

# MOSFET

Metall Oxide Semiconductor Field Effect Transistor

## CoolMOS E6

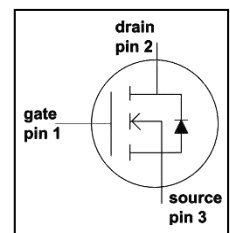
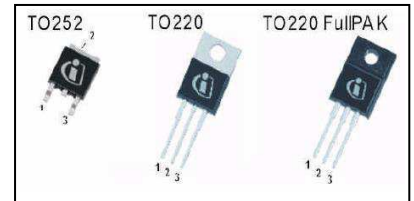
650V CoolMOS™ E6 Power Transistor  
IPx65R600E6

## Data Sheet

Rev. 2.4  
Final

## 1 Description

CoolMOS™ is a revolutionary technology for high voltage power MOSFETs, designed according to the superjunction (SJ) principle and pioneered by Infineon Technologies. CoolMOS™ DE series combines the experience of the leading SJ MOSFET supplier with high class innovation. The resulting 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 mold compound
- Fully qualified according to JEDEC for Industrial Applications

### Applications

PFC stages, hard switching PWM stages and resonant switching PWM stages e.g. PC Silverbox, Adapter, LCD & PDP TV, Lightning, 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
$V_{DS} @ T_{j, max}$	700	V
$R_{DS(on), max}$	0.6	$\Omega$
$Q_G, typ$	23	nC
$I_D, pulse$	18	A
$E_{oss} @ 400V$	2	$\mu J$
Body diode di/dt	500	A/ $\mu s$

Type / Ordering Code	Package	Marking	Related links
IPD65R600E6	PG-TO252	65E6600	<a href="#">IFX CoolMOS Webpage</a> <a href="#">IFX Design tools</a>
IPP65R600E6	PG-TO220		
IPA65R600E6	PG-TO220 FullPAK		

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## 2 Maximum ratings

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

**Table 2 Maximum ratings**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Continuous drain current <sup>1)</sup>	$I_D$	–	–	7.3	A	$T_C = 25^\circ\text{C}$
		–	–	4.6		$T_C = 100^\circ\text{C}$
Pulsed drain current <sup>2)</sup>	$I_{D, pulse}$	–	–	18		$T_C = 25^\circ\text{C}$
Averlanche energy, single pulse	$E_{AS}$	–	–	142	mJ	$I_D = 1.3\text{A}; V_{DD} = 50\text{V};$ $T_C = 25^\circ\text{C}$ (see Table 21)
Averlanche energy, repetitive	$E_{AR}$	–	–	0.21		$I_D = 1.3\text{A}, V_{DD} = 50\text{V}$
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 Non FullPAK	$P_{tot}$	–	–	63	W	$T_C = 25^\circ\text{C}$
Power dissipation for FullPAK	$P_{tot}$	–	–	28	W	$T_C = 25^\circ\text{C}$
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
Continous diode forward current	$I_S$	–	–	6.3	A	$T_C = 25^\circ\text{C}$
Diode pulse current <sup>2)</sup>	$I_{S, pulsed}$	–	–	18	A	$T_C = 25^\circ\text{C}$
Reverse diode dv/dt <sup>3)</sup>	$dv/dt$	–	–	15	V/ns	$V_{DS} = 0 \dots 480\text{V}, I_{SD} \leq I_D,$
Maximum diode commutation speed <sup>3)</sup>	$di/dt$			500	A/ $\mu\text{s}$	$T_C = 125^\circ\text{C}$ (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  $R_\theta$

### 3 Thermal characteristics

**Table 3 Thermal characteristics TO-220 (IPP65R600E6)**

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	1.6mm (0.063 in.) from case for 10 s

**Table 4 Thermal characteristics TO-220 FullPAK (IPA65R600E6)**

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	1.6mm (0.063 in.) from case for 10 s

**Table 5 Thermal characteristics TO-252 (IPD65R600E6)**

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
Thermal resistance, junction-ambient	$R_{thJA}$	–	–	62		
			35			
Soldering temperature, wave- & reflowsoldering only allowed	$T_{sold}$	–	–	260	°C	Reflow MSL1

