
Gate charge total	Q_g	-	44	-	nC	V_{DD}=400V, I_D=11.3A, V_{GS}=0 to 10V
Gate plateau voltage	$V_{plateau}$	-	6.1	-	V	V_{DD}=400V, I_D=11.3A, V_{GS}=0 to 10V

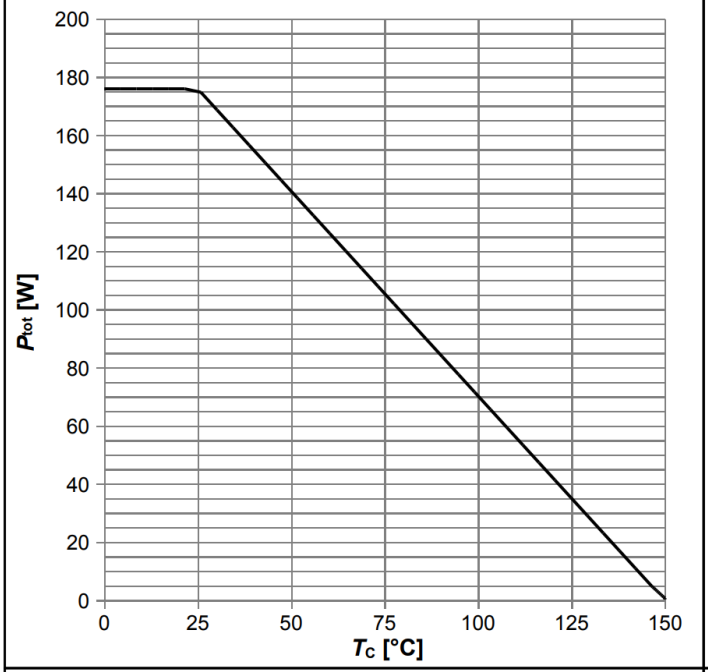
[1)] $C_{o(er)}$ 是一个固定电容， 当 V_{DS} 从 0 上升到 400V 时， 其存储的能量与 C_{oss} 相同
[2)] $C_{o(tr)}$ 为固定电容， 当 V_{DS} 从 0 上升至 400V 时， 其充电时间与 C_{oss} 相同

表 9　　反向二极管特性

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	V_{SD}	-	0.9	-	V	V_{GS}=0V, I_F=11.3A, T_j=25°C
Reverse recovery time	t_{rr}	-	350	-	ns	V_R=400V, I_F=11.3A, di_F/dt=100A/µs; see table 10
Reverse recovery charge	Q_{rr}	-	5.3	-	µC	V_R=400V, I_F=11.3A, di_F/dt=100A/µs; see table 10
Peak reverse recovery current	I_{rrm}	-	28	-	A	V_R=400V, I_F=11.3A, di_F/dt=100A/µs; see table 10

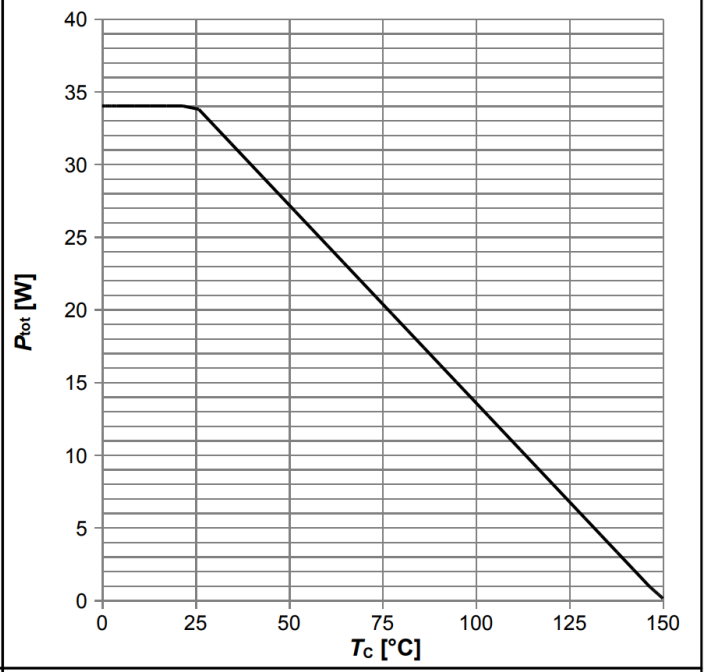
5 电气特性图

Diagram 1: Power dissipation (Non FullPAK)



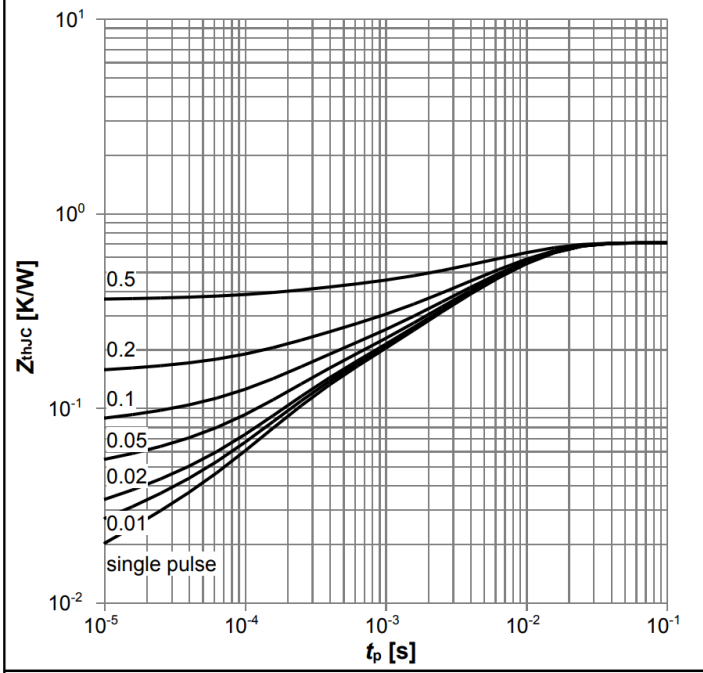
$P_{tot}=f(T_C)$

Diagram 2: Power dissipation (FullPAK)



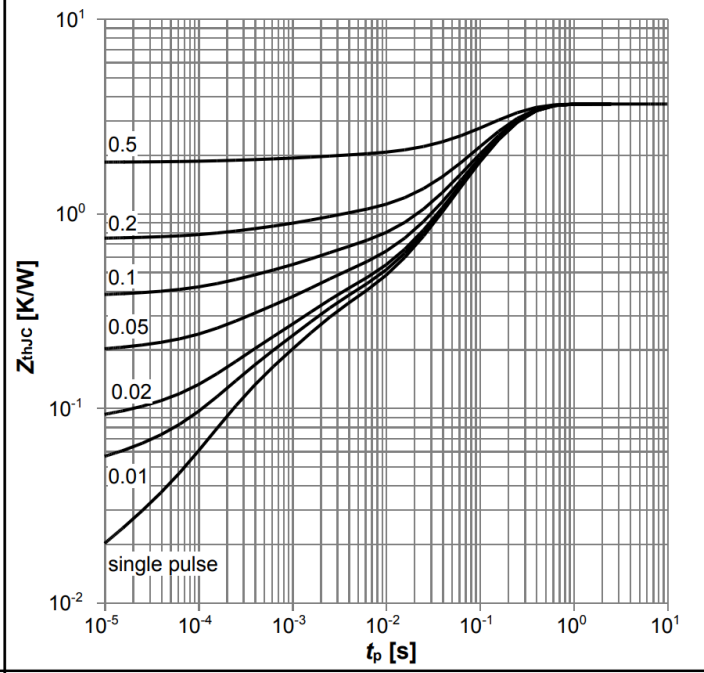
$P_{tot}=f(T_C)$

Diagram 3: Max. transient thermal impedance (Non FullPAK)



