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## SiC JFET Division

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DATASHEET

# UF4SC120023K4S

## Silicon Carbide (SiC) Cascode JFET - EliteSiC, Power N-Channel, TO-247-4L, 1200 V, 23 mohm

Rev. B, January 2025

### Description

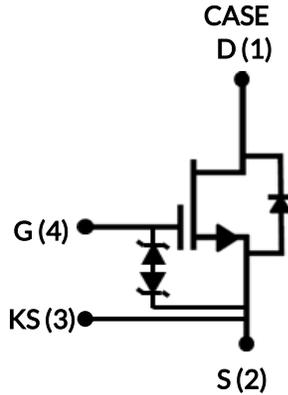
The UF4SC120023K4S is a 1200V, 23mΩ G4 SiC FET. It is based on a unique ‘cascode’ circuit configuration, in which a normally-on SiC JFET is co-packaged with a Si MOSFET to produce a normally-off SiC FET device. The device’s standard gate-drive characteristics allows for a true “drop-in replacement” to Si IGBTs, Si FETs, SiC MOSFETs or Si superjunction devices. Available in the TO-247-4L package, this device exhibits ultra-low gate charge and exceptional reverse recovery characteristics, making it ideal for switching inductive loads and any application requiring standard gate drive.

### Features

- ◆ On-resistance  $R_{DS(on)}$ : 23mΩ (typ)
- ◆ Operating temperature: 175°C (max)
- ◆ Excellent reverse recovery:  $Q_{rr}$  = 341nC
- ◆ Low body diode  $V_{FSD}$ : 1.2V
- ◆ Low gate charge:  $Q_G$  = 37.8nC
- ◆ Threshold voltage  $V_{G(th)}$ : 4.8V (typ) allowing 0 to 15V drive
- ◆ Low intrinsic capacitance
- ◆ ESD protected: HBM class 2 and CDM class C3
- ◆ TO-247-4L package for faster switching, clean gate waveforms

### Typical applications

- ◆ EV charging
- ◆ PV inverters
- ◆ Switch mode power supplies
- ◆ Power factor correction modules
- ◆ Motor drives
- ◆ Induction heating



Part Number	Package	Marking
UF4SC120023K4S	TO-247-4L	UF4SC120023K4S



## Maximum Ratings

Parameter	Symbol	Test Conditions	Value	Units
Drain-source voltage	$V_{DS}$		1200	V
Gate-source voltage	$V_{GS}$	DC	-20 to +20	V
		AC (f > 1Hz)	-25 to +25	V
Continuous drain current <sup>1</sup>	$I_D$	$T_C \leq 95^\circ\text{C}$	53	A
Pulsed drain current <sup>2</sup>	$I_{DM}$	$T_C = 25^\circ\text{C}$	204	A
Single pulsed avalanche energy <sup>3</sup>	$E_{AS}$	L=15mH, $I_{AS}=4.1\text{A}$	126	mJ
SiC FET dv/dt ruggedness	dv/dt	$V_{DS} \leq 800\text{V}$	150	V/ns
Power dissipation	$P_{tot}$	$T_C = 25^\circ\text{C}$	385	W
Maximum junction temperature	$T_{J,max}$		175	$^\circ\text{C}$
Operating and storage temperature	$T_J, T_{STG}$		-55 to 175	$^\circ\text{C}$
Max. lead temperature for soldering, 1/8" from case for 5 seconds	$T_L$		250	$^\circ\text{C}$

1. Limited by bondwires
2. Pulse width  $t_p$  limited by  $T_{J,max}$
3. Starting  $T_J = 25^\circ\text{C}$

## Thermal Characteristics

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
Thermal resistance, junction-to-case	$R_{\theta JC}$			0.3	0.39	$^\circ\text{C/W}$

## Electrical Characteristics ( $T_J = +25^\circ\text{C}$ unless otherwise specified)

### Typical Performance - Static

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
Drain-source breakdown voltage	$BV_{DS}$	$V_{GS}=0V, I_D=1mA$	1200			V
Total drain leakage current	$I_{DSS}$	$V_{DS}=1200V, V_{GS}=0V, T_J=25^\circ\text{C}$		2	60	$\mu\text{A}$
		$V_{DS}=1200V, V_{GS}=0V, T_J=175^\circ\text{C}$		20		
Total gate leakage current	$I_{GSS}$	$V_{DS}=0V, T_J=25^\circ\text{C}, V_{GS}=-20V / +20V$		6	20	$\mu\text{A}$
Drain-source on-resistance	$R_{DS(on)}$	$V_{GS}=12V, I_D=40A, T_J=25^\circ\text{C}$		23	29	m $\Omega$
		$V_{GS}=12V, I_D=40A, T_J=125^\circ\text{C}$		42		
		$V_{GS}=12V, I_D=40A, T_J=175^\circ\text{C}$		57		
Gate threshold voltage	$V_{G(th)}$	$V_{DS}=5V, I_D=10mA$	4	4.8	6	V
Gate resistance	$R_G$	f=1MHz, open drain		4.5		$\Omega$

### Typical Performance - Reverse Diode

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
Diode continuous forward current <sup>1</sup>	$I_S$	$T_C \leq 95^\circ\text{C}$			53	A
Diode pulse current <sup>2</sup>	$I_{S,pulse}$	$T_C = 25^\circ\text{C}$			204	A
Forward voltage	$V_{FSD}$	$V_{GS}=0V, I_S=20A, T_J=25^\circ\text{C}$		1.2	1.35	V
		$V_{GS}=0V, I_S=20A, T_J=175^\circ\text{C}$		1.65		
Reverse recovery charge	$Q_{rr}$	$V_R=800V, I_S=40A, V_{GS}=0V, R_G=30\Omega$		341		nC
Reverse recovery time	$t_{rr}$	di/dt=2100A/ $\mu\text{s}, T_J=25^\circ\text{C}$		27		ns
Reverse recovery charge	$Q_{rr}$	$V_R=800V, I_S=40A, V_{GS}=0V, R_G=30\Omega$		374		nC
Reverse recovery time	$t_{rr}$	di/dt=2100A/ $\mu\text{s}, T_J=150^\circ\text{C}$		30		ns

