

# MOSFET

Metal Oxide Semiconductor Field Effect Transistor

## CoolMOS™ P6

600V CoolMOS™ P6 Power Transistor  
IPW60R041P6

## Data Sheet

Rev. 2.0  
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.

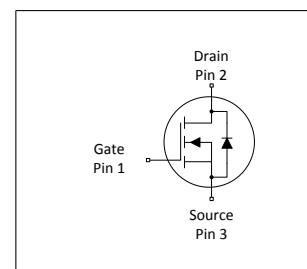
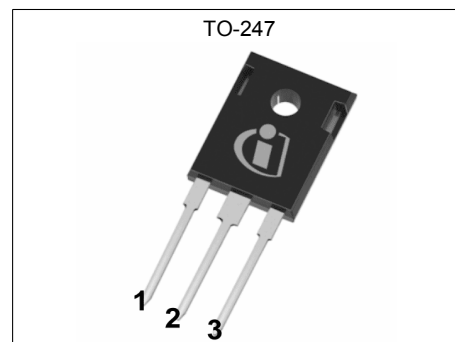
## Features

- 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    |
| $R_{DS(on),max}$     | 41    | mΩ   |
| $Q_{g,typ}$          | 170   | nC   |
| $I_{D,pulse}$        | 267   | A    |
| $E_{oss@400V}$       | 20.5  | μJ   |
| Body diode di/dt     | 300   | A/μs |

| Type / Ordering Code | Package   | Marking | Related Links  |
|----------------------|-----------|---------|----------------|
| IPW60R041P6          | PG-TO 247 | 6R041P6 | see Appendix A |

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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>    | $I_D$         | -      | -    | 77.5<br>49.0 | A                | $T_C=25^\circ\text{C}$<br>$T_C=100^\circ\text{C}$                                     |
| Pulsed drain current <sup>2)</sup>        | $I_{D,pulse}$ | -      | -    | 267          | A                | $T_C=25^\circ\text{C}$                                                                |
| Avalanche energy, single pulse            | $E_{AS}$      | -      | -    | 1954         | mJ               | $I_D=13.4\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 10                               |
| Avalanche energy, repetitive              | $E_{AR}$      | -      | -    | 2.96         | mJ               | $I_D=13.4\text{A}$ ; $V_{DD}=50\text{V}$ ; see table 10                               |
| Avalanche current, repetitive             | $I_{AR}$      | -      | -    | 13.4         | 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-247 | $P_{tot}$     | -      | -    | 481          | 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-247   | -             | -      | -    | 60           | Ncm              | M3 and M3.5 screws                                                                    |
| Continuous diode forward current          | $I_S$         | -      | -    | 67.2         | A                | $T_C=25^\circ\text{C}$                                                                |
| Diode pulse current <sup>2)</sup>         | $I_{S,pulse}$ | -      | -    | 267          | 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 8 |
| Maximum diode commutation speed           | di/dt         | -      | -    | 300          | A/ $\mu\text{s}$ | $V_{DS}=0\dots400\text{V}$ , $I_{SD}\leq I_S$ , $T_j=25^\circ\text{C}$<br>see table 8 |

<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-247**

| Parameter                                                  | Symbol     | Values |      |      | Unit | Note / Test Condition               |
|------------------------------------------------------------|------------|--------|------|------|------|-------------------------------------|
|                                                            |            | Min.   | Typ. | Max. |      |                                     |
| Thermal resistance, junction - case                        | $R_{thJC}$ | -      | -    | 0.26 | °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 |

## 4 Electrical characteristics

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

**Table 4 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             | $V_{DS}=V_{GS}$ , $I_D=2.96\text{mA}$                                                                                                   |
| Zero gate voltage drain current  | $I_{DSS}$     | -      | -              | 5          | $\mu\text{A}$ | $V_{DS}=600$ , $V_{GS}=0\text{V}$ , $T_j=25^\circ\text{C}$<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 | $R_{DS(on)}$  | -      | 0.037<br>0.096 | 0.041<br>- | $\Omega$      | $V_{GS}=10\text{V}$ , $I_D=35.5\text{A}$ , $T_j=25^\circ\text{C}$<br>$V_{GS}=10\text{V}$ , $I_D=35.5\text{A}$ , $T_j=150^\circ\text{C}$ |
| Gate resistance                  | $R_G$         | -      | 1              | -          | $\Omega$      | $f=1\text{MHz}$ , open drain                                                                                                            |

**Table 5 Dynamic characteristics**

| Parameter                                                  | Symbol       | Values |      |      | Unit | Note / Test Condition                                                                           |
|------------------------------------------------------------|--------------|--------|------|------|------|-------------------------------------------------------------------------------------------------|
|                                                            |              | Min.   | Typ. | Max. |      |                                                                                                 |
| Input capacitance                                          | $C_{iss}$    | -      | 8180 | -    | pF   | $V_{GS}=0\text{V}$ , $V_{DS}=100\text{V}$ , $f=1\text{MHz}$                                     |
| Output capacitance                                         | $C_{oss}$    | -      | 310  | -    | pF   | $V_{GS}=0\text{V}$ , $V_{DS}=100\text{V}$ , $f=1\text{MHz}$                                     |
| Effective output capacitance, energy related <sup>1)</sup> | $C_{o(er)}$  | -      | 260  | -    | pF   | $V_{GS}=0\text{V}$ , $V_{DS}=0\dots400\text{V}$                                                 |
| Effective output capacitance, time related <sup>2)</sup>   | $C_{o(tr)}$  | -      | 1200 | -    | pF   | $I_D=\text{constant}$ , $V_{GS}=0\text{V}$ , $V_{DS}=0\dots400\text{V}$                         |
| Turn-on delay time                                         | $t_{d(on)}$  | -      | 29   | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=44.4\text{A}$ , $R_G=1.7\Omega$ ; see table 9 |
| Rise time                                                  | $t_r$        | -      | 27   | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=44.4\text{A}$ , $R_G=1.7\Omega$ ; see table 9 |
| Turn-off delay time                                        | $t_{d(off)}$ | -      | 90   | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=44.4\text{A}$ , $R_G=1.7\Omega$ ; see table 9 |
| Fall time                                                  | $t_f$        | -      | 5    | -    | ns   | $V_{DD}=400\text{V}$ , $V_{GS}=13\text{V}$ , $I_D=44.4\text{A}$ , $R_G=1.7\Omega$ ; see table 9 |

