

## 650V Silicon Carbide Power MOSFET

### Features

- Revolutionary semiconductor material Silicon Carbide
- High blocking voltage with low on-resistance
- High-speed switching with very low switching losses
- High-speed and high robust intrinsic body diode
- Optimized package with separate driver source pin

### Product Summary

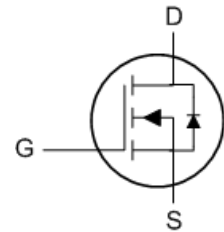
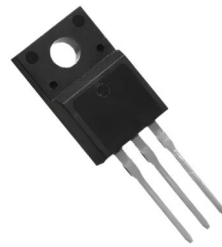


BVDSS	R <sub>DS(on)</sub>	I <sub>D</sub>
650V	260mΩ	15.5A

### Applications

- LED Driver
- PD charger
- PC adapter
- Air-conditioning
- E-bike charger

### TO220F Pin Configuration



### Maximum Ratings For MOSFET (T<sub>VJ</sub>= 25°C unless otherwise specified)

Symbol	Parameter	Value	Unit	Testing Conditions
V <sub>DSS</sub>	Drain-Source Voltage	650	V	
I <sub>D</sub>	Continuous DC Drain Current for R <sub>th(j-c,typ.)</sub> , Limited by T <sub>VJ(max)</sub>	15.5	A	T <sub>C</sub> = 25 °C
		11		T <sub>C</sub> = 100°C
I <sub>DM</sub>	Peak Drain Current, tp Limited by T <sub>VJ(max)</sub>	25	A	T <sub>C</sub> = 25 °C
V <sub>GS, max</sub>	Gate-Source Max Voltage	-10/22	V	
V <sub>GS, op</sub>	Gate-Source Operate Voltage	0/15	V	
E <sub>AS</sub>	Single Pulse Avalanche Energy	25	mJ	L=0.5 mH, I <sub>AS</sub> =10 A, V <sub>DD</sub> =50 V, V <sub>GS</sub> =15 V
P <sub>tot</sub>	Power Dissipation for R <sub>th(j-c,typ.)</sub>	67	W	T <sub>C</sub> = 25°C

### Package Values

Symbol	Parameter	Min.	Typ.	Max.	Unit	Testing Conditions
R <sub>th(j-c)</sub>	MOSFET/Body Diode Junction-Case Thermal Resistance		2.23	2.67	K/W	
T <sub>VJ</sub> , T <sub>STG</sub>	Operating Junction and Storage Temperature	-55		175	°C	
T <sub>SOLD</sub>	Soldering Temperature, Wave Soldering only Allowed at Leads 1.6mm from Case for 10s		260		°C	

**650V Silicon Carbide Power MOSFET**
**MOSFET Characteristics** ( $T_{VJ} = 25^{\circ}\text{C}$  unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Testing Conditions
$V_{(BR)DSS}$	Drain-Source breakdown voltage	650			V	$I_D = 100 \mu\text{A}$
$V_{GS(th)}$	Gate Threshold Voltage	3.2	4.1	5	V	$V_{DS} = V_{GS}, I_D = 10 \text{ mA}$
$I_{DSS}$	Drain-Source Leakage Current		0.1	20	$\mu\text{A}$	$V_{GS} = 0 \text{ V}, V_{DS} = 650 \text{ V}$
$I_{GSS}$	Gate-Source Leakage Current			250	nA	$V_{GS} = 22 \text{ V}, V_{DS} = 0 \text{ V}$
$I_{SGS}$	Source-Gate Leakage Current			250	nA	$V_{GS} = -10 \text{ V}, V_{DS} = 0 \text{ V}$
$R_{DS(on)}$	Drain-Source On-State Resistance		260	300	m $\Omega$	$V_{GS} = 15 \text{ V}, I_D = 5 \text{ A}$
$g_{fs}$	Transconductance		3.6		S	$V_{DS} = 20 \text{ V}, I_D = 5 \text{ A}$
$R_{G(int)}$	Internal Gate Resistance		25.5		$\Omega$	$f = 1\text{MHz}, V_{AC} = 25 \text{ mV}$
$C_{iss}$	Input Capacitance		294		pF	$V_{GS} = 0 \text{ V}, V_{DS} = 650 \text{ V}, f = 1\text{MHz}$
$C_{oss}$	Output Capacitance		25		pF	
$C_{rss}$	Reverse Transfer Capacitance		4		pF	$V_{GS} = 0/15 \text{ V}, V_{DS} = 400\text{V}, I_D = 5 \text{ A}$
$Q_{GS}$	Gate to Source Charge		4.3		nC	
$Q_{GD}$	Gate to Drain Charge		1.6		nC	
$Q_G$	Total Gate Charge		12.5		nC	

**Dynamic MOSFET Characteristics** ( $T_{VJ} = 25^{\circ}\text{C}$  unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Testing Conditions
$t_{d(on)}$	Turn-On Delay Time		6.6		ns	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			6.0		ns	
$t_r$	Rise Time		18.3		ns	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			14.2		ns	
$t_{d(off)}$	Turn-Off Delay Time		17.7		ns	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			21.3		ns	
$t_f$	Fall Time		32.1		ns	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			35.6		ns	
$E_{on}$	Turn-On Switching Loss		43.2		$\mu\text{J}$	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			40.7		$\mu\text{J}$	
$E_{off}$	Turn-Off Switching Loss		5.5		$\mu\text{J}$	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			5.2		$\mu\text{J}$	
$E_{tot}$	Total Switching Energy		48.7		$\mu\text{J}$	$V_{GS} = 0/15\text{V}$ $L=600\mu\text{H}$ $V_{DS} = 400 \text{ V}, I_D = 5 \text{ A},$ $R_{G(on)} = 2.2 \Omega, R_{G(off)} = 2.2 \Omega$
			45.9		$\mu\text{J}$	

Note:  $E_{on}/E_{off}$  result is with body diode.

