

# MOSFET

## CoolSiC™ MOSFET 650 V G2

Built on Infineon's robust 2<sup>nd</sup> generation Silicon Carbide trench technology, the 650 V CoolSiC™ MOSFET delivers unparalleled performance, superior reliability, and great ease of use. It enables cost effective, highly efficient, and simplified designs to fulfill the ever-growing system and market needs.

### Features

- Ultra-low switching losses
- Benchmark gate threshold voltage,  $V_{GS(th)} = 4.5\text{ V}$
- Robust against parasitic turn-on even with 0 V turn-off gate voltage
- Flexible driving voltage and compatible with bipolar driving scheme
- Robust body diode operation under hard commutation events
- .XT interconnection technology for best-in-class thermal performance

### Benefits

- Enables high efficiency and high power density designs
- Facilitates great ease of use and integration
- Provides the best price performance ratio compared to Industry's most ambitious roadmaps
- Reduces the size, weight and bill of materials of the systems
- Enhances system robustness and reliability

### Potential applications

- SMPS
- Solar PV inverters
- Energy storage and battery formation
- UPS
- EV charging infrastructure
- Motor drives

### Product validation

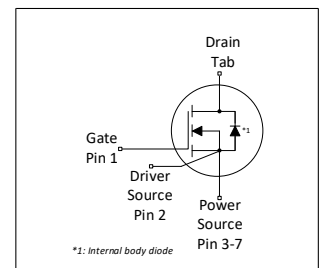
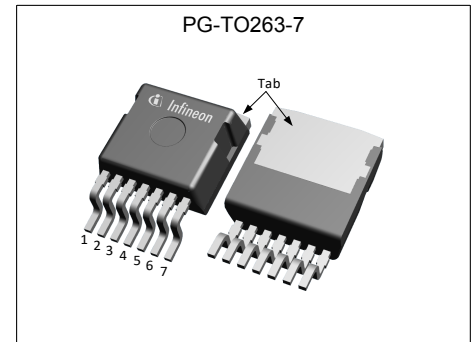
Fully qualified according to JEDEC for Industrial Applications

*Please note: The source and driver source pins are not exchangeable. Their exchange might lead to malfunction.*

**Table 1 Key Performance Parameters**

| Parameter                         | Value | Unit       |
|-----------------------------------|-------|------------|
| $V_{DSS}$ over full $T_{j,range}$ | 650   | V          |
| $R_{DS(on),typ}$                  | 14.5  | m $\Omega$ |
| $R_{DS(on),max}$                  | 18    | m $\Omega$ |
| $Q_{G,typ}$                       | 79    | nC         |
| $I_{D,pulse}$                     | 398   | A          |
| $Q_{oss}$ @ 400 V                 | 148   | nC         |
| $E_{oss}$ @ 400 V                 | 20.1  | $\mu$ J    |

| Type / Ordering Code | Package    | Marking  | Related Links  |
|----------------------|------------|----------|----------------|
| IMBG65R015M2H        | PG-TO263-7 | 65R015M2 | see Appendix A |



RoHS

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## 1 Maximum ratings

at  $T_j = 25\text{ °C}$ , unless otherwise specified.

Note: for optimum lifetime and reliability, Infineon recommends operating conditions that do not exceed 80% of the maximum ratings stated in this datasheet.

**Table 2 Maximum ratings**

| Parameter                                      | Symbol           | Values |      |            | Unit | Note / Test Condition   |
|--|------------------|--------|------|------------|------|---|
|  |                  | Min.   | Typ. | Max.       |      |   |
| Continuous DC drain current <sup>1)</sup>      | $I_{\text{DDC}}$ | -      | -    | 115<br>84  | A    | $T_C = 25\text{ °C}$<br>$T_C = 100\text{ °C}$   |
| Peak drain current <sup>2)</sup>               | $I_{\text{DM}}$  | -      | -    | 398        | A    | $T_C = 25\text{ °C}$ , $V_{\text{GS}} = 18\text{ V}$  |
| Avalanche energy, single pulse                 | $E_{\text{AS}}$  | -      | -    | 372        | mJ   | $I_{\text{D}} = 13.9\text{ A}$ , $V_{\text{DD}} = 50\text{ V}$ ; see table 11                               |
| Avalanche energy, repetitive                   | $E_{\text{AR}}$  | -      | -    | 1.86       | mJ   | $I_{\text{D}} = 13.9\text{ A}$ , $V_{\text{DD}} = 50\text{ V}$ ; see table 11                               |
| Avalanche current, single pulse                | $I_{\text{AS}}$  | -      | -    | 13.9       | A    | -   |
| MOSFET $dv/dt$ ruggedness                      | $dv/dt$          | -      | -    | 200        | V/ns | $V_{\text{DS}} = 0\text{...}400\text{ V}$   |
| Gate source voltage (static) <sup>3)</sup>     | $V_{\text{GS}}$  | -7     | -    | 23         | V    | -   |
| Gate source voltage (transient)                | $V_{\text{GS}}$  | -10    | -    | 25         | V    | $t_p \leq 500\text{ ns}$ , duty cycle $\leq 1\%$  |
| Power dissipation                              | $P_{\text{tot}}$ | -      | -    | 416        | W    | $T_C = 25\text{ °C}$  |
| Storage temperature                            | $T_{\text{stg}}$ | -55    | -    | 150        | °C   | -   |
| Operating junction temperature                 | $T_j$            | -55    | -    | 175        | °C   | -   |
| Mounting torque                                | -                | -      | -    | -          | Ncm  | -   |
| Continuous reverse drain current <sup>1)</sup> | $I_{\text{SDC}}$ | -      | -    | 115<br>77  | A    | $V_{\text{GS}} = 18\text{ V}$ , $T_C = 25\text{ °C}$<br>$V_{\text{GS}} = 0\text{ V}$ , $T_C = 25\text{ °C}$ |
| Peak reverse drain current <sup>2)</sup>       | $I_{\text{SM}}$  | -      | -    | 398<br>121 | A    | $T_C = 25\text{ °C}$ , $t_p \leq 250\text{ ns}$<br>$T_C = 25\text{ °C}$                                     |
| Insulation withstand voltage                   | $V_{\text{ISO}}$ | -      | -    | n.a.       | V    | $V_{\text{rms}}$ , $T_C = 25\text{ °C}$ , $t = 1\text{ min}$  |

<sup>1)</sup> Limited by  $T_{\text{J,max}}$

<sup>2)</sup> Pulse width  $t_{\text{pulse}}$  limited by  $T_{\text{J,max}}$ .

<sup>3)</sup> The maximum gate-source voltage in the application design should be in accordance to IPC-9592B.

