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# Silicon Carbide (SiC) Combo JFET - EliteSiC, Power N-Channel, TO-247-4L, 750 V, 10 mohm (SiC JFET w/ Si MOSFET)

## DATASHEET

# UG4SC075011K4S

Rev. C, January 2025

### Description

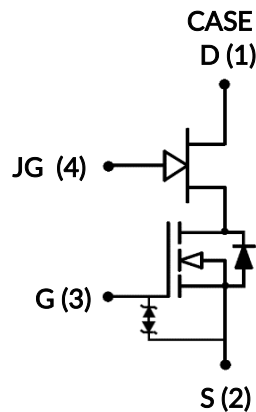
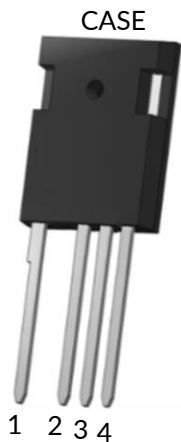
Qorvo's UG4SC075011K4S "Combo-FET" integrates both a 750V SiC JFET and a Low Voltage Si MOSFET into a single TO-247-4L package. This innovative approach allows users to create circuitry that would enable a normally-off switch while leveraging the benefits of a normally-on SiC JFET. These benefits include ultra-low on-resistance ( $R_{DS(on)}$ ) to minimize conduction losses and the exceptional robustness characteristic of a simplified JFET device structure, making it capable of handling the high-energy switching required in circuit protection applications. For switch-mode power conversion application, this device provides separate access to the JFET and MOSFET gates for improved speed control and ease of paralleling multiple devices.

### Features

- ◆ Low  $R_{DS(on)}$
- ◆ Normally-off capability
- ◆ Improved speed control
- ◆ Improved parallel device operation (3+ FETs)
- ◆ Operating temperature: 175°C (max)
- ◆ High pulse current capability
- ◆ Excellent device robustness
- ◆ Silver-sintered die attach for excellent thermal resistance
- ◆ Short circuit rated
- ◆ AECQ Qualified

### Typical applications

- ◆ Solid State / Semiconductor Circuit Breaker
- ◆ Solid State / Semiconductor Relay
- ◆ Battery Disconnects
- ◆ Surge Protection
- ◆ Inrush Current Control
- ◆ High power switch mode converters (>25kW)



Part Number	Package	Marking
UG4SC075011K4S	TO-247-4L	UG4SC075011K4S



## Maximum Ratings

Parameter	Symbol	Test Conditions	Value	Units
Drain-source voltage	$V_{DS}$		750	V
JFET Gate (JG) to source voltage	$V_{JGS}$	DC	-30 to +3	V
		AC <sup>1</sup>	-30 to +30	V
MOSFET Gate (G) to source voltage	$V_{GS}$	DC	-20 to +20	V
		AC ( $f > 1\text{Hz}$ )	-25 to +25	V
Continuous drain current <sup>2</sup>	$I_D$	$T_C = 25^\circ\text{C}$	104	A
		$T_C = 100^\circ\text{C}$	75	A
Pulsed drain current <sup>3</sup>	$I_{DM}$	$T_C = 25^\circ\text{C}$	300	A
Single pulsed avalanche energy <sup>4</sup>	$E_{AS}$	$L=15\text{mH}, I_{AS} = 4.5\text{A}$	151	mJ
Power dissipation	$P_{tot}$	$T_C = 25^\circ\text{C}$	357	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,	$T_L$		250	$^\circ\text{C}$

1. +30V AC rating applies for turn-on pulses <200ns applied with external  $R_G > 1\Omega$ .

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

3. Pulse width  $t_p$  limited by  $T_{J,max}$

4. Starting  $T_J = 25^\circ\text{C}$

## Thermal Characteristics

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
Thermal resistance, junction-to-case	$R_{\theta JC}$			0.33	0.42	$^\circ\text{C/W}$

## Electrical Characteristics ( $T_J = +25^\circ\text{C}$ and $V_{JGS} = 0\text{V}$ unless otherwise specified)

### Typical Performance - Static

Parameter	Symbol	Test Conditions	Value			Units	
			Min	Typ	Max		
Drain-source breakdown voltage	$BV_{DS}$	$V_{GS}=0\text{V}, V_{JGS}=0\text{V}, I_D=1\text{mA}$	750			V	
Total drain leakage current	$I_{DSS}$	$V_{DS}=750\text{V}, V_{GS}=0\text{V}, V_{JGS}=0\text{V}, T_J=25^\circ\text{C}$		3.5	60	$\mu\text{A}$	
		$V_{DS}=750\text{V}, V_{GS}=0\text{V}, V_{JGS}=0\text{V}, T_J=175^\circ\text{C}$		45			
Total JFET gate leakage current	$I_{JGSS}$	$V_{JGS}=-20\text{V}, V_{GS}=+12\text{V}$		0.1	55	$\mu\text{A}$	
Total MOSFET gate leakage current	$I_{GSS}$	$V_{GS}=-20\text{V} / +20\text{V}$		2	20	$\mu\text{A}$	
Drain-source on-resistance	$R_{DS(on)}$	$V_{GS}=12\text{V}$ $I_D=60\text{A}$	$V_{JGS}=2\text{V}$ $T_J=25^\circ\text{C}$		10	$\text{m}\Omega$	
			$T_J=25^\circ\text{C}$		11		14.2
			$T_J=125^\circ\text{C}$		18.4		
			$T_J=175^\circ\text{C}$		24.2		
JFET gate threshold voltage	$V_{JG(th)}$	$V_{DS}=5\text{V}, V_{GS}=12\text{V}, I_D=85\text{mA}$	-11.3	-9.3	-6.7	V	
MOSFET gate threshold voltage	$V_{G(th)}$	$V_{DS}=5\text{V}, V_{JGS}=0\text{V}, I_D=10\text{mA}$	3.5	4.5	5.5	V	
JFET gate resistance	$R_{JG}$	$f=1\text{MHz}, \text{open drain}$		0.7		$\Omega$	
MOSFET gate resistance	$R_G$	$f=1\text{MHz}, \text{open drain}$		2.3		$\Omega$	

### Typical Performance - Reverse Diode

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
Diode continuous forward current <sup>1</sup>	$I_S$	$T_C = 25^\circ\text{C}$			104	A
Diode pulse current <sup>2</sup>	$I_{S,pulse}$	$T_C = 25^\circ\text{C}$			300	A
Forward voltage	$V_{FSD}$	$V_{GS}=0\text{V}, V_{JGS}=0\text{V}, I_S=30\text{A}, T_J=25^\circ\text{C}$		1.1	1.24	V
		$V_{GS}=0\text{V}, V_{JGS}=0\text{V}, I_S=30\text{A}, T_J=175^\circ\text{C}$		1.2		
Reverse recovery charge	$Q_{rr}$	$V_{DS}=400\text{V}, I_S=60\text{A}, V_{GS}=0\text{V}, V_{JGS}=0\text{V}, R_{JG}=0.7\Omega, di/dt=2800\text{A}/\mu\text{s}, T_J=25^\circ\text{C}$		242		nC
Reverse recovery time	$t_{rr}$	$T_J=25^\circ\text{C}$		58		ns
Reverse recovery charge	$Q_{rr}$	$V_{DS}=400\text{V}, I_S=60\text{A}, V_{GS}=0\text{V}, V_{JGS}=0\text{V}, R_{JG}=0.7\Omega, di/dt=2800\text{A}/\mu\text{s}, T_J=150^\circ\text{C}$		280		nC
Reverse recovery time	$t_{rr}$	$T_J=150^\circ\text{C}$		89		ns

