

# CMF10120D-Silicon Carbide Power MOSFET

## Z-FET™ MOSFET

N-Channel Enhancement Mode

$V_{DS}$	= 1200 V
$R_{DS(on)}$	= 160 mΩ
$Q_g$	= 47 nC

### Features

- Industry Leading  $R_{DS(on)}$
- High Speed Switching
- Low Capacitances
- Easy to Parallel
- Simple to Drive
- Pb-Free Plating, RoHS Compliant, Halogen Free

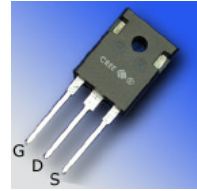
### Benefits

- Higher System Efficiency
- Reduced Cooling Requirements
- Avalanche Ruggedness
- Increased System Switching Frequency

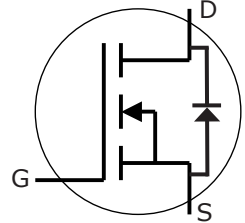
### Applications

- Solar Inverters
- High Voltage DC/DC Converters
- Motor Drives

### Package



TO-247-3



Part Number	Package
CMF10120D	TO-247-3

### Maximum Ratings

Symbol	Parameter	Value	Unit	Test Conditions	Note
$I_D$	Continuous Drain Current	24	A	$V_{GS}@20V, T_C = 25^\circ C$	
		12		$V_{GS}@20V, T_C = 100^\circ C$	
$I_{Dpulse}$	Pulsed Drain Current	49	A	Pulse width $t_p$ limited by $T_{jmax}$ $T_C = 25^\circ C$	
$E_{AS}$	Single Pulse Avalanche Energy	500	mJ	$I_D = 10A, V_{DD} = 50 V,$ $L = 9.5 mH$	
$E_{AR}$	Repetitive Avalanche Energy	400	mJ	$t_{AR}$ limited by $T_{jmax}$	
$I_{AR}$	Repetitive Avalanche Current	10	A	$I_D = 10A, V_{DD} = 50 V, L = 3 mH$ $t_{AR}$ limited by $T_{jmax}$	
$V_{GS}$	Gate Source Voltage	-5/+25	V		
$P_{tot}$	Power Dissipation	152	W	$T_C = 25^\circ C$	
$T_J, T_{stg}$	Operating Junction and Storage Temperature	-55 to +125	$^\circ C$		
$T_L$	Solder Temperature	260	$^\circ C$	1.6mm (0.063") from case for 10s	
$M_d$	Mounting Torque	1	Nm	M3 or 6-32 screw	
		8.8	lbf-in		



## Electrical Characteristics

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions	Note
$V_{(BR)DSS}$	Drain-Source Breakdown Voltage	1200			V	$V_{GS} = -5V, I_D = 50\mu A$	
$V_{GS(th)}$	Gate Threshold Voltage		2.5	4	V	$V_{DS} = V_{GS}, I_D = 500\mu A, T_J = 25^\circ C$	1
			1.8			$V_{DS} = V_{GS}, I_D = 500\mu A, T_J = 125^\circ C$	
$I_{DSS}$	Zero Gate Voltage Drain Current		0.5	50	$\mu A$	$V_{DS} = 1200V, V_{GS} = 0V, T_J = 25^\circ C$	
			5	125		$V_{DS} = 1200V, V_{GS} = 0V, T_J = 125^\circ C$	
$I_{GSS}$	Gate-Source Leakage Current			250	nA	$V_{GS} = 20V, V_{DS} = 0V$	
$R_{DS(on)}$	Drain-Source On-State Resistance		160	220	m $\Omega$	$V_{GS} = 20V, I_D = 10A, T_J = 25^\circ C$	fig. 4
			190	260		$V_{GS} = 20V, I_D = 10A, T_J = 125^\circ C$	
$g_{fs}$	Transconductance		3.7		S	$V_{DS} = 20V, I_{DS} = 10A, T_J = 25^\circ C$	fig. 3
			3.4			$V_{DS} = 20V, I_{DS} = 10A, T_J = 125^\circ C$	
$C_{iss}$	Input Capacitance		928		pF	$V_{GS} = 0V$	fig. 5
$C_{oss}$	Output Capacitance		63			$V_{DS} = 800V$	
$C_{rss}$	Reverse Transfer Capacitance		7.45			$f = 1MHz$ $V_{AC} = 25mV$	
$t_{d(on)i}$	Turn-On Delay Time		7		ns	$V_{DD} = 800V$ $V_{GS} = -2/20V$ $I_D = 10A$ $R_G = 6.8\Omega$ $L = 856\mu H$ Per JEDEC24 Page 27	fig. 12
$t_r$	Rise Time		14				
$t_{d(off)i}$	Turn-Off Delay Time		46				
$t_f$	Fall Time		37				
$E_{ON}$	Turn-On Switching Loss		261				
$E_{Off}$	Turn-Off Switching Loss		120		$\mu J$		
$R_G$	Internal Gate Resistance		13.6		$\Omega$	$V_{GS} = 0V, f = 1MHz, V_{AC} = 25mV$	

