

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

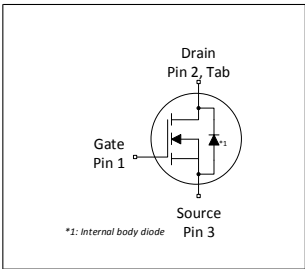
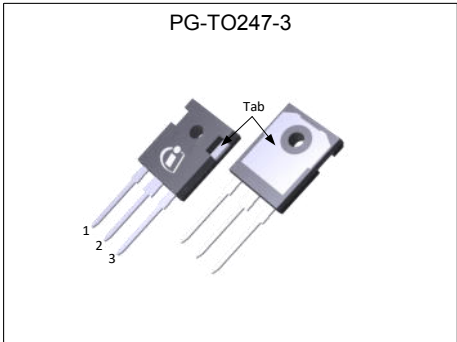
Product validation

Fully qualified according to JEDEC for Industrial Applications

Table 1 Key Performance Parameters

| Parameter                         | Value | Unit |
|-----------------------------------|-------|------|
| $V_{DSS}$ over full $T_{j,range}$ | 650   | V    |
| $R_{DS(on),typ}$                  | 40    | mΩ   |
| $R_{DS(on),max}$                  | 49    | mΩ   |
| $Q_{G,typ}$                       | 28    | nC   |
| $I_{D,pulse}$                     | 142   | A    |
| $Q_{oss} @ 400\text{ V}$          | 53    | nC   |
| $E_{oss} @ 400\text{ V}$          | 7.2   | μJ   |

| Type / Ordering Code | Package    | Marking  | Related Links  |
|----------------------|------------|----------|----------------|
| IMW65R040M2H         | PG-TO247-3 | 65R040M2 | see Appendix A |



RoHS

Table of Contents

Description ..... 1

Maximum ratings ..... 3

Thermal characteristics ..... 4

Operating range ..... 4

Electrical characteristics ..... 5

Electrical characteristics diagrams ..... 8

Test Circuits ..... 13

Package Outlines ..... 14

Appendix A ..... 15

Revision History ..... 16

Trademarks ..... 16

Disclaimer ..... 16

## 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>      | $I_{DDC}$ | -      | -    | 46<br>32   | A    | $T_C = 25\text{ °C}$<br>$T_C = 100\text{ °C}$                                                 |
| Peak drain current <sup>2)</sup>               | $I_{DM}$  | -      | -    | 142        | A    | $T_C = 25\text{ °C}$ , $V_{GS} = 18\text{ V}$                                                 |
| Avalanche energy, single pulse                 | $E_{AS}$  | -      | -    | 132        | mJ   | $I_D = 4.9\text{ A}$ , $V_{DD} = 50\text{ V}$ ; see table 11                                  |
| Avalanche energy, repetitive                   | $E_{AR}$  | -      | -    | 0.66       | mJ   | $I_D = 4.9\text{ A}$ , $V_{DD} = 50\text{ V}$ ; see table 11                                  |
| Avalanche current, single pulse                | $I_{AS}$  | -      | -    | 4.9        | A    | -                                                                                             |
| MOSFET $dv/dt$ ruggedness                      | $dv/dt$   | -      | -    | 200        | V/ns | $V_{DS} = 0\ldots 400\text{ V}$                                                               |
| Gate source voltage (static) <sup>3)</sup>     | $V_{GS}$  | -7     | -    | 23         | V    | -                                                                                             |
| Gate source voltage (transient)                | $V_{GS}$  | -10    | -    | 25         | V    | $t_p \leq 500\text{ ns}$ , duty cycle $\leq 1\%$                                              |
| Power dissipation                              | $P_{tot}$ | -      | -    | 172        | W    | $T_C = 25\text{ °C}$                                                                          |
| Storage temperature                            | $T_{stg}$ | -55    | -    | 150        | °C   | -                                                                                             |
| Operating junction temperature                 | $T_j$     | -55    | -    | 175        | °C   | -                                                                                             |
| Mounting torque                                | -         | -      | -    | 60         | Ncm  | M3 and M3.5 screws                                                                            |
| Continuous reverse drain current <sup>1)</sup> | $I_{SDC}$ | -      | -    | 46<br>30.6 | A    | $V_{GS} = 18\text{ V}$ , $T_C = 25\text{ °C}$<br>$V_{GS} = 0\text{ V}$ , $T_C = 25\text{ °C}$ |
| Peak reverse drain current <sup>2)</sup>       | $I_{SM}$  | -      | -    | 142<br>43  | A    | $T_C = 25\text{ °C}$ , $t_p \leq 250\text{ ns}$<br>$T_C = 25\text{ °C}$                       |
| Insulation withstand voltage                   | $V_{ISO}$ | -      | -    | n.a.       | V    | $V_{rms}$ , $T_C = 25\text{ °C}$ , $t = 1\text{ min}$                                         |

<sup>1)</sup> Limited by  $T_{j,max}$

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

<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                        | $R_{th(j-c)}$ | -      | -    | 0.87 | °C/W | Not subject to production test. Parameter verified by design/characterization according to JESD51-14. |
| Soldering temperature, wavesoldering only allowed at leads | $T_{solder}$  | -      | -    | 260  | °C   | 1.6 mm (0.063 in.) from case for 10 s                                                                 |

## 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                | $V_{GS} = 0\text{ V}$ , $I_D = 0.46\text{ mA}$                                                                                                                                                                                                                                                    |
| Gate threshold voltage <sup>1)</sup> | $V_{GS(th)}$ | 3.5    | 4.5                  | 5.6               | V                | $V_{DS} = V_{GS}$ , $I_D = 4.6\text{ mA}$                                                                                                                                                                                                                                                         |
| 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     | $R_{DS(on)}$ | -      | 52<br>40<br>36<br>65 | -<br>49<br>-<br>- | $\text{m}\Omega$ | $V_{GS} = 15\text{ V}$ , $I_D = 22.9\text{ A}$ , $T_j = 25\text{ °C}$<br>$V_{GS} = 18\text{ V}$ , $I_D = 22.9\text{ A}$ , $T_j = 25\text{ °C}$<br>$V_{GS} = 20\text{ V}$ , $I_D = 22.9\text{ A}$ , $T_j = 25\text{ °C}$<br>$V_{GS} = 18\text{ V}$ , $I_D = 22.9\text{ A}$ , $T_j = 175\text{ °C}$ |
| Internal gate resistance             | $R_{G,int}$  | -      | 3.4                  | -                 | $\Omega$         | $f = 1\text{ MHz}$                                                                                                                                                                                                                                                                                |

