

## MOSFET

Metal Oxide Semiconductor Field Effect Transistor

## CoolMOS™ P6

600V CoolMOS™ P6 Power Transistor  
IPx60R600P6

## Data Sheet

Rev. 2.2  
Final

## 1 Description

CoolMOS™ is a revolutionary technology for high voltage power MOSFETs, designed according to the superjunction (SJ) principle and pioneered by Infineon Technologies. CoolMOS™ P6 series combines the experience of the leading SJ MOSFET supplier with high class innovation. The offered devices provide all benefits of a fast switching SJ MOSFET while not sacrificing ease of use. Extremely low switching and conduction losses make switching applications even more efficient, more compact, lighter and cooler.

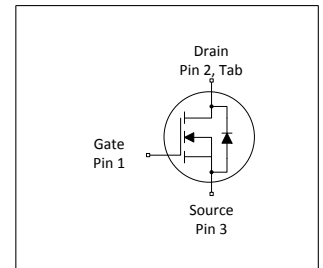
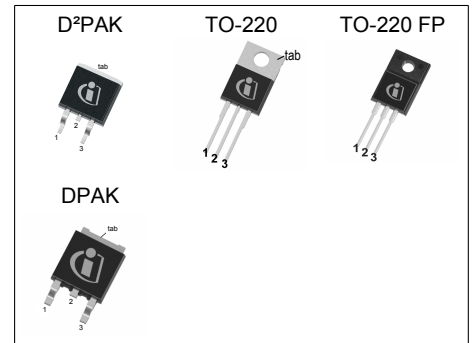
## Features

- Increased MOSFET dv/dt ruggedness
- Extremely low losses due to very low FOM  $R_{DS(on)} \cdot Q_g$  and  $E_{oss}$
- Very high commutation ruggedness
- Easy to use/drive
- Pb-free plating, Halogen free mold compound
- Qualified for industrial grade applications according to JEDEC (J-STD20 and JESD22)

## Applications

PFC stages, hard switching PWM stages and resonant switching stages for e.g. PC Silverbox, Adapter, LCD & PDP TV, Lighting, Server, Telecom and UPS.

*Please note: For MOSFET paralleling the use of ferrite beads on the gate or separate totem poles is generally recommended.*



**Table 1 Key Performance Parameters**

Parameter	Value	Unit
$V_{DS} @ T_{j,max}$	650	V
$R_{DS(on),max}$	600	mΩ
$Q_{g,typ}$	12	nC
$I_{D,pulse}$	18	A
$E_{oss@400V}$	1.8	μJ
Body diode di/dt	500	A/μs

Type / Ordering Code	Package	Marking	Related Links
IPB60R600P6	PG-TO 263	6R600P6	see Appendix A
IPP60R600P6	PG-TO 220		
IPA60R600P6	PG-TO 220 FullPAK		
IPD60R600P6	PG-TO 252		



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## 2 Maximum ratings

at  $T_j = 25^\circ\text{C}$ , unless otherwise specified

**Table 2 Maximum ratings**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Continuous drain current <sup>1)</sup>	$I_D$	-	-	7.3 4.6	A	$T_C=25^\circ\text{C}$ $T_C=100^\circ\text{C}$
Pulsed drain current <sup>2)</sup>	$I_{D,pulse}$	-	-	18	A	$T_C=25^\circ\text{C}$
Avalanche energy, single pulse	$E_{AS}$	-	-	133	mJ	$I_D=1.3\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 12
Avalanche energy, repetitive	$E_{AR}$	-	-	0.20	mJ	$I_D=1.3\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 12
Avalanche current, repetitive	$I_{AR}$	-	-	1.3	A	-
MOSFET dv/dt ruggedness	dv/dt	-	-	100	V/ns	$V_{DS}=0\dots400\text{V}$
Gate source voltage (static)	$V_{GS}$	-20	-	20	V	static;
Gate source voltage (dynamic)	$V_{GS}$	-30	-	30	V	AC ( $f>1\text{ Hz}$ )
Power dissipation (Non FullPAK) TO-220, TO-252, TO-263	$P_{tot}$	-	-	63	W	$T_C=25^\circ\text{C}$
Power dissipation (FullPAK) TO-220FP	$P_{tot}$	-	-	28	W	$T_C=25^\circ\text{C}$
Storage temperature	$T_{stg}$	-55	-	150	$^\circ\text{C}$	-
Operating junction temperature	$T_j$	-55	-	150	$^\circ\text{C}$	-
Mounting torque (Non FullPAK) TO-220	-	-	-	60	Ncm	M3 and M3.5 screws
Mounting torque (FullPAK) TO-220FP	-	-	-	50	Ncm	M2.5 screws
Continuous diode forward current	$I_S$	-	-	6.3	A	$T_C=25^\circ\text{C}$
Diode pulse current <sup>2)</sup>	$I_{S,pulse}$	-	-	18	A	$T_C=25^\circ\text{C}$
Reverse diode dv/dt <sup>3)</sup>	dv/dt	-	-	15	V/ns	$V_{DS}=0\dots400\text{V}$ , $I_{SD}\leq I_S$ , $T_j=25^\circ\text{C}$ see table 10
Maximum diode commutation speed	di/dt	-	-	500	A/ $\mu\text{s}$	$V_{DS}=0\dots400\text{V}$ , $I_{SD}\leq I_S$ , $T_j=25^\circ\text{C}$ see table 10
Insulation withstand voltage for TO-220FP	$V_{ISO}$	-	-	2500	V	$V_{rms}$ , $T_C=25^\circ\text{C}$ , $t=1\text{min}$

<sup>1)</sup> Limited by  $T_{j,max}$ . Maximum duty cycle  $D=0.75$

<sup>2)</sup> Pulse width  $t_p$  limited by  $T_{j,max}$

<sup>3)</sup> Identical low side and high side switch with identical  $R_G$

### 3 Thermal characteristics

**Table 3 Thermal characteristics (Non FullPAK) TO-220**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	$R_{thJC}$	-	-	2	°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

**Table 4 Thermal characteristics (FullPAK) TO-220FP**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	$R_{thJC}$	-	-	4.5	°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

**Table 5 Thermal characteristics TO-252, TO-263**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	$R_{thJC}$	-	-	2	°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 6cm <sup>2</sup> (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 Electrical characteristics

at  $T_j=25^\circ\text{C}$ , unless otherwise specified

**Table 6 Static characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Drain-source breakdown voltage	$V_{(BR)DSS}$	600	-	-	V	$V_{GS}=0\text{V}$ , $I_D=1\text{mA}$
Gate threshold voltage	$V_{(GS)th}$	3.5	4.0	4.5	V	$V_{DS}=V_{GS}$ , $I_D=0.2\text{mA}$
Zero gate voltage drain current	$I_{DSS}$	-	-	1	$\mu\text{A}$	$V_{DS}=600$ , $V_{GS}=0\text{V}$ , $T_j=25^\circ\text{C}$ $V_{DS}=600$ , $V_{GS}=0\text{V}$ , $T_j=150^\circ\text{C}$
Gate-source leakage current	$I_{GSS}$	-	-	100	nA	$V_{GS}=20\text{V}$ , $V_{DS}=0\text{V}$
Drain-source on-state resistance	$R_{DS(on)}$	-	0.540 1.404	0.600	$\Omega$	$V_{GS}=10\text{V}$ , $I_D=2.4\text{A}$ , $T_j=25^\circ\text{C}$ $V_{GS}=10\text{V}$ , $I_D=2.4\text{A}$ , $T_j=150^\circ\text{C}$
Gate resistance	$R_G$	-	11	-	$\Omega$	$f=1\text{MHz}$ , open drain