## Typical Performance - Dynamic

Parameter	Symbol	Test Conditions	Value			Units	
			Min	Typ	Max		
Input capacitance	$C_{iss}$	$V_{DS}=800V, V_{GS}=0V$ $f=100kHz$		1430		pF	
Output capacitance	$C_{oss}$			85			
Reverse transfer capacitance	$C_{rss}$			2			
Effective output capacitance, energy related	$C_{oss(er)}$	$V_{DS}=0V$ to 800V, $V_{GS}=0V$		108		pF	
Effective output capacitance, time related	$C_{oss(tr)}$	$V_{DS}=0V$ to 800V, $V_{GS}=0V$		200		pF	
$C_{OSS}$ stored energy	$E_{oss}$	$V_{DS}=800V, V_{GS}=0V$		35		$\mu J$	
Total gate charge	$Q_G$	$V_{DS}=800V, I_D=40A,$ $V_{GS} = 0V$ to 15V		37.8		nC	
Gate-drain charge	$Q_{GD}$			8			
Gate-source charge	$Q_{GS}$			11.8			
Turn-on delay time	$t_{d(on)}$	Note 4 and 5, $V_{DS}=800V, I_D=40A,$ Gate Driver =0V to +15V, $R_{G\_ON}=1\Omega, R_{G\_OFF}=18\Omega,$ inductive Load, FWD: same device with $V_{GS} = 0V$ and $R_G = 18\Omega,$ Snubber: $R_s=20\Omega,$ $C_s=100pF$ $T_J=25^\circ C$		10		ns	
Rise time	$t_r$			24			
Turn-off delay time	$t_{d(off)}$			72			
Fall time	$t_f$			13.6			
Turn-on energy including $R_S$ energy	$E_{ON}$				599		$\mu J$
Turn-off energy including $R_S$ energy	$E_{OFF}$				195		
Total switching energy	$E_{TOTAL}$				794		
Snubber $R_S$ energy during turn-on	$E_{RS\_ON}$				7		
Snubber $R_S$ energy during turn-off	$E_{RS\_OFF}$				10		
Turn-on delay time	$t_{d(on)}$		Note 4 and 5, $V_{DS}=800V, I_D=40A,$ Gate Driver =0V to +15V, $R_{G\_ON}=1\Omega, R_{G\_OFF}=18\Omega,$ inductive Load, FWD: same device with $V_{GS} = 0V$ and $R_G = 18\Omega,$ Snubber: $R_s=20\Omega,$ $C_s=100pF$ $T_J=150^\circ C$		9.2		ns
Rise time	$t_r$			26			
Turn-off delay time	$t_{d(off)}$			81			
Fall time	$t_f$			14			
Turn-on energy including $R_S$ energy	$E_{ON}$				678		$\mu J$
Turn-off energy including $R_S$ energy	$E_{OFF}$				239		
Total switching energy	$E_{TOTAL}$				917		
Snubber $R_S$ energy during turn-on	$E_{RS\_ON}$				6		
Snubber $R_S$ energy during turn-off	$E_{RS\_OFF}$				9		

4. Measured with the switching test circuit in Figure 26.

5. In this datasheet, all the switching energies (turn-on energy, turn-off energy and total energy) presented in the tables and Figures include the device RC snubber energy losses.