**Table 6 Gate charge characteristics**

| Parameter             | Symbol        | Values |      |      | Unit | Note / Test Condition                                                  |
|-----------------------|---------------|--------|------|------|------|------------------------------------------------------------------------|
|                       |               | Min.   | Typ. | Max. |      |                                                                        |
| Gate to source charge | $Q_{gs}$      | -      | 50   | -    | nC   | $V_{DD}=400\text{V}$ , $I_D=44.4\text{A}$ , $V_{GS}=0$ to $10\text{V}$ |
| Gate to drain charge  | $Q_{gd}$      | -      | 59   | -    | nC   | $V_{DD}=400\text{V}$ , $I_D=44.4\text{A}$ , $V_{GS}=0$ to $10\text{V}$ |
| Gate charge total     | $Q_g$         | -      | 170  | -    | nC   | $V_{DD}=400\text{V}$ , $I_D=44.4\text{A}$ , $V_{GS}=0$ to $10\text{V}$ |
| Gate plateau voltage  | $V_{plateau}$ | -      | 6.1  | -    | V    | $V_{DD}=400\text{V}$ , $I_D=44.4\text{A}$ , $V_{GS}=0$ 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 7 Reverse diode characteristics**

| Parameter                     | Symbol    | Values |      |      | Unit    | Note / Test Condition                                         |
|-------------------------------|-----------|--------|------|------|---------|---------------------------------------------------------------|
|                               |           | Min.   | Typ. | Max. |         |                                                               |
| Diode forward voltage         | $V_{SD}$  | -      | 0.9  | -    | V       | $V_{GS}=0V$ , $I_F=44.4A$ , $T_J=25^{\circ}C$                 |
| Reverse recovery time         | $t_{rr}$  | -      | 630  | -    | ns      | $V_R=400V$ , $I_F=44.4A$ , $di_F/dt=100A/\mu s$ ; see table 8 |
| Reverse recovery charge       | $Q_{rr}$  | -      | 19   | -    | $\mu C$ | $V_R=400V$ , $I_F=44.4A$ , $di_F/dt=100A/\mu s$ ; see table 8 |
| Peak reverse recovery current | $I_{rrm}$ | -      | 56   | -    | A       | $V_R=400V$ , $I_F=44.4A$ , $di_F/dt=100A/\mu s$ ; see table 8 |