**Table 7 Dynamic characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input capacitance	$C_{iss}$	-	557	-	pF	$V_{GS}=0\text{V}$ , $V_{DS}=100\text{V}$ , $f=1\text{MHz}$
Output capacitance	$C_{oss}$	-	28	-	pF	$V_{GS}=0\text{V}$ , $V_{DS}=100\text{V}$ , $f=1\text{MHz}$
Effective output capacitance, energy related <sup>1)</sup>	$C_{o(er)}$	-	23	-	pF	$V_{GS}=0\text{V}$ , $V_{DS}=0\dots400\text{V}$
Effective output capacitance, time related <sup>2)</sup>	$C_{o(tr)}$	-	88	-	pF	$I_D=\text{constant}$ , $V_{GS}=0\text{V}$ , $V_{DS}=0\dots400\text{V}$
Turn-on delay time	$t_{d(on)}$	-	11	-	ns	$V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=3\text{A}$ , $R_G=6.8\Omega$ ; see table 11
Rise time	$t_r$	-	7	-	ns	$V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=3\text{A}$ , $R_G=6.8\Omega$ ; see table 11
Turn-off delay time	$t_{d(off)}$	-	33	-	ns	$V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=3\text{A}$ , $R_G=6.8\Omega$ ; see table 11
Fall time	$t_f$	-	14	-	ns	$V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=3\text{A}$ , $R_G=6.8\Omega$ ; see table 11

**Table 8 Gate charge characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Gate to source charge	$Q_{gs}$	-	3	-	nC	$V_{DD}=400\text{V}$ , $I_D=3\text{A}$ , $V_{GS}=0$ to $10\text{V}$
Gate to drain charge	$Q_{gd}$	-	5	-	nC	$V_{DD}=400\text{V}$ , $I_D=3\text{A}$ , $V_{GS}=0$ to $10\text{V}$
Gate charge total	$Q_g$	-	12	-	nC	$V_{DD}=400\text{V}$ , $I_D=3\text{A}$ , $V_{GS}=0$ to $10\text{V}$
Gate plateau voltage	$V_{plateau}$	-	6.1	-	V	$V_{DD}=400\text{V}$ , $I_D=3\text{A}$ , $V_{GS}=0$ to $10\text{V}$

<sup>1)</sup>  $C_{o(er)}$  is a fixed capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400V

<sup>2)</sup>  $C_{o(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400V

**Table 9 Reverse diode characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	$V_{SD}$	-	0.9	-	V	$V_{GS}=0V, I_F=3A, T_j=25^\circ C$
Reverse recovery time	$t_{rr}$	-	196	-	ns	$V_R=400V, I_F=3A, di_F/dt=100A/\mu s$ ; see table 10
Reverse recovery charge	$Q_{rr}$	-	1.7	-	$\mu C$	$V_R=400V, I_F=3A, di_F/dt=100A/\mu s$ ; see table 10
Peak reverse recovery current	$I_{rrm}$	-	17	-	A	$V_R=400V, I_F=3A, di_F/dt=100A/\mu s$ ; see table 10

## 5 Electrical characteristics diagrams

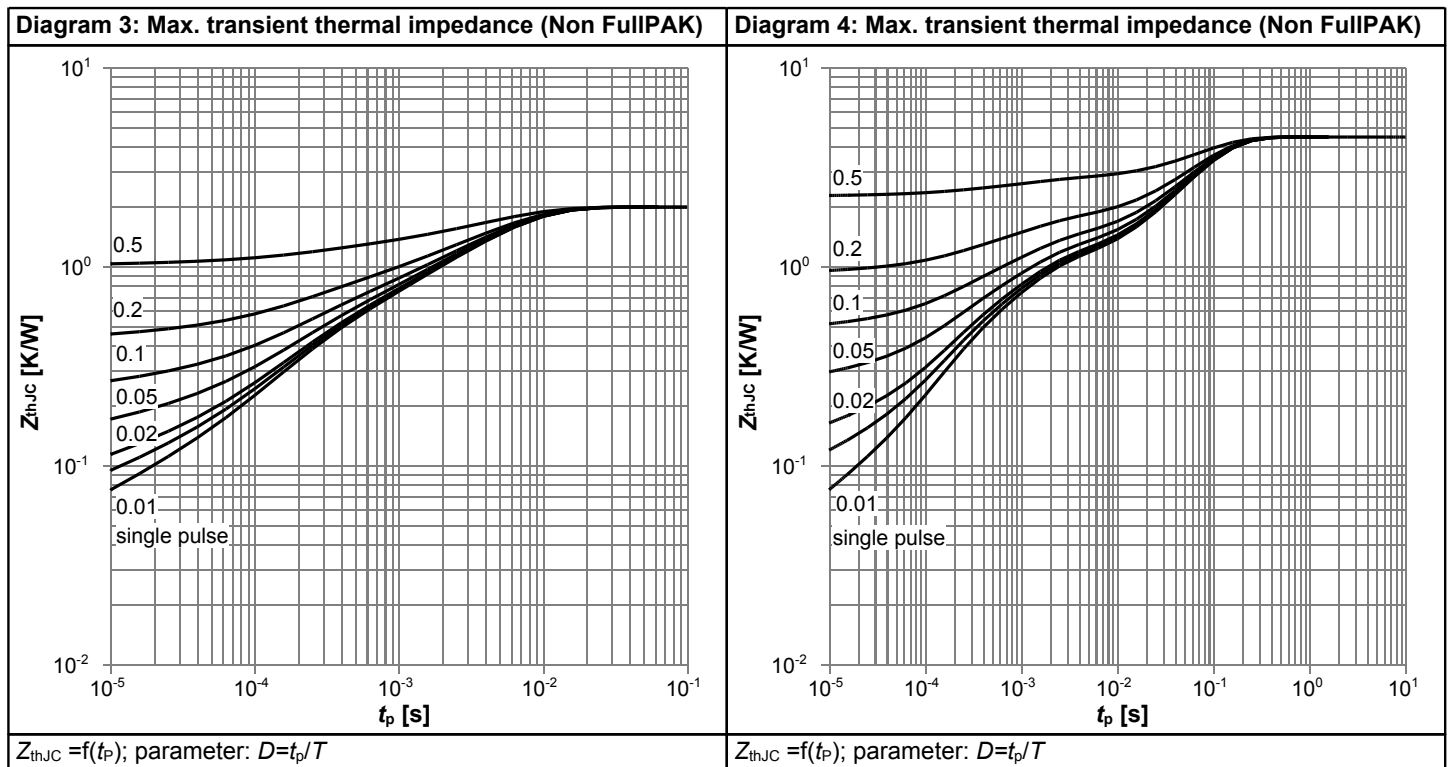
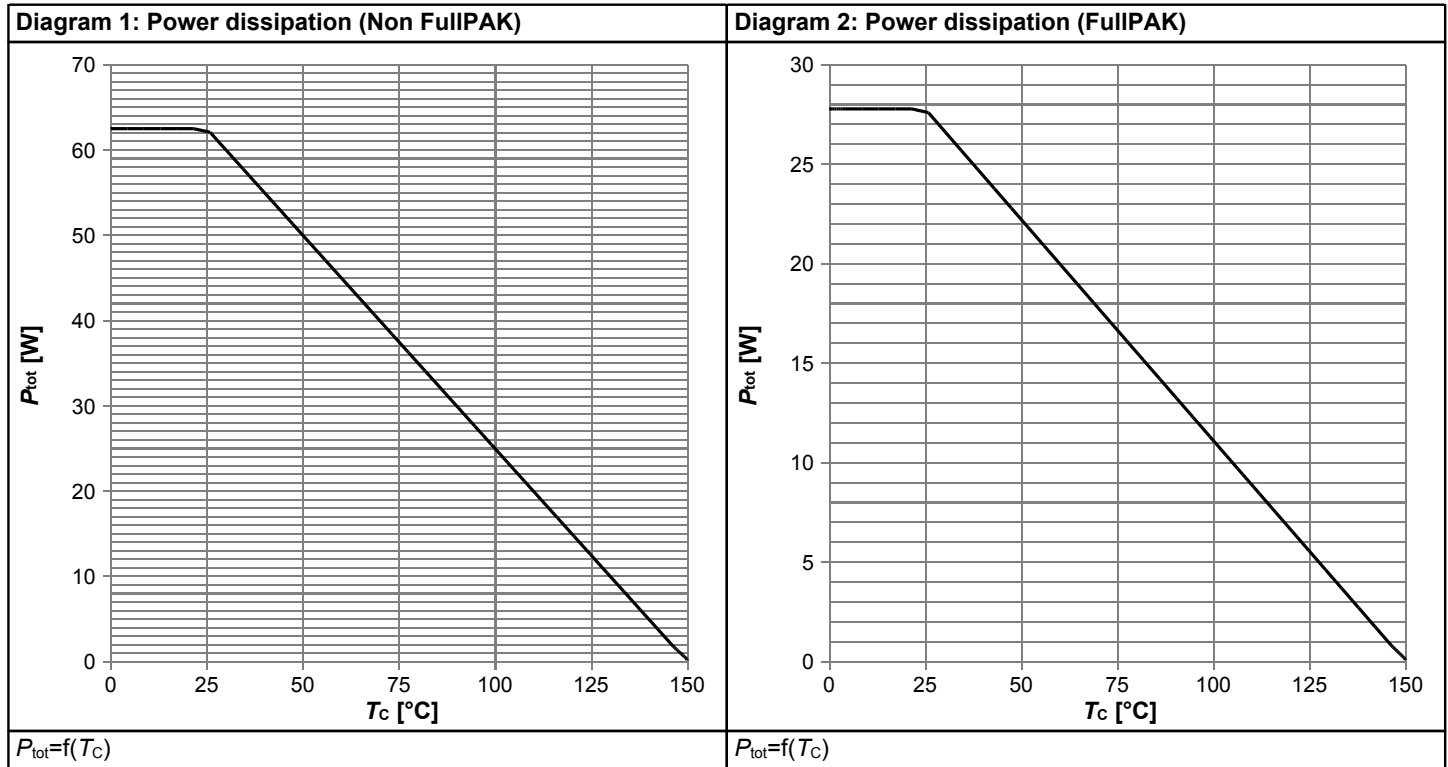
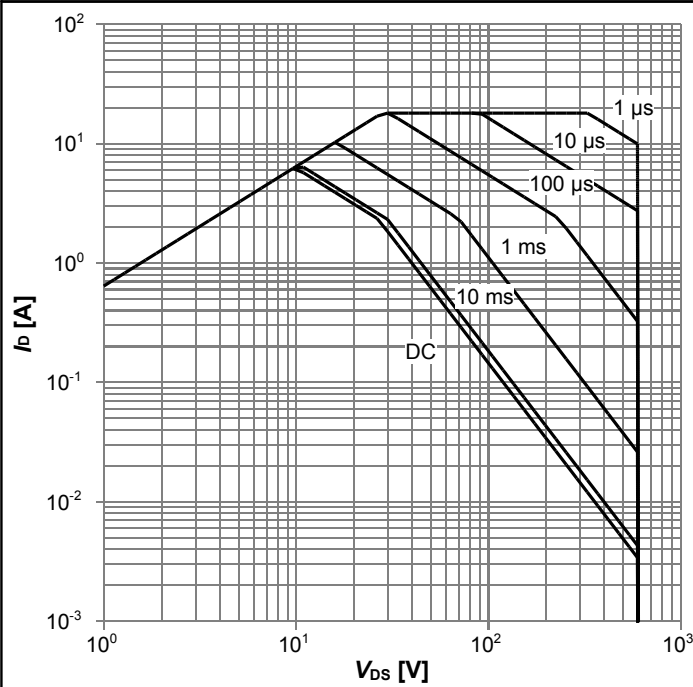