## Typical Performance - Dynamic with MOSFET gate as control terminal and $V_{JGS}=0V$

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
MOSFET input capacitance	$C_{iss}$	$V_{DS}=400V, V_{GS}=0V,$ $V_{JGS}=0V, f=100kHz$		3245		pF
Output capacitance	$C_{oss}$			178		
Reverse transfer capacitance	$C_{rss}$			1.2		
Effective output capacitance, energy	$C_{oss(er)}$	$V_{DS}=0V$ to 400V, $V_{GS}=0V, V_{JGS}=0V$		225		pF
Effective output capacitance, time related	$C_{oss(tr)}$			470		pF
$C_{OSS}$ stored energy	$E_{oss}$	$V_{DS}=400V, V_{GS}=0V,$ $V_{JGS}=0V$		18		$\mu J$
Total Gate charge	$Q_G$	$V_{DS}=400V, I_D=60A, V_{JGS}=0V,$ $V_{GS} = 0V$ to 15V		75		nC
Gate-drain charge	$Q_{GD}$			13		
Gate-source charge	$Q_{GS}$			22		
Turn-on delay time	$t_{d(on)}$	Notes 5 and 6 $V_{DS}=400V, I_D=60A,$ $V_{GS}=0V$ to +15V, $R_{G\_ON}=1\Omega, R_{G\_OFF}=10\Omega,$ $R_{JG\_ON}=0.7\Omega, R_{JG\_OFF}=4.7\Omega,$ Inductive Load, FWD: same device with $V_{GS} = 0V, R_G = 10\Omega, V_{JGS}=0V,$ $R_{JG}=0.7\Omega, T_J=25^\circ C$		50		ns
Rise time	$t_r$			21		
Turn-off delay time	$t_{d(off)}$			107		
Fall time	$t_f$			33		
Turn-on energy	$E_{ON}$			990		
Turn-off energy	$E_{OFF}$		513			
Total switching energy	$E_{TOTAL}$		1503			
Turn-on delay time	$t_{d(on)}$	Notes 5 and 6 $V_{DS}=400V, I_D=60A,$ $V_{GS}=0V$ to +15V, $R_{G\_ON}=1\Omega, R_{G\_OFF}=10\Omega,$ $R_{JG\_ON}=0.7\Omega, R_{JG\_OFF}=4.7\Omega,$ Inductive Load, FWD: same device with $V_{GS} = 0V, R_G = 10\Omega, V_{JGS}=0V,$ $R_{JG}=0.7\Omega, T_J=150^\circ C$		50		ns
Rise time	$t_r$			22		
Turn-off delay time	$t_{d(off)}$			110		
Fall time	$t_f$			30		
Turn-on energy	$E_{ON}$			986		
Turn-off energy	$E_{OFF}$		454			
Total switching energy	$E_{TOTAL}$		1440			

5. Measured with the half-bridge mode switching test circuit in Figure 23.

6. Devices are driven with the ClampDRIVE method as described in the section "Recommended Gate Drive Approach: ClampDRIVE method".

### Typical Performance - Dynamic with JFET gate as control terminal and $V_{GS}=+12V$

Parameter	Symbol	Test Conditions	Value			Units
			Min	Typ	Max	
JFET input capacitance	$C_{Jiss}$	$V_{DS}=400V, V_{JGS}=-20V,$ $f=100kHz$		1385		pF
JFET output capacitance	$C_{Joss}$			175		
JFET reverse transfer capacitance	$C_{Jrss}$			170		
JFET total gate charge	$Q_{JG}$	$V_{DS}=400V, I_D=60A,$ $V_{JGS} = -18V \text{ to } 0V$		223		nC
JFET gate-drain charge	$Q_{JGD}$			126		
JFET gate-source charge	$Q_{JGS}$			35		

### Typical Performance Diagrams - MOSFET gate as control terminal and $V_{JGS}=0V$

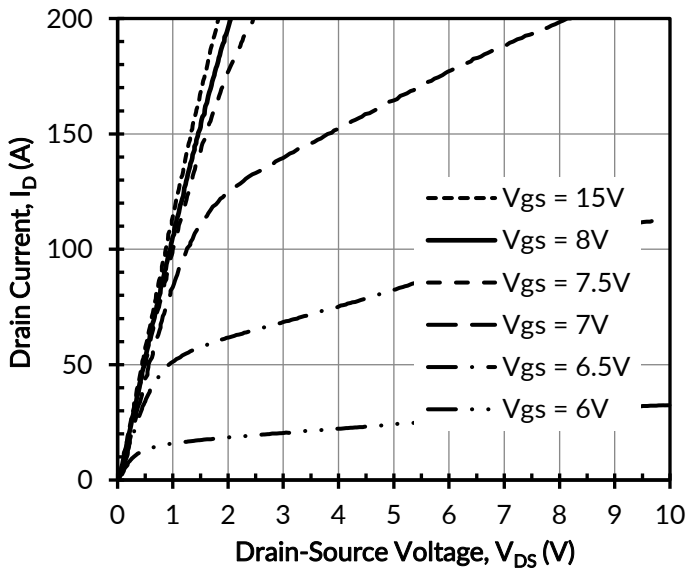


Figure 1. Typical output characteristics at  $T_j = -55^\circ C$ ,  $t_p < 250\mu s$

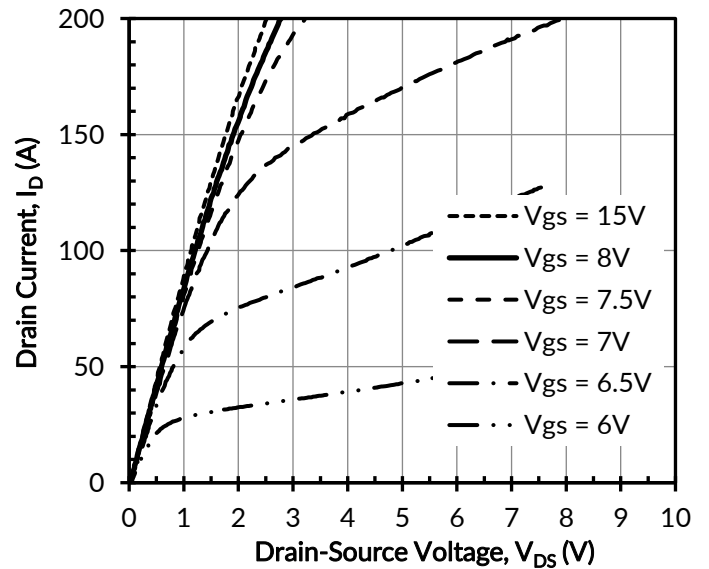


Figure 2. Typical output characteristics at  $T_j = 25^\circ C$ ,  $t_p < 250\mu s$