## 2 Thermal characteristics

**Table 3 Thermal characteristics**

| Parameter                                       | Symbol        | Values |      |      | Unit | Note / Test Condition   |
|---|---------------|--------|------|------|------|---|
|   |               | Min.   | Typ. | Max. |      |   |
| Thermal resistance, junction - case             | $R_{th(j-c)}$ | -      | -    | 0.36 | °C/W | Not subject to production test. Parameter verified by design/characterization according to JESD51-14. |
| Soldering temperature, reflow soldering allowed | $T_{sold}$    | -      | -    | 260  | °C   | reflow MSL1   |

## 3 Operating range

**Table 4 Operating range**

| Parameter                    | Symbol        | Values |      |      | Unit | Note / Test Condition |
|------------------------------|---------------|--------|------|------|------|-----------------------|
|                              |               | Min.   | Typ. | Max. |      |                       |
| Recommended turn-on voltage  | $V_{GS(on)}$  | -      | 18   | -    | V    | -                     |
| Recommended turn-off voltage | $V_{GS(off)}$ | -      | 0    | -    | V    | -                     |

## 4 Electrical characteristics

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

**Table 5 Static characteristics**

| Parameter                            | Symbol       | Values |                              |              | Unit             | Note / Test Condition   |
|--------------------------------------|--------------|--------|------------------------------|--------------|------------------|---|
|                                      |              | Min.   | Typ.                         | Max.         |                  |   |
| Drain-source voltage                 | $V_{DSS}$    | 650    | -                            | -            | V                | $V_{GS} = 0\text{ V}$ , $I_D = 1.30\text{ mA}$  |
| Gate threshold voltage <sup>1)</sup> | $V_{GS(th)}$ | 3.5    | 4.5                          | 5.6          | V                | $V_{DS} = V_{GS}$ , $I_D = 13.0\text{ mA}$  |
| Zero gate voltage drain current      | $I_{DSS}$    | -      | 1<br>3                       | 75<br>-      | $\mu\text{A}$    | $V_{DS} = 650\text{ V}$ , $V_{GS} = 0\text{ V}$ , $T_j = 25\text{ °C}$<br>$V_{DS} = 650\text{ V}$ , $V_{GS} = 0\text{ V}$ , $T_j = 175\text{ °C}$   |
| Gate-source leakage current          | $I_{GSS}$    | -      | -                            | 100          | nA               | $V_{GS} = 20\text{ V}$ , $V_{DS} = 0\text{ V}$  |
| Drain-source on-state resistance     | $R_{DS(on)}$ | -      | 18.9<br>14.5<br>13.2<br>23.7 | -<br>18<br>- | $\text{m}\Omega$ | $V_{GS} = 15\text{ V}$ , $I_D = 64.2\text{ A}$ , $T_j = 25\text{ °C}$<br>$V_{GS} = 18\text{ V}$ , $I_D = 64.2\text{ A}$ , $T_j = 25\text{ °C}$<br>$V_{GS} = 20\text{ V}$ , $I_D = 64.2\text{ A}$ , $T_j = 25\text{ °C}$<br>$V_{GS} = 18\text{ V}$ , $I_D = 64.2\text{ A}$ , $T_j = 175\text{ °C}$ |
| Internal gate resistance             | $R_{G,int}$  | -      | 2.1                          | -            | $\Omega$         | $f = 1\text{ MHz}$  |

<sup>1)</sup> Tested after 1 ms pulse at  $V_{GS} = +20\text{ V}$ . "Linear mode" operation is not recommended. For assessment of potential "linear mode" operation, please contact Infineon sales office.

**Table 6 Dynamic characteristics**

External parasitic elements (PCB layout) influence switching behavior significantly.  
Stray inductances and coupling capacitances must be minimized.

For layout recommendations please use provided application notes or contact Infineon sales office.

| Parameter  | Symbol       | Values |      |      | Unit          | Note / Test Condition   |
|--|--------------|--------|------|------|---------------|---|
|  |              | Min.   | Typ. | Max. |               |   |
| Input capacitance  | $C_{iss}$    | -      | 2792 | -    | pF            | $V_{GS} = 0\text{ V}$ , $V_{DS} = 400\text{ V}$ , $f = 250\text{ kHz}$  |
| Reverse transfer capacitance                               | $C_{rss}$    | -      | 16   | -    | pF            | $V_{GS} = 0\text{ V}$ , $V_{DS} = 400\text{ V}$ , $f = 250\text{ kHz}$  |
| Output capacitance <sup>1)</sup>                           | $C_{oss}$    | -      | 207  | 269  | pF            | $V_{GS} = 0\text{ V}$ , $V_{DS} = 400\text{ V}$ , $f = 250\text{ kHz}$  |
| Output charge <sup>1)</sup>                                | $Q_{oss}$    | -      | 148  | 193  | nC            | calculation based on $C_{oss}$  |
| Effective output capacitance, energy related <sup>2)</sup> | $C_{o(er)}$  | -      | 251  | -    | pF            | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 0...400\text{ V}$  |
| Effective output capacitance, time related <sup>3)</sup>   | $C_{o(tr)}$  | -      | 371  | -    | pF            | $I_D = \text{constant}$ , $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 0...400\text{ V}$  |
| Turn-on delay time   | $t_{d(on)}$  | -      | 11.6 | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$ ;<br>see table 10 |
| Rise time  | $t_r$        | -      | 14.7 | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$ ;<br>see table 10 |
| Turn-off delay time  | $t_{d(off)}$ | -      | 22   | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$ ;<br>see table 10 |
| Fall time  | $t_f$        | -      | 6.4  | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$ ;<br>see table 10 |
| Turn-ON switching losses <sup>4)</sup>                     | $E_{on}$     | -      | 84   | -    | $\mu\text{J}$ | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$                   |
| Turn-OFF switching losses <sup>4)</sup>                    | $E_{off}$    | -      | 138  | -    | $\mu\text{J}$ | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$                   |
| Total switching losses <sup>4)</sup>                       | $E_{tot}$    | -      | 222  | -    | $\mu\text{J}$ | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 64.2\text{ A}$ , $R_{G,ext} = 1.8\ \Omega$                   |

**Table 7 Gate charge characteristics**

| Parameter                     | Symbol       | Values |      |      | Unit | Note / Test Condition   |
|-------------------------------|--------------|--------|------|------|------|---|
|                               |              | Min.   | Typ. | Max. |      |   |
| Plateau gate to source charge | $Q_{GS(pl)}$ | -      | 20   | -    | nC   | $V_{DD} = 400\text{ V}$ , $I_D = 64.2\text{ A}$ ,<br>$V_{GS} = 0\text{ to }18\text{ V}$ |
| Gate to drain charge          | $Q_{GD}$     | -      | 15   | -    | nC   | $V_{DD} = 400\text{ V}$ , $I_D = 64.2\text{ A}$ ,<br>$V_{GS} = 0\text{ to }18\text{ V}$ |
| Total gate charge             | $Q_G$        | -      | 79   | -    | nC   | $V_{DD} = 400\text{ V}$ , $I_D = 64.2\text{ A}$ ,<br>$V_{GS} = 0\text{ to }18\text{ V}$ |

<sup>1)</sup> Maximum specification is defined by calculated six sigma upper confidence bound

<sup>2)</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 400 V.

<sup>3)</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 400 V.