<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                                          | $C_{iss}$    | -      | 997  | -    | pF            | $V_{GS} = 0\text{ V}$ , $V_{DS} = 400\text{ V}$ , $f = 250\text{ kHz}$                                                            |
| Reverse transfer capacitance                               | $C_{rss}$    | -      | 5.8  | -    | pF            | $V_{GS} = 0\text{ V}$ , $V_{DS} = 400\text{ V}$ , $f = 250\text{ kHz}$                                                            |
| Output capacitance <sup>1)</sup>                           | $C_{oss}$    | -      | 74   | 96   | pF            | $V_{GS} = 0\text{ V}$ , $V_{DS} = 400\text{ V}$ , $f = 250\text{ kHz}$                                                            |
| Output charge <sup>1)</sup>                                | $Q_{oss}$    | -      | 53   | 69   | nC            | calculation based on $C_{oss}$                                                                                                    |
| Effective output capacitance, energy related <sup>2)</sup> | $C_{o(er)}$  | -      | 90   | -    | pF            | $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 0...400\text{ V}$                                                                            |
| Effective output capacitance, time related <sup>3)</sup>   | $C_{o(tr)}$  | -      | 133  | -    | pF            | $I_D = \text{constant}$ , $V_{GS} = 0\text{ V}$ ,<br>$V_{DS} = 0...400\text{ V}$                                                  |
| Turn-on delay time                                         | $t_{d(on)}$  | -      | 23   | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$ ;<br>see table 10 |
| Rise time                                                  | $t_r$        | -      | 10.0 | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$ ;<br>see table 10 |
| Turn-off delay time                                        | $t_{d(off)}$ | -      | 15   | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$ ;<br>see table 10 |
| Fall time                                                  | $t_f$        | -      | 5.0  | -    | ns            | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$ ;<br>see table 10 |
| Turn-ON switching losses <sup>4)</sup>                     | $E_{on}$     | -      | 163  | -    | $\mu\text{J}$ | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$                   |
| Turn-OFF switching losses <sup>4)</sup>                    | $E_{off}$    | -      | 18   | -    | $\mu\text{J}$ | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$                   |
| Total switching losses <sup>4)</sup>                       | $E_{tot}$    | -      | 181  | -    | $\mu\text{J}$ | $V_{DD} = 400\text{ V}$ , $V_{GS} = 0/18\text{ V}$ ,<br>$I_D = 22.9\text{ A}$ , $R_{G,ext} = 1.8\text{ }\Omega$                   |

**Table 7 Gate charge characteristics**

| Parameter                     | Symbol       | Values |      |      | Unit | Note / Test Condition                                                                   |
|-------------------------------|--------------|--------|------|------|------|-----------------------------------------------------------------------------------------|
|                               |              | Min.   | Typ. | Max. |      |                                                                                         |
| Plateau gate to source charge | $Q_{GS(pl)}$ | -      | 7.3  | -    | nC   | $V_{DD} = 400\text{ V}$ , $I_D = 22.9\text{ A}$ ,<br>$V_{GS} = 0\text{ to }18\text{ V}$ |
| Gate to drain charge          | $Q_{GD}$     | -      | 5.3  | -    | nC   | $V_{DD} = 400\text{ V}$ , $I_D = 22.9\text{ A}$ ,<br>$V_{GS} = 0\text{ to }18\text{ V}$ |
| Total gate charge             | $Q_G$        | -      | 28   | -    | nC   | $V_{DD} = 400\text{ V}$ , $I_D = 22.9\text{ A}$ ,<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.