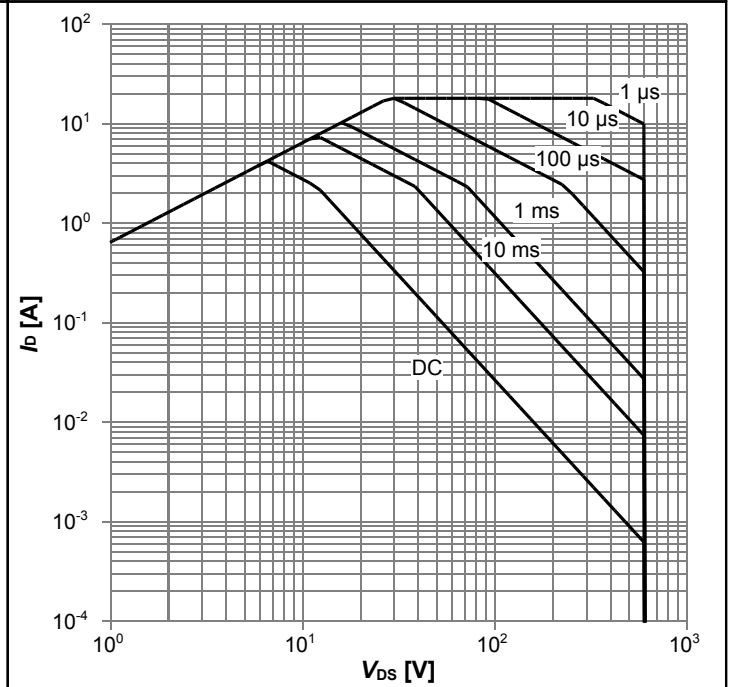


Diagram 5: Safe operating area (Non FullPAK)



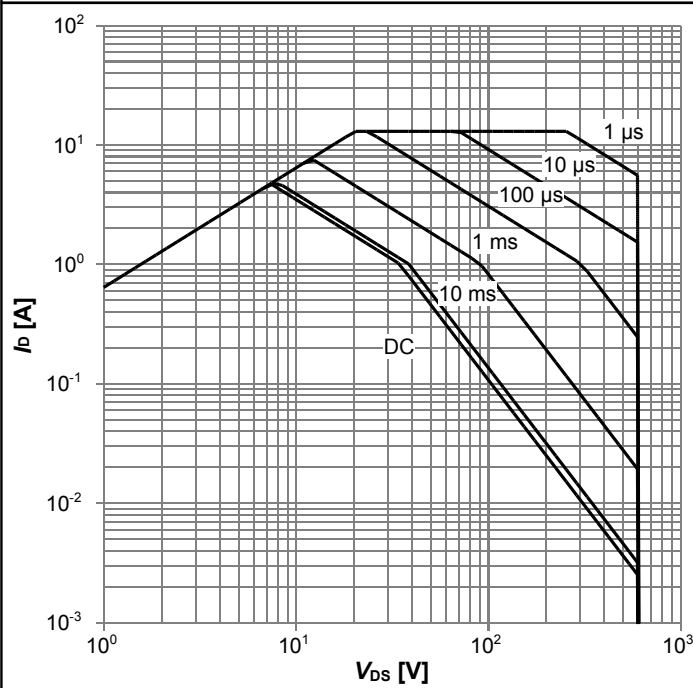
$I_D=f(V_{DS}); T_C=25\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 6: Safe operating area (FullPAK)



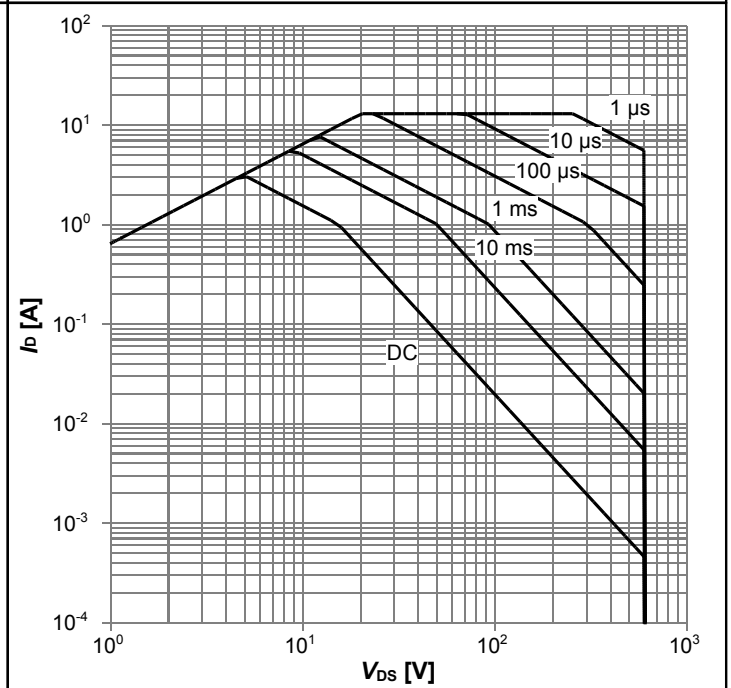
$I_D=f(V_{DS}); T_C=25\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 7: Safe operating area (Non FullPAK)



