

# INN650D02

## 650V GaN Enhancement-mode Power Transistor

### Features

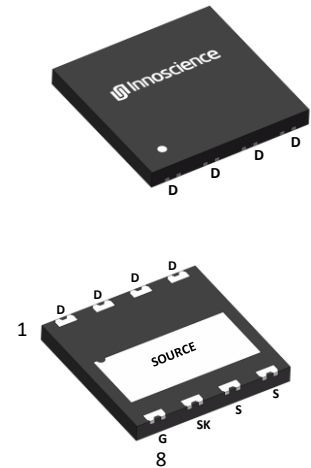
- Enhancement mode transistor-Normally off power switch
- Ultra high switching frequency
- No reverse-recovery charge
- Low gate charge, low output charge
- Qualified for industrial applications according to JEDEC Standards
- ESD safeguard

### Benefits

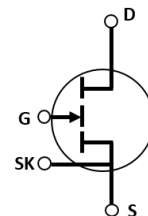
- High efficiency power switching
- High power density
- Enables higher switching frequency
- System cost savings

### Applications

- AC-DC converters
- DC-DC converters
- Totem pole PFC
- Fast battery charging
- High density power conversion
- High efficiency power conversion



|               |         |
|---------------|---------|
| Gate          | 8       |
| Drain         | 1,2,3,4 |
| Kelvin Source | 7       |
| Source        | 5,6     |



**Table 1 Key Performance Parameters at  $T_j = 25\text{ }^\circ\text{C}$**

| Parameter        | Value | Unit      |
|------------------|-------|-----------|
| $V_{DS,max}$     | 650   | V         |
| $R_{DS(on),max}$ | 200   | $m\Omega$ |
| $Q_{G,typ}$      | 1.0   | nC        |
| $I_{DS,Pulse}$   | 20    | A         |
| $Q_{OSS} @ 400V$ | 18    | nC        |
| $Q_{rr}$         | 0     | nC        |

**Table 2 Ordering Information**

| Type/Ordering Code | Package | Marking   |
|--------------------|---------|-----------|
| INN650D02          | DFN 8X8 | INN650D02 |

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## 1 Maximum ratings

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

Continuous application of maximum ratings can deteriorate transistor lifetime. For further information, contact Innoscence sales office.

**Table 3 Maximum ratings**

| Parameter                                    | Symbol              | Values |      |      | Unit | Note/Test Condition   |
|--|---------------------|--------|------|------|------|---|
|  |                     | Min.   | Typ. | Max. |      |   |
| Drain source voltage                         | $V_{DS,max}$        | -      | -    | 650  | V    | $V_{GS} = 0\text{ V}$ , $I_D = 100\text{ }\mu\text{A}$  |
| Drain source voltage transient <sup>1</sup>  | $V_{DS(transient)}$ | -      | -    | 750  | V    | $V_{GS} = 0\text{ V}$ , $V_{DS} = 750\text{ V}$   |
| Continuous current, drain source             | $I_D$               | -      | -    | 11   | A    | $T_c = 25\text{ °C}$  |
| Pulsed current, drain source <sup>2</sup>    | $I_{D,pulse}$       | -      | -    | 20   | A    | $T_c = 25\text{ °C}$ ; $V_G = 6\text{ V}$ ;<br>See Figure 15;   |
| Pulsed current, drain source <sup>2</sup>    | $I_{D,Pulse}$       | -      | -    | 15   | A    | $T_c = 125\text{ °C}$ ; $V_G = 6\text{ V}$ ; See<br>Figure 16;  |
| Gate source voltage, continuous <sup>3</sup> | $V_{GS}$            | -1.4   | -    | +7   | V    | $T_j = -55\text{ °C}$ to $150\text{ °C}$  |
| Gate source voltage, pulsed                  | $V_{GS,pulse}$      | -20    | -    | +10  | V    | $T_j = -55\text{ °C}$ to $150\text{ °C}$ ;<br>$t_{PLUSE} = 50\text{ ns}$ , $f = 100\text{ kHz}$<br>open drain |
| Power dissipation                            | $P_{tot}$           | -      | -    | 97   | W    | $T_c = 25\text{ °C}$  |
| Operating temperature                        | $T_j$               | -55    | -    | +150 | °C   |   |
| Storage temperature                          | $T_{stg}$           | -55    | -    | +150 | °C   |   |

1  $V_{DS(transient)}$  is intended for surge rating during non-repetitive events,  $t_{Pulse} < 1\text{ }\mu\text{s}$

2 Pulse = 300  $\mu\text{s}$

3 The minimum  $V_{GS}$  is clamped by ESD protection circuit, as shown in Figure 10

## 2 Thermal characteristics

Table 4 Thermal characteristics

| Parameter                         | Symbol     | Values |      |      | Unit | Note/Test Condition |
|-----------------------------------|------------|--------|------|------|------|---------------------|
|                                   |            | Min.   | Typ. | Max. |      |                     |
| Thermal resistance, junction-case | $R_{thJC}$ | -      | -    | 1.28 | °C/W |                     |
| Reflow soldering temperature      | $T_{sold}$ | -      | -    | 260  | °C   | MSL3                |

