

# Silicon Carbide (SiC) Combo JFET – EliteSiC, Power N-Channel, TO247-4, 750 V, 11 mohm

SiC JFET w/ Si MOSFET

## UG4SC075011K4S

### Description

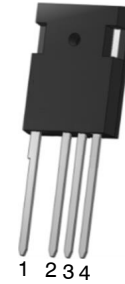
onsemi's UG4SC075011K4S "Combo-FET" integrates both a 750 V SiC JFET and a Low Voltage Si MOSFET into a single TO247-4 Package. This innovative approach allows users to create circuitry that would enable a normally-off switch while leveraging the benefits of a normally-on SiC JFET. These benefits include 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
- This Device is Pb-Free, Halogen Free and is RoHS Compliant

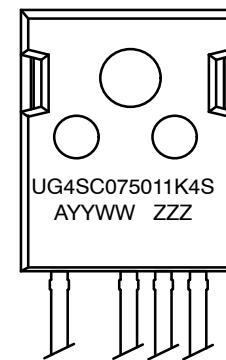
### Typical Applications

- Solid State / Semiconductor Circuit Breaker
- Solid State / Semiconductor Relay
- Battery Disconnects
- Surge Protection
- Inrush Current Control
- High Power Switch Mode Converters (>25 kW)



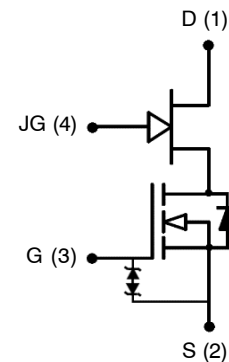
TO247-4  
CASE 340AN

### MARKING DIAGRAM



UG4SC075011K4S = Specific Device Code  
 A = Assembly Location  
 YY = Year  
 WW = Work Week  
 ZZZ = Lot ID

### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information on page 9 of this data sheet.

## MAXIMUM RATINGS

Parameter	Symbol	Test Conditions	Value	Unit
Drain-source Voltage	$V_{DS}$		750	V
JFET Gate (JG) to Source Voltage	$V_{JGS}$	DC	-30 to +3	V
		AC (Note 1)	-30 to +30	V
MOSFET Gate (G) to Source Voltage	$V_{GS}$	DC	-20 to +20	V
		AC (f > 1 Hz)	-25 to +25	V
Continuous Drain Current (Note 2)	$I_D$	$T_C = 25\text{ }^\circ\text{C}$	104	A
		$T_C = 100\text{ }^\circ\text{C}$	75	A
Pulsed Drain Current (Note 3)	$I_{DM}$	$T_C = 25\text{ }^\circ\text{C}$	300	A
Single Pulsed Avalanche Energy (Note 4)	$E_{AS}$	L = 15 mH, $I_{AS} = 4.5\text{ A}$	151	mJ
Power Dissipation	$P_{tot}$	$T_C = 25\text{ }^\circ\text{C}$	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	$^\circ\text{C}$

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

- +30 V AC Rating Applies for Turn-on pulses <200 ns applied with external  $R_G > 10$ .
- Limited by  $T_{J,max}$
- Pulse width  $t_p$  limited by  $T_{J,max}$
- Starting  $T_J = 25\text{ }^\circ\text{C}$

## THERMAL CHARACTERISTICS

Parameter	Symbol	Test Conditions	Value			
			Min	Typ	Max	Unit
Thermal Resistance, Junction-to-Case	$R_{\theta JC}$		-	0.33	0.42	$^\circ\text{C/W}$

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

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
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### TYPICAL PERFORMANCE – STATIC

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	$I_{DSS}$	$V_{DS} = 750\text{ V}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, T_J = 25\text{ }^\circ\text{C}$	-	3.5	60	$\mu\text{A}$	
		$V_{DS} = 750\text{ V}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, T_J = 175\text{ }^\circ\text{C}$	-	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	$R_{DS(on)}$	$V_{GS} = 12\text{ V}, I_D = 60\text{ A}$	$V_{JGS} = 2\text{ V}, T_J = 25\text{ }^\circ\text{C}$	-	10	-	$\text{m}\Omega$
			$T_J = 25\text{ }^\circ\text{C}$	-	11	14.2	
			$T_J = 125\text{ }^\circ\text{C}$	-	18.4	-	
			$T_J = 175\text{ }^\circ\text{C}$	-	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 MHz, open drain	-	0.7	-	$\Omega$	
MOSFET Gate Resistance	$R_G$	f = 1 MHz, open drain	-	2.3	-	$\Omega$	

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

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
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### TYPICAL PERFORMANCE – REVERSE DIODE

Diode Continuous Forward Current (Note 1)	$I_S$	$T_C = 25\text{ }^\circ\text{C}$	–	–	104	A
Diode Pulse Current (Note 2)	$I_{S,pulse}$	$T_C = 25\text{ }^\circ\text{C}$	–	–	300	A
Forward Voltage	$V_{FSD}$	$V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, I_S = 30\text{ A}, T_J = 25\text{ }^\circ\text{C}$	–	1.1	1.24	V
		$V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, I_S = 30\text{ A}, T_J = 175\text{ }^\circ\text{C}$	–	1.2	–	
Reverse Recovery Charge	$Q_{rr}$	$V_{DS} = 400\text{ V}, I_S = 60\text{ A}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, R_{JG} = 0.7\text{ }\Omega, di/dt = 2800\text{ A}/\mu\text{s}, T_J = 25\text{ }^\circ\text{C}$	–	242	–	nC
Reverse Recovery Time	$t_{rr}$		–	58	–	ns
Reverse Recovery Charge	$Q_{rr}$	$V_{DS} = 400\text{ V}, I_S = 60\text{ A}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, R_{JG} = 0.7\text{ }\Omega, di/dt = 2800\text{ A}/\mu\text{s}, T_J = 150\text{ }^\circ\text{C}$	–	280	–	nC
Reverse Recovery Time	$t_{rr}$		–	89	–	ns

