

# 650 V 42 mΩ SiC MOSFET

## Silicon Carbide MOSFET

Trench-Assisted Planar Technology

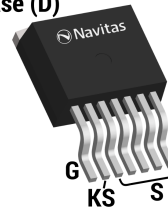
$V_{DS}$	=	650 V
$R_{DS(ON)}(Typ.)$	=	42 mΩ
$I_D(T_C = 100^\circ\text{C})$	=	39 A

### Features

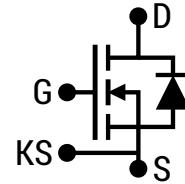
- Gen3F (3rd Generation) Technology
- Most Stable  $R_{DS(ON)}$  over Temperature
- Low  $C_{OSS}$ ,  $C_{RSS}$  and Balanced  $C_{ISS}/C_{RSS}$
- Lower  $Q_{GD}$  and Balanced  $R_{G(INT)}$
- Electromagnetically Optimized Design
- Robust Body Diode with Low  $V_F$  and Low  $Q_{RR}$
- 100% Avalanche (UIL) Tested
- AEC-Q101 Qualified

### Package

Case (D)



TO-263-7



D = Drain  
G = Gate  
S = Source  
KS = Kelvin Source



### Advantages

- Superior Performance and Robustness
- Lowest Conduction Losses at all Temperatures
- Lesser Switching Spikes and Lower Losses
- Faster and More Efficient Switching
- Reduced Ringing
- Ease of Paralleling without Thermal Runaway
- Excellent Power Density and System Efficiency
- Enhanced System Reliability

### Applications

- xEV - OBC & DC-DC
- EV Fast Charging Infrastructure
- Solar / PV
- Energy Storage System
- Server & Telecom Power Supply
- Uninterruptible Power Supply
- Motor Control
- Class D Amplifiers

### Absolute Maximum Ratings (At $T_C = 25^\circ\text{C}$ Unless Otherwise Stated)

Parameter	Symbol	Conditions	Values	Unit	Note
Drain-Source Voltage	$V_{DS(max)}$	$V_{GS} = 0\text{ V}, I_D = 100\text{ }\mu\text{A}$	650	V	
Gate-Source Voltage (Dynamic)	$V_{GS(max)}$		-10 / +22	V	
Gate-Source Voltage (Static)	$V_{GS(op)-ON}$	Recommended Operation	15 to 18	V	Note 1
	$V_{GS(op)-OFF}$		-5 to -3		
Continuous Drain Current	$I_D$	$T_C = 25^\circ\text{C}, V_{GS} = -5 / +18\text{ V}$	56	A	Fig. 16
		$T_C = 100^\circ\text{C}, V_{GS} = -5 / +18\text{ V}$	39		
		$T_C = 135^\circ\text{C}, V_{GS} = -5 / +18\text{ V}$	29		
Pulsed Drain Current	$I_{D(pulse)}$	$t_P \leq 3\text{ }\mu\text{s}, D \leq 1\%, V_{GS} = 18\text{ V}$	100	A	Note 2
Power Dissipation	$P_D$	$T_C = 25^\circ\text{C}$	187	W	Fig. 17
Non-Repetitive Avalanche Energy	$E_{AS}$	$L = 36\text{ mH}, I_{AV} = 3\text{ A}$	162	mJ	
Operating Junction and Storage Temperature	$T_J, T_{stg}$		-55 to 175	$^\circ\text{C}$	

Note 1: This product can support 0V turn-off gate drive voltage with optimized PCB layout and gate drive circuit configuration.

Note 2: Pulse Width  $t_P$  Limited by  $T_{J(max)}$



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Electrical Characteristics (At  $T_C = 25^\circ\text{C}$  Unless Otherwise Stated)

Parameter	Symbol	Conditions	Values			Unit	Note
			Min.	Typ.	Max.		
Drain-Source Breakdown Voltage	$V_{DS}$	$V_{GS} = 0\text{ V}, I_D = 100\text{ }\mu\text{A}$	650			V	
Zero Gate Voltage Drain Current	$I_{DSS}$	$V_{DS} = 650\text{ V}, V_{GS} = 0\text{ V}$		1	50	$\mu\text{A}$	
Gate Source Leakage Current	$I_{GSS}$	$V_{DS} = 0\text{ V}, V_{GS} = 22\text{ V}$			100	nA	
		$V_{DS} = 0\text{ V}, V_{GS} = -10\text{ V}$			-100		
Gate Threshold Voltage	$V_{GS(th)}$	$V_{DS} = V_{GS}, I_D = 8\text{ mA}$	2.2	2.8	4.3	V	Note 3
Transconductance	$g_{fs}$	$V_{DS} = 10\text{ V}, I_D = 20\text{ A}$		10.8		S	Fig. 5
		$V_{DS} = 10\text{ V}, I_D = 20\text{ A}, T_j = 175^\circ\text{C}$		10.5			
Drain-Source On-State Resistance	$R_{DS(on)}$	$V_{GS} = 18\text{ V}, I_D = 20\text{ A}$		42	54	m $\Omega$	Fig. 5-9
		$V_{GS} = 18\text{ V}, I_D = 20\text{ A}, T_j = 175^\circ\text{C}$		60			
		$V_{GS} = 15\text{ V}, I_D = 20\text{ A}$		55			
		$V_{GS} = 15\text{ V}, I_D = 20\text{ A}, T_j = 175^\circ\text{C}$		68			
Input Capacitance	$C_{iss}$			1640		pF	Fig. 12
Output Capacitance	$C_{oss}$			112			
Reverse Transfer Capacitance	$C_{rss}$			5.6			
$C_{oss}$ Stored Energy	$E_{oss}$	$V_{DS} = 400\text{ V}, V_{GS} = 0\text{ V}$ $f = 500\text{ KHz}, V_{AC} = 25\text{ mV}$		10		$\mu\text{J}$	Fig. 13
$C_{oss}$ Stored Charge	$Q_{oss}$			71		nC	
Effective Output Capacitance (Energy Related)	$C_{o(er)}$			125		pF	Note 4
Effective Output Capacitance (Time Related)	$C_{o(tr)}$			178			
Gate-Source Charge	$Q_{gs}$	$V_{DS} = 400\text{ V}, V_{GS} = -5 / +18\text{ V}$		13		nC	Fig. 11
Gate-Drain Charge	$Q_{gd}$	$I_D = 20\text{ A}$		16			
Total Gate Charge	$Q_g$	Per JEDEC JEP-192		55			
Internal Gate Resistance	$R_{G(int)}$	$V_{GS} = 18\text{ V}, f = 1\text{ MHz}, V_{AC} = 25\text{ mV}$		1.3		$\Omega$	
Turn-On Switching Energy (Body Diode)	$E_{on}$	$T_j = 25^\circ\text{C}, V_{GS} = -5/+18\text{ V}, R_{G(ext)} = 6.8\text{ }\Omega, L = 80.0\text{ }\mu\text{H}, I_D = 20\text{ A}, V_{DD} = 400\text{ V}$		67		$\mu\text{J}$	Fig. 24-27
Turn-Off Switching Energy (Body Diode)	$E_{off}$			34			
Turn-On Delay Time	$t_{d(on)}$	$V_{DD} = 400\text{ V}, V_{GS} = -5/+18\text{ V}$ $R_{G(ext)} = 6.8\text{ }\Omega, L = 80.0\text{ }\mu\text{H}, I_D = 20\text{ A}$ Timing relative to $V_{DS}$ , Inductive load		21		ns	Fig. 26
Rise Time	$t_r$			9			
Turn-Off Delay Time	$t_{d(off)}$			16			
Fall Time	$t_f$			8			

Note 3: Tested after applying 30ms pulse at  $V_{GS} = +25\text{V}$

Note 4:  $C_{o(er)}$ , a lumped capacitance that gives same stored energy as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400V.