**Maximum Ratings For Body Diode** ( $T_{VJ} = 25^{\circ}\text{C}$  unless otherwise specified)

Symbol	Parameter	Value	Unit	Testing Conditions
$V_{DSS}$	Drain-Source Voltage	650	V	
$I_S$	Continuous DC Source Current, Limited by $T_{VJ(max)}$	12	A	$T_C = 25^{\circ}\text{C}$
		7	A	$T_C = 100^{\circ}\text{C}$
$I_{SM}$	Peak Reverse Drain Current, tp Limited by $T_{VJ(max)}$	23	A	$T_C = 25^{\circ}\text{C}$

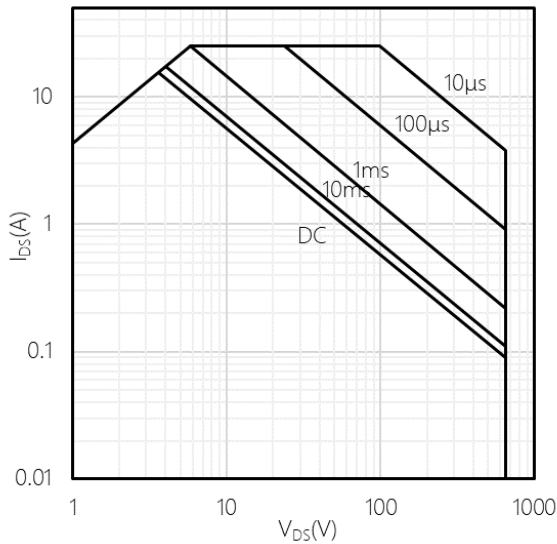
**Body Diode Characteristics** ( $T_{VJ} = 25^{\circ}\text{C}$  unless otherwise specified)

Symbol	Parameter	Min.	Typ.	Max.	Unit	Testing Conditions	
$V_{SD}$	Body Diode Forward Voltage		3.3		V	$V_{GS} = 0\text{ V}, I_{SD} = 2.5\text{ A}$	$T_{VJ} = 25^{\circ}\text{C}$
			2.8				$T_{VJ} = 175^{\circ}\text{C}$
$I_{rrm}$	Peak Reverse Recovery Current		5.8		A	$V_{DS} = 400\text{ V}, V_{GS} = -0\text{ V}, I_{SD} = 5\text{ A}, di/dt = 1.6\text{ kA}/\mu\text{s}$	$T_{VJ} = 25^{\circ}\text{C}$
			6.2				$T_{VJ} = 175^{\circ}\text{C}$
$Q_{rr}$	Reverse Recovery Charge		32.6		nC		$T_{VJ} = 25^{\circ}\text{C}$
			36.1				$T_{VJ} = 175^{\circ}\text{C}$
$t_{rr}$	Reverse Recovery Time		9.9		ns		$T_{VJ} = 25^{\circ}\text{C}$
			9.4				$T_{VJ} = 175^{\circ}\text{C}$
$E_{rr}$	Reverse Recovery Energy		0.31		$\mu\text{J}$	$T_{VJ} = 25^{\circ}\text{C}$	
			0.39			$T_{VJ} = 175^{\circ}\text{C}$	

Typical Performances

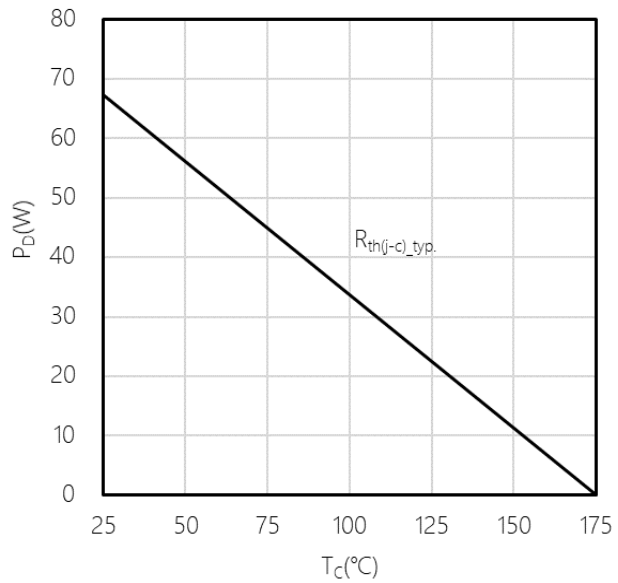
Safe operating area (SOA)

$R_{th(j-c)} = 2.67 \text{ }^\circ\text{C/W}$ , Single Pulse,  $T_{vj} = 25^\circ\text{C}$