### TYPICAL PERFORMANCE – DYNAMIC WITH MOSFET GATE AS CONTROL TERMINAL AND $V_{JGS} = 0\text{ V}$

MOSFET Input Capacitance	$C_{iss}$	$V_{DS} = 400\text{ V}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}, f = 100\text{ kHz}$	–	3245	–	pF		
Output Capacitance	$C_{oss}$		–	178	–			
Reverse Transfer Capacitance	$C_{rss}$		–	1.2	–			
Effective Output Capacitance, Energy	$C_{oss(er)}$	$V_{DS} = 0\text{ V to } 400\text{ V}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}$	–	225	–	pF		
Effective Output Capacitance, Time Related	$C_{oss(tr)}$		–	470	–	pF		
$C_{oss}$ Stored Energy	$E_{oss}$	$V_{DS} = 400\text{ V}, V_{GS} = 0\text{ V}, V_{JGS} = 0\text{ V}$	–	18	–	$\mu\text{J}$		
Total Gate Charge	$Q_G$	$V_{DS} = 400\text{ V}, I_D = 60\text{ A}, V_{GS} = 0\text{ V to } 15\text{ V}$	–	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 $V_{DS} = 400\text{ V}, I_D = 60\text{ A}, V_{GS} = 0\text{ V to } +15\text{ V}, R_{G\_ON} = 1\text{ }\Omega, R_{G\_OFF} = 10\text{ }\Omega, R_{JG\_ON} = 0.7\text{ }\Omega, R_{JG\_OFF} = 4.7\text{ }\Omega, \text{Inductive Load, FWD: same device with } V_{GS} = 0\text{ V}, R_{JG} = 0.7\text{ }\Omega, T_J = 25\text{ }^\circ\text{C}$	–	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	–		$\mu\text{J}$	
Turn-off Energy	$E_{OFF}$		–	513	–			
Total Switching Energy	$E_{TOT}$		–	1503	–			
Turn-on Delay Time	$t_{d(on)}$		Notes 5 and 6 $V_{DS} = 400\text{ V}, I_D = 60\text{ A}, V_{GS} = 0\text{ V to } +15\text{ V}, R_{G\_ON} = 1\text{ }\Omega, R_{G\_OFF} = 10\text{ }\Omega, R_{JG\_ON} = 0.7\text{ }\Omega, R_{JG\_OFF} = 4.7\text{ }\Omega, \text{Inductive Load, FWD: same device with } V_{GS} = 0\text{ V}, R_{JG} = 0.7\text{ }\Omega, T_J = 150\text{ }^\circ\text{C}$	–	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	–	$\mu\text{J}$		
Turn-off Energy	$E_{OFF}$	–		454	–			
Total Switching Energy	$E_{TOT}$	–		1440	–			

### TYPICAL PERFORMANCE – DYNAMIC WITH JFET GATE AS CONTROL TERMINAL AND $V_{GS} = +12\text{ V}$

JFET Input Capacitance	$C_{Jiss}$	$V_{DS} = 400\text{ V}, V_{JGS} = -20\text{ V}, f = 100\text{ kHz}$	–	1385	–	pF
JFET Output Capacitance	$C_{Joss}$		–	175	–	
JFET Reverse Transfer Capacitance	$C_{Jrss}$		–	170	–	
JFET Total Gate Charge	$Q_{JG}$	$V_{DS} = 400\text{ V}, I_D = 60\text{ A}, V_{JGS} = -18\text{ V to } 0\text{ V}$	–	223	–	nC
JFET Gate-drain Charge	$Q_{JGD}$		–	126	–	
JFET Gate-source Charge	$Q_{JGS}$		–	35	–	

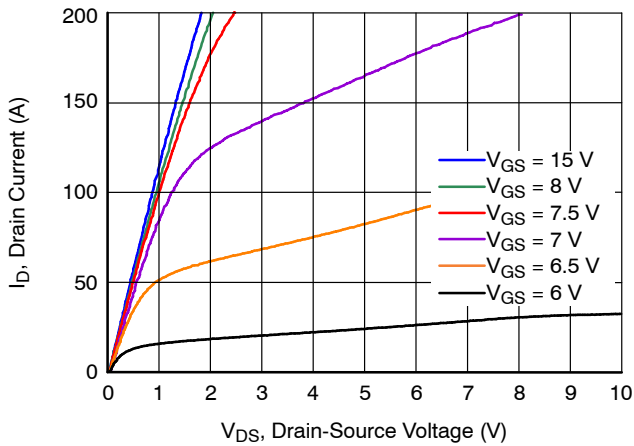
Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

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

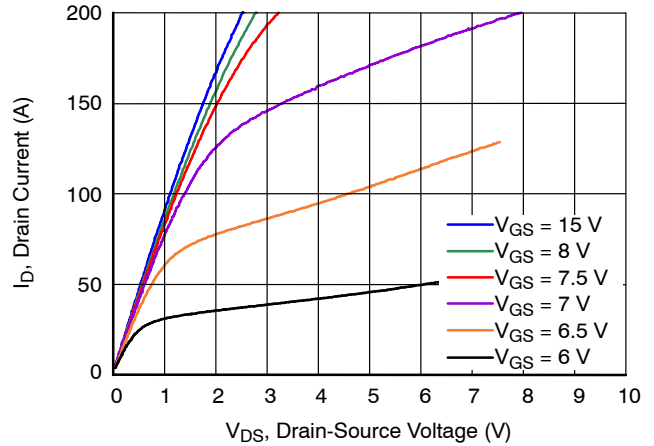
6. Devices are driven with the ClampDRIVE method as described in the section “Recommended Gate Drive Approach: ClampDRIVE method”



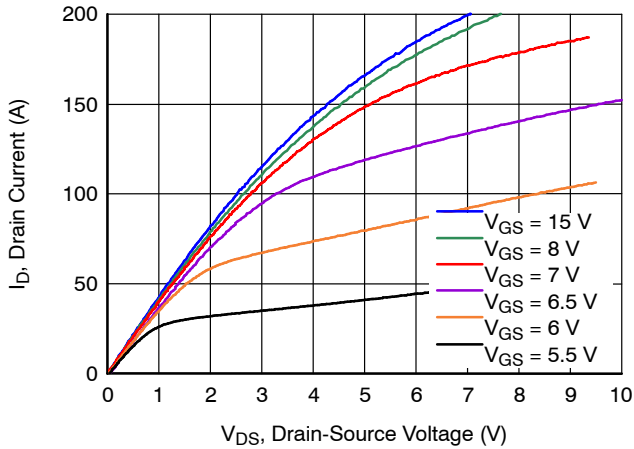
**TYPICAL PERFORMANCE DIAGRAMS – MOSFET GATE AS CONTROL TERMINAL AND  $V_{JGS} = 0\text{ V}$**