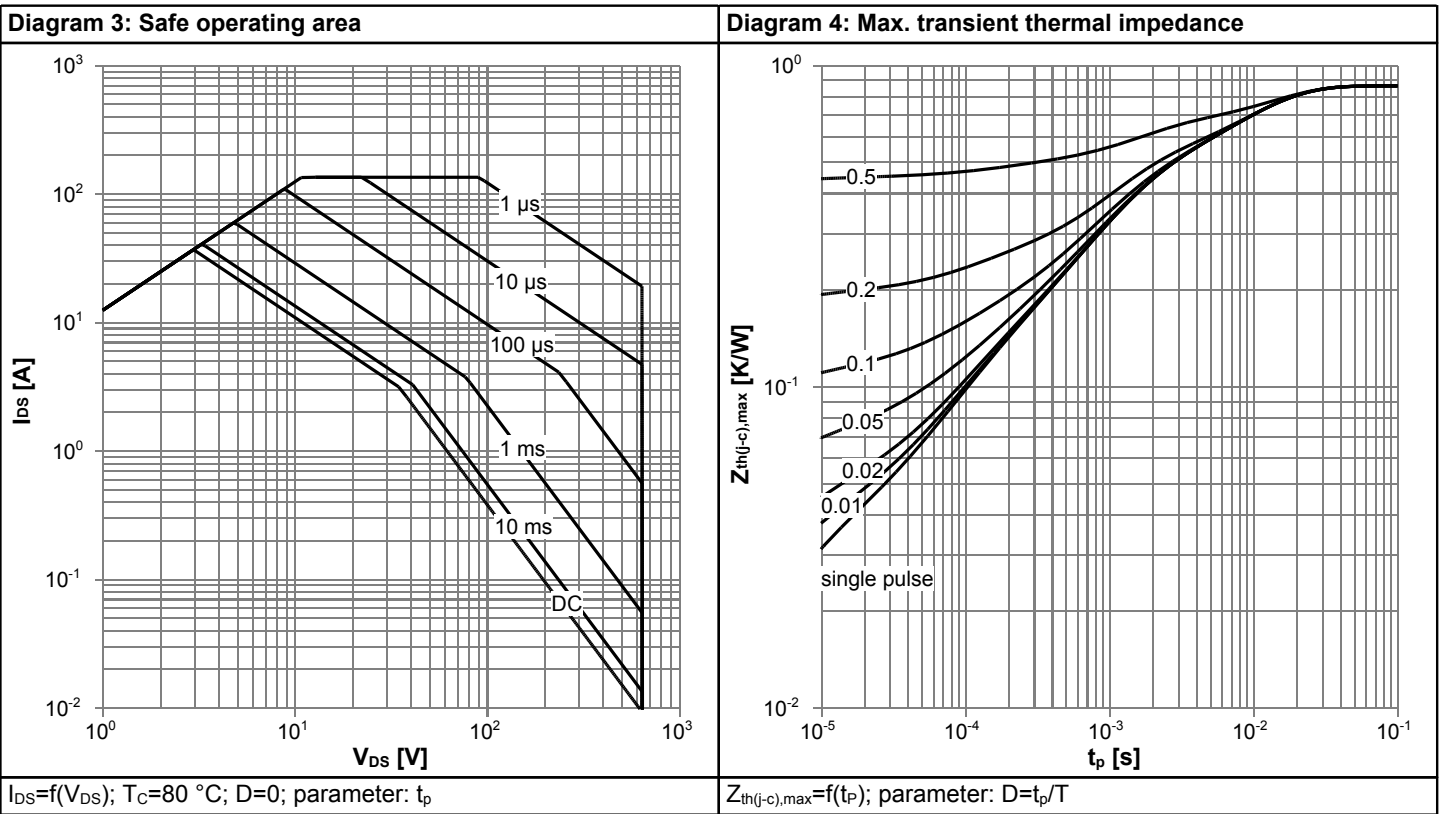
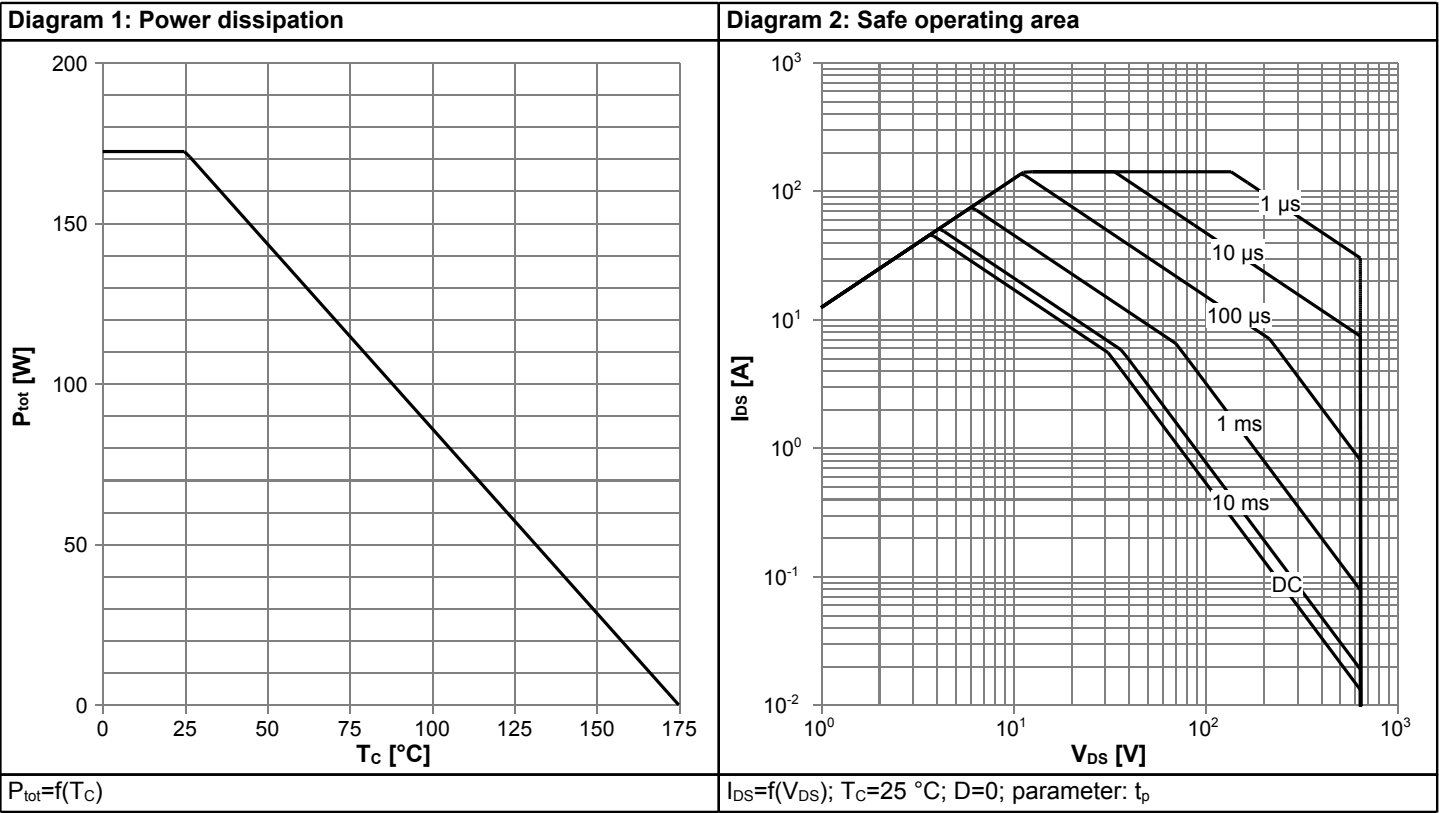
<sup>4)</sup> MOSFET used in half-bridge configuration without external diode

**Table 8 Reverse diode characteristics**

| Parameter                                    | Symbol    | Values |      |      | Unit | Note / Test Condition                                                                                       |
|----------------------------------------------|-----------|--------|------|------|------|-------------------------------------------------------------------------------------------------------------|
|                                              |           | Min.   | Typ. | Max. |      |                                                                                                             |
| Drain-source reverse voltage                 | $V_{SD}$  | -      | 4.3  | -    | V    | $V_{GS} = 0 \text{ V}$ , $I_S = 22.9 \text{ A}$ , $T_j = 25 \text{ °C}$                                     |
| MOSFET forward recovery time                 | $t_{fr}$  | -      | 29.3 | -    | ns   | $V_{DD} = 400 \text{ V}$ , $I_S = 22.9 \text{ A}$ ,<br>$di_S/dt = 1000 \text{ A}/\mu\text{s}$ ; see table 9 |
| MOSFET forward recovery charge <sup>1)</sup> | $Q_{fr}$  | -      | 94   | -    | nC   | $V_{DD} = 400 \text{ V}$ , $I_S = 22.9 \text{ A}$ ,<br>$di_S/dt = 1000 \text{ A}/\mu\text{s}$ ; see table 9 |
| MOSFET peak forward recovery current         | $I_{frm}$ | -      | 6.4  | -    | A    | $V_{DD} = 400 \text{ V}$ , $I_S = 22.9 \text{ A}$ ,<br>$di_S/dt = 1000 \text{ A}/\mu\text{s}$ ; see table 9 |

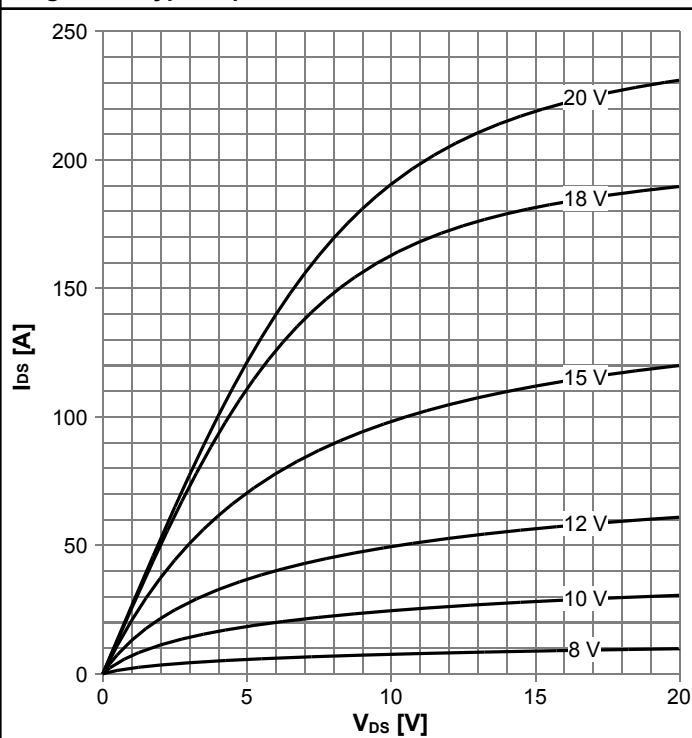
<sup>1)</sup>  $Q_{fr}$  includes  $Q_{oss}$