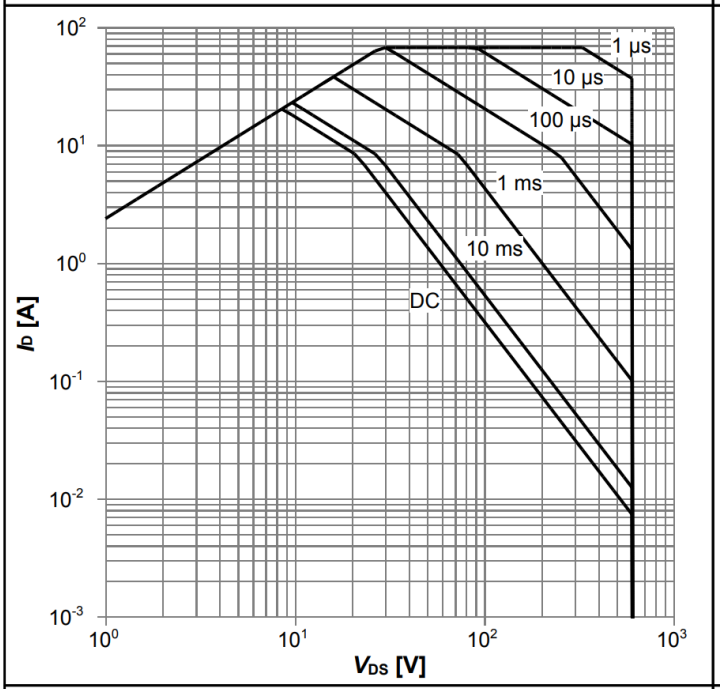
$Z_{thJC}=f(t_P)$; parameter: $D=t_p/T$

Diagram 4: Max. transient thermal impedance (FullPAK)



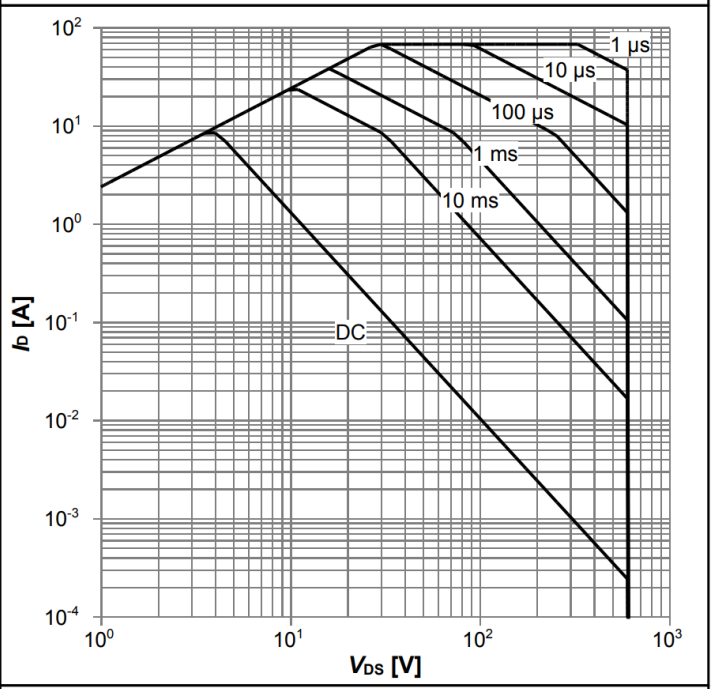
$Z_{thJC}=f(t_P)$; parameter: $D=t_p/T$

Diagram 5: Safe operating area (Non FullPAK)



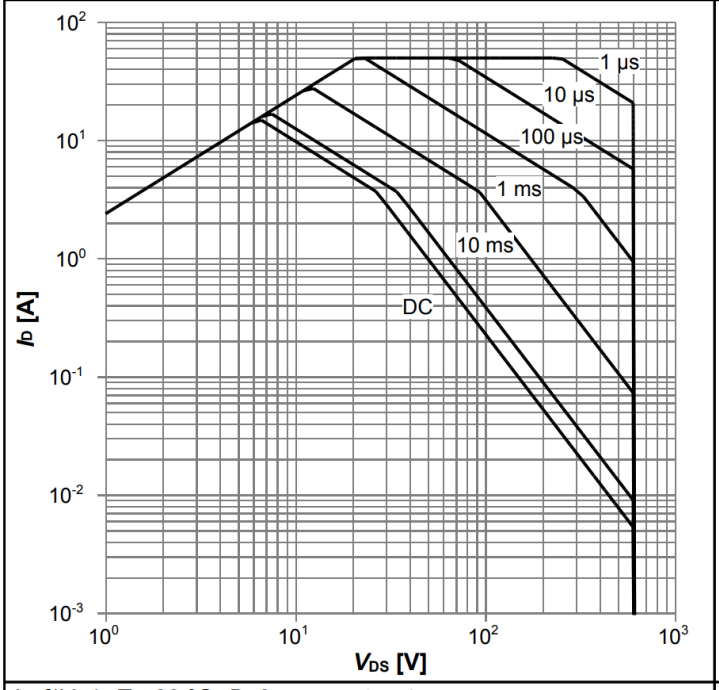
I_D=f(V_{DS}); T_C=25 °C; D=0; parameter: t_p

Diagram 6: Safe operating area (FullPAK)



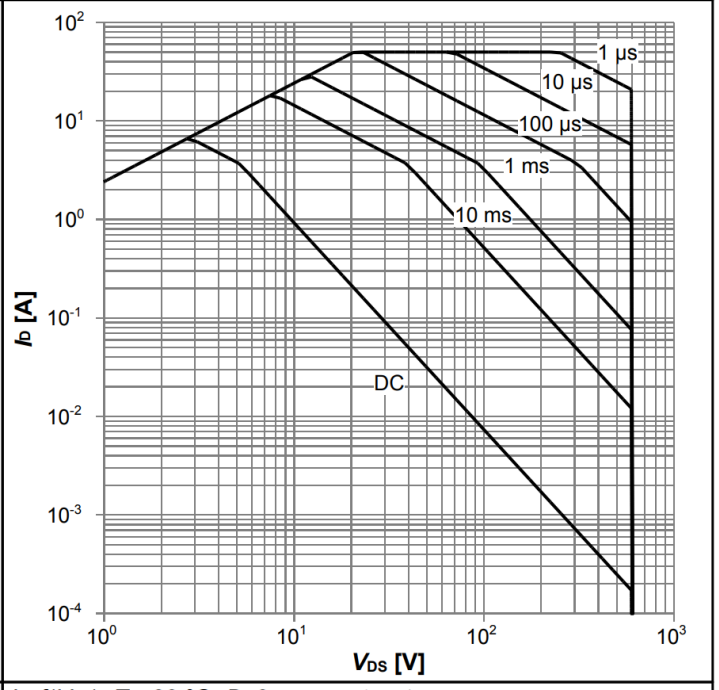
I_D=f(V_{DS}); T_C=25 °C; D=0; parameter: t_p

