

# MOSFET

Metal Oxide Semiconductor Field Effect Transistor

## CoolMOS™ E6 600V

600V CoolMOS™ E6 Power Transistor  
IPx60R600E6

## Data Sheet

Rev. 2.4  
Final

## 600V CoolMOS™ E6 Power Transistor

IPD60R600E6, IPP60R600E6  
IPA60R600E6

### 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™ E6 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.

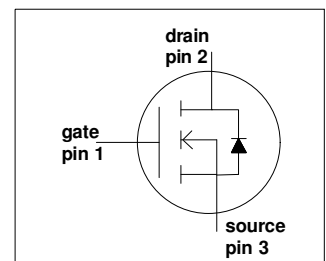
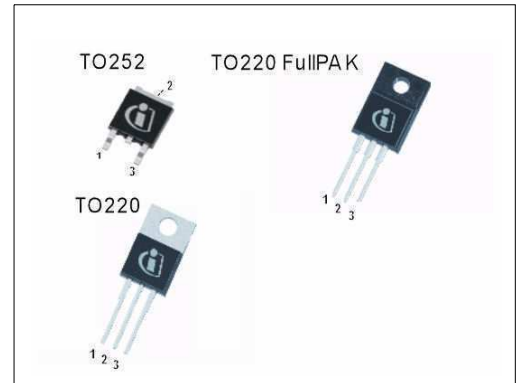
#### Features

- 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
- Fully qualified according to JEDEC for Industrial Applications

#### Applications

PFC stages, hard switching PWM stages and resonant switching PWM 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          |
| $R_{DS(on),max}$     | 0.6   | $\Omega$   |
| $Q_{g,typ}$          | 20.5  | nC         |
| $I_{D,pulse}$        | 19    | A          |
| $E_{oss} @ 400V$     | 1.9   | $\mu J$    |
| Body diode $di/dt$   | 500   | A/ $\mu s$ |

| Type / Ordering Code | Package          | Marking | Related Links                       |
|----------------------|------------------|---------|-------------------------------------|
| IPD60R600E6          | PG-TO252         | 6R600E6 | <a href="#">IFX CoolMOS Webpage</a> |
| IPP60R600E6          | PG-TO220         |         | <a href="#">IFX Design tools</a>    |
| IPA60R600E6          | PG-TO220 FullPAK |         |                                     |

## Table of Contents

|   |                                           |    |
|---|-------------------------------------------|----|
| 1 | Description .....                         | 2  |
|   | Table of Contents .....                   | 3  |
| 2 | Maximum ratings .....                     | 4  |
| 3 | Thermal characteristics .....             | 5  |
| 4 | Electrical characteristics .....          | 6  |
| 5 | Electrical characteristics diagrams ..... | 8  |
| 6 | Test circuits .....                       | 13 |
| 7 | Package outlines .....                    | 14 |
| 8 | Revision History .....                    | 18 |

## 2 Maximum ratings

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

**Table 2 Maximum ratings**

| Parameter                                     | Symbol         | Values |      |      | Unit | Note / Test Condition                                                         |
|-----------------------------------------------|----------------|--------|------|------|------|-------------------------------------------------------------------------------|
|                                               |                | Min.   | Typ. | Max. |      |                                                                               |
| Continuous drain current <sup>1)</sup>        | $I_D$          | -      | -    | 7.3  | A    | $T_C = 25\text{ °C}$                                                          |
|                                               |                |        |      | 4.6  |      | $T_C = 100\text{ °C}$                                                         |
| Pulsed drain current <sup>2)</sup>            | $I_{D,pulse}$  | -      | -    | 19   | A    | $T_C = 25\text{ °C}$                                                          |
| Avalanche energy, single pulse                | $E_{AS}$       | -      | -    | 133  | mJ   | $I_D = 1.3\text{ A}$ , $V_{DD} = 50\text{ V}$<br>(see table 21)               |
| Avalanche energy, repetitive                  | $E_{AR}$       | -      | -    | 0.2  |      | $I_D = 1.3\text{ A}$ , $V_{DD} = 50\text{ V}$                                 |
| Avalanche current, repetitive                 | $I_{AR}$       | -      | -    | 1.3  | A    |                                                                               |
| MOSFET dv/dt ruggedness                       | dv/dt          | -      | -    | 50   | V/ns | $V_{DS} = 0 \dots 480\text{ V}$                                               |
| Gate source voltage                           | $V_{GS}$       | -20    | -    | 20   | V    | static                                                                        |
|                                               |                | -30    |      | 30   |      | AC ( $f > 1\text{ Hz}$ )                                                      |
| Power dissipation for TO-220, TO-252          | $P_{tot}$      | -      | -    | 63   | W    | $T_C = 25\text{ °C}$                                                          |
| Power dissipation for TO-220 FullPAK          | $P_{tot}$      | -      | -    | 28   | W    | $T_C = 25\text{ °C}$                                                          |
| Operating and storage temperature             | $T_j, T_{stg}$ | -55    | -    | 150  | °C   |                                                                               |
| Mounting torque TO-220                        |                | -      | -    | 60   | Ncm  | M3 and M3.5 screws                                                            |
| Mounting torque TO-220 FullPAK                |                |        |      | 50   |      | M2.5 screws                                                                   |
| Continuous diode forward current              | $I_S$          | -      | -    | 6.3  | A    | $T_C = 25\text{ °C}$                                                          |
| Diode pulse current <sup>2)</sup>             | $I_{S,pulse}$  | -      | -    | 19   | A    | $T_C = 25\text{ °C}$                                                          |
| Reverse diode dv/dt <sup>3)</sup>             | dv/dt          | -      | -    | 15   | V/ns | $V_{DS} = 0 \dots 400\text{ V}$ , $I_{SD} \leq I_D$ ,<br>$T_j = 25\text{ °C}$ |
| Maximum diode commutation speed <sup>3)</sup> | di/dt          |        |      | 500  | A/μs | (see table 22)                                                                |

1) Limited by  $T_{j,max}$ . Maximum duty cycle  $D = 0.75$

2) Pulse width  $t_p$  limited by  $T_{j,max}$

3) Identical low side and high side switch with identical  $R_G$

### 3 Thermal characteristics

**Table 3 Thermal characteristics TO-220 (IPP60R600E6)**

| Parameter                                                  | Symbol     | Values |      |      | Unit | Note / Test Condition                 |
|------------------------------------------------------------|------------|--------|------|------|------|---------------------------------------|
|                                                            |            | Min.   | Typ. | Max. |      |                                       |
| Thermal resistance, junction - case                        | $R_{thJC}$ | -      | -    | 2.0  | °C/W | leaded                                |
| Thermal resistance, junction - ambient                     | $R_{thJA}$ | -      | -    | 62   |      |                                       |
| Soldering temperature, wavesoldering only allowed at leads | $T_{sold}$ | -      | -    | 260  | °C   | 1.6 mm (0.063 in.) from case for 10 s |

**Table 4 Thermal characteristics TO-220FullPAK (IPA60R600E6)**

| Parameter                                                  | Symbol     | Values |      |      | Unit | Note / Test Condition                 |
|------------------------------------------------------------|------------|--------|------|------|------|---------------------------------------|
|                                                            |            | Min.   | Typ. | Max. |      |                                       |
| Thermal resistance, junction - case                        | $R_{thJC}$ | -      | -    | 4.5  | °C/W | leaded                                |
| Thermal resistance, junction - ambient                     | $R_{thJA}$ | -      | -    | 80   |      |                                       |
| Soldering temperature, wavesoldering only allowed at leads | $T_{sold}$ | -      | -    | 260  | °C   | 1.6 mm (0.063 in.) from case for 10 s |