### 3 Electrical characteristics

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

**Table 5 Static characteristics**

| Parameter                        | Symbol       | Values |      |      | Unit             | Note/Test Condition   |
|----------------------------------|--------------|--------|------|------|------------------|---|
|                                  |              | Min.   | Typ. | Max. |                  |   |
| Gate threshold voltage           | $V_{GS(TH)}$ | 1.2    | 1.7  | 2.2  | V                | $I_D = 11\text{ mA}; V_{DS} = V_{GS}; T_j = 25\text{ }^\circ\text{C}$         |
|                                  |              | -      | 2    | -    |                  | $I_D = 11\text{ mA}; V_{DS} = V_{GS}; T_j = 125\text{ }^\circ\text{C}$        |
| Drain-source leakage current     | $I_{DSS}$    | -      | 0.5  | 100  | $\mu\text{A}$    | $V_{DS} = 650\text{ V}; V_{GS} = 0\text{ V}; T_j = 25\text{ }^\circ\text{C}$  |
|                                  |              | -      | 5    | -    |                  | $V_{DS} = 650\text{ V}; V_{GS} = 0\text{ V}; T_j = 150\text{ }^\circ\text{C}$ |
| Gate-source leakage current      | $I_{GSS}$    | -      | 10   | -    | $\mu\text{A}$    | $V_{GS} = 6\text{ V}; V_{DS} = 0\text{ V}$                                    |
| Drain-source on-state resistance | $R_{DS(on)}$ | -      | 180  | 200  | $\text{m}\Omega$ | $V_{GS} = 6\text{ V}; I_D = 3\text{ A}; T_j = 25\text{ }^\circ\text{C}$       |
|                                  |              | -      | 370  | -    |                  | $V_{GS} = 6\text{ V}; I_D = 3\text{ A}; T_j = 150\text{ }^\circ\text{C}$      |
| Gate resistance                  | $R_G$        | -      | 1.4  | -    | $\Omega$         | $F = 5\text{ MHz}; \text{open drain}$   |

**Table 6 Dynamic characteristics**

| Parameter   | Symbol      | Values |      |      | Unit | Note/Test Condition  |
|---|-------------|--------|------|------|------|--|
|   |             | Min.   | Typ. | Max. |      |  |
| Input capacitance   | $C_{iss}$   | -      | 70   | -    | pF   | $V_{GS} = 0\text{ V}; V_{DS} = 400\text{ V}; f = 100\text{ kHz}$ |
| Output capacitance  | $C_{oss}$   | -      | 18   | -    | pF   | $V_{GS} = 0\text{ V}; V_{DS} = 400\text{ V}; f = 100\text{ kHz}$ |
| Reverse transfer capacitance                              | $C_{rss}$   | -      | 0.3  | -    | pF   | $V_{GS} = 0\text{ V}; V_{DS} = 400\text{ V}; f = 100\text{ kHz}$ |
| Effective output capacitance, energy related <sup>1</sup> | $C_{o(er)}$ | -      | 29   | -    | pF   | $V_{GS} = 0\text{ V}; V_{DS} = 0\text{ to }400\text{ V}$         |
| Effective output capacitance, time related <sup>2</sup>   | $C_{o(tr)}$ | -      | 44   | -    | pF   | $V_{GS} = 0\text{ V}; V_{DS} = 0\text{ to }400\text{ V}$         |
| Output Charge   | $Q_{oss}$   | -      | 18   | -    | nC   | $V_{GS} = 0\text{ V}; V_{DS} = 0\text{ to }400\text{ V}$         |

<sup>1</sup>  $C_{o(er)}$  is the fixed capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400 V

<sup>2</sup>  $C_{o(tr)}$  is the fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400 V

**Table 7 Gate charge characteristics**

| Parameter            | Symbol     | Values |      |      | Unit | Note/Test Condition                                   |
|----------------------|------------|--------|------|------|------|---|
|                      |            | Min.   | Typ. | Max. |      |   |
| Gate charge          | $Q_G$      | -      | 1.0  | -    | nC   | $V_{GS} = 0$ to 6 V; $V_{DS} = 400$ V;<br>$I_D = 3$ A |
| Gate-source charge   | $Q_{GS}$   | -      | 0.16 | -    | nC   |   |
| Gate-drain charge    | $Q_{GD}$   | -      | 0.62 | -    | nC   |   |
| Gate Plateau Voltage | $V_{Plat}$ | -      | 2.2  | -    | V    | $V_{DS} = 400$ V; $I_D = 3$ A                         |

**Table 8 Reverse conduction characteristics**

| Parameter                     | Symbol        | Values |      |      | Unit | Note/Test Condition              |
|-------------------------------|---------------|--------|------|------|------|----------------------------------|
|                               |               | Min.   | Typ. | Max. |      |                                  |
| Source-Drain reverse voltage  | $V_{SD}$      | -      | 3    | -    | V    | $V_{GS} = 0$ V; $I_{SD} = 5$ A   |
| Pulsed current, reverse       | $I_{S,pulse}$ | -      | -    | 22   | A    | $V_G = -4$ V                     |
| Reverse recovery charge       | $Q_{rr}$      | -      | 0    | -    | nC   | $I_{SD} = 5$ A; $V_{DS} = 400$ V |
| Reverse recovery time         | $t_{rr}$      | -      | 0    | -    | ns   |                                  |
| Peak reverse recovery current | $I_{rrm}$     | -      | 0    | -    | A    |                                  |

