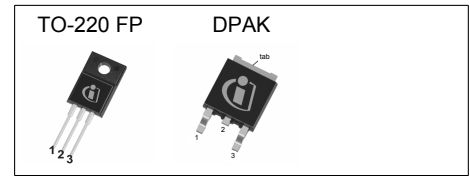


# MOSFET

## 600V CoolMOS™ CE Power Transistor

CoolMOS™ is a revolutionary technology for high voltage power MOSFETs, designed according to the superjunction (SJ) principle and pioneered by Infineon Technologies. CoolMOS™ CE is a price-performance optimized platform enabling to target cost sensitive applications in Consumer and Lighting markets by still meeting highest efficiency standards. The new series provides all benefits of a fast switching Superjunction MOSFET while not sacrificing ease of use and offering the best cost down performance ratio available on the market.



### Features

- 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 standard grade applications

### Applications

PFC stages, hard switching PWM stages and resonant switching stages for e.g. PC Silverbox, Adapter, LCD & PDP TV and indoor lighting.

*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
$R_{DS(on),max}$	650	mΩ
$I_d$	9.9	A
$Q_{g,typ}$	20.5	nC
$I_{D,pulse}$	19	A
$E_{oss}@400V$	1.9	μJ

Type / Ordering Code	Package	Marking	Related Links
IPA60R650CE	PG-TO 220 FullPAK	60S650CE	see Appendix A
IPD60R650CE	PG-TO 252		

## Table of Contents

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## 1 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>	$I_D$	-	-	9.9 6.2	A	$T_C=25^\circ\text{C}$ $T_C=100^\circ\text{C}$
Pulsed drain current <sup>2)</sup>	$I_{D,pulse}$	-	-	19	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 11
Avalanche energy, repetitive	$E_{AR}$	-	-	0.20	mJ	$I_D=1.3\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 11
Avalanche current, repetitive	$I_{AR}$	-	-	1.3	A	-
MOSFET dv/dt ruggedness	dv/dt	-	-	50	V/ns	$V_{DS}=0\dots480\text{V}$
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-251	$P_{tot}$	-	-	82	W	$T_C=25^\circ\text{C}$
Storage temperature	$T_{stg}$	-40	-	150	$^\circ\text{C}$	-
Operating junction temperature	$T_j$	-40	-	150	$^\circ\text{C}$	-
Continuous diode forward current	$I_S$	-	-	7	A	$T_C=25^\circ\text{C}$
Diode pulse current <sup>2)</sup>	$I_{S,pulse}$	-	-	19	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 9
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 9
Power dissipation (FullPAK) TO-220FP	$P_{tot}$	-	-	28	W	$T_C=25^\circ\text{C}$
Mounting torque (FullPAK) TO-220FP	-	-	-	50	Ncm	M2.5 screws
Insulation withstand voltage for TO-220FP	$V_{ISO}$	-	-	2500	V	$V_{rms}$ , $T_C=25^\circ\text{C}$ , $t=1\text{min}$

## 2 Thermal characteristics

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

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	$R_{thJC}$	-	-	4.5	$^\circ\text{C/W}$	-
Thermal resistance, junction - ambient	$R_{thJA}$	-	-	80	$^\circ\text{C/W}$	leaded
Soldering temperature, wavesoldering only allowed at leads	$T_{sold}$	-	-	260	$^\circ\text{C}$	1.6mm (0.063 in.) from case for 10s

<sup>1)</sup> Limited by  $T_{j,max}$ . TO252 equivalent, Maximum duty cycle  $D=0.50$

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

<sup>3)</sup> Identical low side and high side switch with identical  $R_\theta$

**Table 4 Thermal characteristics TO-252**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Thermal resistance, junction - case	$R_{thJC}$	-	-	1.52	°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

### 3 Electrical characteristics

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

**Table 5 Static characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Drain-source breakdown voltage	$V_{(BR)DSS}$	600	-	-	V	$V_{GS}=0V, I_D=0.25mA$
Gate threshold voltage	$V_{(GS)th}$	2.5	3.0	3.5	V	$V_{DS}=V_{GS}, I_D=0.2mA$
Zero gate voltage drain current	$I_{DSS}$	-	-	1	$\mu A$	$V_{DS}=600, V_{GS}=0V, T_j=25^\circ C$ $V_{DS}=600, V_{GS}=0V, T_j=150^\circ C$
Gate-source leakage current	$I_{GSS}$	-	-	100	nA	$V_{GS}=20V, V_{DS}=0V$
Drain-source on-state resistance	$R_{DS(on)}$	-	0.54	0.65	$\Omega$	$V_{GS}=10V, I_D=2.4A, T_j=25^\circ C$ $V_{GS}=10V, I_D=2.4A, T_j=150^\circ C$
Gate resistance	$R_G$	-	10	-	$\Omega$	$f=1MHz, \text{open drain}$

**Table 6 Dynamic characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Input capacitance	$C_{iss}$	-	440	-	pF	$V_{GS}=0V, V_{DS}=100V, f=1MHz$
Output capacitance	$C_{oss}$	-	30	-	pF	$V_{GS}=0V, V_{DS}=100V, f=1MHz$
Effective output capacitance, energy related <sup>1)</sup>	$C_{o(er)}$	-	21	-	pF	$V_{GS}=0V, V_{DS}=0...480V$
Effective output capacitance, time related <sup>2)</sup>	$C_{o(tr)}$	-	88	-	pF	$I_D=\text{constant}, V_{GS}=0V, V_{DS}=0...480V$
Turn-on delay time	$t_{d(on)}$	-	10	-	ns	$V_{DD}=400V, V_{GS}=13V, I_D=3A,$ $R_G=6.8\Omega; \text{see table 10}$
Rise time	$t_r$	-	8	-	ns	$V_{DD}=400V, V_{GS}=13V, I_D=3A,$ $R_G=6.8\Omega; \text{see table 10}$
Turn-off delay time	$t_{d(off)}$	-	58	-	ns	$V_{DD}=400V, V_{GS}=13V, I_D=3A,$ $R_G=6.8\Omega; \text{see table 10}$
Fall time	$t_f$	-	11	-	ns	$V_{DD}=400V, V_{GS}=13V, I_D=3A,$ $R_G=6.8\Omega; \text{see table 10}$