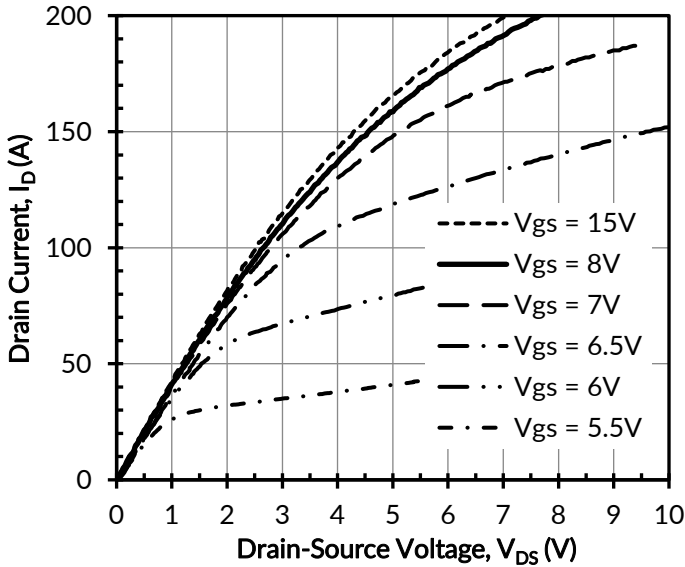


Figure 3. Typical output characteristics at  $T_j = 175^\circ\text{C}$ ,  $t_p < 250\mu\text{s}$

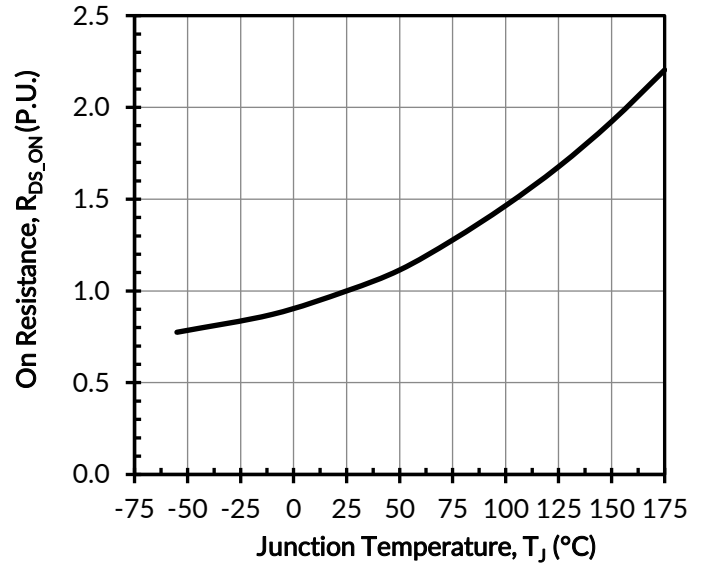


Figure 4. Normalized on-resistance vs. temperature at  $V_{GS} = 12\text{V}$  and  $I_D = 60\text{A}$

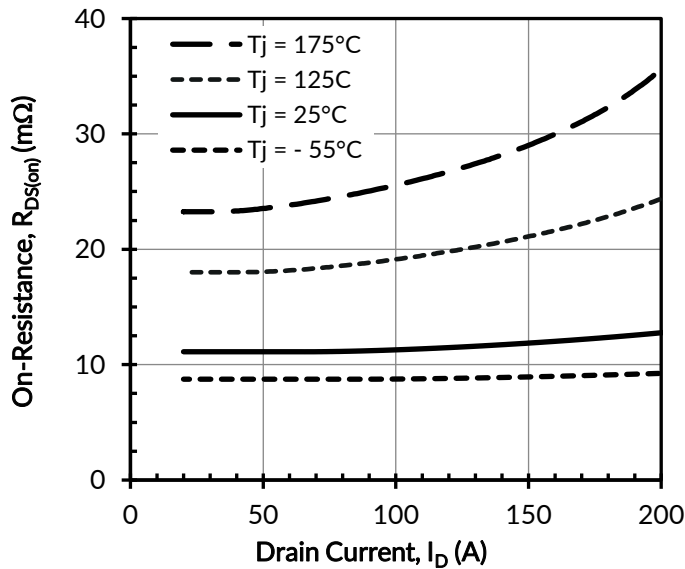


Figure 5. Typical drain-source on-resistances at  $V_{GS} = 12\text{V}$

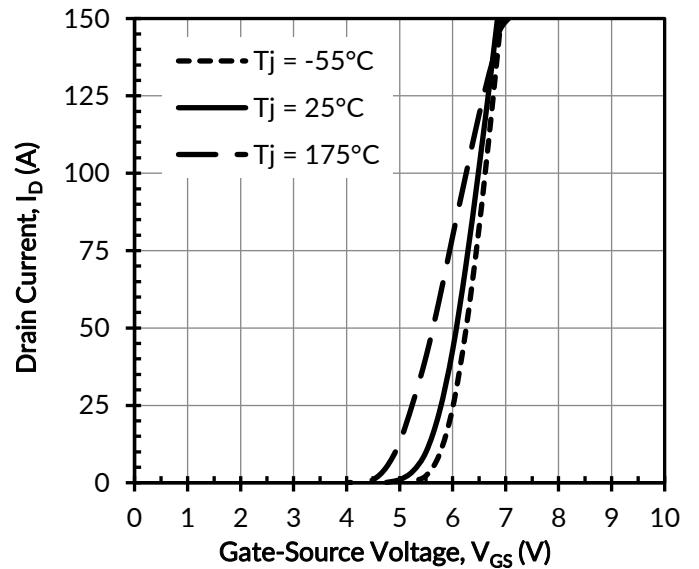


Figure 6. Typical transfer characteristics at  $V_{DS} = 5\text{V}$

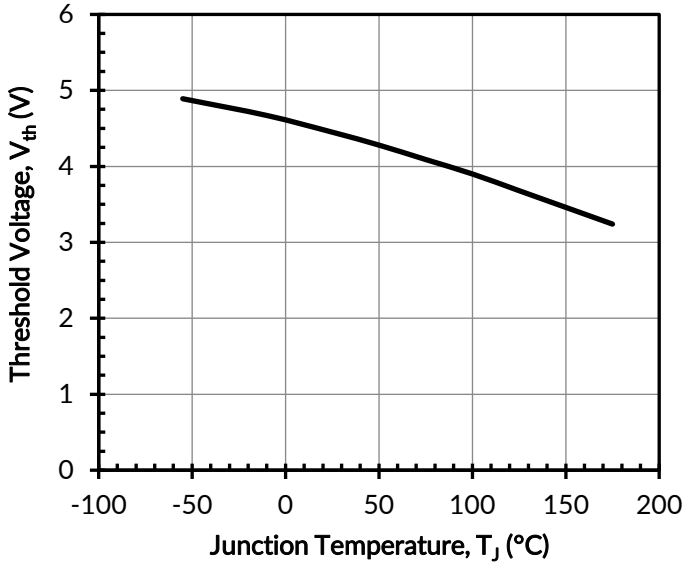


Figure 7. Threshold voltage vs. junction temperature at  $V_{DS} = 5V$  and  $I_D = 10mA$