5 Electrical characteristics diagrams



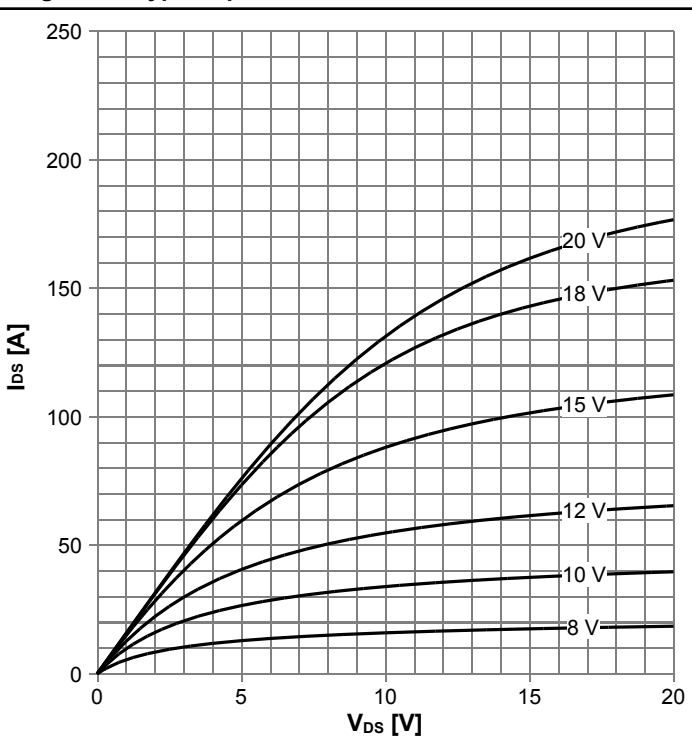
CoolSiC™ MOSFET 650 V G2  
IMW65R040M2H

Diagram 5: Typ. output characteristics



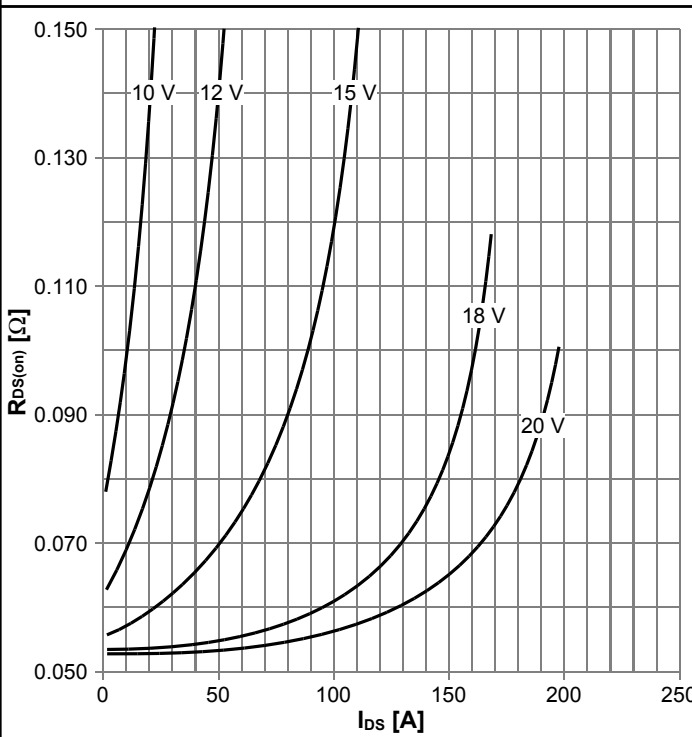
$I_{DS}=f(V_{DS})$ ;  $T_J=25\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 6: Typ. output characteristics



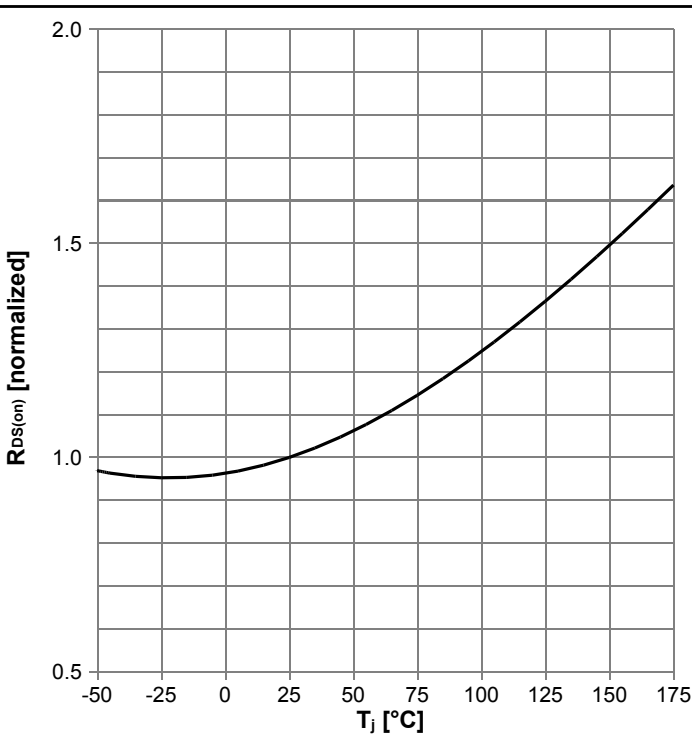
$I_{DS}=f(V_{DS})$ ;  $T_J=175\text{ °C}$ ; parameter:  $V_{GS}$

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



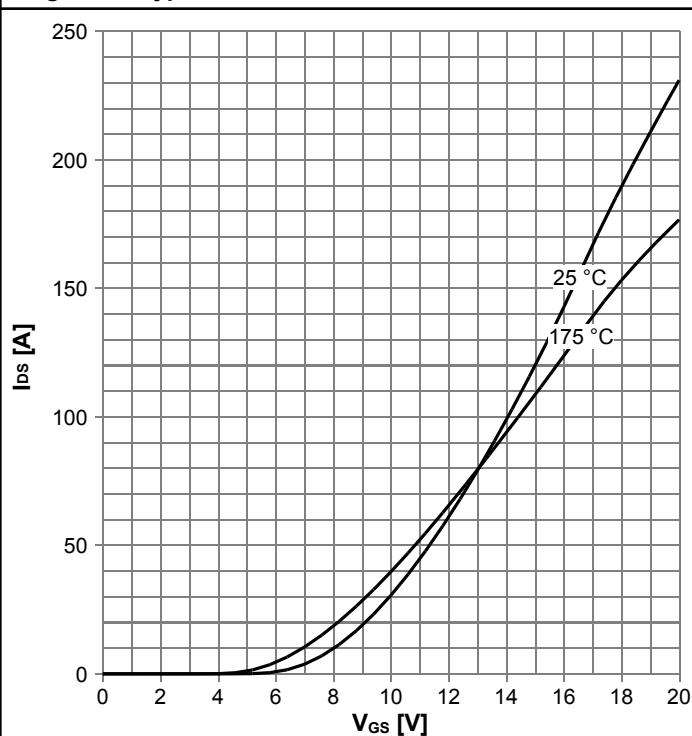
$R_{DS(on)}=f(I_{DS})$ ;  $T_J=125\text{ °C}$ ; parameter:  $V_{GS}$