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

## 4 Electrical characteristics

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

**Table 6 Static characteristics**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Drain-source Breakdown voltage	$V_{(BR)DSS}$	650	–	–	V	$V_{GS}=0V, I_D=1.0mA$
Gate threshold voltage	$V_{GS(th)}$	2.5	3	3.5		$V_{DS}=V_{GS}, I_D=0.21mA$
Zero gate Voltage drain current	$I_{DSS}$	–	–	1	$\mu\text{A}$	$V_{DS}=600V, V_{GS}=0V,$ $T_f=25^\circ\text{C}$
		–	10	–		$V_{DS}=600V, V_{GS}=0V,$ $T_f=150^\circ\text{C}$
Gate- source leakage current	$I_{GSS}$	–	–	100	nA	$V_{GS}=20V, V_{DS}=0V$
Drain- source on- state resistance	$R_{DS(on)}$	–	0.54	0.6	$\Omega$	$V_{GS}=10V, I_D=2.1A,$ $T_f=25^\circ\text{C}$
		–	1.40	–		$V_{GS}=10V, I_D=2.1A,$ $T_f=150^\circ\text{C}$
Gate resistance	$R_G$	–	10.5	–	$\Omega$	$f=1\text{MHz}, \text{open drain}$

**Table7 Dynamic characteristics**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Input capacitance	$C_{iss}$	–	440	–	pF	$V_{GS}=0V, V_{DS}=100V,$ $f=1\text{MHz}$
Output capacitance	$C_{oss}$	–	30	–		
Effective output capacitance, energy related <sup>1)</sup>	$C_{o(er)}$	–	21	–		
Effective output capacitance, time related <sup>2)</sup>	$C_{o(tr)}$	–	88	–		
Turn- on delay time	$t_{d(on)}$	–	10	–	ns	$V_{DD}=400V$ $V_{GS}=13V, I_D=3.2A,$ $R_G=6.8\Omega$ (see table 20)
Rise time	$t_r$	–	8	–		
Turn- off delay time	$t_{d(off)}$	–	64	–		
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	$Q_{GS}$	–	2.75	–	nC	$V_{DD}=480V, I_D=3.2A,$ $V_{GS}=0$ to 10 V
Gate to drain charge	$Q_{GD}$	–	12	–		
Gate charge, total	$Q_G$	–	23	–		
Gate plateau voltage	$V_{plateau}$	–	5.5	–	V	

**Table 8 Reverse diode characteristics**

Parameter	Symbol	Values			Unit	Note/Test Condition
		Min.	Typ.	Max.		
Diode forward voltage	$V_{SD}$	–	0.9	–	V	$V_{GS}=0V, I_F=3.2A,$ $T_J=25^\circ C$
Reverse recovery time	$t_{rr}$	–	270	–	ns	$V_R=400V, I_F=3.2A,$ $diF/dt=100A/\mu s$ (see table 22)
Reverse recovery charge	$Q_{rr}$	–	2.0	–	nC	
Peak reverse recovery current	$I_{rrm}$	–	13	–	A	

## 5 Electrical characteristics diagrams

Table 10

Power dissipation Non FullPAK	Power dissipation FULLPAK
$P_{tot} = f(T_c)$	$P_{tot} = f(T_c)$

Table 11

Max. transient thermal impedance Non FullPAK	Max. transient thermal impedance Non FullPAK
$Z_{th(jc)} = f(t_p)$ ; parameter: $D = t_p/T$	$Z_{th(jc)} = f(t_p)$ ; parameter: $D = t_p/T$