Diagram 7: Safe operating area (Non FullPAK)



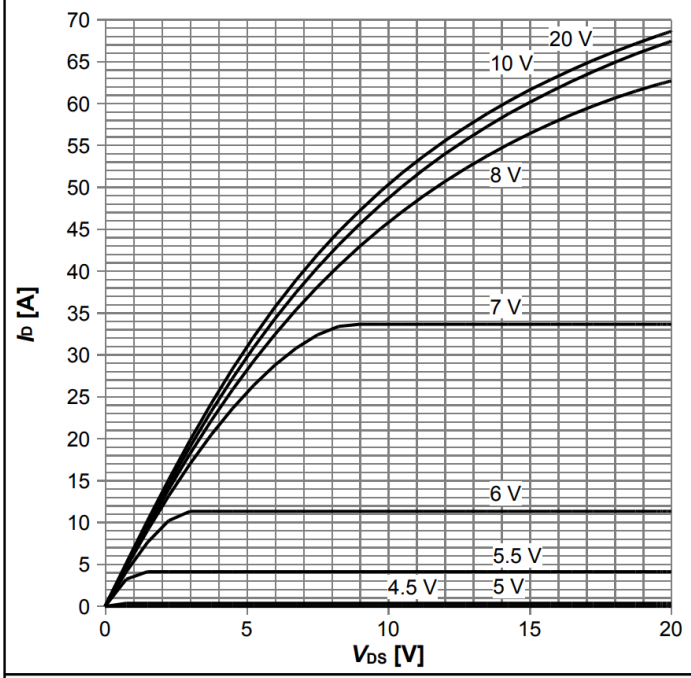
I_D=f(V_{DS}); T_C=80 °C; D=0; parameter: t_p

Diagram 8: Safe operating area (FullPAK)



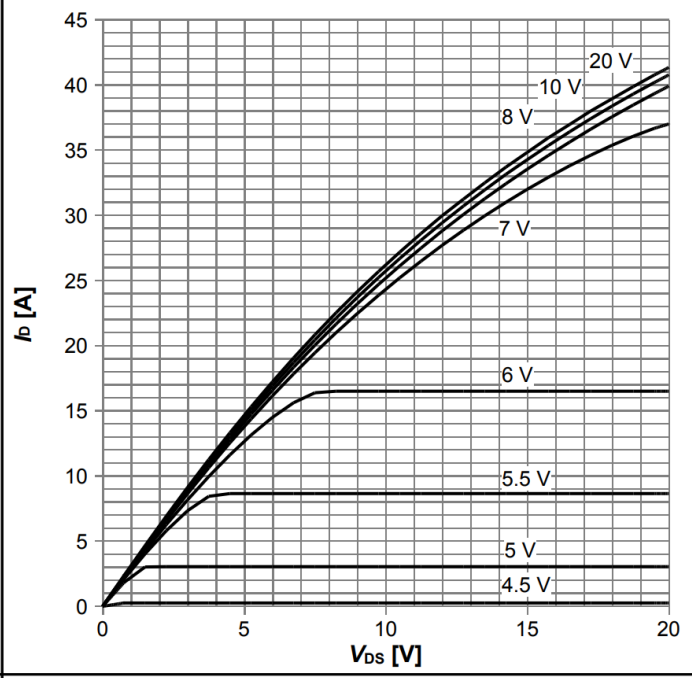
I_D=f(V_{DS}); T_C=80 °C; D=0; parameter: t_p

Diagram 9: Typ. output characteristics



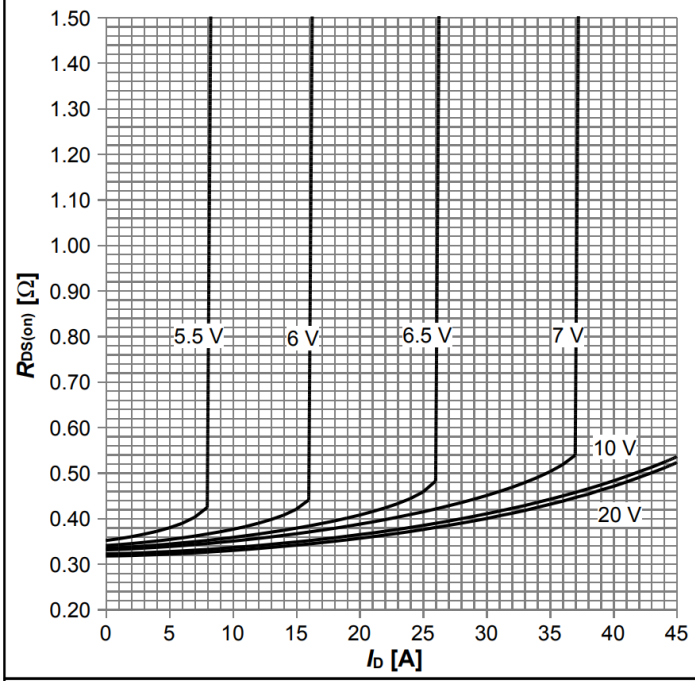
$I_D=f(V_{DS})$; $T_j=25$ °C; parameter: V_{GS}

Diagram 10: Typ. output characteristics



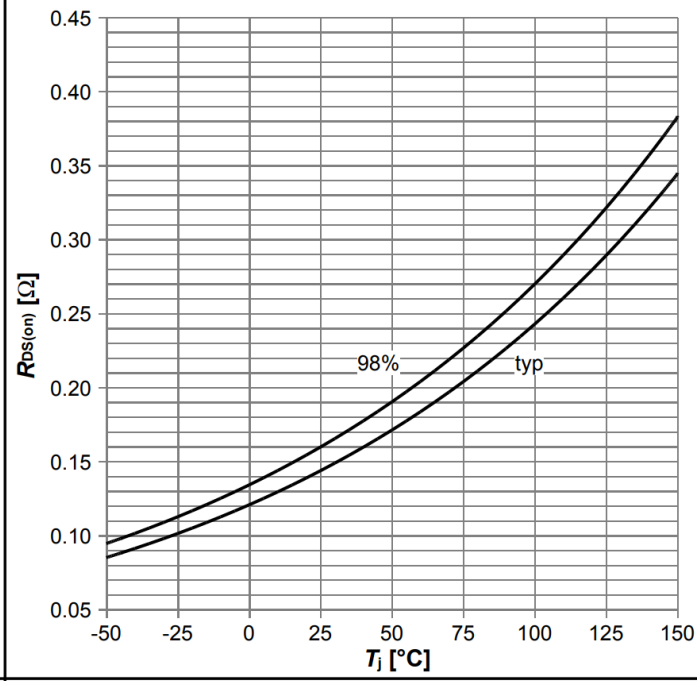
$I_D=f(V_{DS})$; $T_j=125$ °C; parameter: V_{GS}