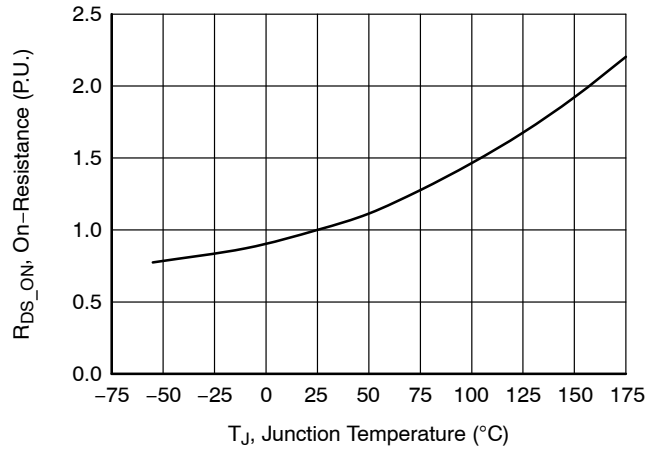
**Figure 1. Typical Output Characteristics at  $T_J = -55\text{ }^\circ\text{C}$ ,  $t_p < 250\text{ }\mu\text{s}$**



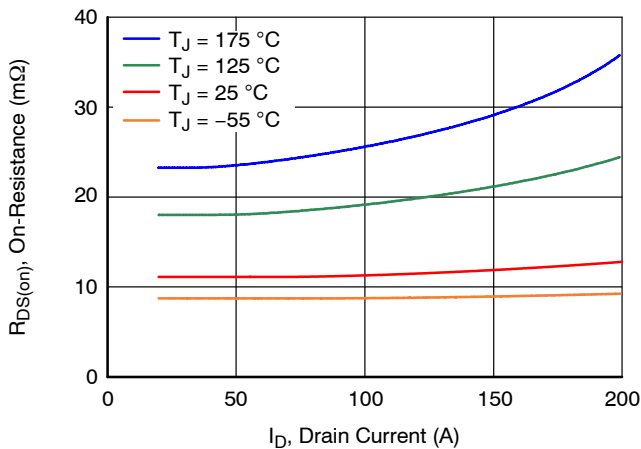
**Figure 2. Typical Output Characteristics at  $T_J = 25\text{ }^\circ\text{C}$ ,  $t_p < 250\text{ }\mu\text{s}$**



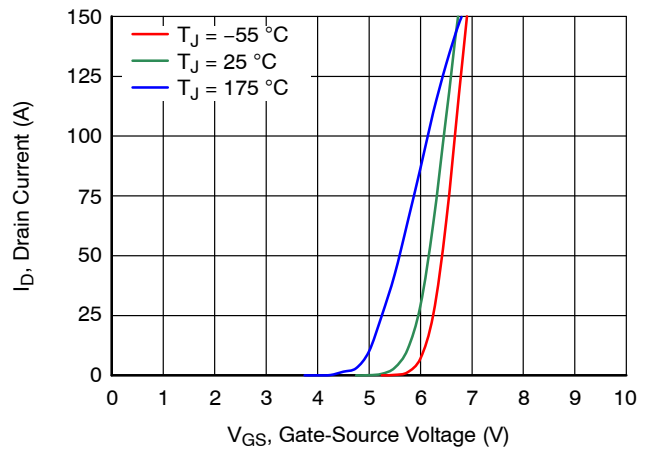
**Figure 3. Typical Output Characteristics at  $T_J = 175\text{ }^\circ\text{C}$ ,  $t_p < 250\text{ }\mu\text{s}$**



**Figure 4. Normalized On-Resistance vs. Temperature at  $V_{GS} = 12\text{ V}$  and  $I_D = 60\text{ A}$**



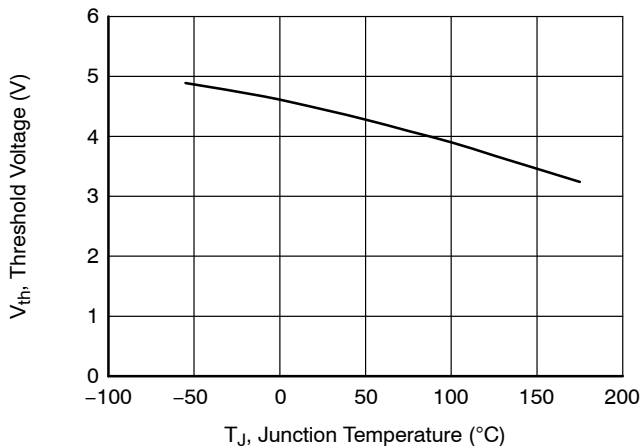
**Figure 5. Typical Drain-Source On-Resistances at  $V_{GS} = 12\text{ V}$**



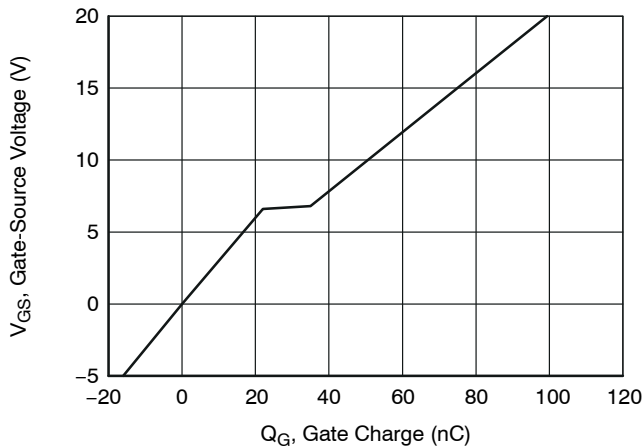
**Figure 6. Typical Transfer Characteristics at  $V_{DS} = 5\text{ V}$**