**Table 7 Gate charge characteristics**

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Gate to source charge	$Q_{gs}$	-	2.5	-	nC	$V_{DD}=480V, I_D=3A, V_{GS}=0 \text{ to } 10V$
Gate to drain charge	$Q_{gd}$	-	10.5	-	nC	$V_{DD}=480V, I_D=3A, V_{GS}=0 \text{ to } 10V$
Gate charge total	$Q_g$	-	20.5	-	nC	$V_{DD}=480V, I_D=3A, V_{GS}=0 \text{ to } 10V$
Gate plateau voltage	$V_{plateau}$	-	5.4	-	V	$V_{DD}=480V, I_D=3A, V_{GS}=0 \text{ to } 10V$

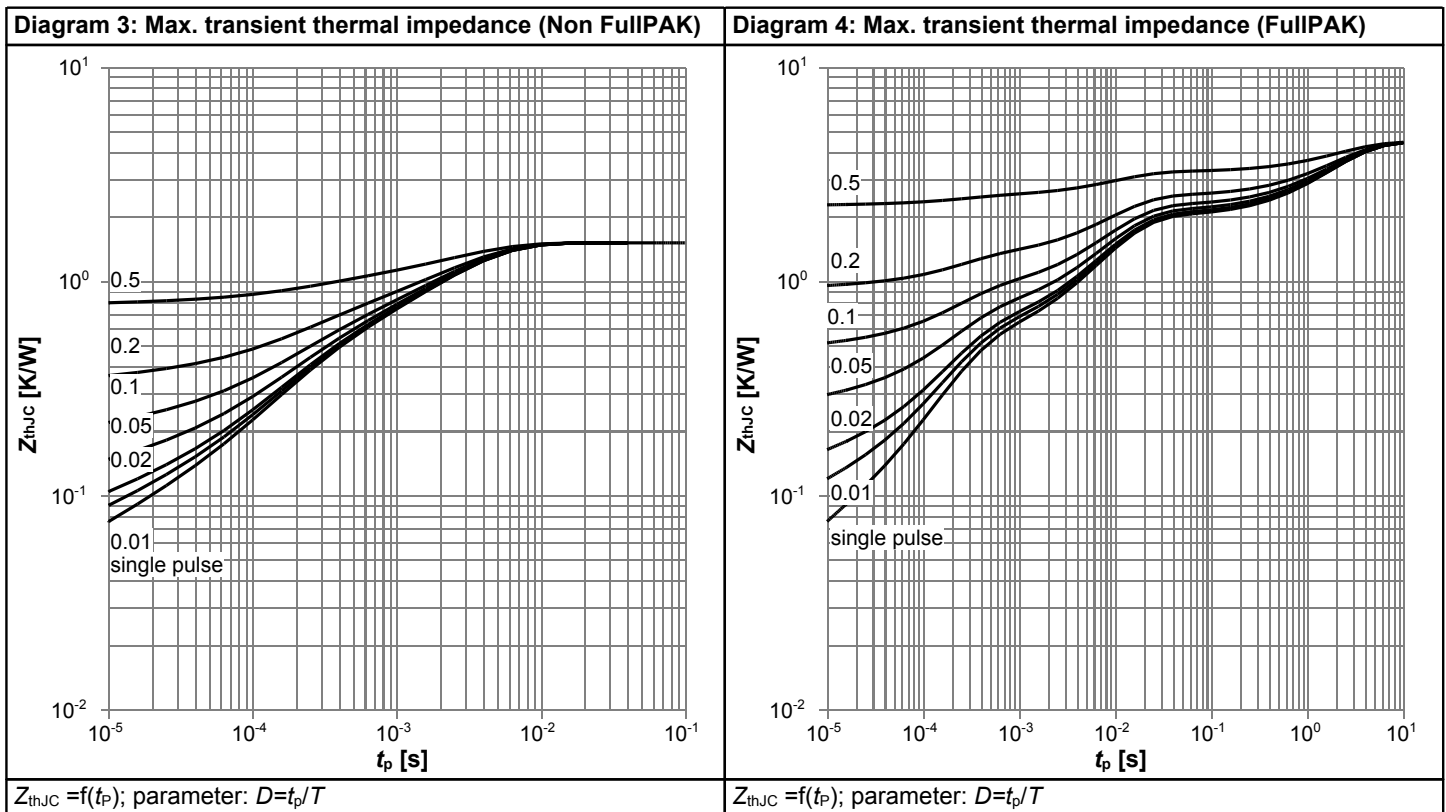
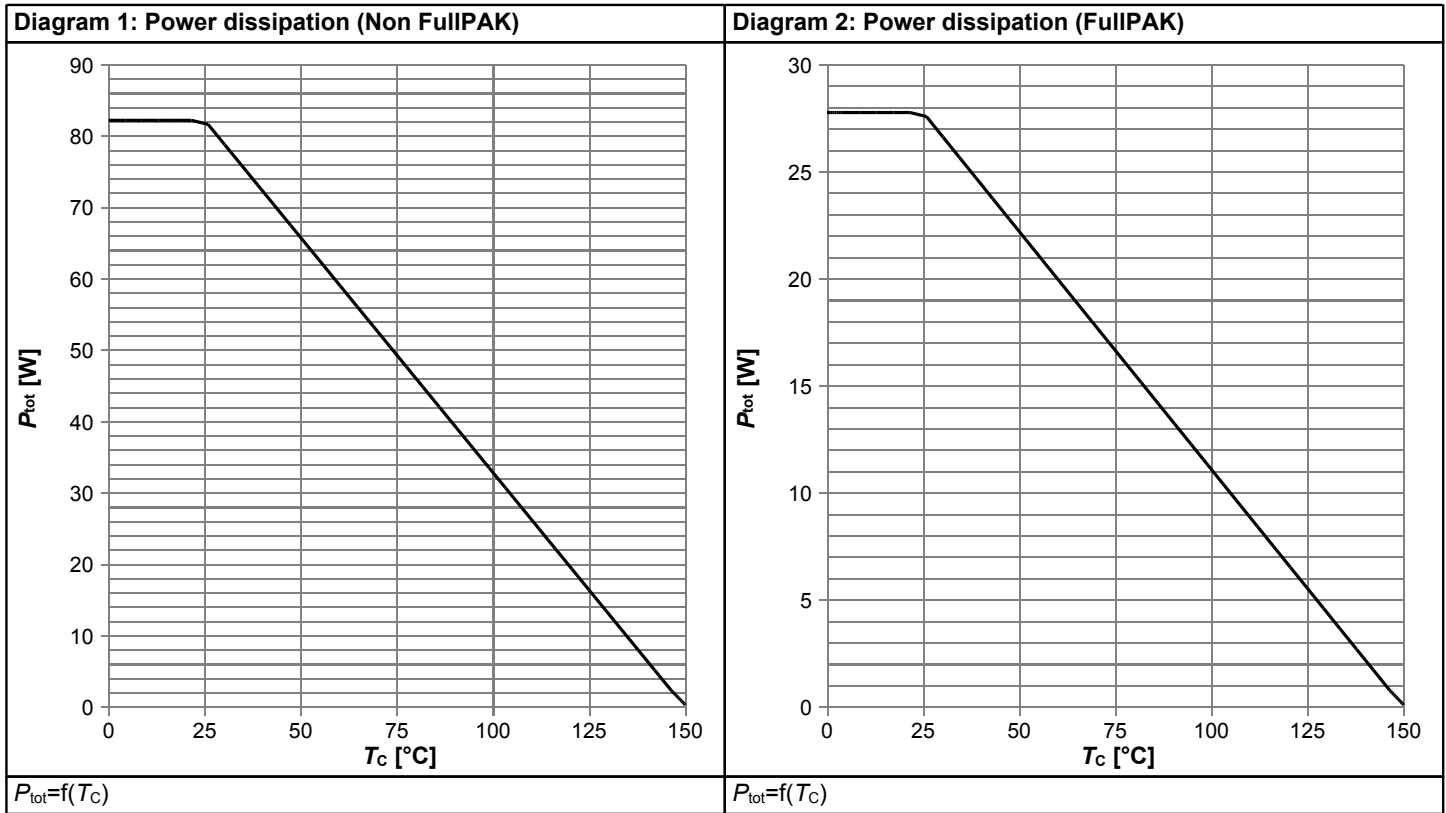
<sup>1)</sup>  $C_{o(er)}$  is a fixed capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{(BR)DSS}$