**NOTES:** 1. The recommended on-state  $V_{GS}$  is +20V and the recommended off-state  $V_{GS}$  is between -2V and -5V

## Reverse Diode Characteristics

Symbol	Parameter	Typ.	Max.	Unit	Test Conditions	Note
$V_{sd}$	Diode Forward Voltage	3.5		V	$V_{GS} = -5V, I_F = 5A, T_J = 25^\circ C$	
		3.1			$V_{GS} = -2V, I_F = 5A, T_J = 25^\circ C$	
$t_{rr}$	Reverse Recovery Time	138		ns	$V_{GS} = -5V, I_F = 10A, T_J = 25^\circ C$ $V_R = 800V,$ $di_f/dt = 100A/\mu s$	fig. 13,14
$Q_{rr}$	Reverse Recovery Charge	94		nC		
$I_{rrm}$	Peak Reverse Recovery Current	1.57		A		

## Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Unit	Test Conditions	Note
$R_{\theta JC}$	Thermal Resistance from Junction to Case	0.66		$^\circ C/W$		fig. 6
$R_{\theta CS}$	Case to Sink, w/ Thermal Compound	0.25				
$R_{\theta JA}$	Thermal Resistance From Junction to Ambient		40			

## Gate Charge Characteristics

Symbol	Parameter	Typ.	Max.	Unit	Test Conditions	Note
$Q_{gs}$	Gate to Source Charge	11.8		nC	$V_{DD} = 800V$ $I_D = 10A$ $V_{GS} = -2/20V$ Per JEDEC24-2	fig.9
$Q_{gd}$	Gate to Drain Charge	21.5				
$Q_g$	Gate Charge Total	47.1				