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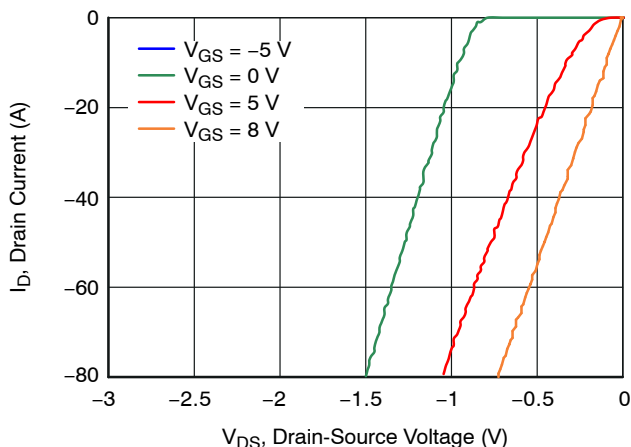
## TYPICAL PERFORMANCE DIAGRAMS – MOSFET GATE AS CONTROL TERMINAL AND $V_{JGS} = 0\text{ V}$ (CONTINUED)



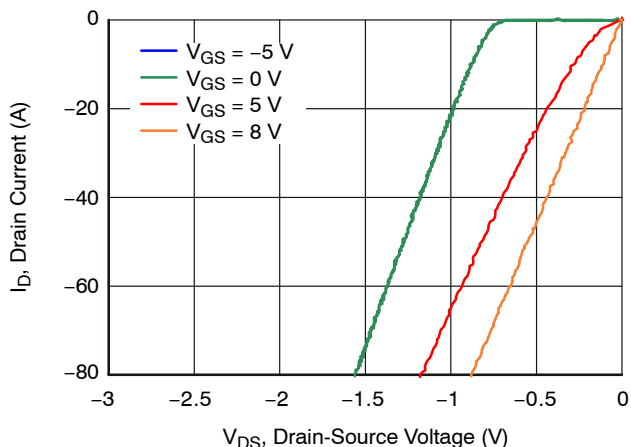
**Figure 7. Threshold Voltage vs. Junction Temperature at  $V_{DS} = 5\text{ V}$  and  $I_D = 10\text{ mA}$**



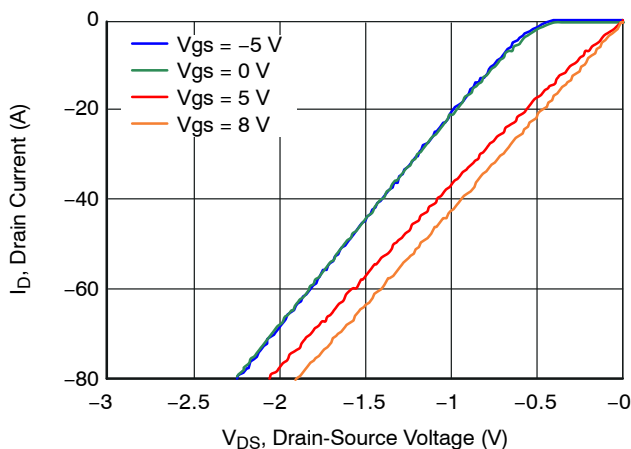
**Figure 8. Typical Gate Charge at  $V_{DS} = 400\text{ V}$  and  $I_D = 60\text{ A}$**



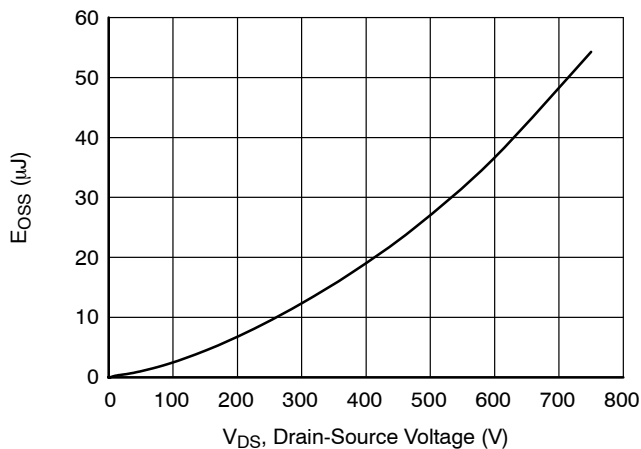
**Figure 9. 3<sup>rd</sup> Quadrant Characteristics at  $T_J = -55\text{ °C}$**