Power dissipation as a function of case temperature limited by bond wire

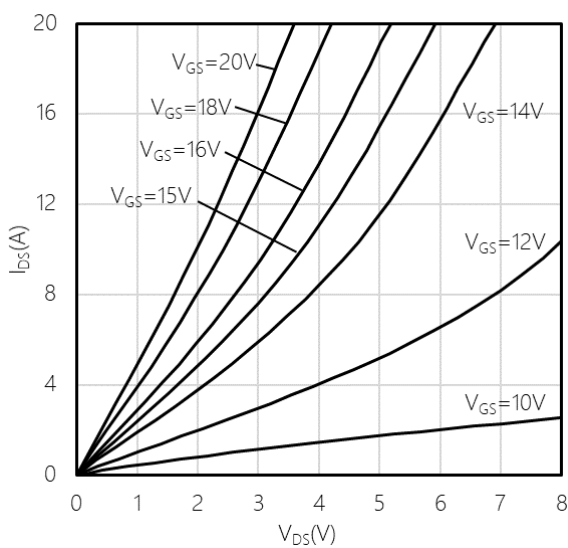
$P_D = f(T_c)$



Typical output characteristic,  $V_{GS}$  as parameter

$I_{DS} = f(V_{DS})$

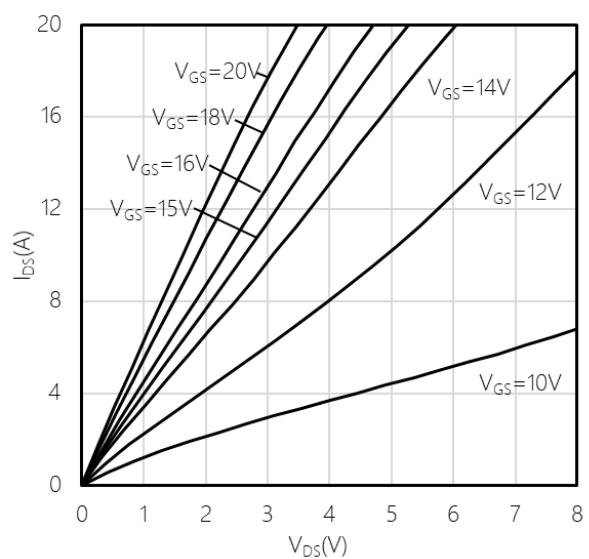
$T_{vj} = -55^\circ\text{C}$



Typical output characteristic,  $V_{GS}$  as parameter

$I_{DS} = f(V_{DS})$

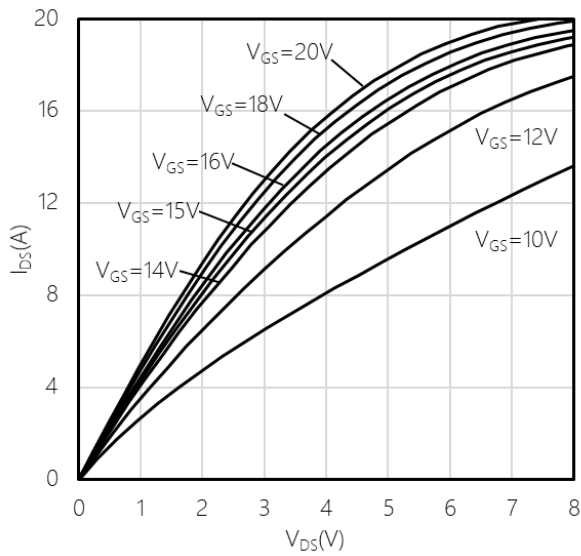
$T_{vj} = 25^\circ\text{C}$



**Typical output characteristic,  $V_{GS}$  as parameter**

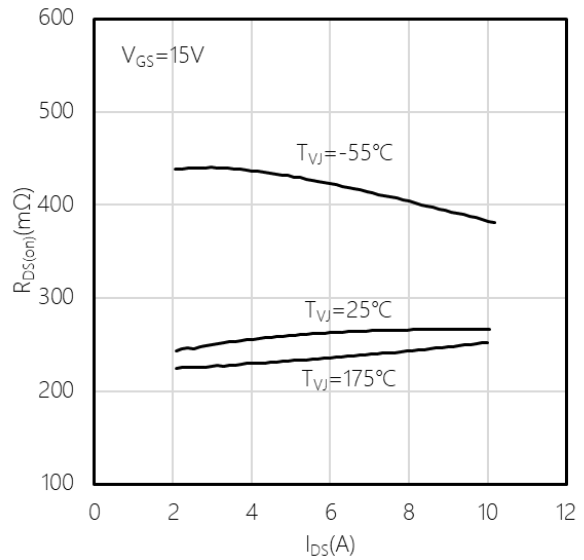
$I_{DS} = f(V_{DS})$

$T_{VJ} = 175^{\circ}\text{C}$



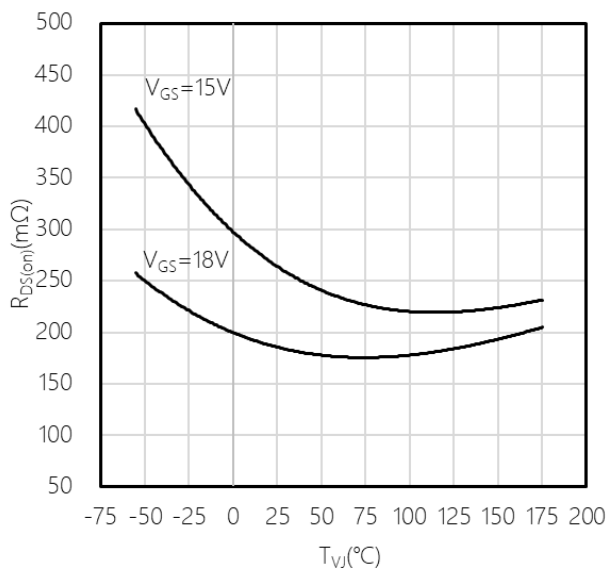
**Typical on-state resistance as a function of drain current**