**Table 5 Thermal characteristics TO-252 (IPD60R600E6)**

| Parameter                                               | Symbol     | Values |      |      | Unit | Note / Test Condition                                                                                                                   |
|---------------------------------------------------------|------------|--------|------|------|------|-----------------------------------------------------------------------------------------------------------------------------------------|
|                                                         |            | Min.   | Typ. | Max. |      |                                                                                                                                         |
| Thermal resistance, junction - case                     | $R_{thJC}$ | -      | -    | 2.0  | °C/W | SMD version, device on PCB, minimal footprint<br>SMD version, device on PCB, 6cm <sup>2</sup> cooling area <sup>1)</sup><br>reflow MSL1 |
| Thermal resistance, junction - ambient                  | $R_{thJA}$ | -      | -    | 62   |      |                                                                                                                                         |
|                                                         |            |        | 35   |      |      |                                                                                                                                         |
| Soldering temperature, wave- & reflow soldering allowed | $T_{sold}$ | -      | -    | 260  | °C   |                                                                                                                                         |

1) Device on 40mm\*40mm\*1.5mm one layer epoxy PCB FR4 with 6cm<sup>2</sup> copper area (thickness 70µm) for drain connection. PCB is vertical without air stream cooling.

## 4 Electrical characteristics

Electrical characteristics, at  $T_J=25\text{ °C}$ , unless otherwise specified.

**Table 6 Static characteristics**

| Parameter                        | Symbol        | Values |      |      | Unit          | Note / Test Condition                                                |
|----------------------------------|---------------|--------|------|------|---------------|----------------------------------------------------------------------|
|                                  |               | Min.   | Typ. | Max. |               |                                                                      |
| Drain-source breakdown voltage   | $V_{(BR)DSS}$ | 600    | -    | -    | V             | $V_{GS}=0\text{ V}$ , $I_D=0.25\text{ mA}$                           |
| Gate threshold voltage           | $V_{GS(th)}$  | 2.5    | 3    | 3.5  |               | $V_{DS}=V_{GS}$ , $I_D=0.20\text{ mA}$                               |
| Zero gate voltage drain current  | $I_{DSS}$     | -      | -    | 1    | $\mu\text{A}$ | $V_{DS}=600\text{ V}$ , $V_{GS}=0\text{ V}$ ,<br>$T_J=25\text{ °C}$  |
|                                  |               | -      | 10   | -    |               | $V_{DS}=600\text{ V}$ , $V_{GS}=0\text{ V}$ ,<br>$T_J=150\text{ °C}$ |
| Gate-source leakage current      | $I_{GSS}$     | -      | -    | 100  | nA            | $V_{GS}=20\text{ V}$ , $V_{DS}=0\text{ V}$                           |
| Drain-source on-state resistance | $R_{DS(on)}$  | -      | 0.54 | 0.60 | $\Omega$      | $V_{GS}=10\text{ V}$ , $I_D=2.4\text{ A}$ ,<br>$T_J=25\text{ °C}$    |
|                                  |               | -      | 1.40 | -    |               | $V_{GS}=10\text{ V}$ , $I_D=2.4\text{ A}$ ,<br>$T_J=150\text{ °C}$   |
| Gate resistance                  | $R_G$         | -      | 10   | -    | $\Omega$      | $f=1\text{ MHz}$ , open drain                                        |

**Table 7 Dynamic characteristics**

| Parameter                                                  | Symbol       | Values |      |      | Unit | Note / Test Condition                                                                                             |
|------------------------------------------------------------|--------------|--------|------|------|------|-------------------------------------------------------------------------------------------------------------------|
|                                                            |              | Min.   | Typ. | Max. |      |                                                                                                                   |
| Input capacitance                                          | $C_{iss}$    | -      | 440  | -    | pF   | $V_{GS}=0\text{ V}$ , $V_{DS}=100\text{ V}$ ,<br>$f=1\text{ MHz}$                                                 |
| Output capacitance                                         | $C_{oss}$    | -      | 30   | -    |      |                                                                                                                   |
| Effective output capacitance, energy related <sup>1)</sup> | $C_{o(er)}$  | -      | 21   | -    |      | $V_{GS}=0\text{ V}$ ,<br>$V_{DS}=0\ldots 480\text{ V}$                                                            |
| Effective output capacitance, time related <sup>2)</sup>   | $C_{o(tr)}$  | -      | 88   | -    |      | $I_D=\text{constant}$ , $V_{GS}=0\text{ V}$<br>$V_{DS}=0\ldots 480\text{ V}$                                      |
| Turn-on delay time                                         | $t_{d(on)}$  | -      | 10   | -    | ns   | $V_{DD}=400\text{ V}$ ,<br>$V_{GS}=13\text{ V}$ , $I_D=3\text{ A}$ ,<br>$R_G=6.8\text{ }\Omega$<br>(see table 20) |
| Rise time                                                  | $t_r$        | -      | 8    | -    |      |                                                                                                                   |
| Turn-off delay time                                        | $t_{d(off)}$ | -      | 58   | -    |      |                                                                                                                   |
| Fall time                                                  | $t_f$        | -      | 11   | -    |      |                                                                                                                   |

1)  $C_{o(er)}$  is a fixed capacitance that gives the same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{(BR)DSS}$

2)  $C_{o(tr)}$  is a fixed capacitance that gives the same charging time as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 80%  $V_{(BR)DSS}$

**Table 8 Gate charge characteristics**

| Parameter             | Symbol               | Values |      |      | Unit | Note / Test Condition                                                            |
|-----------------------|----------------------|--------|------|------|------|----------------------------------------------------------------------------------|
|                       |                      | Min.   | Typ. | Max. |      |                                                                                  |
| Gate to source charge | $Q_{gs}$             | -      | 2.5  | -    | nC   | $V_{DD}=480\text{ V}$ , $I_D=3.0\text{ A}$ ,<br>$V_{GS}=0\text{ to }10\text{ V}$ |
| Gate to drain charge  | $Q_{gd}$             | -      | 10.5 | -    |      |                                                                                  |
| Gate charge total     | $Q_g$                | -      | 20.5 | -    |      |                                                                                  |
| Gate plateau voltage  | $V_{\text{plateau}}$ | -      | 5.4  | -    | V    |                                                                                  |

**Table 9 Reverse diode characteristics**

| Parameter                     | Symbol    | Values |      |      | Unit          | Note / Test Condition                                                                             |
|-------------------------------|-----------|--------|------|------|---------------|---------------------------------------------------------------------------------------------------|
|                               |           | Min.   | Typ. | Max. |               |                                                                                                   |
| Diode forward voltage         | $V_{SD}$  | -      | 0.9  | -    | V             | $V_{GS}=0\text{ V}$ , $I_F=3.0\text{ A}$ ,<br>$T_j=25\text{ °C}$                                  |
| Reverse recovery time         | $t_{rr}$  | -      | 250  | -    | ns            | $V_R=400\text{ V}$ , $I_F=3.0\text{ A}$ ,<br>$di_F/dt=100\text{ A}/\mu\text{s}$<br>(see table 22) |
| Reverse recovery charge       | $Q_{rr}$  | -      | 2.1  | -    | $\mu\text{C}$ |                                                                                                   |
| Peak reverse recovery current | $I_{rrm}$ | -      | 16   | -    | A             |                                                                                                   |