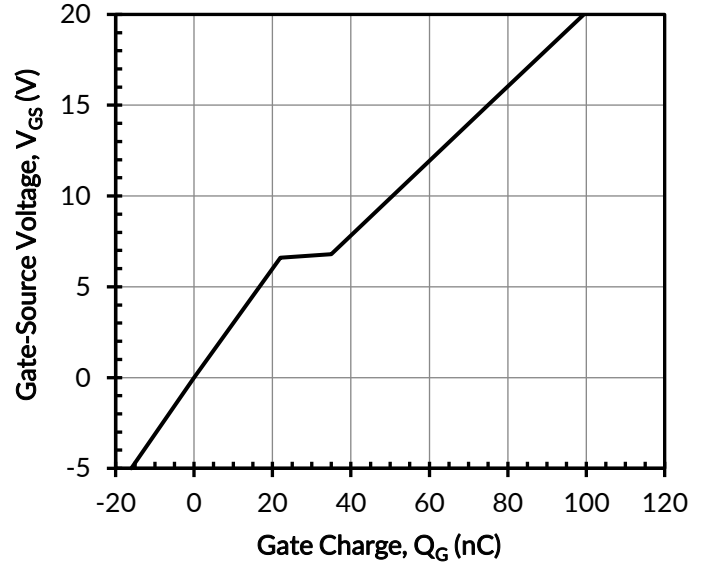


Figure 8. Typical gate charge at  $V_{DS}=400V$  and  $I_D = 60A$

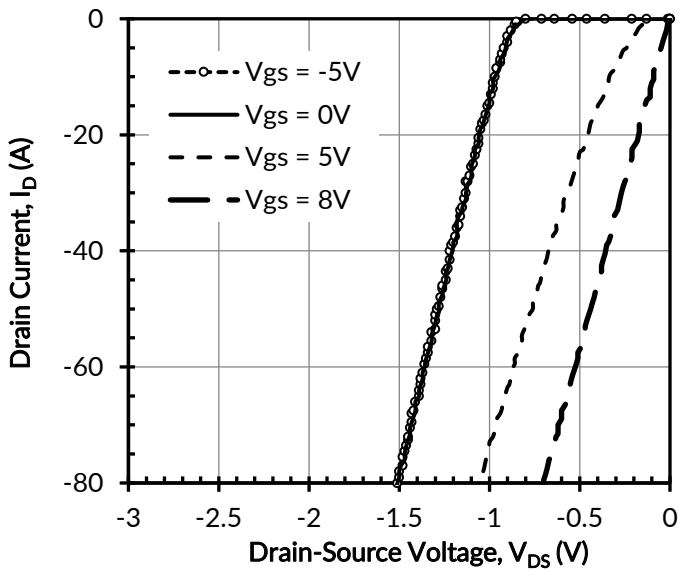


Figure 9. 3rd quadrant characteristics at  $T_j = -55^\circ C$

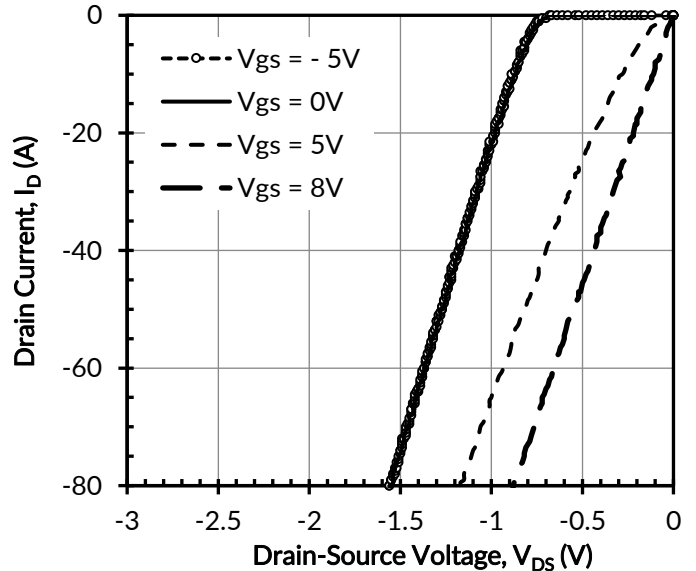


Figure 10. 3rd quadrant characteristics at  $T_j = 25^\circ C$



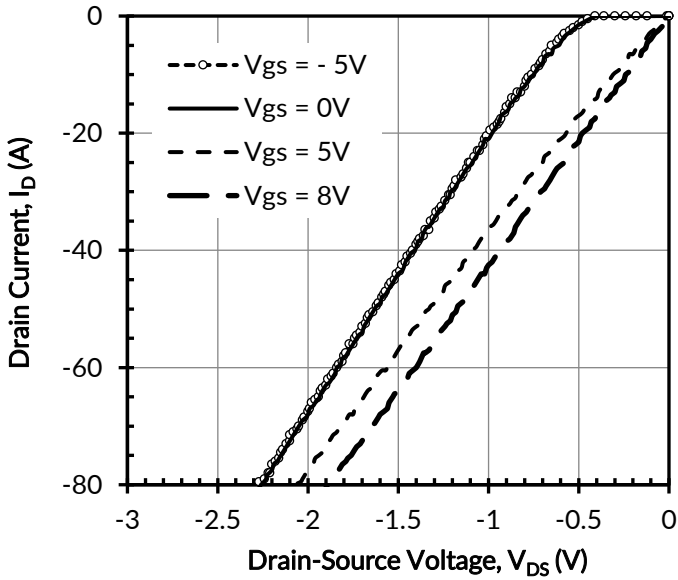


Figure 11. 3rd quadrant characteristics at  $T_J = 175^\circ\text{C}$

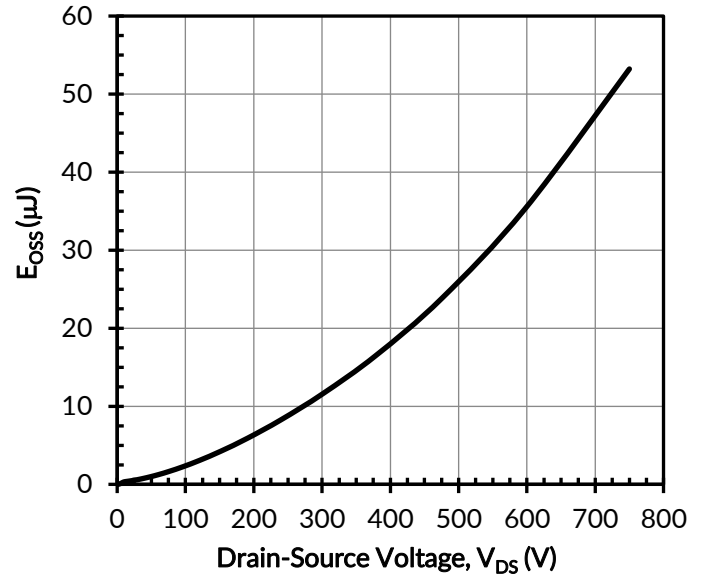


Figure 12. Typical stored energy in  $C_{OSS}$  at  $V_{GS} = 0\text{V}$