## 5 Electrical characteristics diagrams

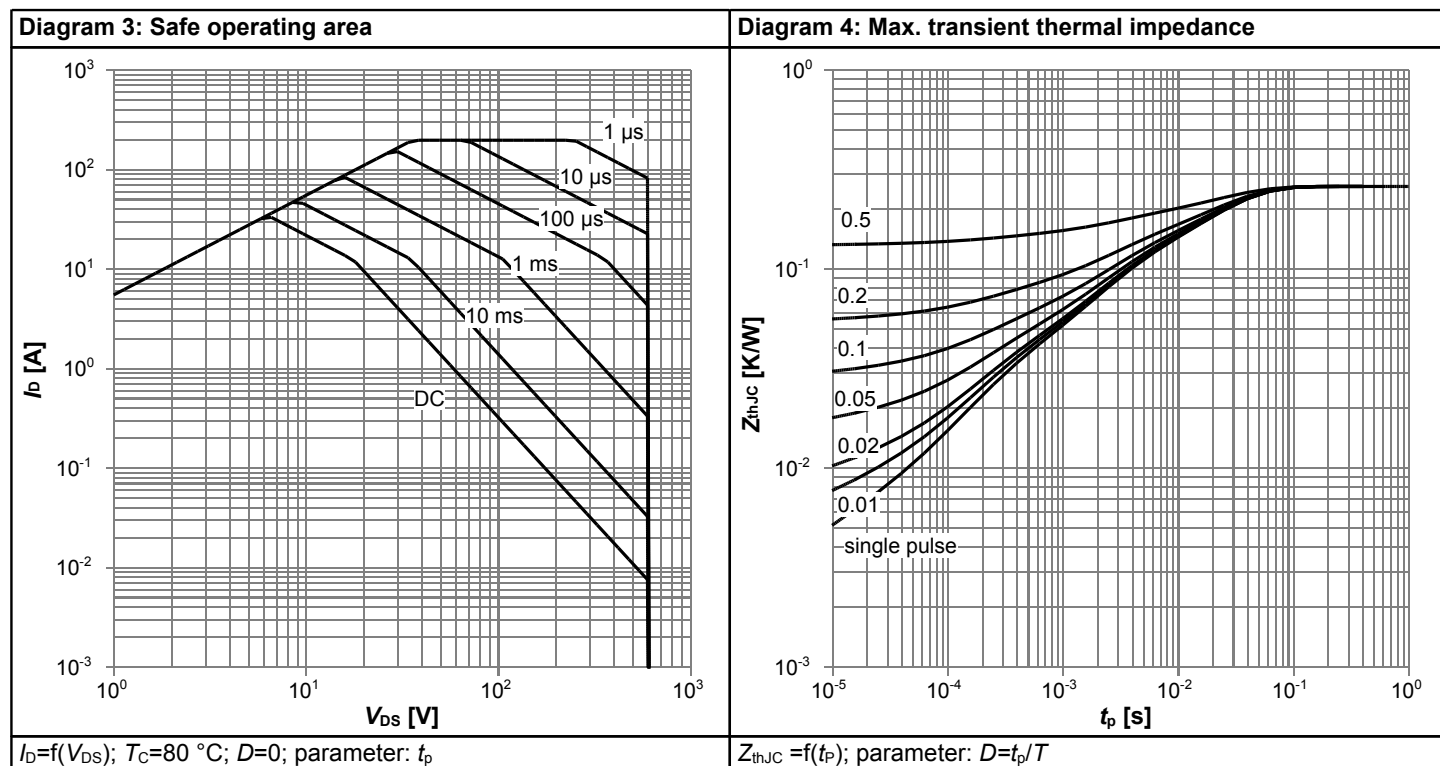
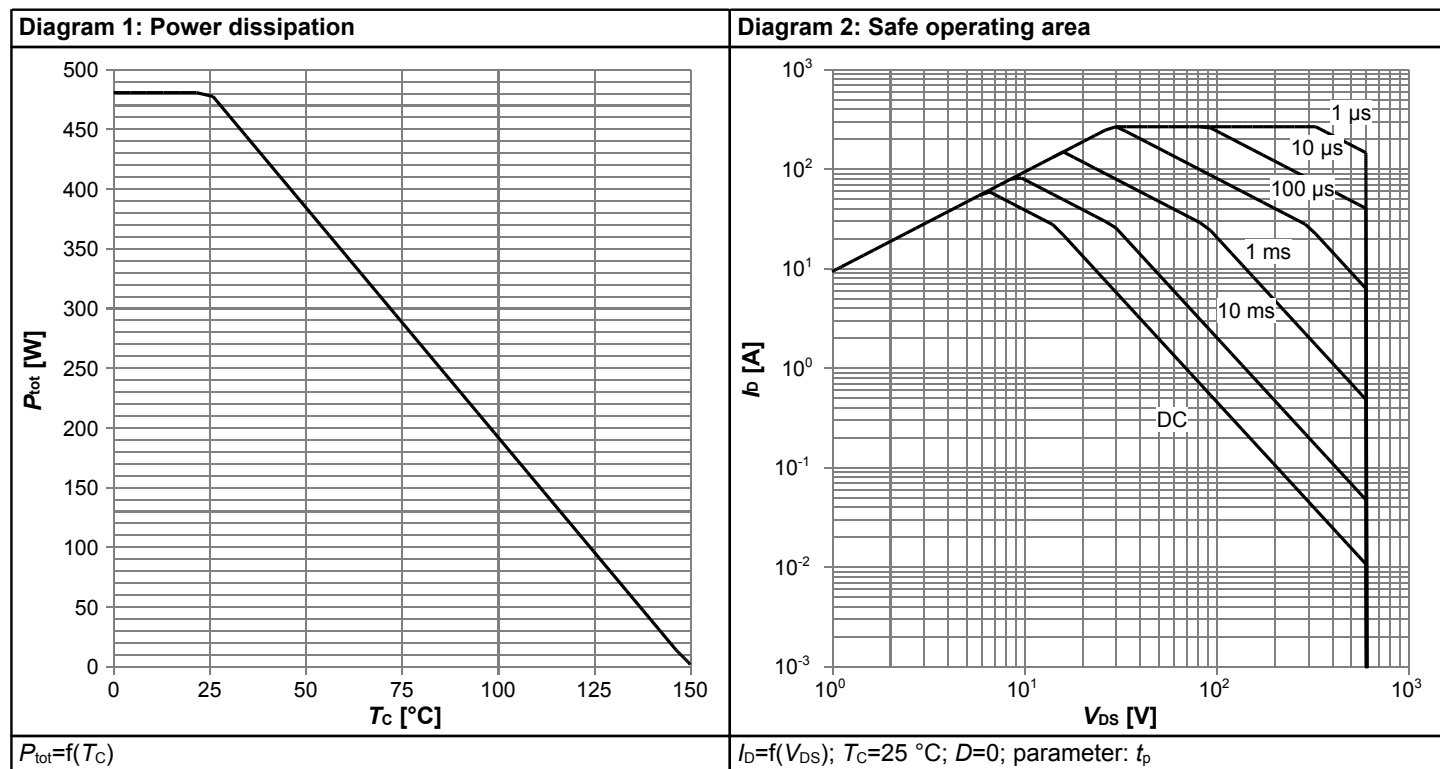