## Typical Performance

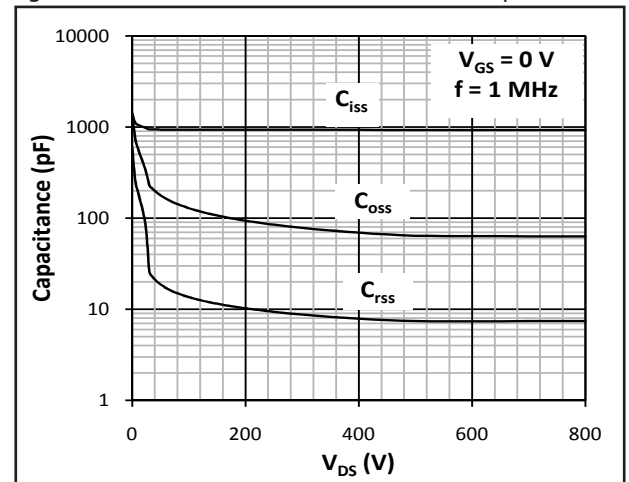
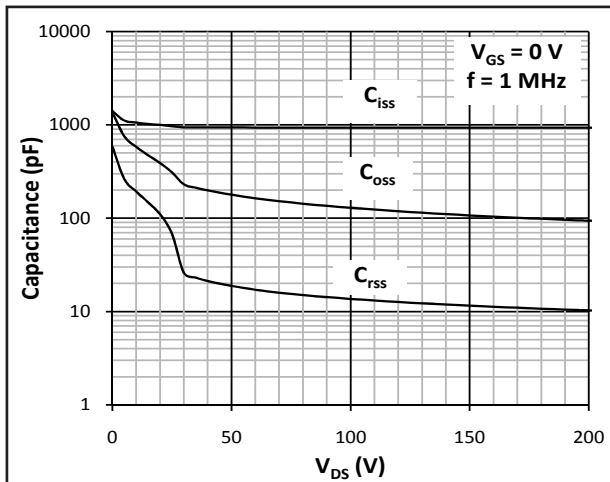
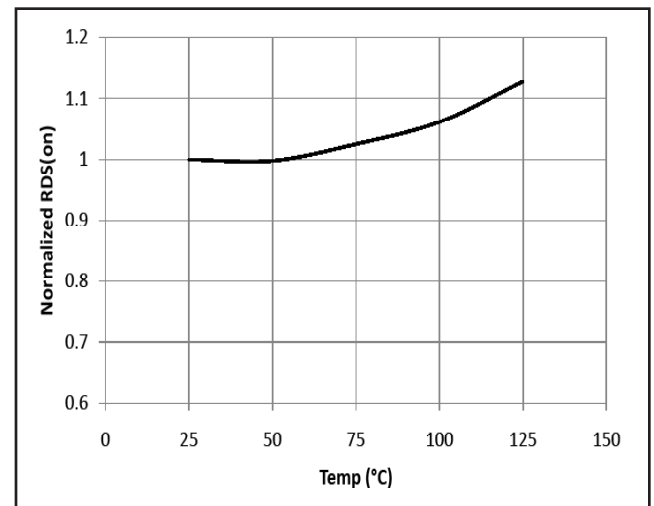
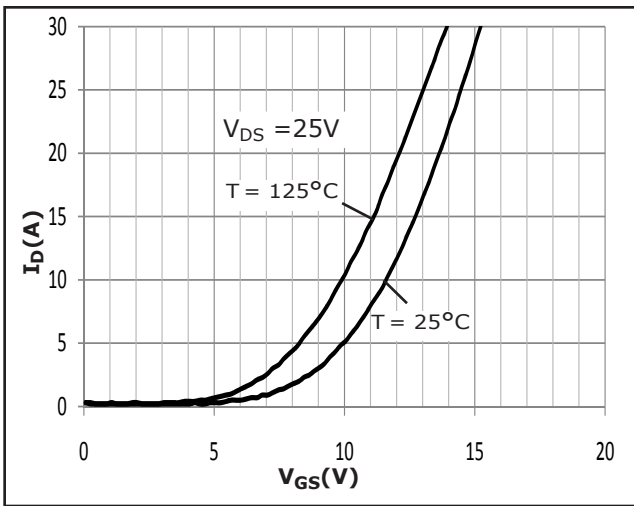
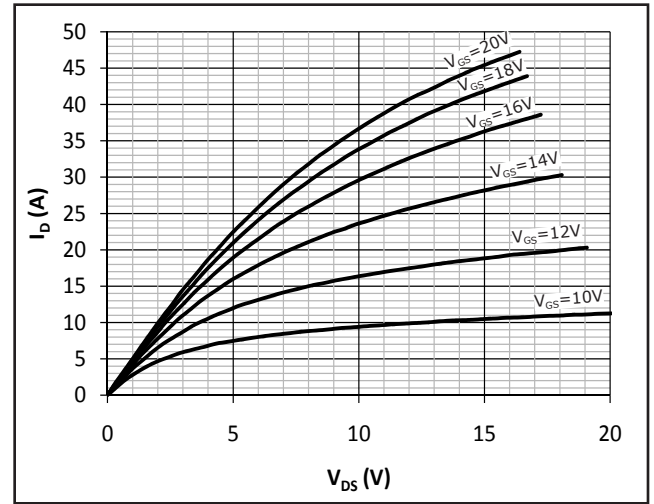
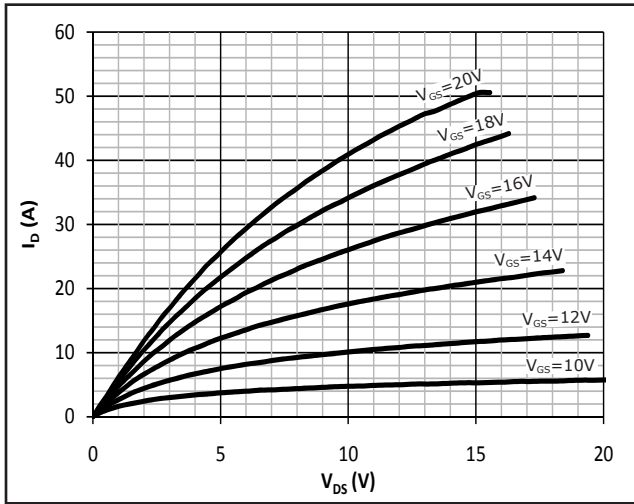