Diagram 11: Typ. drain-source on-state resistance



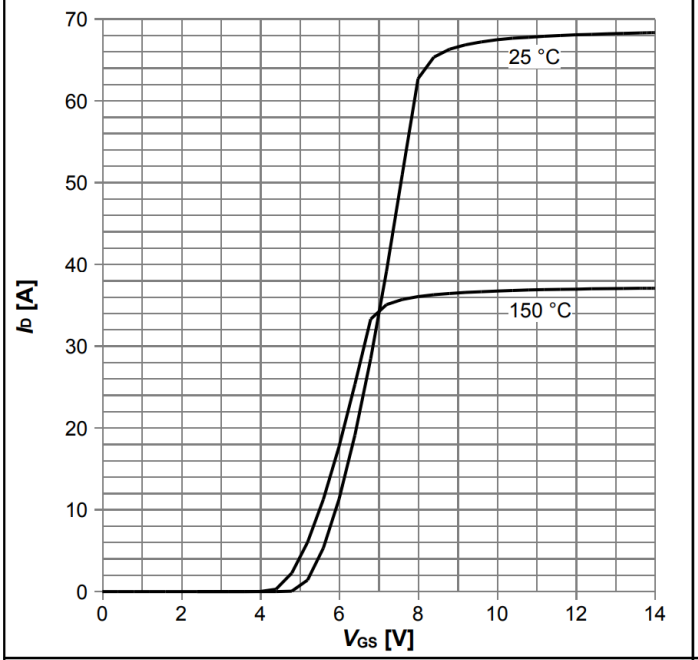
$R_{DS(on)}=f(I_D)$; $T_j=125$ °C; parameter: V_{GS}

Diagram 12: Drain-source on-state resistance



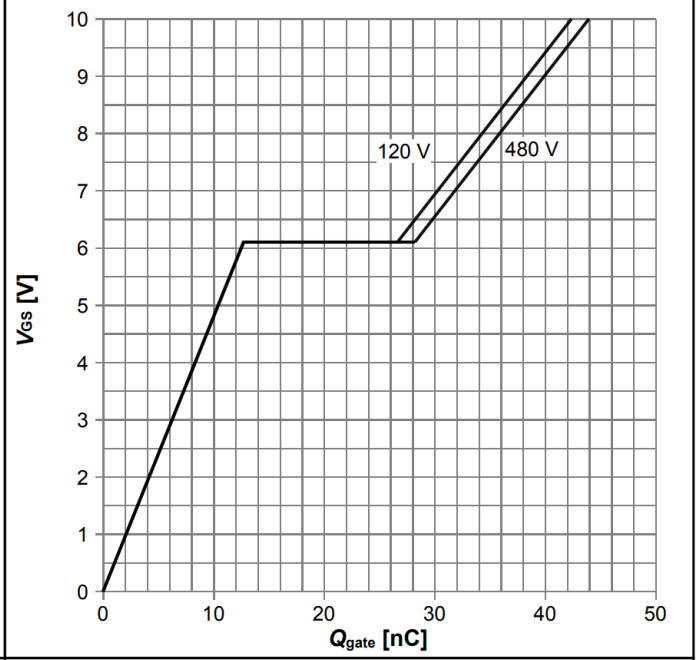
$R_{DS(on)}=f(T_j)$; $I_D=9.0$ A; $V_{GS}=10$ V

Diagram 13: Typ. transfer characteristics



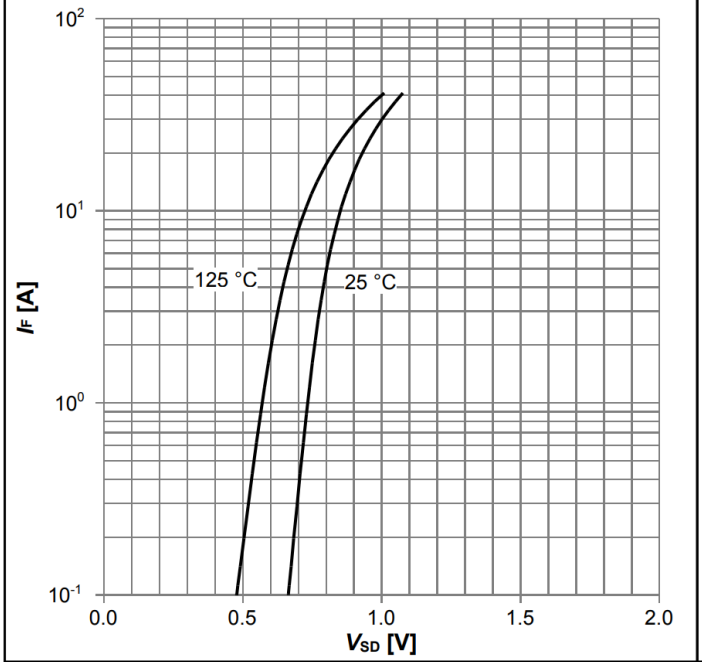
I_D=f(V_{GS}); V_{DS}=20V; parameter: T_j

Diagram 14: Typ. gate charge



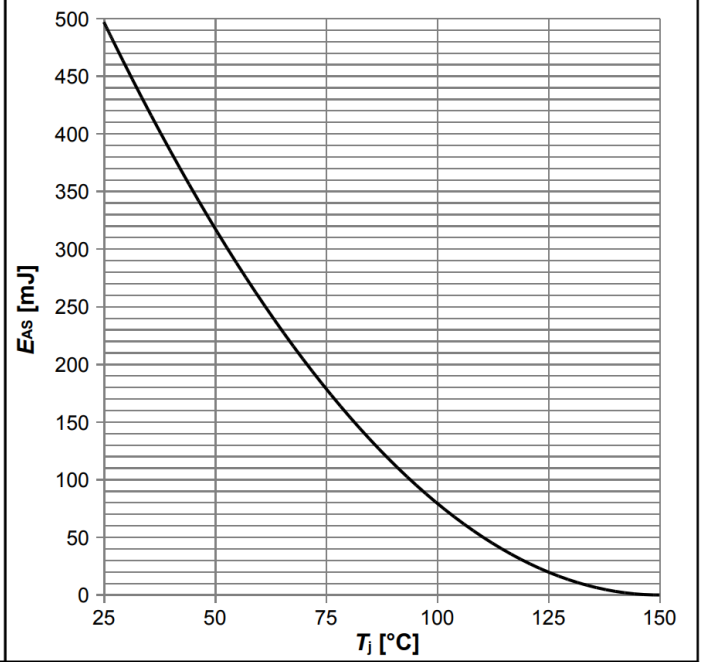
V_{GS}=f(Q_{gate}); I_D=11.3 A pulsed; parameter: V_{DD}