Typical Performance Diagrams

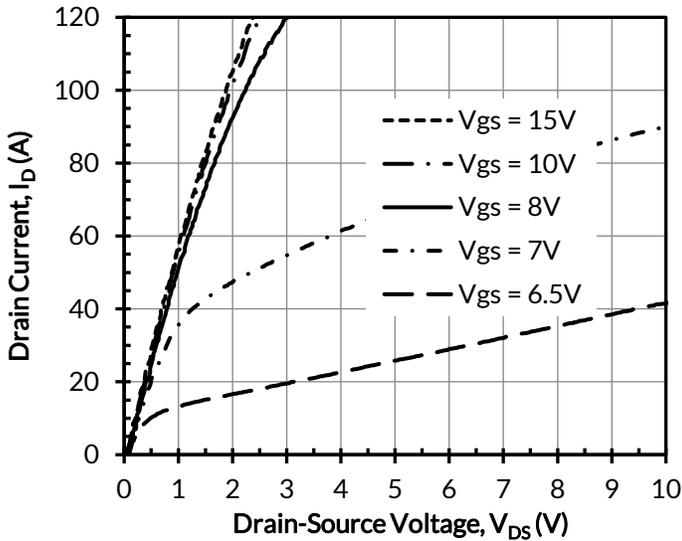


Figure 1. Typical output characteristics at  $T_j = -55^\circ\text{C}$ ,

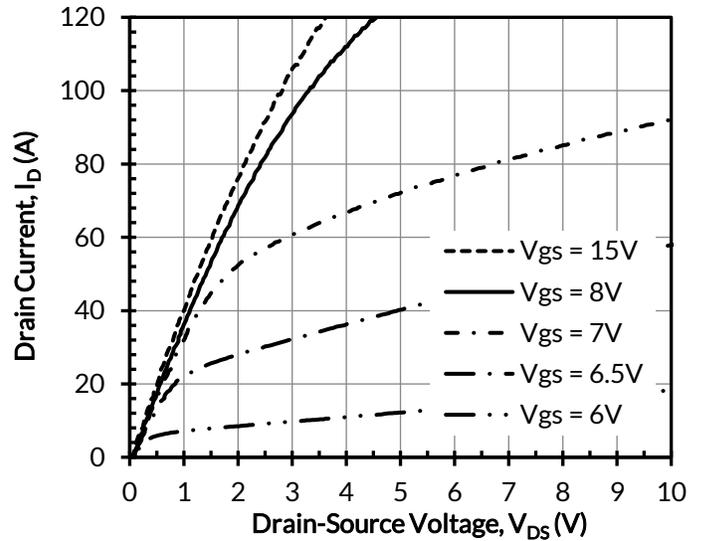


Figure 2. Typical output characteristics at  $T_j = 25^\circ\text{C}$ ,

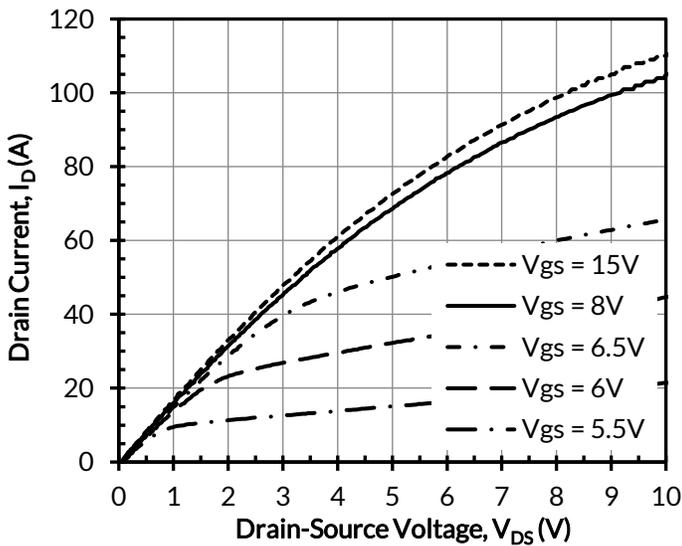


Figure 3. Typical output characteristics at  $T_j = 175^\circ\text{C}$ ,  $t_p < 250\mu\text{s}$

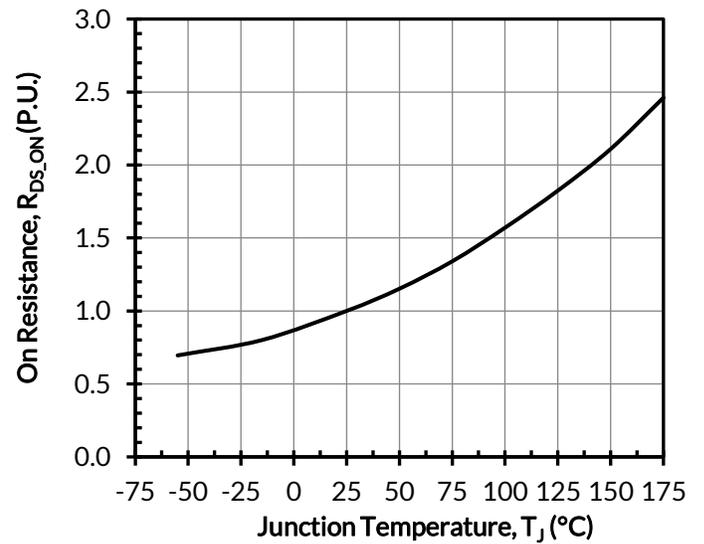


Figure 4. Normalized on-resistance vs. temperature at  $V_{GS} = 12\text{V}$  and  $I_D = 40\text{A}$