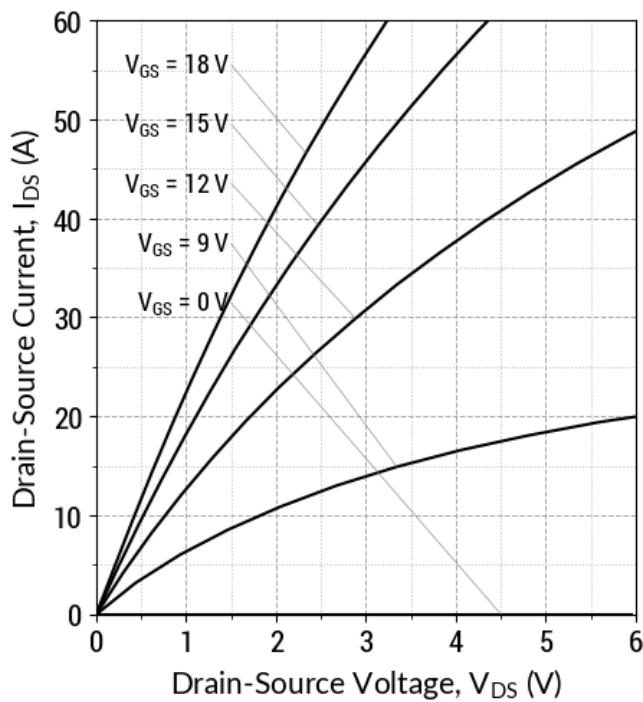
$C_{o(tr)}$ , a lumped capacitance that gives same charging times as  $C_{oss}$  while  $V_{DS}$  is rising from 0 to 400V.

## Reverse Diode Characteristics

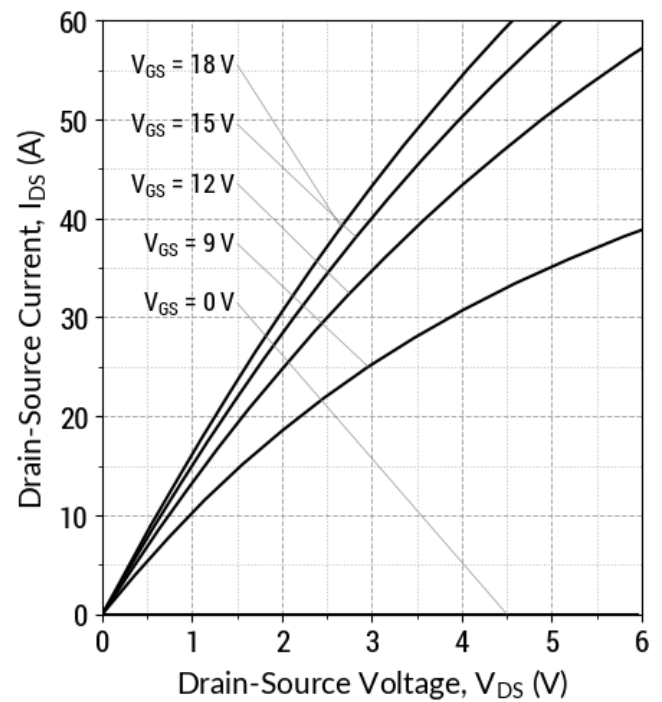
Parameter	Symbol	Conditions	Values			Unit	Note
			Min.	Typ.	Max.		
Diode Forward Voltage	$V_{SD}$	$V_{GS} = -5\text{ V}, I_{SD} = 10\text{ A}$ $V_{GS} = -5\text{ V}, I_{SD} = 10\text{ A}, T_j = 175^\circ\text{C}$		4.4 3.9		V	Fig. 18-19
Continuous Diode Forward Current	$I_S$	$V_{GS} = -5\text{ V}, T_c = 25^\circ\text{C}$ $V_{GS} = -5\text{ V}, T_c = 100^\circ\text{C}$			30 18	A	
Diode Pulse Current	$I_{S(pulse)}$	$V_{GS} = -5\text{ V}$		72		A	Note 2
Reverse Recovery Time	$t_{rr}$	$V_{GS} = -5\text{ V}, I_{SD} = 20\text{ A}, V_R = 400\text{ V}$ $dif/dt = 4800\text{ A}/\mu\text{s}, T_j = 25^\circ\text{C}$		8		ns	
Reverse Recovery Charge	$Q_{rr}$			83		nC	
Peak Reverse Recovery Current	$I_{rrm}$			17		A	
Reverse Recovery Time	$t_{rr}$	$V_{GS} = -5\text{ V}, I_{SD} = 20\text{ A}, V_R = 400\text{ V}$ $dif/dt = 4800\text{ A}/\mu\text{s}, T_j = 175^\circ\text{C}$		9.5		ns	
Reverse Recovery Charge	$Q_{rr}$			158		nC	
Peak Reverse Recovery Current	$I_{rrm}$			24		A	

## Package Characteristics

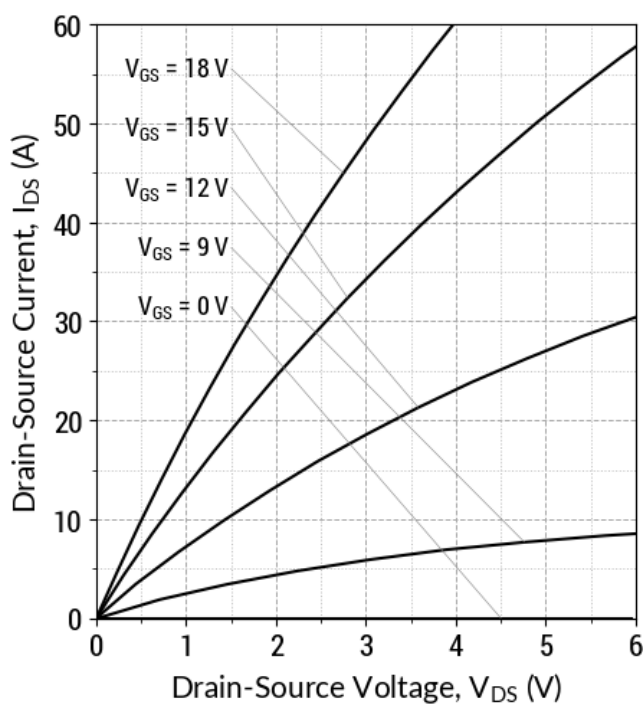
Parameter	Symbol	Conditions	Values	Unit	Note
Max Thermal Resistance, Junction - Case	$R_{thJC-Max}$	Maximum	0.8	$^\circ\text{C}/\text{W}$	Fig. 14
Weight	$W_T$		1.45	g	
Moisture Sensitivity Level	MSL		1		
EMC Material Group			II		

Fig 1: Typical Output Characteristics ( $T_J = 25^\circ\text{C}$ )

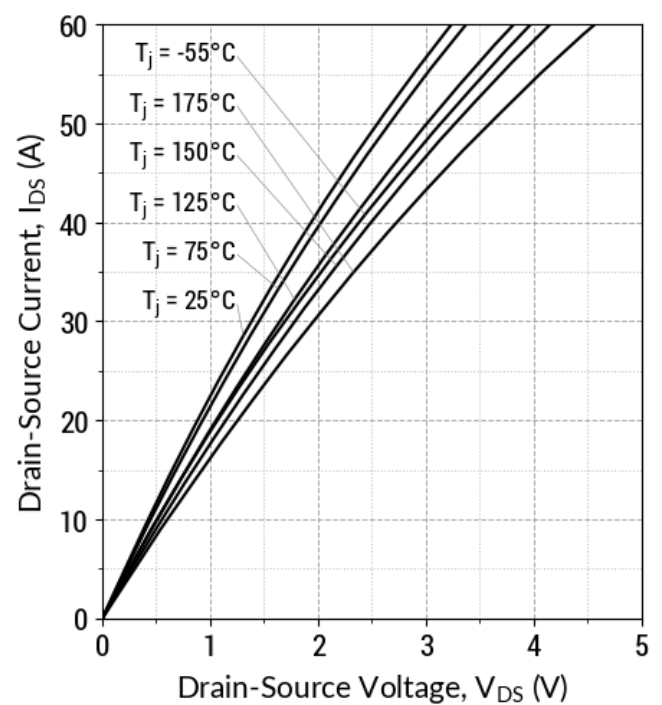
$$I_D = f(V_{DS}, V_{GS}); t_P = 50\ \mu\text{s}$$

Fig 2: Typical Output Characteristics ( $T_J = 175^\circ\text{C}$ )