Diagram 15: Forward characteristics of reverse diode



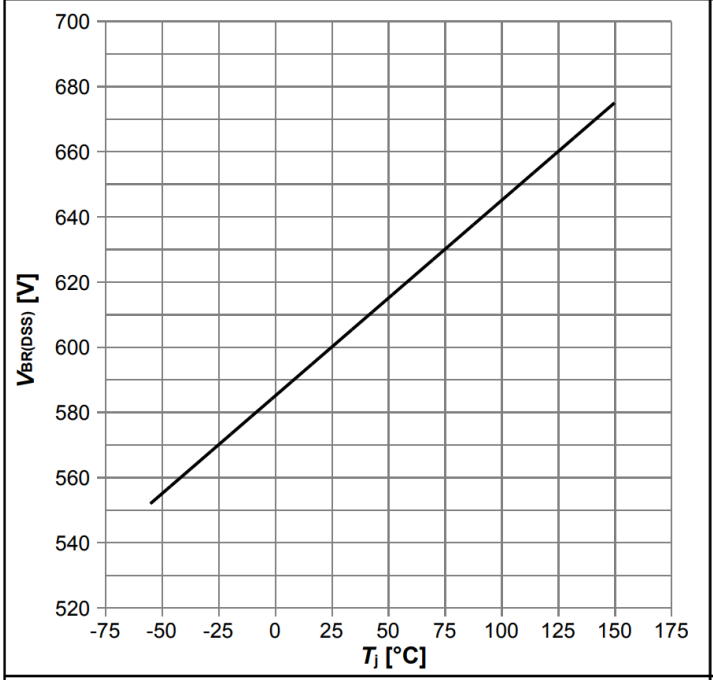
I_F=f(V_{SD}); parameter: T_j

Diagram 16: Avalanche energy



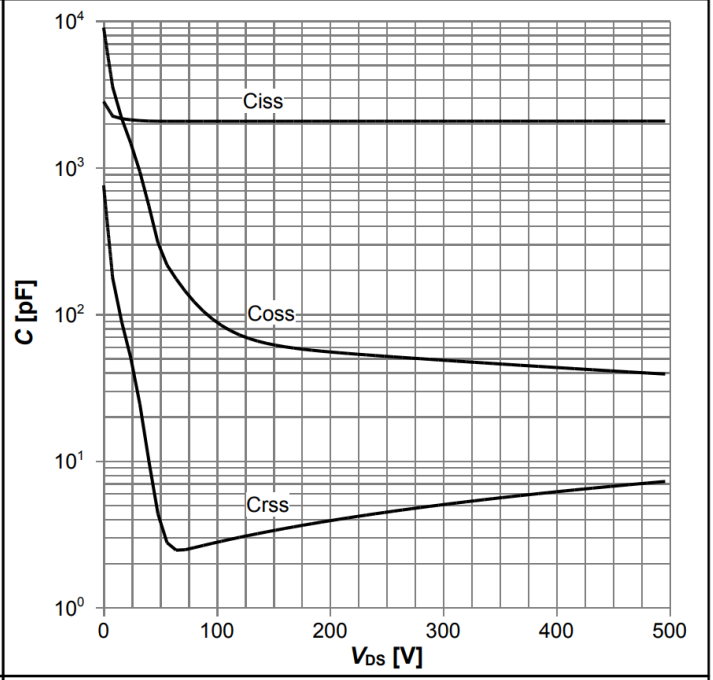
E_{AS}=f(T_j); I_D=4.1 A; V_{DD}=50 V

Diagram 17: Drain-source breakdown voltage



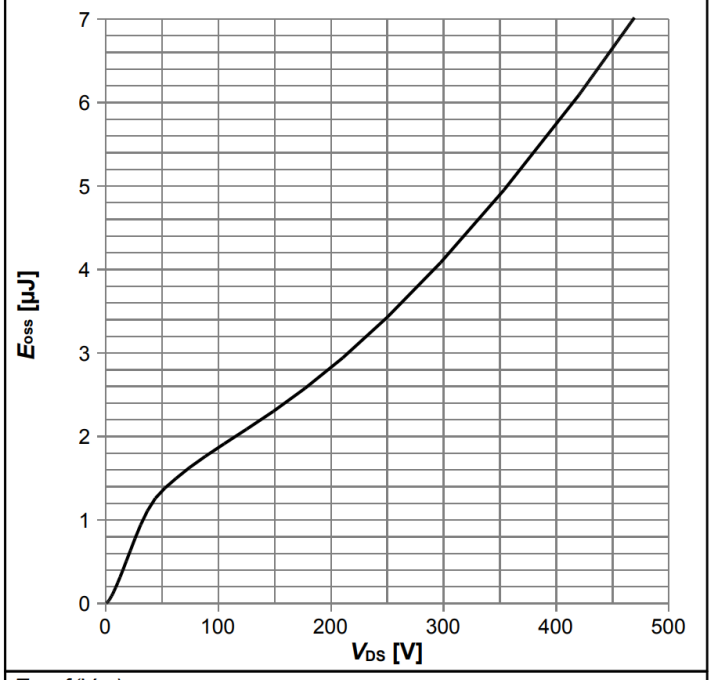
$V_{BR(DSS)}$=f(T_j); I_D=1 mA

Diagram 18: Typ. capacitances



C=f(V_{DS}); V_{GS}=0 V; f=1 MHz

Diagram 19: Typ. Coss stored energy



E_{oss}=f(V_{DS})

6 测试电路

表10 二极管特性

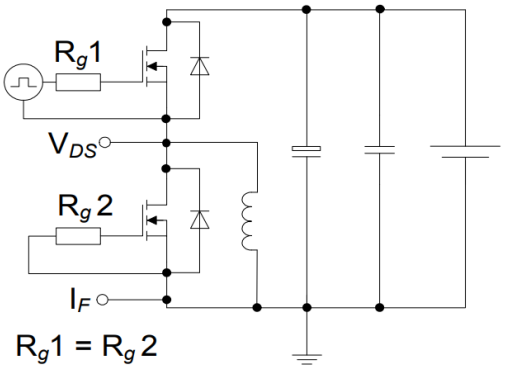
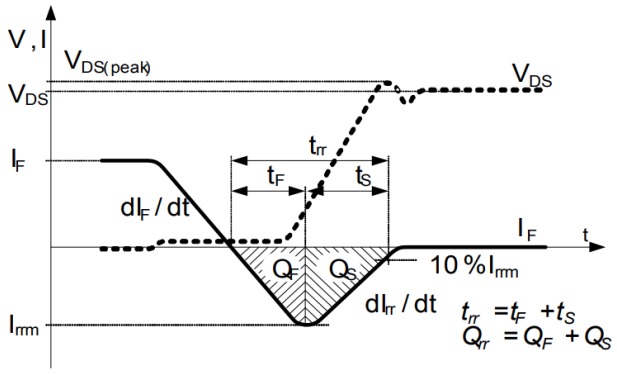
Test circuit for diode characteristics	Diode recovery waveform
	