## 4 Electrical characteristics diagrams

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

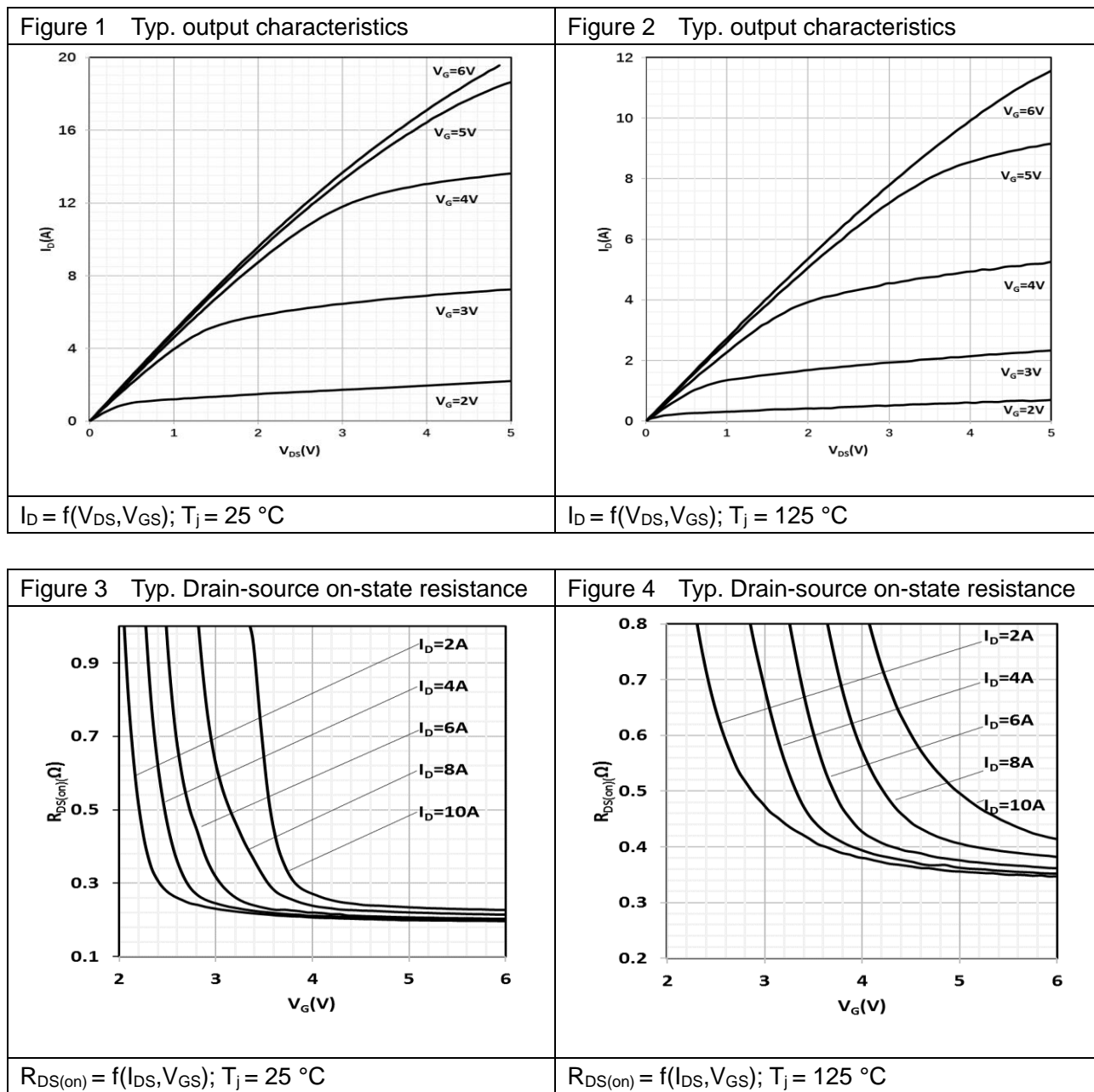
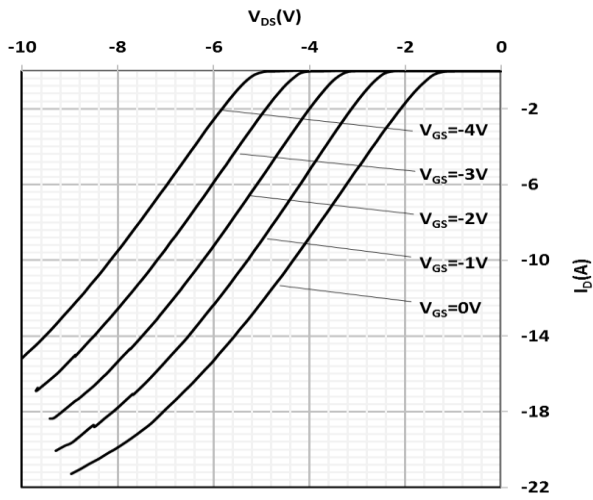
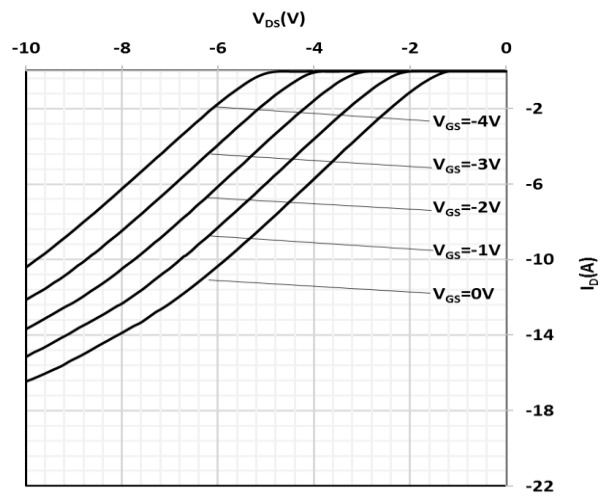


Figure 5 Typ. channel reverse characteristics



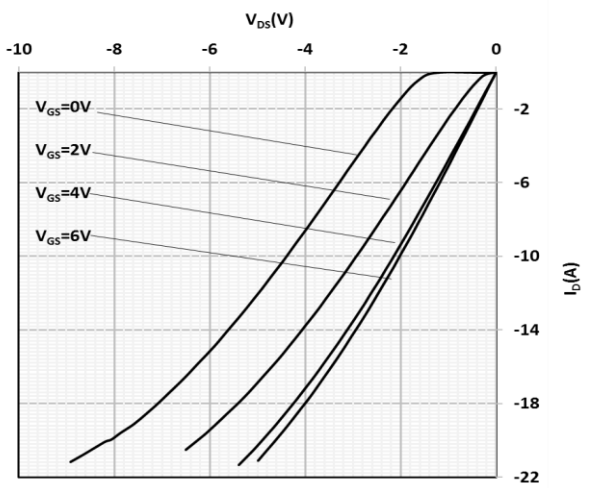
$I_D = f(V_{DS}, V_{GS}); T_j = 25\text{ °C}$