<sup>4)</sup> MOSFET used in half-bridge configuration without external diode

**Table 8 Reverse diode characteristics**

| Parameter                                    | Symbol    | Values |              |        | Unit | Note / Test Condition  |
|--|-----------|--------|--------------|--------|------|--|
|  |           | Min.   | Typ.         | Max.   |      |  |
| Drain-source reverse voltage                 | $V_{SD}$  | -      | 4.3          | -      | V    | $V_{GS} = 0\text{ V}$ , $I_S = 64.2\text{ A}$ , $T_J = 25\text{ °C}$   |
| MOSFET forward recovery time                 | $t_{fr}$  | -<br>- | 21.5<br>16.0 | -<br>- | ns   | $V_{DD} = 400\text{ V}$ , $I_S = 64.2\text{ A}$ ,<br>$di_S/dt = 1000\text{ A}/\mu\text{s}$ ; see table 9<br>$V_{DD} = 400\text{ V}$ , $I_S = 64.2\text{ A}$ ,<br>$di_S/dt = 4000\text{ A}/\mu\text{s}$ ; see table 9 |
| MOSFET forward recovery charge <sup>1)</sup> | $Q_{fr}$  | -<br>- | 154<br>258   | -<br>- | nC   | $V_{DD} = 400\text{ V}$ , $I_S = 64.2\text{ A}$ ,<br>$di_S/dt = 1000\text{ A}/\mu\text{s}$ ; see table 9<br>$V_{DD} = 400\text{ V}$ , $I_S = 64.2\text{ A}$ ,<br>$di_S/dt = 4000\text{ A}/\mu\text{s}$ ; see table 9 |
| MOSFET peak forward recovery current         | $I_{frm}$ | -<br>- | 14.3<br>32.3 | -<br>- | A    | $V_{DD} = 400\text{ V}$ , $I_S = 64.2\text{ A}$ ,<br>$di_S/dt = 1000\text{ A}/\mu\text{s}$ ; see table 9<br>$V_{DD} = 400\text{ V}$ , $I_S = 64.2\text{ A}$ ,<br>$di_S/dt = 4000\text{ A}/\mu\text{s}$ ; see table 9 |

<sup>1)</sup>  $Q_{fr}$  includes  $Q_{oss}$

## 5 Electrical characteristics diagrams

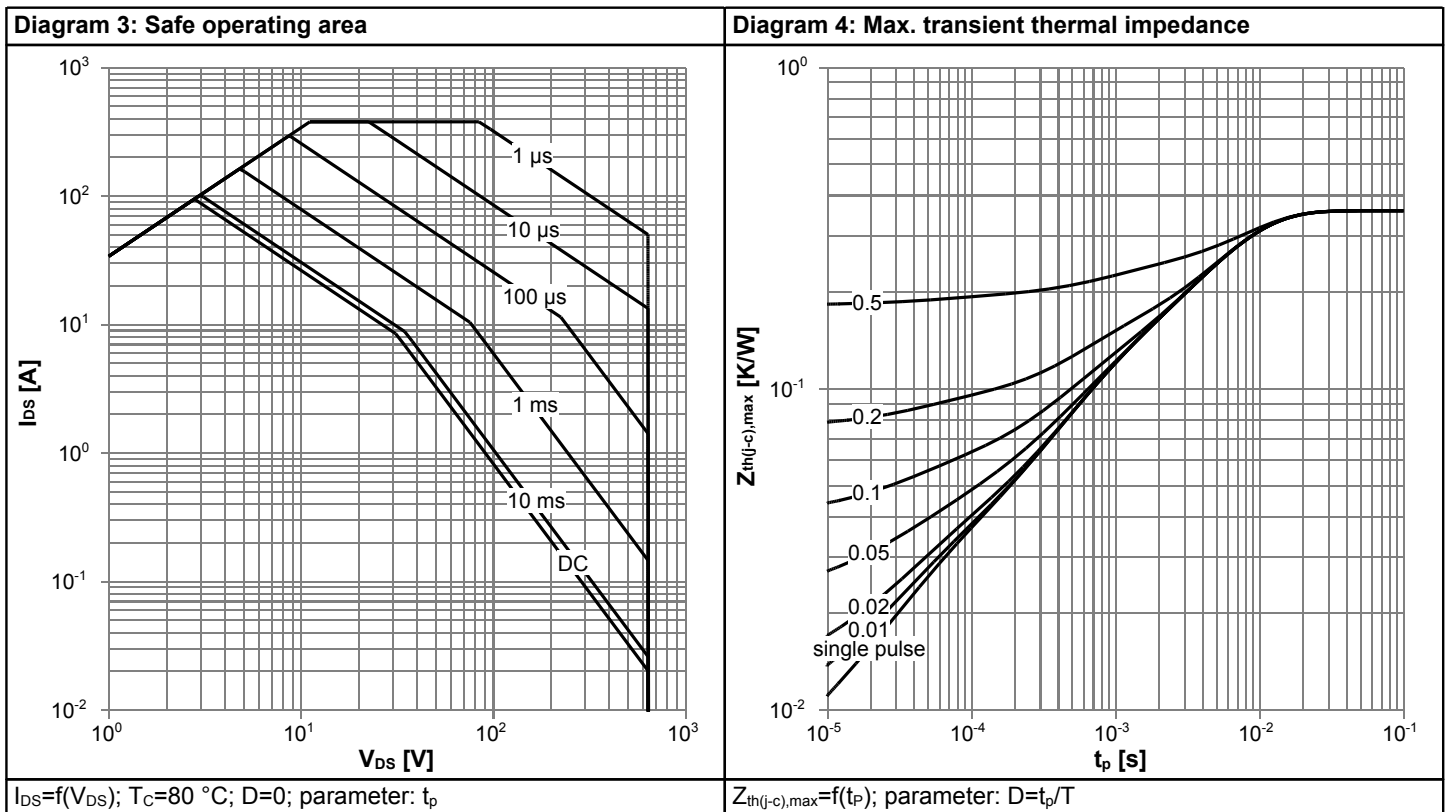
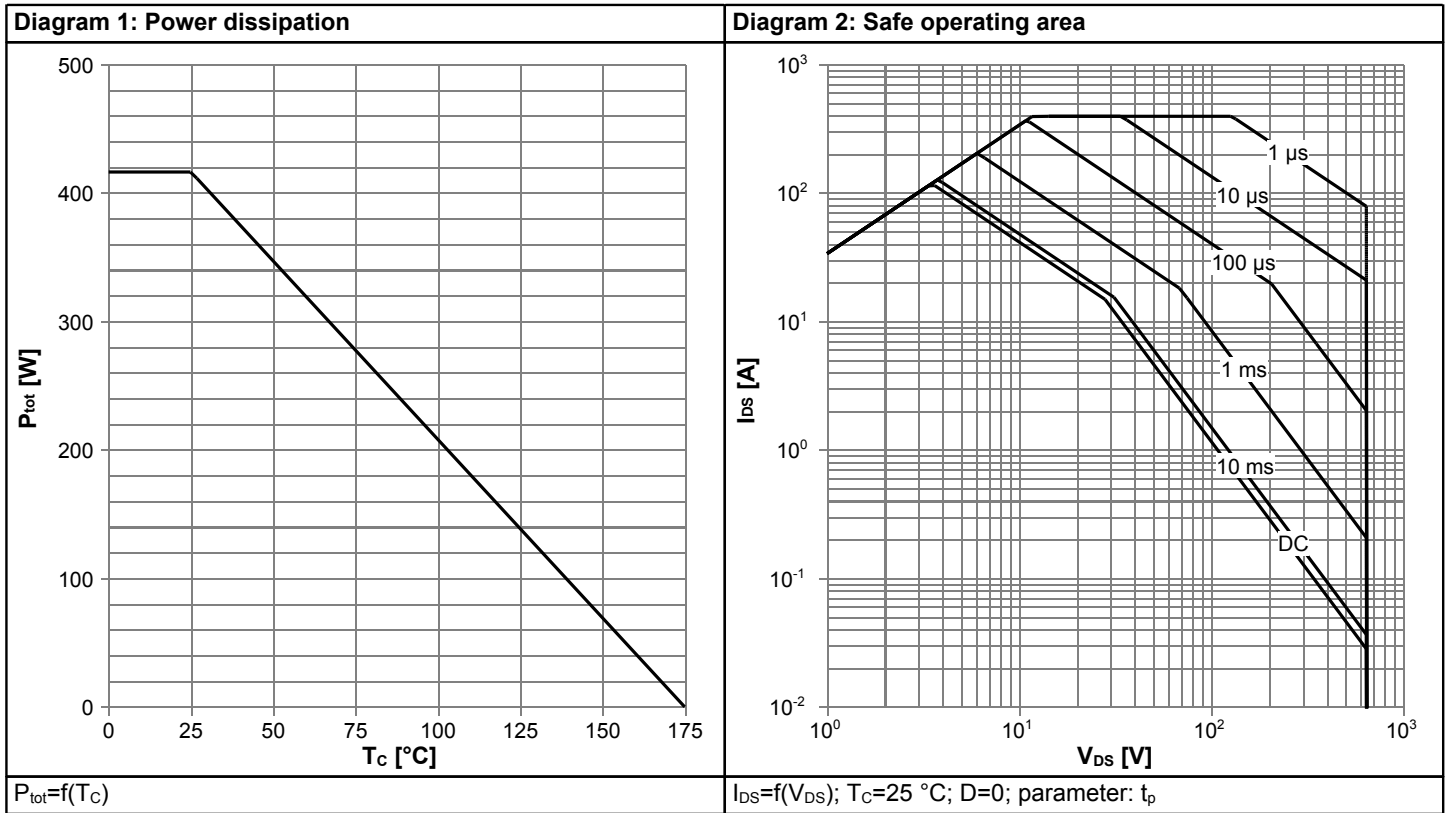
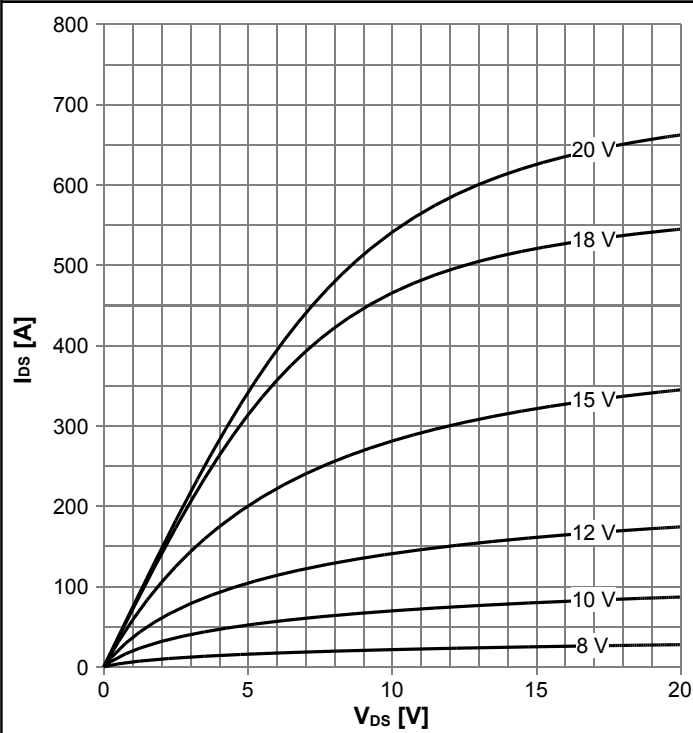