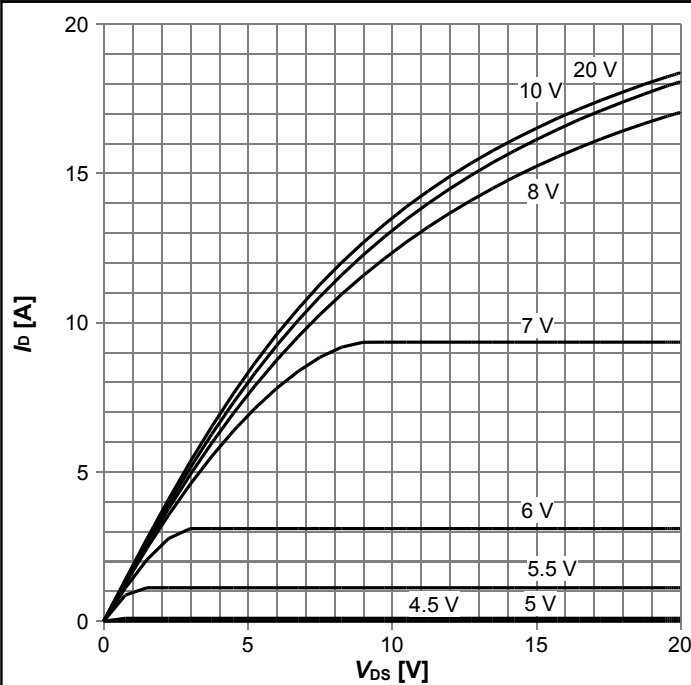
$I_D=f(V_{DS}); T_C=80\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 8: Safe operating area (FullPAK)



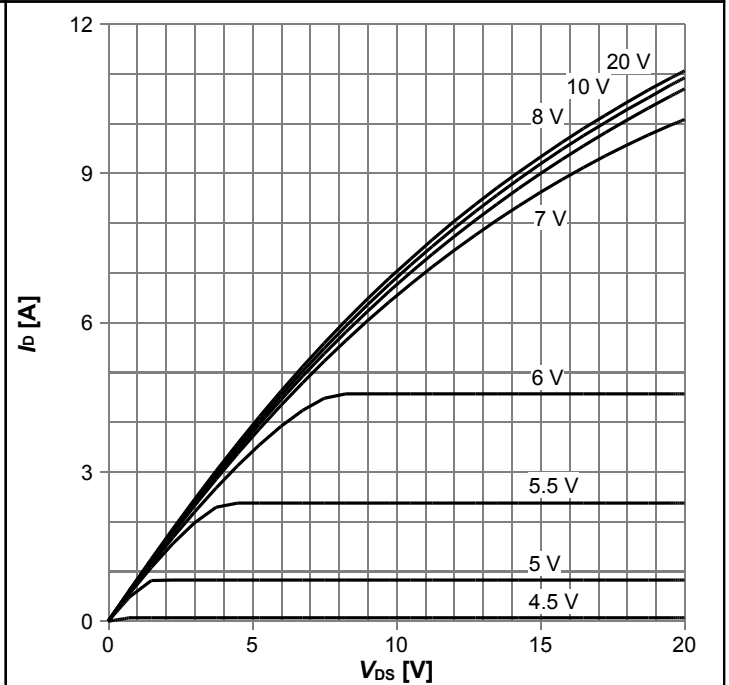
$I_D=f(V_{DS}); T_C=80\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 9: Typ. output characteristics



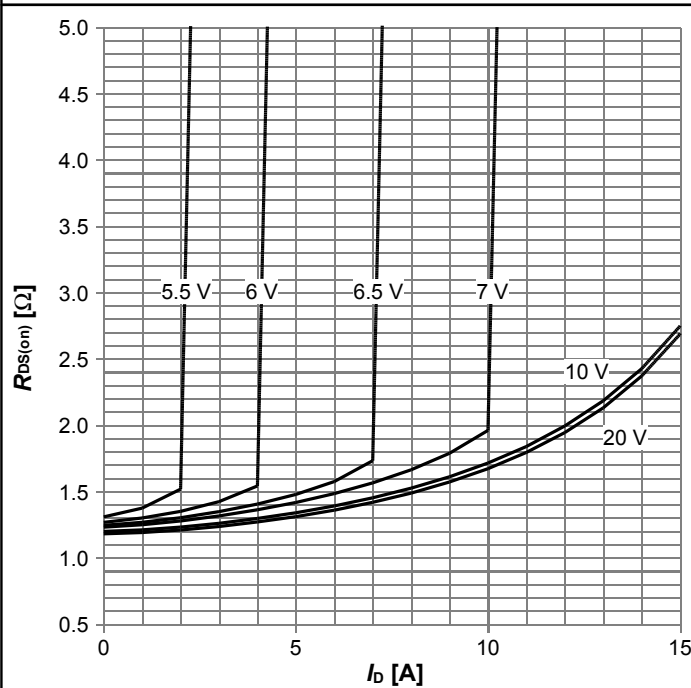
$I_D=f(V_{DS})$ ;  $T_j=25\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 10: Typ. output characteristics



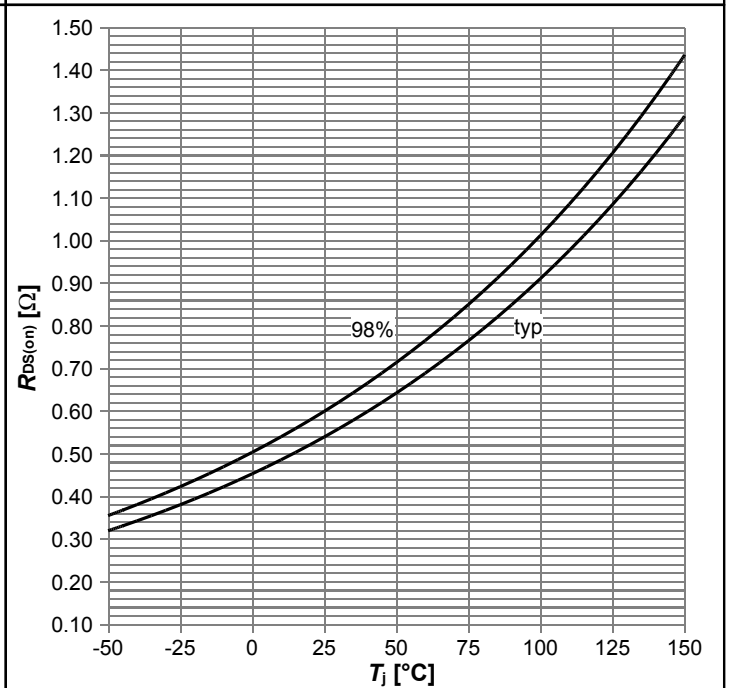
$I_D=f(V_{DS})$ ;  $T_j=125\text{ °C}$ ; parameter:  $V_{GS}$

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



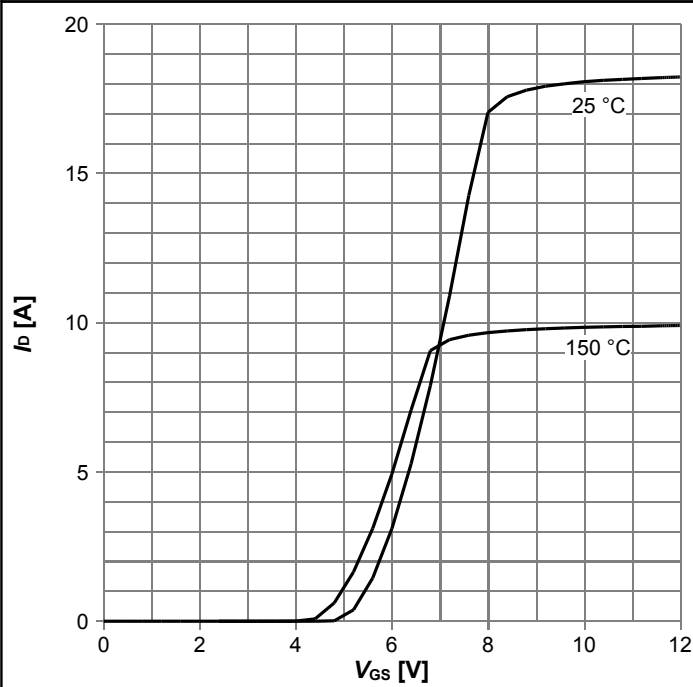
$R_{DS(on)}=f(I_D)$ ;  $T_j=125\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 12: Drain-source on-state resistance