$R_{DS(on)} = f(I_{DS}), V_{GS} = 18\text{V}$



**Typical on-state resistance as a function of temperature**

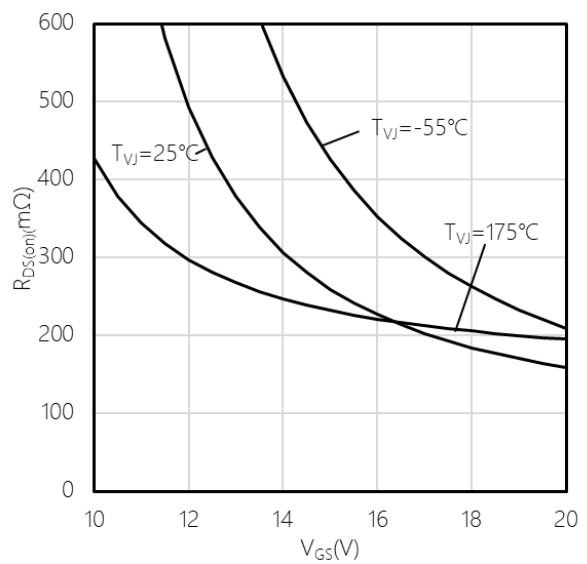
$R_{DS(on)} = f(T_{VJ}), I_{DS} = 5\text{A}$



**Typical on-state resistance as a function of  $V_{GS}$**

$R_{DS(on)} = f(V_{GS})$

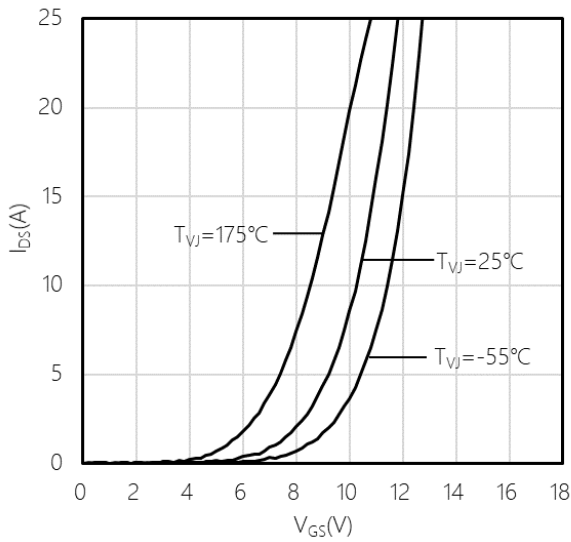
$I_{DS} = 5\text{A}$



**Typical transfer characteristic**

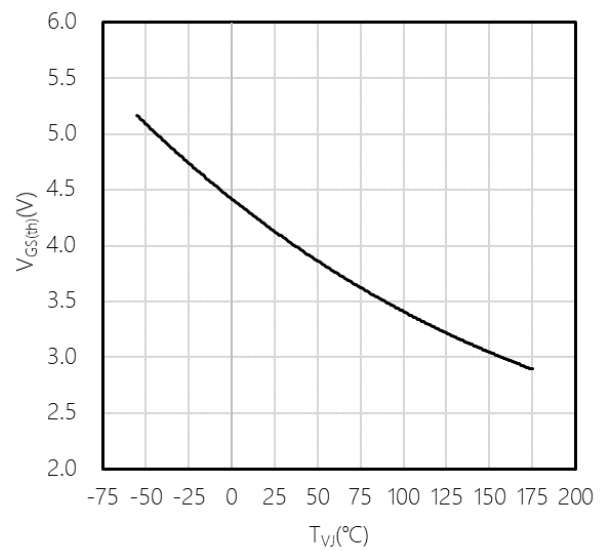
$I_{DS} = f(V_{GS})$

$V_{DS} = 20\text{ V}$



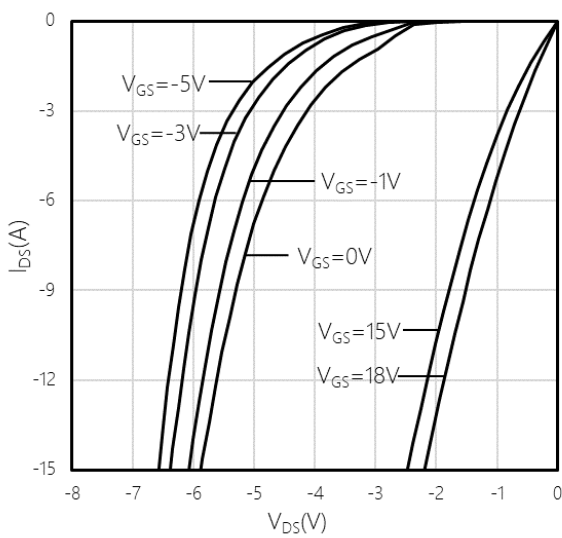
**Typical gate-source threshold voltage as a function of junction temperature**