Diagram 8: Drain-source on-state resistance



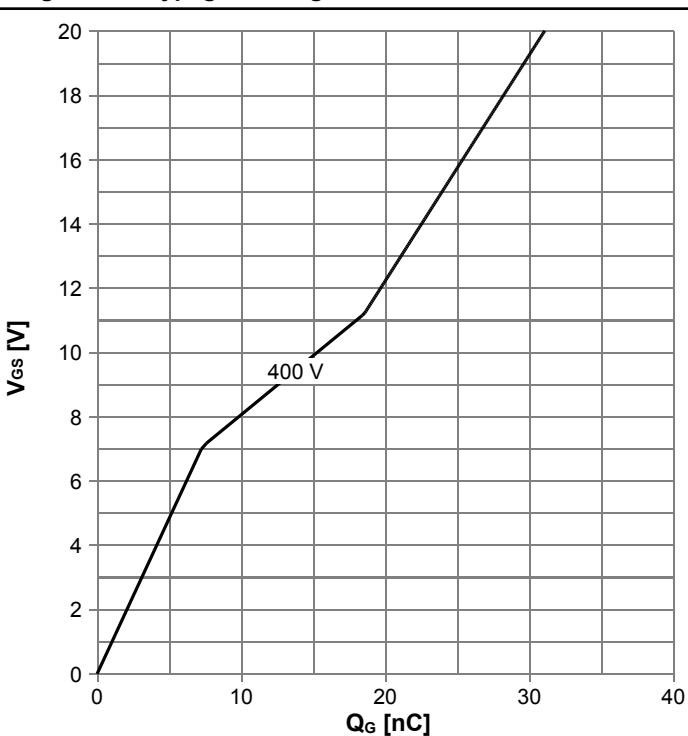
$R_{DS(on)}=f(T_J)$ ;  $I_D=22.9\text{ A}$ ;  $V_{GS}=18\text{ V}$

Diagram 9: Typ. transfer characteristics



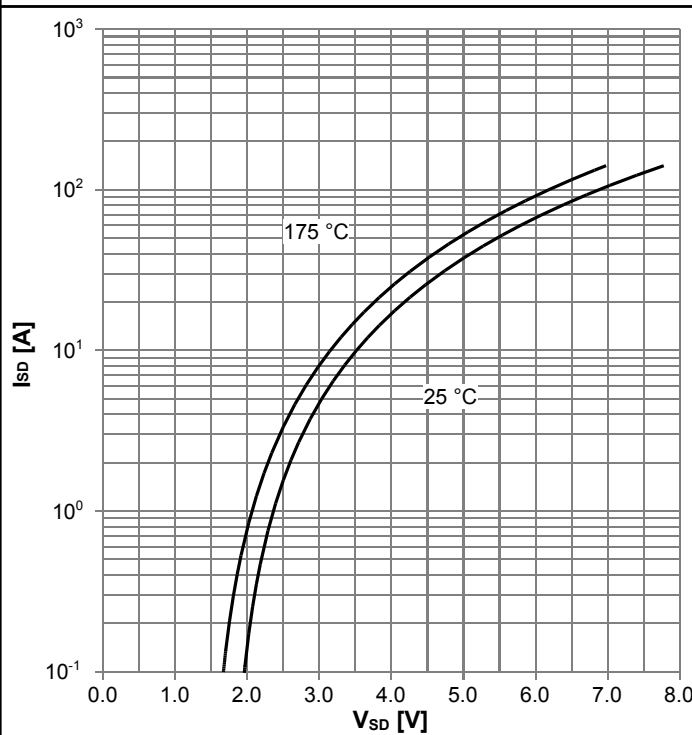
$I_{DS}=f(V_{GS})$ ;  $V_{DS}=20$  V; parameter:  $T_j$

Diagram 10: Typ. gate charge



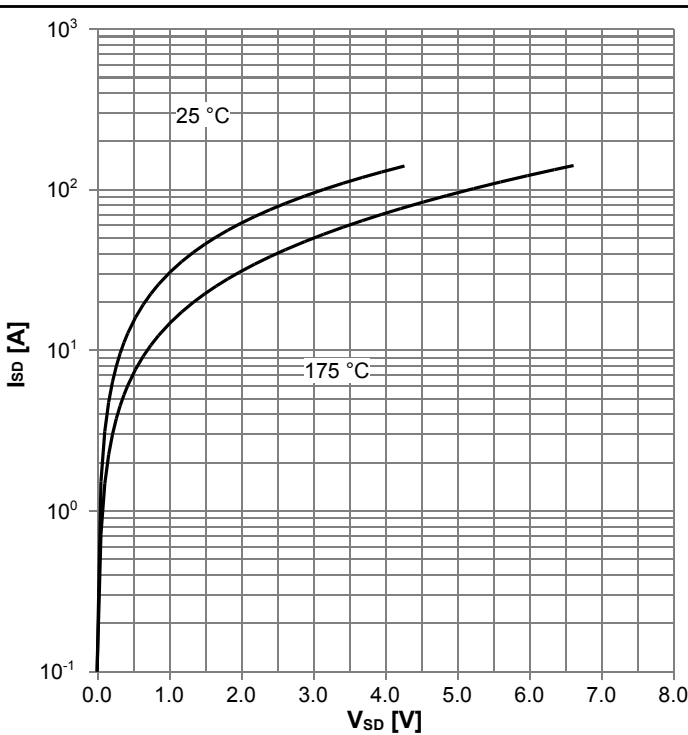
$V_{GS}=f(Q_G)$ ;  $I_D=22.9$  A pulsed; parameter:  $V_{DD}$