Diagram 5: Typ. output characteristics

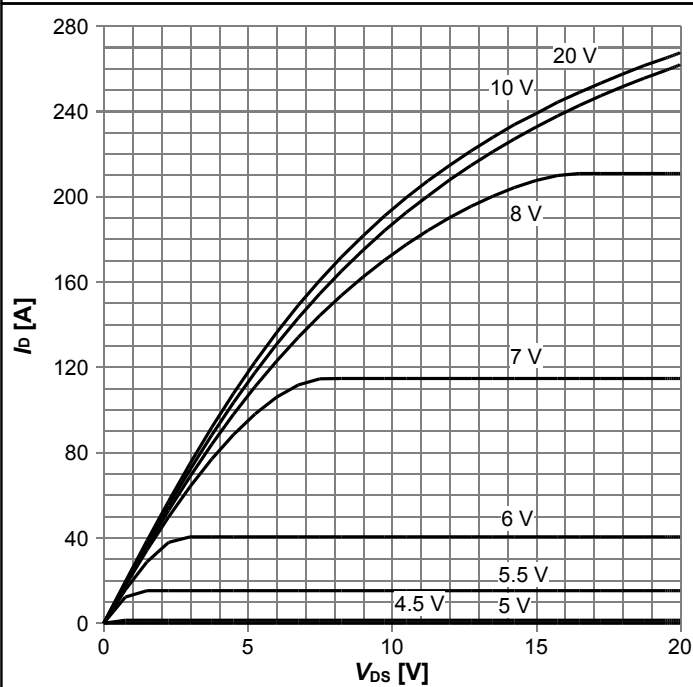

 $I_D = f(V_{DS}); T_J = 25^\circ\text{C}; \text{parameter: } V_{GS}$ 

Diagram 6: Typ. output characteristics

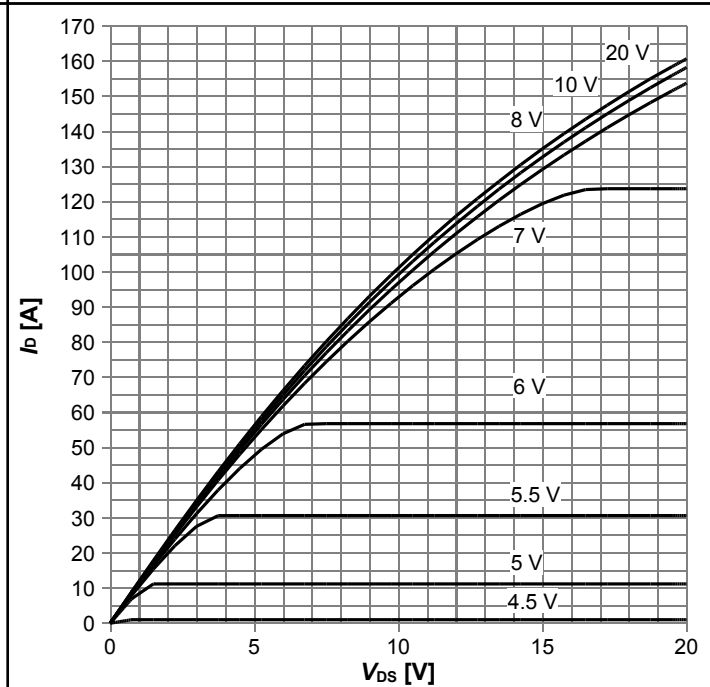

 $I_D = f(V_{DS}); T_J = 125^\circ\text{C}; \text{parameter: } V_{GS}$ 

Diagram 7: Typ. drain-source on-state resistance

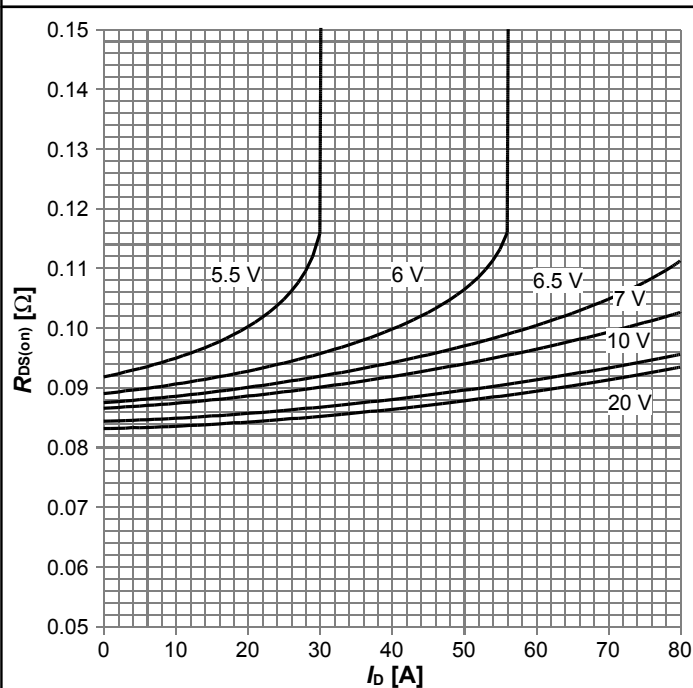