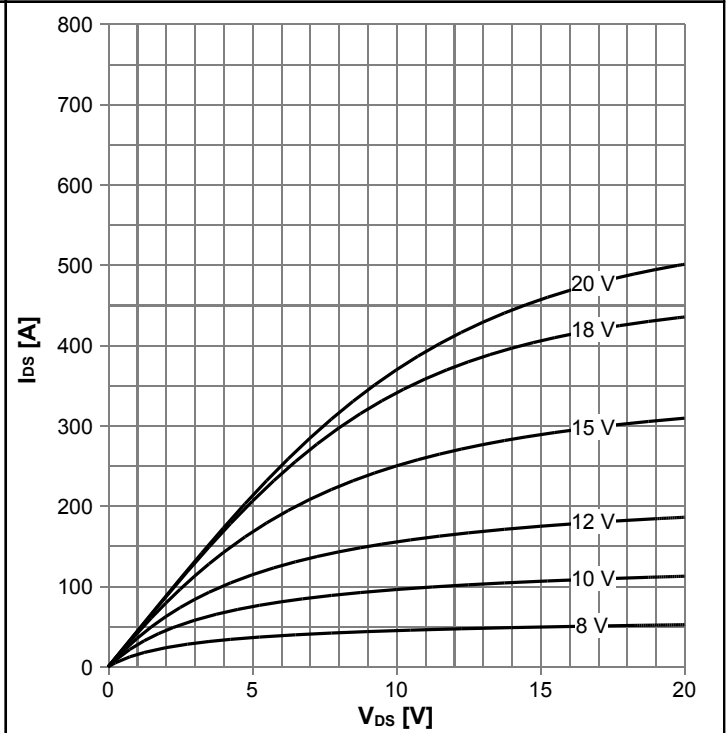


Diagram 5: Typ. output characteristics



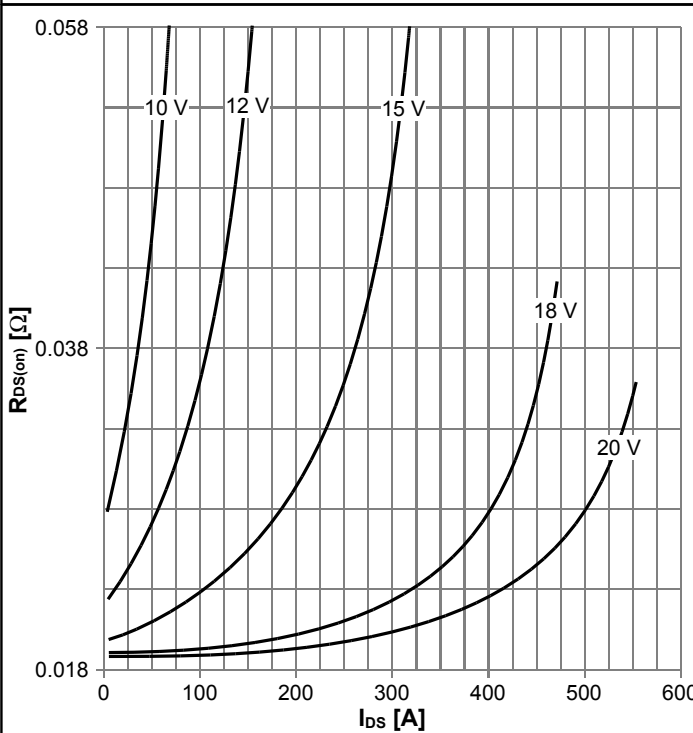
$I_{DS}=f(V_{DS})$ ;  $T_j=25\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 6: Typ. output characteristics