$V_{GS(th)} = f(T_{VJ}), I_{DS} = 10\text{ mA}$



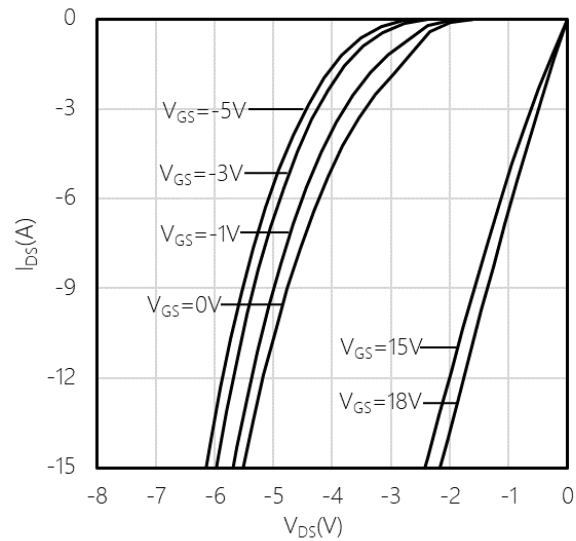
**Typical reverse drain current as function of reverse drain voltage,  $V_{GS}$  as parameter**

$I_{DS} = f(V_{DS}), T_{VJ} = -55^\circ\text{C}$



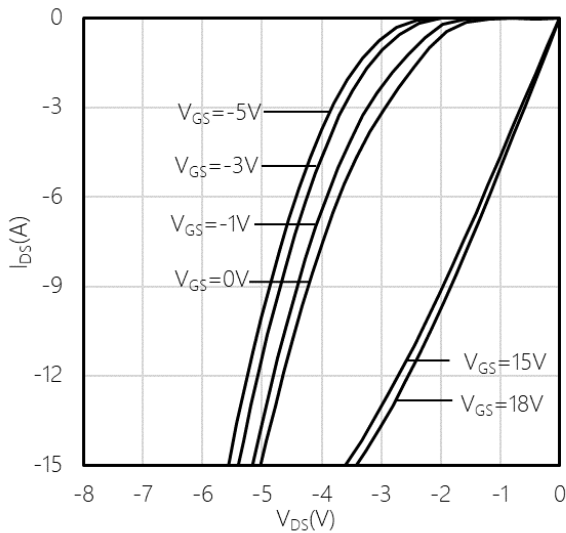
**Typical reverse drain current as function of reverse drain voltage,  $V_{GS}$  as parameter**

$I_{DS} = f(V_{DS}), T_{VJ} = 25^\circ\text{C}$



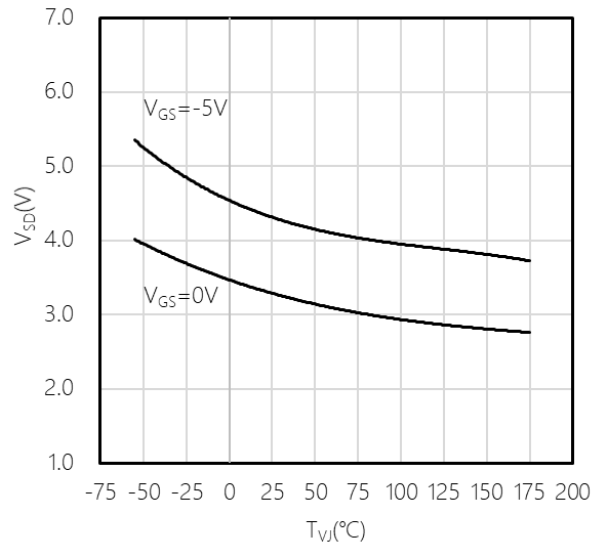
**Typical reverse drain current as function of reverse drain voltage,  $V_{GS}$  as parameter**

$I_{DS} = f(V_{DS}), T_{VJ} = 175\text{ }^{\circ}\text{C}$



**Typical reverse drain voltage as function of junction temperature**

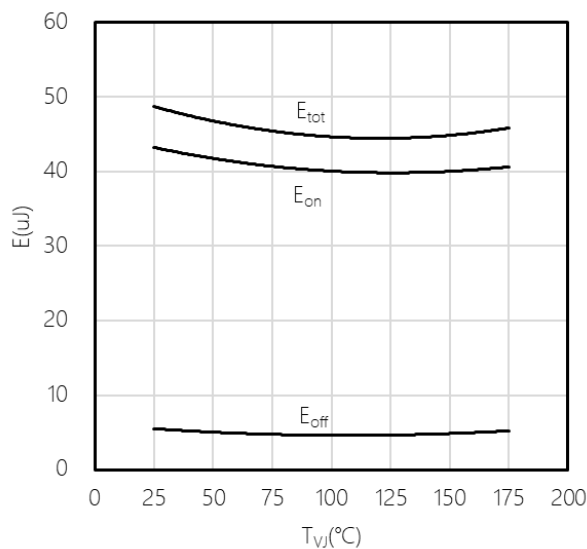
$V_{SD} = f(T_{VJ}), I_{SD} = 2.5\text{ A}$



