

## MOSFET

Metal Oxide Semiconductor Field Effect Transistor

## CoolMOS™ P6

600V CoolMOS™ P6 Power Transistor  
IPx60R230P6

## 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.

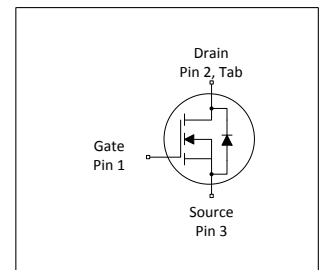
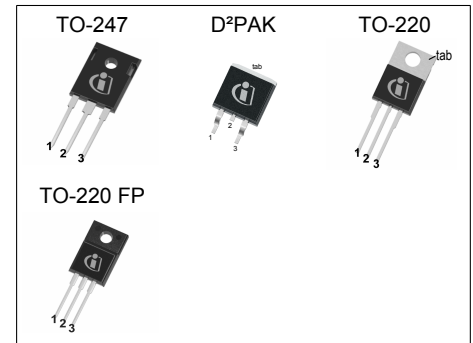
## Features

- 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    |
| $R_{DS(on),max}$     | 230   | mΩ   |
| $Q_{g,typ}$          | 31    | nC   |
| $I_{D,pulse}$        | 48    | A    |
| $E_{oss@400V}$       | 4.2   | μJ   |
| Body diode di/dt     | 500   | A/μs |

| Type / Ordering Code | Package           | Marking | Related Links  |
|----------------------|-------------------|---------|----------------|
| IPW60R230P6          | PG-TO 247         | 6R230P6 | see Appendix A |
| IPB60R230P6          | PG-TO 263         |         |                |
| IPP60R230P6          | PG-TO 220         |         |                |
| IPA60R230P6          | PG-TO 220 FullPAK |         |                |



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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>                    | $I_D$         | -      | -    | 16.8<br>10.7 | A                | $T_C=25^\circ\text{C}$<br>$T_C=100^\circ\text{C}$                                      |
| Pulsed drain current <sup>2)</sup>                        | $I_{D,pulse}$ | -      | -    | 48           | A                | $T_C=25^\circ\text{C}$   |
| Avalanche energy, single pulse                            | $E_{AS}$      | -      | -    | 352          | mJ               | $I_D=2.9\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 12                                 |
| Avalanche energy, repetitive                              | $E_{AR}$      | -      | -    | 0.53         | mJ               | $I_D=2.9\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 12                                 |
| Avalanche current, repetitive                             | $I_{AR}$      | -      | -    | 2.9          | 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)<br>TO-220, TO-263, TO-247 | $P_{tot}$     | -      | -    | 126          | W                | $T_C=25^\circ\text{C}$   |
| Power dissipation (FullPAK)<br>TO-220FP                   | $P_{tot}$     | -      | -    | 33           | 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)<br>TO-220, TO-247           | -             | -      | -    | 60           | Ncm              | M3 and M3.5 screws   |
| Mounting torque (FullPAK)<br>TO-220FP                     | -             | -      | -    | 50           | Ncm              | M2.5 screws  |
| Continuous diode forward current                          | $I_S$         | -      | -    | 14.5         | A                | $T_C=25^\circ\text{C}$   |
| Diode pulse current <sup>2)</sup>                         | $I_{S,pulse}$ | -      | -    | 48           | A                | $T_C=25^\circ\text{C}$   |
| Reverse diode dv/dt <sup>3)</sup>                         | dv/dt         | -      | -    | 15           | V/ns             | $V_{DS}=0\dots400\text{V}$ , $I_{SD}\leq I_S$ , $T_j=25^\circ\text{C}$<br>see table 10 |
| Maximum diode commutation speed                           | di/dt         | -      | -    | 500          | A/ $\mu\text{s}$ | $V_{DS}=0\dots400\text{V}$ , $I_{SD}\leq I_S$ , $T_j=25^\circ\text{C}$<br>see table 10 |
| Insulation withstand voltage for<br>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, TO-247**

| Parameter  | Symbol     | Values |      |      | Unit | Note / Test Condition               |
|--|------------|--------|------|------|------|-------------------------------------|
|  |            | Min.   | Typ. | Max. |      |                                     |
| Thermal resistance, junction - case                        | $R_{thJC}$ | -      | -    | 0.99 | °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                        | $R_{thJC}$ | -      | -    | 3.8  | °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-263**

| Parameter  | Symbol     | Values |      |      | Unit | Note / Test Condition   |
|--|------------|--------|------|------|------|---|
|  |            | Min.   | Typ. | Max. |      |   |
| Thermal resistance, junction - case                    | $R_{thJC}$ | -      | -    | 0.99 | °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             | $V_{DS}=V_{GS}$ , $I_D=0.53\text{mA}$   |
| Zero gate voltage drain current  | $I_{DSS}$     | -      | -              | 1          | $\mu\text{A}$ | $V_{DS}=600$ , $V_{GS}=0\text{V}$ , $T_j=25^\circ\text{C}$<br>$V_{DS}=600$ , $V_{GS}=0\text{V}$ , $T_j=150^\circ\text{C}$             |
| Gate-source leakage current      | $I_{GSS}$     | -      | -              | 100        | nA            | $V_{GS}=20\text{V}$ , $V_{DS}=0\text{V}$  |
| Drain-source on-state resistance | $R_{DS(on)}$  | -      | 0.207<br>0.538 | 0.230<br>- | $\Omega$      | $V_{GS}=10\text{V}$ , $I_D=6.4\text{A}$ , $T_j=25^\circ\text{C}$<br>$V_{GS}=10\text{V}$ , $I_D=6.4\text{A}$ , $T_j=150^\circ\text{C}$ |
| Gate resistance                  | $R_G$         | -      | 4.4            | -          | $\Omega$      | $f=1\text{MHz}$ , open drain  |

**Table 7 Dynamic characteristics**

| Parameter  | Symbol       | Values |      |      | Unit | Note / Test Condition  |
|--|--------------|--------|------|------|------|--|
|  |              | Min.   | Typ. | Max. |      |  |
| Input capacitance  | $C_{iss}$    | -      | 1450 | -    | pF   | $V_{GS}=0\text{V}$ , $V_{DS}=100\text{V}$ , $f=1\text{MHz}$                                      |
| Output capacitance   | $C_{oss}$    | -      | 64   | -    | pF   | $V_{GS}=0\text{V}$ , $V_{DS}=100\text{V}$ , $f=1\text{MHz}$                                      |
| Effective output capacitance, energy related <sup>1)</sup> | $C_{o(er)}$  | -      | 52   | -    | pF   | $V_{GS}=0\text{V}$ , $V_{DS}=0\dots400\text{V}$  |
| Effective output capacitance, time related <sup>2)</sup>   | $C_{o(tr)}$  | -      | 220  | -    | pF   | $I_D=\text{constant}$ , $V_{GS}=0\text{V}$ , $V_{DS}=0\dots400\text{V}$                          |
| Turn-on delay time   | $t_{d(on)}$  | -      | 12   | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=8\text{A}$ ,<br>$R_G=3.4\Omega$ ; see table 11 |
| Rise time  | $t_r$        | -      | 7    | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=8\text{A}$ ,<br>$R_G=3.4\Omega$ ; see table 11 |
| Turn-off delay time  | $t_{d(off)}$ | -      | 38   | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=8\text{A}$ ,<br>$R_G=3.4\Omega$ ; see table 11 |
| Fall time  | $t_f$        | -      | 6    | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=8\text{A}$ ,<br>$R_G=3.4\Omega$ ; see table 11 |

