

DATASHEET

UF3C065040B3

Silicon Carbide (SiC) Cascode JFET - EliteSiC, Power N-Channel, D2PAK-3L, 650 V, 42 mohm

Rev. D, January 2025

Description

This SiC FET device 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 D²PAK-3L package, this device exhibits ultra-low gate charge and exceptional reverse recovery characteristics, making it ideal for switching inductive loads when used with recommended RC-snubbers, and any application requiring standard gate drive.

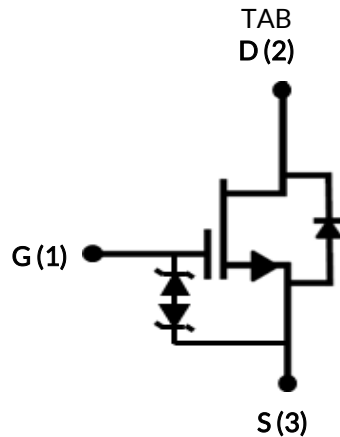
Features

- ◆ Typical on-resistance $R_{DS(on),typ}$ of 42mΩ
- ◆ Maximum operating temperature of 175°C
- ◆ Excellent reverse recovery
- ◆ Low gate charge
- ◆ Low intrinsic capacitance
- ◆ ESD protected, HBM class 2
- ◆ Very low switching losses (required RC-snubber loss negligible under typical operating conditions)

Typical applications

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

TAB



Part Number	Package	Marking
UF3C065040B3	D ² PAK-3L	UF3C065040B3



Maximum Ratings

Parameter	Symbol	Test Conditions	Value	Units
Drain-source voltage	V_{DS}		650	V
Gate-source voltage	V_{GS}	DC	-25 to +25	V
Continuous drain current ¹	I_D	$T_C = 25^\circ\text{C}$	41	A
		$T_C = 100^\circ\text{C}$	30	A
Pulsed drain current ²	I_{DM}	$T_C = 25^\circ\text{C}$	125	A
Single pulsed avalanche energy ³	E_{AS}	$L = 15\text{mH}, I_{AS} = 3.19\text{A}$	76	mJ
Power dissipation	P_{tot}	$T_C = 25^\circ\text{C}$	176	W
Maximum junction temperature	$T_{J,max}$		175	$^\circ\text{C}$
Operating and storage temperature	T_J, T_{STG}		-55 to 175	$^\circ\text{C}$
Reflow soldering temperature	T_{solder}	reflow MSL 1	245	$^\circ\text{C}$

1. Limited by $T_{J,max}$

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	$R_{\theta JC}$			0.65	0.85	$^\circ\text{C}/\text{W}$

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}	$V_{GS}=0V, I_D=1mA$	650			V
Total drain leakage current	I_{DSS}	$V_{DS}=650V, V_{GS}=0V, T_J=25^\circ\text{C}$		0.7	150	μA
		$V_{DS}=650V, V_{GS}=0V, T_J=175^\circ\text{C}$		10		
Total gate leakage current	I_{GSS}	$V_{DS}=0V, T_J=25^\circ\text{C}, V_{GS}=-20V / +20V$		6	± 20	μA
Drain-source on-resistance	$R_{DS(on)}$	$V_{GS}=12V, I_D=30A, T_J=25^\circ\text{C}$		42	52	m Ω
		$V_{GS}=12V, I_D=30A, T_J=125^\circ\text{C}$		59		
		$V_{GS}=12V, I_D=30A, T_J=175^\circ\text{C}$		78		
Gate threshold voltage	$V_{G(th)}$	$V_{DS}=5V, I_D=10mA$	4	5	6	V
Gate resistance	R_G	f=1MHz, open drain		4.5		Ω

Typical Performance - Reverse Diode

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
Diode continuous forward current ¹	I_S	$T_C=25^\circ\text{C}$			41	A
Diode pulse current ²	$I_{S,pulse}$	$T_C=25^\circ\text{C}$			125	A
Forward voltage	V_{FSD}	$V_{GS}=0V, I_S=20A, T_J=25^\circ\text{C}$		1.5	1.75	V
		$V_{GS}=0V, I_S=20A, T_J=175^\circ\text{C}$		1.8		
Reverse recovery charge	Q_{rr}	$V_R=400V, I_S=30A, V_{GS}=-5V, R_{G,EXT}=22\Omega, di/dt=1600A/\mu\text{s}, T_J=25^\circ\text{C}$		138		nC
Reverse recovery time	t_{rr}	$T_J=25^\circ\text{C}$		26		ns
Reverse recovery charge	Q_{rr}	$V_R=400V, I_S=30A, V_{GS}=-5V, R_{G,EXT}=22\Omega, di/dt=1600A/\mu\text{s}, T_J=150^\circ\text{C}$		137		nC
Reverse recovery time	t_{rr}	$T_J=150^\circ\text{C}$		26		ns