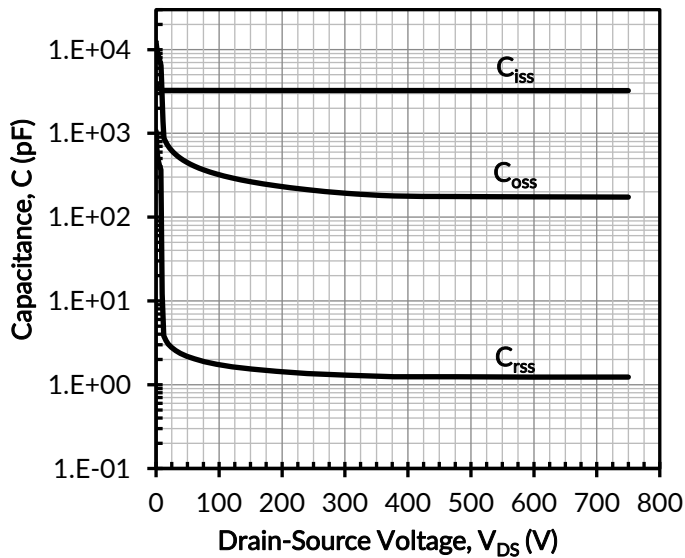


Figure 13. Typical capacitances at  $f = 100\text{kHz}$  and  $V_{GS} = 0\text{V}$

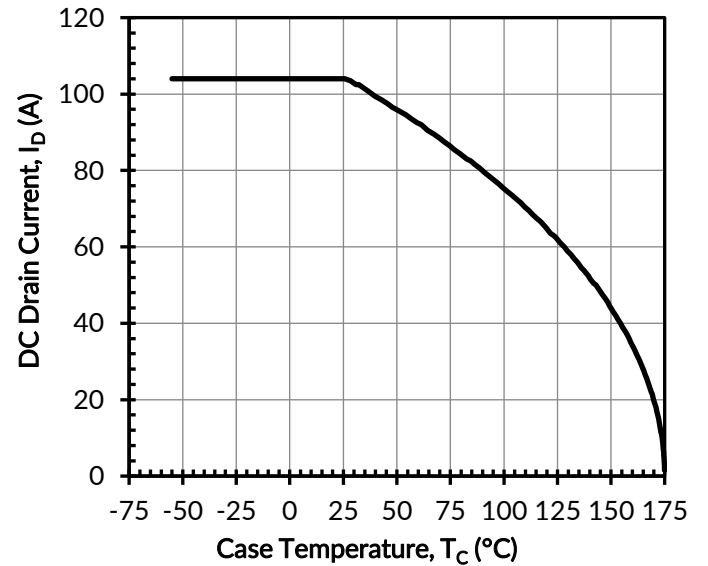


Figure 14. DC drain current derating

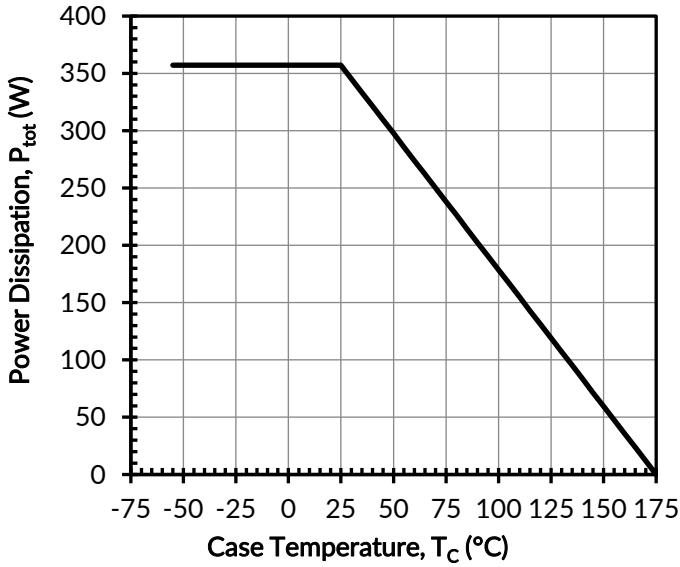


Figure 15. Total power dissipation

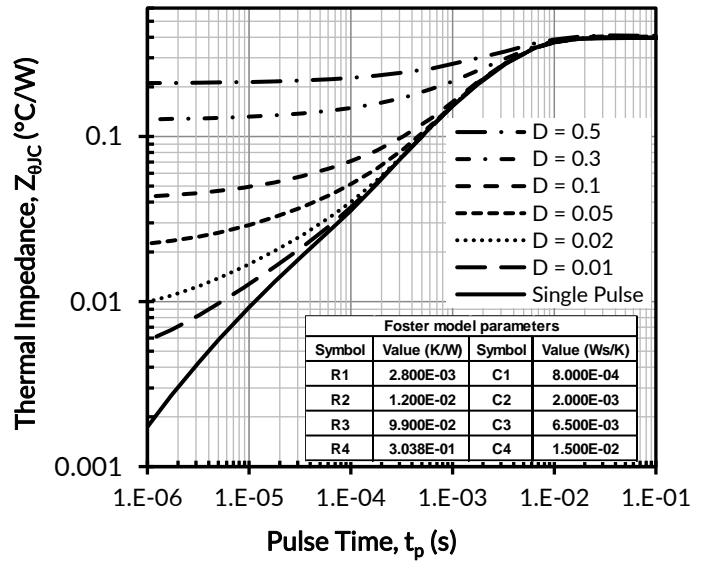


Figure 16. Maximum transient thermal impedance

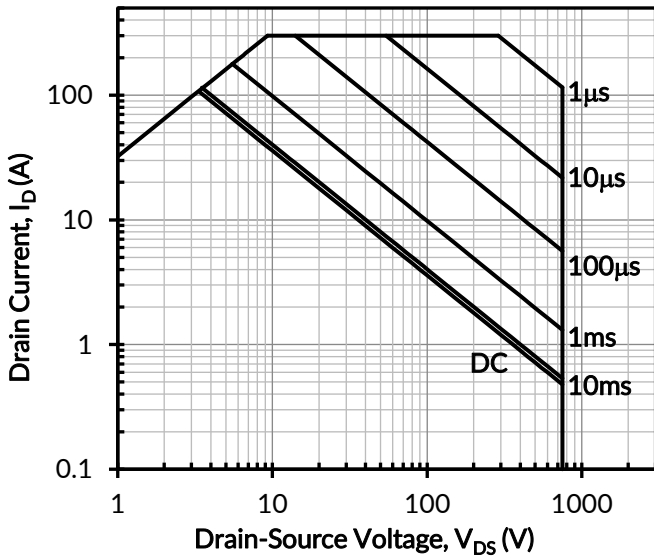


Figure 17. Safe operation area at  $T_c = 25^\circ\text{C}$ ,  $D = 0$ , Parameter  $t_p$