**Figure 10. 3<sup>rd</sup> Quadrant Characteristics at  $T_J = 25\text{ °C}$**

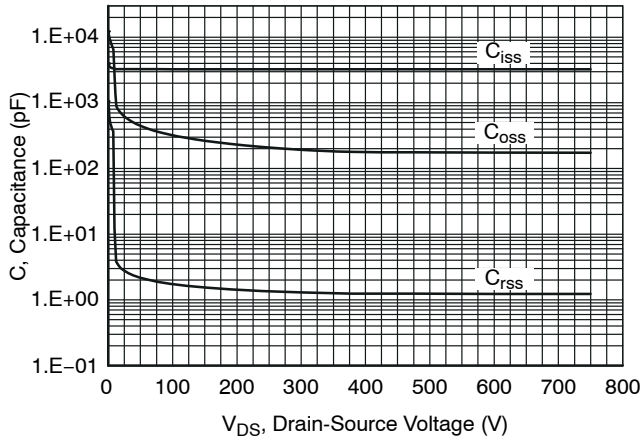


**Figure 11. 3<sup>rd</sup> Quadrant Characteristics at  $T_J = 175\text{ °C}$**

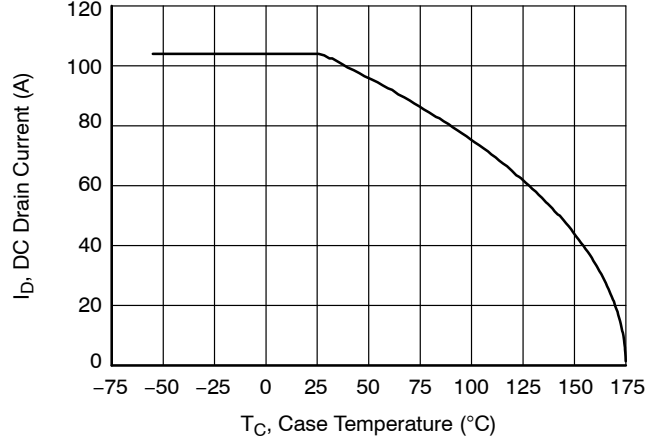


**Figure 12. Typical Stored Energy in  $C_{OSS}$  at  $V_{GS} = 0\text{ V}$**

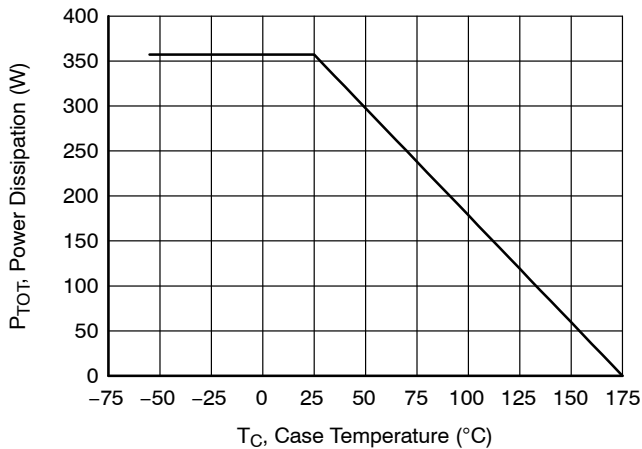
**TYPICAL PERFORMANCE DIAGRAMS – MOSFET GATE AS CONTROL TERMINAL AND  $V_{JGS} = 0\text{ V}$**   
(CONTINUED)



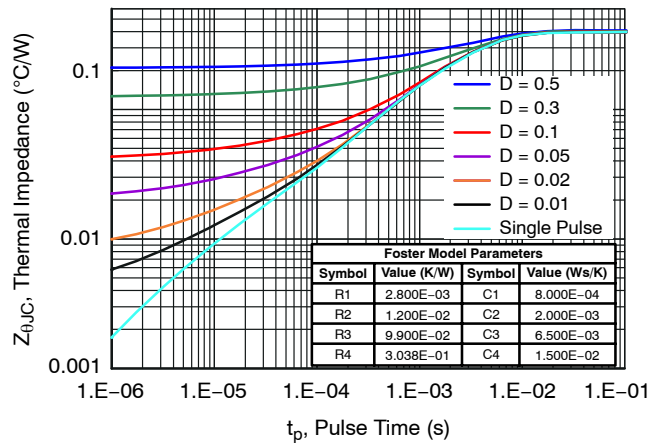
**Figure 13. Typical Capacitances at  $f = 100\text{ kHz}$  and  $V_{GS} = 0\text{ V}$**



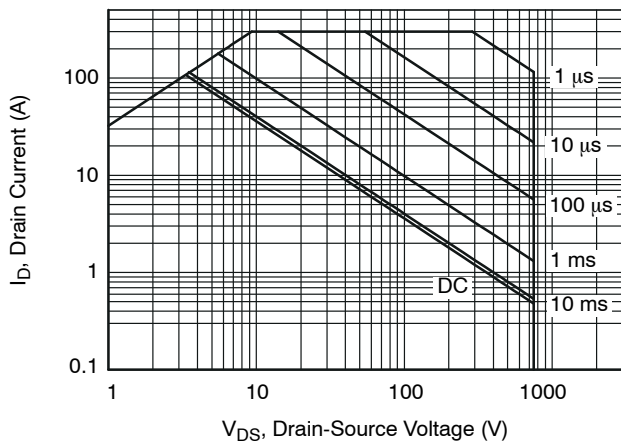
**Figure 14. DC Drain Current Derating**



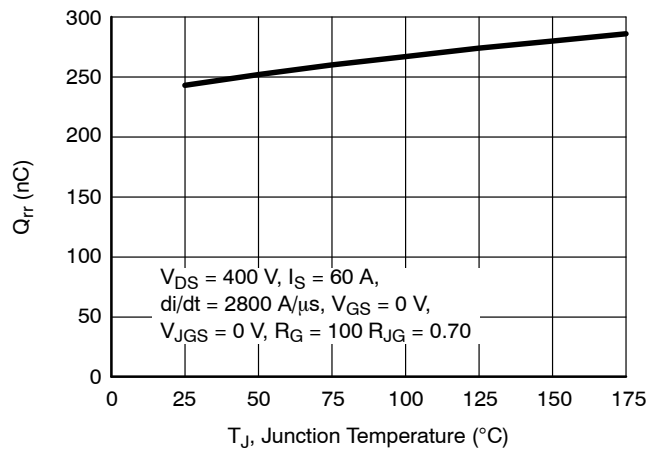
**Figure 15. Total Power Dissipation**



**Figure 16. Maximum Transient Thermal Impedance**



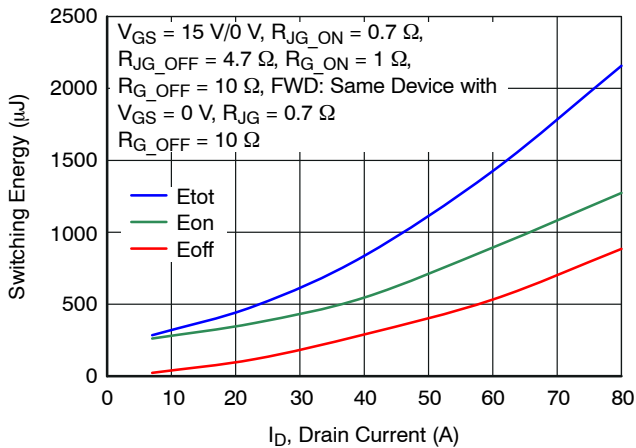
**Figure 17. Safe Operation Area at  $T_C = 25\text{ °C}$ ,  $D = 0$ , Parameter  $t_p$**



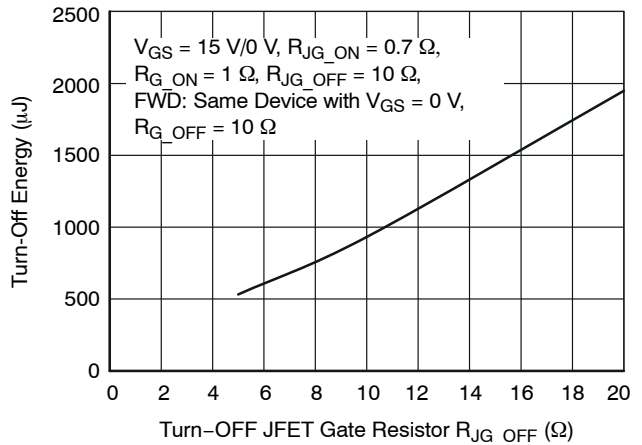
**Figure 18. Reverse Recovery Charge  $Q_{rr}$  vs. Junction Temperature**