**Typical switching energy as a function of junction temperature, 2nd device own body diode:  $V_{GS} = -5\text{ V}$**

$E = f(T_{VJ})$

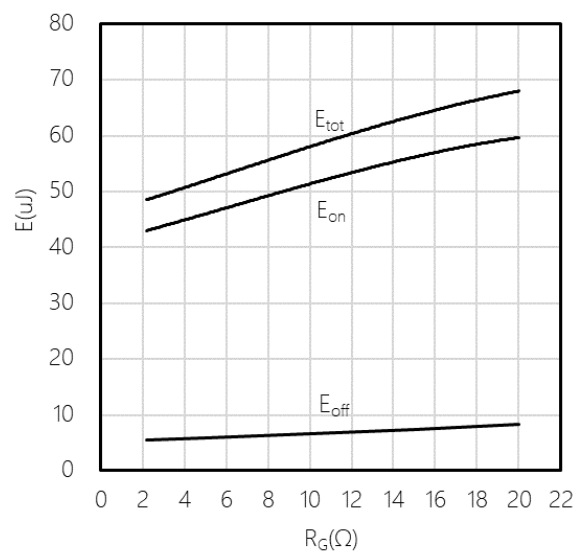
$V_{DS} = 400\text{ V}, R_{G(ext)} = 2.2\text{ }\Omega, V_{GS} = 0/15\text{ V}, I_{DS} = 5\text{ A}$



**Typical switching energy losses as a function of gate resistance, 2nd device own body diode:  $V_{GS} = -5\text{ V}$**

$E = f(R_{G(ext)})$

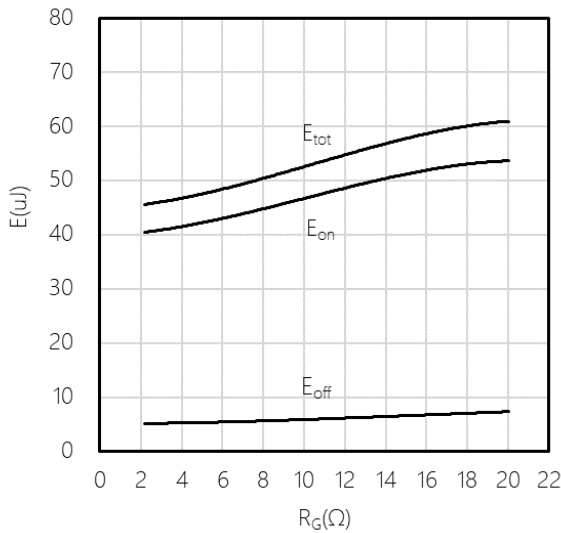
$V_{VGS} = 0/15\text{ V}, I_{DS} = 5\text{ A}, T_{VJ} = 25\text{ }^{\circ}\text{C}, V_{DS} = 400\text{ V}$



**Typical switching energy losses as a function of gate resistance, 2nd device own body diode:  $V_{GS} = 0\text{ V}$**

$E = f(R_{G(ext)})$

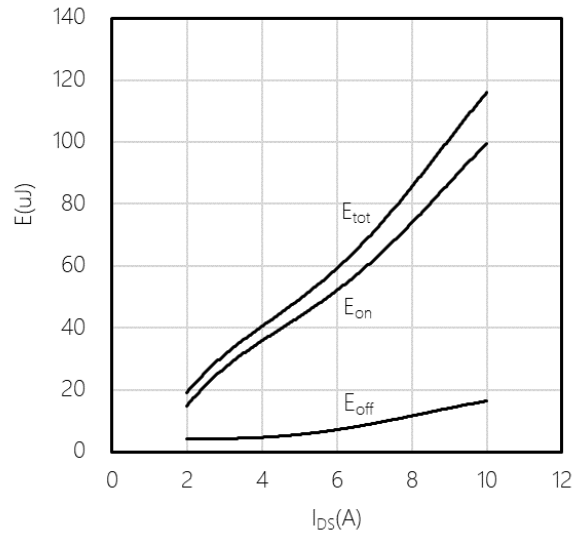
$V_{GS} = 0/15\text{ V}$ ,  $I_{DS} = 5\text{ A}$ ,  $T_{VJ} = 175\text{ }^\circ\text{C}$ ,  $V_{DS} = 400\text{ V}$



**Typical switching energy losses as a function of  $I_{DS}$ , 2nd device own body diode:  $V_{GS} = 0\text{ V}$**

$E = f(I_{DS})$

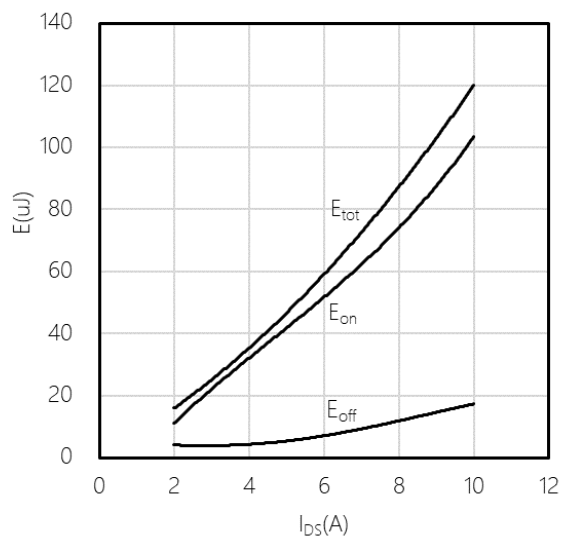
$V_{GS} = 0/15\text{ V}$ ,  $R_{G(ext)} = 2.2\text{ }\Omega$ ,  $T_{VJ} = 25\text{ }^\circ\text{C}$ ,  $V_{DS} = 400\text{ V}$