Typical Performance - Dynamic

Parameter	Symbol	Test Conditions	Value			Units		
			Min	Typ	Max			
Input capacitance	C_{iss}	$V_{DS}=100V, V_{GS}=0V$ $f=100kHz$		1500		pF		
Output capacitance	C_{oss}			200				
Reverse transfer capacitance	C_{rss}			2.2				
Effective output capacitance, energy related	$C_{oss(er)}$	$V_{DS}=0V$ to 400V, $V_{GS}=0V$		146		pF		
Effective output capacitance, time related	$C_{oss(tr)}$	$V_{DS}=0V$ to 400V, $V_{GS}=0V$		325		pF		
C_{oss} stored energy	E_{oss}	$V_{DS}=400V, V_{GS}=0V$		11.7		μJ		
Total gate charge	Q_G	$V_{DS}=400V, I_D=30A,$ $V_{GS} = -5V$ to 15V		51		nC		
Gate-drain charge	Q_{GD}			11				
Gate-source charge	Q_{GS}			19				
Turn-on delay time	$t_{d(on)}$	$V_{DS}=400V, I_D=30A, \text{Gate Driver} = -5V$ to +15V, Turn-on $R_{G,EXT}=1.8\Omega,$ Turn-off $R_{G,EXT}=22\Omega$ Inductive Load,		34		ns		
Rise time	t_r			15				
Turn-off delay time	$t_{d(off)}$			57				
Fall time	t_f			12				
Turn-on energy including R_S energy ⁴	E_{ON}			327				
Turn-off energy including R_S energy ⁴	E_{OFF}			65				
Total switching energy including R_S energy ⁴	E_{TOTAL}	FWD: same device with $V_{GS} = -5V$ and $R_G = 22\Omega,$ RC snubber: $R_S=5\Omega$ and $C_S=150pF, T_J=25^\circ C$		392		μJ		
Snubber R_S energy during turn-on	E_{RS_ON}			1.5				
Snubber R_S energy during turn-off	E_{RS_OFF}			3				
Turn-on delay time	$t_{d(on)}$			33				
Rise time	t_r			15				
Turn-off delay time	$t_{d(off)}$			58				
Fall time	t_f	$V_{DS}=400V, I_D=30A, \text{Gate Driver} = -5V$ to +15V, Turn-on $R_{G,EXT}=1.8\Omega,$ Turn-off $R_{G,EXT}=22\Omega$ Inductive Load,		13		ns		
Turn-on energy including R_S energy ⁴	E_{ON}			314				
Turn-off energy including R_S energy ⁴	E_{OFF}			66				
Total switching energy including R_S energy ⁴	E_{TOTAL}		FWD: same device with $V_{GS} = -5V$ and $R_G = 22\Omega,$ RC snubber: $R_S=5\Omega$ and $C_S=150pF, T_J=150^\circ C$		380			μJ
Snubber R_S energy during turn-on	E_{RS_ON}				1.5			
Snubber R_S energy during turn-off	E_{RS_OFF}				2.9			

4. The switching performance are evaluated with a RC snubber circuit as shown in Figure 24.

Typical Performance Diagrams

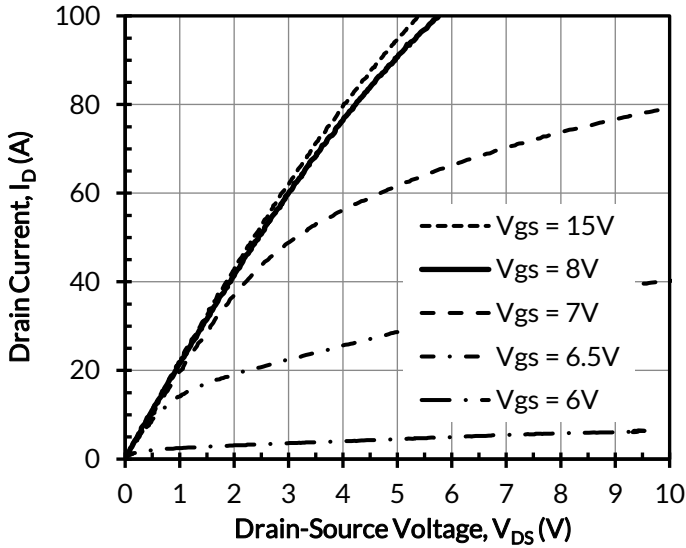


Figure 1. Typical output characteristics at $T_J = -55^\circ\text{C}$, $t_p < 250\mu\text{s}$

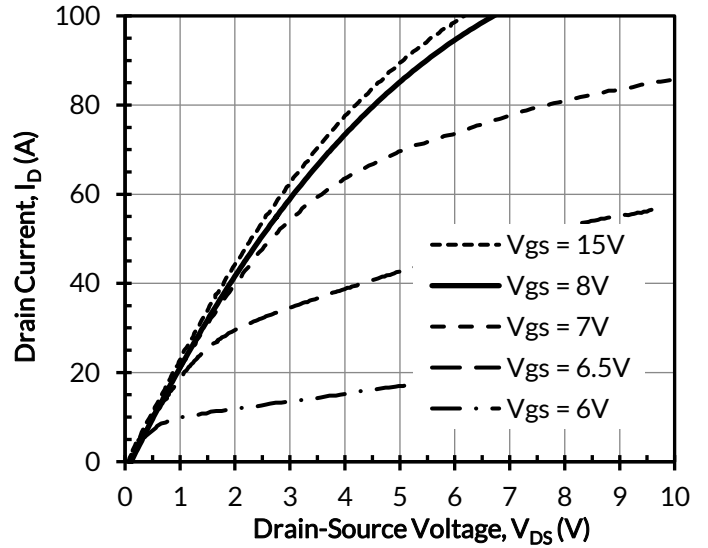


Figure 2. Typical output characteristics at $T_J = 25^\circ\text{C}$, $t_p < 250\mu\text{s}$

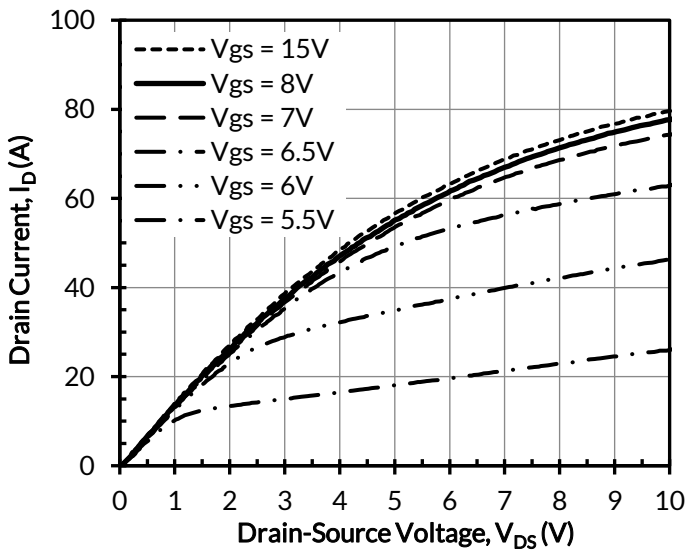


Figure 3. Typical output characteristics at $T_J = 175^\circ\text{C}$, $t_p < 250\mu\text{s}$