<sup>2)</sup>  $C_{o(tr)}$  is a fixed capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{(BR)DSS}$

**Table 8 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	$t_{rr}$	-	250	-	ns	$V_R=400V, I_F=3A, di_F/dt=100A/\mu s$ ; see table 9
Reverse recovery charge	$Q_{rr}$	-	2.1	-	$\mu C$	$V_R=400V, I_F=3A, di_F/dt=100A/\mu s$ ; see table 9
Peak reverse recovery current	$I_{rrm}$	-	16	-	A	$V_R=400V, I_F=3A, di_F/dt=100A/\mu s$ ; see table 9

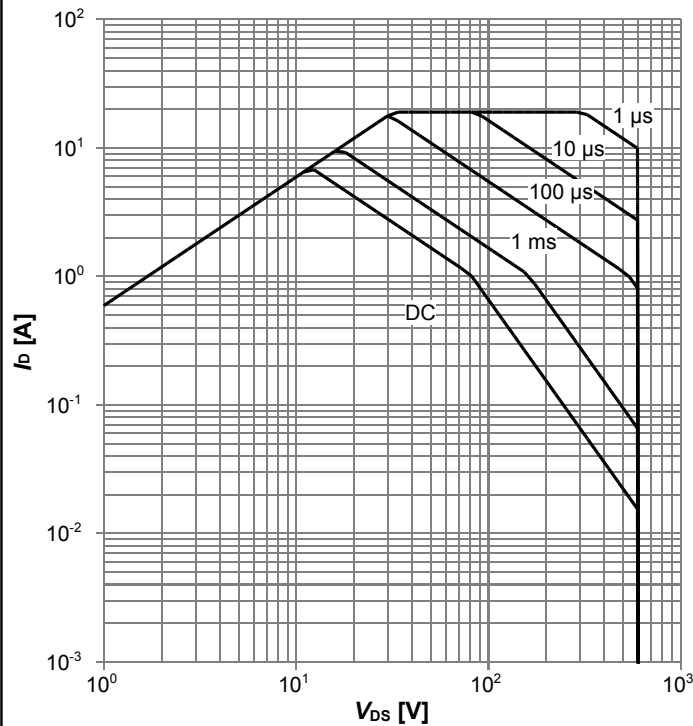
## 4 Electrical characteristics diagrams