Figure 6 Typ. channel reverse characteristics



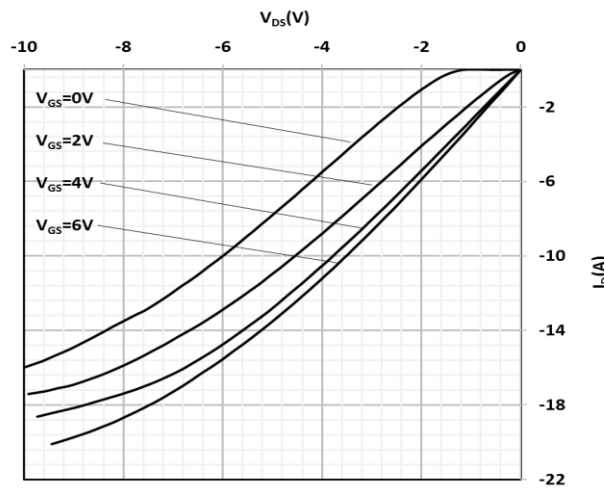
$I_D = f(V_{DS}, V_{GS}); T_j = 125\text{ °C}$

Figure 7 Typ. channel reverse characteristics



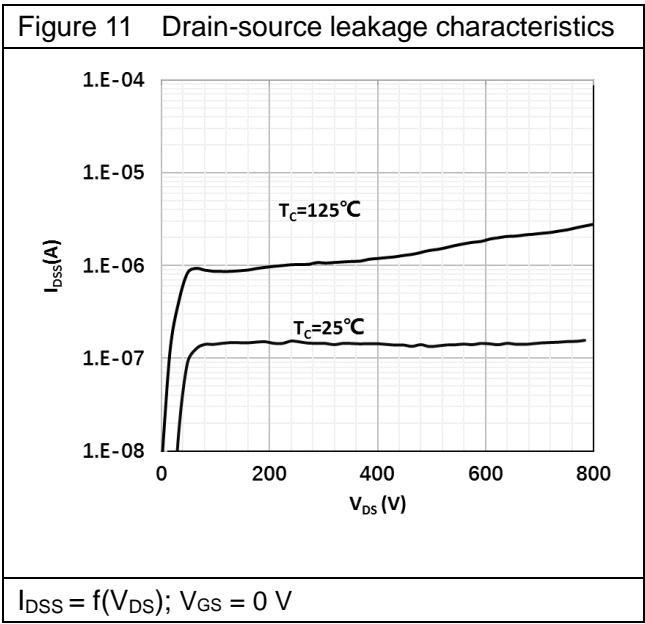
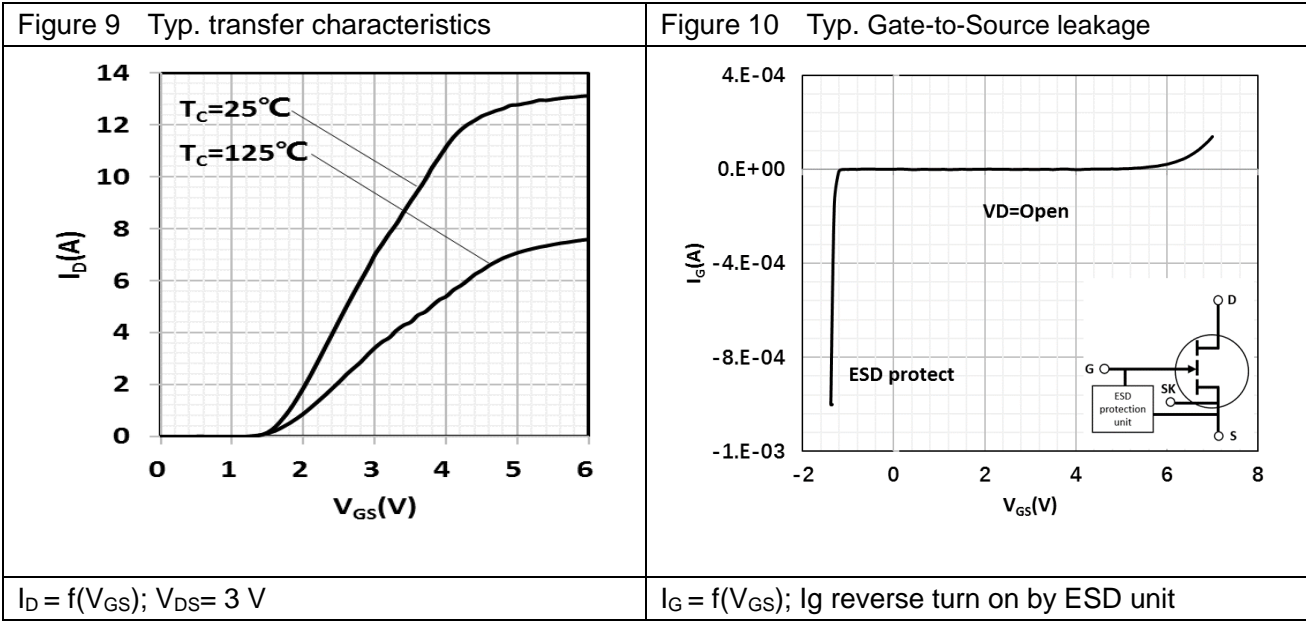
$I_D = f(V_{DS}, V_{GS}); T_j = 25\text{ °C}$