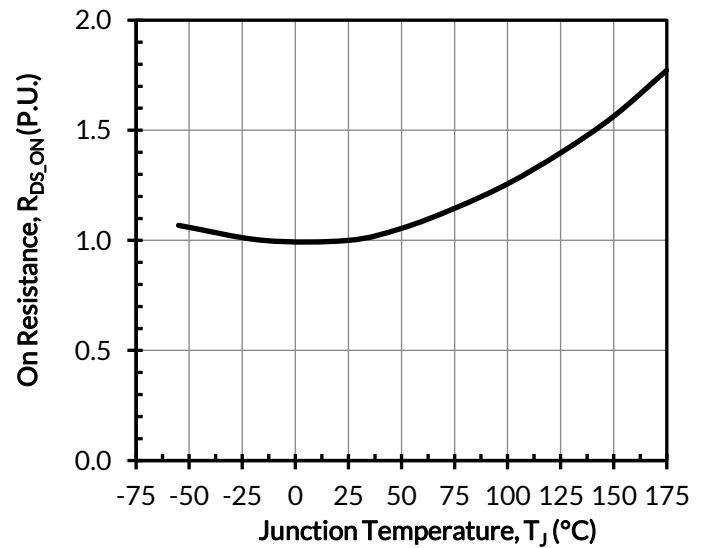


Figure 4. Normalized on-resistance vs. temperature at $V_{GS} = 12\text{V}$ and $I_D = 30\text{A}$

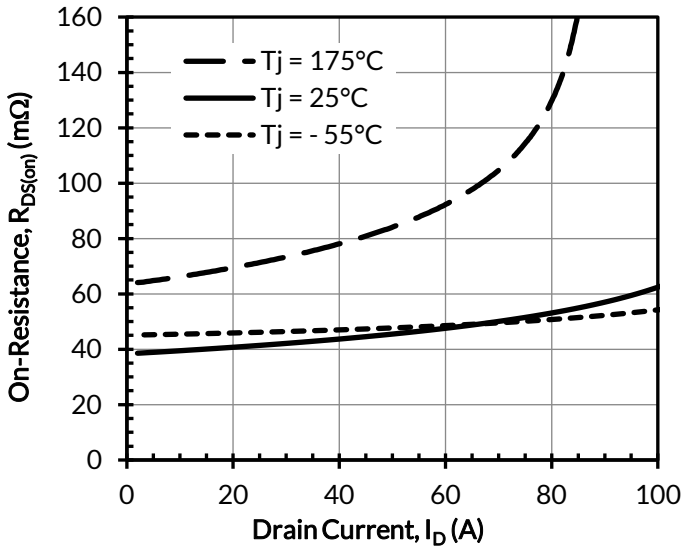


Figure 5. Typical drain-source on-resistances at $V_{GS} = 12\text{V}$

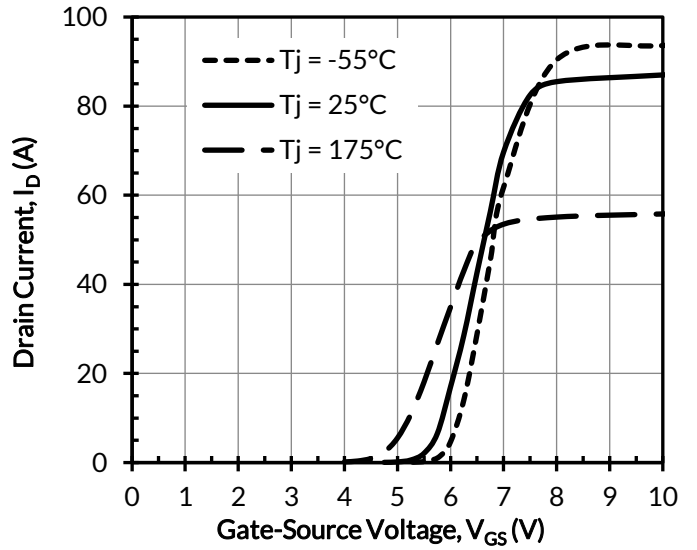


Figure 6. Typical transfer characteristics at $V_{DS} = 5\text{V}$

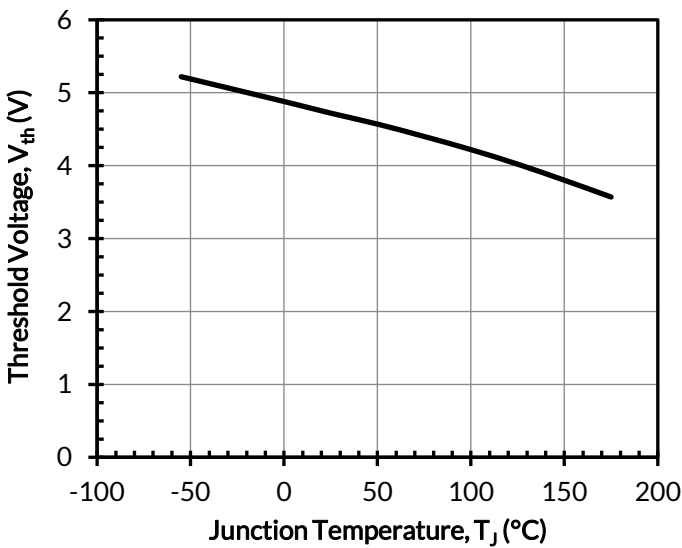


Figure 7. Threshold voltage vs. junction temperature at $V_{DS} = 5\text{V}$ and $I_D = 10\text{mA}$