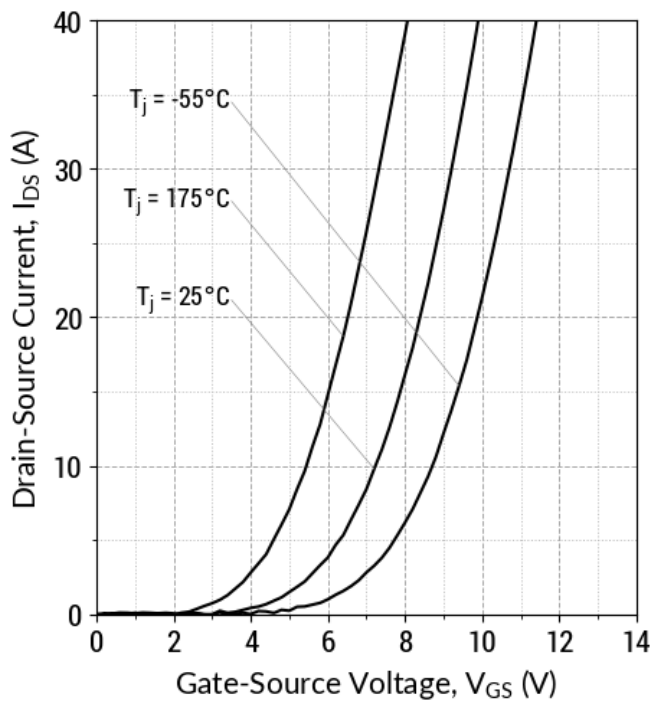
$$I_D = f(V_{DS}, V_{GS}); t_P = 50\ \mu\text{s}$$

Fig 3: Typical Output Characteristics ( $T_J = -55^\circ\text{C}$ )

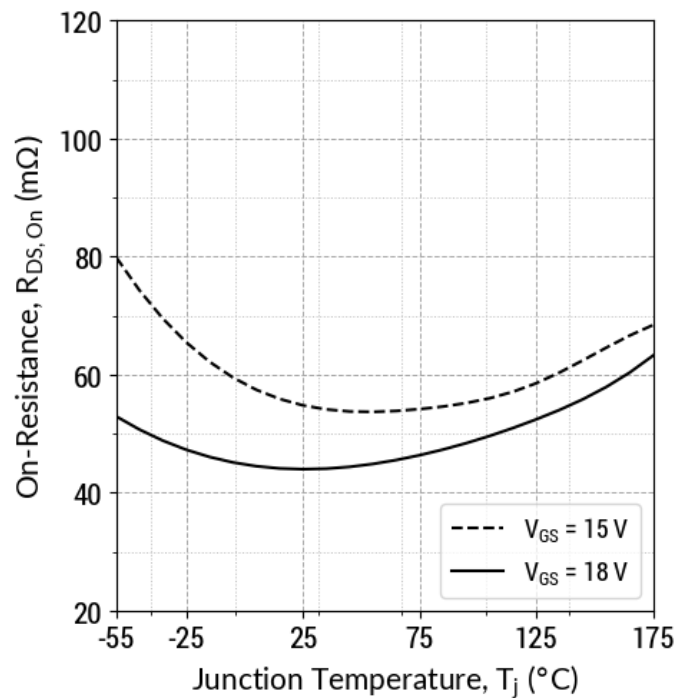
$$I_D = f(V_{DS}, V_{GS}); t_P = 50\ \mu\text{s}$$

Fig 4: Typical Output Characteristics ( $V_{GS} = 18\text{ V}$ )

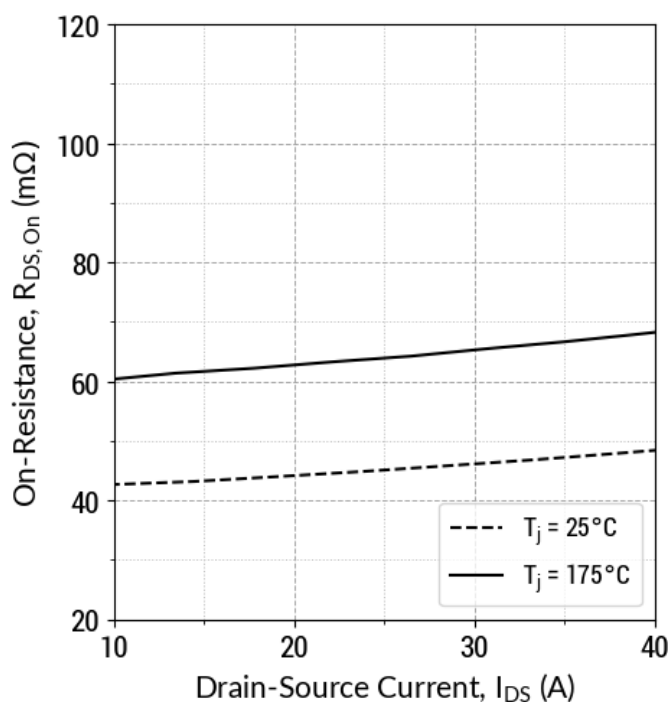
$$I_D = f(V_{DS}, T_J); t_P = 50\ \mu\text{s}$$

Fig 5: Typical Transfer Characteristics ( $V_{DS} = 10\text{ V}$ )

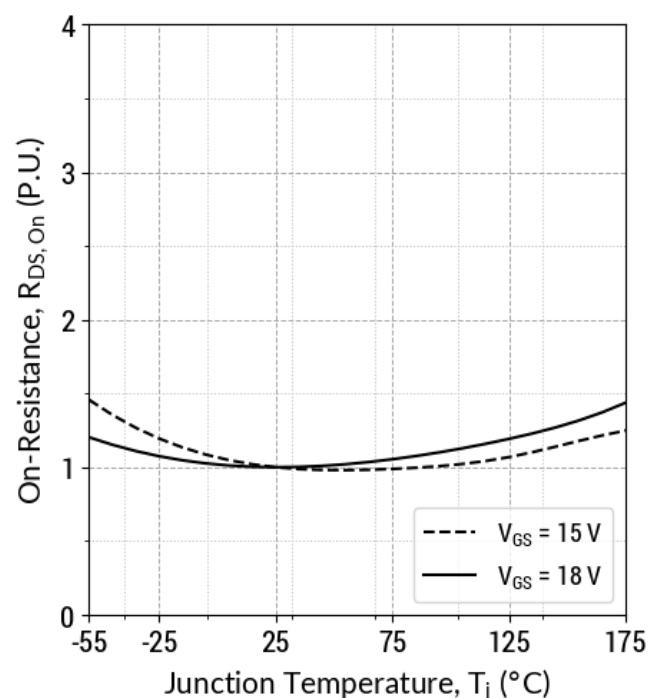
$$I_D = f(V_{GS}, T_j); t_P = 100\ \mu\text{s}$$

Fig 6: Typical  $R_{DS(ON)}$  v/s Temperature

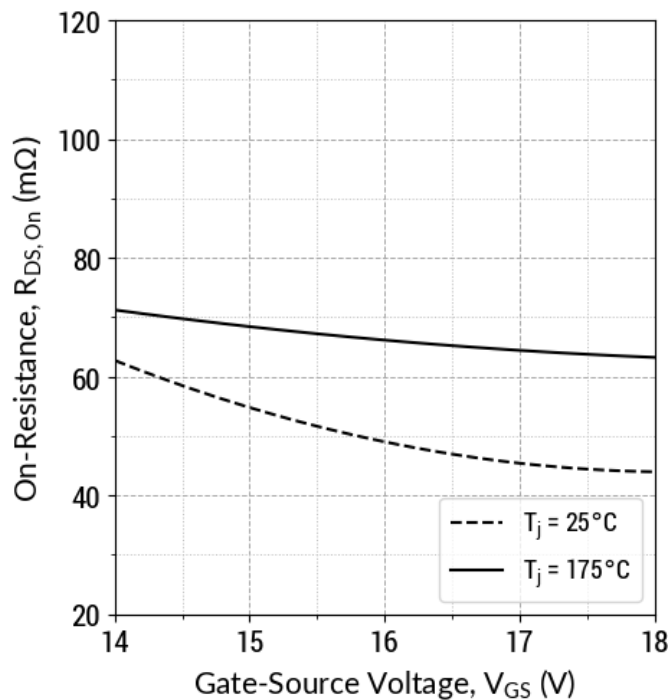
$$R_{DS(ON)} = f(T_j, V_{GS}); t_P = 50\ \mu\text{s}; I_D = 20\text{ A}$$