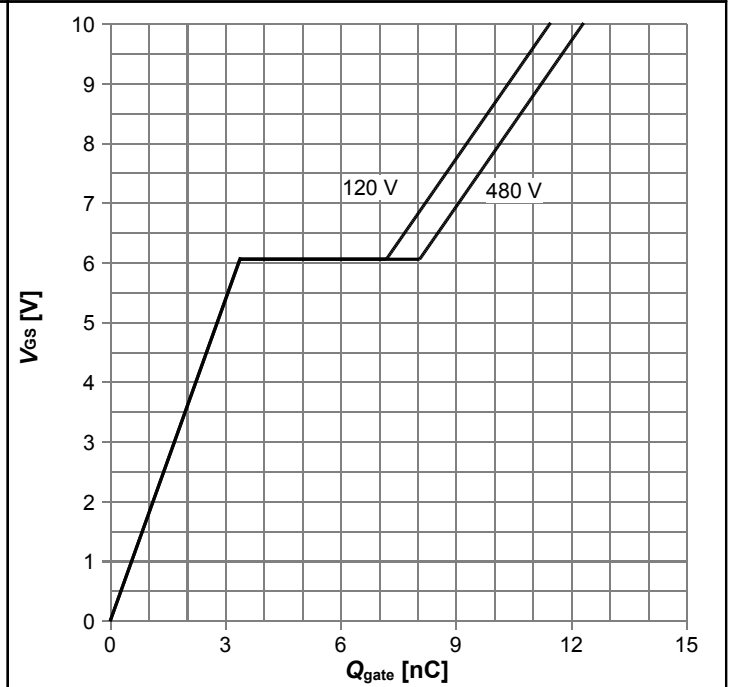
$R_{DS(on)}=f(T_j)$ ;  $I_D=2.4\text{ A}$ ;  $V_{GS}=10\text{ V}$

Diagram 13: Typ. transfer characteristics



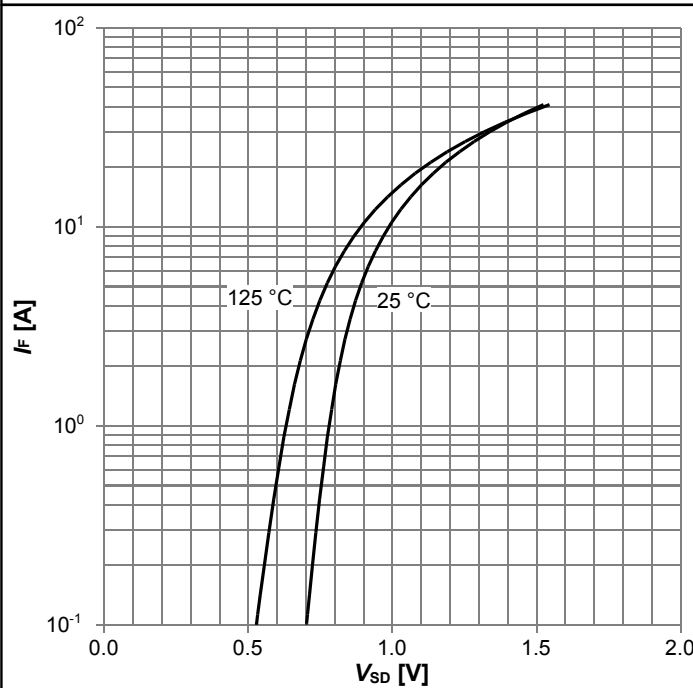
$I_D=f(V_{GS}); V_{DS}=20V$ ; parameter:  $T_j$

Diagram 14: Typ. gate charge



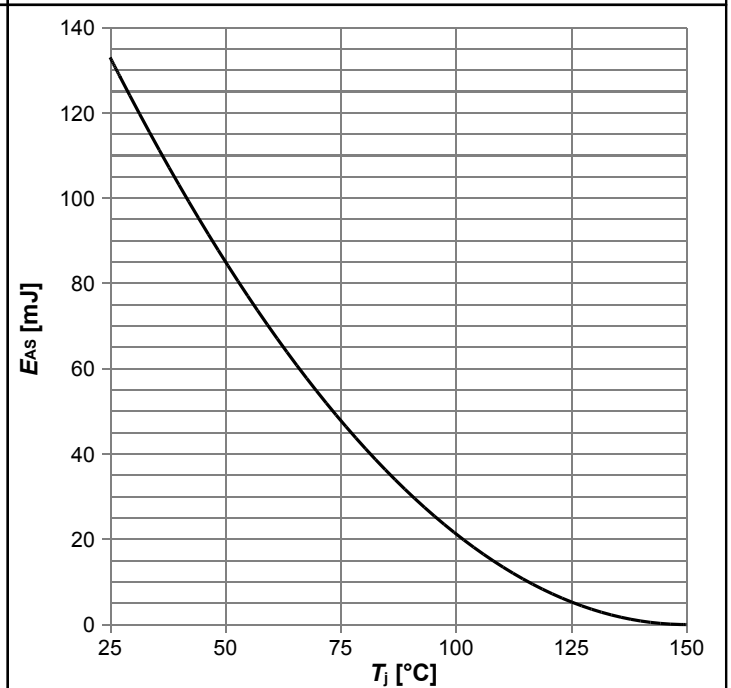
$V_{GS}=f(Q_{gate}); I_D=3.0\text{ A pulsed}$ ; parameter:  $V_{DD}$

Diagram 15: Forward characteristics of reverse diode



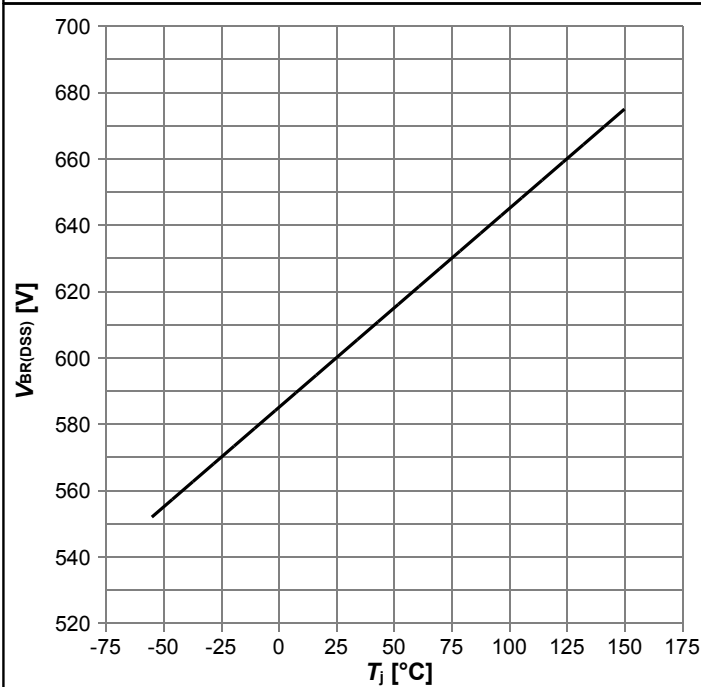
$I_F=f(V_{SD})$ ; parameter:  $T_j$

Diagram 16: Avalanche energy



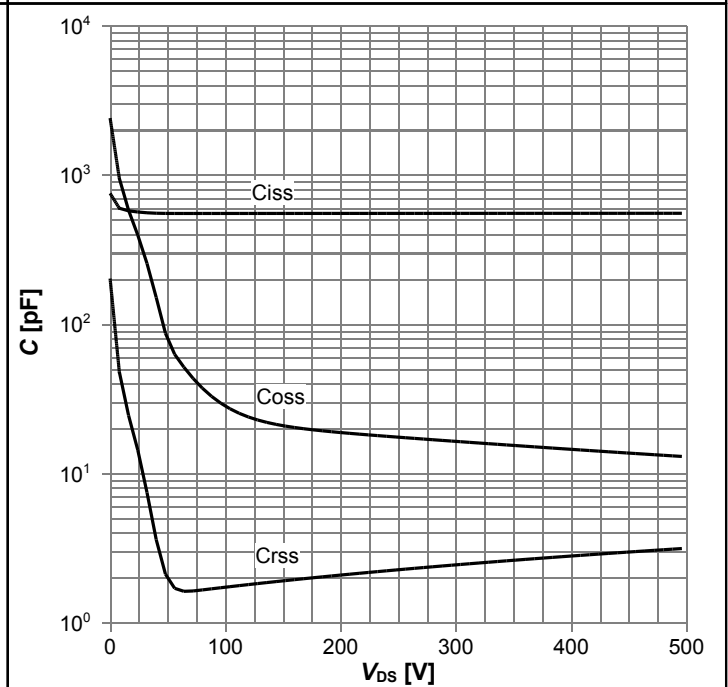
$E_{AS}=f(T_j); I_D=1.3\text{ A}; V_{DD}=50\text{ V}$