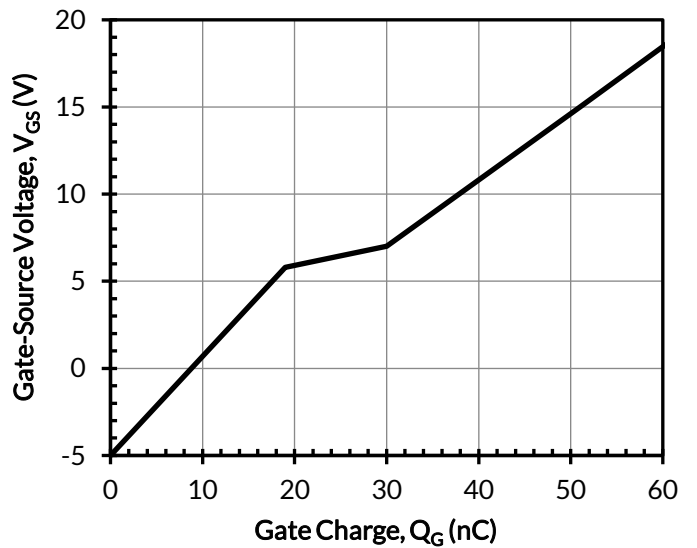


Figure 8. Typical gate charge at $V_{DS} = 400\text{V}$ and $I_D = 30\text{A}$

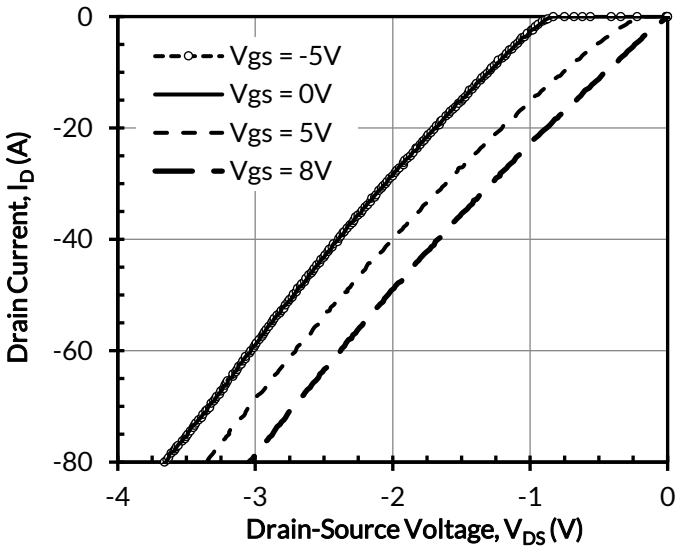


Figure 9. 3rd quadrant characteristics at $T_j = -55^\circ\text{C}$

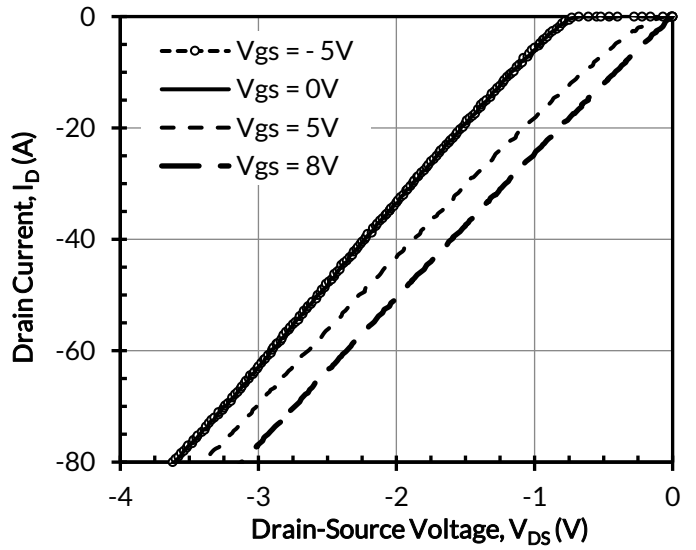


Figure 10. 3rd quadrant characteristics at $T_j = 25^\circ\text{C}$

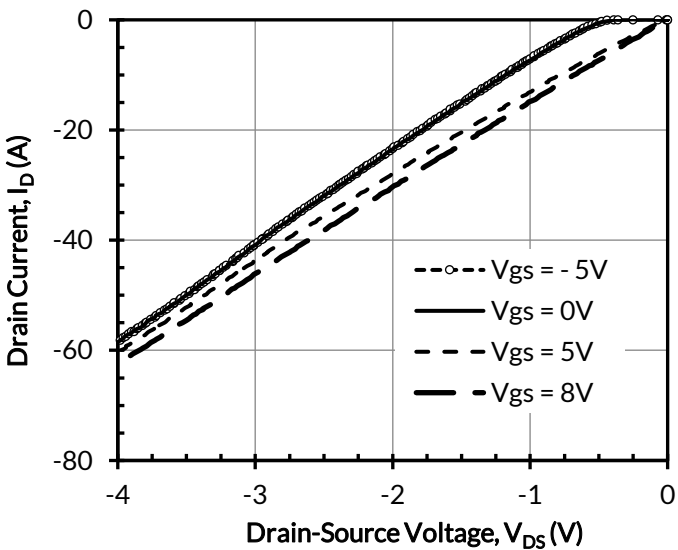


Figure 11. 3rd quadrant characteristics at $T_j = 175^\circ\text{C}$