**Table 8 Gate charge characteristics**

| Parameter             | Symbol        | Values |      |      | Unit | Note / Test Condition   |
|-----------------------|---------------|--------|------|------|------|---|
|                       |               | Min.   | Typ. | Max. |      |   |
| Gate to source charge | $Q_{gs}$      | -      | 9    | -    | nC   | $V_{DD}=400\text{V}$ , $I_D=8\text{A}$ , $V_{GS}=0$ to $10\text{V}$ |
| Gate to drain charge  | $Q_{gd}$      | -      | 11   | -    | nC   | $V_{DD}=400\text{V}$ , $I_D=8\text{A}$ , $V_{GS}=0$ to $10\text{V}$ |
| Gate charge total     | $Q_g$         | -      | 31   | -    | nC   | $V_{DD}=400\text{V}$ , $I_D=8\text{A}$ , $V_{GS}=0$ to $10\text{V}$ |
| Gate plateau voltage  | $V_{plateau}$ | -      | 6.1  | -    | V    | $V_{DD}=400\text{V}$ , $I_D=8\text{A}$ , $V_{GS}=0$ 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       | $V_{GS}=0V, I_F=8A, T_j=25^\circ C$                      |
| Reverse recovery time         | $t_{rr}$  | -      | 282  | -    | ns      | $V_R=400V, I_F=8A, di_F/dt=100A/\mu s$ ;<br>see table 10 |
| Reverse recovery charge       | $Q_{rr}$  | -      | 3.4  | -    | $\mu C$ | $V_R=400V, I_F=8A, di_F/dt=100A/\mu s$ ;<br>see table 10 |
| Peak reverse recovery current | $I_{rrm}$ | -      | 24   | -    | A       | $V_R=400V, I_F=8A, di_F/dt=100A/\mu s$ ;<br>see table 10 |

## 5 Electrical characteristics diagrams

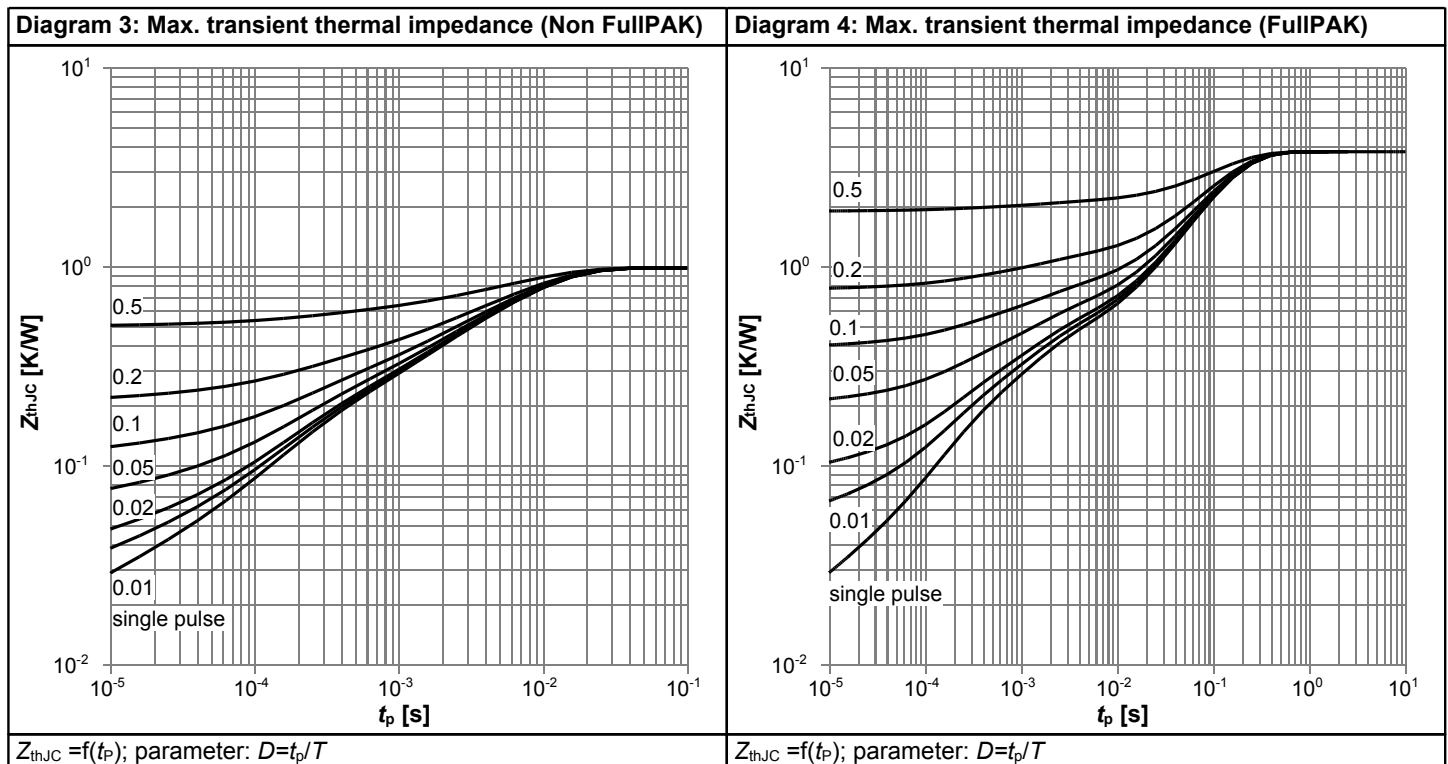
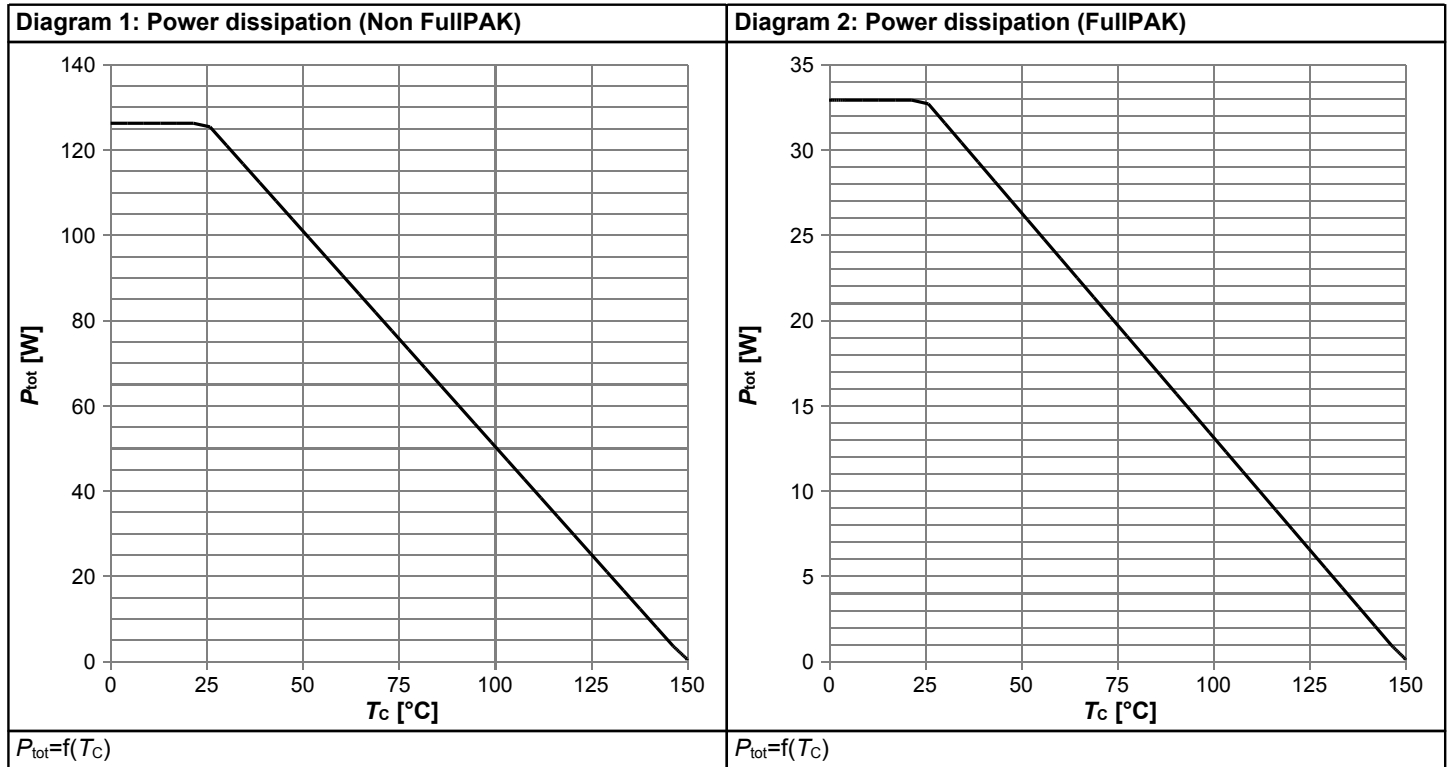
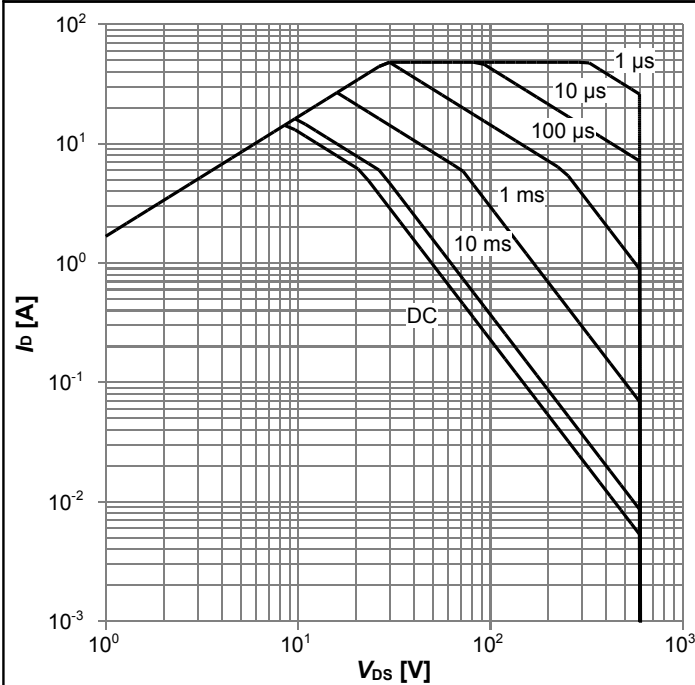