Fig 7: Typical  $R_{DS(ON)}$  v/s Drain Current

$$R_{DS(ON)} = f(T_j, I_D); t_P = 50\ \mu\text{s}; V_{GS} = 18\text{ V}$$

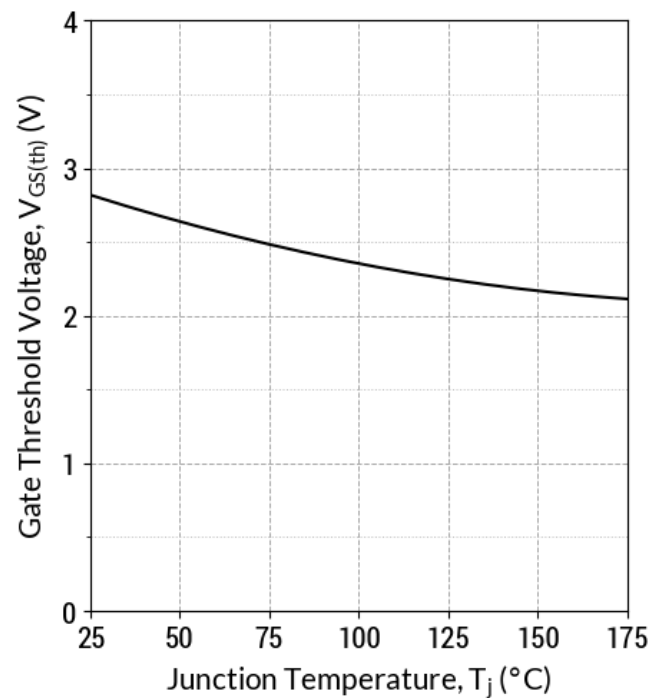
Fig 8: Typical Normalized  $R_{DS(ON)}$  v/s Temperature

$$R_{DS(ON)} = f(T_j); t_P = 50\ \mu\text{s}; I_D = 20\text{ A}$$

Fig 9: Typical  $R_{DS(ON)}$  v/s Gate Voltage

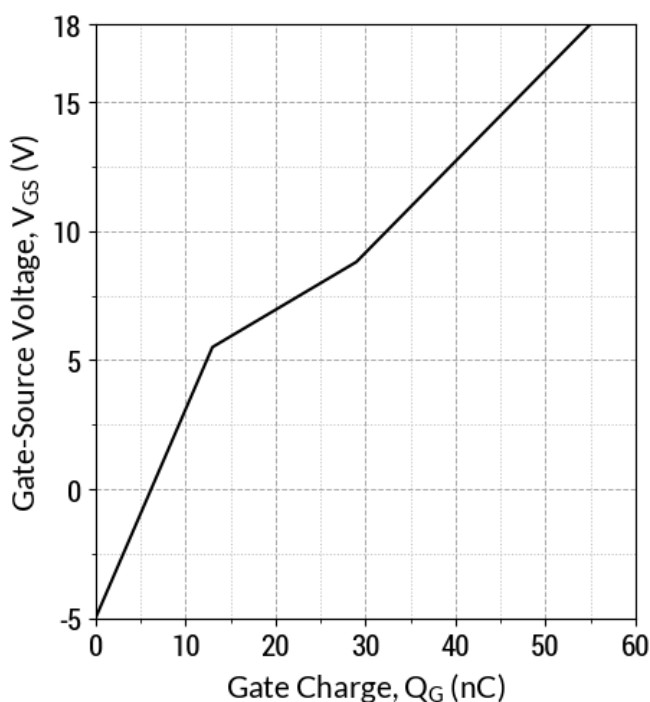
$$R_{DS(ON)} = f(T_j, V_{GS}); t_P = 50 \mu\text{s}; I_D = 20 \text{ A}$$

Fig 10: Typical Threshold Voltage Characteristics



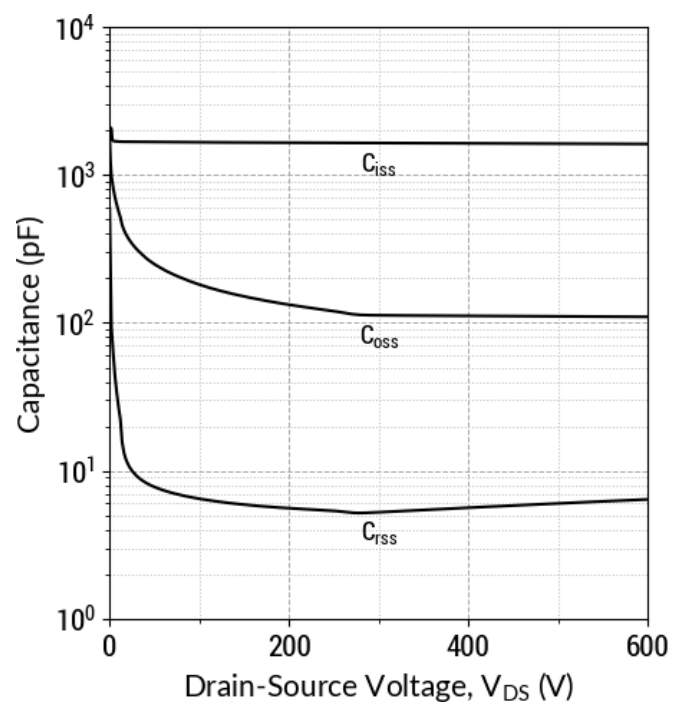
$$V_{GS(th)} = f(T_j); V_{DS} = V_{GS}; I_D = 8 \text{ mA}$$

Fig 11: Typical Gate Charge Characteristics



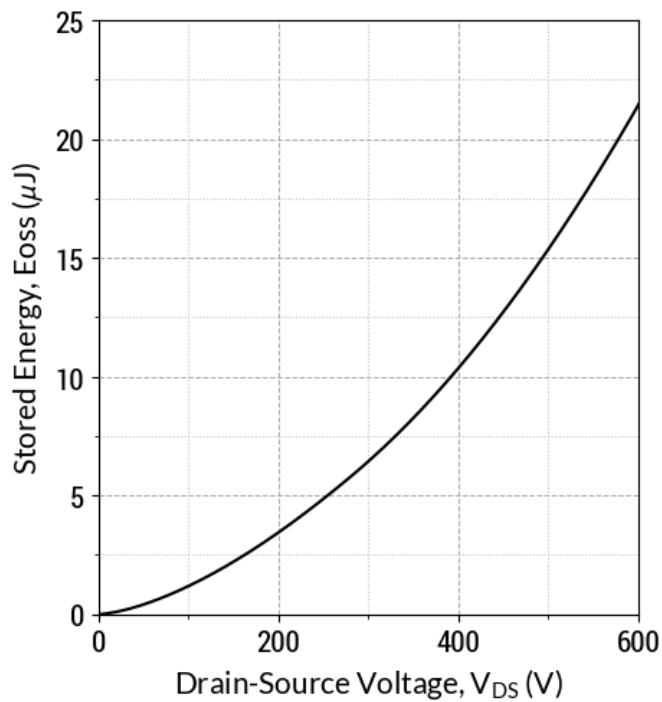
$$I_D = 20 \text{ A}; V_{DS} = 400 \text{ V}; T_c = 25^\circ\text{C}$$

Fig 12: Typical Capacitance v/s Drain-Source Voltage



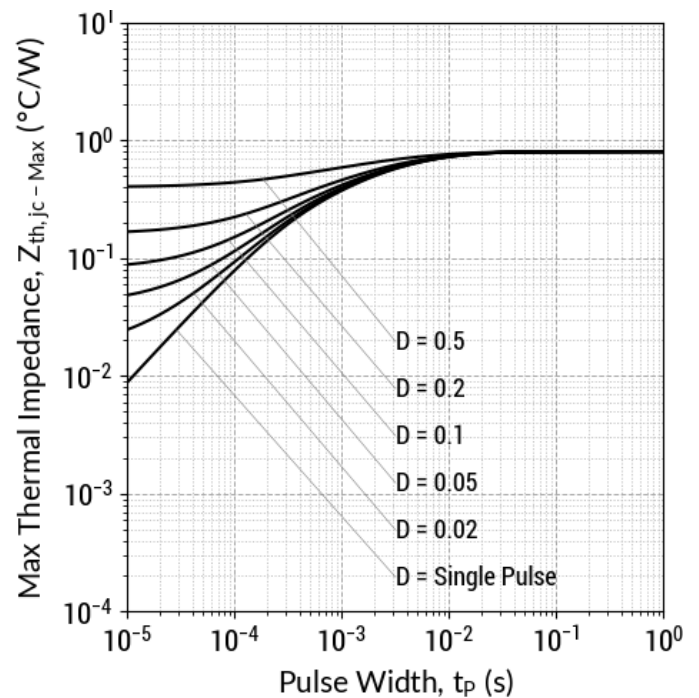
$$f = 500 \text{ KHz}; V_{AC} = 25 \text{ mV}$$