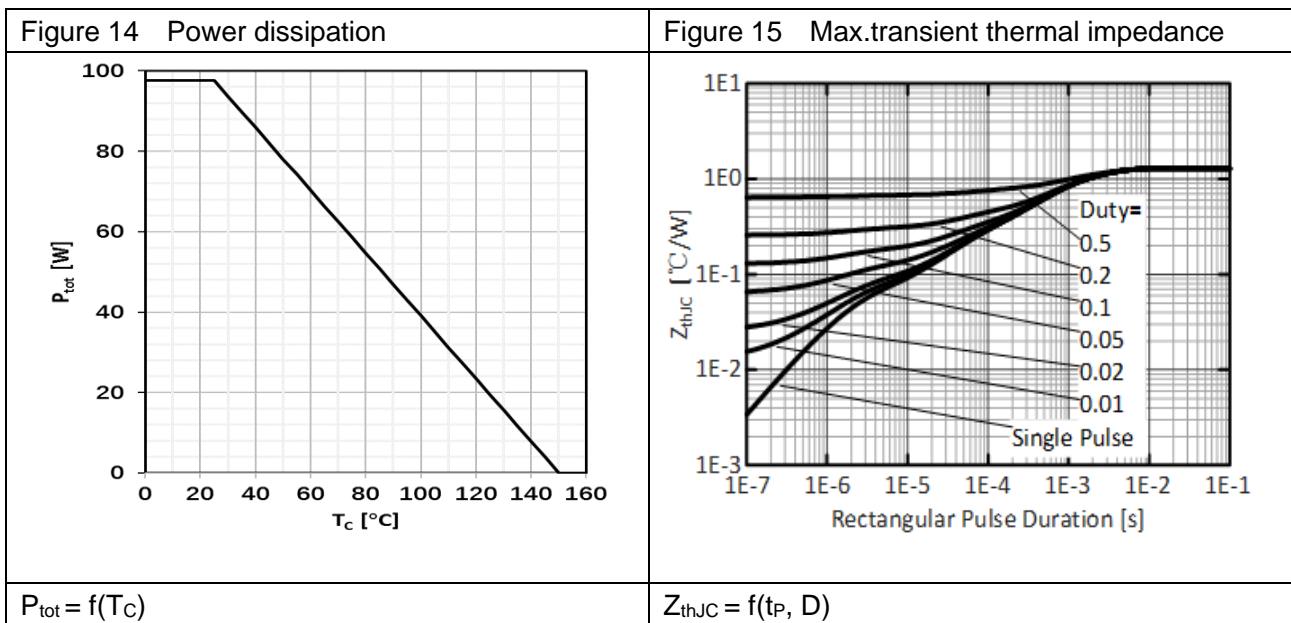
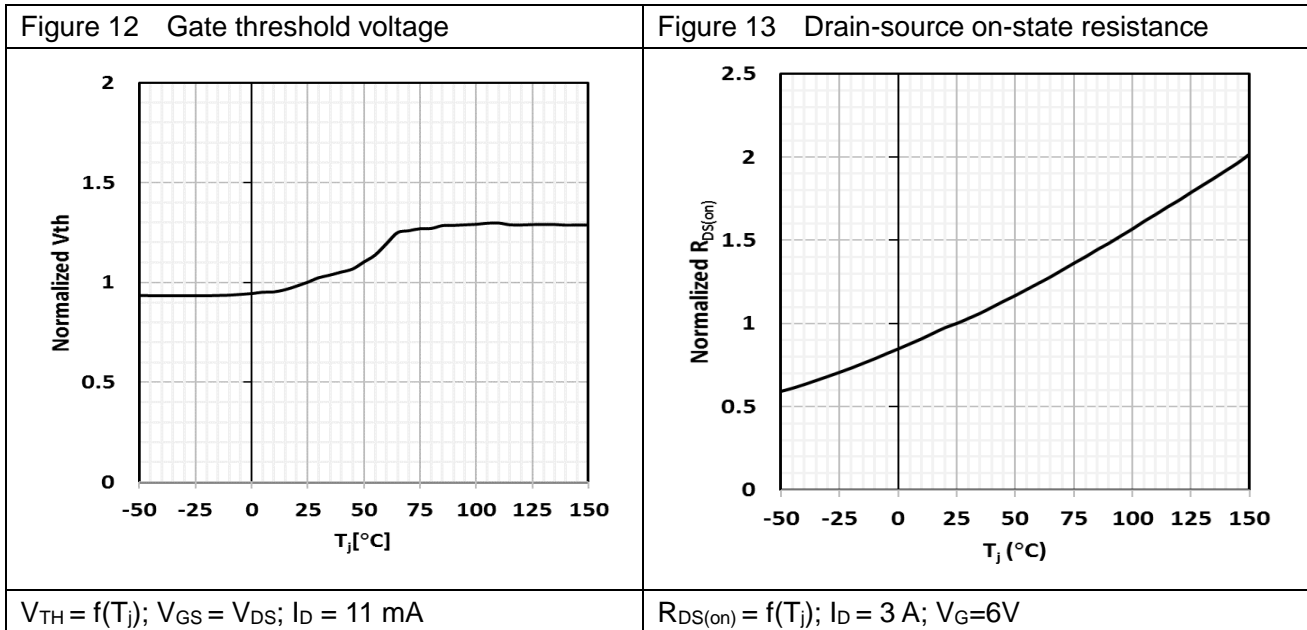
Figure 8 Typ. channel reverse characteristics