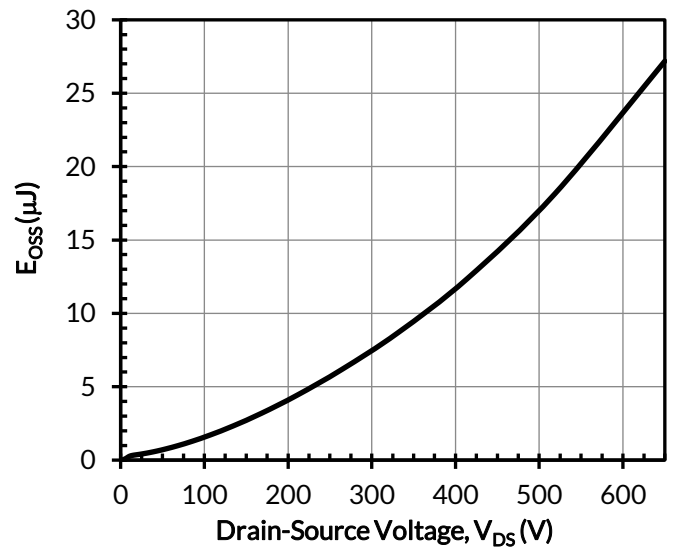


Figure 12. Typical stored energy in C_{oss} at $V_{GS} = 0\text{V}$

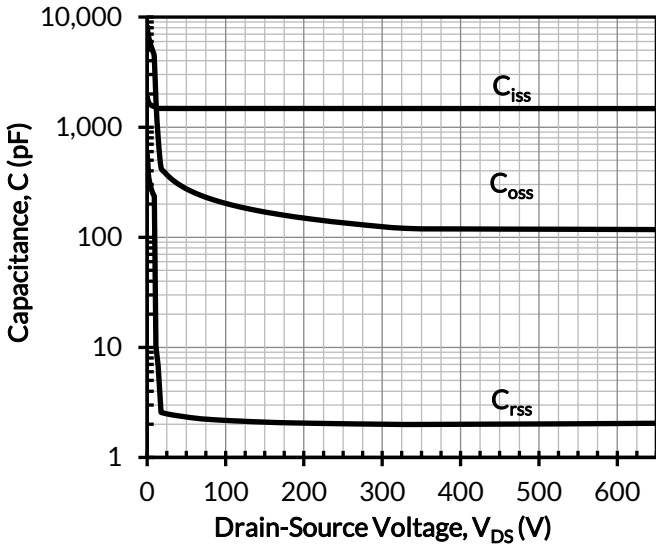


Figure 13. Typical capacitances at $f = 100\text{kHz}$ and $V_{GS} = 0\text{V}$

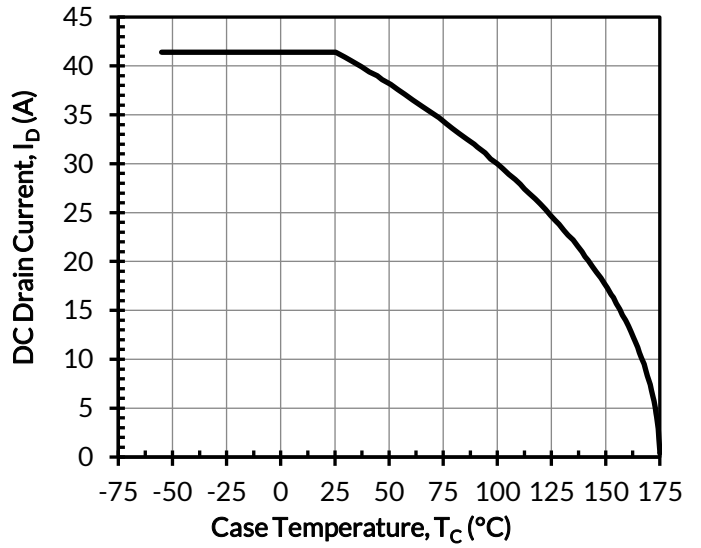


Figure 14. DC drain current derating

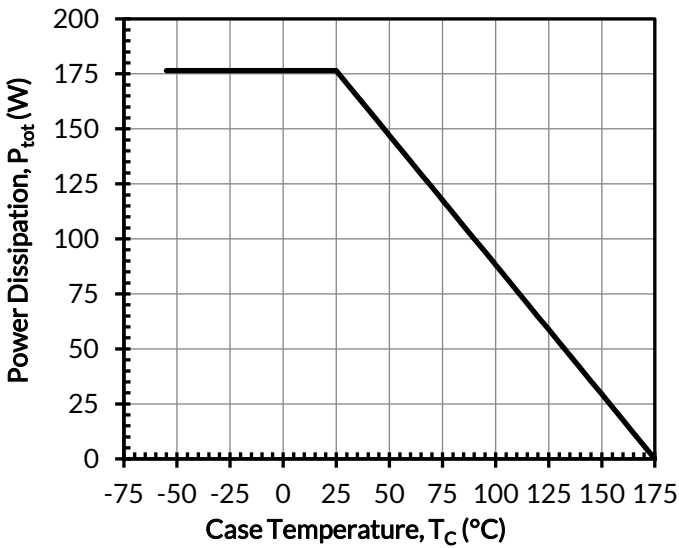


Figure 15. Total power dissipation