Diagram 17: Drain-source breakdown voltage



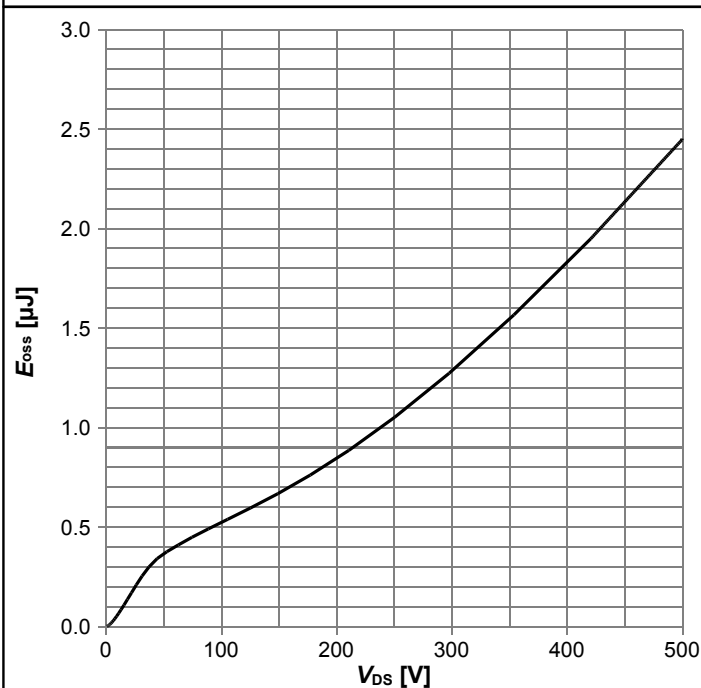
$V_{BR(DSS)}=f(T_j); I_D=1 \text{ mA}$

Diagram 18: Typ. capacitances



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

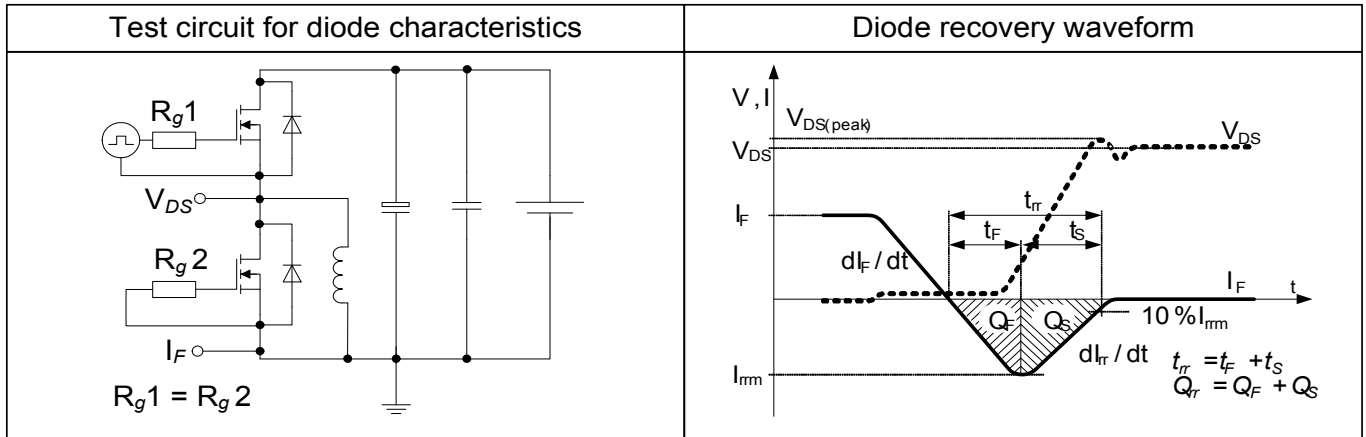
Diagram 19: Typ. Coss stored energy



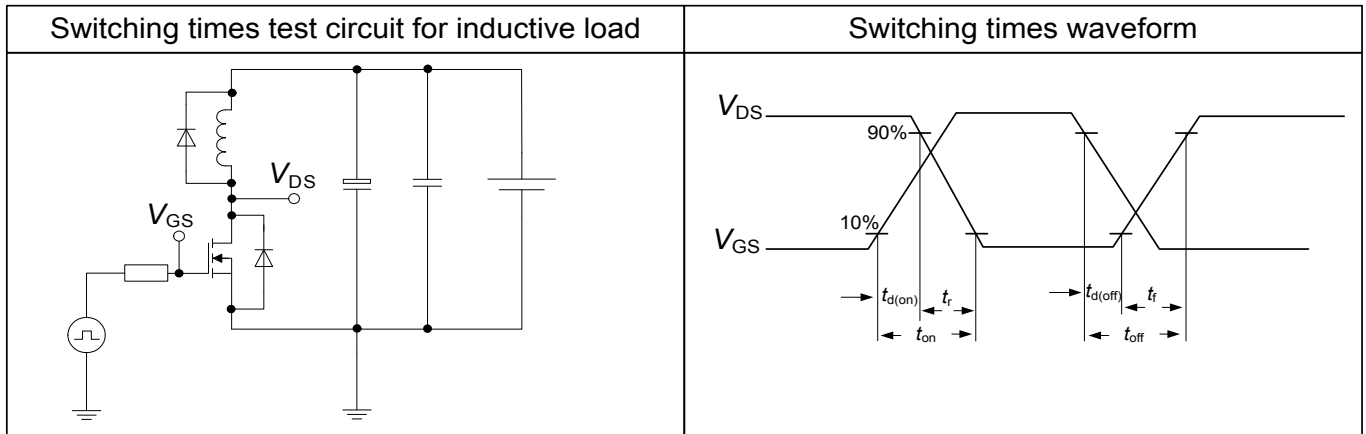
$E_{oss}=f(V_{DS})$