Fig 5A and 5B. Typical Capacitance vs. Drain – Source Voltage

# Typical Performance

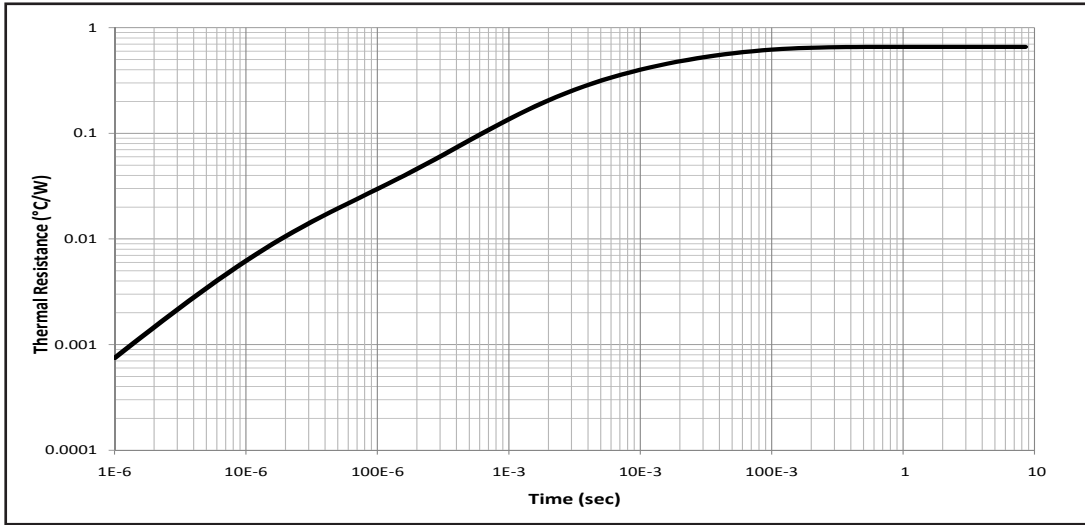


Fig 6. Transient Thermal Impedence, Junction - Case

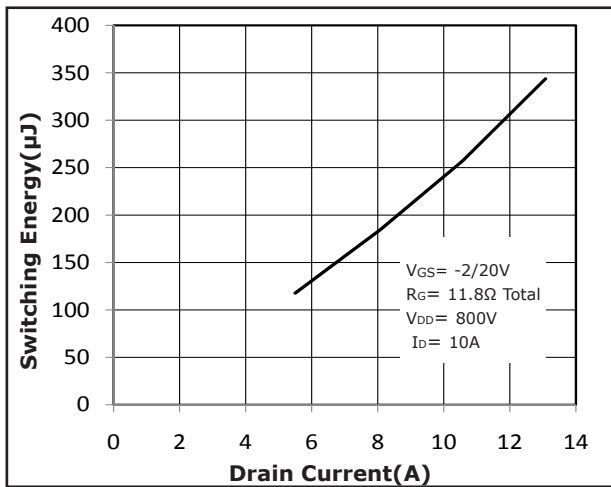


Fig 7. Inductive Switching Energy(Turn-on) vs. ID

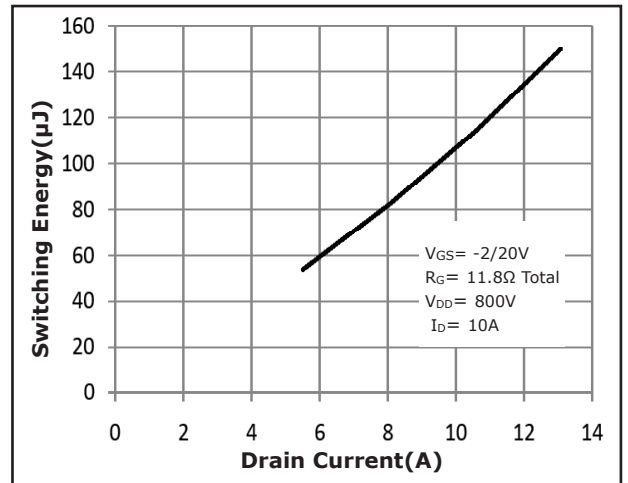


Fig 8. Inductive Switching Energy(Turn-off) vs ID