表 11 开关时间

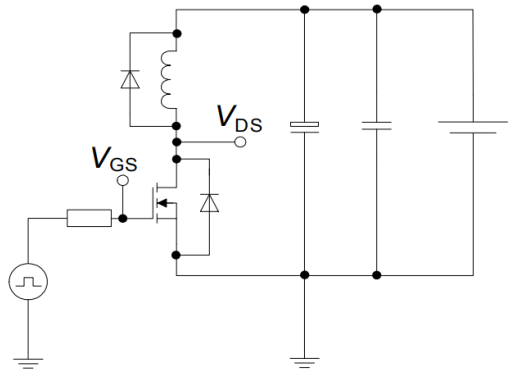
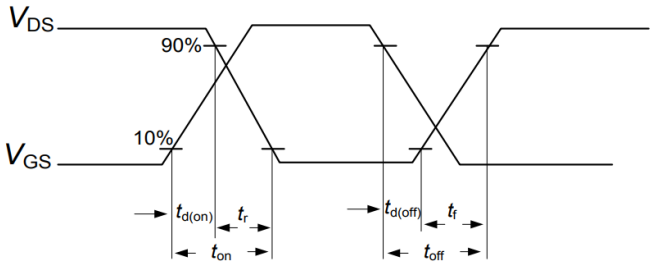
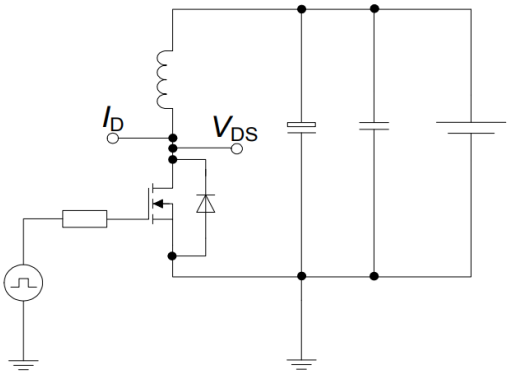
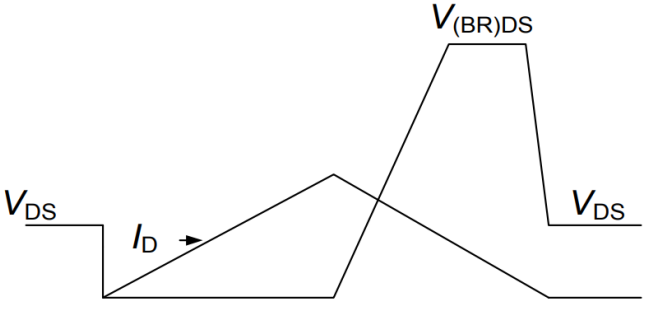
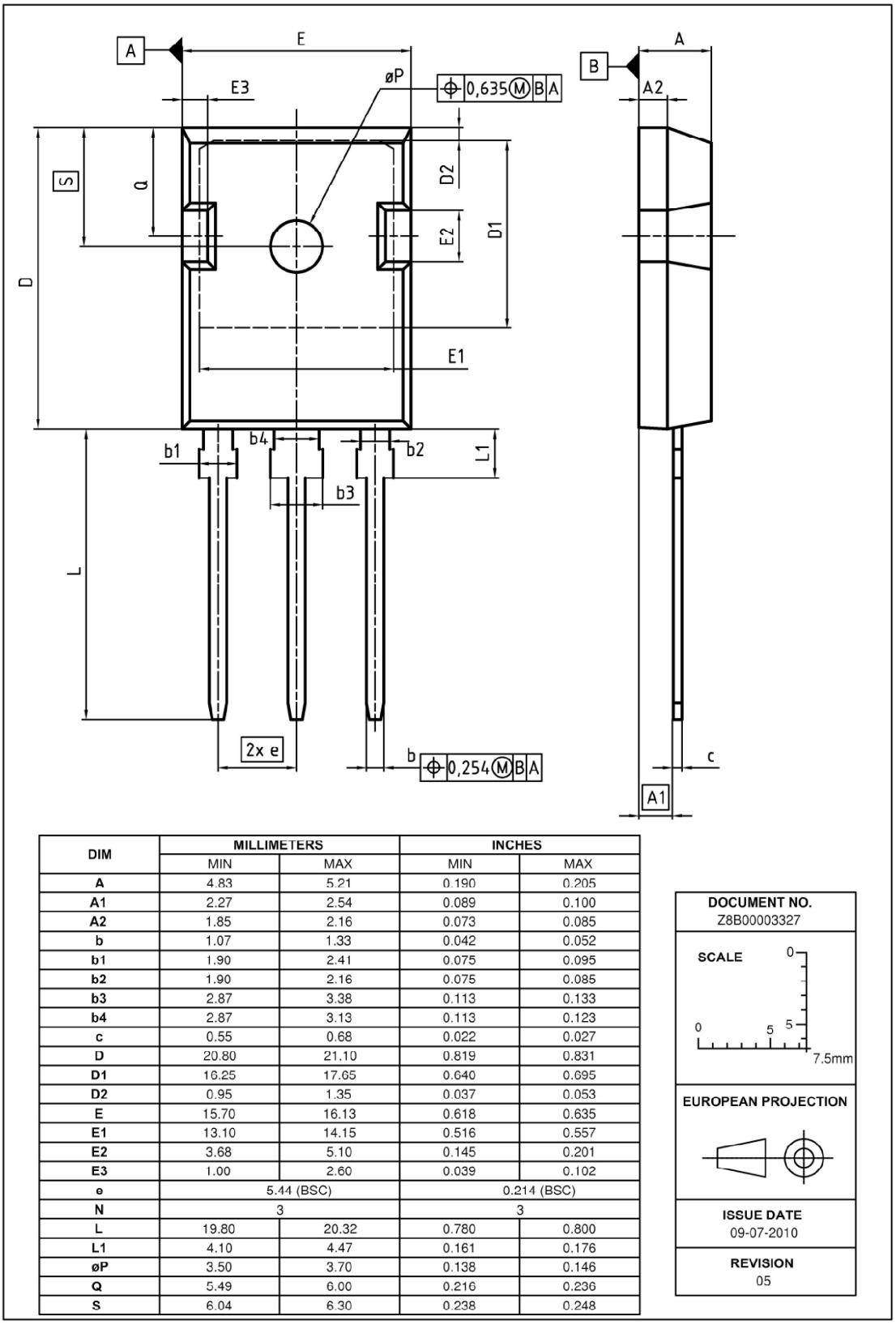
Switching times test circuit for inductive load	Switching times waveform
	

表 12 非钳位感性负载

Unclamped inductive load test circuit	Unclamped inductive waveform
	

7 封装外形



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.83	5.21	0.190	0.205
A1	2.27	2.54	0.089	0.100
A2	1.85	2.16	0.073	0.085
b	1.07	1.33	0.042	0.052
b1	1.90	2.41	0.075	0.095
b2	1.90	2.16	0.075	0.085
b3	2.87	3.38	0.113	0.133
b4	2.87	3.13	0.113	0.123
c	0.55	0.68	0.022	0.027
D	20.80	21.10	0.819	0.831
D1	16.25	17.65	0.640	0.695
D2	0.95	1.35	0.037	0.053
E	15.70	16.13	0.618	0.635
E1	13.10	14.15	0.516	0.557
E2	3.68	5.10	0.145	0.201
E3	1.00	2.60	0.039	0.102
e	5.44 (BSC)		0.214 (BSC)	
N	3		3	
L	19.80	20.32	0.780	0.800
L1	4.10	4.47	0.161	0.176
øP	3.50	3.70	0.138	0.146
Q	5.49	6.00	0.216	0.236
S	6.04	6.30	0.238	0.248