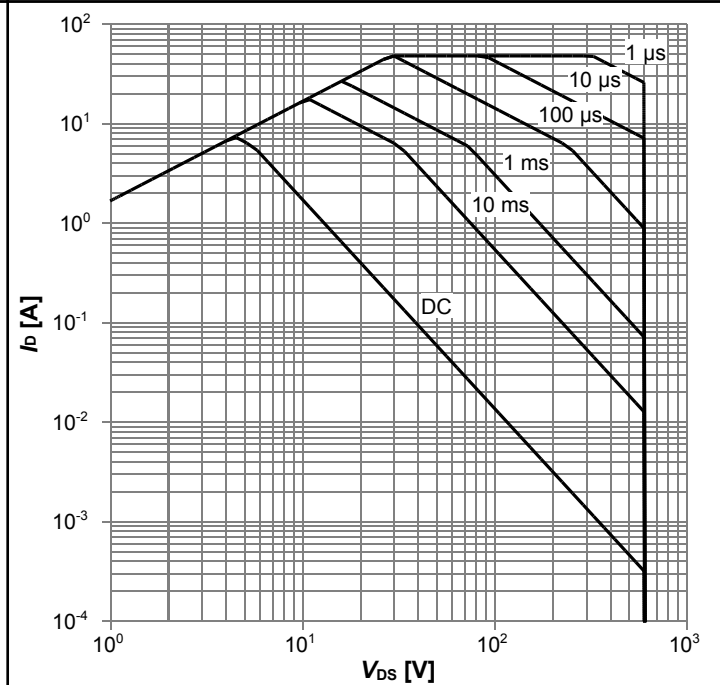


Diagram 5: Safe operating area (Non FullPAK)



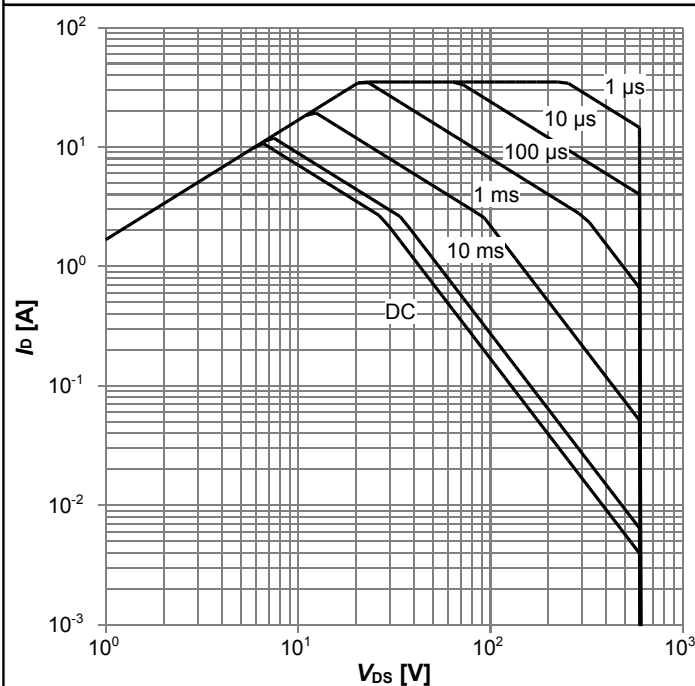
$I_D=f(V_{DS}); T_C=25\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 6: Safe operating area (FullPAK)