 $R_{DS(on)} = f(I_D); T_J = 125^\circ\text{C}; \text{parameter: } V_{GS}$ 

Diagram 8: Drain-source on-state resistance

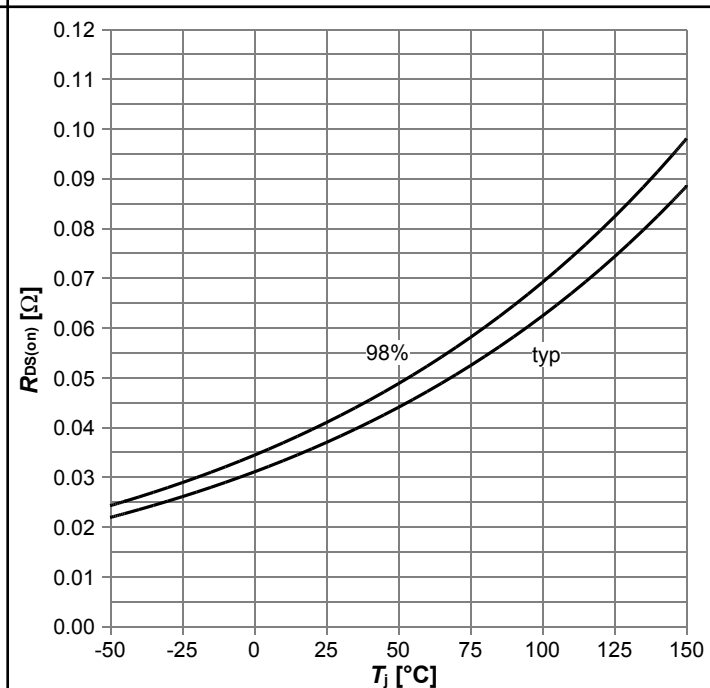

 $R_{DS(on)} = f(T_J); I_D = 35.5\text{ A}; V_{GS} = 10\text{ V}$

Diagram 9: Typ. transfer characteristics

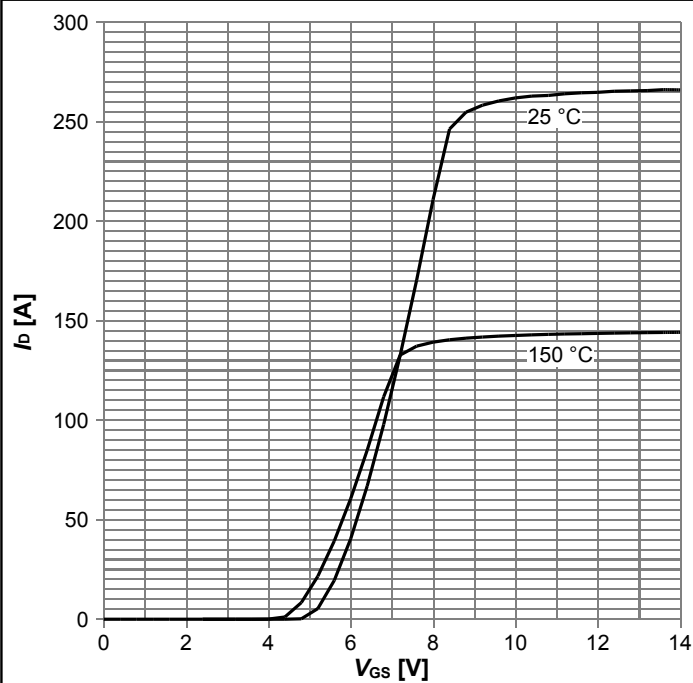

 $I_D = f(V_{GS})$ ;  $V_{DS} = 20V$ ; parameter:  $T_j$ 

Diagram 10: Typ. gate charge