## 6 Test Circuits

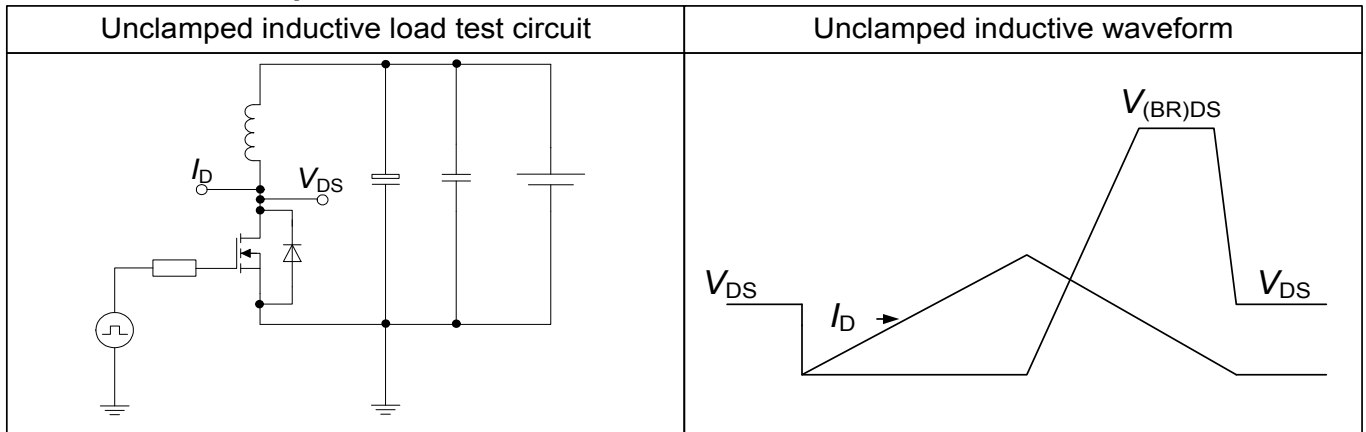
**Table 10 Diode characteristics**



**Table 11 Switching times**



**Table 12 Unclamped inductive load**



## 7 Package Outlines

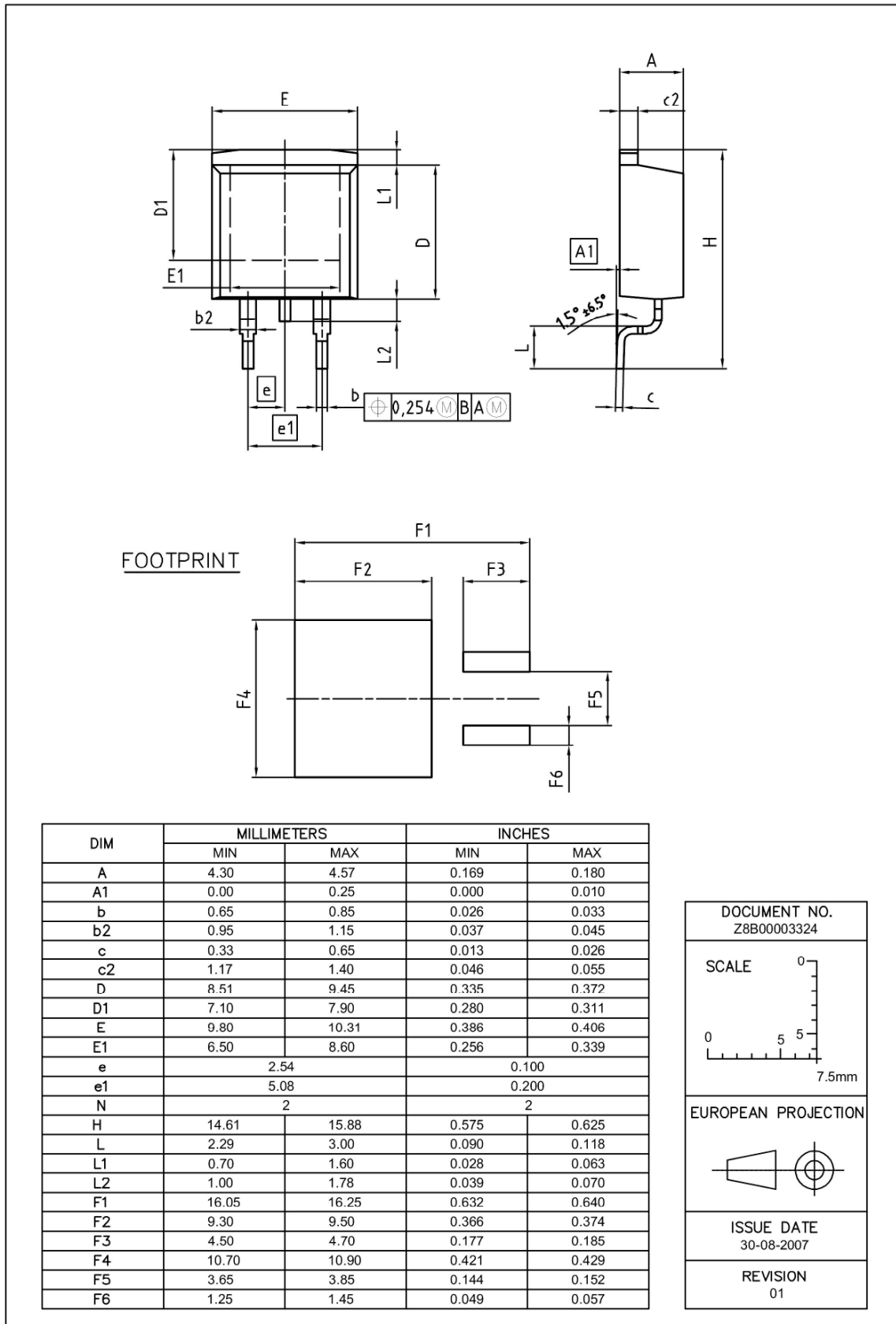


Figure 1 Outline PG-TO 263, dimensions in mm/inches

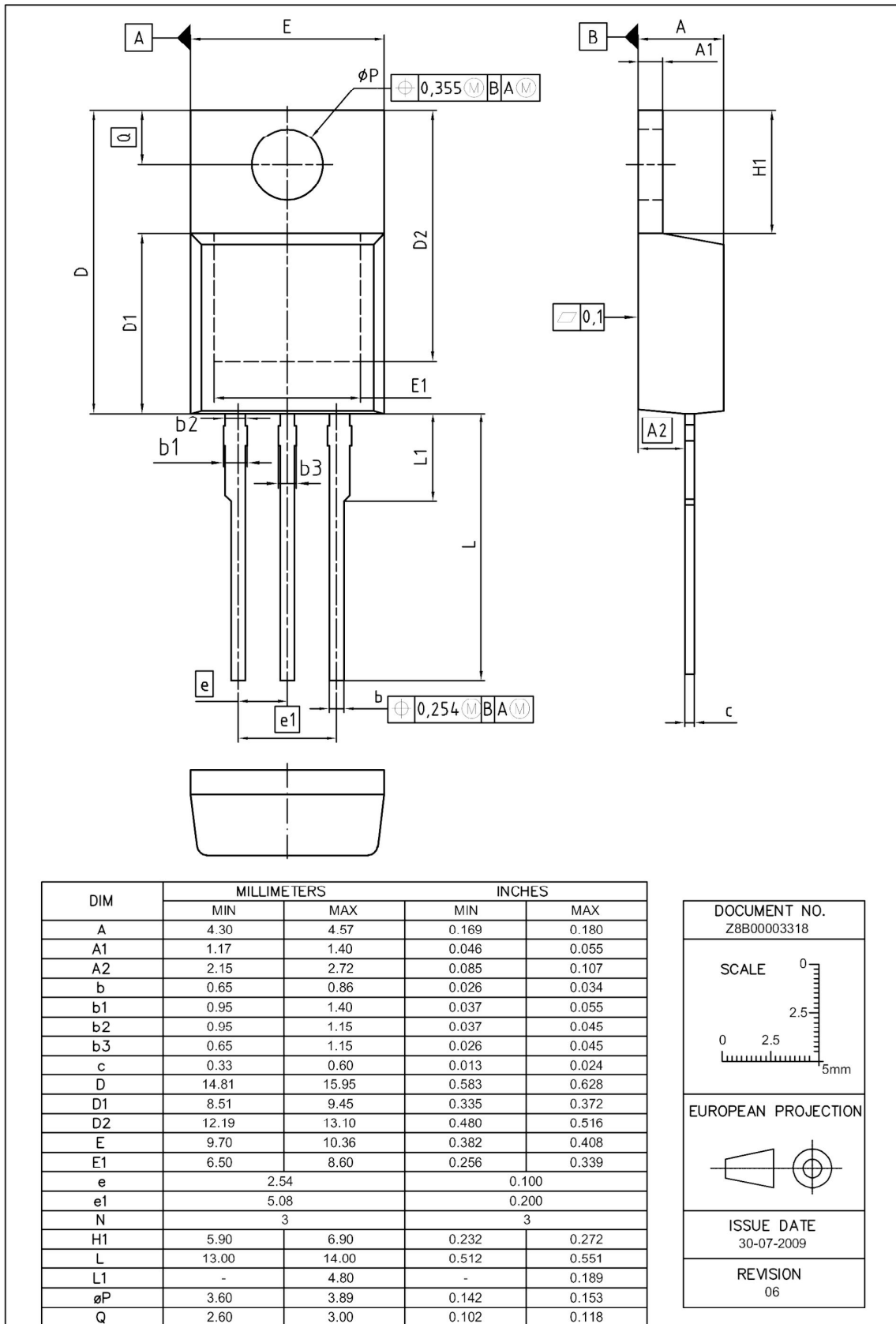
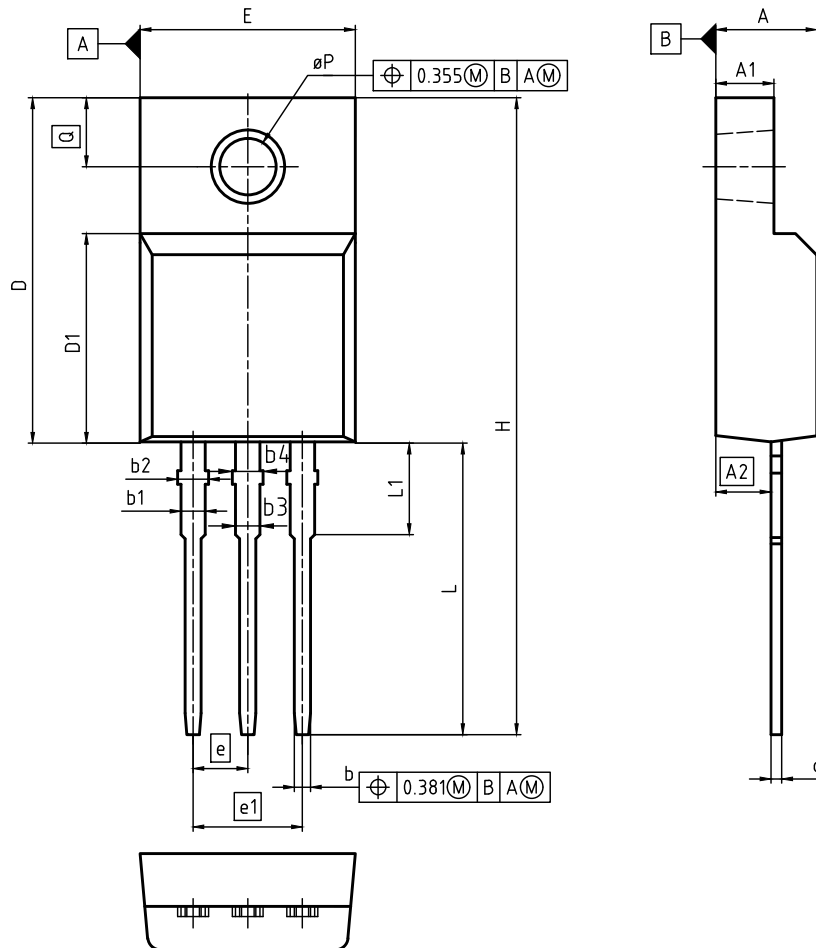