# 600V CoolMOS™ CE Power Transistor

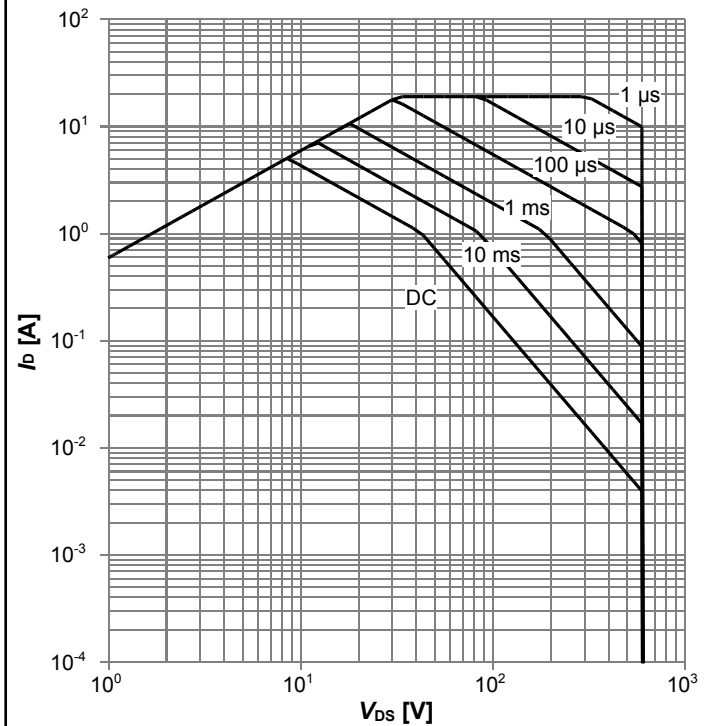
## IPA60R650CE, IPD60R650CE

**Diagram 5: Safe operating area (Non FullIPAK)**



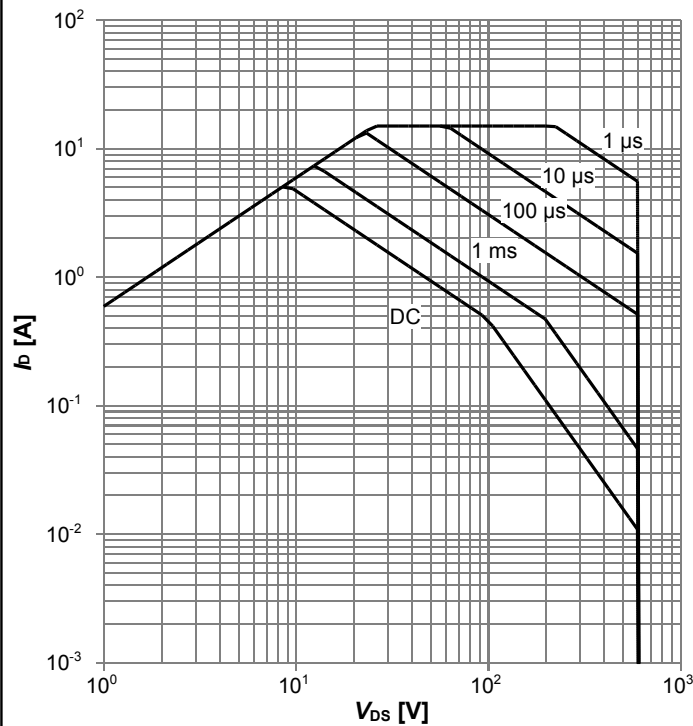
$I_b=f(V_{Ds}); T_C=25\text{ }^\circ\text{C}; D=0; \text{parameter: } t_p$

**Diagram 6: Safe operating area (FullIPAK)**



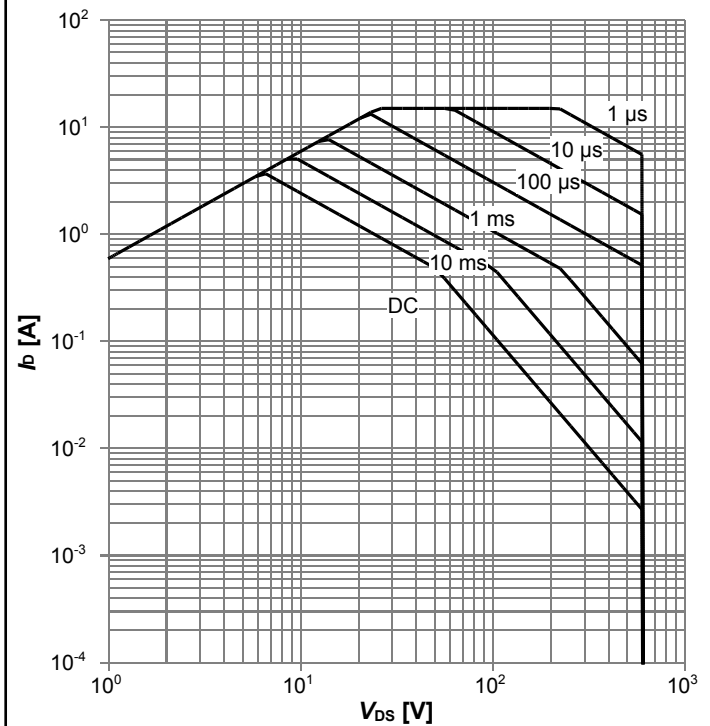
$I_b=f(V_{Ds}); T_C=25\text{ }^\circ\text{C}; D=0; \text{parameter: } t_p$