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

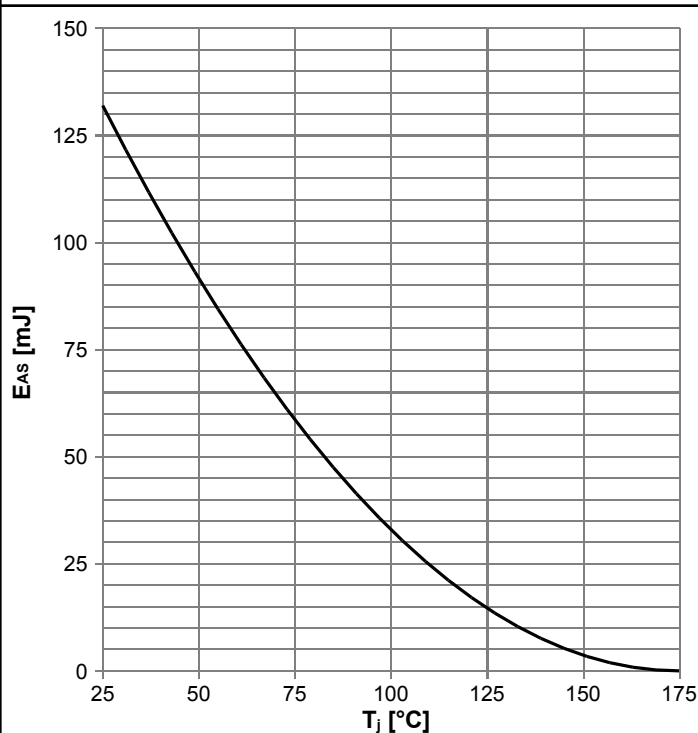


$I_{SD}=f(V_{SD})$ ;  $V_{GS}=18$  V; parameter:  $T_j$

# CoolSiC™ MOSFET 650 V G2

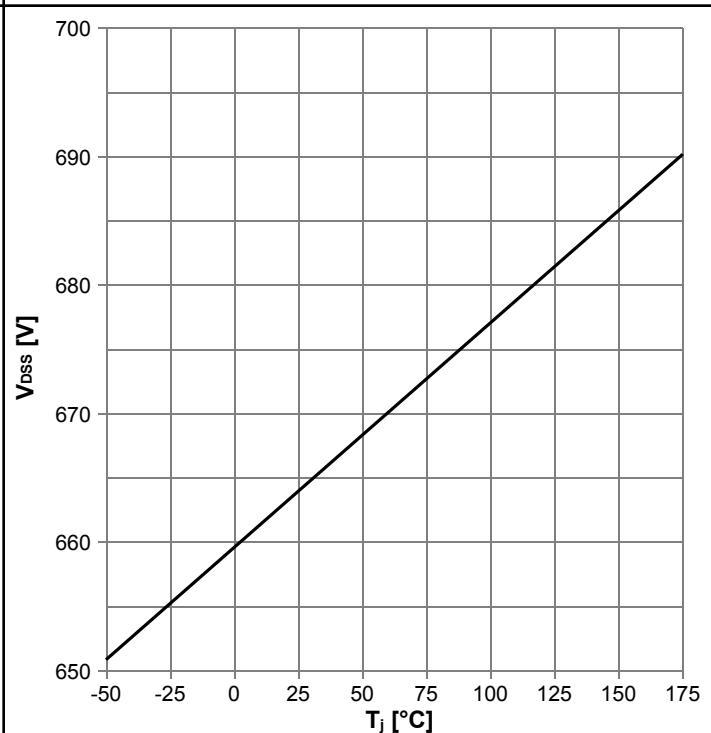
## IMW65R040M2H

Diagram 13: Avalanche energy



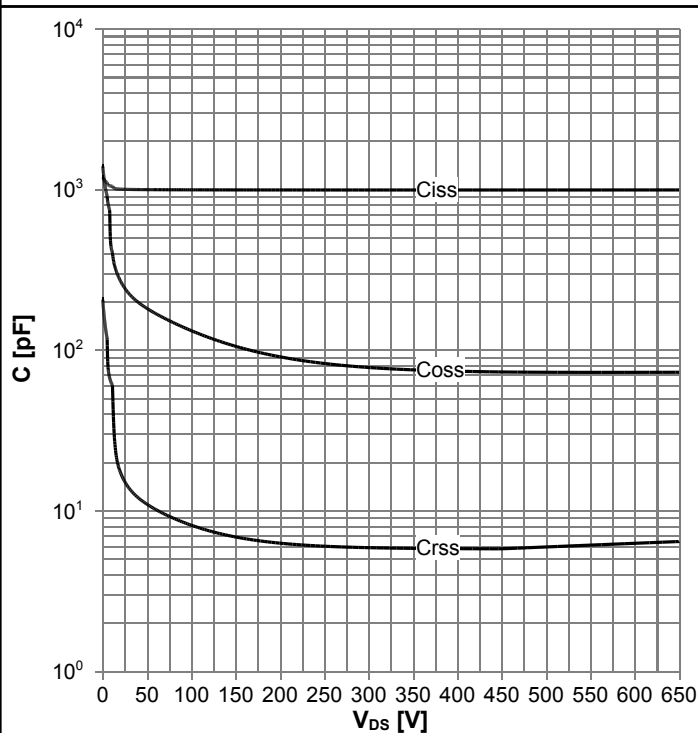
$E_{AS}=f(T_j)$ ;  $I_D=4.9$  A;  $V_{DD}=50$  V