**Typical switching energy losses as a function of  $I_{DS}$ , 2nd device own body diode:  $V_{GS} = 0\text{ V}$**

$E = f(I_{DS})$

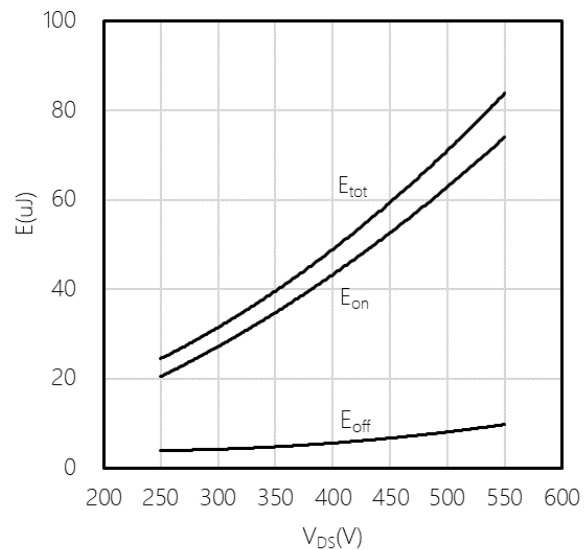
$V_{GS} = 0/15\text{ V}$ ,  $R_{G(ext)} = 2.2\text{ }\Omega$ ,  $T_{VJ} = 175\text{ }^\circ\text{C}$ ,  $V_{DS} = 400\text{ V}$



**Typical switching energy losses as a function of  $V_{DS}$ , 2nd device own body diode:  $V_{GS} = 0\text{ V}$**

$E = f(V_{DS})$

$V_{GS} = 0/15\text{ V}$ ,  $R_{G(ext)} = 2.2\text{ }\Omega$ ,  $T_{VJ} = 25\text{ }^\circ\text{C}$ ,  $I_{DS} = 5\text{ A}$

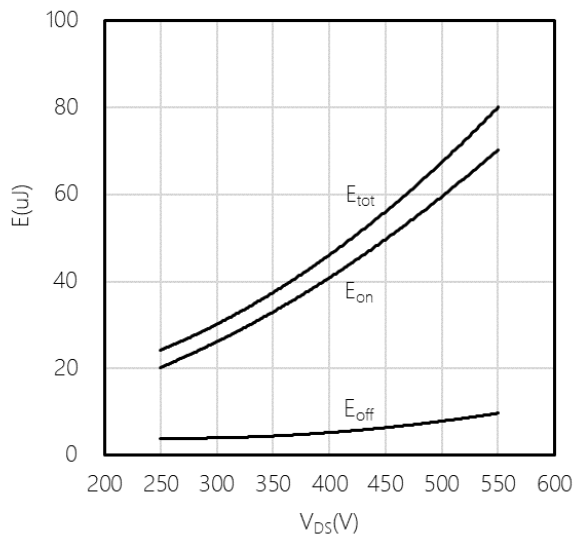


**Typical switching energy losses as a function of  $V_{DS}$ ,**

**2nd device own body diode:  $V_{GS} = 0\text{ V}$**

$E = f(V_{DS})$

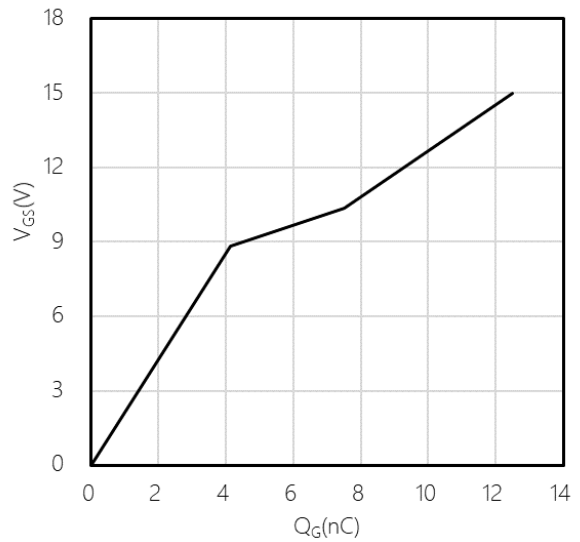
$V_{VGS} = 0/15\text{ V}$ ,  $R_{G(ext)} = 2.2\ \Omega$ ,  $T_{VJ} = 175\ ^\circ\text{C}$ ,  $I_{DS} = 5\text{ A}$



**Typical gate charge**

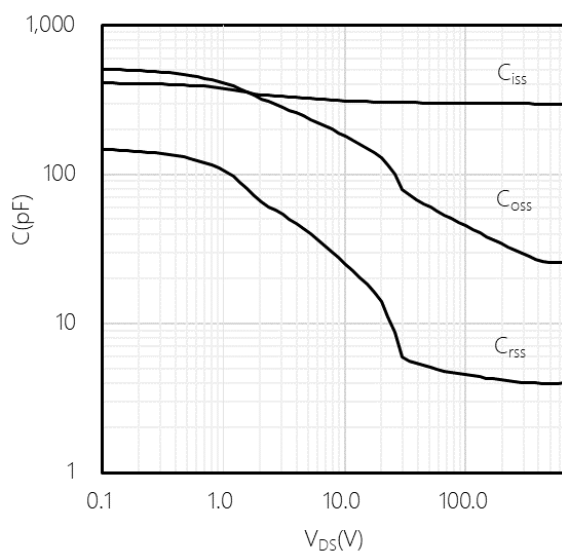
$V_{GS} = f(Q_G)$ ,  $I_{DS} = 5\text{ A}$ ,  $V_{DS} = 400\text{ V}$