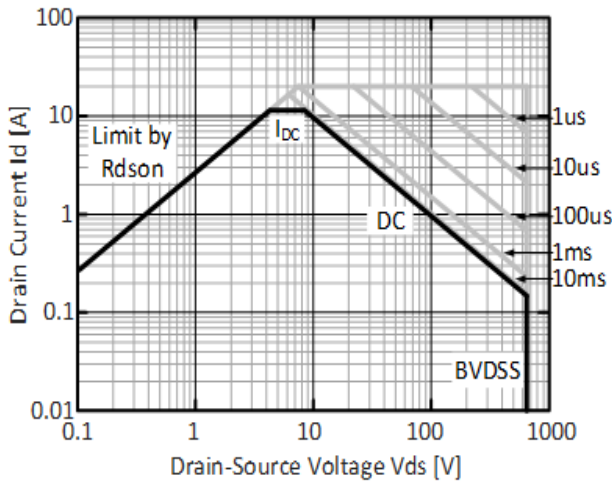
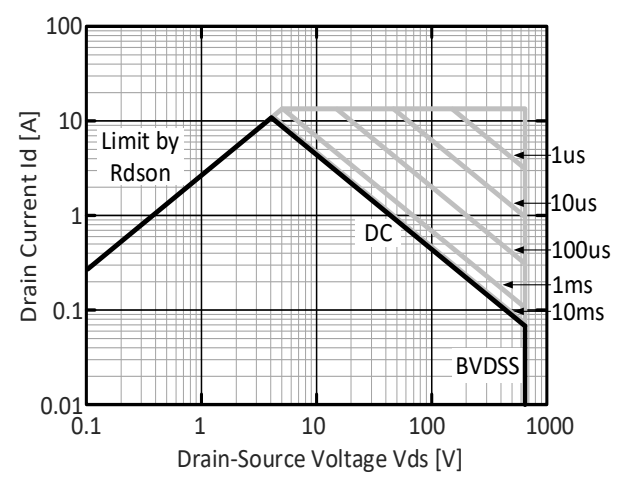
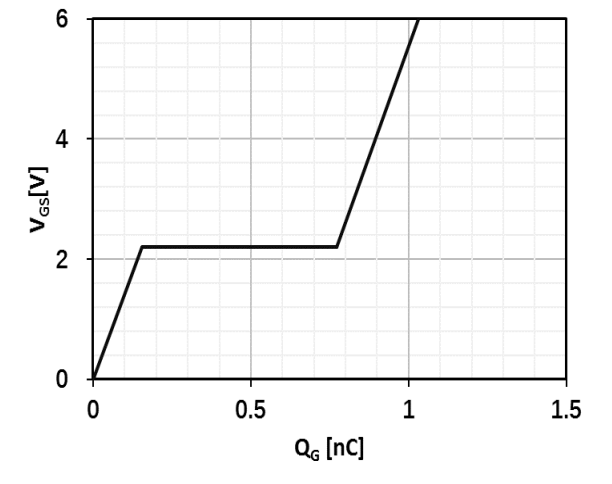
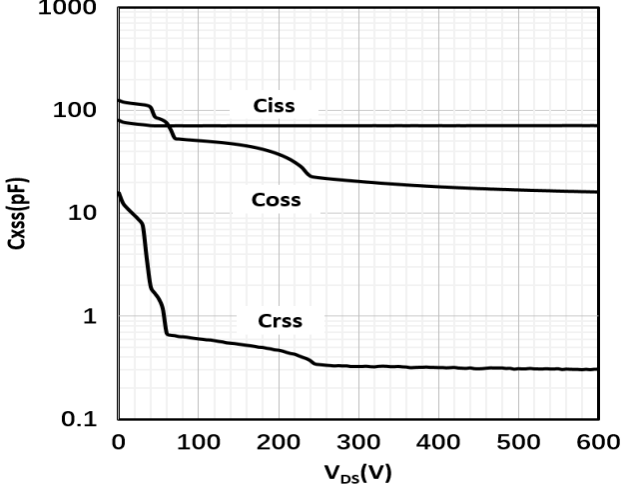


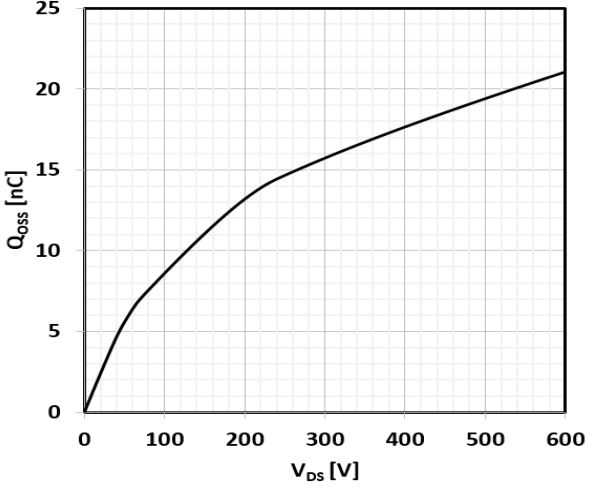
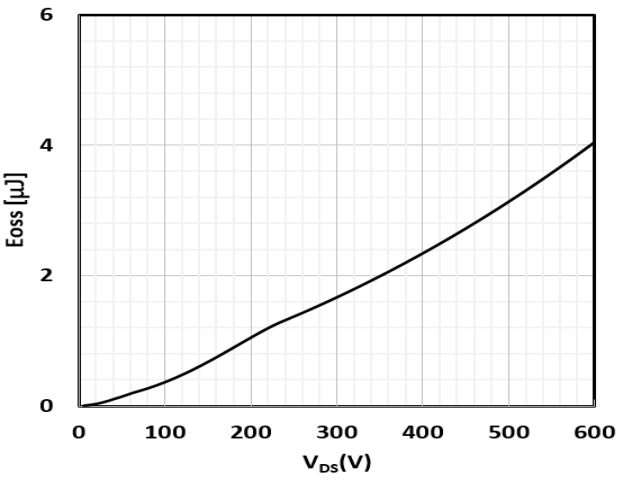
$I_D = f(V_{DS}, V_{GS}); T_j = 125\text{ °C}$