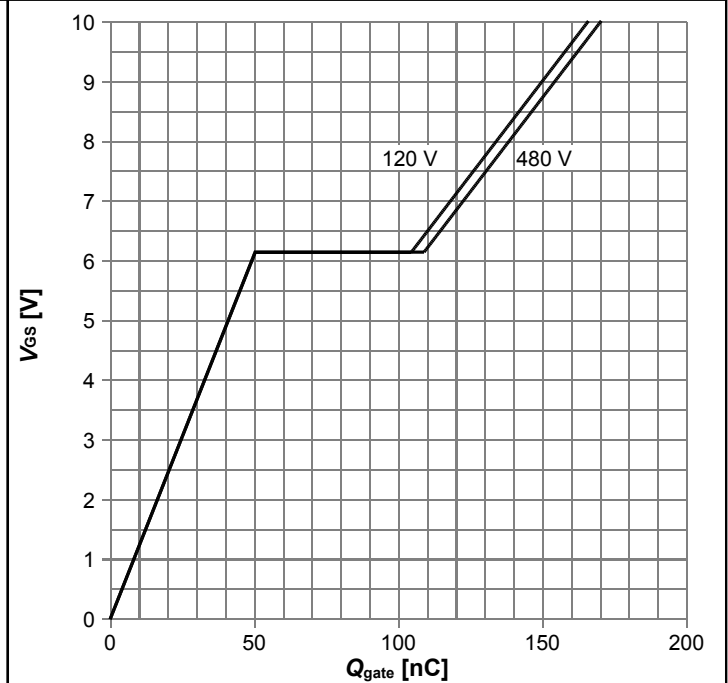

 $V_{GS} = f(Q_{gate})$ ;  $I_D = 44.4\text{ A}$  pulsed; parameter:  $V_{DD}$ 

Diagram 11: Forward characteristics of reverse diode

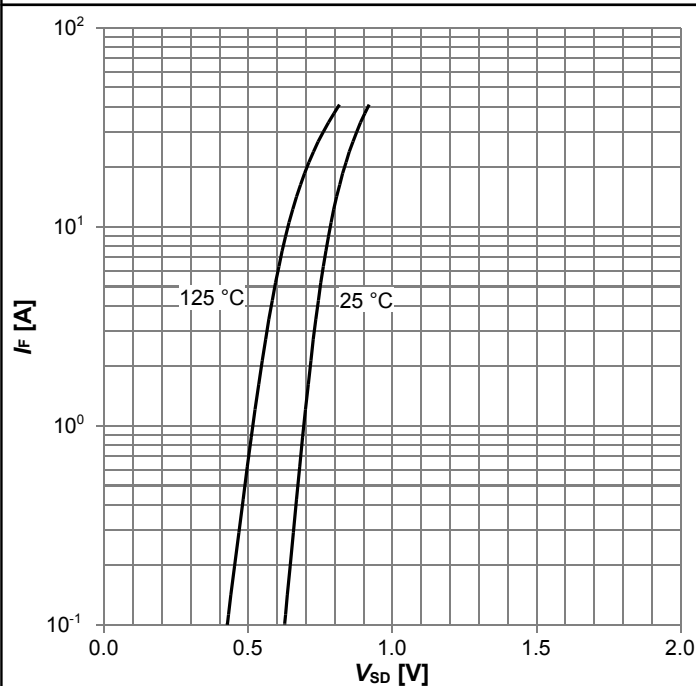

 $I_F = f(V_{SD})$ ; parameter:  $T_j$ 

Diagram 12: Avalanche energy

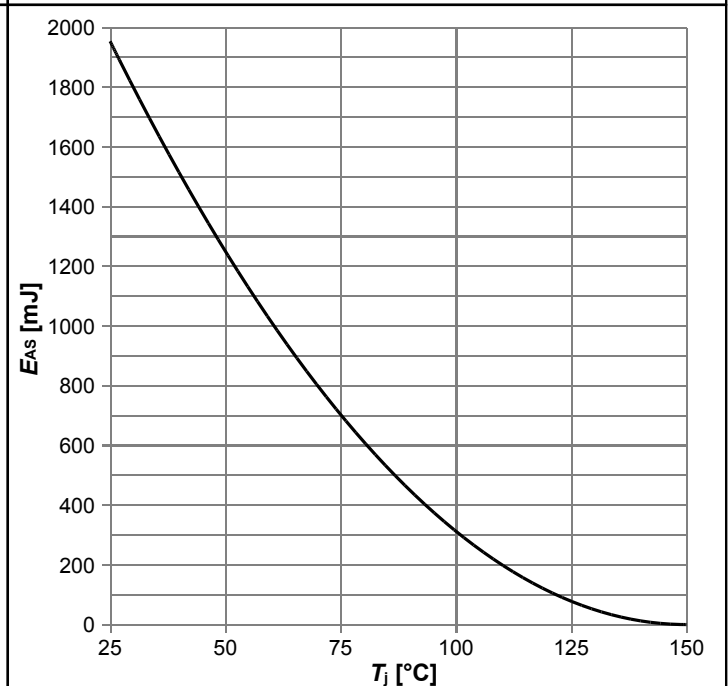
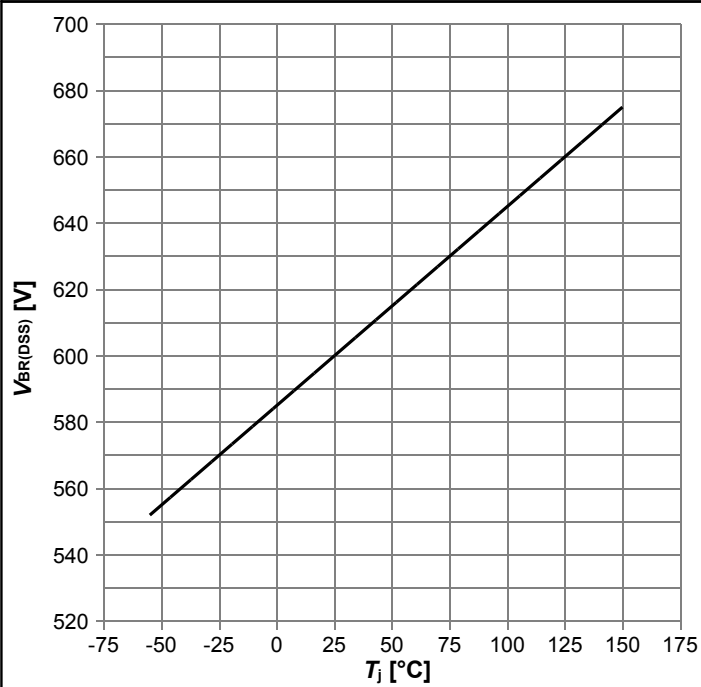
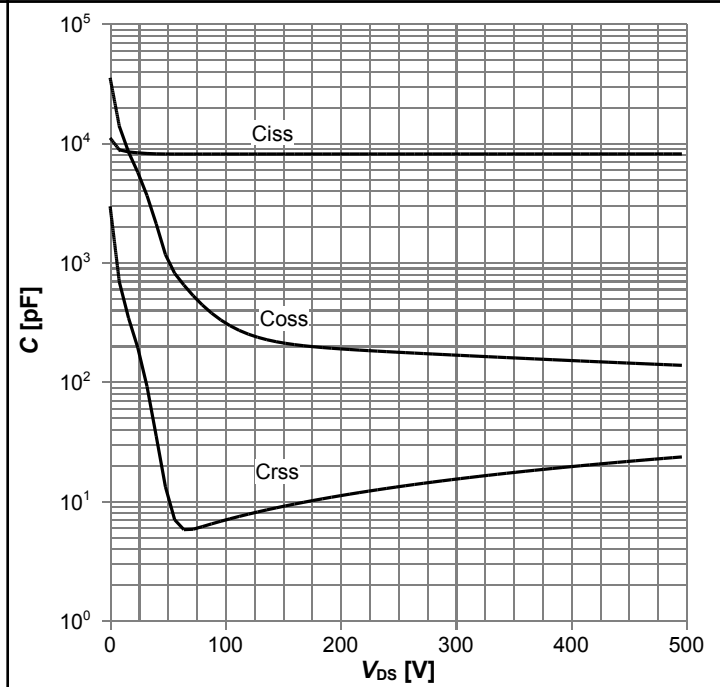