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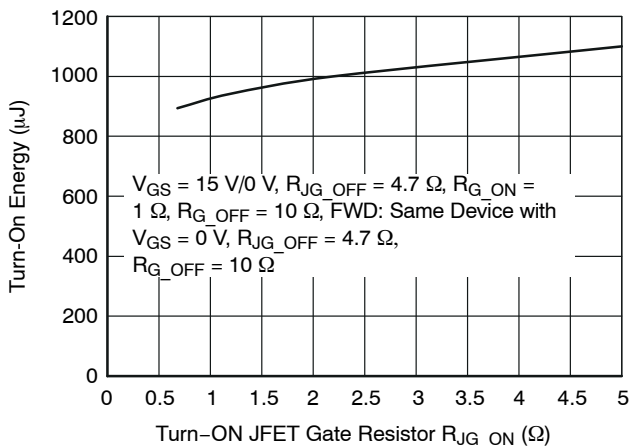
## TYPICAL PERFORMANCE DIAGRAMS – MOSFET GATE AS CONTROL TERMINAL AND $V_{JGS} = 0\text{ V}$ (CONTINUED)



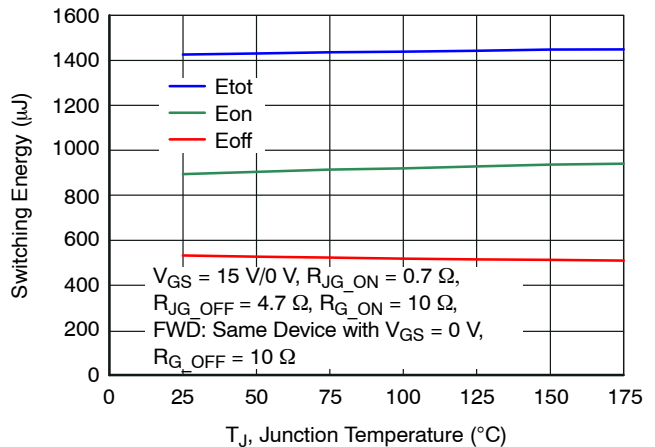
**Figure 19. Clamped Inductive Switching Energy vs. Drain Current at  $V_{DS} = 400\text{ V}$  and  $T_J = 25\text{ °C}$**



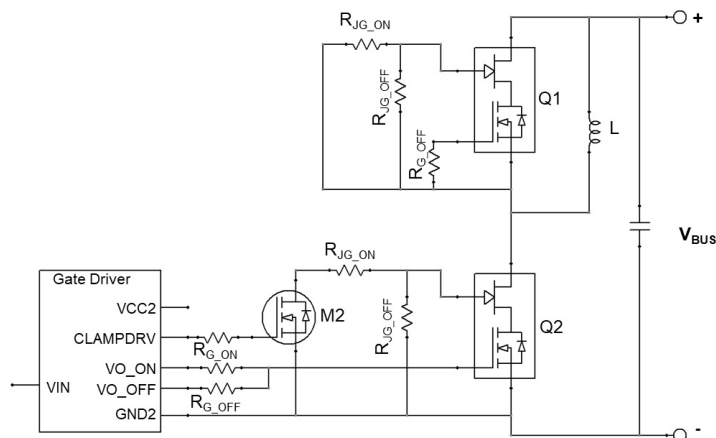
**Figure 20. Clamped Inductive Turn-Off Energy vs. JFET Gate Resistor  $R_{JG\_OFF}$  at  $V_{DS} = 400\text{ V}$ ,  $I_D = 60\text{ A}$ , and  $T_J = 25\text{ °C}$**



**Figure 21. Clamped Inductive Switching Turn-On Energy vs. JFET Gate Resistor  $R_{JG\_ON}$  at  $V_{DS} = 400\text{ V}$ ,  $I_D = 60\text{ A}$ , and  $T_J = 25\text{ °C}$**

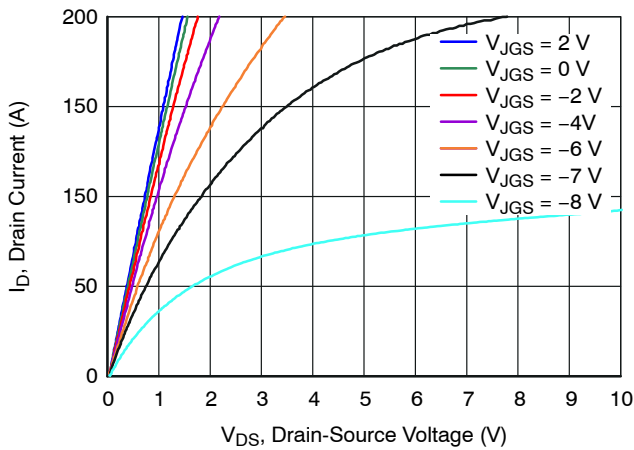


**Figure 22. Clamped Inductive Switching Energy vs. Junction Temperature at  $V_{DS} = 400\text{ V}$  and  $I_D = 60\text{ A}$**