Table 12

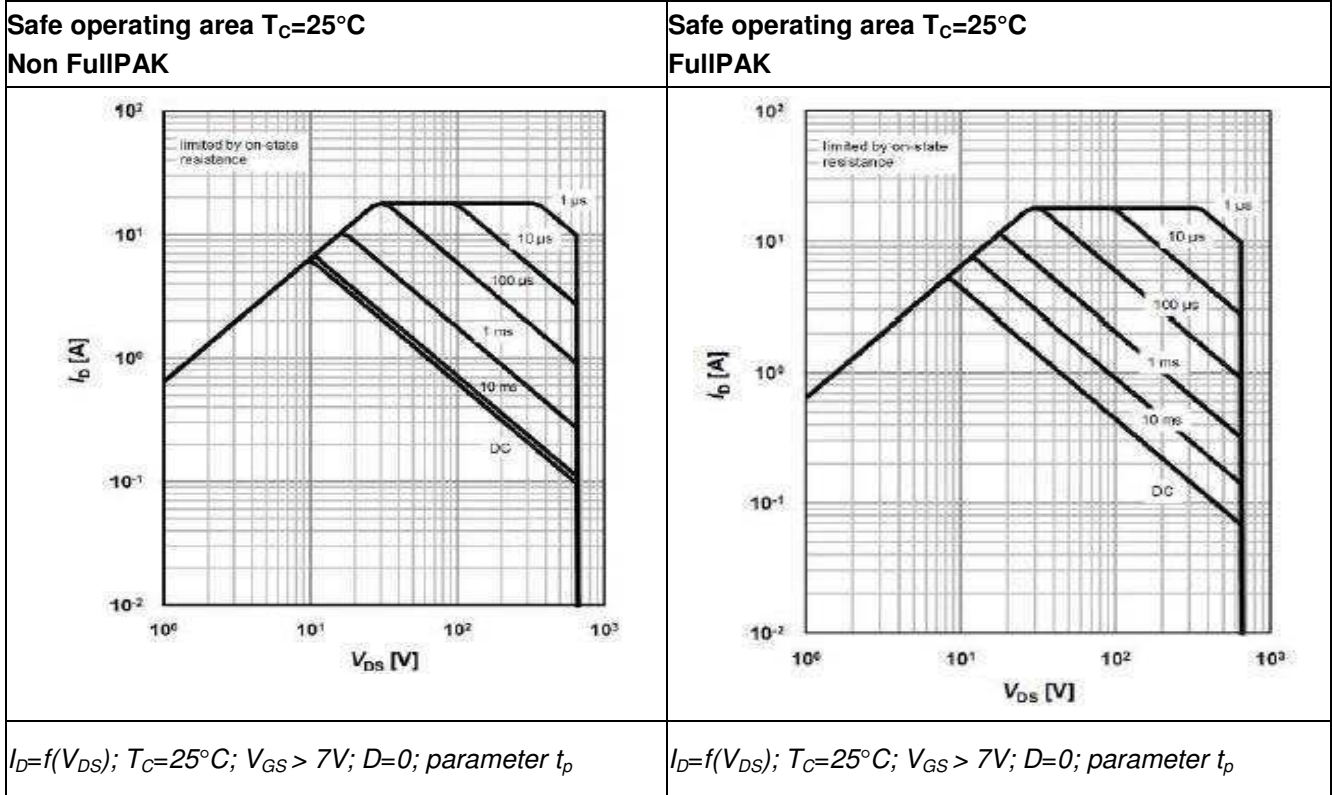


Table 13

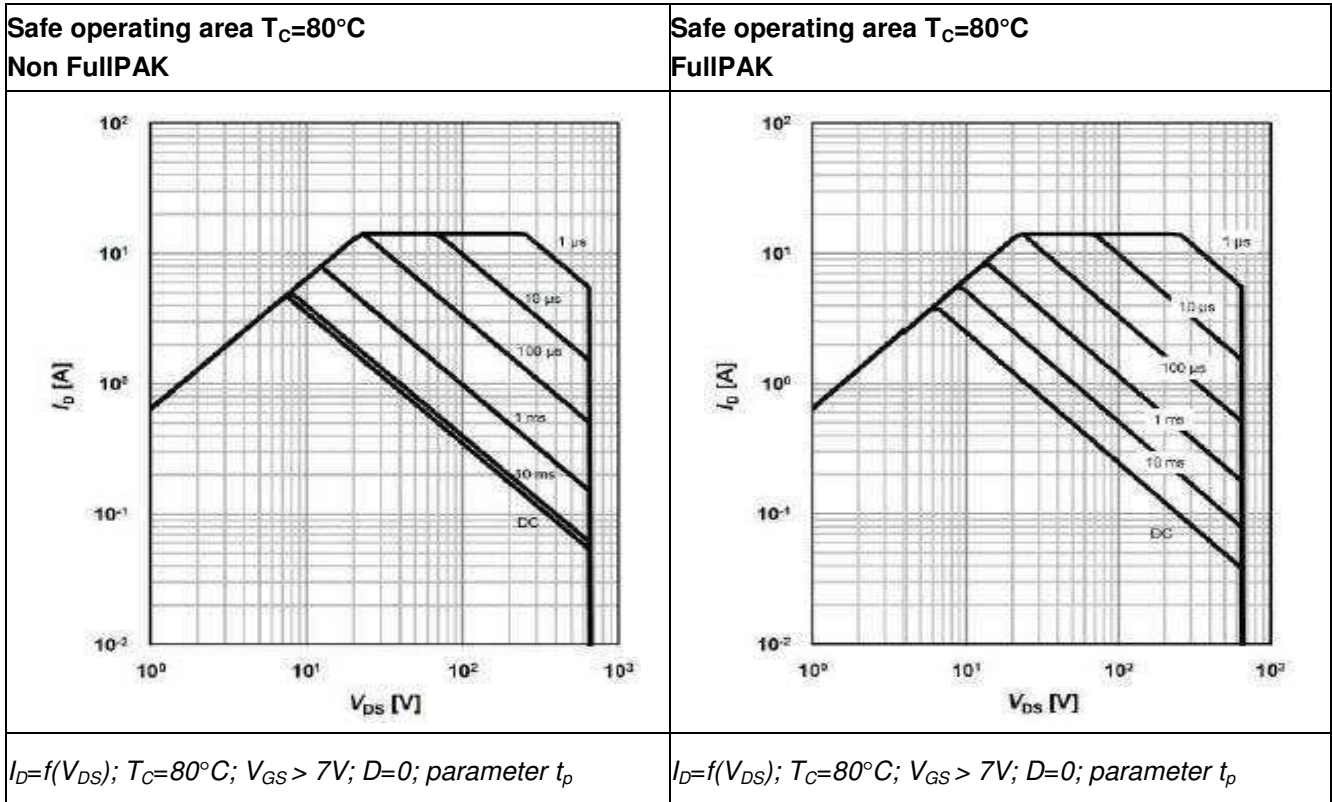


Table 14

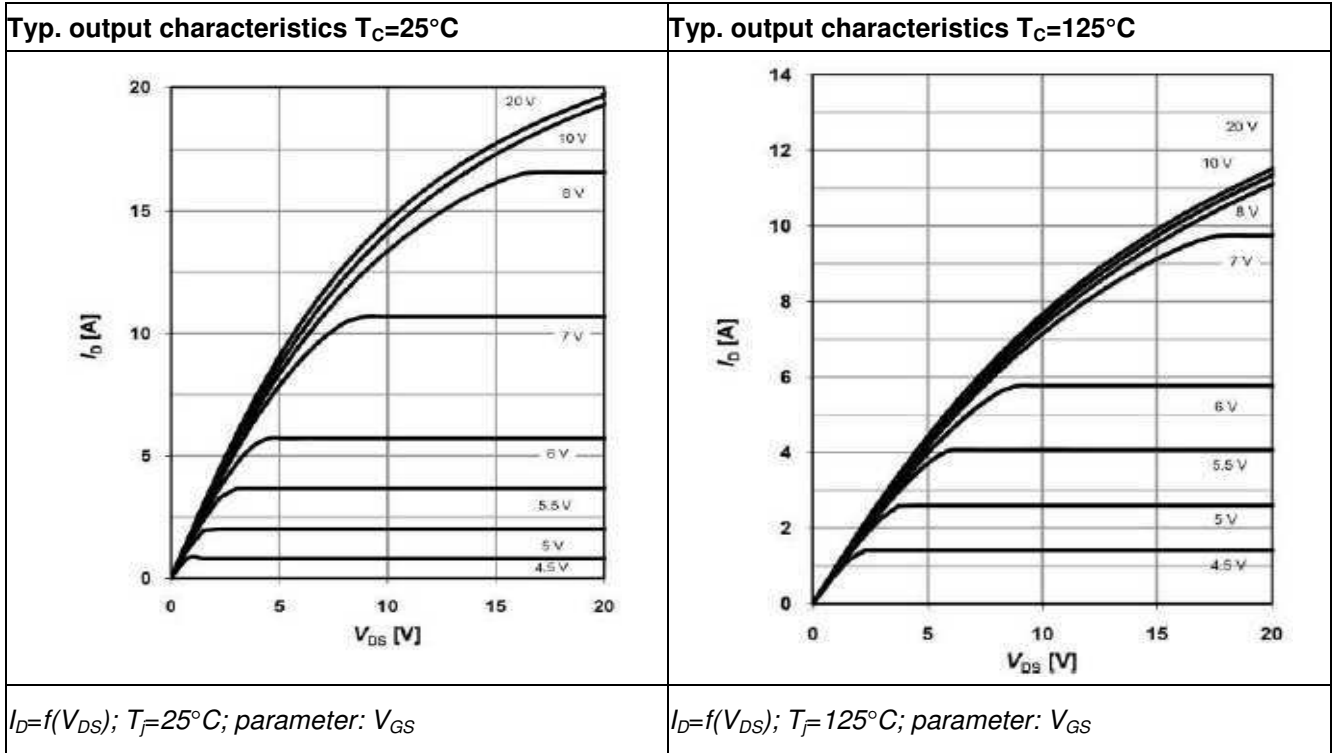


Table 15