 $E_{AS} = f(T_j)$ ;  $I_D = 13.4\text{ A}$ ;  $V_{DD} = 50\text{ V}$

Diagram 13: Drain-source breakdown voltage



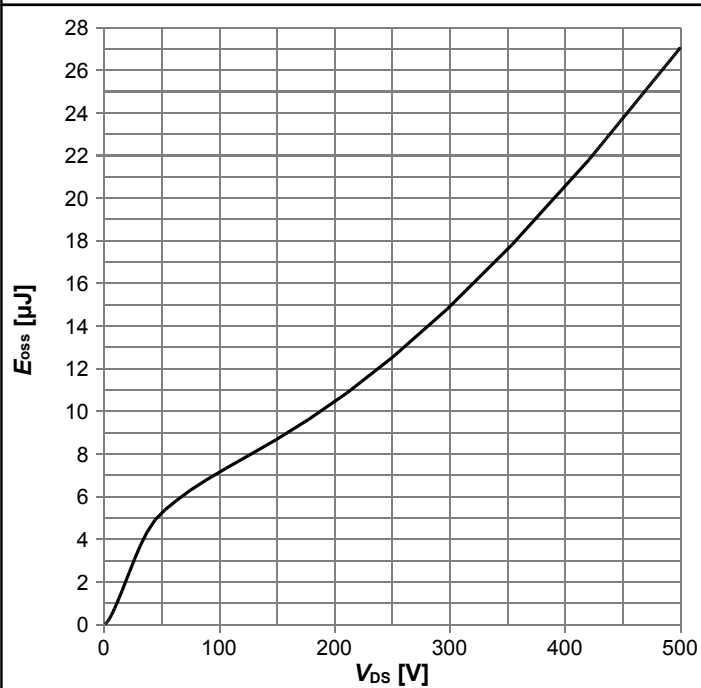
$$V_{BR(DSS)} = f(T_j); I_D = 1 \text{ mA}$$

Diagram 14: Typ. capacitances



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

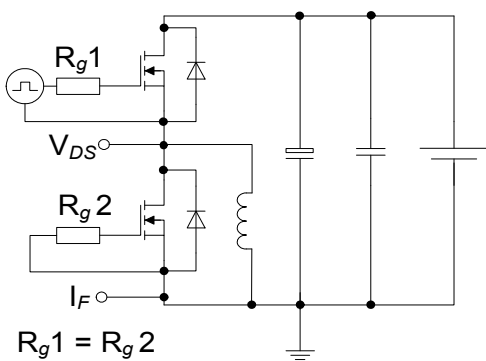
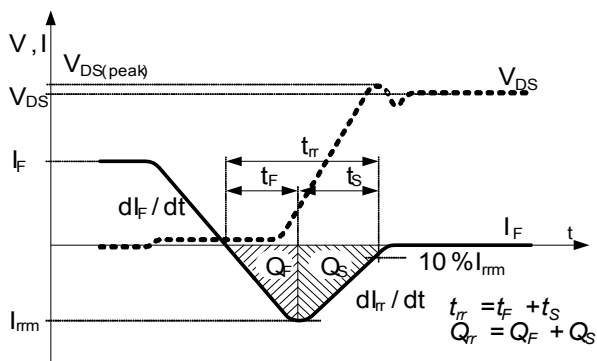
Diagram 15: Typ. Coss stored energy



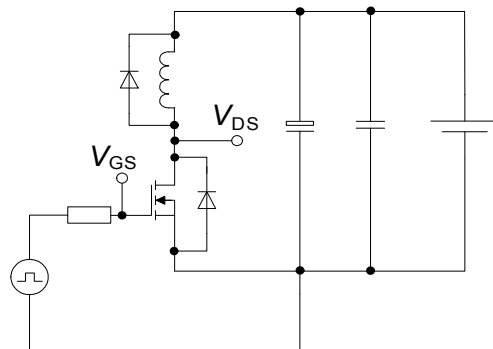
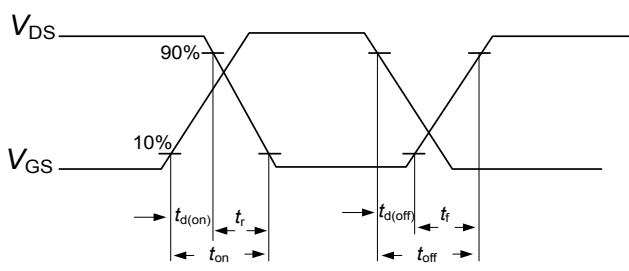
$$E_{oss} = f(V_{DS})$$