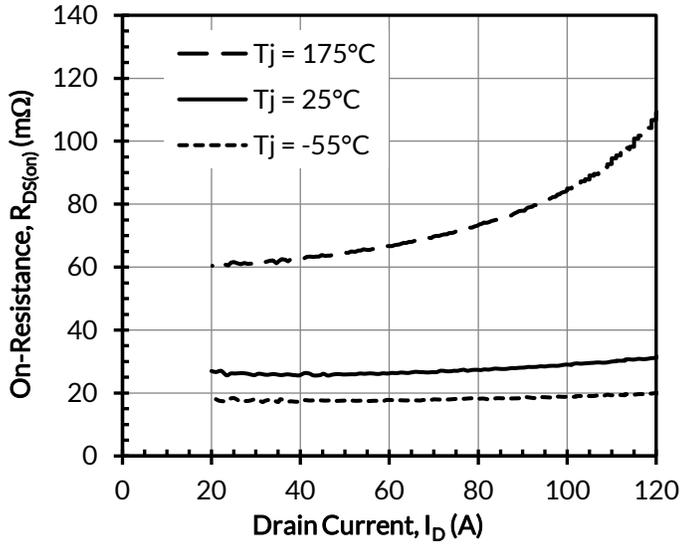


Figure 5. Typical drain-source on-resistances at  $V_{GS} = 12V$

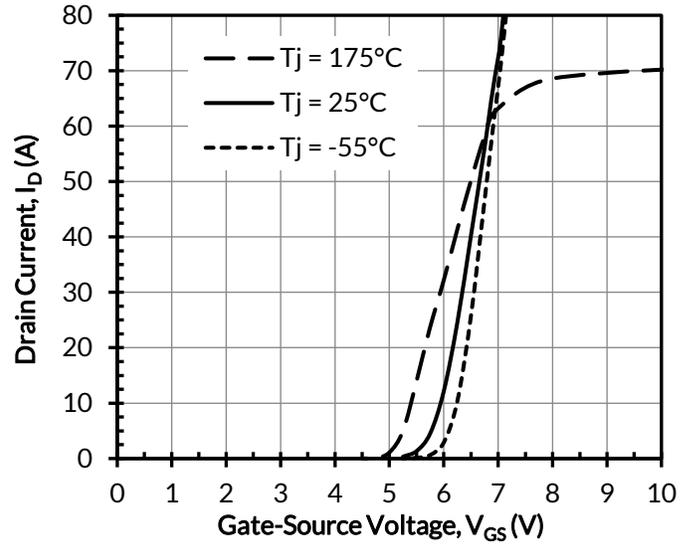


Figure 6. Typical transfer characteristics at  $V_{DS} = 5V$

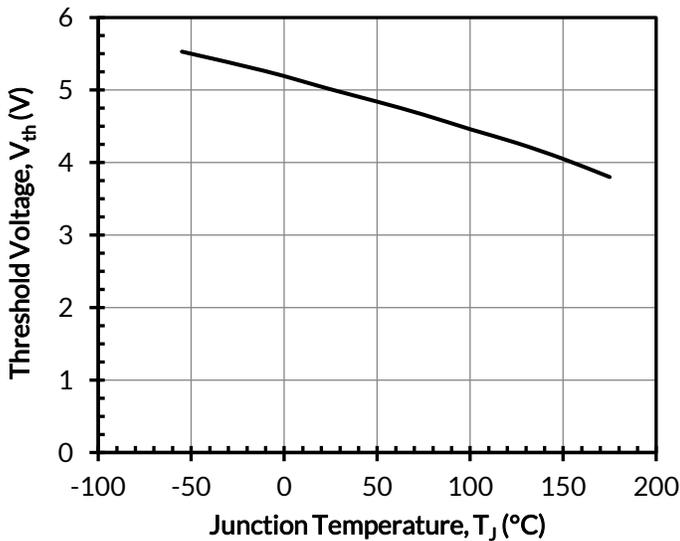


Figure 7. Threshold voltage vs. junction temperature at  $V_{DS} = 5V$  and  $I_D = 10mA$