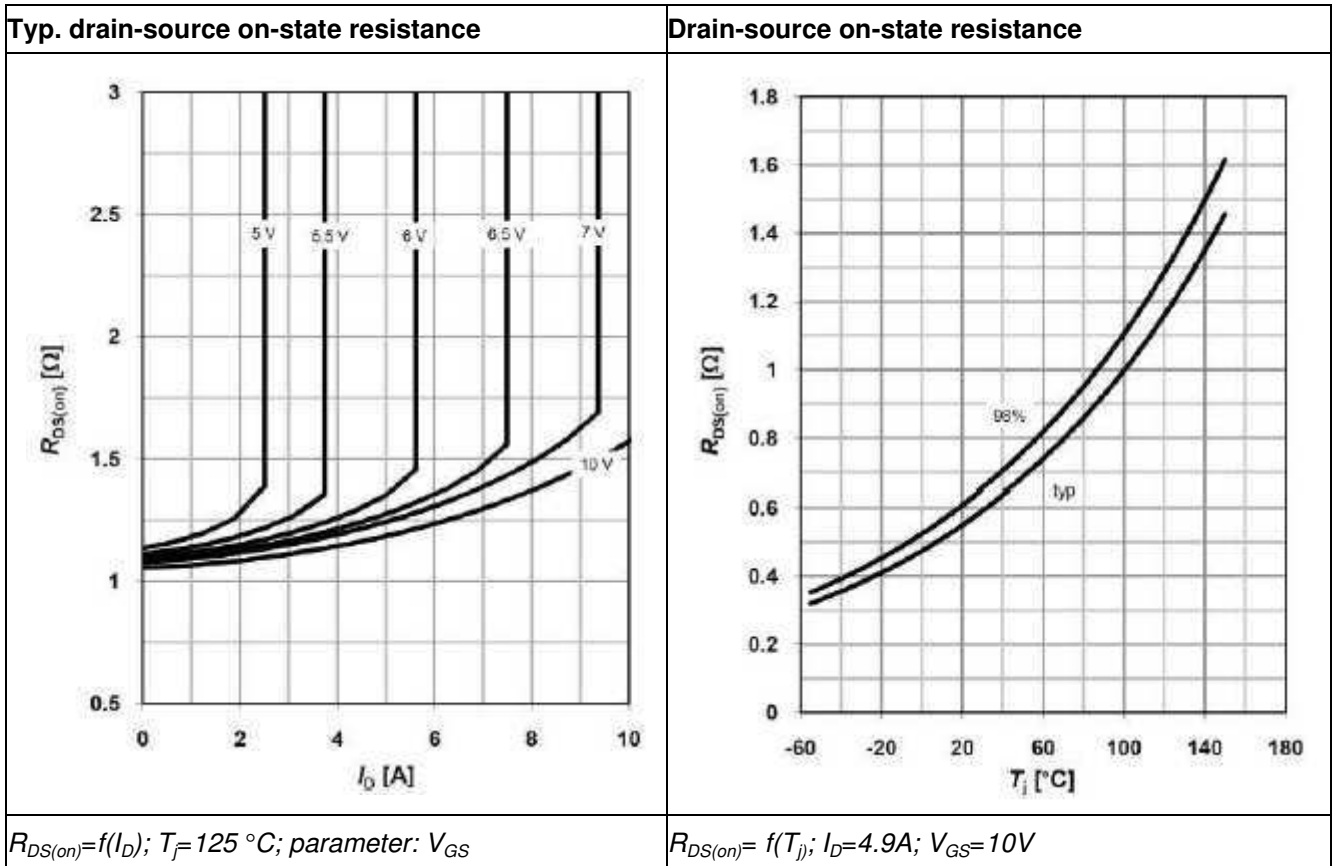


Table 16

Typ. transfer characteristics	Typ. gate charge
$I_D = f(V_{GS}); V_{DS} = 20V$	$V_{GS} = f(Q_{gate}), I_D = 4.9 A \text{ pulsed}$

Table 17

Avalanche energy	Drain-source breakdown voltage
$E_{AS} = f(T_j); I_D = 1.8 A; V_{DD} = 50 V$	$V_{BR(DSS)} = f(T_j); I_D = 1.0 mA$