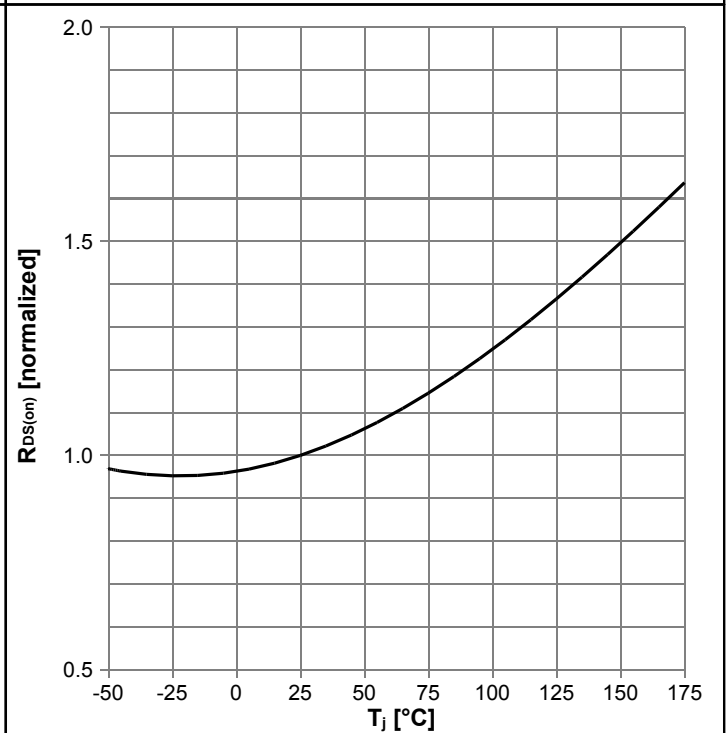
$I_{DS}=f(V_{DS})$ ;  $T_j=175\text{ °C}$ ; parameter:  $V_{GS}$

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



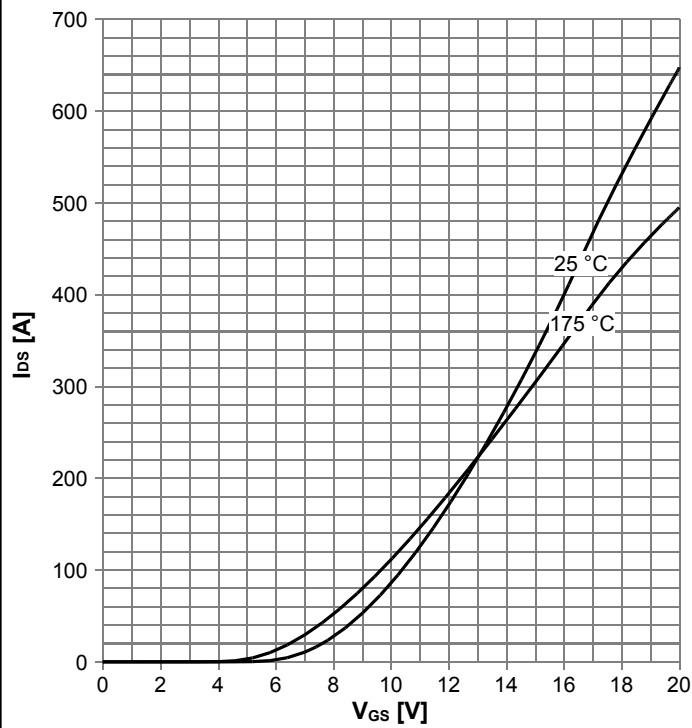
$R_{DS(on)}=f(I_{DS})$ ;  $T_j=125\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 8: Drain-source on-state resistance



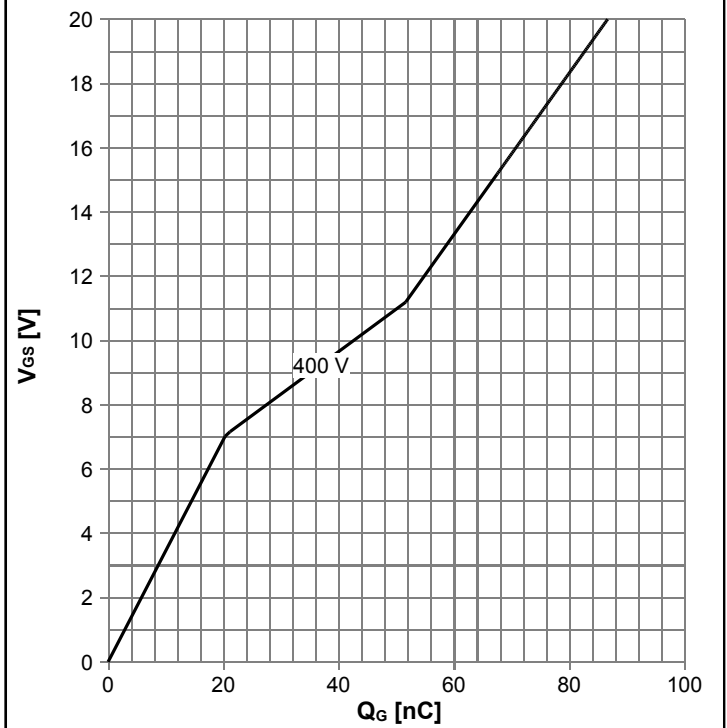
$R_{DS(on)}=f(T_j)$ ;  $I_D=64.2\text{ A}$ ;  $V_{GS}=18\text{ V}$

**Diagram 9: Typ. transfer characteristics**



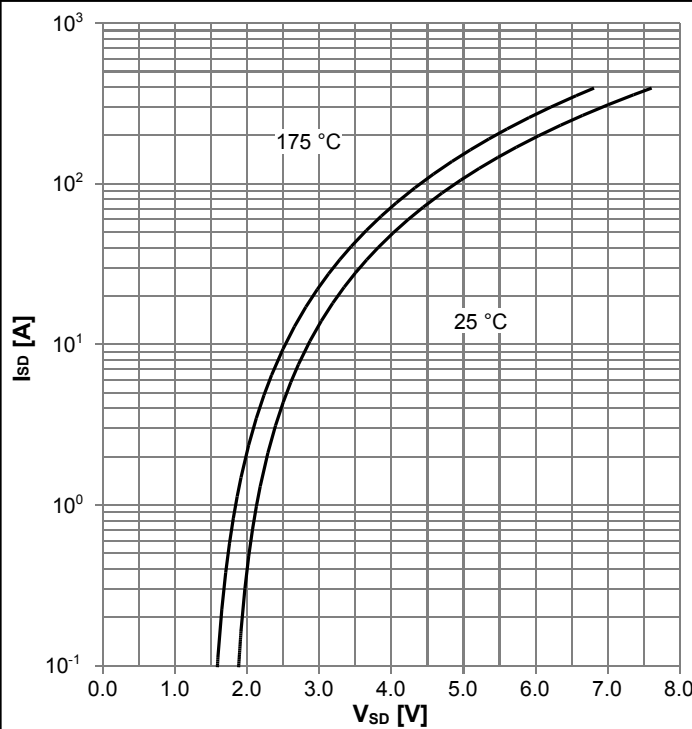
$I_{DS}=f(V_{GS})$ ;  $V_{DS}=20$  V; parameter:  $T_j$