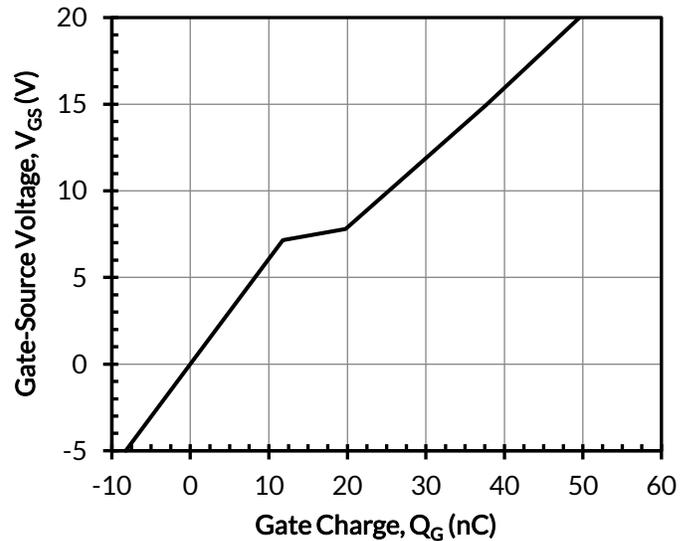


Figure 8. Typical gate charge at  $V_{DS} = 800V$   $I_D = 40A$

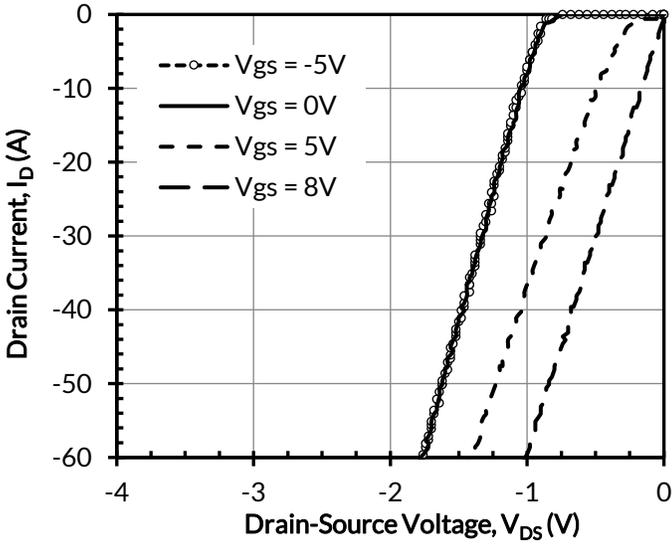


Figure 9. 3rd quadrant characteristics at  $T_J = -55^\circ\text{C}$

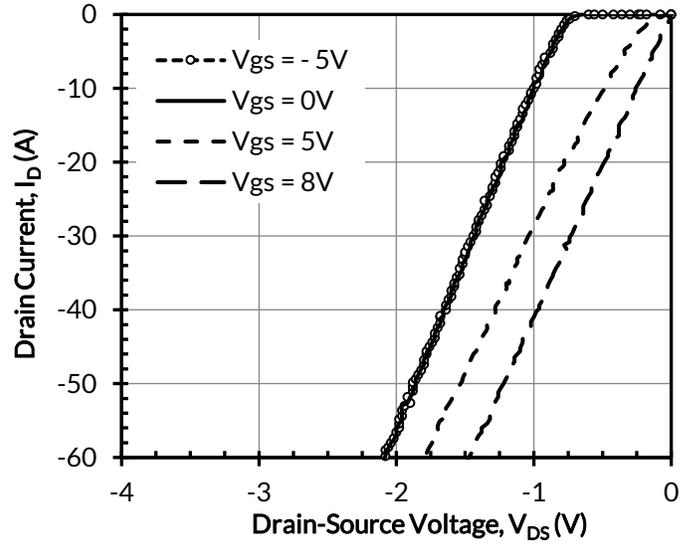


Figure 10. 3rd quadrant characteristics at  $T_J = 25^\circ\text{C}$

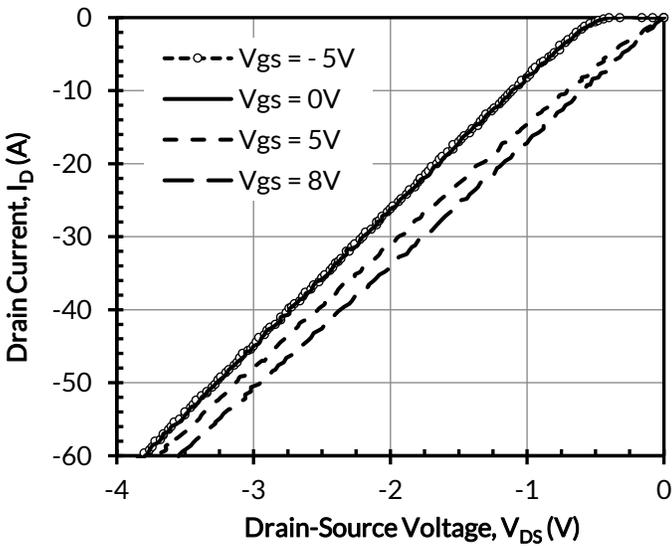


Figure 11. 3rd quadrant characteristics at  $T_J = 175^\circ\text{C}$

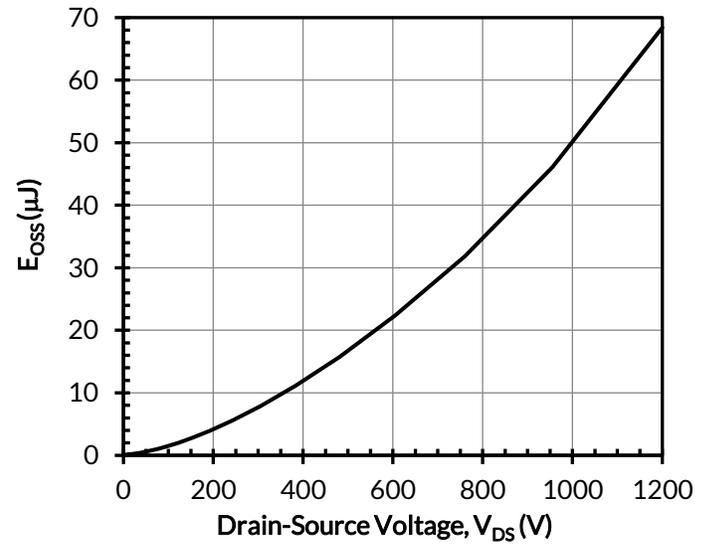


Figure 12. Typical stored energy in  $C_{OSS}$  at  $V_{GS} = 0\text{V}$

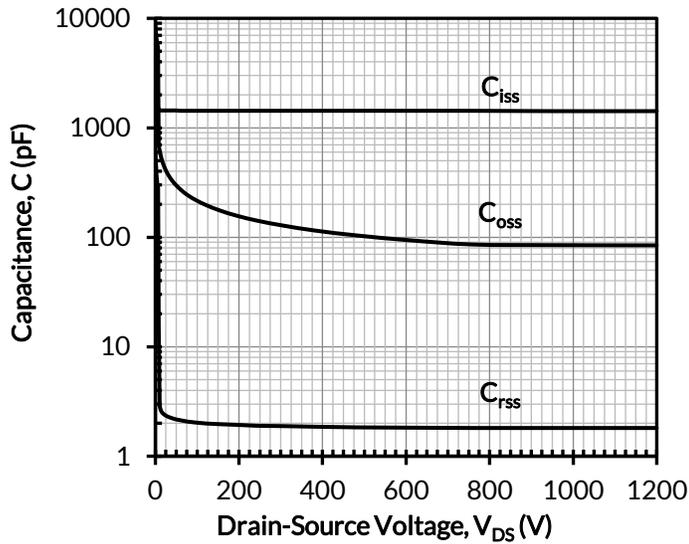


Figure 13. Typical capacitances at  $f = 100\text{kHz}$  and  $V_{GS} = 0\text{V}$