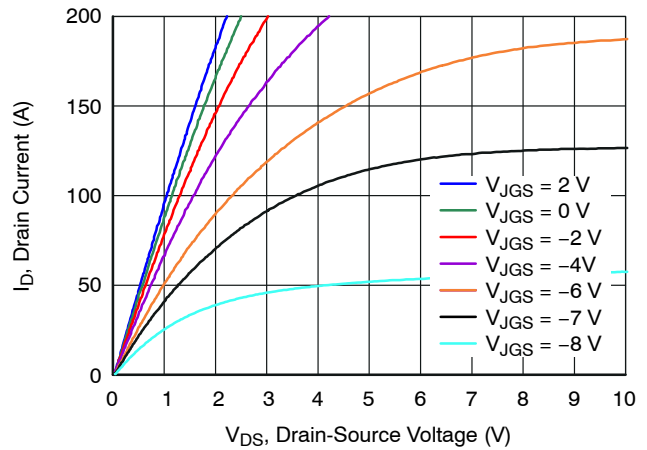


**Figure 23. Schematic of the Half-bridge Mode Switching Test Circuit with ClampDRIVE Method.**

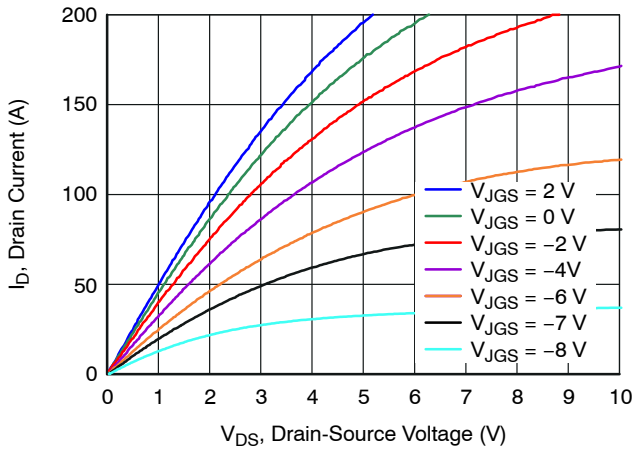
**TYPICAL PERFORMANCE DIAGRAMS – JFET GATE AS CONTROL TERMINAL AND  $V_{GS} = +12\text{ V}$**



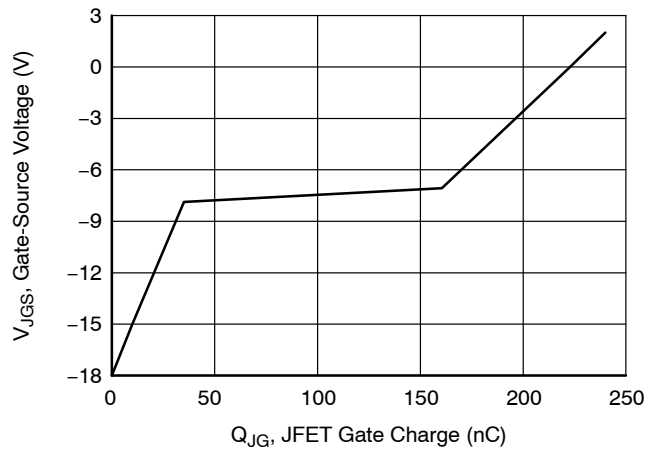
**Figure 24. Typical Output Characteristics with JFET Gate as Control at  $T_J = -55\text{ }^\circ\text{C}$ ,  $t_p < 250\text{ }\mu\text{s}$**



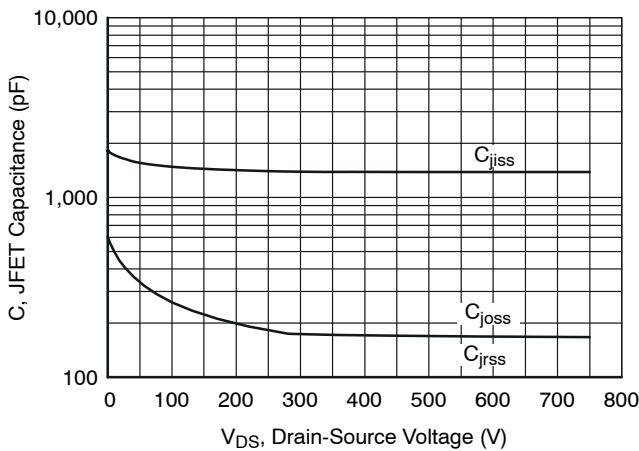
**Figure 25. Typical Output Characteristics with JFET Gate as Control at  $T_J = 25\text{ }^\circ\text{C}$ ,  $t_p < 250\text{ }\mu\text{s}$**



**Figure 26. Typical Output Characteristics with JFET Gate as Control at  $T_J = 175\text{ }^\circ\text{C}$ ,  $t_p < 250\text{ }\mu\text{s}$**



**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 behavior 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 well controlled 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  $R_{JG\_OFF}$  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  $R_{JG\_OFF}$ .

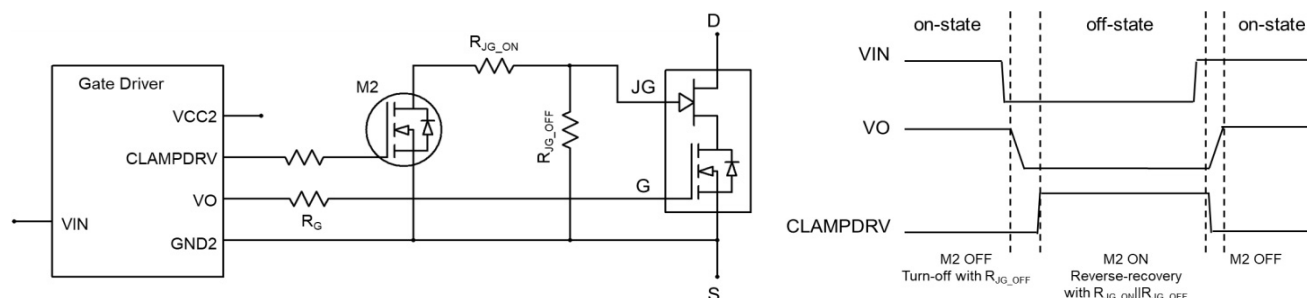
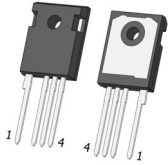