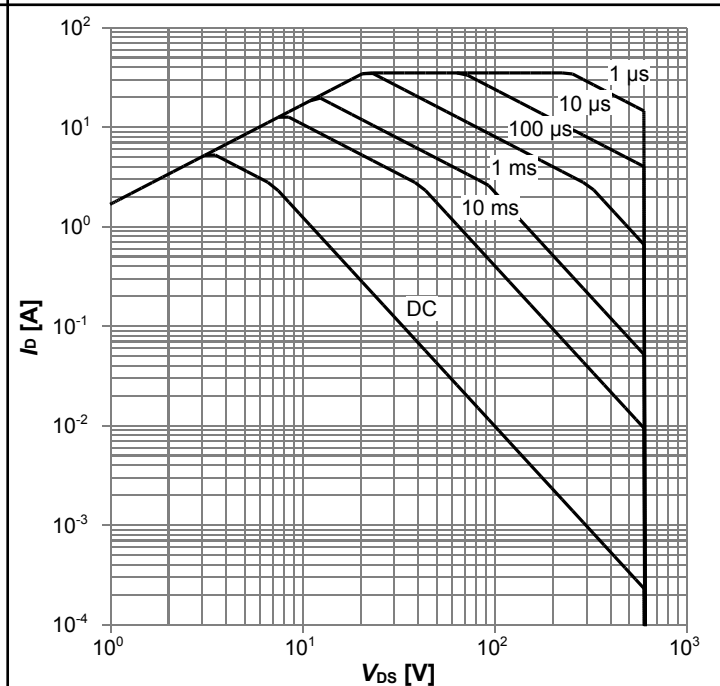
$I_D=f(V_{DS}); T_C=25\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 7: Safe operating area (Non FullPAK)



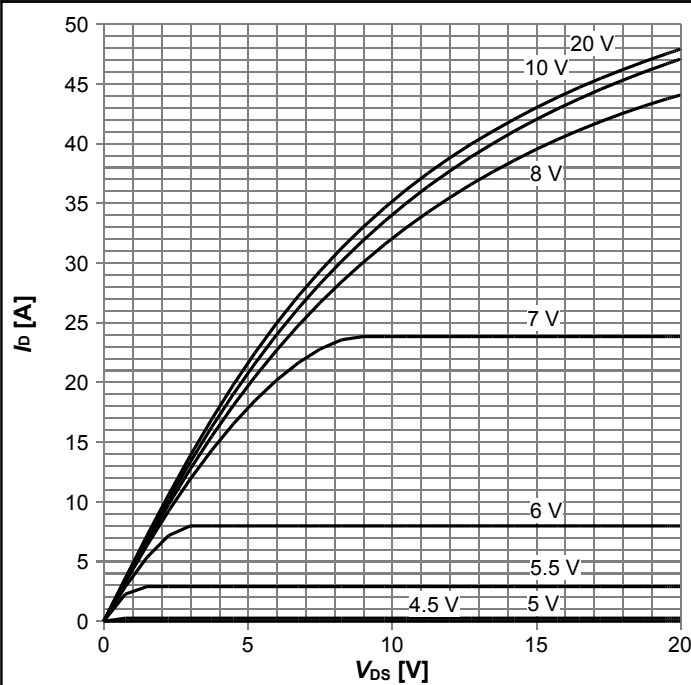
$I_D=f(V_{DS}); T_C=80\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 8: Safe operating area (FullPAK)



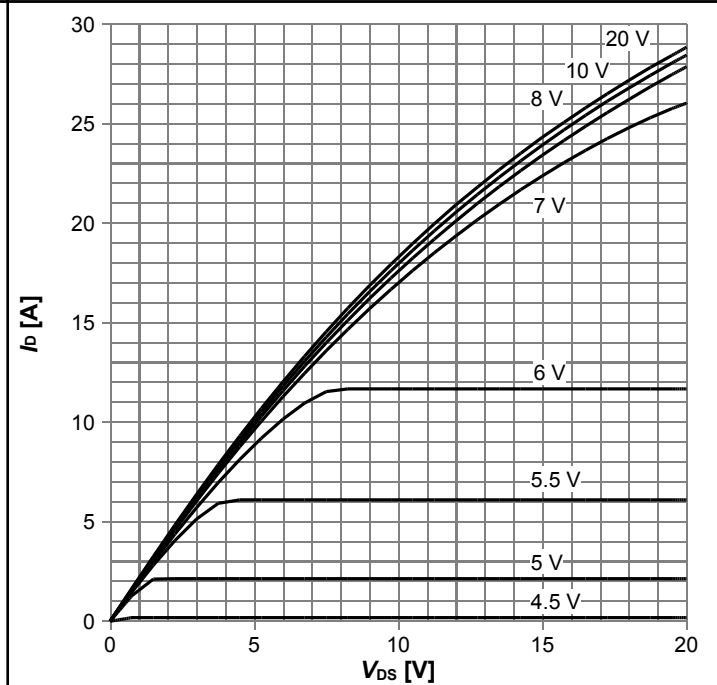
$I_D=f(V_{DS}); T_C=80\text{ °C}; D=0$ ; parameter:  $t_p$

Diagram 9: Typ. output characteristics



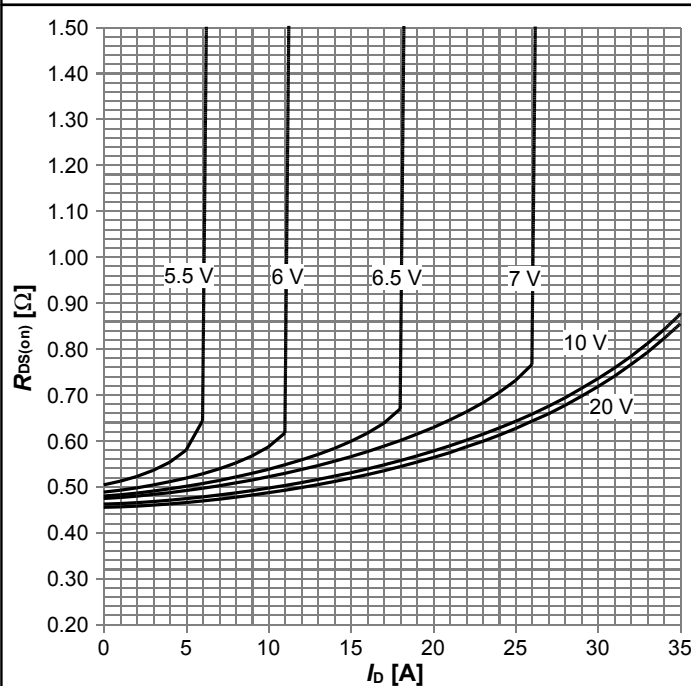
$I_D=f(V_{DS})$ ;  $T_j=25\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 10: Typ. output characteristics