## 5 Electrical characteristics diagrams

Table 10

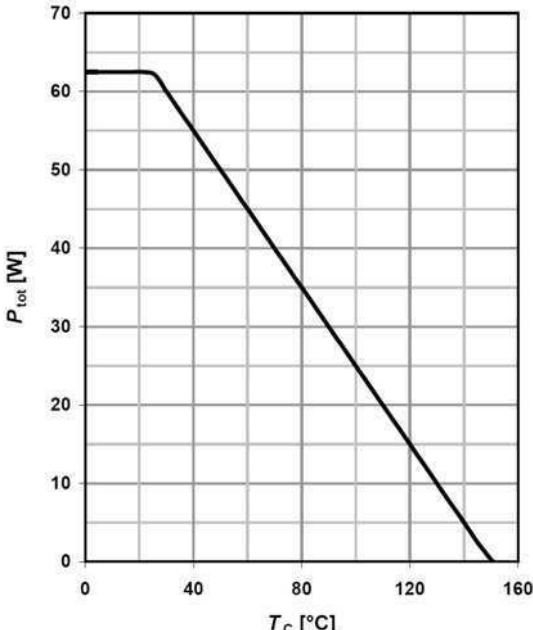
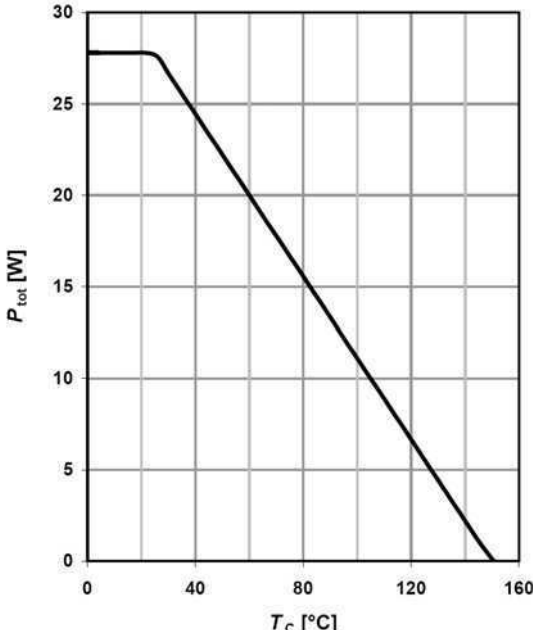
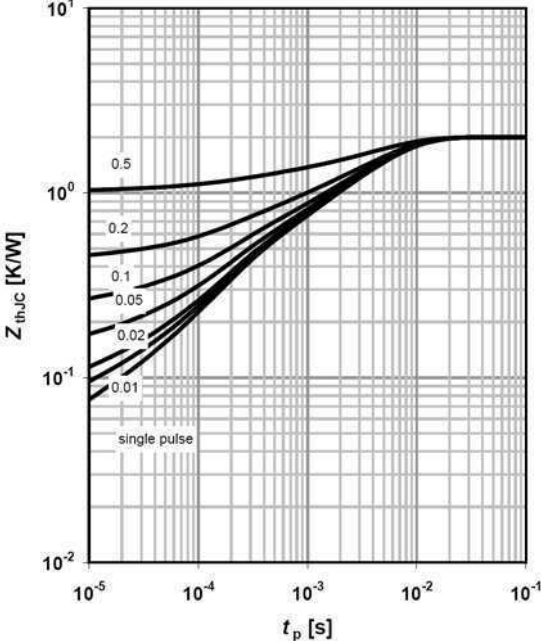
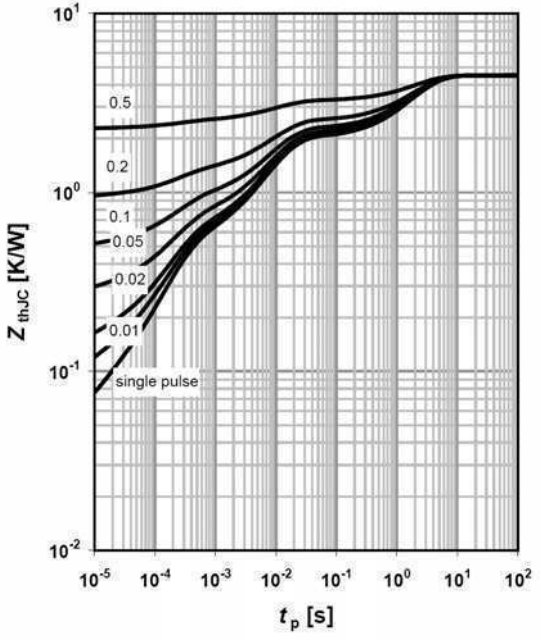
| Power dissipation<br>TO-220, TO-252                                                | Power dissipation<br>TO-220 FullPAK                                                 |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |
| $P_{\text{tot}} = f(T_c)$                                                          | $P_{\text{tot}} = f(T_c)$                                                           |

Table 11

| Max. transient thermal impedance<br>TO-220, TO-252                                  | Max. transient thermal impedance<br>TO-220 FullPAK                                   |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| $Z_{(\text{thJC})} = f(t_p)$ ; parameter: $D = t_p / T$                             | $Z_{(\text{thJC})} = f(t_p)$ ; parameter: $D = t_p / T$                              |