**Diagram 7: Safe operating area (Non FullIPAK)**



$I_b=f(V_{Ds}); T_C=80\text{ }^\circ\text{C}; D=0; \text{parameter: } t_p$

**Diagram 8: Safe operating area (FullIPAK)**

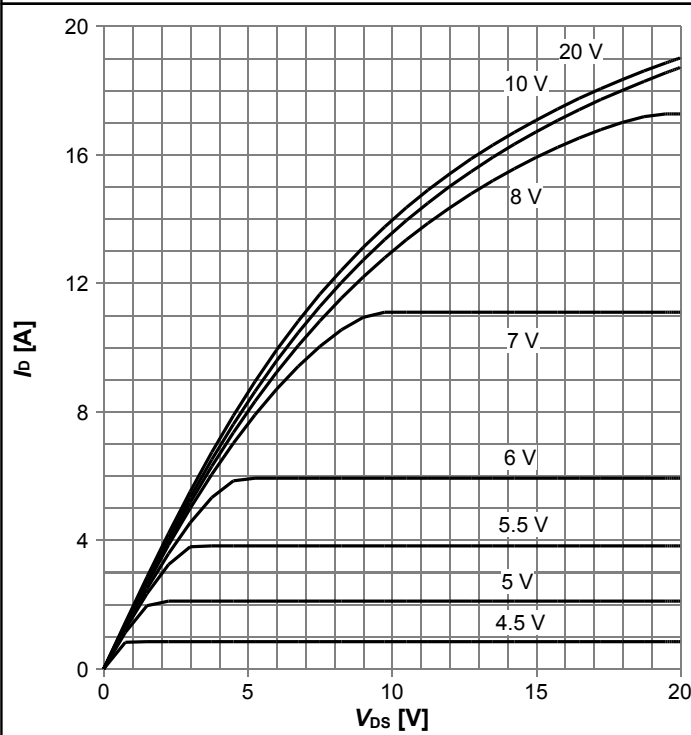


$I_b=f(V_{Ds}); T_C=80\text{ }^\circ\text{C}; D=0; \text{parameter: } t_p$



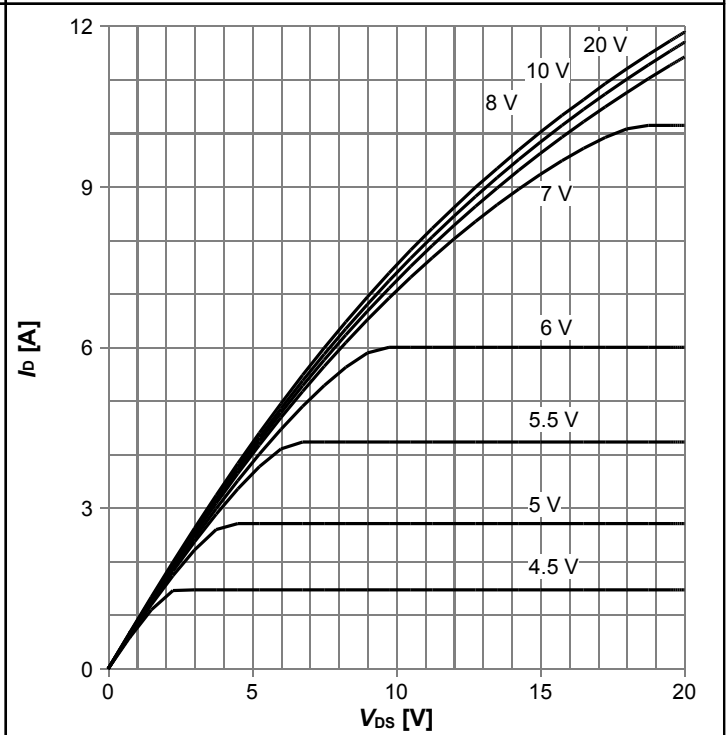
**600V CoolMOS™ CE Power Transistor**  
**IPA60R650CE, IPD60R650CE**

**Diagram 9: Typ. output characteristics**



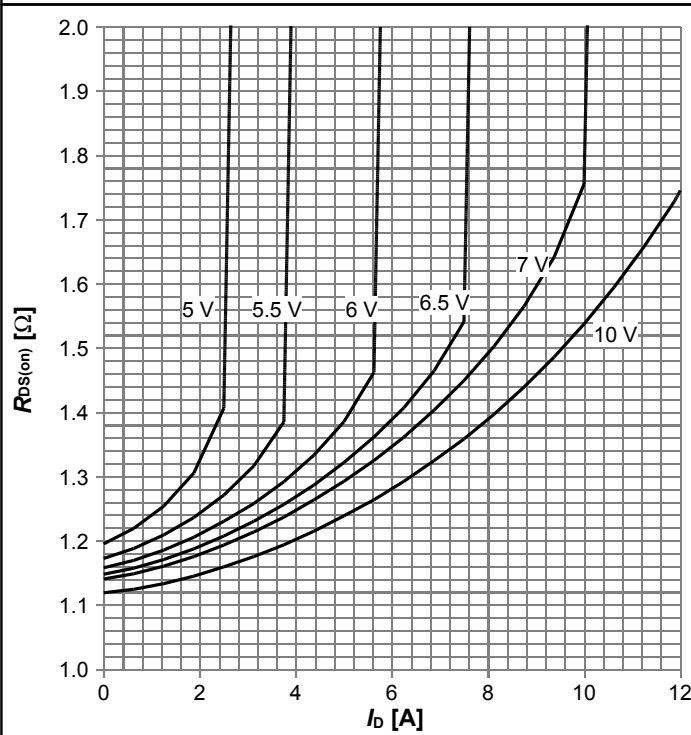
$I_D = f(V_{DS})$ ;  $T_j = 25^\circ\text{C}$ ; parameter:  $V_{GS}$

**Diagram 10: Typ. output characteristics**



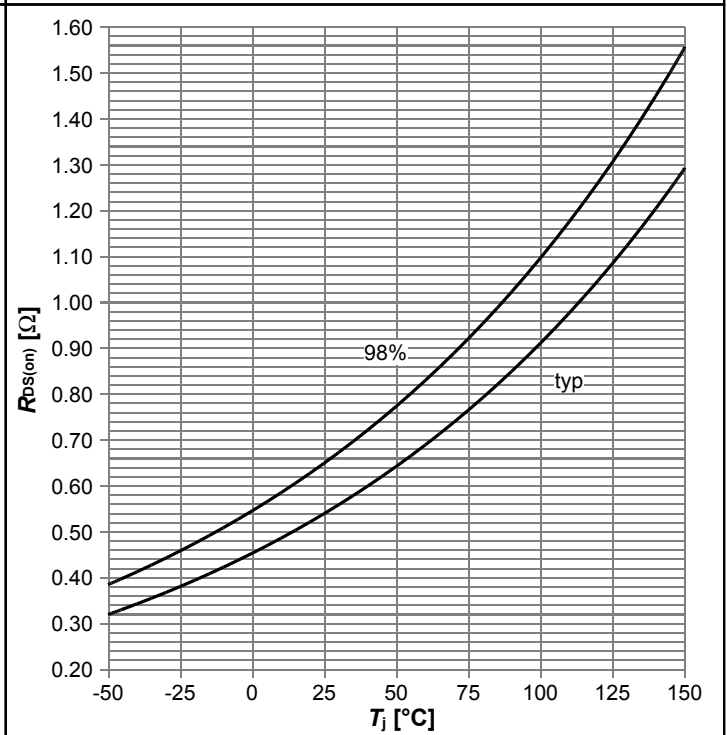
$I_D = f(V_{DS})$ ;  $T_j = 125^\circ\text{C}$ ; parameter:  $V_{GS}$

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



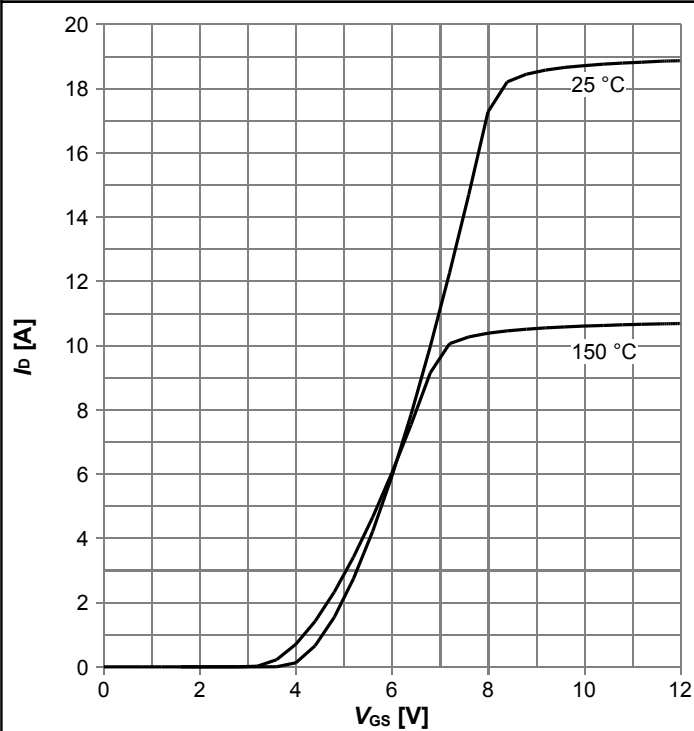
$R_{DS(on)} = f(I_D)$ ;  $T_j = 125^\circ\text{C}$ ; parameter:  $V_{GS}$