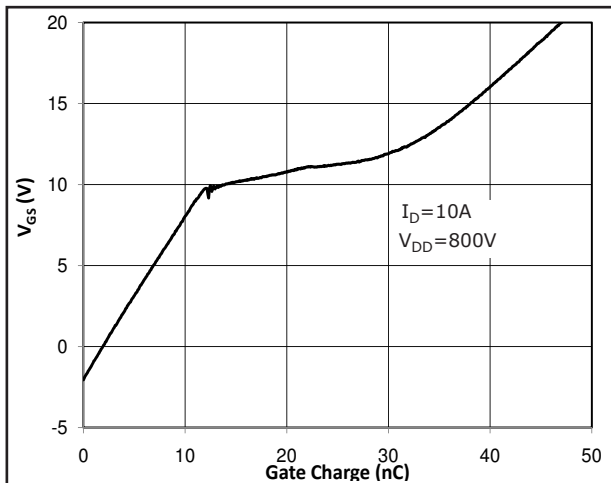


Fig 9. Typical Gate Charge Characteristics @ 25°C

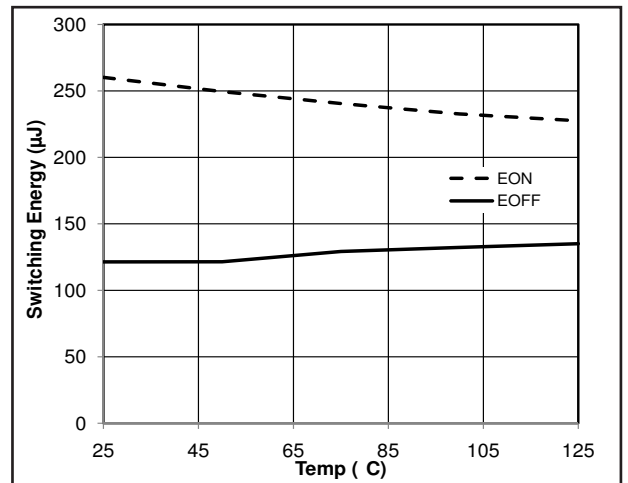


Fig 10. Inductive Switching Energy vs. Temp

# Clamped Inductive Switch Testing Fixture

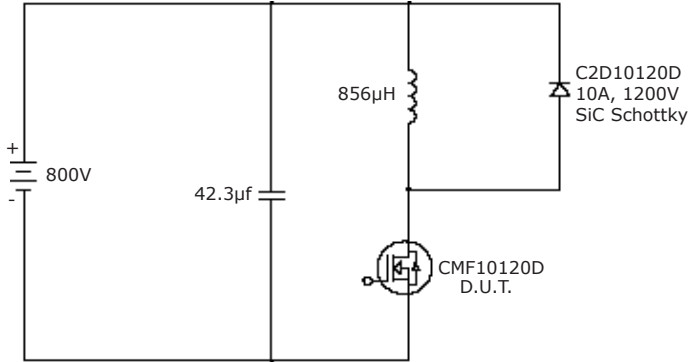


Fig 11. Switching Waveform Test Circuit

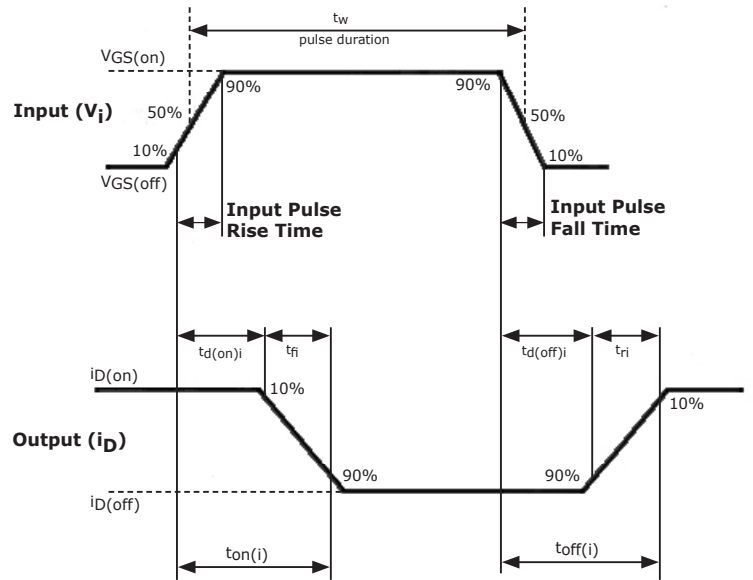