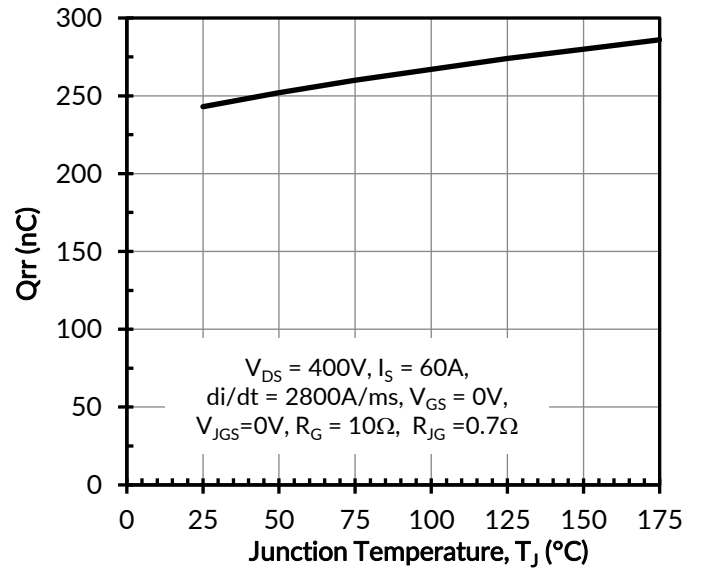


Figure 18. Reverse recovery charge  $Q_{rr}$  vs. junction temperature

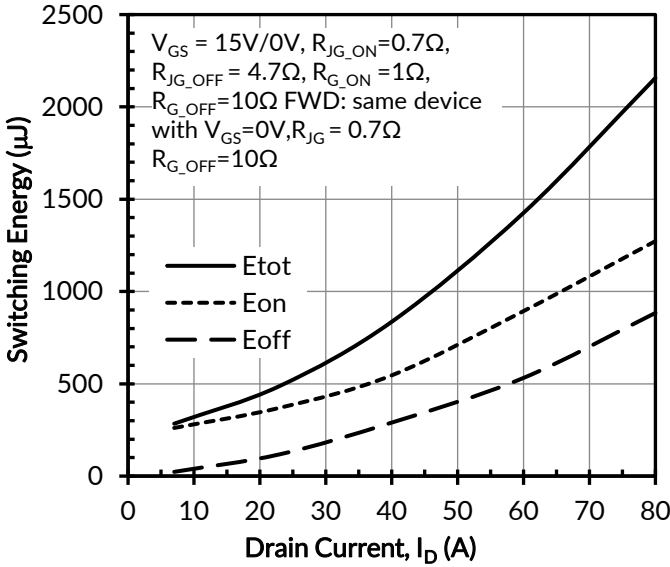


Figure 19. Clamped inductive switching energy vs. drain current at  $V_{DS} = 400V$  and  $T_J = 25^\circ C$



Figure 20. Clamped inductive switching turn-off energy vs. JFET gate resistor  $R_{JG\_OFF}$  at  $V_{DS} = 400V$ ,  $I_D = 60A$ , and  $T_J = 25^\circ C$

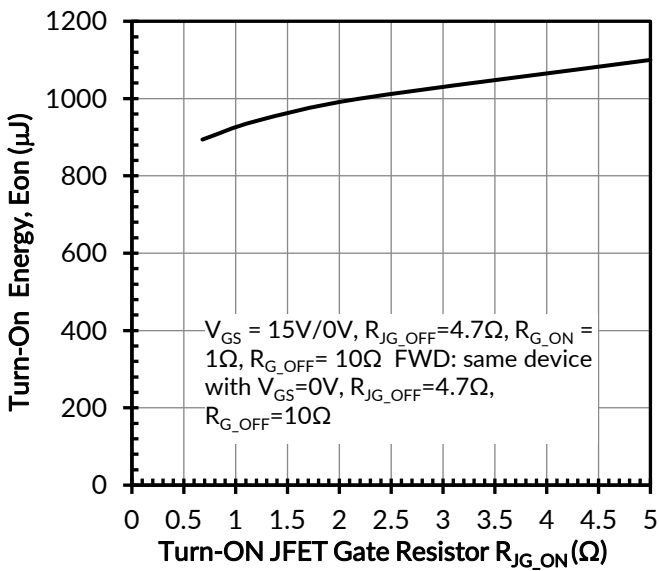


Figure 21. Clamped inductive switching turn-on energy vs. JFET gate resistor  $R_{JG\_ON}$  at  $V_{DS} = 400V$ ,  $I_D = 60A$ , and  $T_J = 25^\circ C$

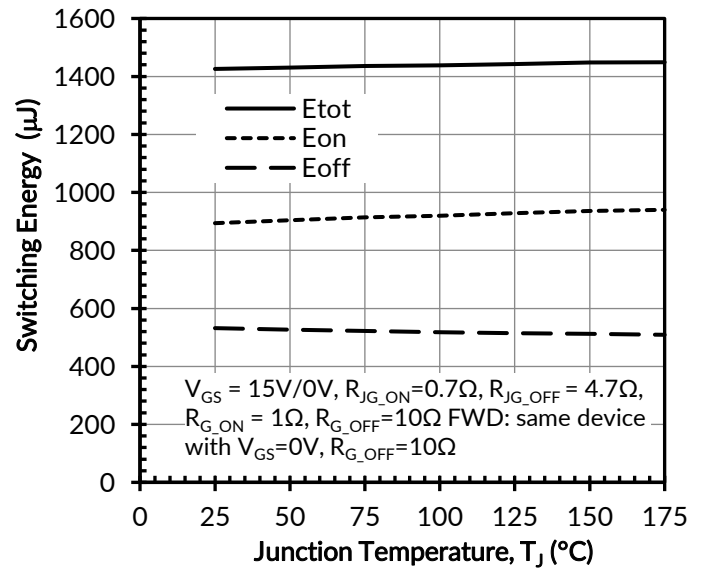


Figure 22. Clamped inductive switching energy vs. junction temperature at  $V_{DS} = 400V$  and  $I_D = 60A$

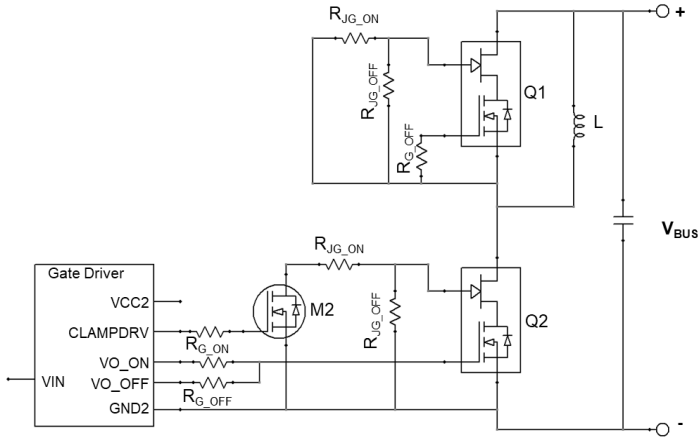


Figure 23. Schematic of the half-bridge mode switching test circuit with ClampDRIVE method.