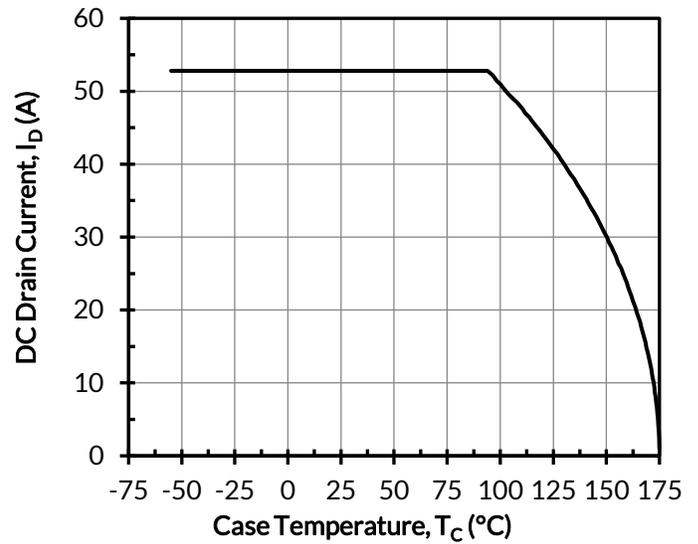


Figure 14. DC drain current derating

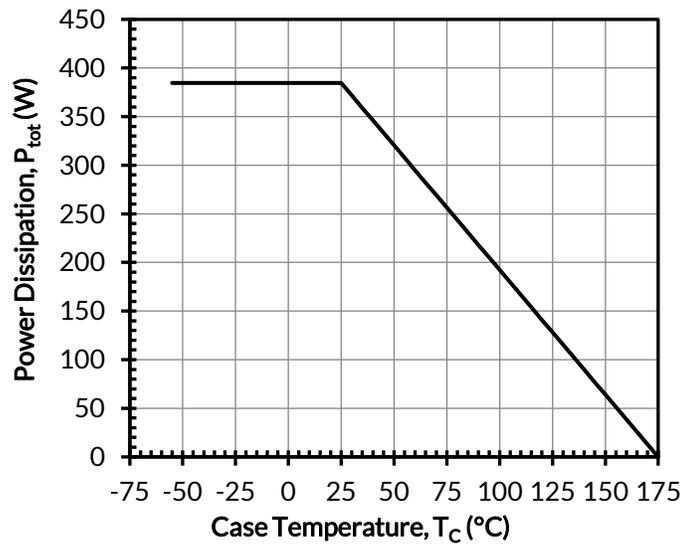


Figure 15. Total power dissipation

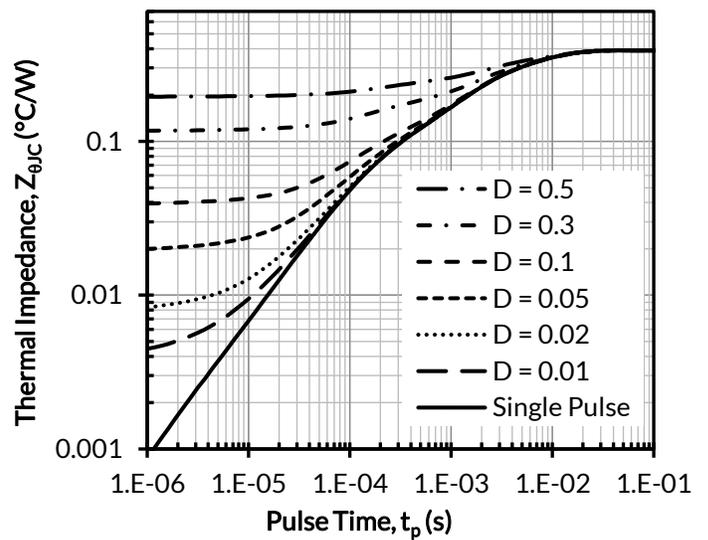


Figure 16. Maximum transient thermal impedance

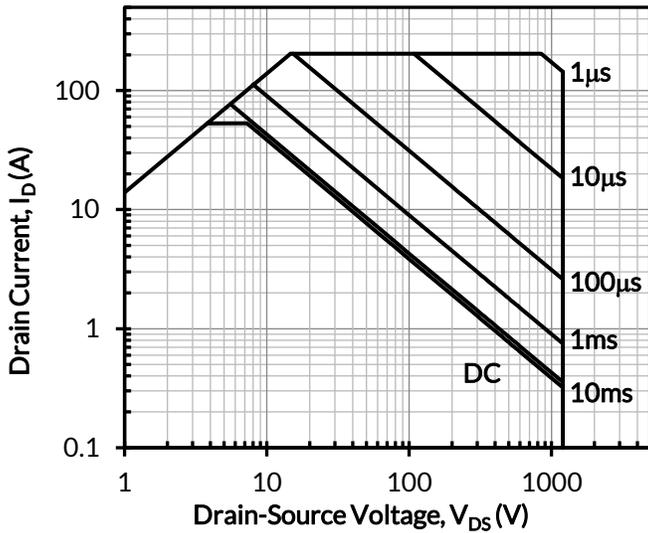


Figure 17. Safe operation area at  $T_C = 25^\circ\text{C}$ ,  $D = 0$ , Parameter  $t_p$

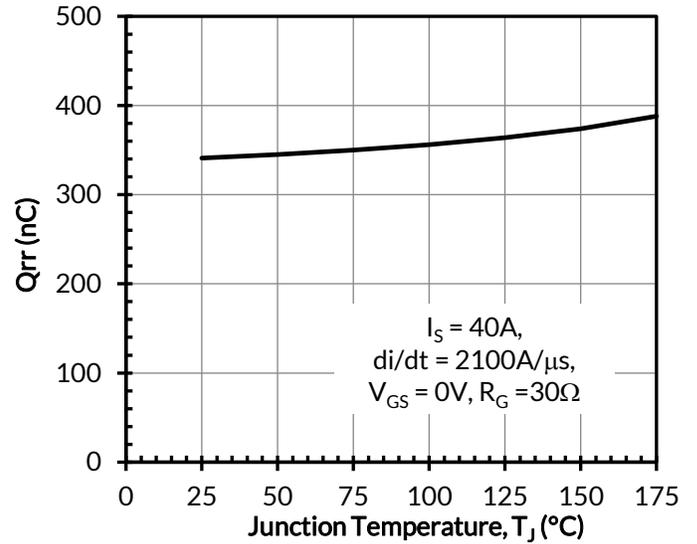


Figure 18. Reverse recovery charge  $Q_{rr}$  vs. junction temperature at  $V_{DS} = 800\text{V}$

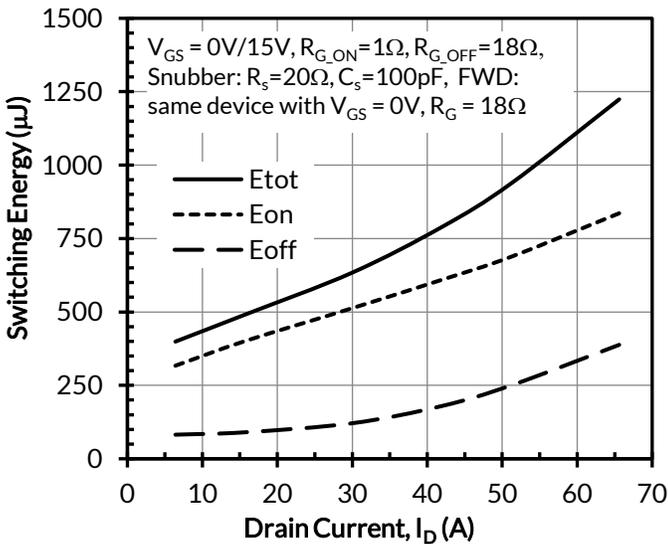


Figure 19. Clamped inductive switching energy vs. drain current at  $V_{DS} = 800\text{V}$  and  $T_J = 25^\circ\text{C}$