DOCUMENT NO.
Z8B00003327

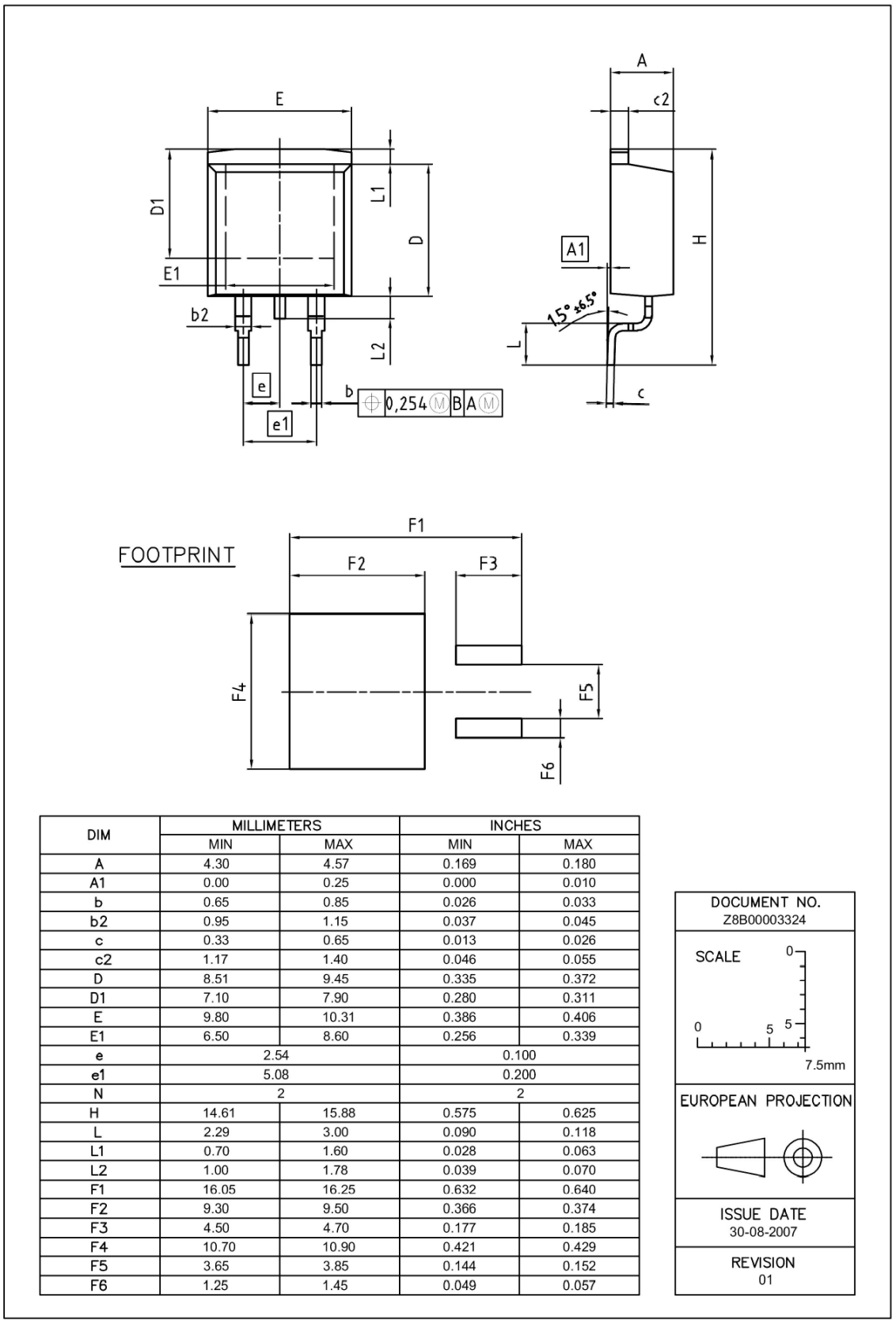
SCALE
0 5 5 7.5mm

EUROPEAN PROJECTION

ISSUE DATE
09-07-2010

REVISION
05

图 1 PG-TO 247 封装外形，尺寸单位：毫米/英寸



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.57	0.169	0.180
A1	0.00	0.25	0.000	0.010
b	0.65	0.85	0.026	0.033
b2	0.95	1.15	0.037	0.045
c	0.33	0.65	0.013	0.026
c2	1.17	1.40	0.046	0.055
D	8.51	9.45	0.335	0.372
D1	7.10	7.90	0.280	0.311
E	9.80	10.31	0.386	0.406
E1	6.50	8.60	0.256	0.339
e	2.54		0.100	
e1	5.08		0.200	
N	2		2	
H	14.61	15.88	0.575	0.625
L	2.29	3.00	0.090	0.118
L1	0.70	1.60	0.028	0.063
L2	1.00	1.78	0.039	0.070
F1	16.05	16.25	0.632	0.640
F2	9.30	9.50	0.366	0.374
F3	4.50	4.70	0.177	0.185
F4	10.70	10.90	0.421	0.429
F5	3.65	3.85	0.144	0.152
F6	1.25	1.45	0.049	0.057