Typical Performance Diagrams - JFET gate as control terminal and  $V_{GS}=+12V$

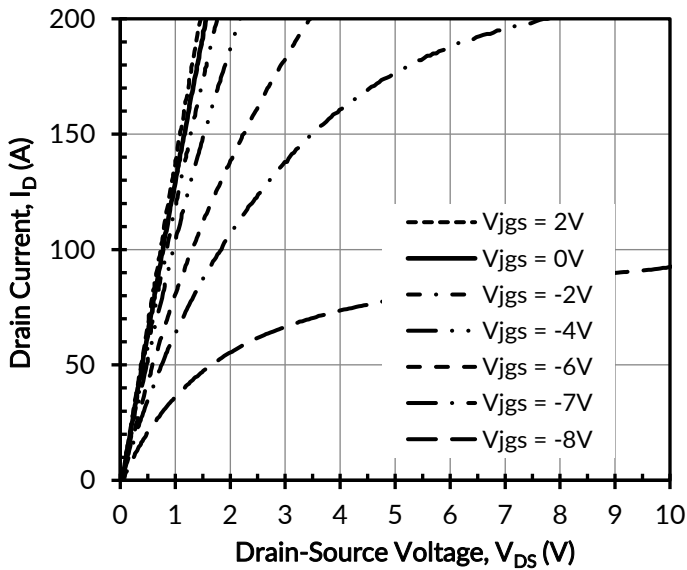


Figure 24. Typical output characteristics with JFET

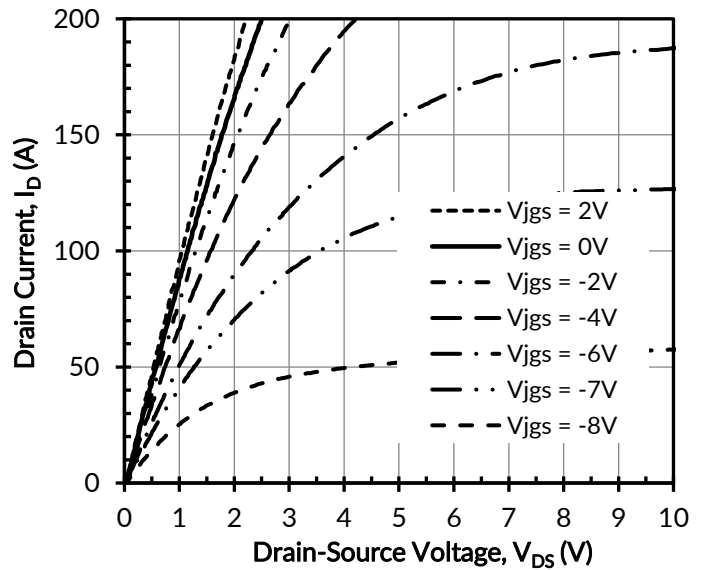


Figure 25. Typical output characteristics with JFET

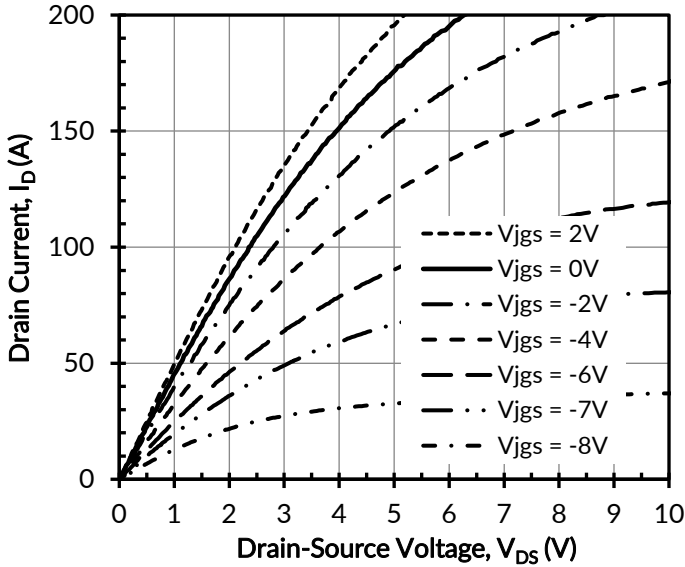


Figure 26. Typical output characteristics with JFET gate as control at  $T_J = 175^\circ\text{C}$ ,  $t_p < 250\mu\text{s}$

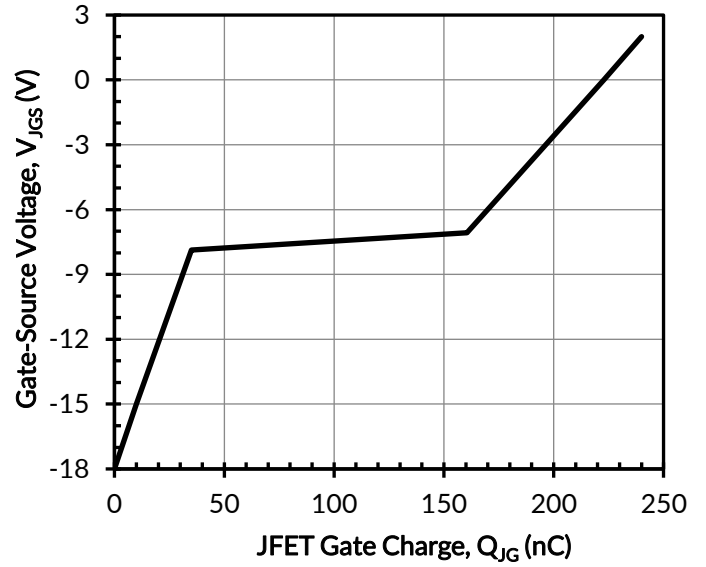


Figure 27. Typical JFET gate charge at  $V_{DS} = 400\text{V}$  and  $I_D = 60\text{A}$

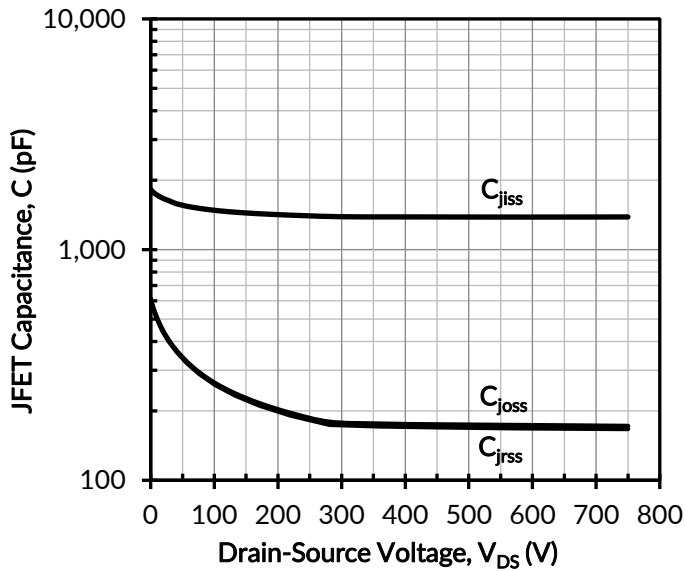


Figure 28. Typical JFET capacitances at  $f = 100\text{kHz}$  and  $V_{JGS} = -20\text{V}$