**Diagram 12: Drain-source on-state resistance**



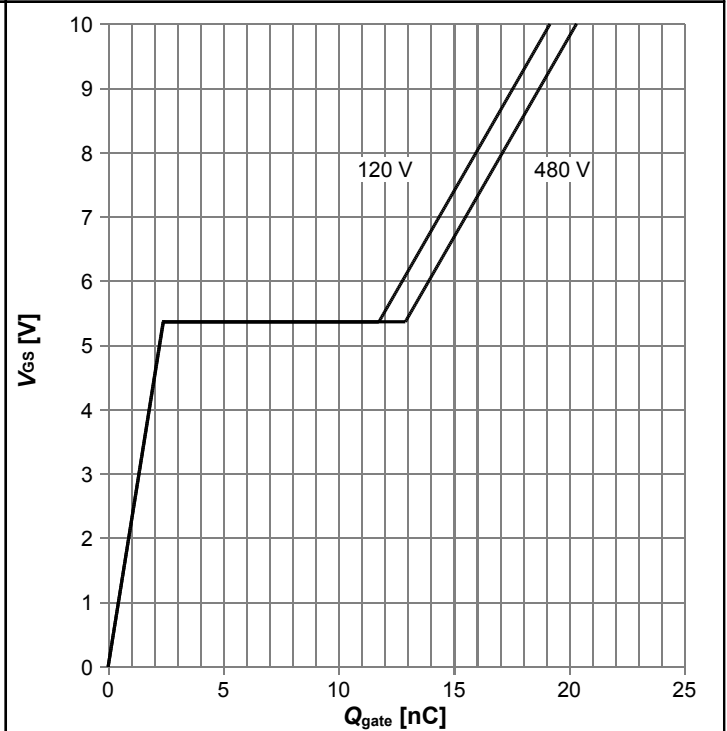
$R_{DS(on)} = f(T_j)$ ;  $I_D = 2.4\text{ A}$ ;  $V_{GS} = 10\text{ V}$

**Diagram 13: Typ. transfer characteristics**



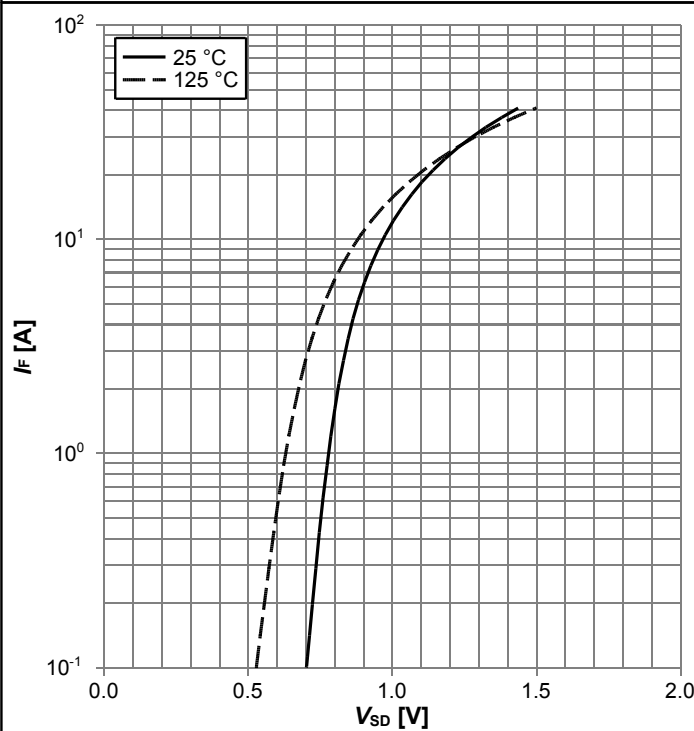
$I_D = f(V_{GS}); V_{DS} = 20V; \text{parameter: } T_j$

**Diagram 14: Typ. gate charge**



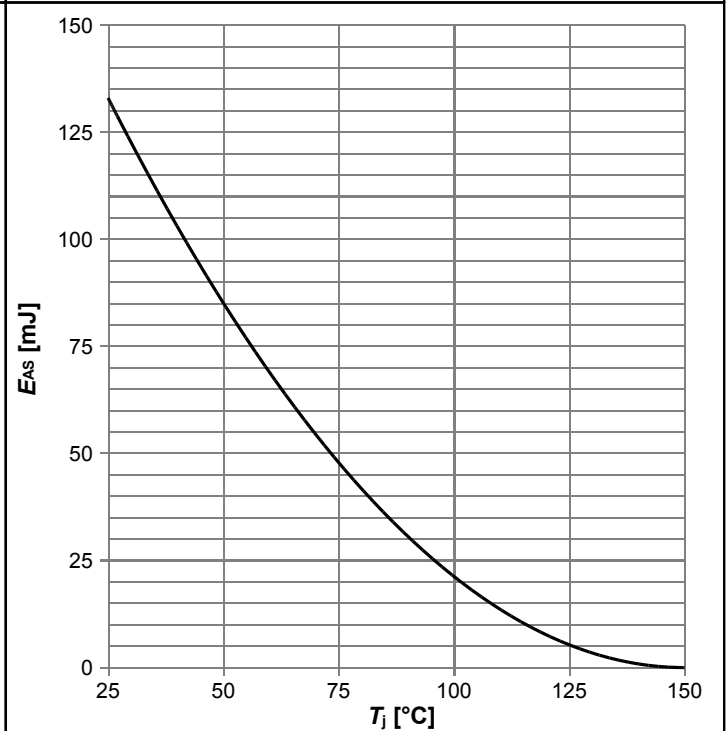
$V_{GS} = f(Q_{gate}); I_D = 3.0 \text{ A pulsed}; \text{parameter: } V_{DD}$