Fig 12. Switching Test Waveform Times

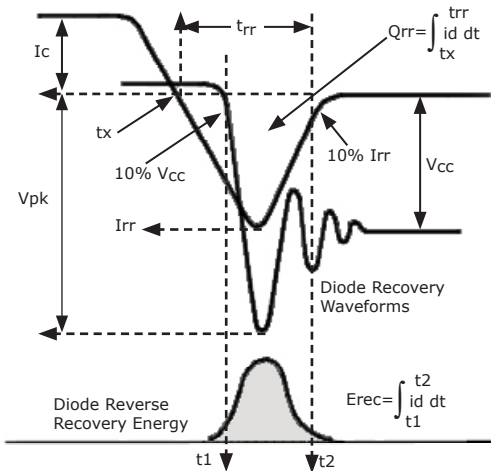


Fig 13. Body Diode Recovery Waveform

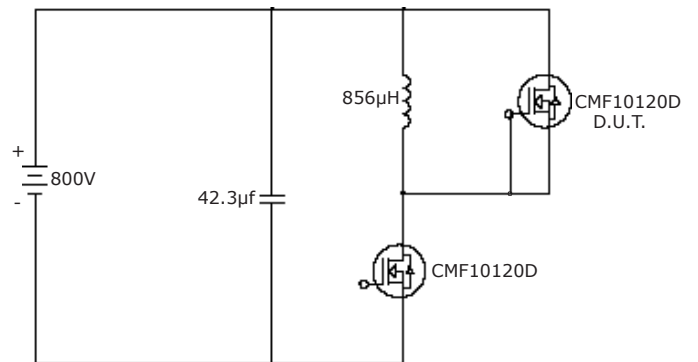


Fig 14. Body Diode Recovery Test

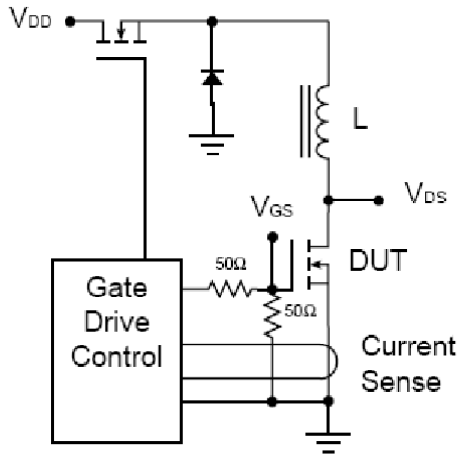


Fig 15. Avalanche Test Circuit

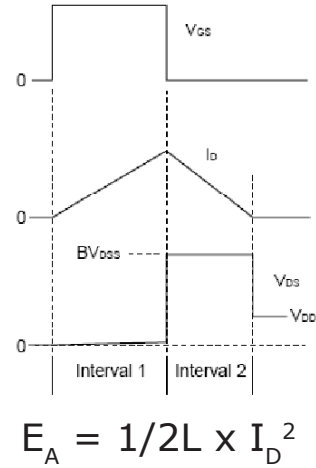
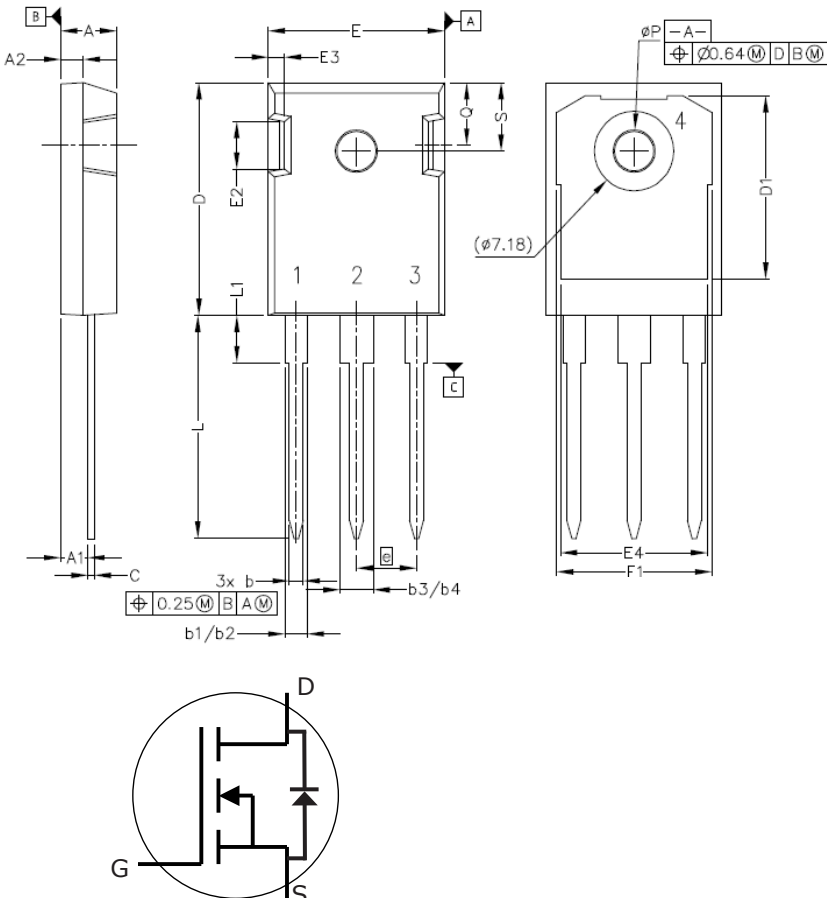