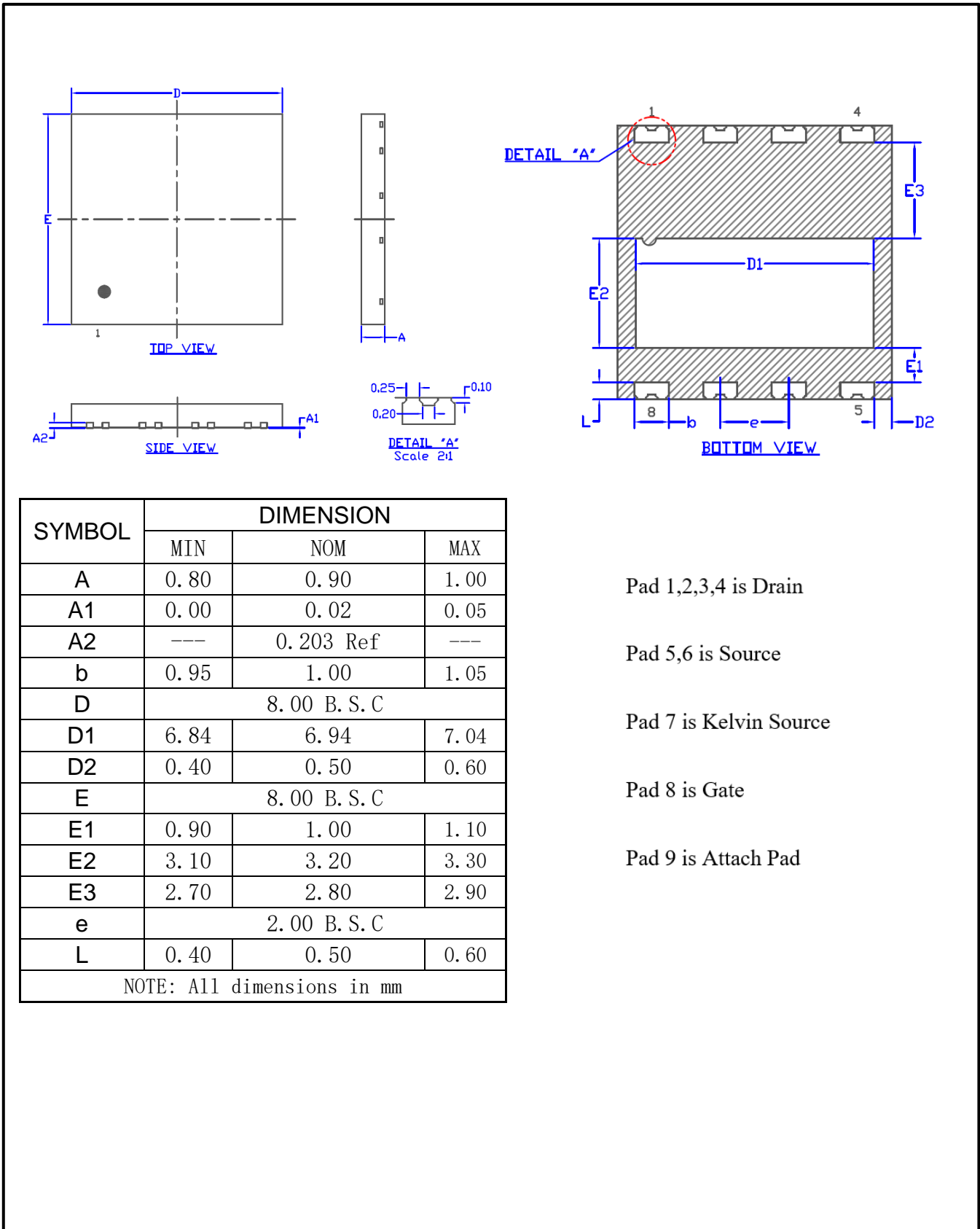




|   |  |
|---|--|
| <p><b>Figure 16 Safe operating area</b></p>  | <p><b>Figure 17 Safe operating area</b></p>  |
| <p><math>I_D = f(V_{DS}); T_C = 25\text{ }^\circ\text{C}</math></p>   | <p><math>I_D = f(V_{DS}); T_C = 125\text{ }^\circ\text{C}</math></p>   |
| <p><b>Figure 18 Typ. gate charge</b></p>    | <p><b>Figure 19 Typ. capacitances</b></p>   |
| <p><math>V_{GS} = f(Q_G); V_{DCLINK} = 400\text{ V}; I_D = 3\text{ A}</math></p>  | <p><math>C_{XSS} = f(V_{DS}); \text{Freq.} = 100\text{ kHz}</math></p>   |

| <p>Figure 20 Typ. output charge</p>  | <p>Figure 21 Typ. C<sub>oss</sub> stored Energy</p>         |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
|--|---|-----------------------|---|---|-----|---|-----|----|-----|----|-----|----|-----|----|-----|----|--|---------------------|-----------------------|---|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|  <table border="1"> <caption>Data for Figure 20: Typical output charge</caption> <thead> <tr> <th>V<sub>DS</sub> [V]</th> <th>Q<sub>oss</sub> [nC]</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td></tr> <tr><td>100</td><td>8</td></tr> <tr><td>200</td><td>13</td></tr> <tr><td>300</td><td>16</td></tr> <tr><td>400</td><td>18</td></tr> <tr><td>500</td><td>20</td></tr> <tr><td>600</td><td>21</td></tr> </tbody> </table> | V <sub>DS</sub> [V]   | Q <sub>oss</sub> [nC] | 0 | 0 | 100 | 8 | 200 | 13 | 300 | 16 | 400 | 18 | 500 | 20 | 600 | 21 |  <table border="1"> <caption>Data for Figure 21: Typical C<sub>oss</sub> stored Energy</caption> <thead> <tr> <th>V<sub>DS</sub> (V)</th> <th>E<sub>oss</sub> [μJ]</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td></tr> <tr><td>100</td><td>0.5</td></tr> <tr><td>200</td><td>1.2</td></tr> <tr><td>300</td><td>1.8</td></tr> <tr><td>400</td><td>2.5</td></tr> <tr><td>500</td><td>3.2</td></tr> <tr><td>600</td><td>4.2</td></tr> </tbody> </table> | V <sub>DS</sub> (V) | E <sub>oss</sub> [μJ] | 0 | 0 | 100 | 0.5 | 200 | 1.2 | 300 | 1.8 | 400 | 2.5 | 500 | 3.2 | 600 | 4.2 |
| V <sub>DS</sub> [V]  | Q <sub>oss</sub> [nC]                                       |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 0  | 0   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 100  | 8   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 200  | 13  |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 300  | 16  |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 400  | 18  |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 500  | 20  |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 600  | 21  |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| V <sub>DS</sub> (V)  | E <sub>oss</sub> [μJ]                                       |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 0  | 0   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 100  | 0.5   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 200  | 1.2   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 300  | 1.8   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 400  | 2.5   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 500  | 3.2   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| 600  | 4.2   |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |
| <p>Q<sub>oss</sub> = f(V<sub>DS</sub>); Freq. = 100 kHz</p>  | <p>E<sub>oss</sub> = f(V<sub>DS</sub>); Freq. = 100 kHz</p> |                       |   |   |     |   |     |    |     |    |     |    |     |    |     |    |  |                     |                       |   |   |     |     |     |     |     |     |     |     |     |     |     |     |