Fig 13: Output Capacitor Stored Energy

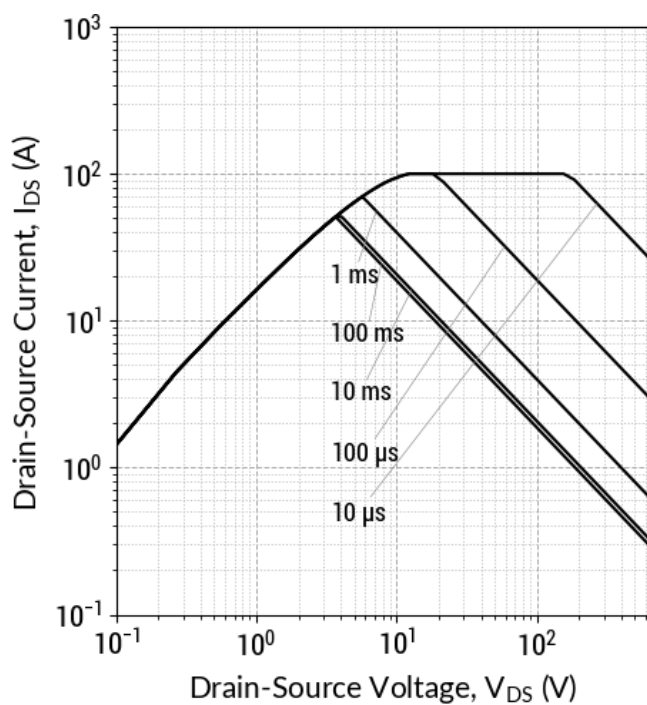


$$E_{oss} = f(V_{DS})$$

Fig 14: Max. Transient Thermal Impedance

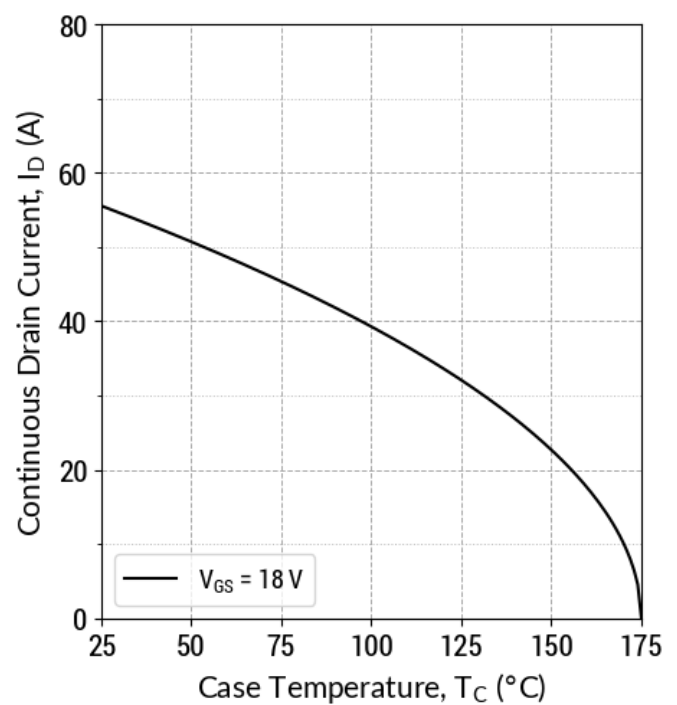


$$Z_{th,jc} = f(t_p, D); D = t_p/T$$

Fig 15: Safe Operating Area ( $T_c = 25^{\circ}C$ )