Fig 16. Theoretical Avalanche Waveform

## Package Dimensions

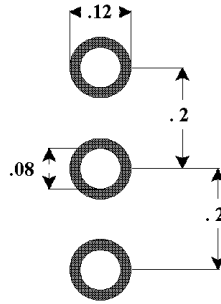
Package TO-247-3



POS	Inches		Millimeters	
	Min	Max	Min	Max
A	.190	.205	4.83	5.21
A1	.090	.100	2.29	2.54
A2	.075	.085	1.91	2.16
b	.042	.052	1.07	1.33
b1	.075	.095	1.91	2.41
b2	.075	.085	1.91	2.16
b3	.113	.133	2.87	3.38
b4	.113	.123	2.87	3.13
c	.022	.027	0.55	0.68
D	.819	.831	20.80	21.10
D1	.640	.695	16.25	17.65
D2	.037	.049	0.95	1.25
E	.620	.635	15.75	16.13
E1	.516	.557	13.10	14.15
E2	.145	.201	3.68	5.10
E3	.039	.075	1.00	1.90
E4	.487	.529	12.38	13.43
e	.214 BSC		5.44 BSC	
N	3		3	
L	.780	.800	19.81	20.32
L1	.161	.173	4.10	4.40
ØP	.138	.144	3.51	3.65
Q	.216	.236	5.49	6.00
S	.238	.248	6.04	6.30

## Recommended Solder Pad Layout

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TO-247-3

Part Number	Package
CMF10120D	TO-247-3

"The levels of environmentally sensitive, persistent biologically toxic (PBT), persistent organic pollutants (POP), or otherwise restricted materials in this product are below the maximum concentration values (also referred to as the threshold limits) permitted for such substances, or are used in an exempted application, in accordance with EU Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), as amended through April 21, 2006.

This product has not been designed or tested for use in, and is not intended for use in, applications implanted into the human body nor in applications in which failure of the product could lead to death, personal injury or property damage, including but not limited to equipment used in the operation of nuclear facilities, life-support machines, cardiac defibrillators or similar emergency medical equipment, aircraft navigation or communication or control systems, air traffic control systems, or weapons systems.

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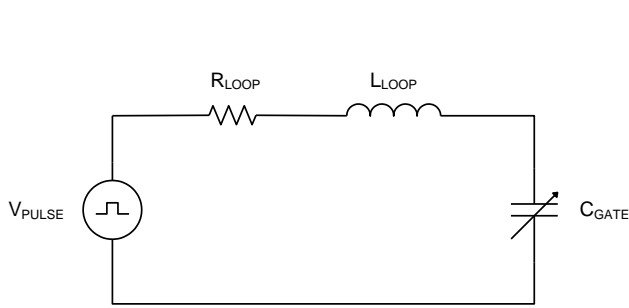
## Applications Information:

The Cree SiC DMOSFET has removed the upper voltage limit of silicon MOSFETs. However, there are some differences in characteristics when compared to what is usually expected with high voltage silicon MOSFETs. These differences need to be carefully addressed to get maximum benefit from the SiC DMOSFET. In general, although the SiC DMOSFET is a superior switch compared to its silicon counterparts, it should not be considered as a direct drop-in replacement in existing applications.