**Diagram 15: Forward characteristics of reverse diode**



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

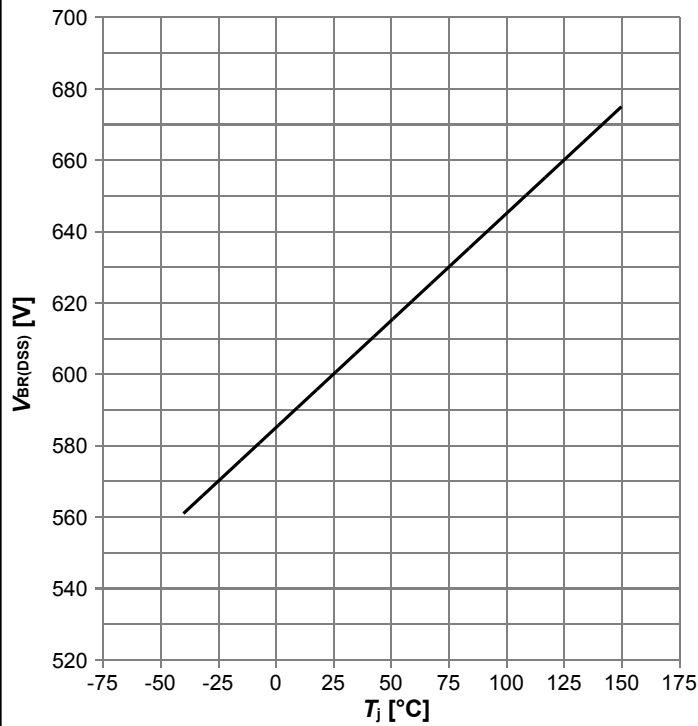
**Diagram 16: Avalanche energy**



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

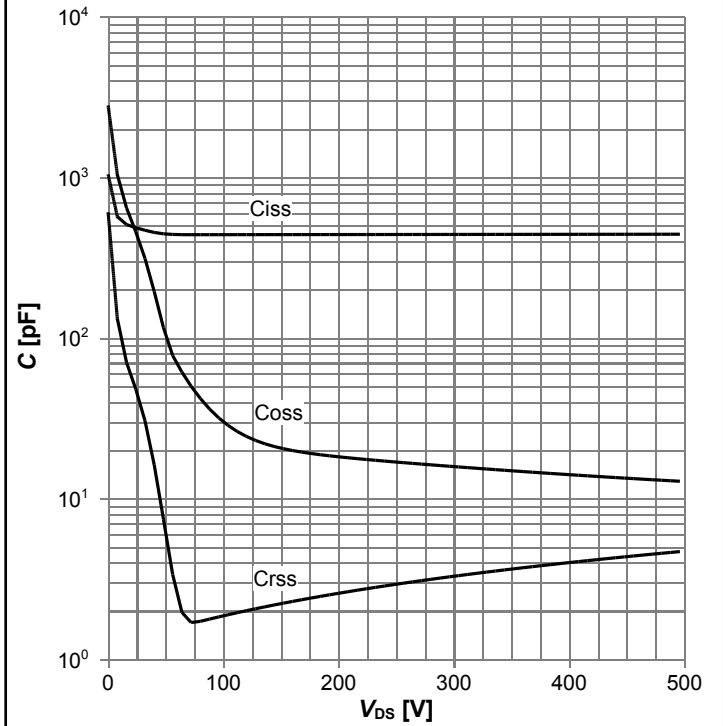
**600V CoolMOS™ CE Power Transistor**  
**IPA60R650CE, IPD60R650CE**

**Diagram 17: Drain-source breakdown voltage**



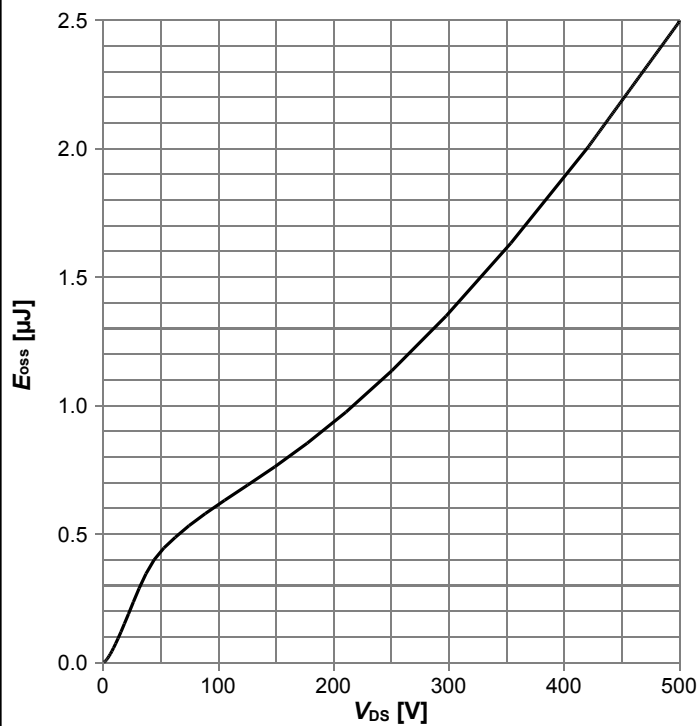
$V_{BR(DSS)}=f(T_j); I_D=0.25\text{ mA}$

**Diagram 18: Typ. capacitances**



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

**Diagram 19: Typ. Coss stored energy**



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

## 5 Test Circuits

**Table 9 Diode characteristics**

Test circuit for diode characteristics	Diode recovery waveform
<p><math>R_{g1} = R_{g2}</math></p>	<p><math>t_{tr} = t_F + t_S</math>  <math>Q_{tr} = Q_F + Q_S</math></p>