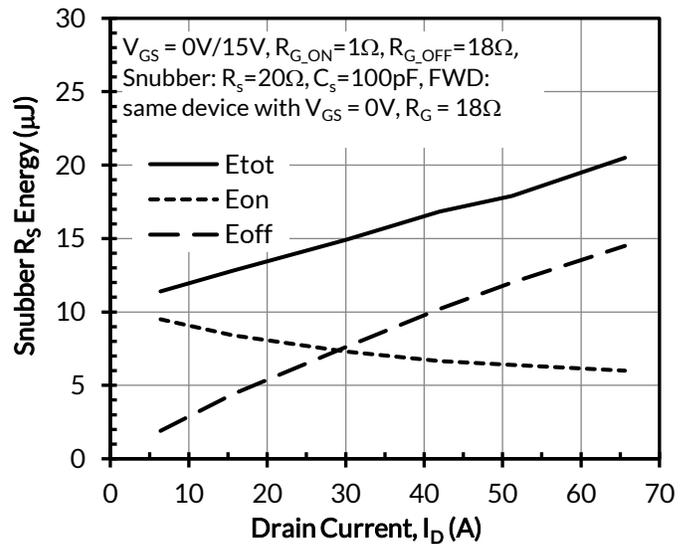


Figure 20. RC snubber energy loss vs. drain current at  $V_{DS} = 800\text{V}$  and  $T_J = 25^\circ\text{C}$

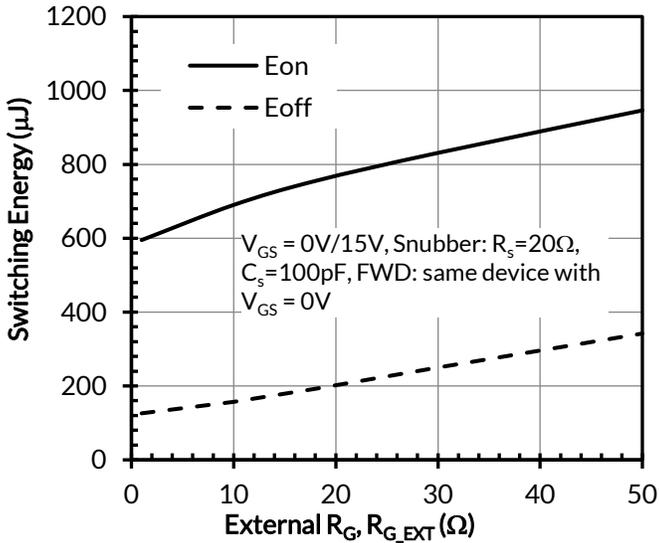


Figure 21. Clamped inductive switching energies vs.  $R_{G\_EXT}$  at  $V_{DS} = 800V$ ,  $I_D = 40A$ , and  $T_J = 25^\circ C$

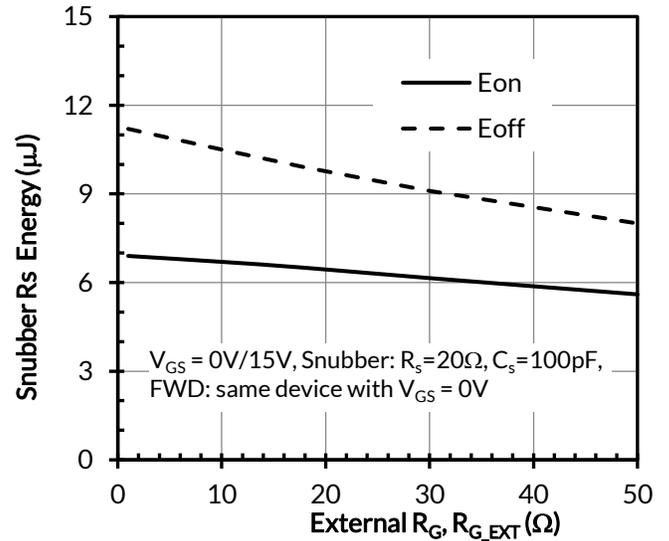


Figure 22. RC snubber energy loss vs.  $R_{G\_EXT}$  at  $V_{DS} = 800V$ ,  $I_D = 40A$ , and  $T_J = 25^\circ C$

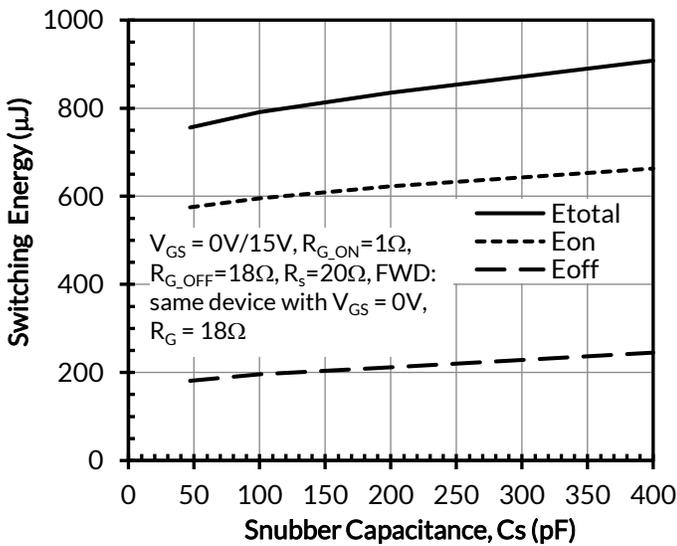


Figure 23. Clamped inductive switching energies vs. snubber capacitance  $C_s$  at  $V_{DS} = 800V$ ,  $I_D = 40A$ , and  $T_J = 25^\circ C$