Table 18

Typ. capacitances	Typ. $C_{OSS}$ stored energy
<p>The graph shows three capacitance curves against drain-source voltage <math>V_{DS}</math> from 0 to 600 V. The y-axis is capacitance <math>C</math> in pF on a logarithmic scale from <math>10^0</math> to <math>10^5</math>. <math>C_{iss}</math> is a horizontal line at approximately 500 pF. <math>C_{oss}</math> starts at ~1000 pF at 0 V and drops to ~15 pF at 600 V. <math>C_{rss}</math> starts at ~1000 pF at 0 V, drops sharply to ~2 pF at 100 V, and then slightly increases to ~5 pF at 600 V.</p>	<p>The graph shows stored energy <math>E_{oss}</math> in microJoules against <math>V_{DS}</math> from 0 to 600 V. The y-axis is linear from 0 to 4. The curve starts at (0,0) and rises to approximately 3.5 microJoules at 600 V.</p>
<p><math>C=f(V_{DS}); V_{GS}=0\text{ V}; f=1\text{ MHz}</math></p>	<p><math>E_{OSS}=f(V_{DS})</math></p>

Table 19

Forward characteristics of reverse diode
<p>The graph shows reverse current <math>I_r</math> in Amperes against reverse voltage <math>V_{SD}</math> from 0 to 2 V. The y-axis is logarithmic from <math>10^{-1}</math> to <math>10^2</math>. Two curves are shown: one for 125°C and one for 25°C. Both curves show an exponential-like increase in current with voltage, with the 125°C curve being significantly higher than the 25°C curve.</p>
<p><math>I_r=f(V_{SD}); \text{parameter: } T_j</math></p>