**Diagram 10: Typ. gate charge**



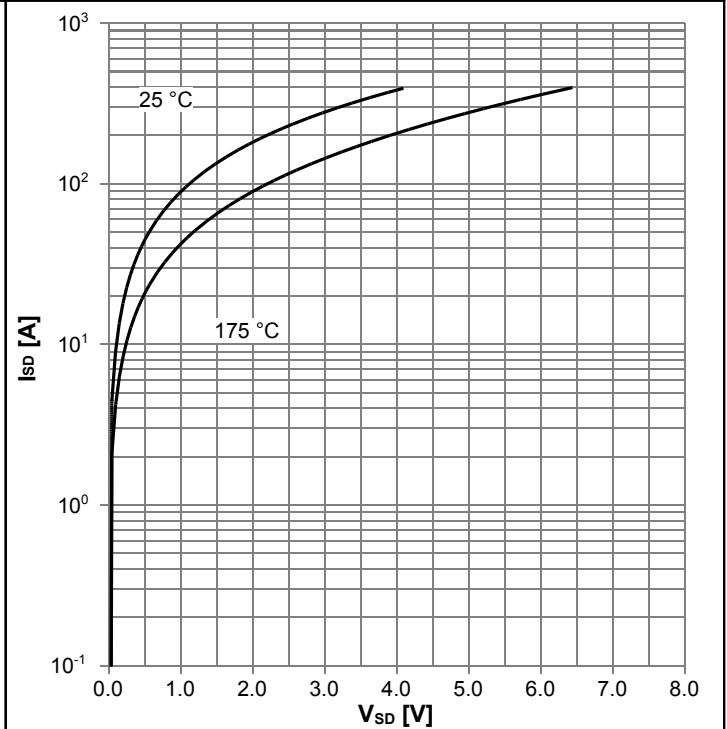
$V_{GS}=f(Q_G)$ ;  $I_D=64.2$  A pulsed; parameter:  $V_{DD}$

**Diagram 11: Typ. reverse drain current characteristics**



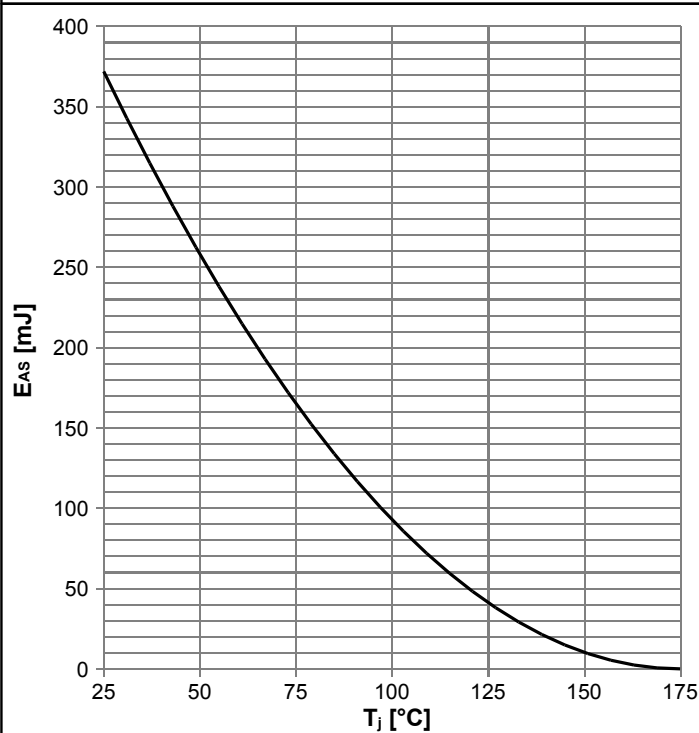
$I_{SD}=f(V_{SD})$ ;  $V_{GS}=0$  V; parameter:  $T_j$

**Diagram 12: Typ. reverse drain current characteristics**



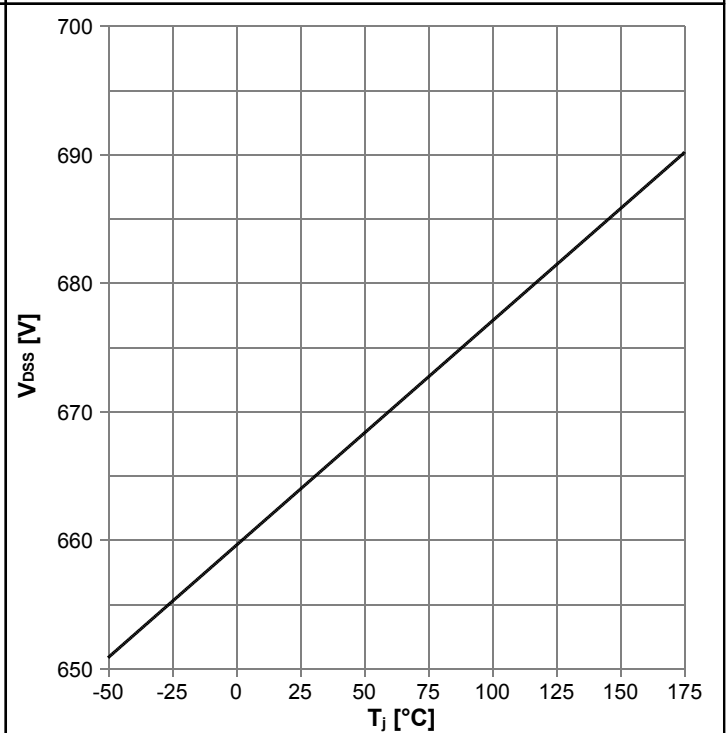
$I_{SD}=f(V_{SD})$ ;  $V_{GS}=18$  V; parameter:  $T_j$

Diagram 13: Avalanche energy



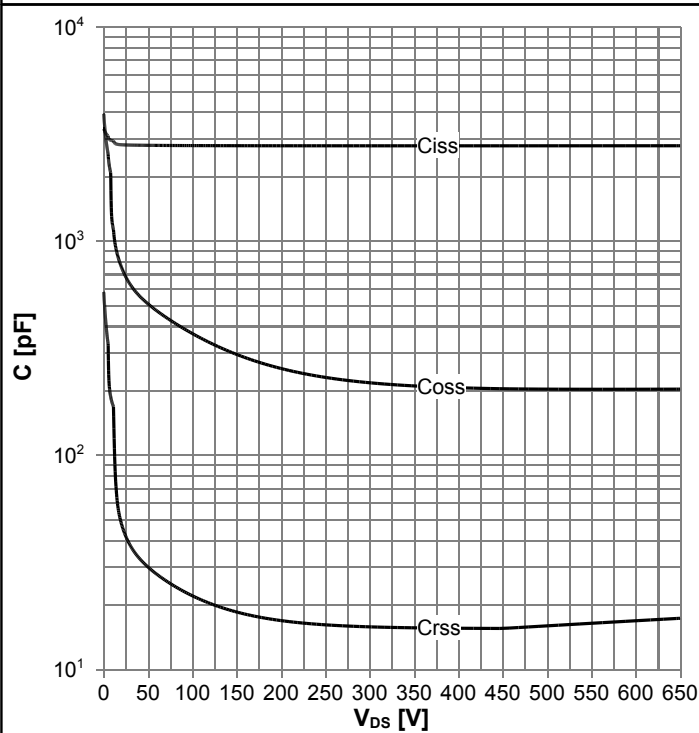
$E_{AS}=f(T_j)$ ;  $I_D=13.9\text{ A}$ ;  $V_{DD}=50\text{ V}$