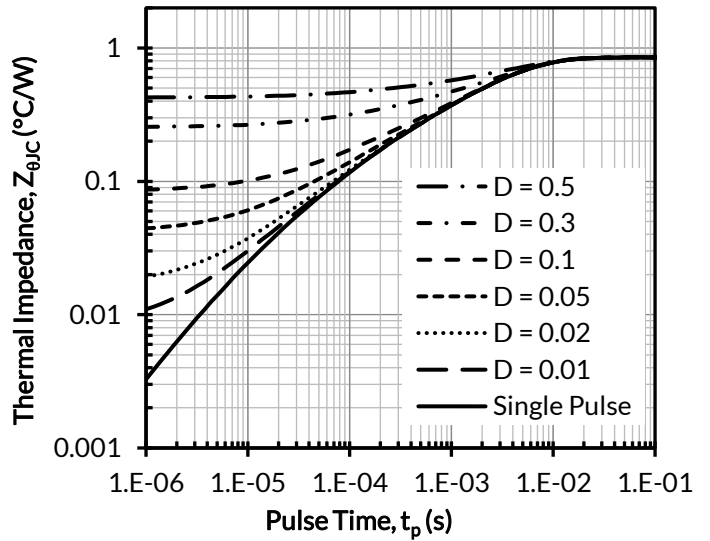


Figure 16. Maximum transient thermal impedance

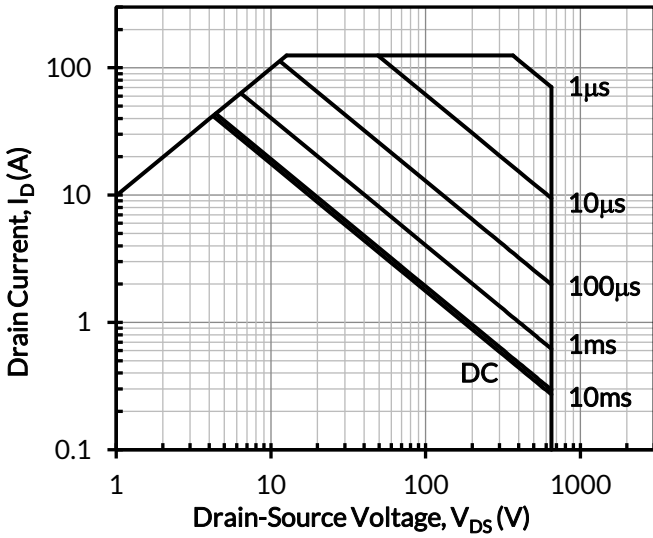


Figure 17. Safe operation area at $T_C = 25^\circ\text{C}$, $D = 0$, Parameter t_p

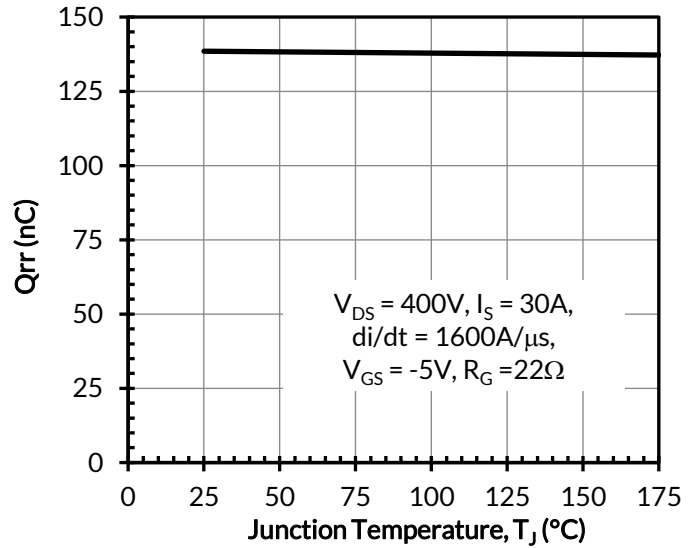
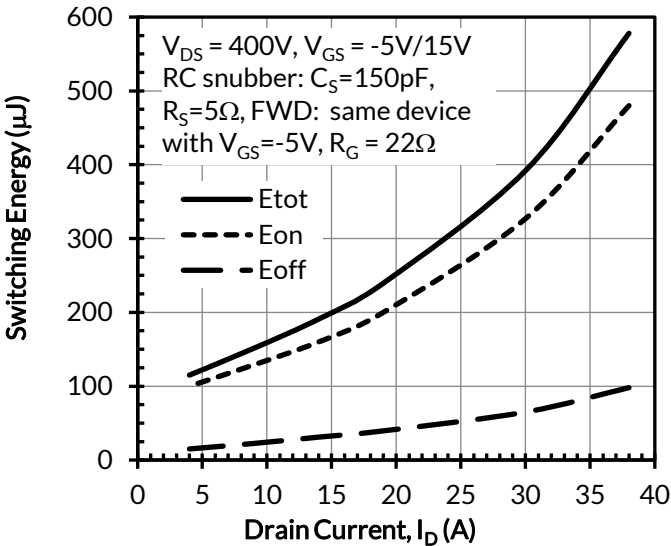
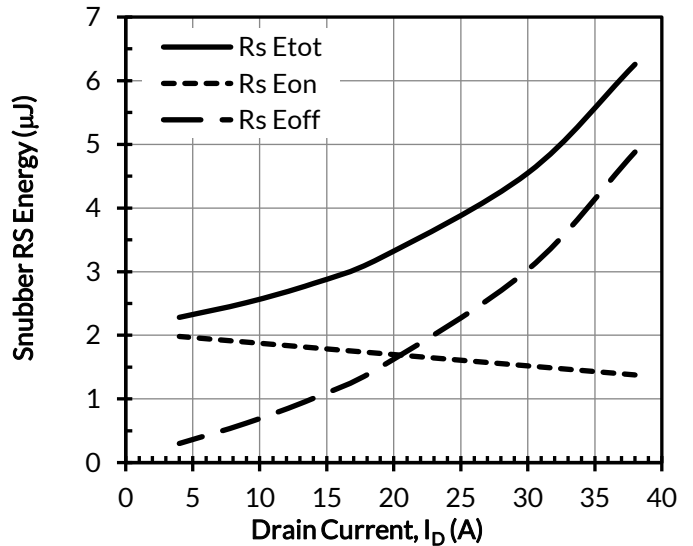


Figure 18. Reverse recovery charge Q_{rr} vs. junction temperature

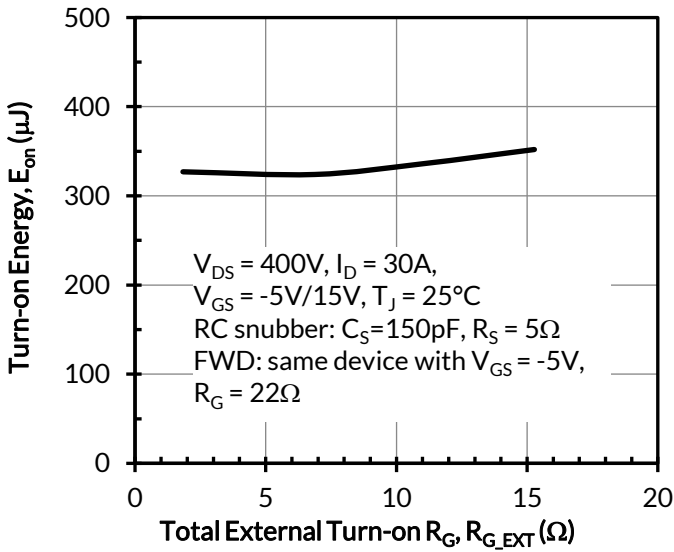


(a)