Electrical characteristics diagrams

Table 12

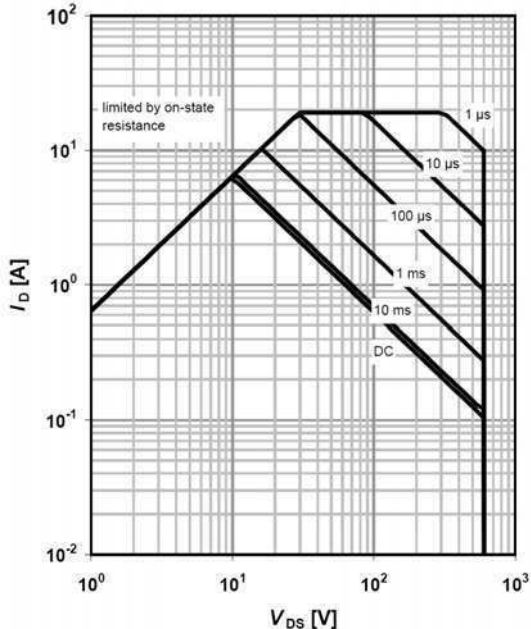
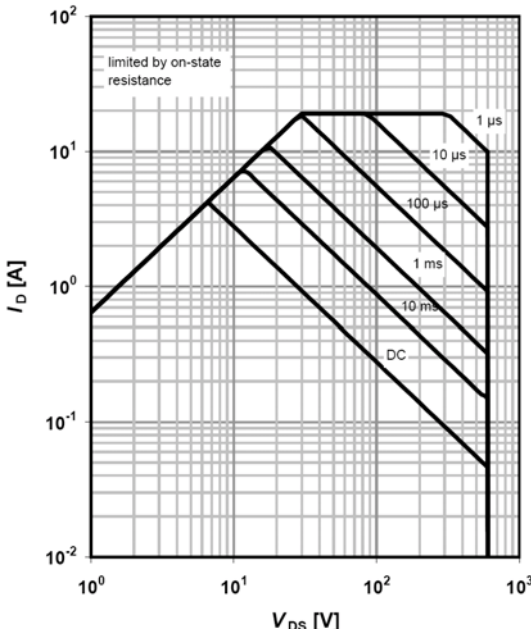
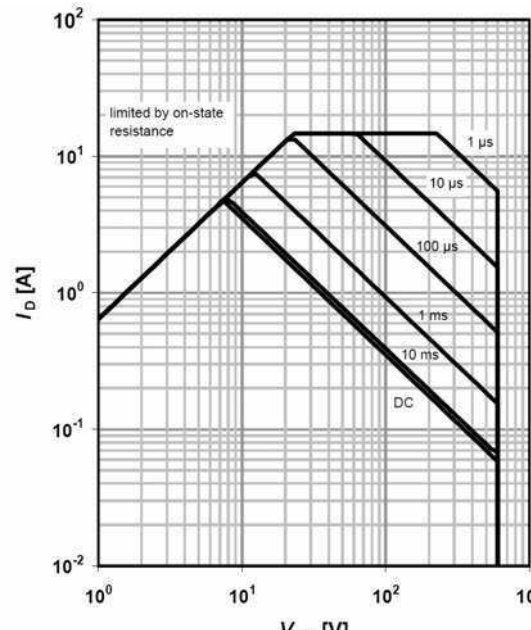
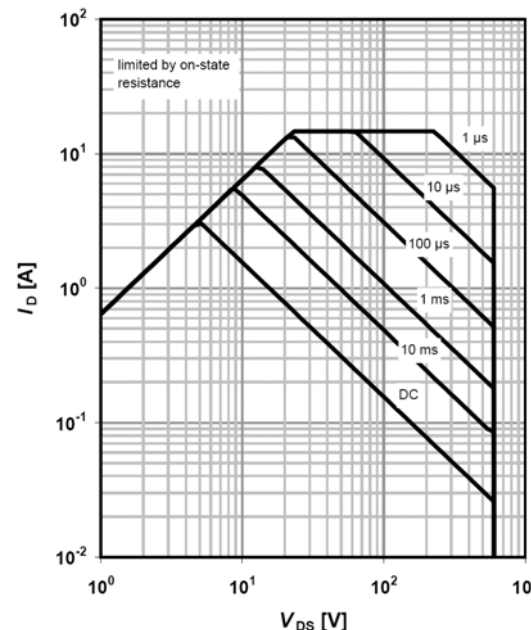
| Safe operating area $T_C=25\text{ °C}$<br>TO-220, TO-252                                                                                                           | Safe operating area $T_C=25\text{ °C}$<br>TO-220 FullPAK                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p><math>I_D=f(V_{DS}); T_C=25\text{ °C}; D=0; \text{parameter } t_p</math></p> |  <p><math>I_D=f(V_{DS}); T_C=25\text{ °C}; D=0; \text{parameter } t_p</math></p> |

Table 13

| Safe operating area $T_C=80\text{ °C}$<br>TO-220, TO-252                                                                                                            | Safe operating area $T_C=80\text{ °C}$<br>TO-220 FullPAK                                                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p><math>I_D=f(V_{DS}); T_C=80\text{ °C}; D=0; \text{parameter } t_p</math></p> |  <p><math>I_D=f(V_{DS}); T_C=80\text{ °C}; D=0; \text{parameter } t_p</math></p> |

Electrical characteristics diagrams

Table 14

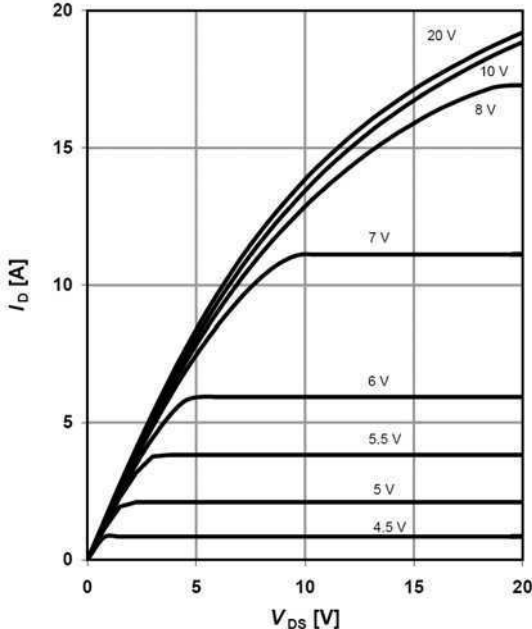
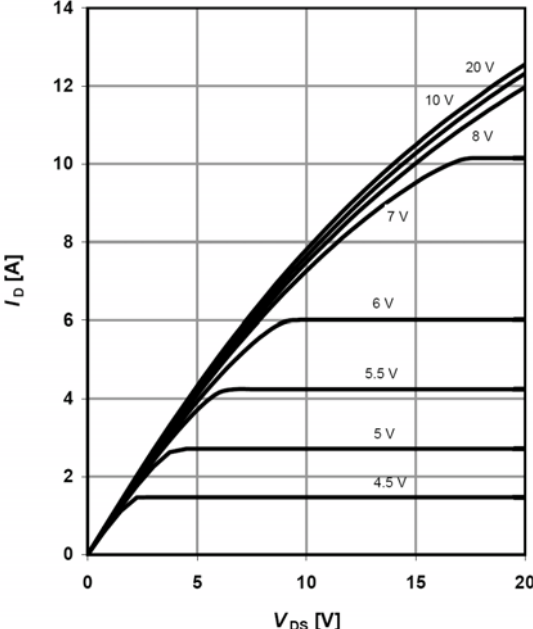
| Typ. output characteristics $T_c=25\text{ °C}$                                     | Typ. output characteristics $T_j=125\text{ °C}$                                     |
|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
|  |  |
| $I_D=f(V_{DS}); T_j=25\text{ °C}; \text{parameter: } V_{GS}$                       | $I_D=f(V_{DS}); T_j=125\text{ °C}; \text{parameter: } V_{GS}$                       |

Table 15

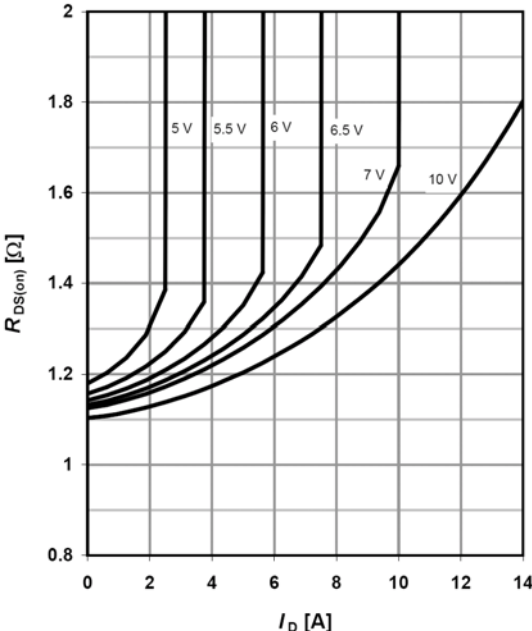
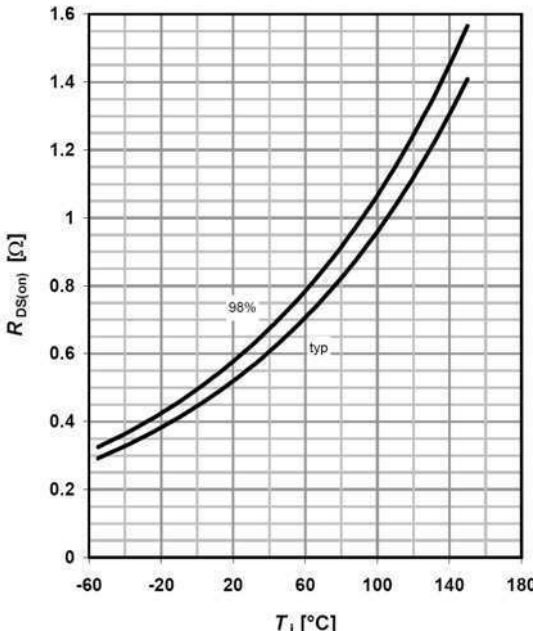
| Typ. drain-source on-state resistance                                               | Drain-source on-state resistance                                                     |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |
| $R_{DS(on)}=f(I_D); T_j=125\text{ °C}; \text{parameter: } V_{GS}$                   | $R_{DS(on)}=f(T_j); I_D=2.4\text{ A}; V_{GS}=10\text{ V}$                            |