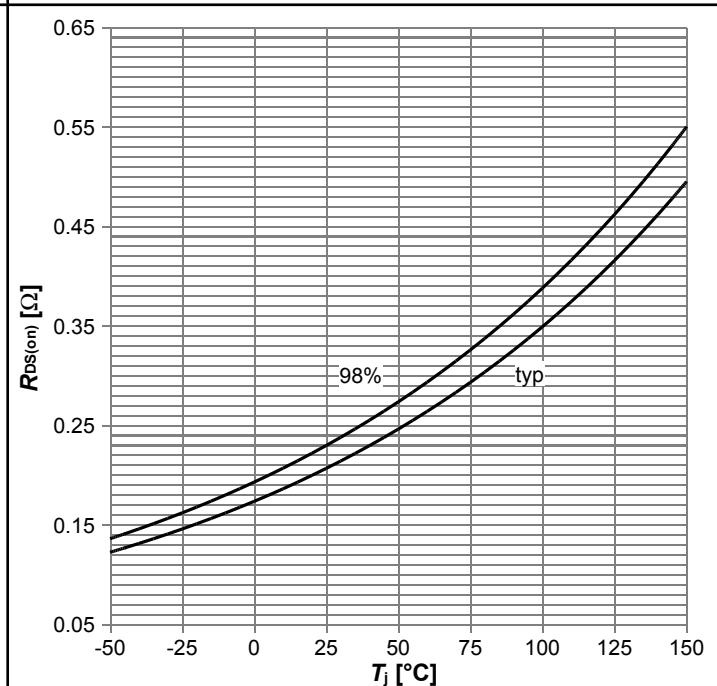
$I_D=f(V_{DS})$ ;  $T_j=125\text{ °C}$ ; parameter:  $V_{GS}$

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



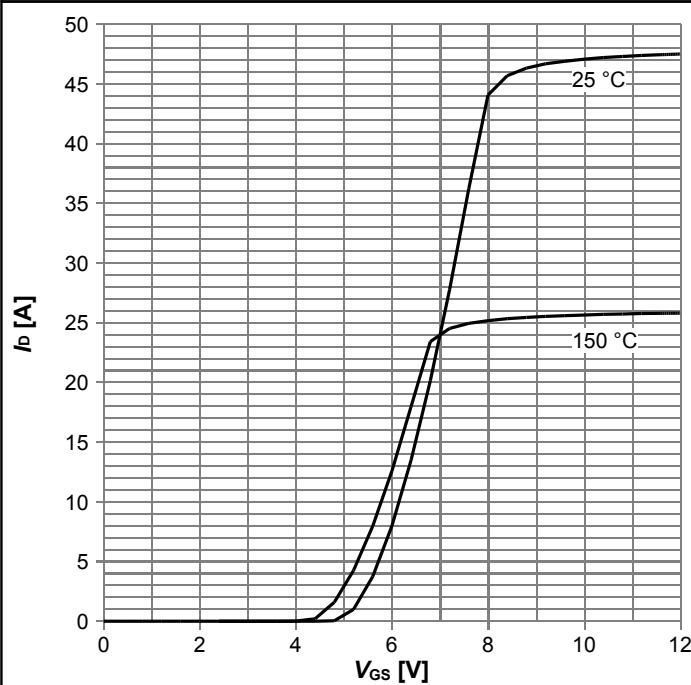
$R_{DS(on)}=f(I_D)$ ;  $T_j=125\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 12: Drain-source on-state resistance



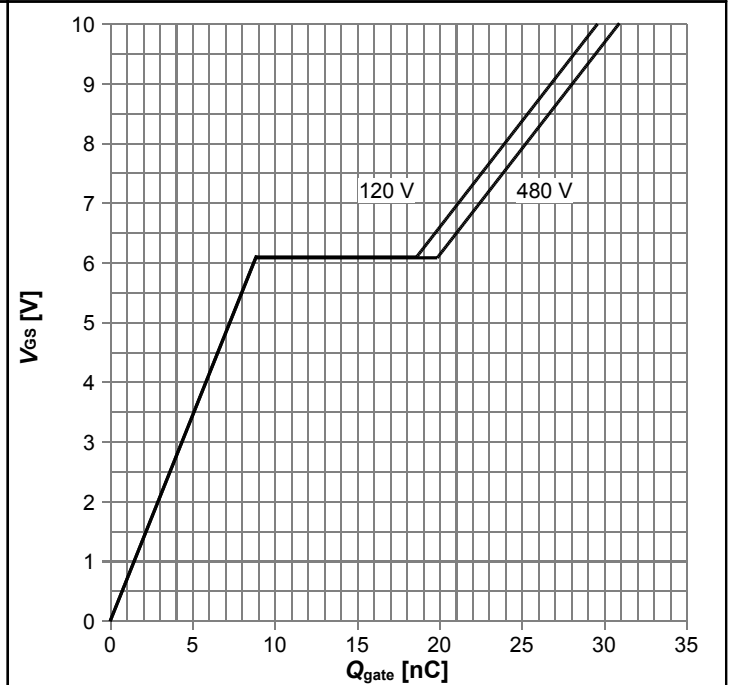
$R_{DS(on)}=f(T_j)$ ;  $I_D=6.4$  A;  $V_{GS}=10$  V

Diagram 13: Typ. transfer characteristics



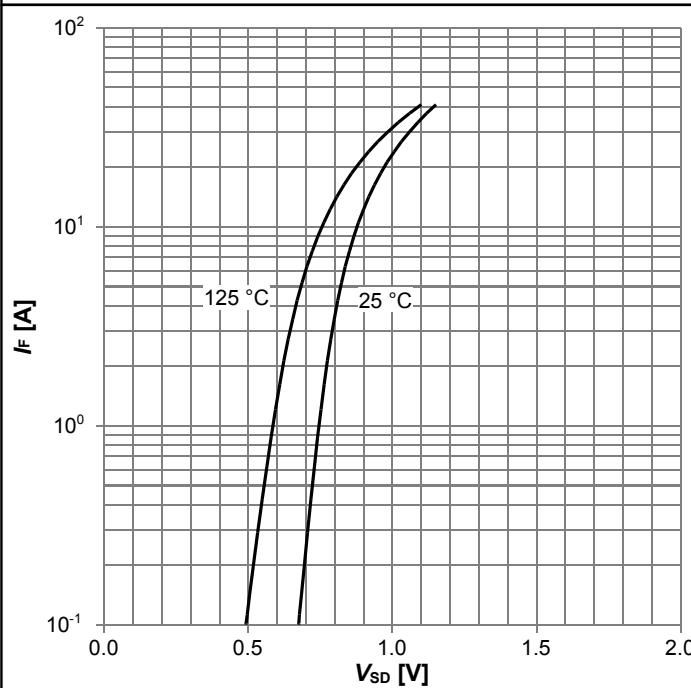
$I_D=f(V_{GS}); V_{DS}=20V; \text{parameter: } T_j$