$$I_D = f(V_{DS}, t_p); T_j \leq 175^{\circ}C; D = 0$$

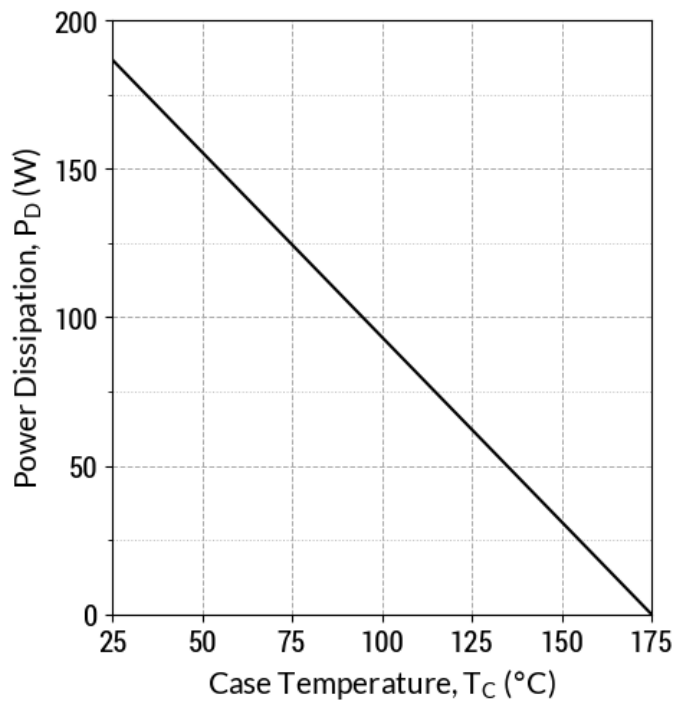
Fig 16: Current De-rating Curve



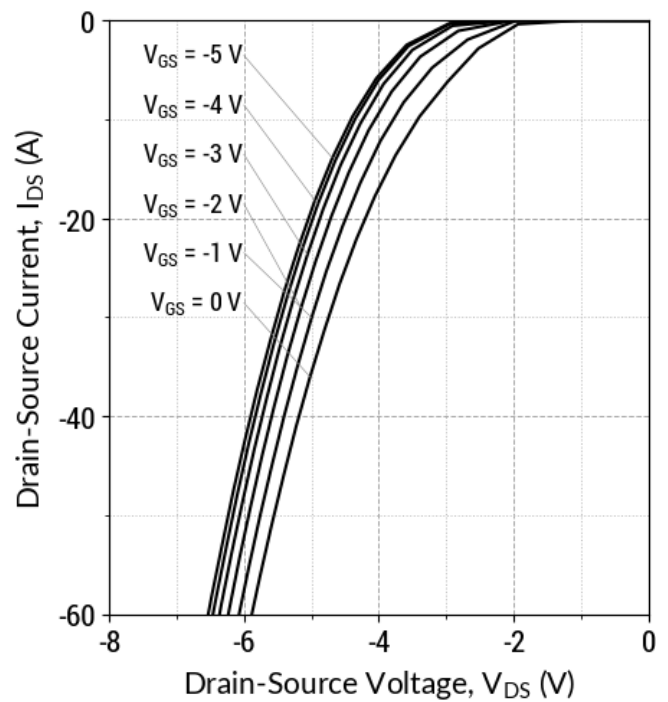
$$I_D = f(T_C); T_j \leq 175^{\circ}C$$



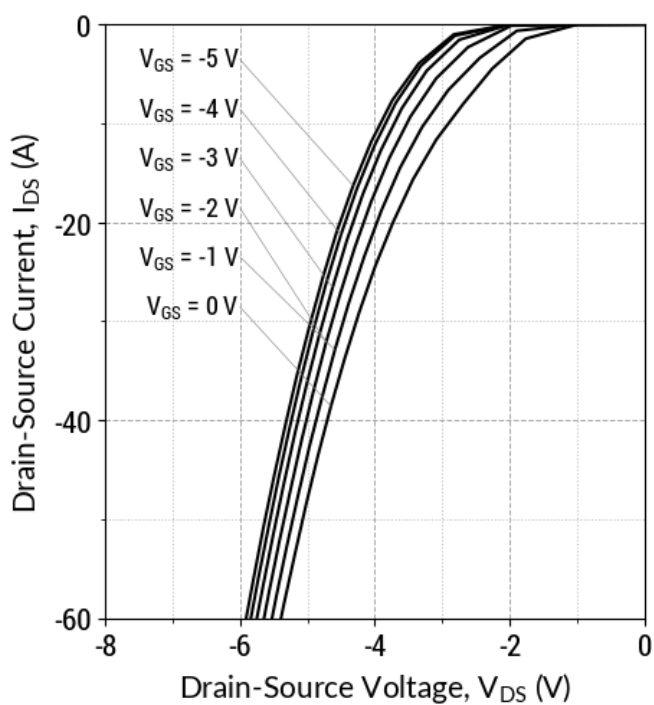
Fig 17: Power De-rating Curve



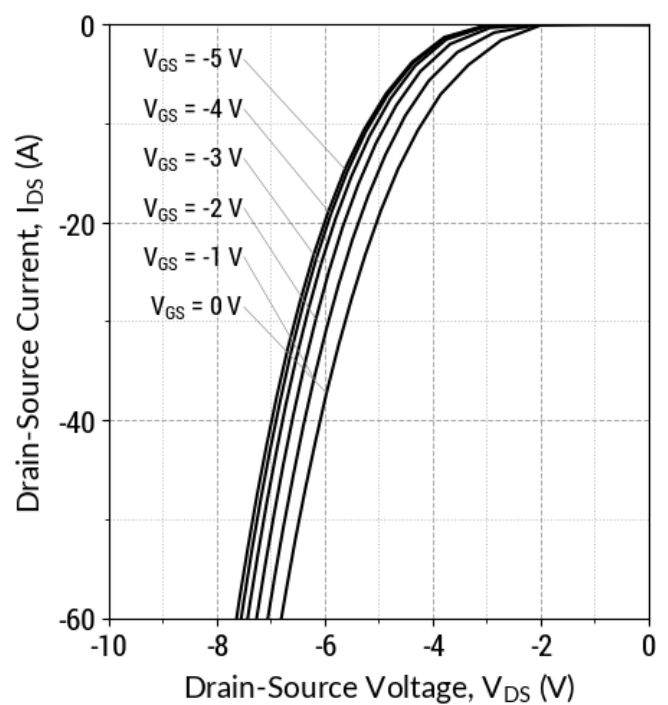
$$P_D = f(T_C); T_j \leq 175^\circ\text{C}$$

Fig 18: Typical Body Diode Characteristics ( $T_j = 25^\circ\text{C}$ )

$$I_D = f(V_{DS}, V_{GS}); t_P = 50\text{ }\mu\text{s}$$

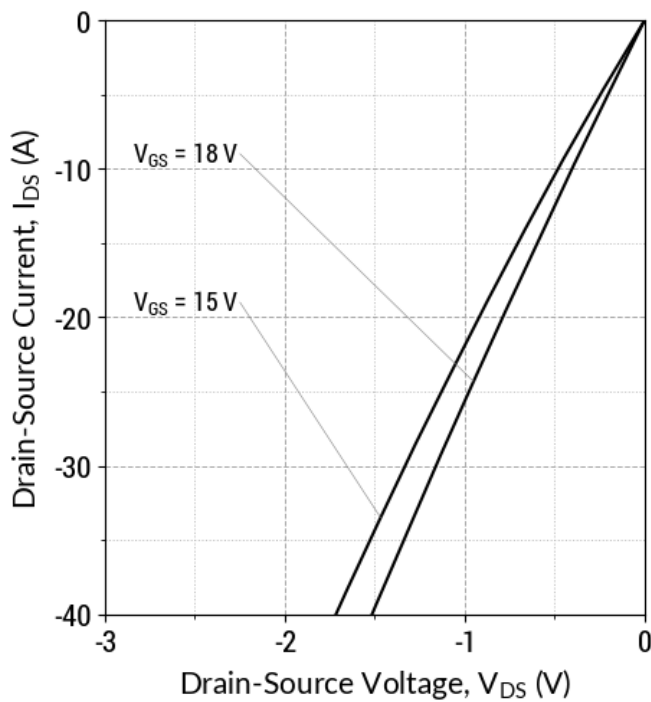
Fig 19: Typical Body Diode Characteristics ( $T_j = 175^\circ\text{C}$ )

$$I_D = f(V_{DS}, V_{GS}); t_P = 50\text{ }\mu\text{s}$$

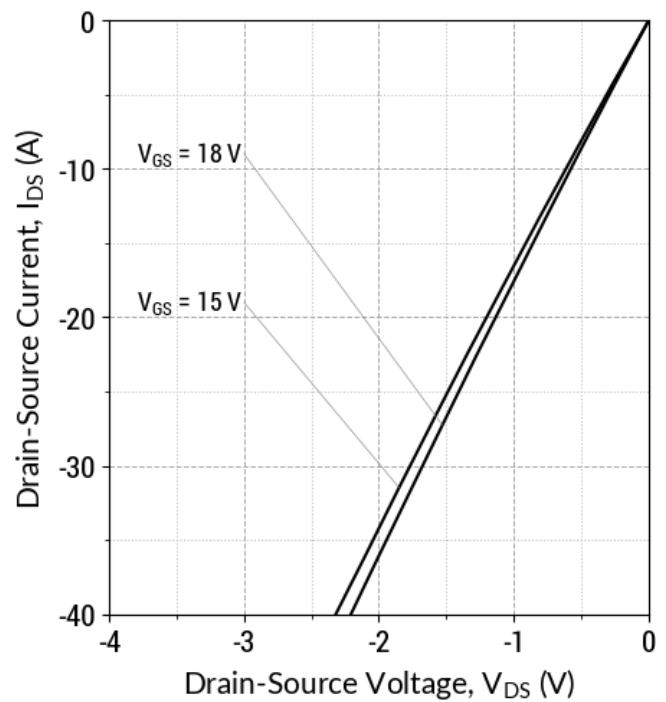
Fig 20: Typical Body Diode Characteristics ( $T_j = -55^\circ\text{C}$ )

$$I_D = f(V_{DS}, V_{GS}); t_P = 50\text{ }\mu\text{s}$$

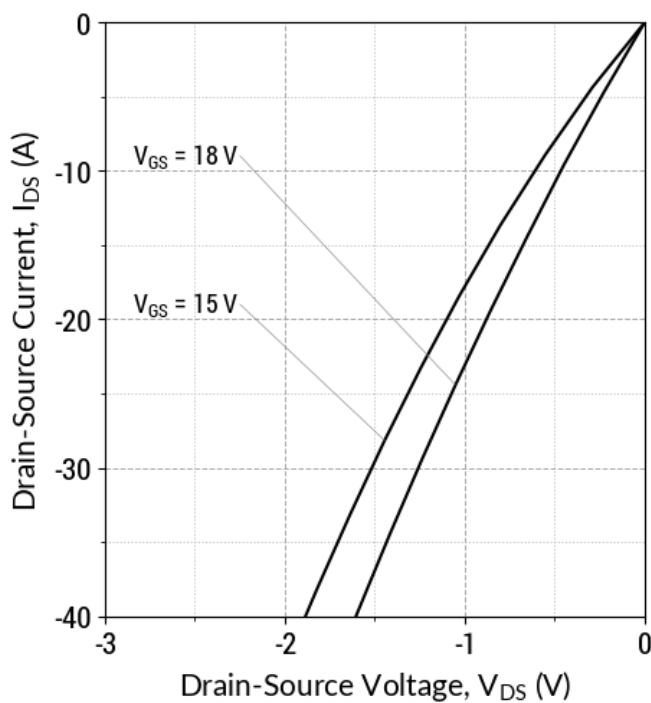


Fig 21: Typical Third Quadrant Characteristics ( $T_j = 25^\circ\text{C}$ )

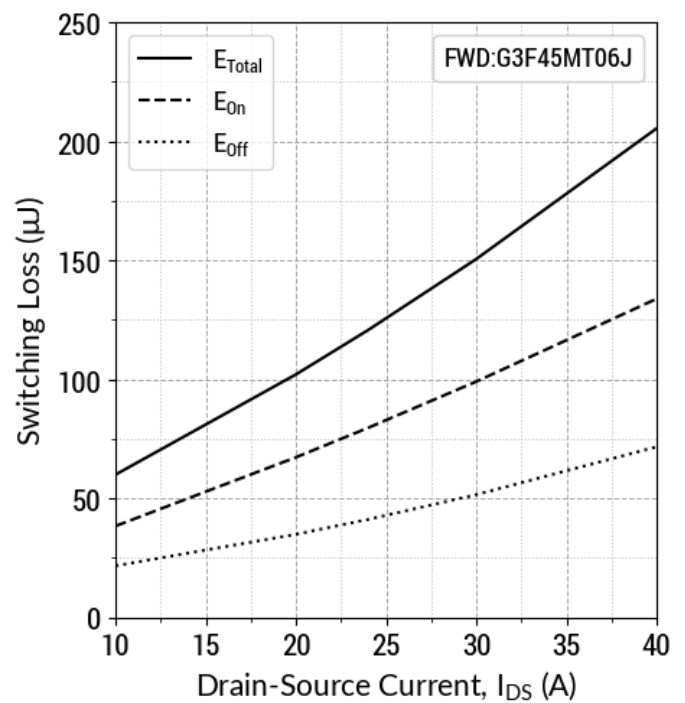
$$I_D = f(V_{DS}, V_{GS}); t_P = 50 \mu\text{s}$$