Table 16

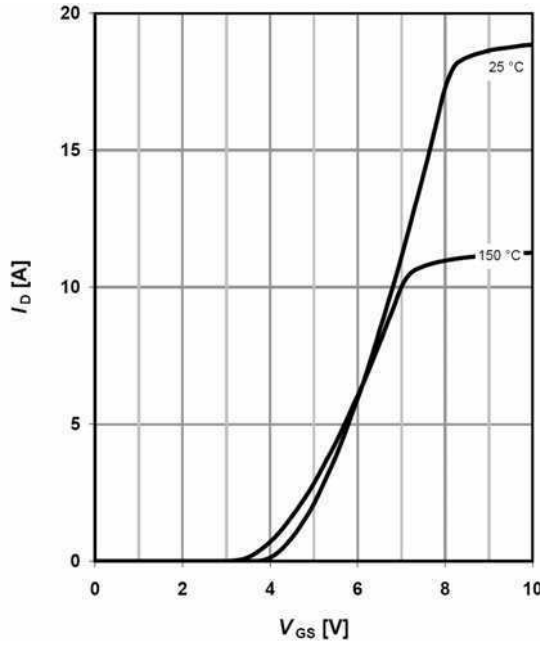
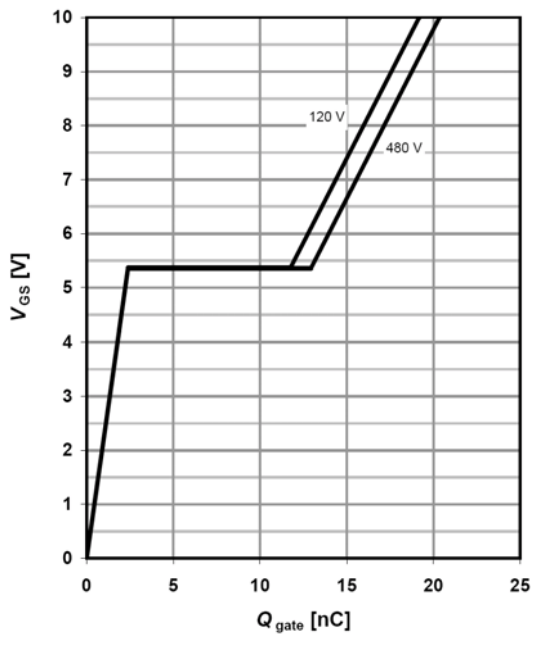
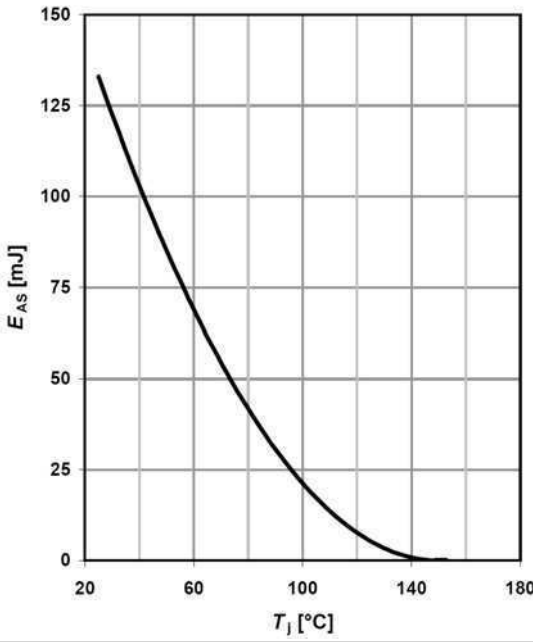
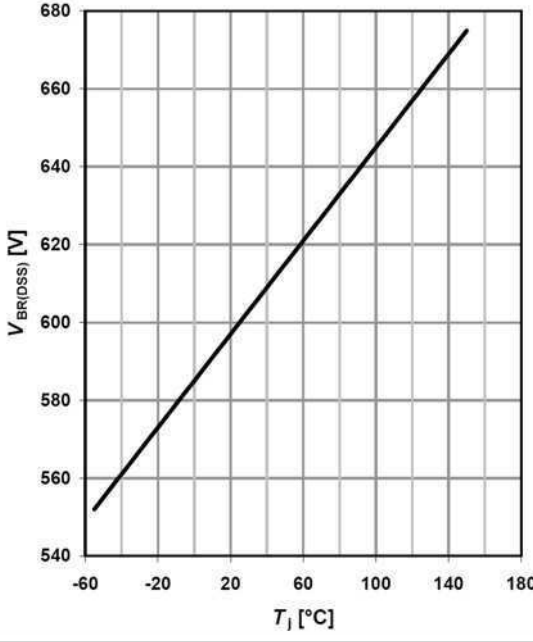
| Typ. transfer characteristics                                                                                                        | Typ. gate charge                                                                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p><math>I_D = f(V_{GS}); V_{DS} = 20V</math></p> |  <p><math>V_{GS} = f(Q_{gate}), I_D = 3.0A</math> pulsed</p> |

Table 17

| Avalanche energy                                                                                                                                    | Drain-source breakdown voltage                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
|  <p><math>E_{AS} = f(T_j); I_D = 1.3 A; V_{DD} = 50 V</math></p> |  <p><math>V_{BR(DSS)} = f(T_j); I_D = 0.25 mA</math></p> |