## 5 Package outlines



| SYMBOL                     | DIMENSION    |           |      |
|----------------------------|--------------|-----------|------|
|                            | MIN          | NOM       | MAX  |
| A                          | 0.80         | 0.90      | 1.00 |
| A1                         | 0.00         | 0.02      | 0.05 |
| A2                         | ---          | 0.203 Ref | ---  |
| b                          | 0.95         | 1.00      | 1.05 |
| D                          | 8.00 B. S. C |           |      |
| D1                         | 6.84         | 6.94      | 7.04 |
| D2                         | 0.40         | 0.50      | 0.60 |
| E                          | 8.00 B. S. C |           |      |
| E1                         | 0.90         | 1.00      | 1.10 |
| E2                         | 3.10         | 3.20      | 3.30 |
| E3                         | 2.70         | 2.80      | 2.90 |
| e                          | 2.00 B. S. C |           |      |
| L                          | 0.40         | 0.50      | 0.60 |
| NOTE: All dimensions in mm |              |           |      |

Pad 1,2,3,4 is Drain

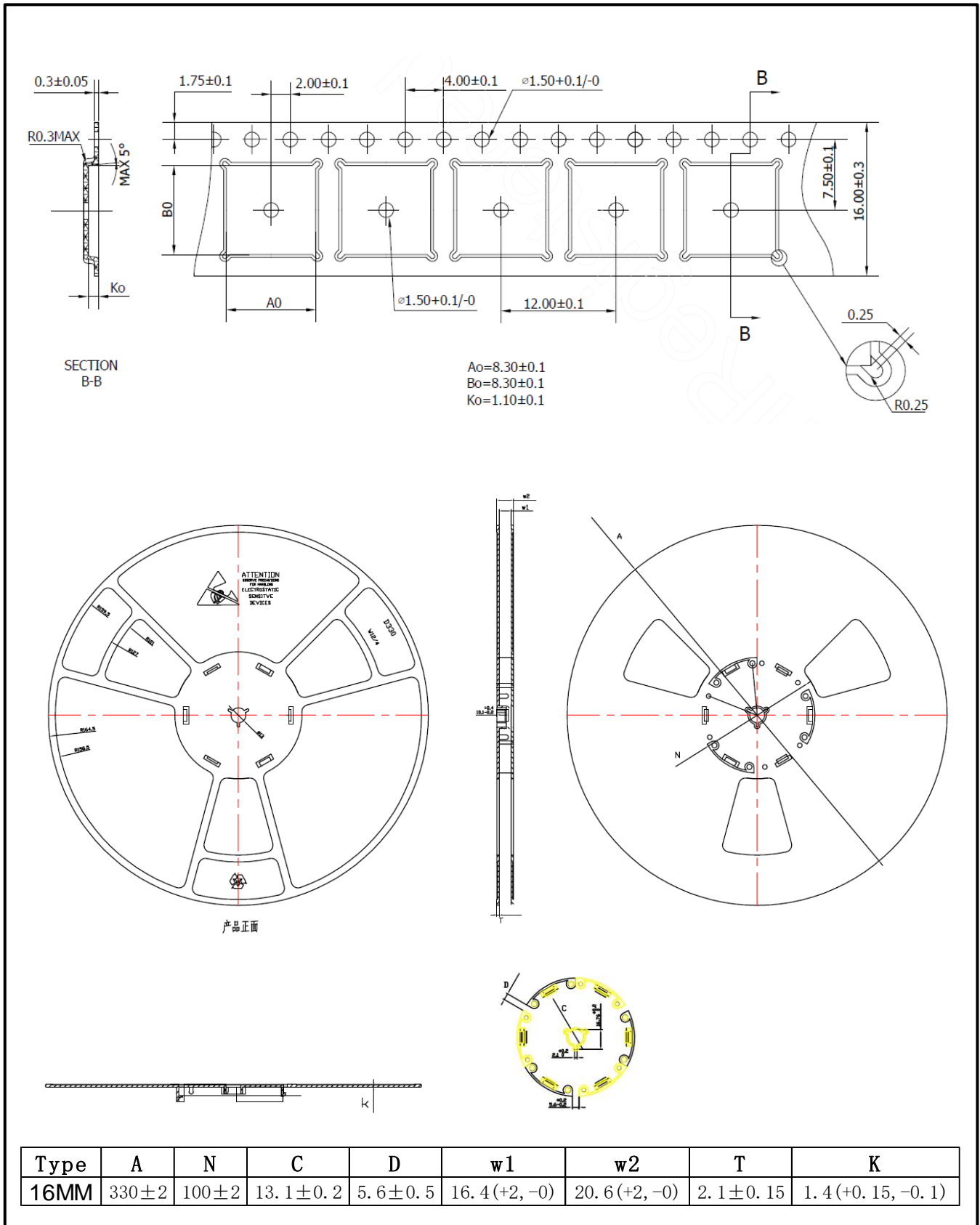
Pad 5,6 is Source

Pad 7 is Kelvin Source

Pad 8 is Gate

Pad 9 is Attach Pad

## 6 Reel information



## 7 Revision history

Major changes since the last revision

| Revision | Date       | Description of changes |
|----------|------------|------------------------|
| 1.0      | 2020-03-10 | Final version release  |
|          |            |                        |
|          |            |                        |