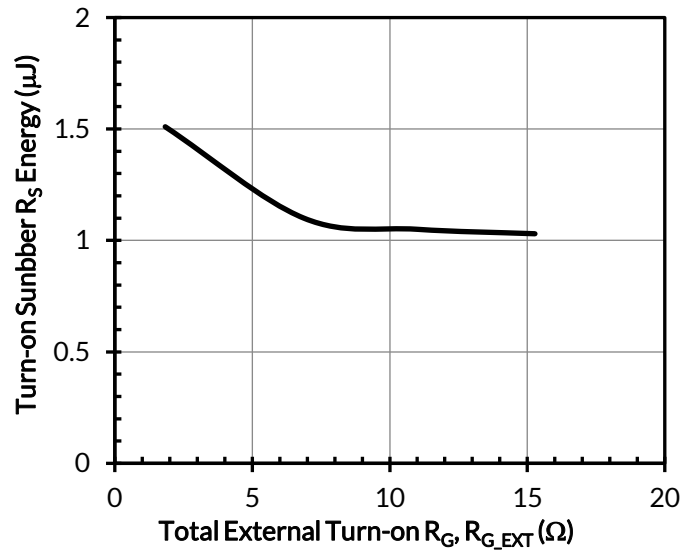


(b)

Figure 19. Clamped inductive switching energy (a) and RC snubber energy loss (b) vs. drain current at $T_J = 25^\circ\text{C}$, turn-on $R_{G_EXT} = 1.8\Omega$, and turn-off $R_{G_EXT} = 22\Omega$

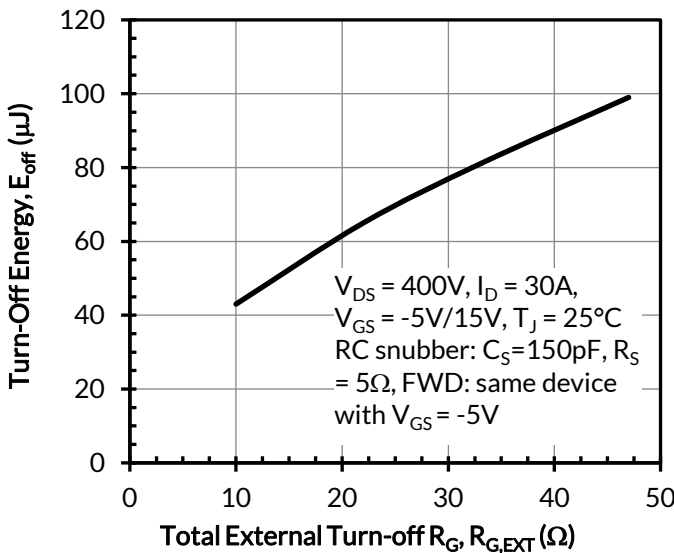


(a)

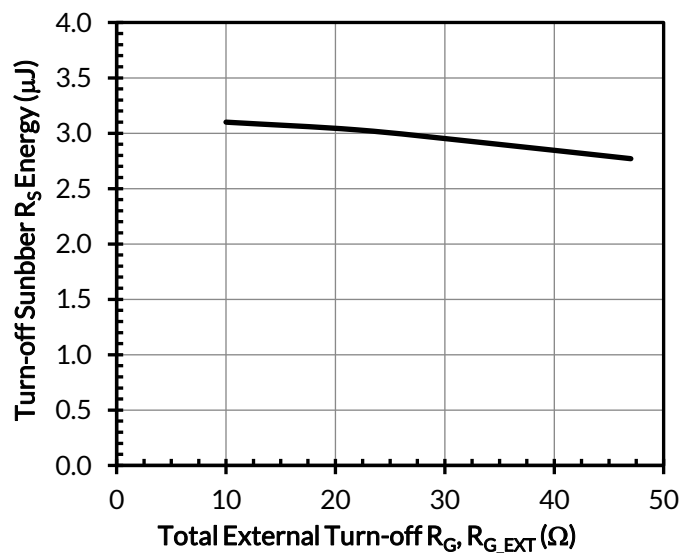


(b)

Figure 20. Clamped inductive switching turn-on energy including RC snubber energy loss (a) and RC snubber energy loss (b) as a function of total external turn-on gate resistor R_{G_EXT}

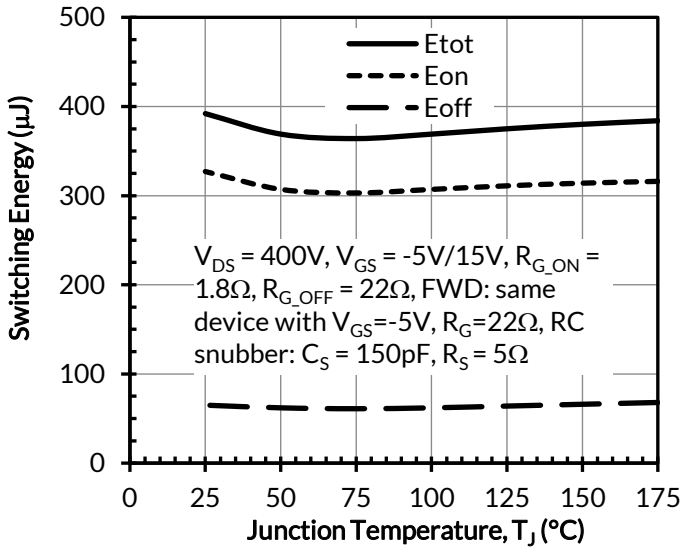


(a)