Electrical characteristics diagrams

Table 18

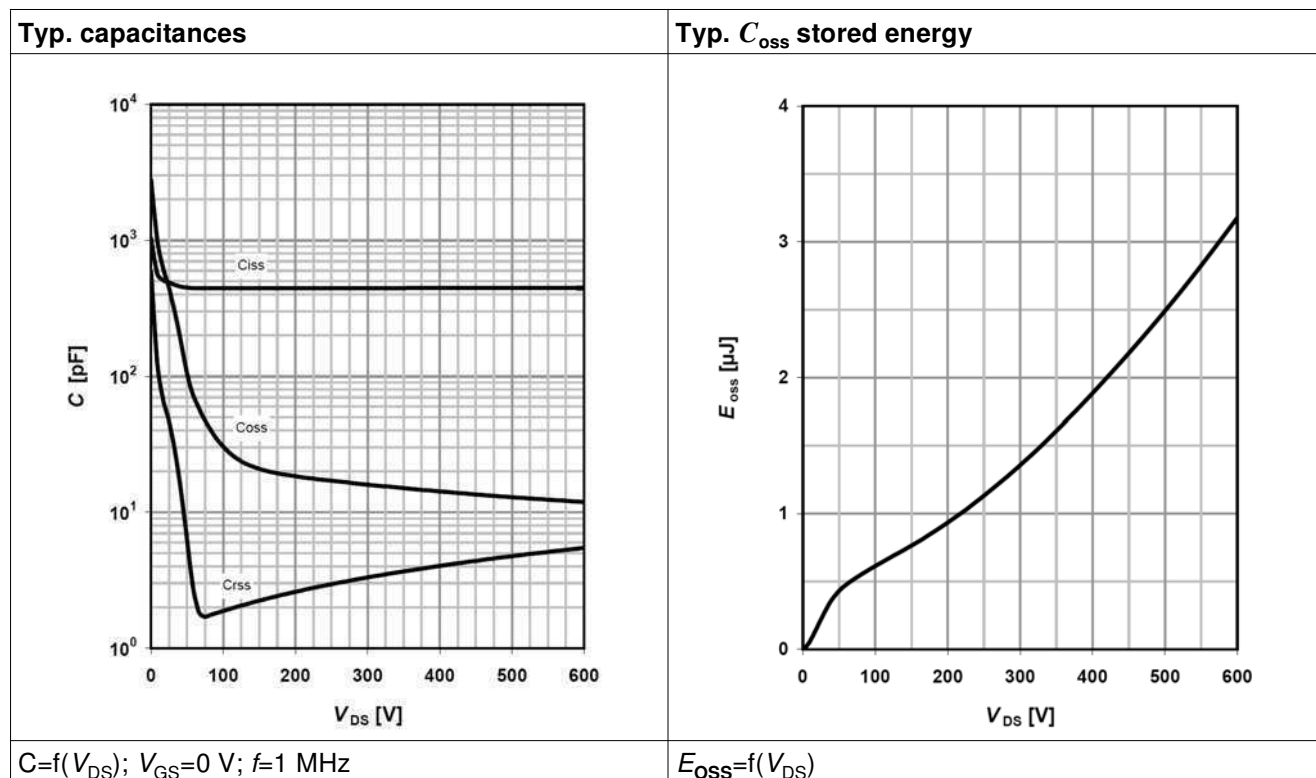
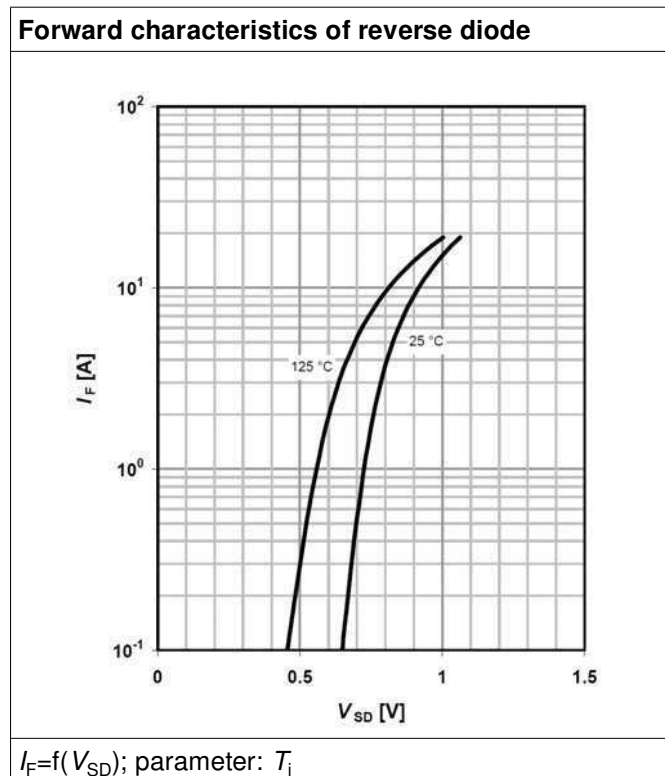


Table 19



## 6 Test circuits

Table 20 Switching times test circuit and waveform for inductive load

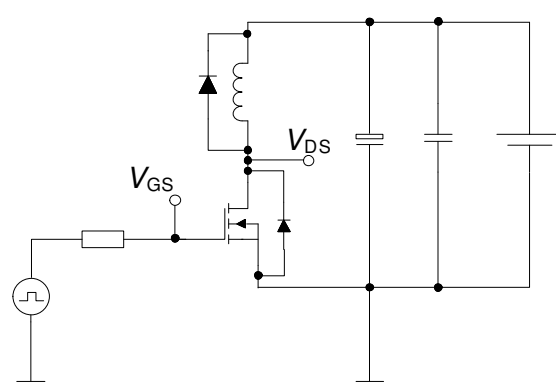
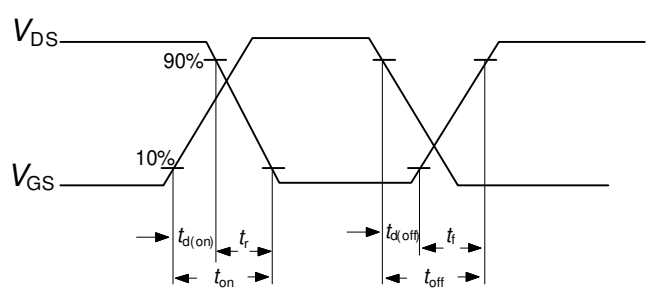
| Switching times test circuit for inductive load                                   | Switching time waveform                                                            |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|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