Fig 22: Typical Third Quadrant Characteristics ( $T_j = 175^\circ\text{C}$ )

$$I_D = f(V_{DS}, V_{GS}); t_P = 50 \mu\text{s}$$

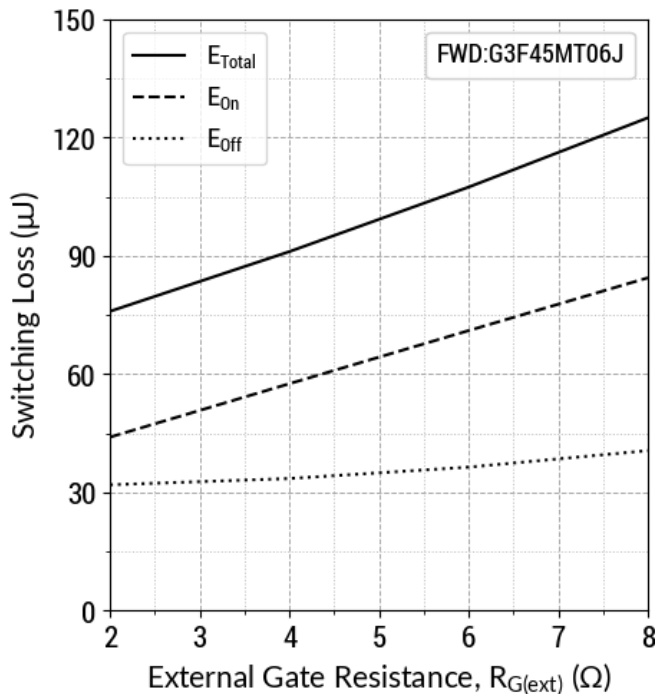
Fig 23: Typical Third Quadrant Characteristics ( $T_j = -55^\circ\text{C}$ )

$$I_D = f(V_{DS}, V_{GS}); t_P = 50 \mu\text{s}$$

Fig 24: Inductive Switching Energy v/s Drain Current ( $V_{DD} = 400\text{V}$ )

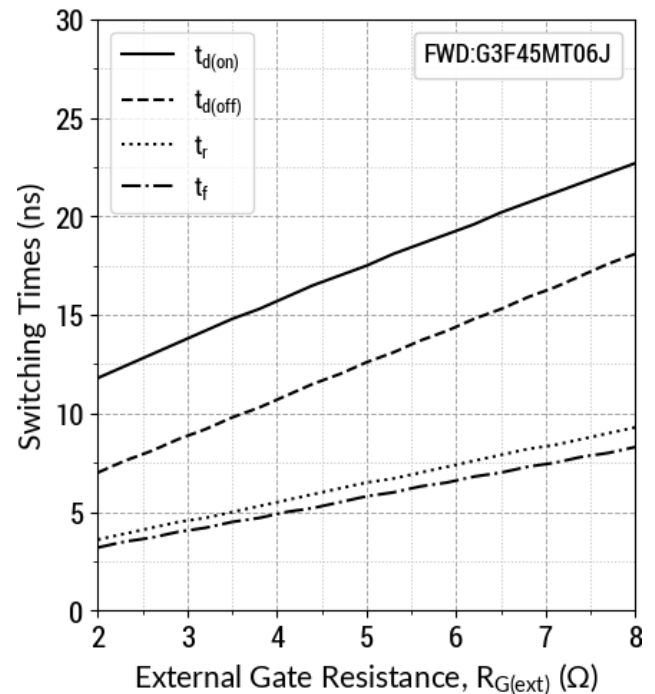
$$T_j = 25^\circ\text{C}; V_{GS} = -5/+18\text{V}; R_{G(\text{ext})} = 6.8 \Omega; L = 80.0 \mu\text{H}$$

Fig 25: Inductive Switching Energy v/s  $R_{G(ext)}$   
( $V_{DD} = 400V$ )



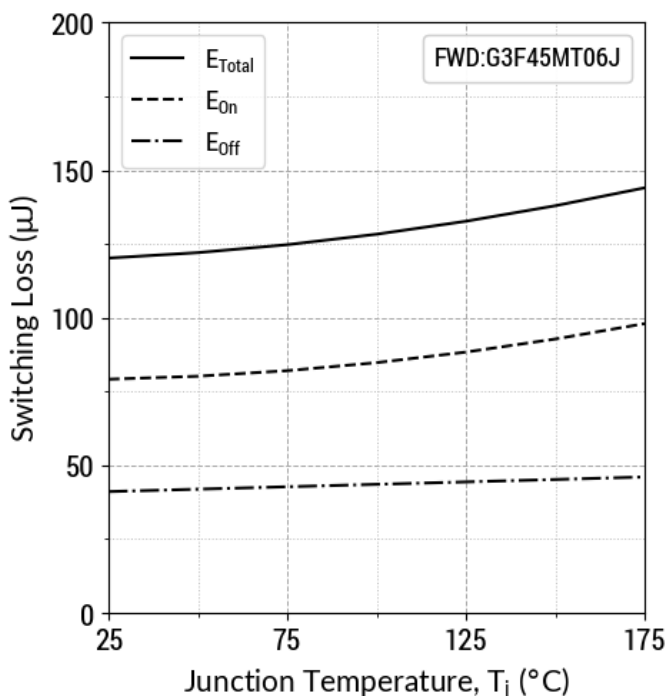
$T_j = 25^\circ C$ ;  $V_{GS} = -5/+18V$ ;  $I_{DS} = 20 A$ ;  $L = 80.0\mu H$

Fig 26: Switching Time v/s  $R_{G(ext)}$   
( $V_{DD} = 400V$ )



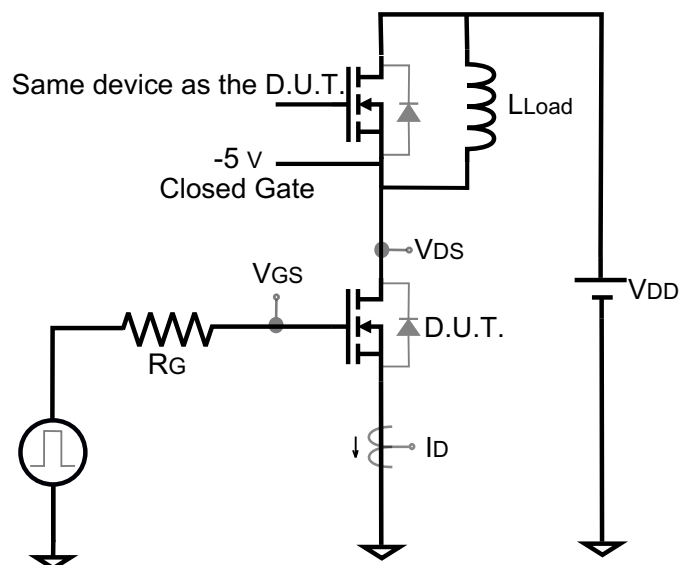
$T_j = 25^\circ C$ ;  $V_{GS} = -5/+18V$ ;  $I_{DS} = 20 A$ ;  $L = 80.0\mu H$

Fig 27: Inductive Switching Energy v/s Temperature  
( $V_{DD} = 400V$ )

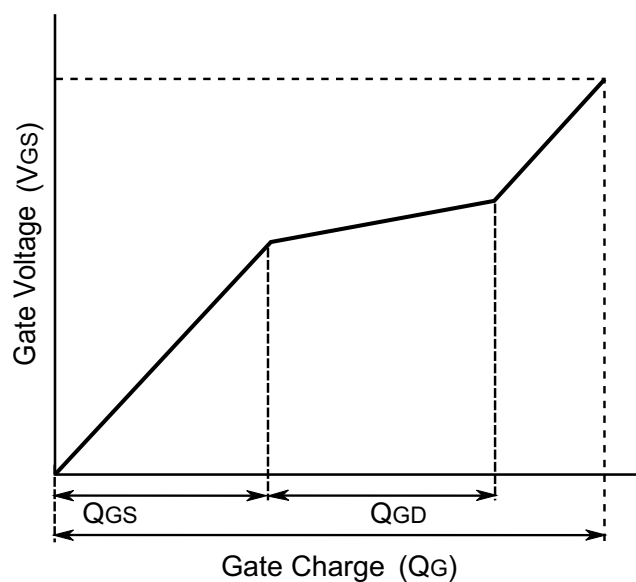


$T_j = 25^\circ C$ ;  $V_{GS} = -5/+18V$ ;  $R_{G(ext)} = 6.8 \Omega$ ;  $I_{DS} = 20 A$ ;  $L = 80.0\mu H$