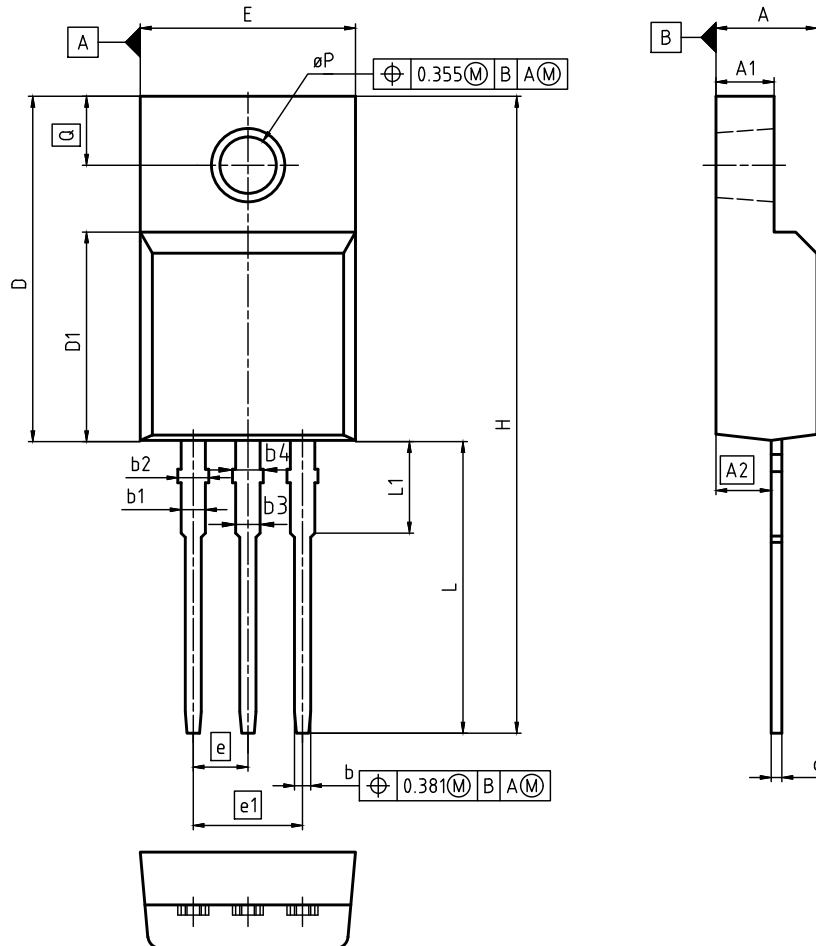
**Table 10 Switching times**

Switching times test circuit for inductive load	Switching times waveform

**Table 11 Unclamped inductive load**

Unclamped inductive load test circuit	Unclamped inductive waveform

## 6 Package Outlines



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
$\varnothing P$	2.95	3.38	0.116	0.133
Q	3.15	3.50	0.124	0.138

Dimensions do not include mold flash, protrusions or gate burrs

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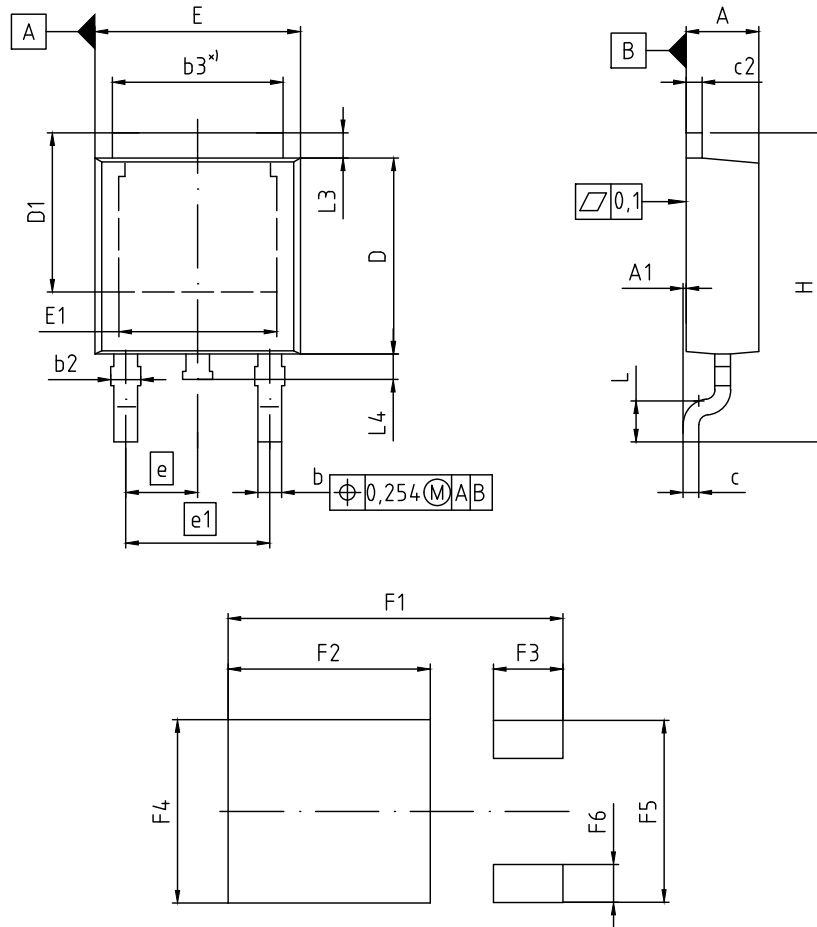
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05-05-2014

REVISION  
04

Figure 1 Outline PG-TO 220 FullPAK, dimensions in mm/inches



\*) mold flash not included

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	2.16	2.41	0.085	0.095
A1	0.00	0.15	0.000	0.006
b	0.64	0.89	0.025	0.035
b2	0.65	1.15	0.026	0.045
b3	5.00	5.50	0.197	0.217
c	0.46	0.60	0.018	0.024
c2	0.46	0.98	0.018	0.039
D	5.97	6.22	0.235	0.245
D1	5.02	5.84	0.198	0.230
E	6.40	6.73	0.252	0.265
E1	4.70	5.60	0.185	0.220
e	2.29 (BSC)		0.090 (BSC)	
e1	4.57 (BSC)		0.180 (BSC)	
N	3		3	
H	9.40	10.48	0.370	0.413
L	1.18	1.70	0.046	0.067
L3	0.90	1.25	0.035	0.049
L4	0.51	1.00	0.020	0.039
F1	10.60		0.417	
F2	6.40		0.252	
F3	2.20		0.087	
F4	5.80		0.228	
F5	5.76		0.227	
F6	1.20		0.047	

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Figure 2 Outline PG-TO 252, dimensions in mm/inches

## 7 Appendix A

Table 12 Related Links

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

## Revision History

IPA60R650CE, IPD60R650CE

Revision: 2016-03-31

### Previous Revision

Date	Subjects (major changes since last revision)
2014-09-25	Release of final version
2016-03-31	Modified Id, Rthjc. Modified SOA and Zthjc curves

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