Figure 29. Circuit Schematic and Timing Diagram of the ClampDRIVE Method

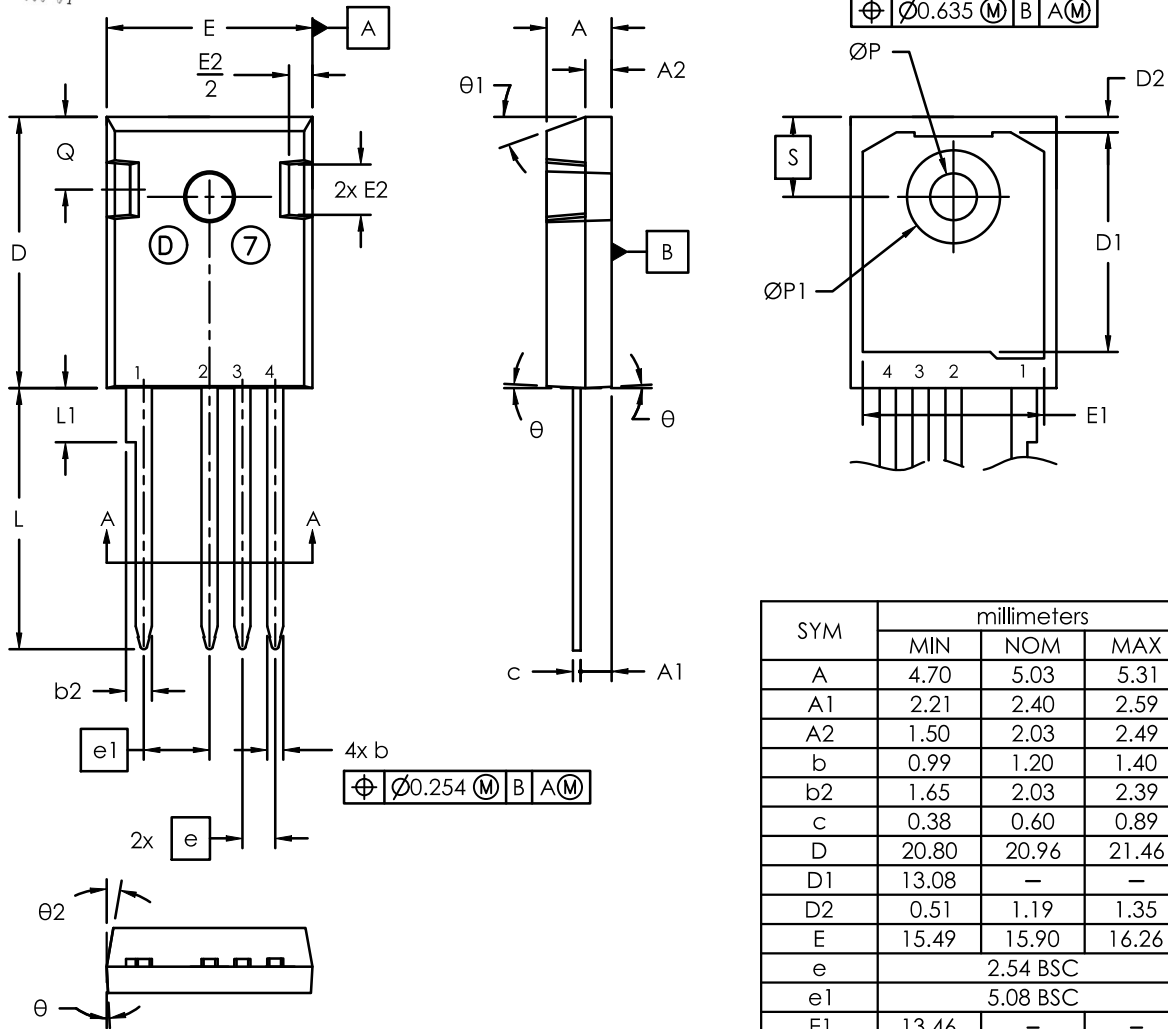
### ORDERING INFORMATION

Part Number	Marking	Package	Shipping
UG4SC075011K4S	UG4SC075011K4S	TO247-4 (Pb-Free, Halogen Free)	600 Units / Tube



TO247-4 15.90x20.96x5.03, 5.44P  
CASE 340AN  
ISSUE E

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$\text{Ø} \ 0.254 \text{ (M)} \ B \ A \text{ (M)}$

$\text{Ø} \ 0.635 \text{ (M)} \ B \ A \text{ (M)}$

SYM	millimeters		
	MIN	NOM	MAX
A	4.70	5.03	5.31
A1	2.21	2.40	2.59
A2	1.50	2.03	2.49
b	0.99	1.20	1.40
b2	1.65	2.03	2.39
c	0.38	0.60	0.89
D	20.80	20.96	21.46
D1	13.08	—	—
D2	0.51	1.19	1.35
E	15.49	15.90	16.26
e	2.54 BSC		
e1	5.08 BSC		
E1	13.46	—	—
E2	3.43	3.89	5.20
L	19.81	20.17	20.32
L1	—	—	4.50
ØP	3.40	3.60	3.80
ØP1	7.06	7.19	7.39
Q	5.38	5.62	6.20
S	6.17 BSC		
θ	3°		
θ1	20°		
θ2	10°		

NOTE:

1. Dimensioning and tolerancing as per ASME Y14.5 - 2018
2. Controlling dimension : millimeters
3. Package Outline in compliance with JEDEC standard var. AD.
4. Dimensions D & E does not include mold flash.
5. ØP to have max draft angle of 1.7° to the top with max. hole diameter of 3.91mm.
5. Through Hole diameter value = End Hole diameter
6. PCB Through Hole pattern as per IPC-2221/IPC-2222

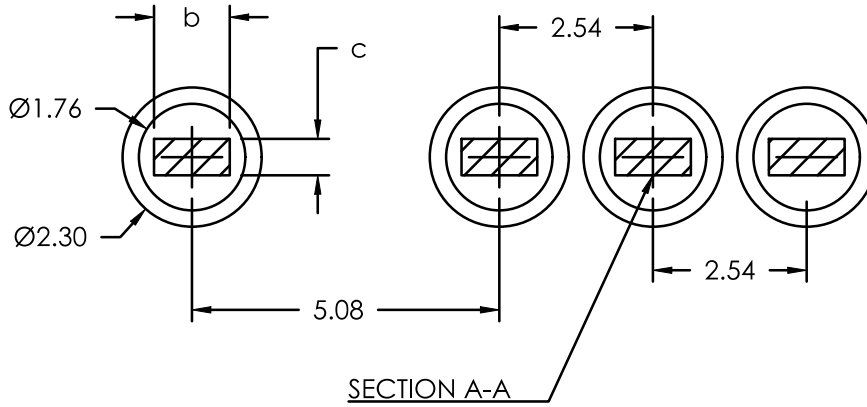
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RECOMMENDED PCB THROUGH HOLE



NOTE: LAND PATTERN AND THROUGH HOLE DIMENSIONS SERVE ONLY AS AN INITIAL GUIDE.  
 END-USER PCB DESIGN RULES AND TOLERANCES SHOULD ALWAYS PREVAIL.

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