## 6 Test circuits

Table 20 Switching times test circuit and waveform for inductive load

Switching times test circuit for inductive load	Switching time waveform

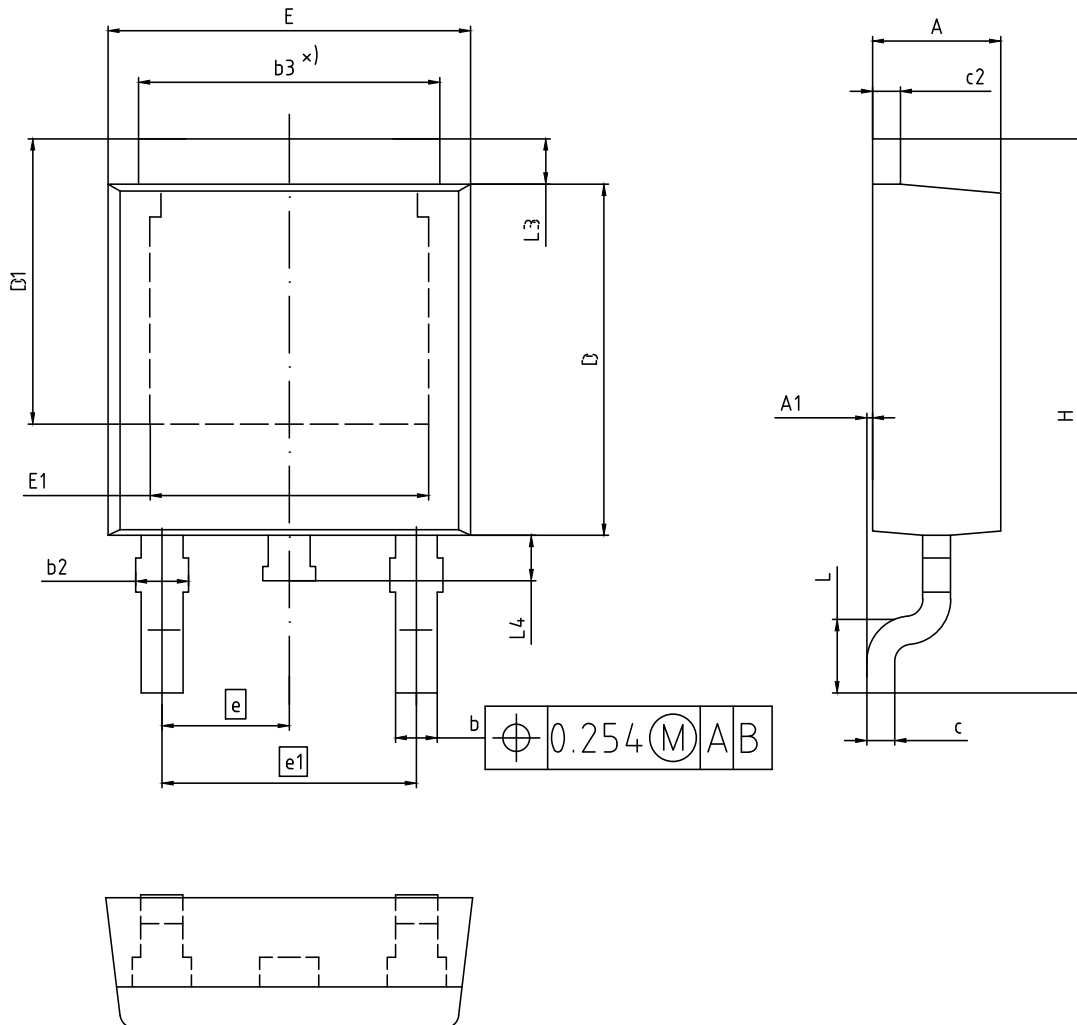
Table 21

Unclamped inductive load test circuit	Unclamped inductive waveform

Table 22

Test circuit for diode characteristics	Diode recovery waveform

7 Package outlines

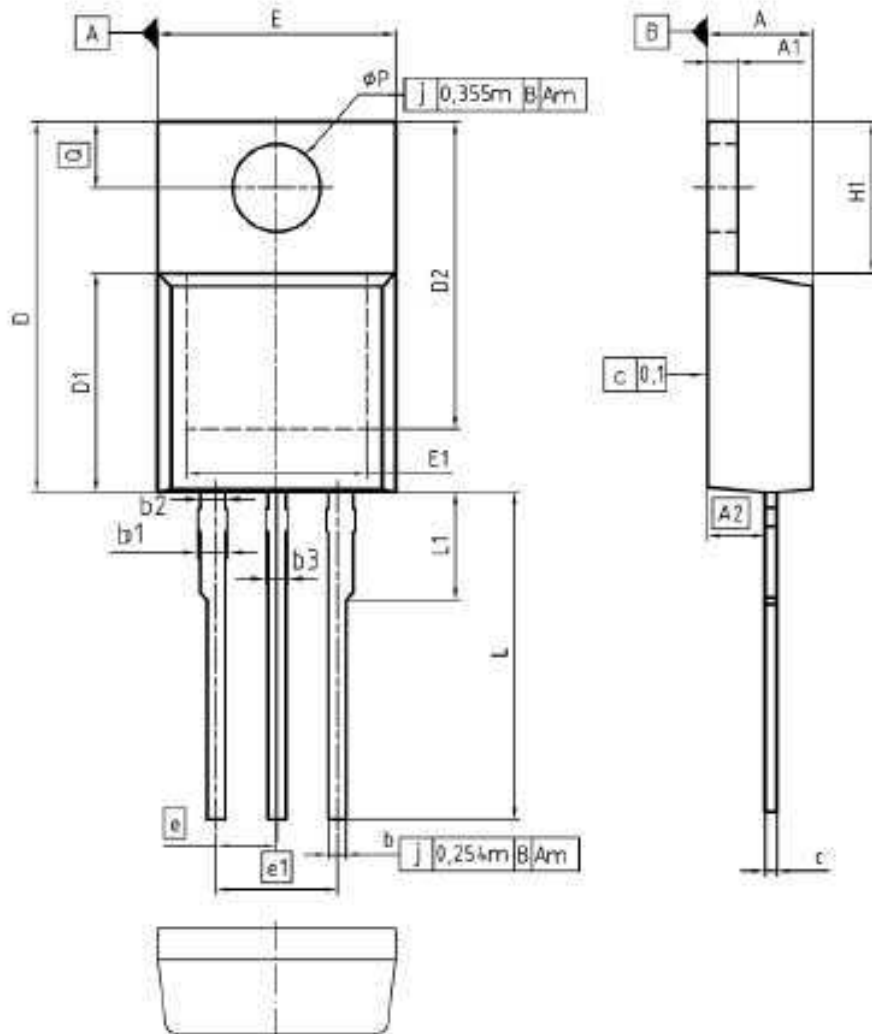


ALL DIMENSIONS REFER TO JEDEC STANDARD TO-252 AND DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.