Diagram 14: Drain-source breakdown voltage



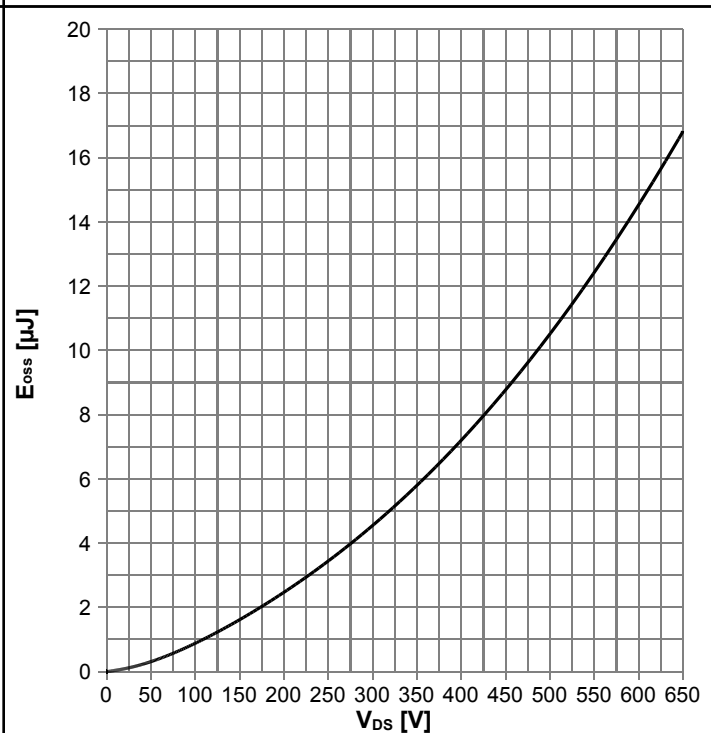
$V_{DSS}=f(T_j)$ ;  $I_D=0.46$  mA

Diagram 15: Typ. capacitances



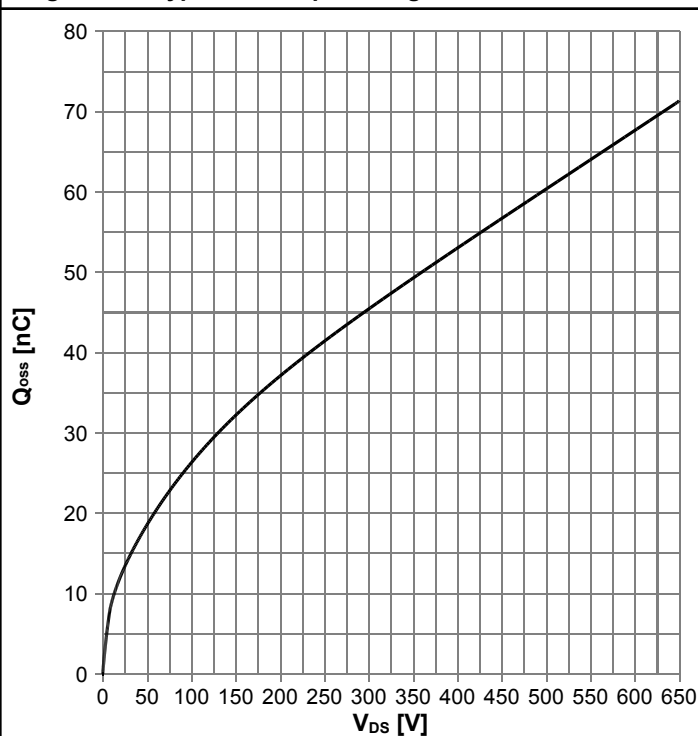
$C=f(V_{DS})$ ;  $V_{GS}=0$  V;  $f=250$  kHz

Diagram 16: Typ. Coss stored energy



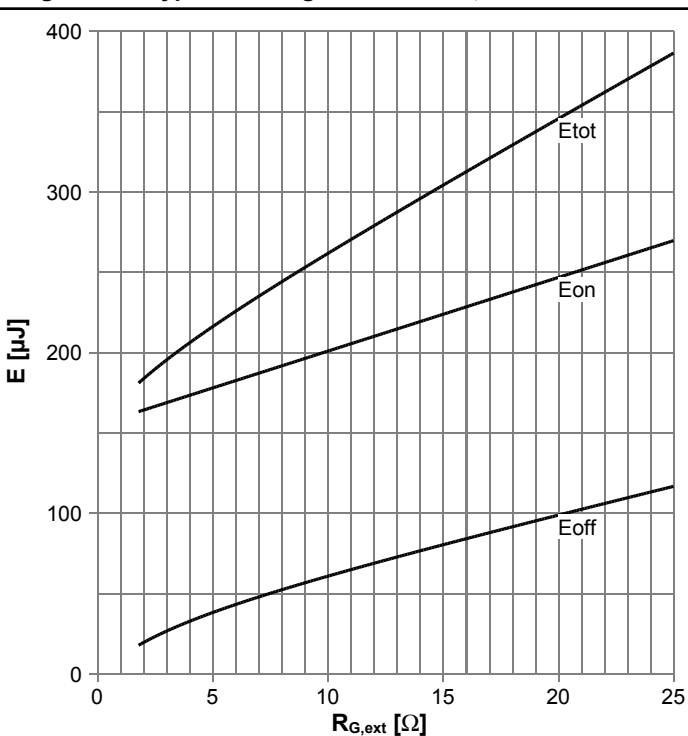
$E_{OSS}=f(V_{DS})$

Diagram 17: Typ. Qoss output charge



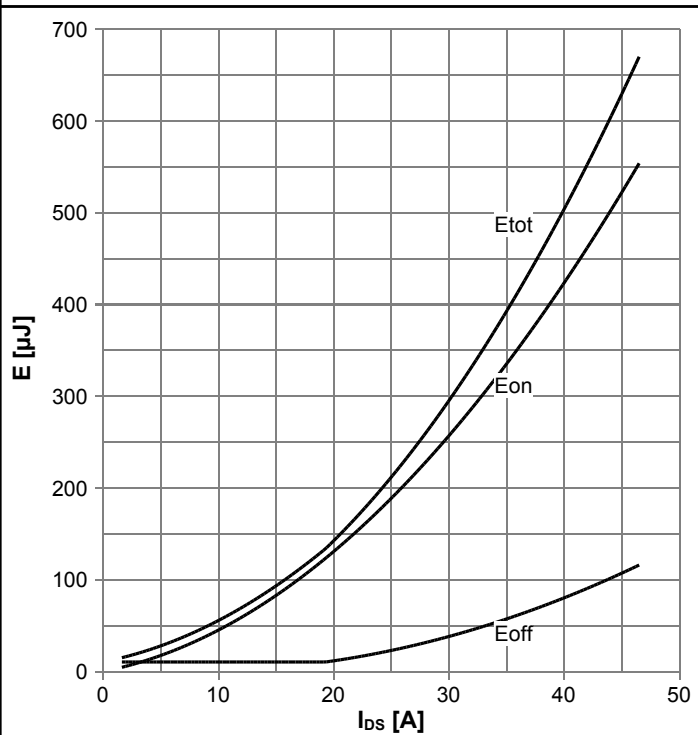
$Q_{oss}=f(V_{DS})$

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



$E=f(R_{G,ext}); V_{DD}=400\text{ V}; V_{GS}=0/18\text{ V}; I_D=22.9\text{ A}$

Diagram 19: Typ. Switching Losses vs switching current



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

## 6 Test Circuits

Table 9 Body diode characteristics

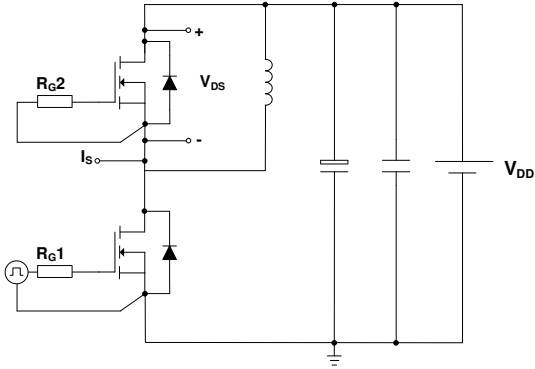
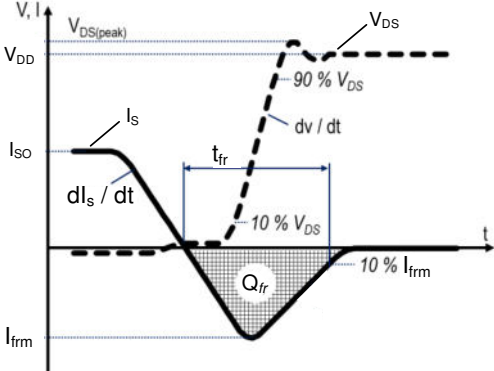
| Test circuit for body diode characteristics                                       | Body diode recovery waveform                                                       |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|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