Figure 2 Outline PG-TO 220, dimensions in mm/inches



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

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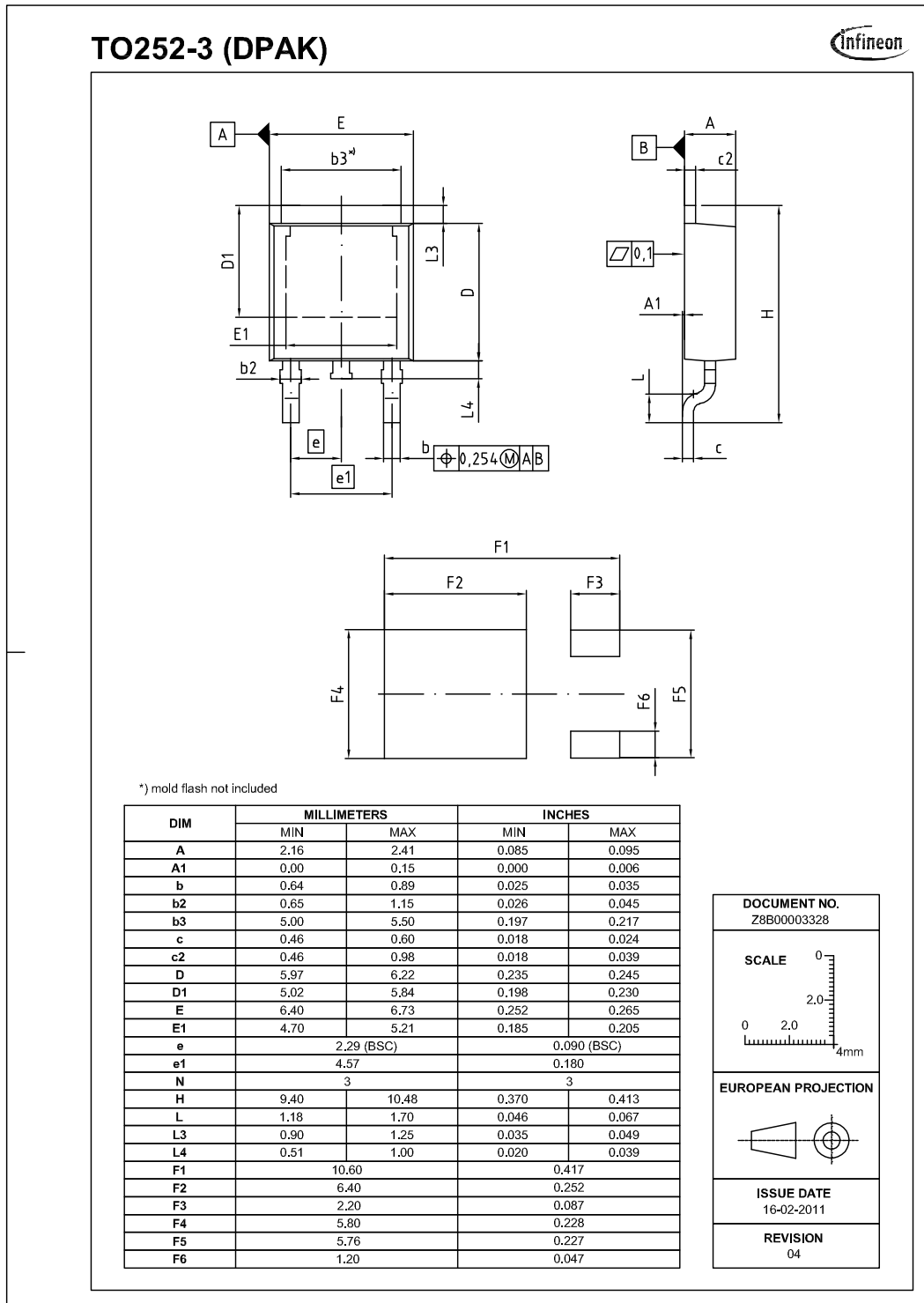
EUROPEAN PROJECTION

ISSUE DATE  
05-05-2014

REVISION  
04

Figure 3 Outline PG-TO 220 FullPAK, dimensions in mm/inches





**Figure 4 Outline PG-TO 252, dimensions in mm/inches**

## 8 Appendix A

### Table 13 Related Links

- IFX CoolMOS™ P6 Webpage: [www.infineon.com](http://www.infineon.com)
- IFX CoolMOS™ P6 application note: [www.infineon.com](http://www.infineon.com)
- IFX CoolMOS™ P6 simulation model: [www.infineon.com](http://www.infineon.com)
- IFX Design tools: [www.infineon.com](http://www.infineon.com)

## Revision History

IPB60R600P6, IPP60R600P6, IPA60R600P6, IPD60R600P6

### Revision: 2015-07-10, Rev. 2.2

#### Previous Revision

Revision	Date	Subjects (major changes since last revision)
2.0	2013-12-05	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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[2SK1691-DL-E](#) [2SK2545\(Q,T\)](#) [D2294UK](#) [405094E](#) [423220D](#) [MCH6646-TL-E](#) [TPCC8103,L1Q\(CM](#) [367-8430-0972-503](#) [VN1206L](#)  
[424134F](#) [026935X](#) [051075F](#) [SBVS138LT1G](#) [614234A](#) [715780A](#) [NTNS3166NZT5G](#) [751625C](#) [873612G](#) [IRF7380TRHR](#)  
[IPS70R2K0CEAKMA1](#) [RJK60S3DPP-E0#T2](#) [RJK60S5DPK-M0#T0](#) [APT5010JVFR](#) [APT12031JFLL](#) [APT12040JVR](#) [DMN3404LQ-7](#)  
[NTE6400](#) [JANTX2N6796U](#) [JANTX2N6784U](#) [JANTXV2N5416U4](#) [SQM110N05-06L-GE3](#) [SIHF35N60E-GE3](#)