turn-on pulse



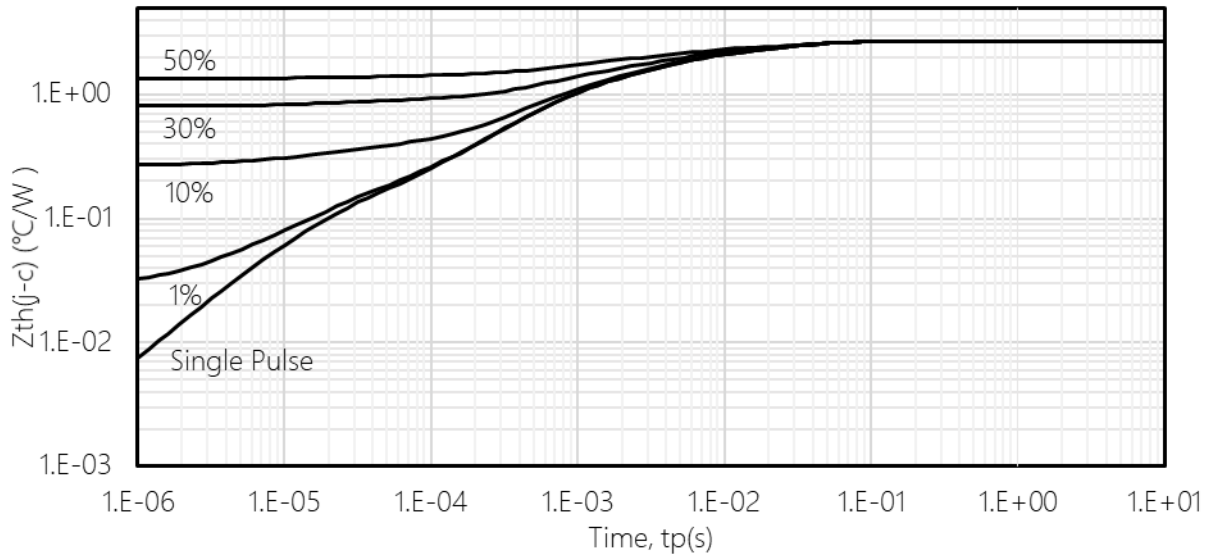
**Typical capacitance as a function of drain-source voltage**

$C = f(V_{DS})$ ,  $V_{GS} = 0\text{ V}$ ,  $f = 1\text{ MHz}$



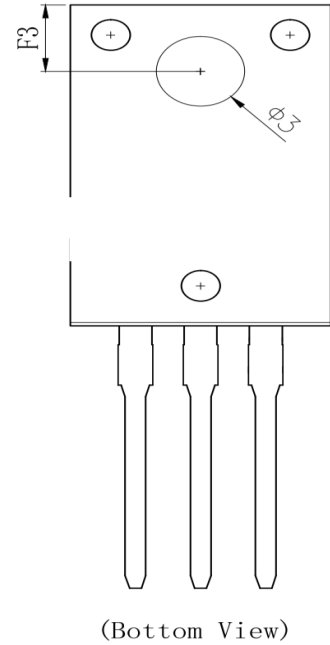
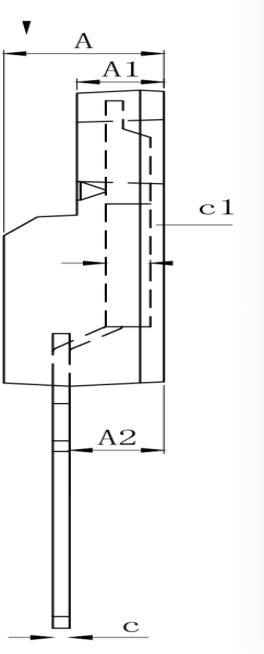
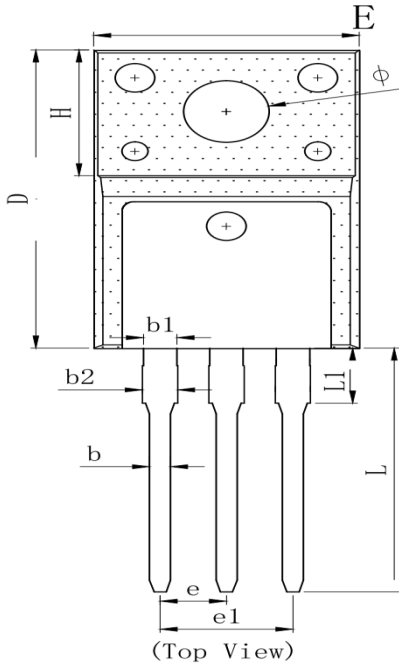
**Transient thermal resistance (MOSFET)**

$(Z_{th(j-c,max)} = f(t_p), \text{Parameter } D = t_p/T$



Package Dimensions

Mechanical Dimensions for TO-220F



SYMBOL	MILLIMETER		
	MIN	Typ.	MAX
A	4.500	4.700	4.900
A1	2.340	2.540	2.740
A2	2.560	2.760	2.960
b	0.700	0.800	0.950
b1	1.180	1.280	1.430
b2	1.250	1.350	1.550
c	0.400	0.500	0.650
c1	1.200	1.300	1.350
D	15.570	15.870	16.170
H	6.700 REF		
E	9.960	10.160	10.360
e	2.540 BSC		
e1	5.080 BSC		
L	12.680	12.980	13.280
L1	2.780	2.930	3.080
F3	3.150	3.300	3.450
phi	3.030	3.180	3.450
phi3	3.150	3.450	3.650