## Recommended Gate Drive Approach: ClampDRIVE method

Since both JFET gate and MOSFET gate are accessible, more parameters and approaches can be used to control the switching behaviors of the device and make the device suitable for a wide range applications from solid state circuit breakers requiring ultra-high current turn-off capability to motor drives requiring fast switching speed. The recommended gate drive approach is the ClampDRIVE method, with which the desired turn-on speed, turn-off speed and reverse recovery performance can be achieved at the same time. The main idea of this method is to dynamically tune the JFET gate resistor value  $R_{JG}$  such that, in the off-state,  $R_{JG}$  is small enough not to cause a reverse recovery issue, and during turn-off transient,  $R_{JG}$  is set to a higher value for the desired turn-off performance. This method can be easily implemented using a commercial off-the-shelf gate driver with miller clamp pre-driver output, as illustrated in Figure A.  $V_{IN}$  is the gate driver input signal.  $V_O$  is the gate driver output and CLAMPDRV is the gate driver miller clamp pre-driver output. M2 is the clamp MOSFET used to control the JFET gate resistance. The MOSFET M2 is directly controlled by the CLAMPDRV signal.

In the on-state, CLAMPDRV is low which turns the MOSFET M2 off, thus, the effective JFET gate resistance is  $R_{JG\_OFF}$ . During the turn-off transient, CLAMPDRV is kept low until the device is fully off. This means the JFET gate resistance is  $R_{JG\_OFF}$  during the turn-off process, and  $R_{G\_OFF}$  can be used to effectively control turn-off speed. After the device is fully off, CLAMPDRV is changed to high level, which turns the MOSFET M2 on.

In the off-state, CLAMPDRV is high and the clamp MOSFET M2 is in on-state. The effective JFET gate resistance is equal to the parallel combination of  $R_{JG\_OFF}$  and  $R_{JG\_ON}$ .  $R_{JG\_ON}$  can be selected small enough to prevent the reverse recovery issue. During the turn-on transient, the JFET gate current may flow from the cascode source through the body diode of the MOSFET M2 and  $R_{JG\_ON}$  into the JFET gate, so, the turn-on process is also determined by  $R_{JG\_ON}$ .

In summary, the optimum switching performance of the SiC cascode FETs can be realized with the ClampDRIVE method by selecting proper JFET gate resistors  $R_{JG\_ON}$  and  $R_{JG\_OFF}$ .

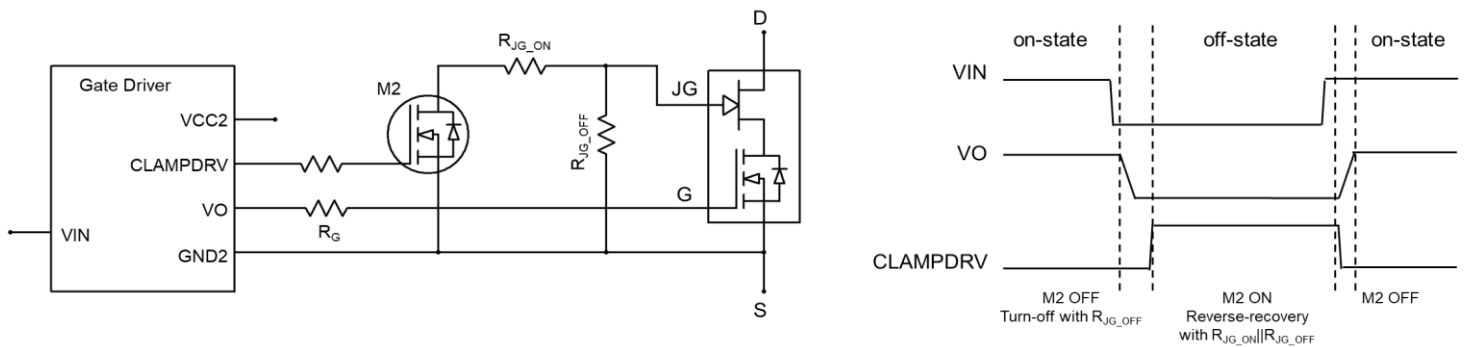
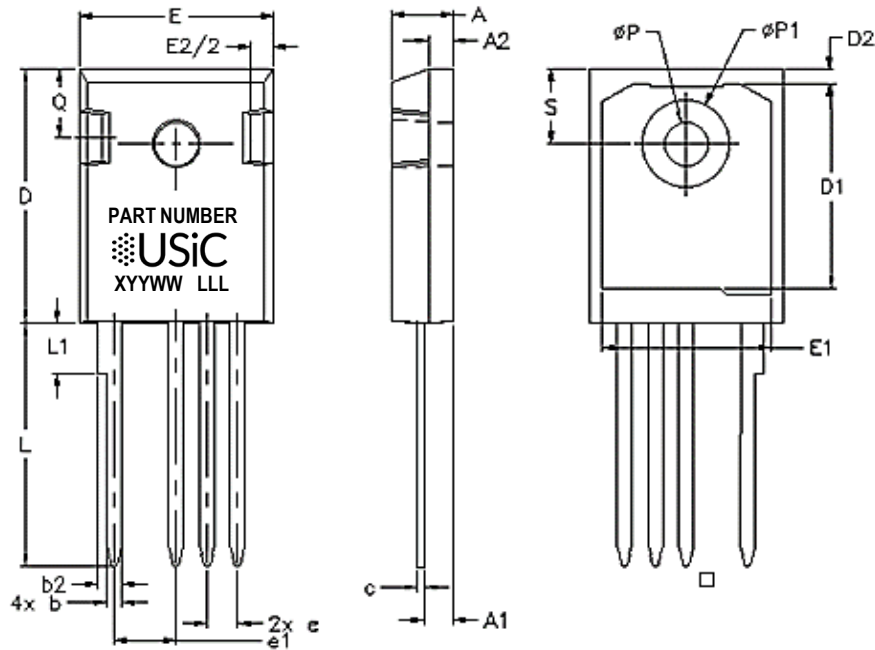


Figure A. Circuit schematic and timing diagram of the ClampDRIVE method

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**PACKAGE OUTLINE**



DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.185	0.209	4.7	5.31
A1	0.087	0.102	2.21	2.59
A2	0.059	0.098	1.5	2.49
b	0.039	0.055	0.99	1.4
b2	0.065	0.094	1.65	2.39
c	0.015	0.035	0.38	0.89
D	0.819	0.845	20.8	21.46
D1	0.515	-	13.08	-
D2	0.02	0.053	0.51	1.35
E	0.61	0.64	15.49	16.26
e	0.100 BSC		2.54 BSC	
e1	0.19	0.21	4.83	5.33
E1	0.53	-	13.46	-
E2	0.14	0.16	3.56	4.06
L	0.78	0.8	19.81	20.32
L1	-	0.177	-	4.5
$\phi P$	0.14	0.144	3.56	3.66
$\phi P1$	0.278	0.291	7.06	7.39
Q	0.212	0.244	5.38	6.2
S	0.243 BSC		6.17 BSC	





## PART MARKING

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

# PART NUMBER

The logo for USiC, featuring a circular pattern of black dots on the left and the text "USiC" in a large, bold, black sans-serif font on the right.  
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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