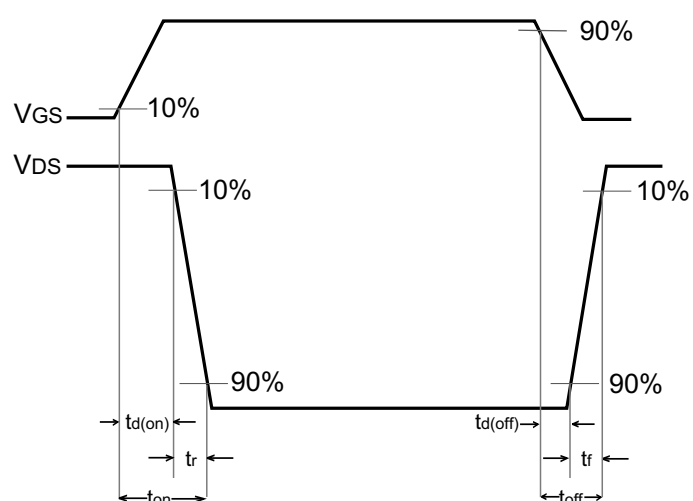
## Gate Charge Waveform



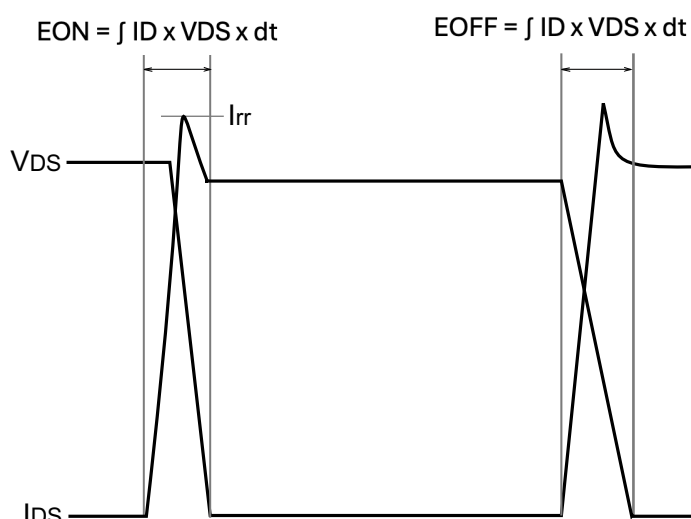
Note: Gate Charge, Switching Time and Energy Circuit



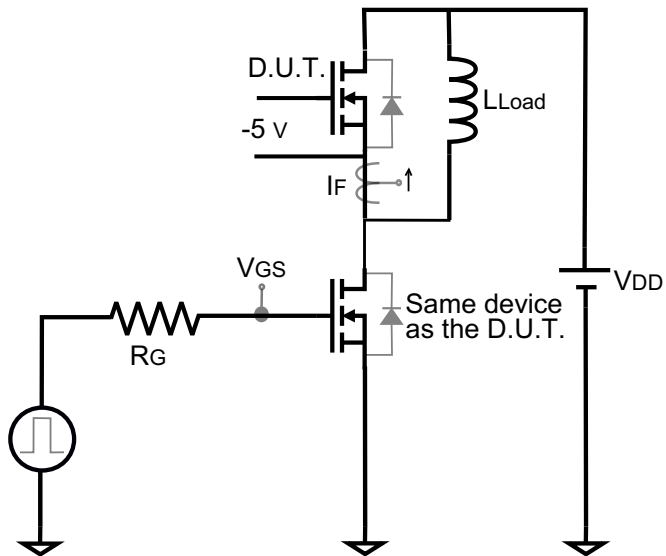
## Switching Time Waveform



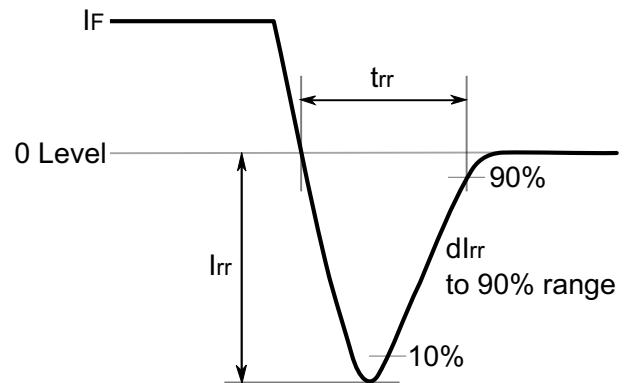
## Switching Energy Waveform



## Reverse Recovery Circuit

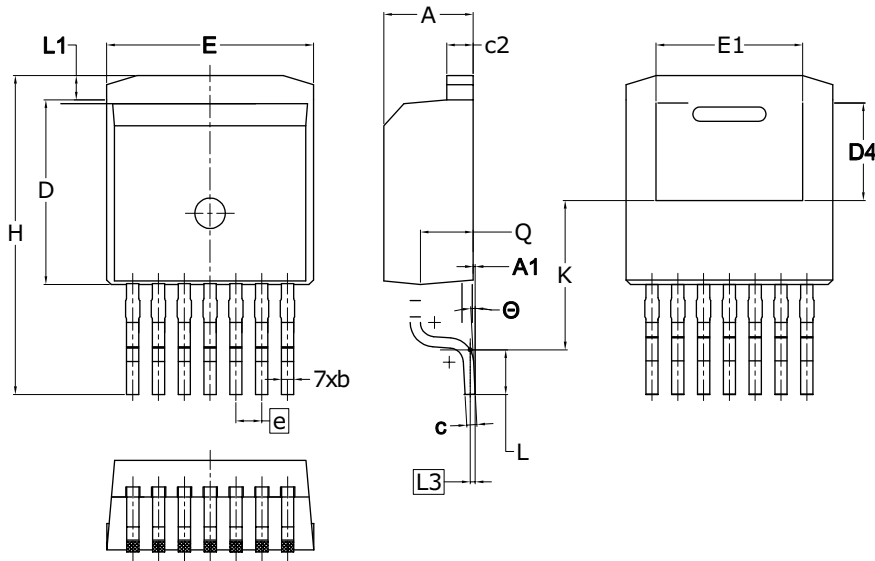


## Reverse Recovery Waveform



## Package Dimensions

## TO-263-7 Package Outline



## Note:

1. All Dimensions Are In mm.
2. Dimension D & E Do Not Include Mold Flash.  
These Dimensions Are Measured At The Outermost Extreme Of The Plastic Body.
3. Thermal Pad Contour Optional Within Dimensions E, L1, D4 & E1.
4. Dimension D4 & E1 Establish A Minimum Mounting Surface for The Thermal Pad.
5. ■ is Exposed Cu.
6. There Is Exposed Cu and Molding Flash Bleeding At The Pin Which Is Close To Package.

SYMBOL	DIMENSIONS	
	MIN.	MAX.
A	4.30	4.50
A1	0.00	0.25
b	0.50	0.70
c	0.45	0.60
c2	1.20	1.40
D	8.93	9.23
D4	4.65	4.95
E	10.08	10.28
E1	6.82	7.62
e	1.27 BSC	
H	15.00	16.00
K	7.30	
L	1.90	2.50
L1	1.00	1.40
L3	0.25 BSC	
Q	2.45	2.75
Θ	0°	7°

## NOTE

1. CONTROLLED DIMENSION IS MILLIMETER.
2. DIMENSIONS DO NOT INCLUDE END FLASH, MOLD FLASH, MATERIAL PROTRUSIONS.
3. THE SOURCE AND KELVIN-SOURCE PINS ARE NOT INTERCHANGABLE. THEIR EXCHANGE MIGHT LEAD TO MALFUNCTION.

## Revision History

• Rev 24/Aug: Initial Release (Rev 1.0)

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