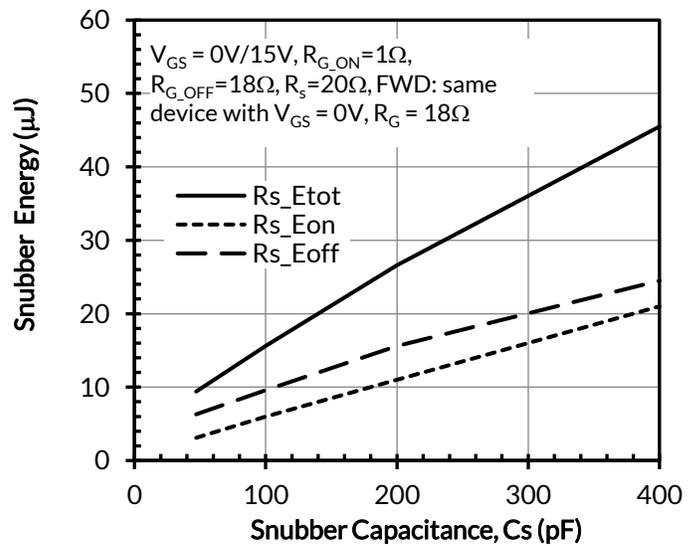


Figure 24. RC snubber energy losses vs. snubber capacitance  $C_s$  at  $V_{DS} = 800V$ ,  $I_D = 40A$ , and  $T_J = 25^\circ C$

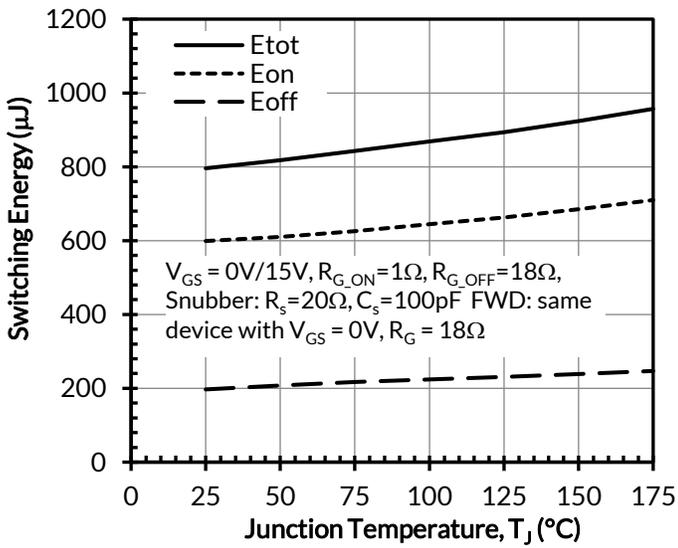


Figure 25. Clamped inductive switching energy vs. junction temperature at  $V_{DS} = 800V$  and  $I_D = 40A$

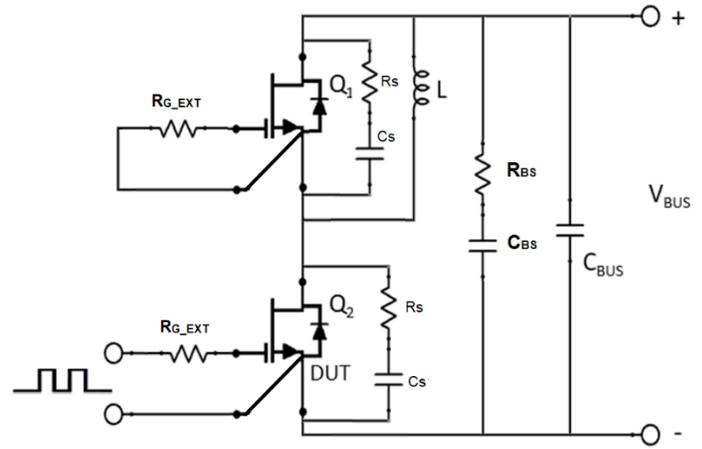


Figure 26. Schematic of the half-bridge mode switching test circuit. Note, a bus RC snubber ( $R_{BS} = 5\Omega$ ,  $C_{BS} = 100nF$ ) is used to reduce the power loop high frequency oscillations.

## Applications Information

SiC FETs are enhancement-mode power switches formed by a high-voltage SiC depletion-mode JFET and a low-voltage silicon MOSFET connected in series. The silicon MOSFET serves as the control unit while the SiC JFET provides high voltage blocking in the off state. This combination of devices in a single package provides compatibility with standard gate drivers and offers superior performance in terms of low on-resistance ( $R_{DS(on)}$ ), output capacitance ( $C_{oss}$ ), gate charge ( $Q_G$ ), and reverse recovery charge ( $Q_{rr}$ ) leading to low conduction and switching losses. The SiC FETs also provide excellent reverse conduction capability eliminating the need for an external anti-parallel diode.

Like other high performance power switches, proper PCB layout design to minimize circuit parasitics is strongly recommended due to the high  $dv/dt$  and  $di/dt$  rates. An external gate resistor is recommended when the FET is working in the diode mode in order to achieve the optimum reverse recovery performance. For more information on SiC FET operation, see [www.unitedsic.com](http://www.unitedsic.com).

A snubber circuit with a small  $R_{(G)}$ , or gate resistor, provides better EMI suppression with higher efficiency compared to using a high  $R_{(G)}$  value. There is no extra gate delay time when using the snubber circuitry, and a small  $R_{(G)}$  will better control both the turn-off  $V_{(DS)}$  peak spike and ringing duration, while a high  $R_{(G)}$  will damp the peak spike but result in a longer delay time. In addition, the total switching loss when using a snubber circuit is less than using high  $R_{(G)}$ , while greatly reducing  $E_{(OFF)}$  from mid-to-full load range with only a small increase in  $E_{(ON)}$ . Efficiency will therefore improve with higher load current. For more information on how a snubber circuit will improve overall system performance, visit the UnitedSiC website at [www.unitedsic.com](http://www.unitedsic.com)

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## PART MARKING

# TO-247-4L PACKAGE OUTLINE, PART MARKING AND TUBE SPECIFICATIONS

PART NUMBER  
  
XYYWW LLL

PART NUMBER = REFER TO  
DS\_PN DECODER FOR DETAILS

X = ASSEMBLY SITE

YY = YEAR

WW = WORK WEEK

LLL = LOT ID

## PACKING TYPE

ANTI-STATIC TUBE

QUANTITY /TUBE : 30 UNITS

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