Table 10 Switching times

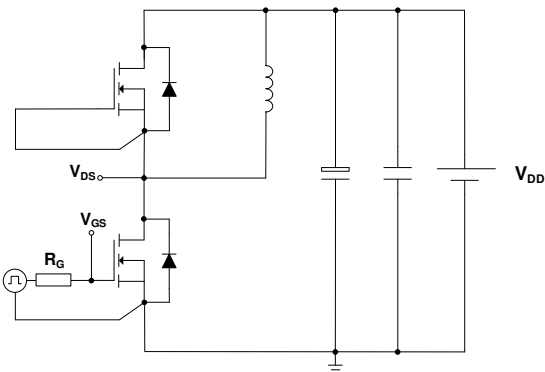
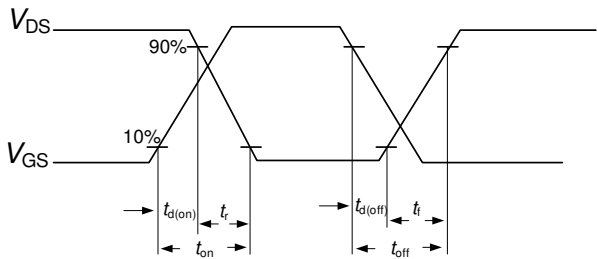
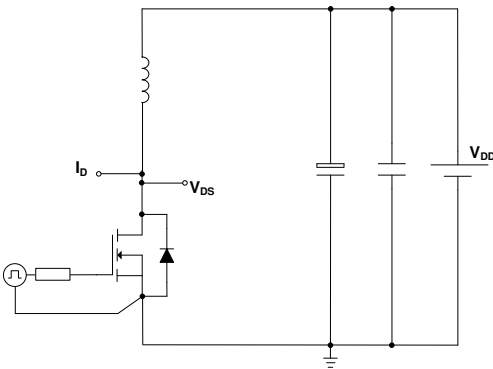
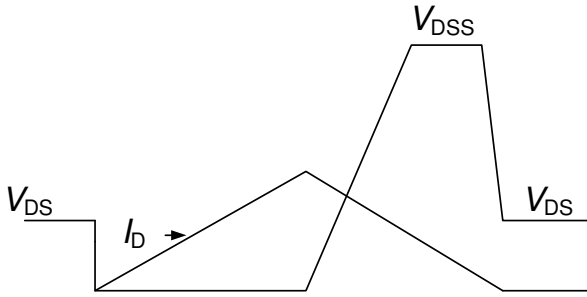
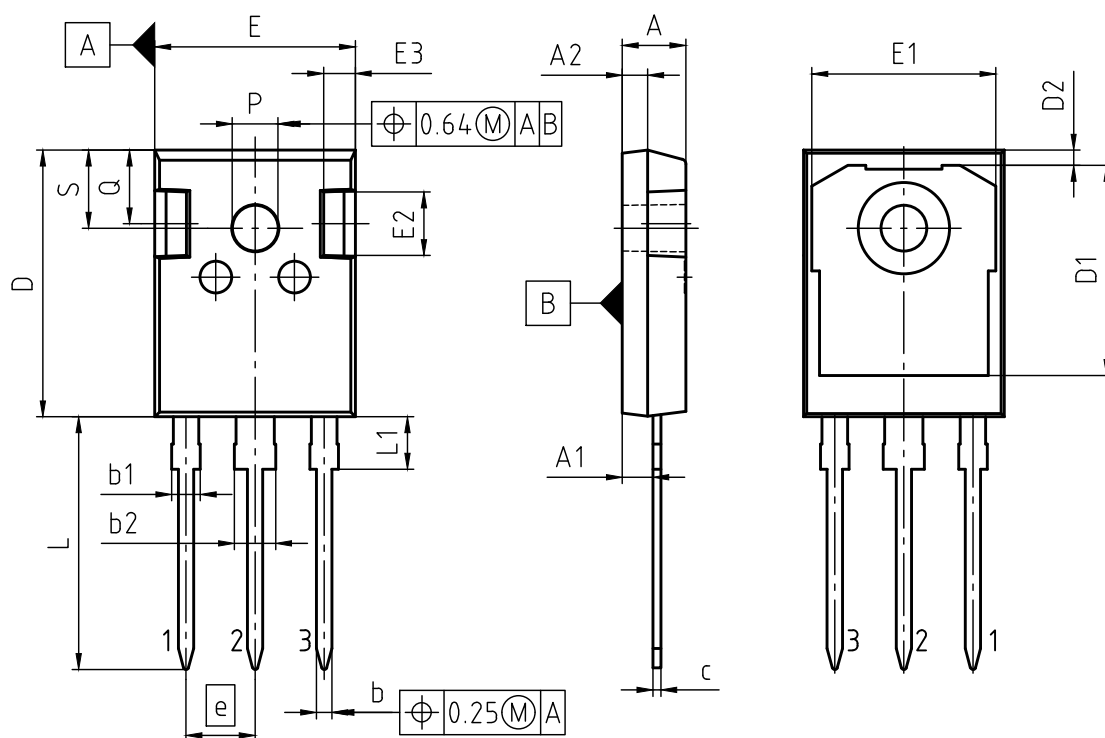
| Switching times test circuit for inductive load                                     | Switching times waveform                                                             |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|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

Table 11 Unclamped inductive load

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

## 7 Package Outlines



| PACKAGE - GROUP<br>NUMBER: <b>PG-TO247-3-U06</b> |             |       |
|--------------------------------------------------|-------------|-------|
| DIMENSIONS                                       | MILLIMETERS |       |
|                                                  | MIN.        | MAX.  |
| <b>A</b>                                         | 4.83        | 5.21  |
| <b>A1</b>                                        | 2.27        | 2.54  |
| <b>A2</b>                                        | 1.85        | 2.16  |
| <b>b</b>                                         | 1.07        | 1.33  |
| <b>b1</b>                                        | 1.90        | 2.41  |
| <b>b2</b>                                        | 2.87        | 3.38  |
| <b>c</b>                                         | 0.55        | 0.68  |
| <b>D</b>                                         | 20.80       | 21.10 |
| <b>D1</b>                                        | 16.25       | 17.65 |
| <b>D2</b>                                        | 0.95        | 1.35  |
| <b>E</b>                                         | 15.70       | 16.13 |
| <b>E1</b>                                        | 13.10       | 14.15 |
| <b>E2</b>                                        | 3.68        | 5.10  |
| <b>E3</b>                                        | 1.00        | 2.60  |
| <b>e</b>                                         | 5.44        |       |
| <b>N</b>                                         | 3           |       |
| <b>L</b>                                         | 19.80       | 20.32 |
| <b>L1</b>                                        | 4.10        | 4.47  |
| <b>øP</b>                                        | 3.50        | 3.70  |
| <b>Q</b>                                         | 5.49        | 6.00  |
| <b>S</b>                                         | 6.04        | 6.30  |

NOTE:  
DIMENSIONS DO NOT INCLUDE MOLDFLASH; PROTRUSION OR GATE BURRS

Figure 1 Outline PG-TO247-3, 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

IMW65R040M2H

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

Previous Revision

| Revision | Date       | Subjects (major changes since last revision)                      |
|----------|------------|-------------------------------------------------------------------|
| 2.0      | 2023-11-02 | 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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