Diagram 14: Typ. gate charge



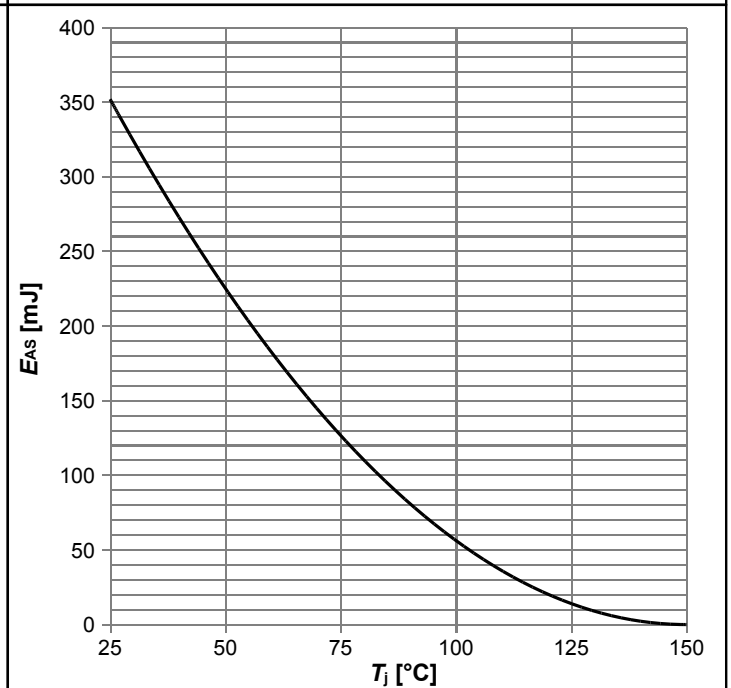
$V_{GS}=f(Q_{gate}); I_D=8.0 \text{ A pulsed}; \text{parameter: } V_{DD}$

Diagram 15: Forward characteristics of reverse diode



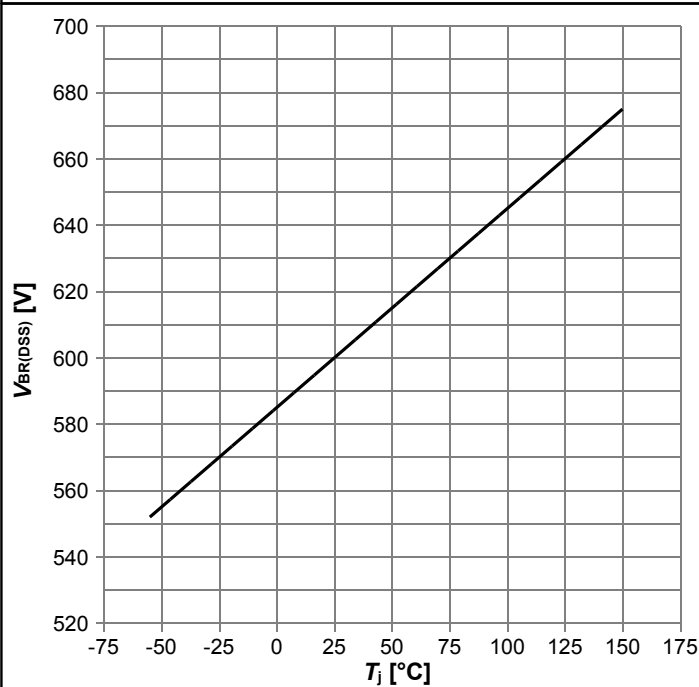
$I_F=f(V_{SD}); \text{parameter: } T_j$

Diagram 16: Avalanche energy



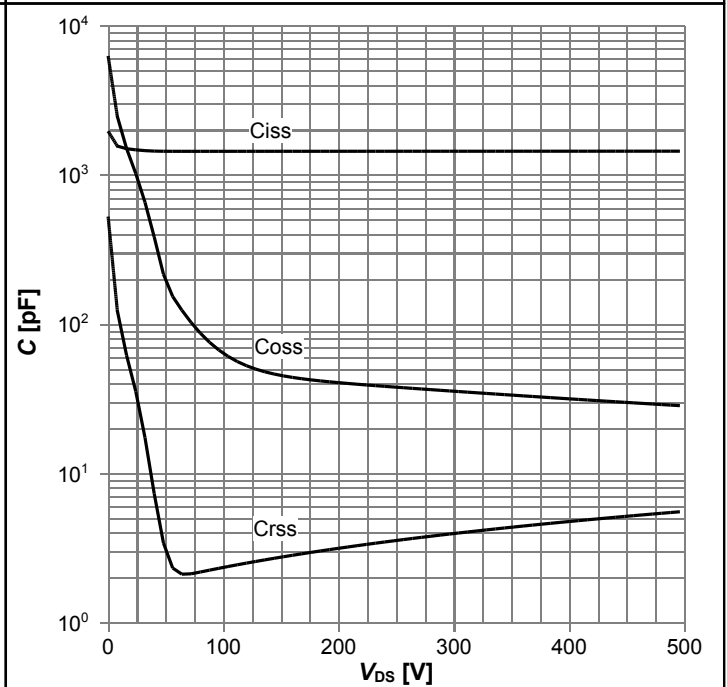
$E_{AS}=f(T_j); I_D=2.9 \text{ A}; V_{DD}=50 \text{ V}$