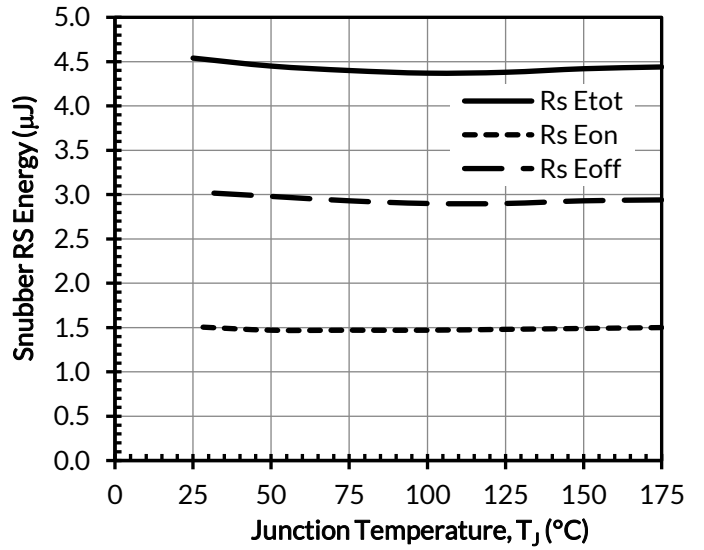


(b)

Figure 21. Clamped inductive switching turn-off energy including RC snubber energy loss (a) and RC snubber energy loss (b) as a function of total external turn-off gate resistor R_{G_EXT}

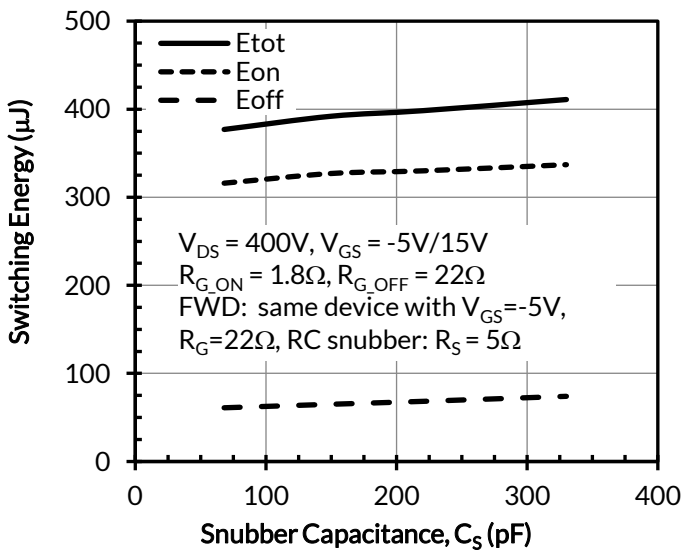


(a)

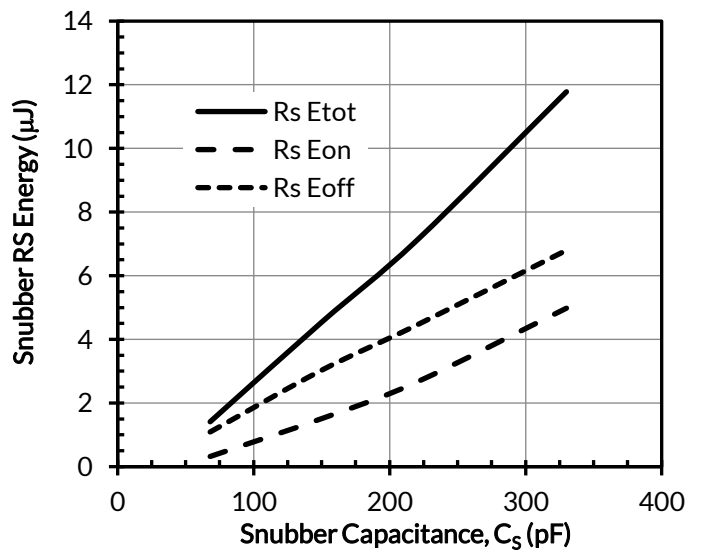


(b)

Figure 22. Clamped inductive switching energy including RC snubber energy loss (a) and RC snubber energy loss (b) as a function of junction temperature at $I_D = 30A$



(a)



(b)

Figure 23. Clamped inductive switching energy including RC snubber energy loss (a) and RC snubber energy loss (b) as a function of snubber capacitance at $I_D = 30A$ and $T_J = 25^\circ C$

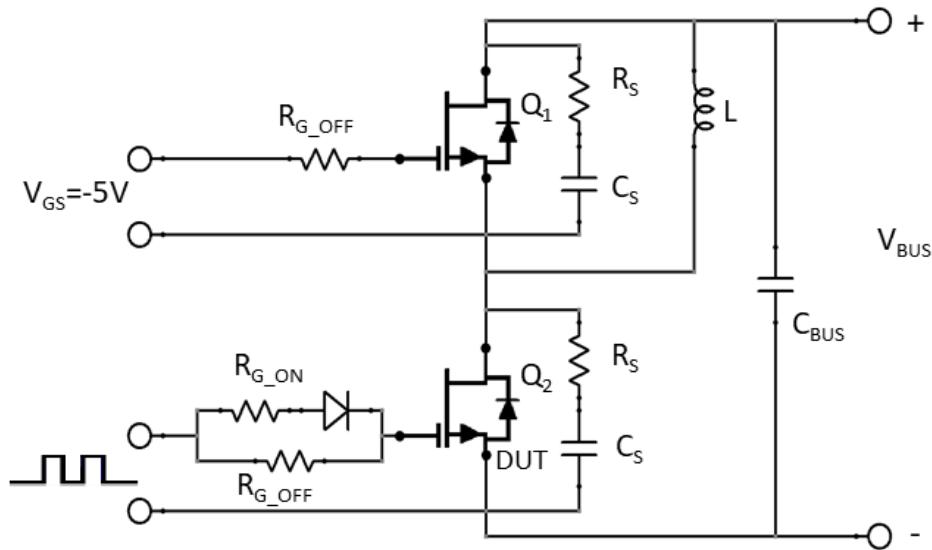


Figure 24. Clamped inductive load switching test circuit
 An RC snubber ($R_S = 5\Omega$ and $C_S = 150\text{pF}$) is required to improve the turn-off waveforms.

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.

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

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