DOCUMENT NO.
Z8B00003324

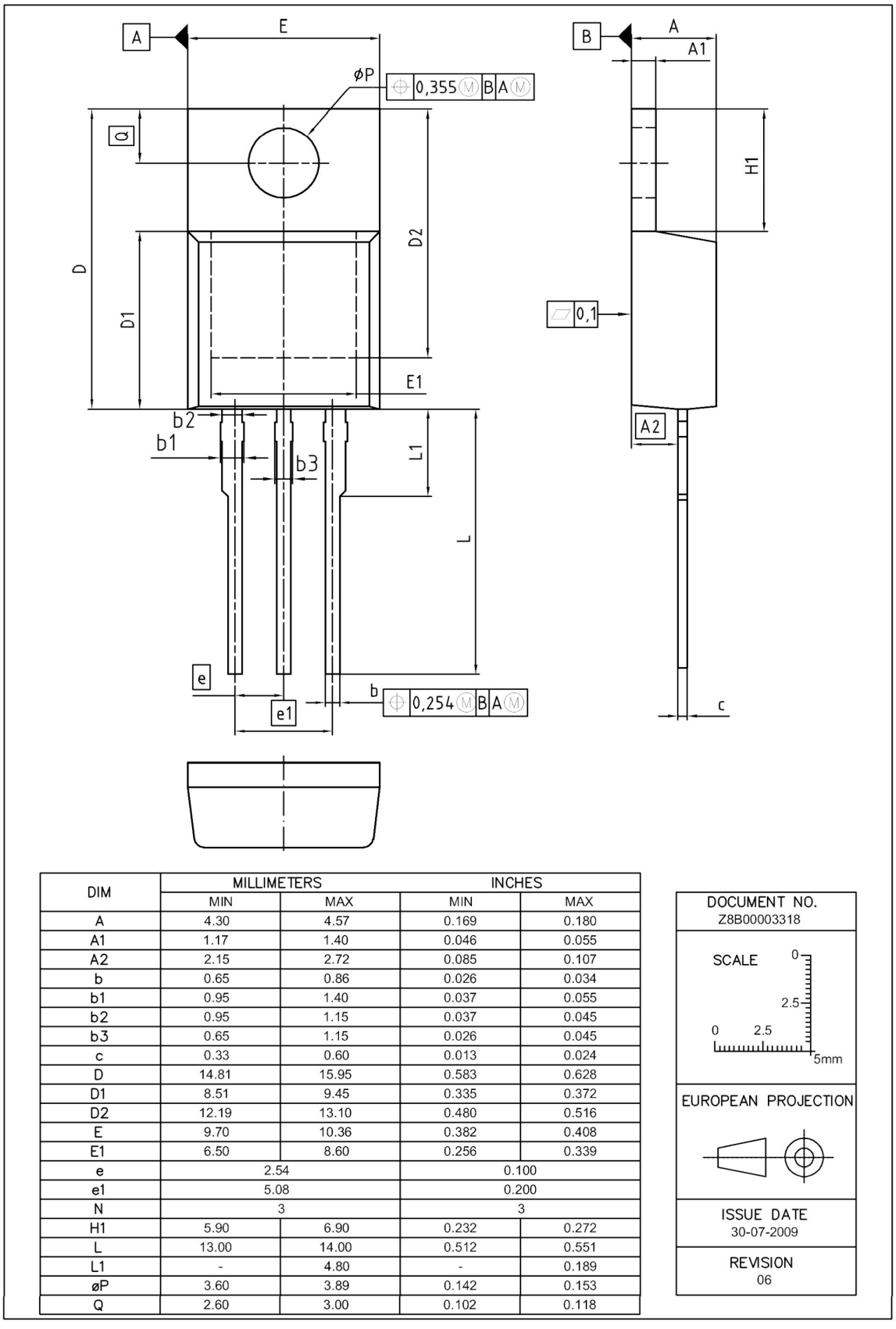
SCALE 0 5 5 7.5mm

EUROPEAN PROJECTION

ISSUE DATE
30-08-2007

REVISION
01

图 2　　PG-TO 263 封装外形，尺寸单位：毫米/英寸



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.30	4.57	0.169	0.180
A1	1.17	1.40	0.046	0.055
A2	2.15	2.72	0.085	0.107
b	0.65	0.86	0.026	0.034
b1	0.95	1.40	0.037	0.055
b2	0.95	1.15	0.037	0.045
b3	0.65	1.15	0.026	0.045
c	0.33	0.60	0.013	0.024
D	14.81	15.95	0.583	0.628
D1	8.51	9.45	0.335	0.372
D2	12.19	13.10	0.480	0.516
E	9.70	10.36	0.382	0.408
E1	6.50	8.60	0.256	0.339
e	2.54		0.100	
e1	5.08		0.200	
N	3		3	
H1	5.90	6.90	0.232	0.272
L	13.00	14.00	0.512	0.551
L1	-	4.80	-	0.189
øP	3.60	3.89	0.142	0.153
Q	2.60	3.00	0.102	0.118

DOCUMENT NO.
Z8B00003318

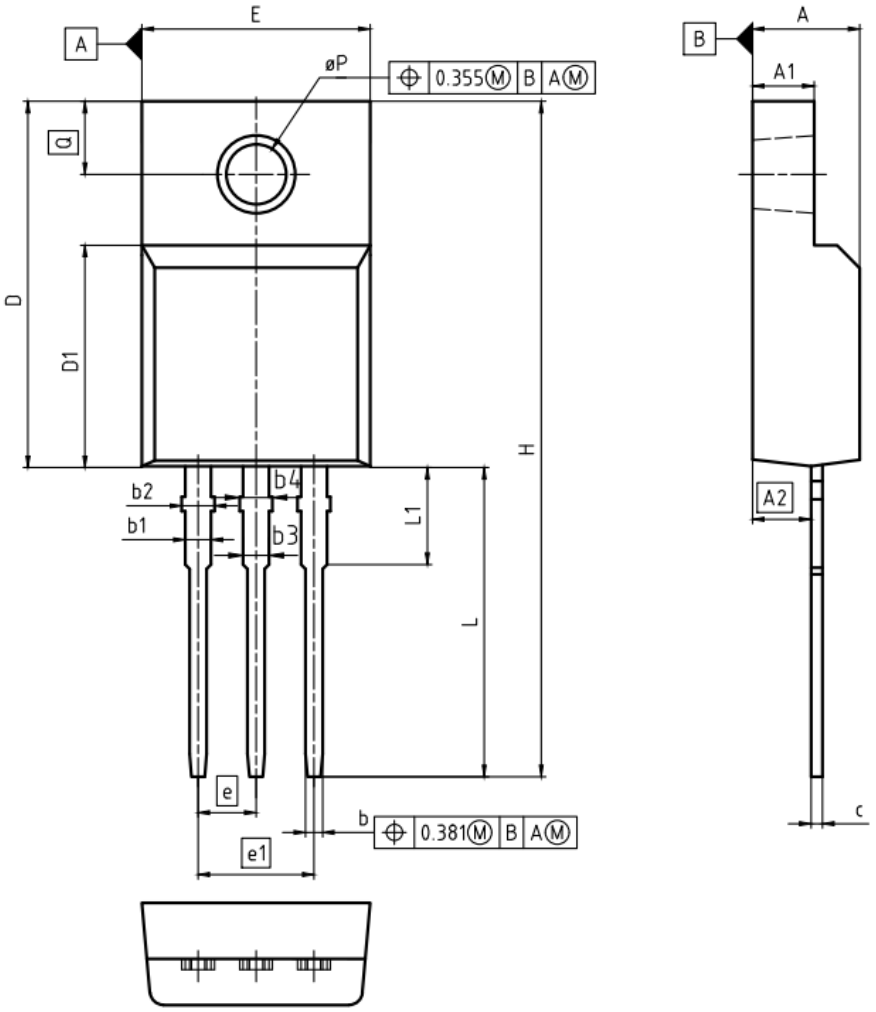
SCALE 0 2.5 0 2.5 5mm

EUROPEAN PROJECTION

ISSUE DATE
30-07-2009

REVISION
06

图 3　　PG-TO 220 封装外形，尺寸单位为毫米/英寸



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.50	4.90	0.177	0.193
A1	2.34	2.85	0.092	0.112
A2	2.42	2.86	0.095	0.113
b	0.65	0.90	0.026	0.035
b1	0.95	1.38	0.037	0.054
b2	0.95	1.51	0.037	0.059
b3	0.65	1.38	0.026	0.054
b4	0.65	1.51	0.026	0.059
c	0.40	0.63	0.016	0.025
D	15.67	16.15	0.617	0.636
D1	8.97	9.83	0.353	0.387
E	10.00	10.65	0.394	0.419
e	2.54 (BSC)		0.100 (BSC)	
e1	5.08		0.200	
N	3		3	
H	28.70	29.75	1.130	1.171
L	12.78	13.75	0.503	0.541
L1	2.83	3.45	0.111	0.136
øP	2.95	3.38	0.116	0.133
Q	3.15	3.50	0.124	0.138

DOCUMENT NO.
Z8B00003319

SCALE
0 2.5 5mm

EUROPEAN PROJECTION

ISSUE DATE
05-05-2014

REVISION
04

图 4　　PG-TO 220 FullPAK 封装外形，尺寸单位为毫米

8 附录 A

表 13 相关链接

- **IFX CoolMOS™ P6 网页：**www.infineon.com
- **IFX CoolMOS™ P6 应用笔记：**www.infineon.com
- **IFX CoolMOS™ P6 仿真模型：**www.infineon.com
- **IFX 设计工具：**www.infineon.com

修订记录

IPW60R160P6, IPB60R160P6, IPP60R160P6, IPA60R160P6

Revision: 2015-07-10, Rev. 2.2

历史修订版本

Revision	Date	Subjects (major changes since last revision)
2.0	2013-12-04	Release of final version
2.1	2013-12-05	Release of multi-package datasheet
2.2	2015-07-10	PG-TO 263 package added

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版本 **2026-1-26**

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