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

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Figure 1 Outlines TO-252, dimensions in mm



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	8.00	0.256	0.313
e	2.54		0.100	
e1	5.08		0.200	
N	3		3	
H1	6.90	6.90	0.272	0.272
L	13.00	14.00	0.512	0.551
L1	-	4.90	-	0.193
φP	3.60	3.60	0.142	0.153
G	2.60	3.00	0.102	0.118

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Figure 2 Outlines TO220, dimensions in mm/inches

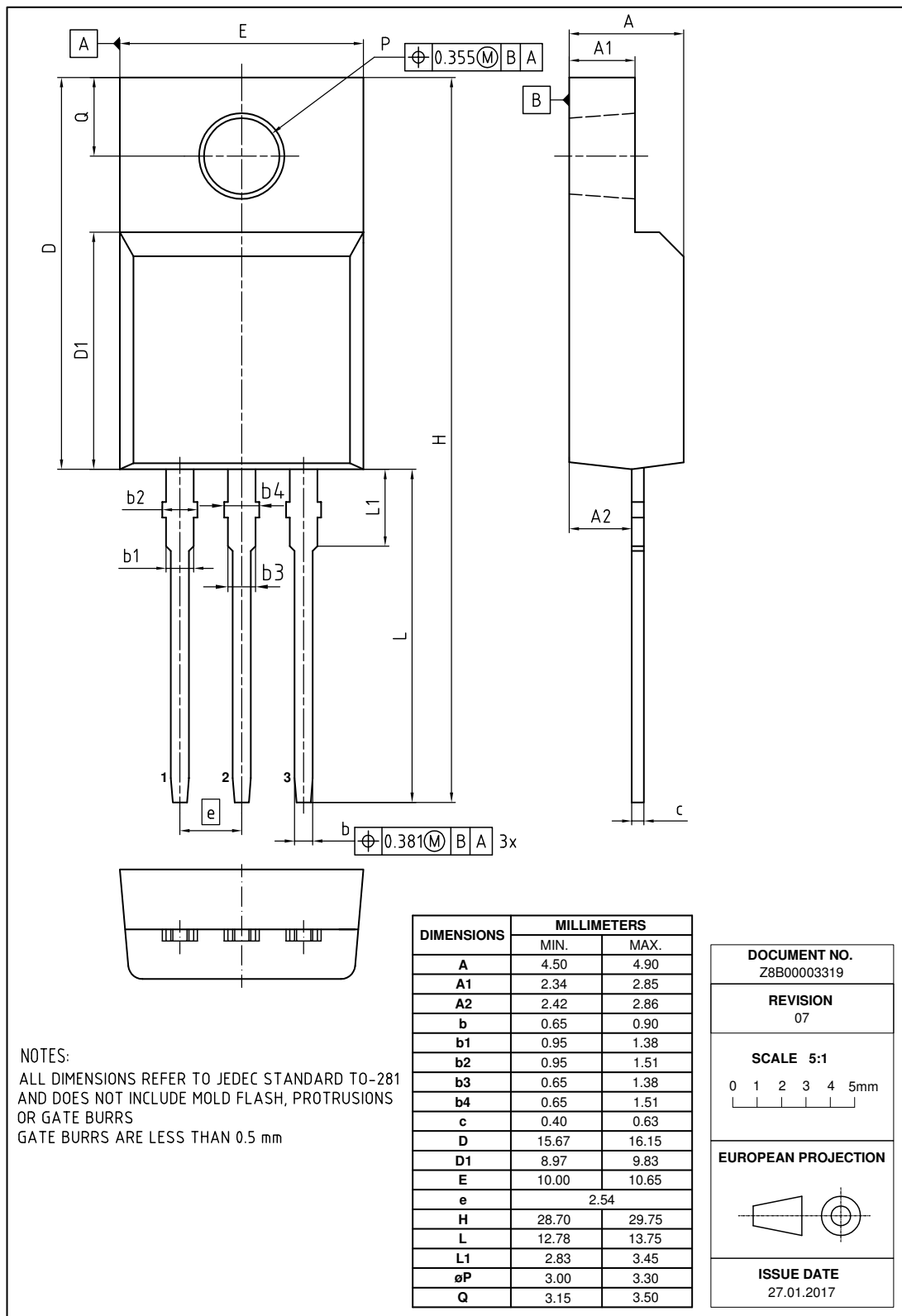


Figure 3 Outlines TO220 FullPAK, dimensions in mm



## Revision History

IPx65R600E6

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

Previous Revision

Revision	Date	Subjects (major changes since last revision)
2.2	2016-08-04	Revised TO220 Full PAK package drawing on page 16
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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