Diagram 14: Drain-source breakdown voltage



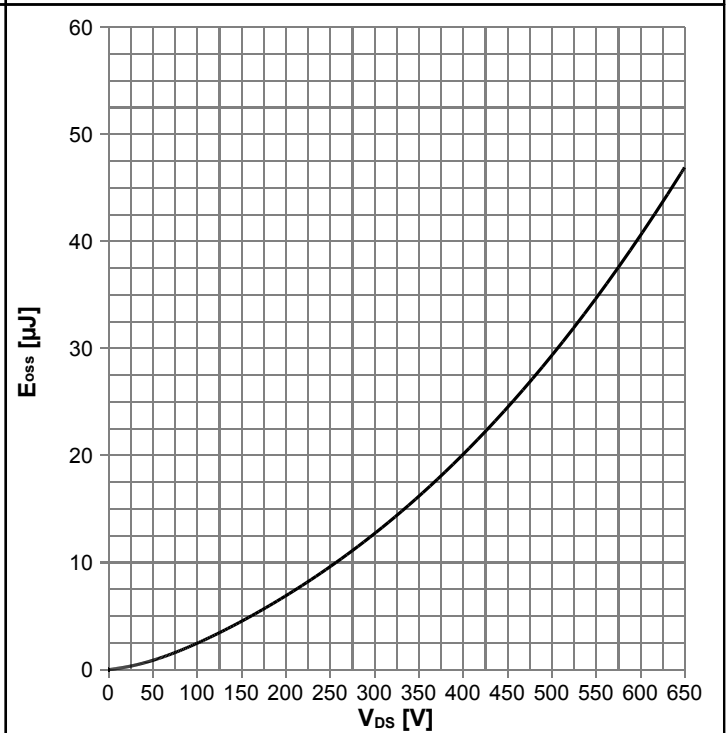
$V_{DSS}=f(T_j)$ ;  $I_D=1.3\text{ mA}$

Diagram 15: Typ. capacitances



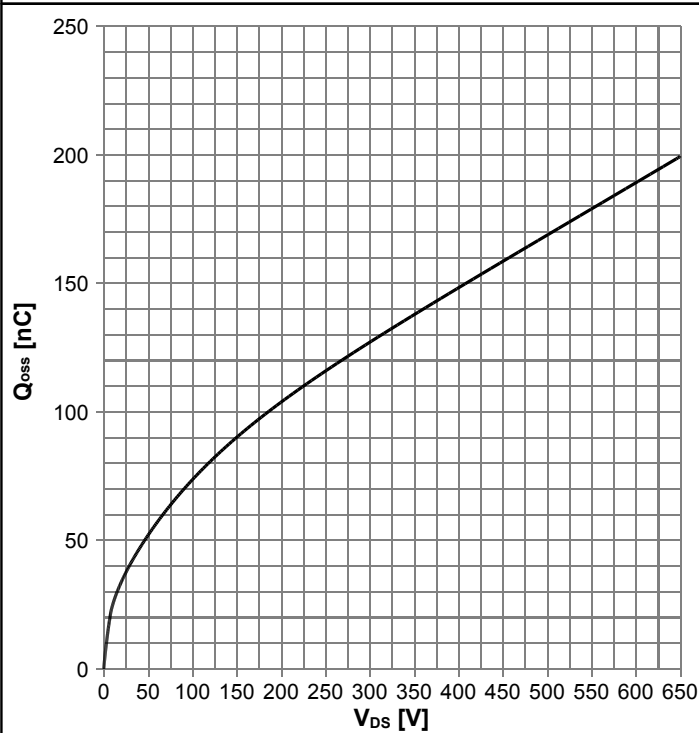
$C=f(V_{DS})$ ;  $V_{GS}=0\text{ V}$ ;  $f=250\text{ kHz}$

Diagram 16: Typ. Coss stored energy



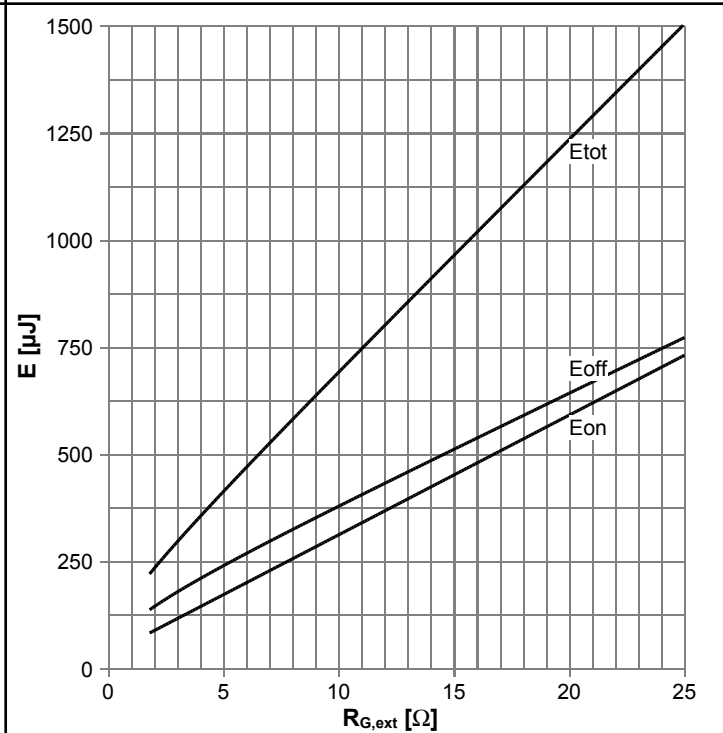
$E_{oss}=f(V_{DS})$

**Diagram 17: Typ. Q<sub>oss</sub> output charge**



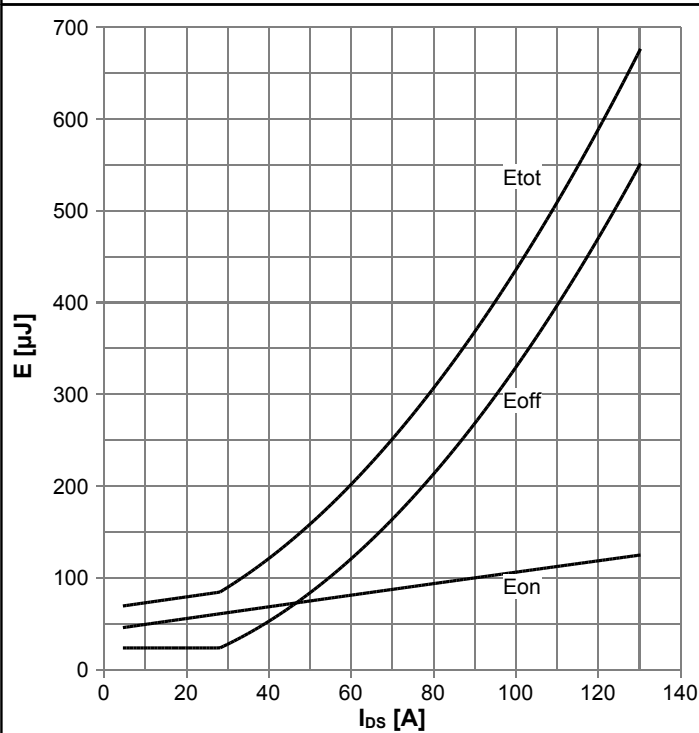
$Q_{oss}=f(V_{DS})$

**Diagram 18: Typ. Switching Losses vs  $R_{G,ext}$**



$E=f(R_{G,ext}); V_{DD}=400\text{ V}; V_{GS}=0/18\text{ V}; I_D=64.3\text{ A}$

**Diagram 19: Typ. Switching Losses vs switching current**



$E=f(I_{DS}); V_{DD}=400\text{ V}; V_{GS}=0/18\text{ V}; R_{G,ext}=1.8\ \Omega$

## 6 Test Circuits

**Table 9 Body diode characteristics**

| Test circuit for body diode characteristics | Body diode recovery waveform |
|---|------------------------------|
|   |                              |