Table 21 Unclamped inductive load test circuit and waveform

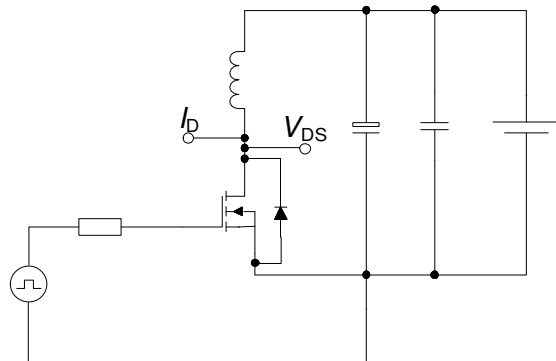
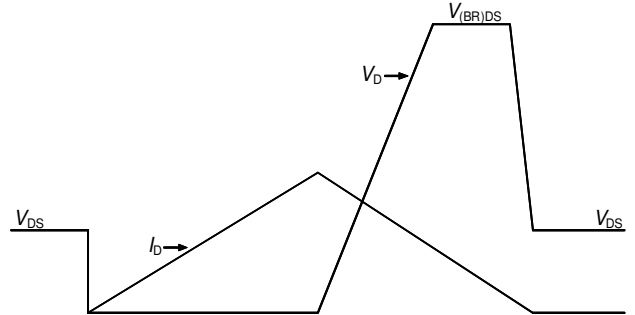
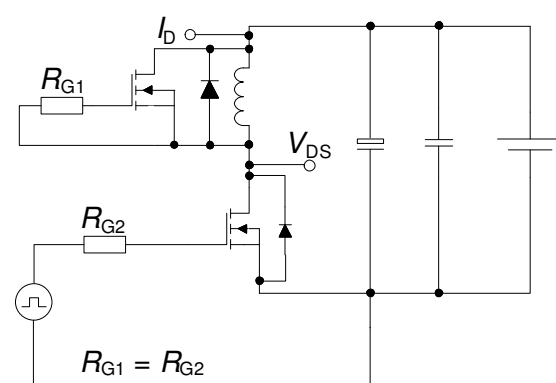
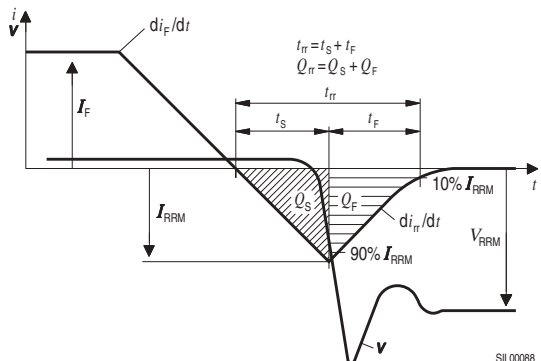
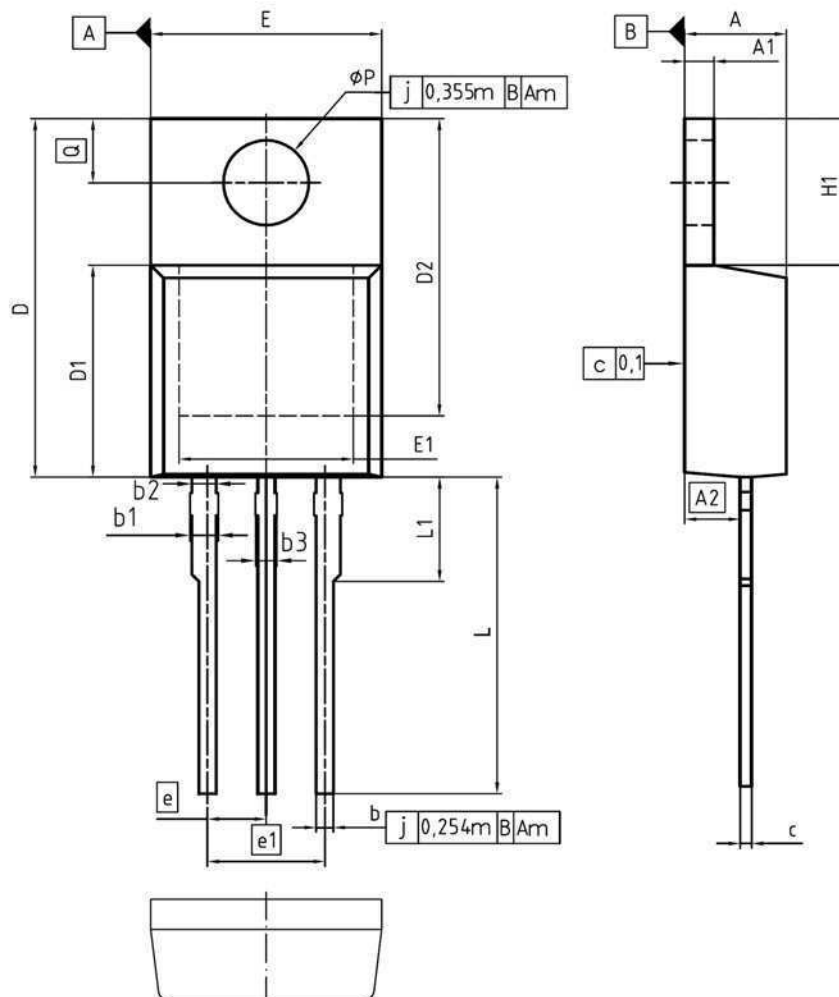
| Unclamped inductive load test circuit                                               | Unclamped inductive waveform                                                         |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|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

Table 22 Test circuit and waveform for diode characteristics

| Test circuit for diode characteristics                                              | Diode recovery waveform                                                              |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|  |  |

## 7 Package outlines



| DIM | MILLIMETERS |       | INCHES |       |
|-----|-------------|-------|--------|-------|
|     | MIN         | MAX   | MIN    | MAX   |
| A   | 4.30        | 4.57  | 0.169  | 0.180 |
| A1  | 1.17        | 1.40  | 0.046  | 0.055 |
| A2  | 2.15        | 2.72  | 0.085  | 0.107 |
| b   | 0.65        | 0.86  | 0.026  | 0.034 |
| b1  | 0.95        | 1.40  | 0.037  | 0.055 |
| b2  | 0.95        | 1.15  | 0.037  | 0.045 |
| b3  | 0.65        | 1.15  | 0.026  | 0.045 |
| c   | 0.33        | 0.60  | 0.013  | 0.024 |
| D   | 14.81       | 15.95 | 0.583  | 0.628 |
| D1  | 8.51        | 9.45  | 0.335  | 0.372 |
| D2  | 12.19       | 13.10 | 0.480  | 0.516 |
| E   | 9.70        | 10.36 | 0.382  | 0.408 |
| E1  | 6.50        | 8.60  | 0.256  | 0.339 |
| e   | 2.54        |       | 0.100  |       |
| e1  | 5.08        |       | 0.200  |       |
| N   | 3           |       | 3      |       |
| H1  | 5.90        | 6.90  | 0.232  | 0.272 |
| L   | 13.00       | 14.00 | 0.512  | 0.551 |
| L1  | -           | 4.80  | -      | 0.189 |
| ϕP  | 3.60        | 3.89  | 0.142  | 0.153 |
| Q   | 2.60        | 3.00  | 0.102  | 0.118 |