Diagram 17: Drain-source breakdown voltage



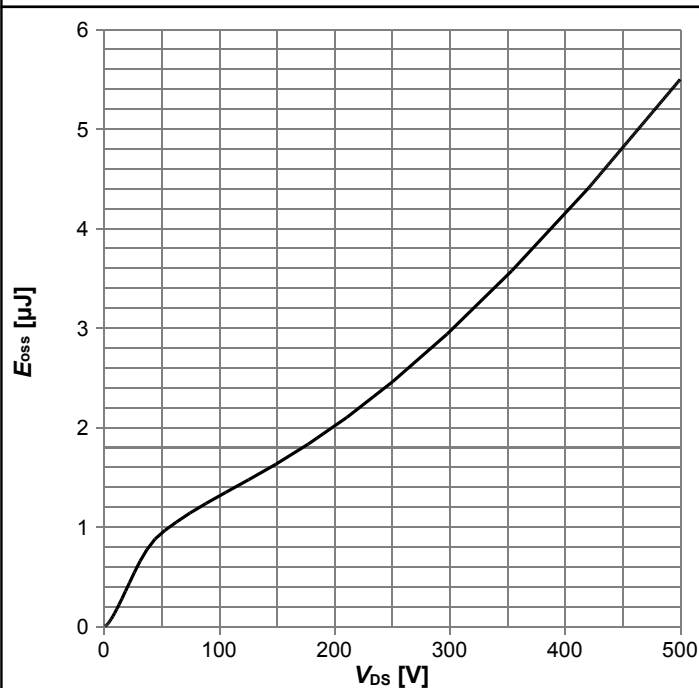
$V_{BR(DSS)}=f(T_j); I_D=1 \text{ mA}$

Diagram 18: Typ. capacitances



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

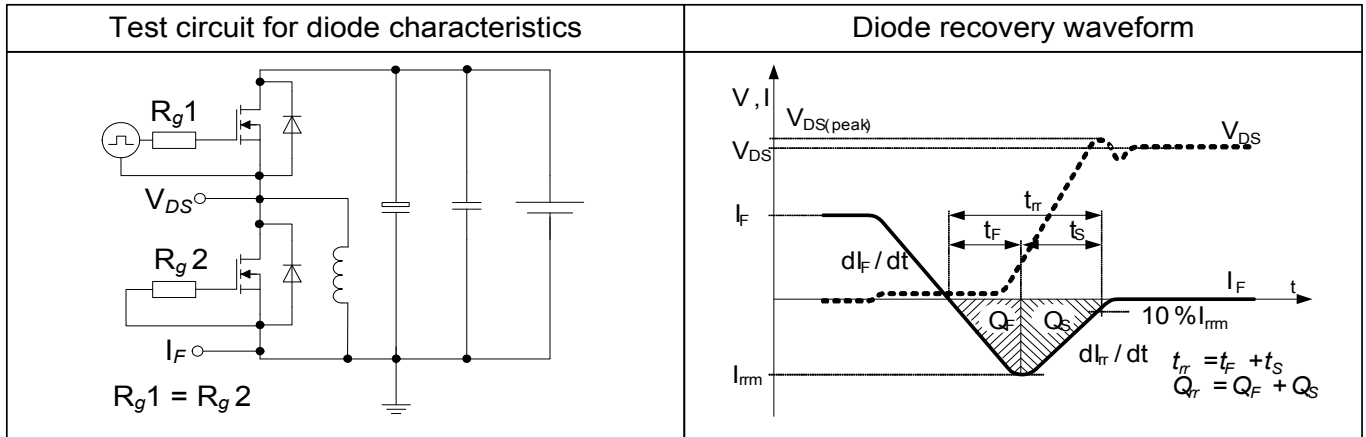
Diagram 19: Typ. Coss stored energy



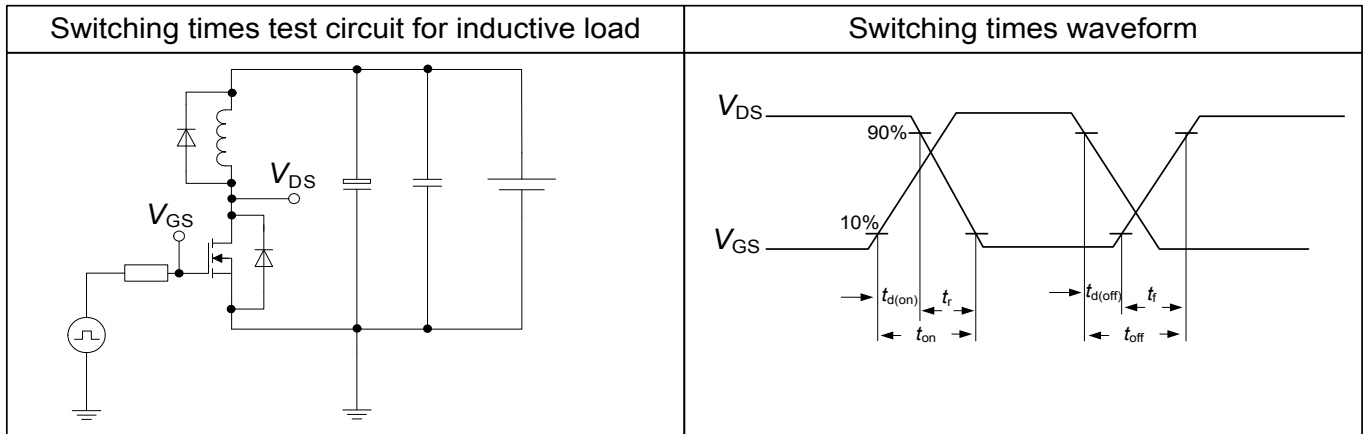
$E_{oss}=f(V_{DS})$

## 6 Test Circuits

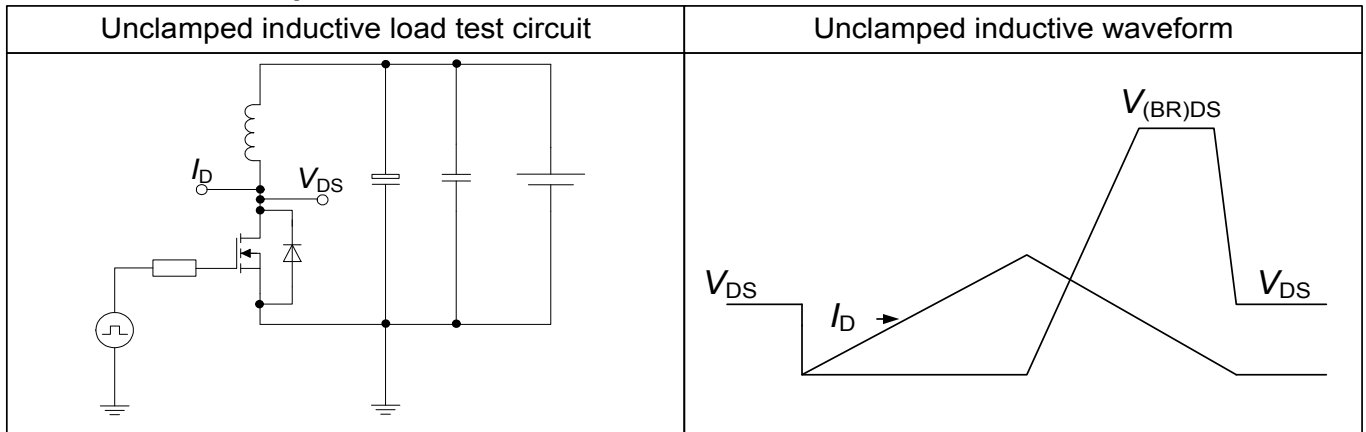
**Table 10 Diode characteristics**



**Table 11 Switching times**



**Table 12 Unclamped inductive load**



## 7 Package Outlines



Figure 1 Outline PG-TO 247, dimensions in mm/inches



Figure 2 Outline PG-TO 263, dimensions in mm/inches

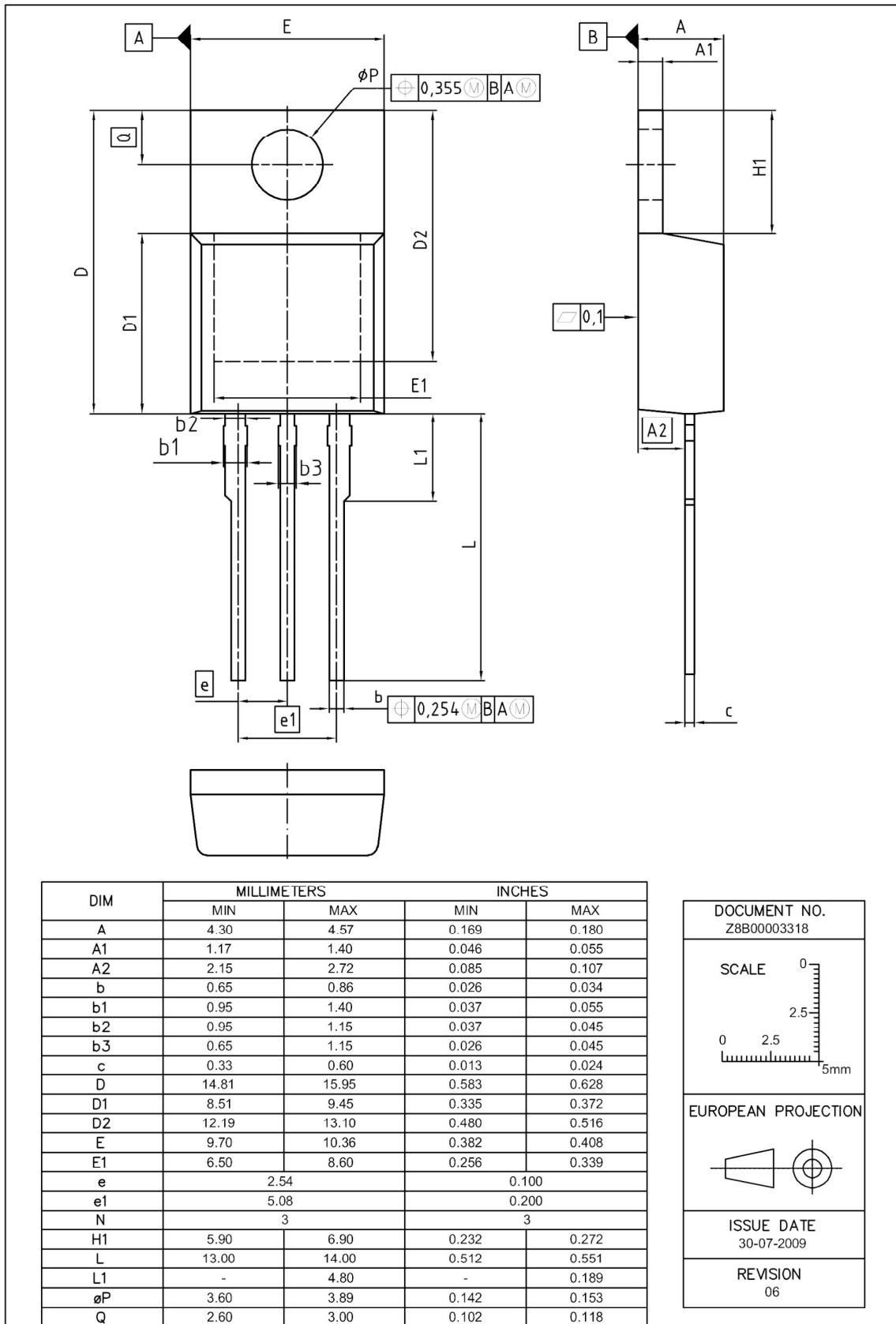
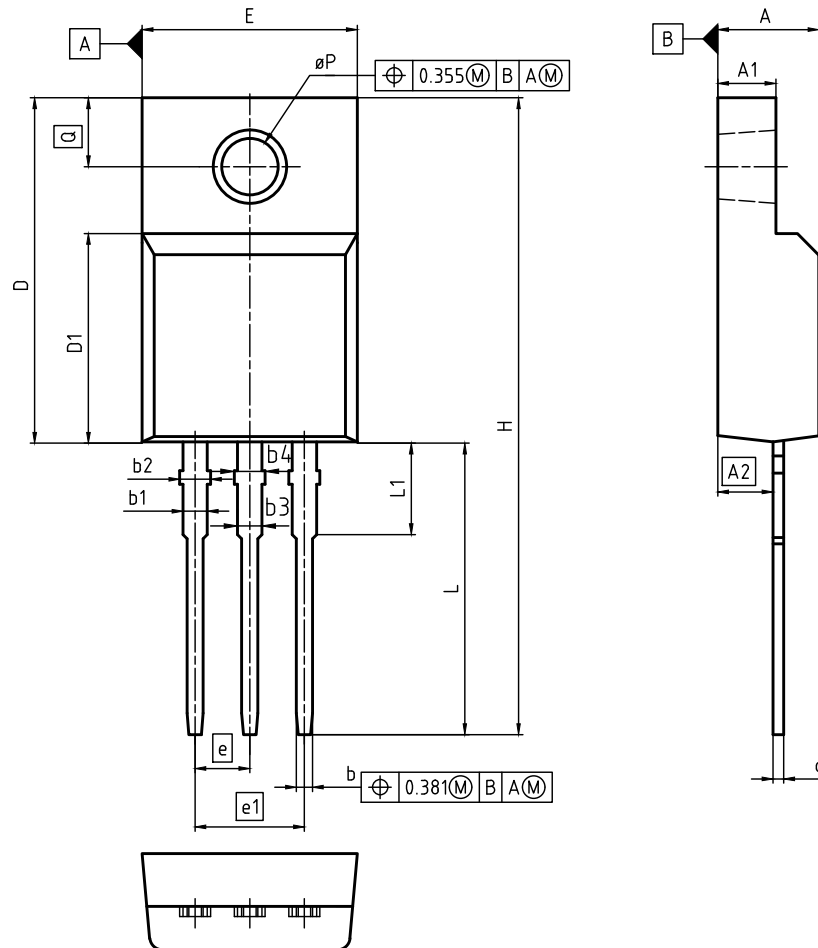


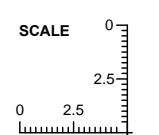
Figure 3 Outline PG-TO 220, dimensions in mm/inches

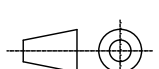




| DIM | MILLIMETERS |       | INCHES      |       |
|-----|-------------|-------|-------------|-------|
|     | MIN         | MAX   | MIN         | MAX   |
| A   | 4.50        | 4.90  | 0.177       | 0.193 |
| A1  | 2.34        | 2.85  | 0.092       | 0.112 |
| A2  | 2.42        | 2.86  | 0.095       | 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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SCALE 

EUROPEAN PROJECTION 

ISSUE DATE  
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04

Figure 4 Outline PG-TO 220 FullPAK, 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

IPW60R230P6, IPB60R230P6, IPP60R230P6, IPA60R230P6

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

Previous Revision

| 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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[erratum@infineon.com](mailto:erratum@infineon.com)

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