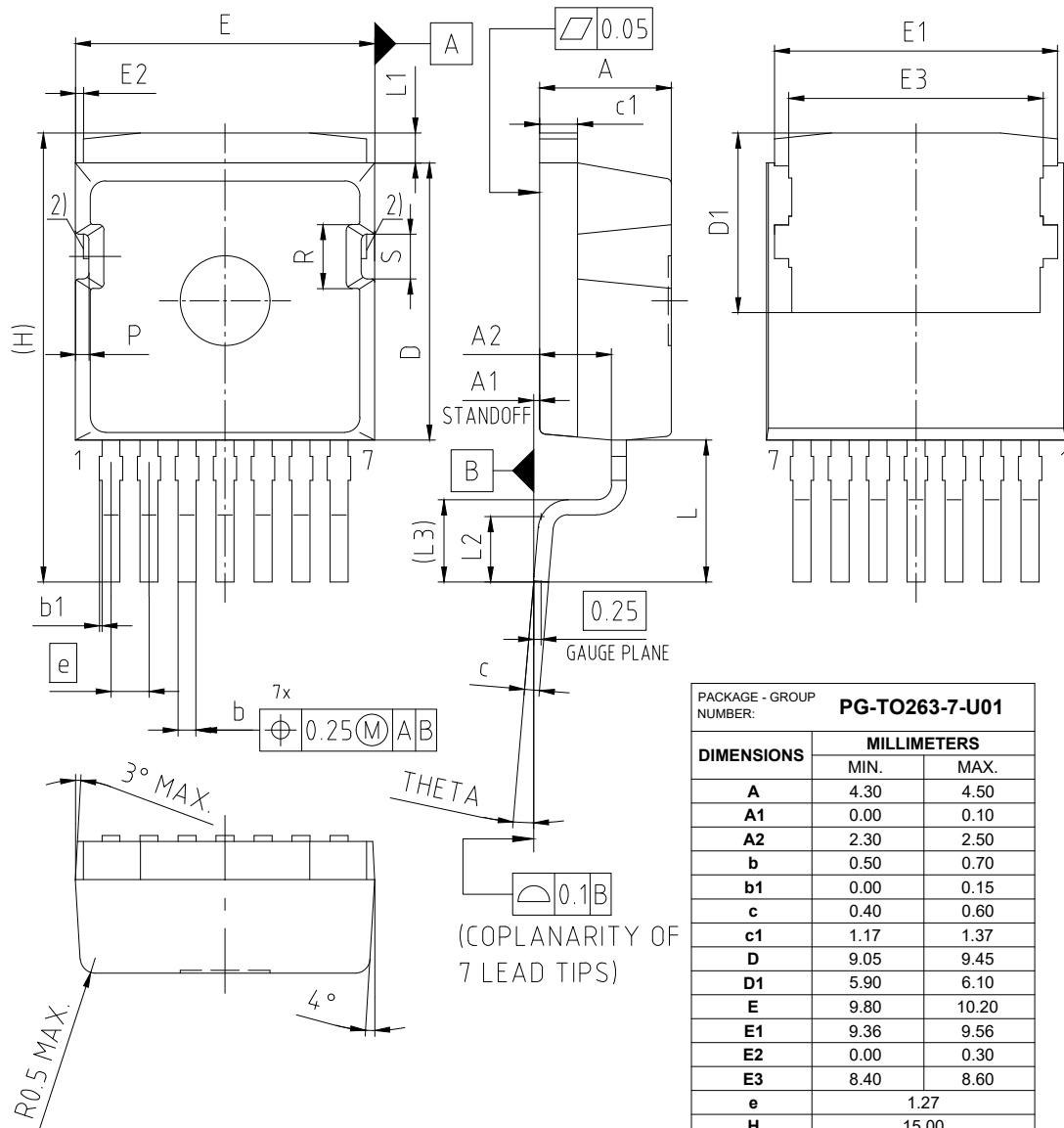
**Table 10 Switching times**

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

**Table 11 Unclamped inductive load**

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

## 7 Package Outlines



**NOTES:**

- 1) ALL METAL SURFACES TIN PLATED EXCEPT AREA OF CUT
- 2) MOLD FILLING IS ACCEPTABLE AT THIS AREA

| PACKAGE - GROUP NUMBER: <b>PG-TO263-7-U01</b> |             |       |
|---|-------------|-------|
| DIMENSIONS                                    | MILLIMETERS |       |
|   | MIN.        | MAX.  |
| <b>A</b>                                      | 4.30        | 4.50  |
| <b>A1</b>                                     | 0.00        | 0.10  |
| <b>A2</b>                                     | 2.30        | 2.50  |
| <b>b</b>                                      | 0.50        | 0.70  |
| <b>b1</b>                                     | 0.00        | 0.15  |
| <b>c</b>                                      | 0.40        | 0.60  |
| <b>c1</b>                                     | 1.17        | 1.37  |
| <b>D</b>                                      | 9.05        | 9.45  |
| <b>D1</b>                                     | 5.90        | 6.10  |
| <b>E</b>                                      | 9.80        | 10.20 |
| <b>E1</b>                                     | 9.36        | 9.56  |
| <b>E2</b>                                     | 0.00        | 0.30  |
| <b>E3</b>                                     | 8.40        | 8.60  |
| <b>e</b>                                      | 1.27        |       |
| <b>H</b>                                      | 15.00       |       |
| <b>L</b>                                      | 4.20        | 5.20  |
| <b>L1</b>                                     | 0.70        | 1.30  |
| <b>L2</b>                                     | 1.70        | 2.30  |
| <b>L3</b>                                     | 2.70        |       |
| <b>P</b>                                      | 0.35        | 0.55  |
| <b>R</b>                                      | 2.03        | 2.23  |
| <b>S</b>                                      | 1.40        | 1.60  |
| <b>THETA</b>                                  | 0.00°       | 8.00° |

**Figure 1 Outline PG-TO263-7, dimensions in mm**

## 8 Appendix A

### Table 12 Related Links

- IFX CoolSiC CoolSiC™ MOSFET 650 V G2 Webpage: [www.infineon.com](http://www.infineon.com)
- IFX CoolSiC CoolSiC™ MOSFET 650 V G2 application note: [www.infineon.com](http://www.infineon.com)
- IFX CoolSiC CoolSiC™ MOSFET 650 V G2 simulation model: [www.infineon.com](http://www.infineon.com)
- IFX Design tools: [www.infineon.com](http://www.infineon.com)

## Revision History

IMBG65R015M2H

**Revision: 2024-03-05, Rev. 2.2**

Previous Revision

| Revision | Date       | Subjects (major changes since last revision)                      |
|----------|------------|---|
| 2.0      | 2023-09-26 | Release of final version  |
| 2.1      | 2024-02-29 | updated simulation model; included Eon and Eoff data and diagrams |
| 2.2      | 2024-03-05 | minor layout changes  |

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