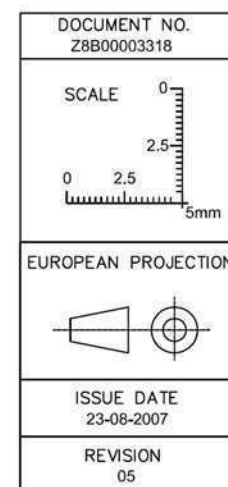


Figure 1 Outlines TO-220, dimensions in mm/inches

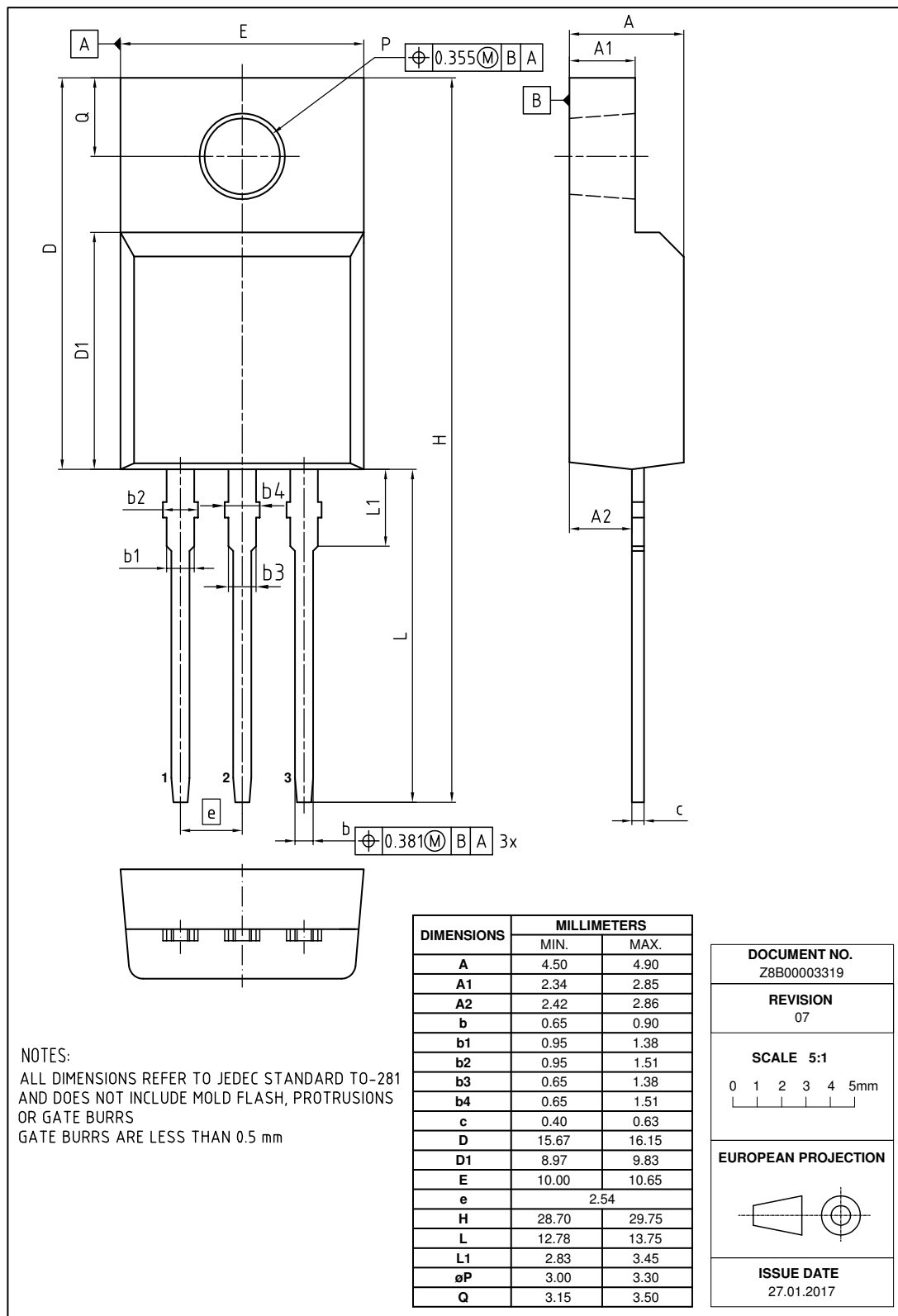
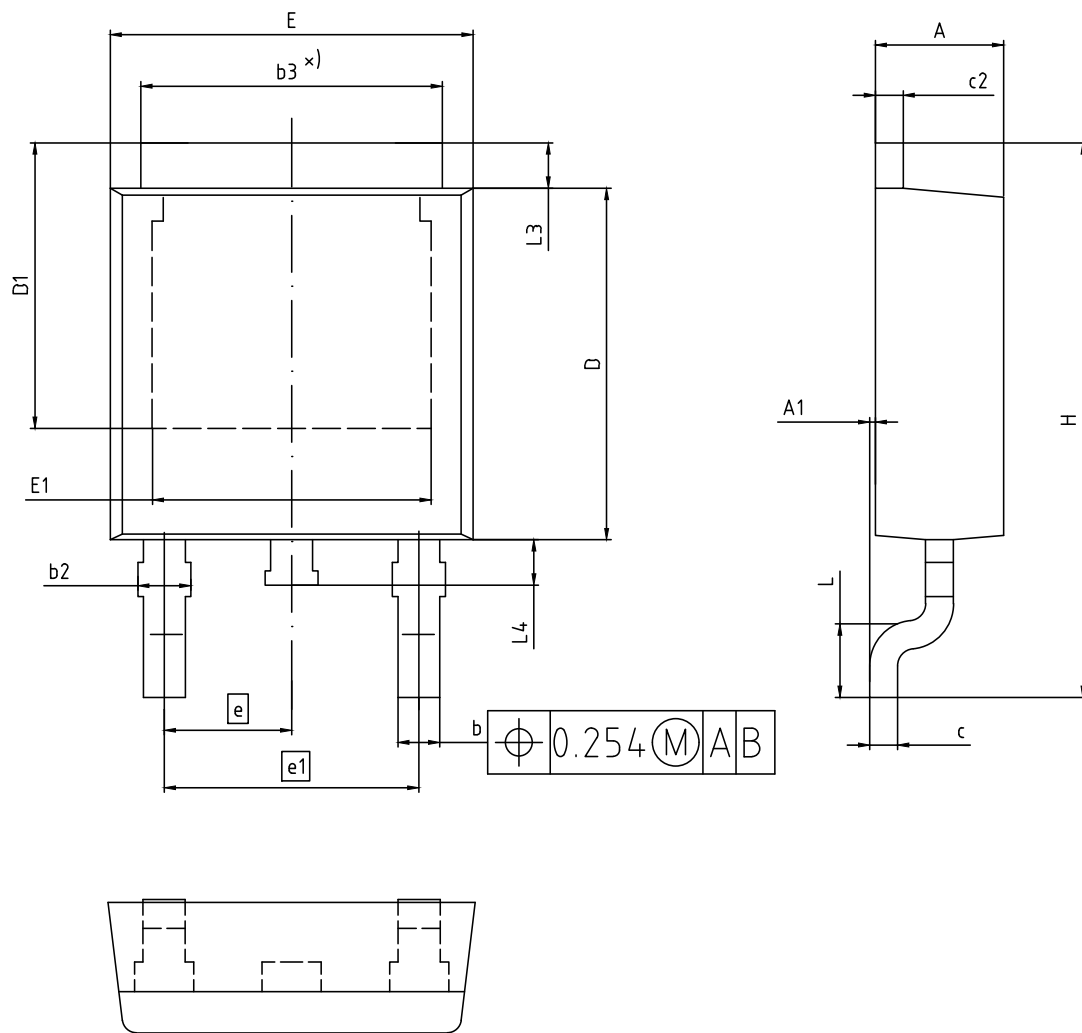


Figure 2 Outline PG-TO 220 FullPAK, dimensions in mm



ALL DIMENSIONS REFER TO JEDEC  
STANDARD TO-252 AND DO NOT INCLUDE MOLD  
FLASH OR PROTRUSIONS.

| DIMENSION | MILLIMETERS |       |
|-----------|-------------|-------|
|           | MIN.        | MAX.  |
| A         | 2.16        | 2.41  |
| A1        | 0.00        | 0.15  |
| b         | 0.64        | 0.89  |
| b2        | 0.65        | 1.15  |
| b3        | 4.95        | 5.50  |
| c         | 0.46        | 0.61  |
| c2        | 0.40        | 0.98  |
| D         | 5.97        | 6.22  |
| D1        | 5.02        | 5.84  |
| E         | 6.35        | 6.73  |
| E1        | 4.32        | 5.50  |
| e         | 2.29        |       |
| e1        | 4.57        |       |
| N         | 3           |       |
| H         | 9.40        | 10.48 |
| L         | 1.18        | 1.78  |
| L3        | 0.89        | 1.27  |
| L4        | 0.51        | 1.02  |

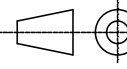
|                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------|
| <b>DOCUMENT NO.</b><br>Z8B00003328                                                                                        |
| <b>REVISION</b><br>07                                                                                                     |
| <b>SCALE:</b><br>10:1<br>0 1 2mm<br> |
| <b>EUROPEAN PROJECTION</b><br>       |
| <b>ISSUE DATE</b><br>01.04.2020                                                                                           |

Figure 3 Outlines TO-252, dimensions in mm



## Revision History

IPx60R600E6

**Revision: 2020-05-20, Rev. 2.4**

Previous Revision

| Revision | Date       | Subjects (major changes since last revision)                  |
|----------|------------|---------------------------------------------------------------|
| 2.0      | 2011-06-08 | Release final data sheet                                      |
| 2.1      | 2011-09-14 | -                                                             |
| 2.2      | 2015-02-11 | PG-TO220 FullPAK package outline update (creation:2014-12-10) |
| 2.3      | 2018-03-04 | Outline PG-TO-220 FullPAK update                              |
| 2.4      | 2020-05-20 | Update of the package outlines TO-252                         |

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