## 6 Test Circuits

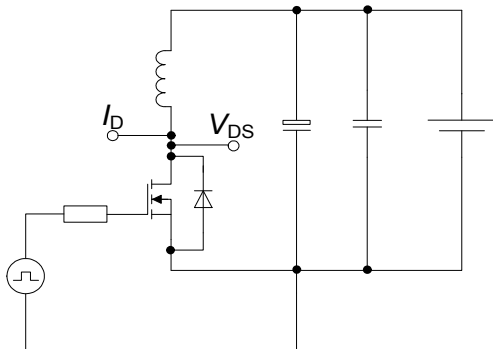
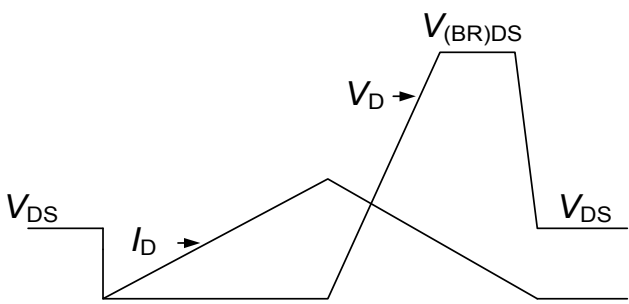
**Table 8 Diode characteristics**

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

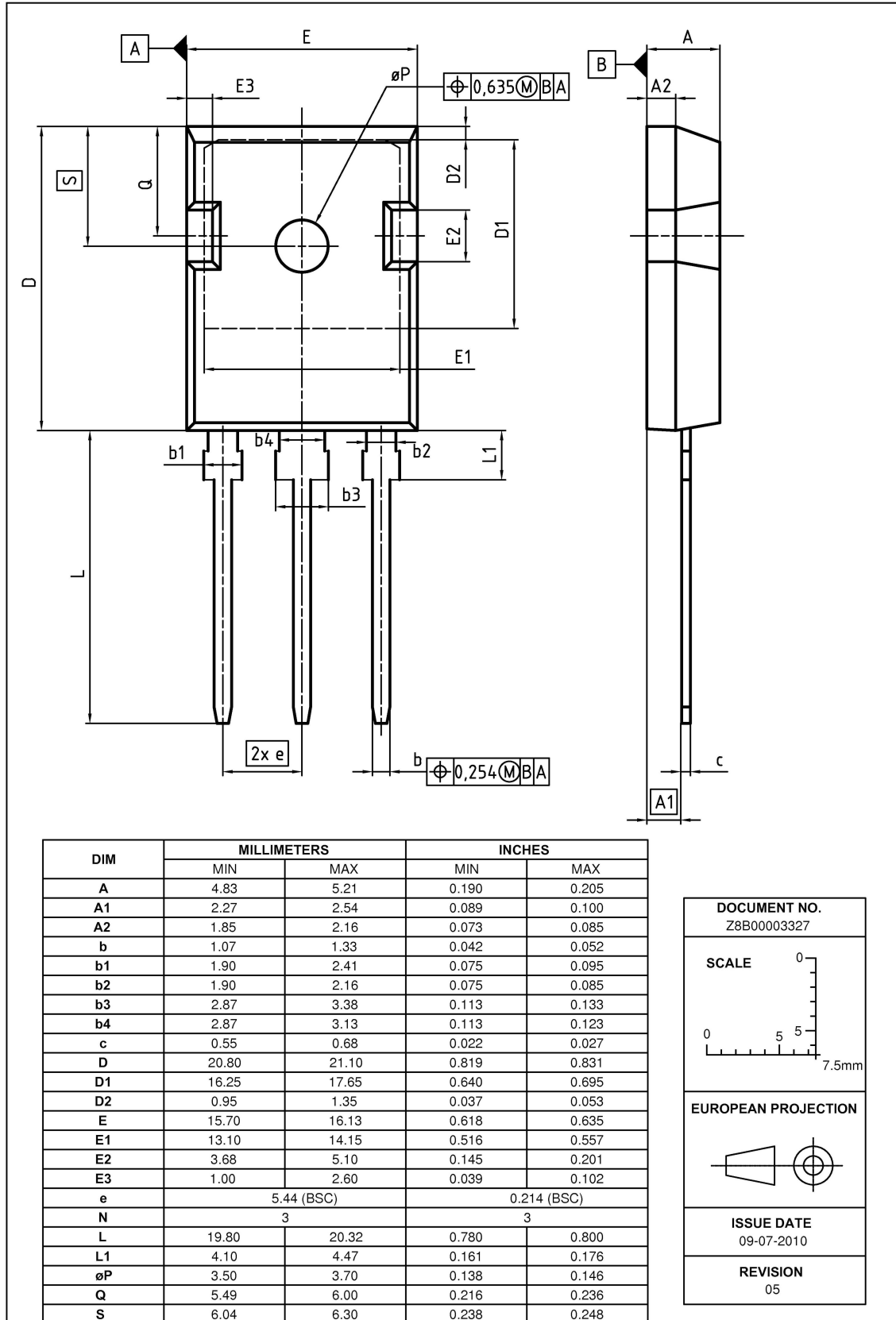
**Table 9 Switching times**

| Switching times test circuit for inductive load                                     | Switching times waveform                                                             |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |

**Table 10 Unclamped inductive load**

| Unclamped inductive load test circuit                                               | Unclamped inductive waveform                                                         |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |

## 7 Package Outlines



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

## 8 Appendix A

### Table 11 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

IPW60R041P6

**Revision: 2014-03-07, Rev. 2.0**

Previous Revision

| Revision | Date       | Subjects (major changes since last revision) |
|----------|------------|----------------------------------------------|
| 2.0      | 2014-03-07 | Release of final version                     |

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