There are two key characteristics that need to be kept in mind when applying the SiC DMOSFETs; modest transconductance and no turn-off tail. The modest transconductance requires that  $V_{GS}$  needs to be 20V to optimize performance. This can be seen the Output and Transfer Characteristics shown in Figures 1-3. The modest transconductance also affects the transition where the device behaves as a voltage controlled resistance to where it behaves as a voltage controlled current source as a function of  $V_{DS}$ . The result is that the transition occurs over higher values of  $V_{DS}$  than is usually experienced with Si MOSFETs and IGBTs. This might affect the operation anti-desaturation circuits, especially if the circuit takes advantage of the device entering the constant current region at low values of forward voltage.

The modest transconductance needs to be carefully considered in the design of the gate drive circuit. The first obvious requirement is that the gate driver be capable of a 22V (or higher) swing. The recommended on state  $V_{GS}$  is +20V and the recommended off state  $V_{GS}$  is between -2V to -5V. Please carefully note that although the gate voltage swing is higher than typical silicon MOSFETs and IGBTs, the total gate charge of the SiC DMOSFET is considerably lower. In fact, the product of gate voltage swing and gate charge for the SiC DMOSFET is lower than comparable silicon devices. The gate voltage must have a fast  $dV/dt$  to achieve fast switching times which indicates that a very low impedance driver is necessary. Lastly, the fidelity of the gate drive pulse must be carefully controlled. The nominal threshold voltage is 2.3V and the device is not fully on ( $dV_{DS}/dt \approx 0$ ) until the  $V_{GS}$  is above 16V. This is a noticeably wider range than what is typically experienced with silicon MOSFETs and IGBTs. The net result of this is that the SiC DMOSFET has a somewhat lower 'noise margin'. Any excessive ringing that is present on the gate drive signal could cause unintentional turn-on or partial turn-off of the device. The gate resistance should be carefully selected to insure that the gate drive pulse is adequately dampened. To first order, the gate circuit can be approximated as a

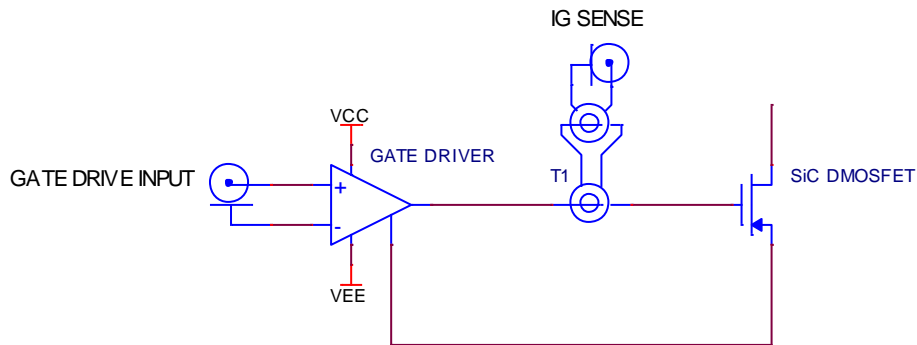




$$\zeta = \frac{R_{LOOP}}{2} \sqrt{\frac{C_{GATE}}{L_{LOOP}}} \geq 1$$

$$\therefore R_{LOOP} \geq 2 \sqrt{\frac{L_{LOOP}}{C_{GATE}}}$$

As shown, minimizing  $L_{LOOP}$  minimizes the value of  $R_{LOOP}$  needed for critical dampening. Minimizing  $L_{LOOP}$  also minimizes the rise/fall time. Therefore, it is strongly recommended that the gate drive be located as close to the SiC DMOSFET as possible to minimize  $L_{LOOP}$ . An external resistance of  $6.8 \Omega$  was used to characterize this device. Lower values of external gate resistance can be used so long as the gate pulse fidelity is maintained. In the event that no external gate resistance is used, it is suggested that the gate current be checked to indirectly verify that there is no ringing present in the gate circuit. This can be accomplished with a very small current transformer. A recommended setup is a two-stage current transformer as shown below:

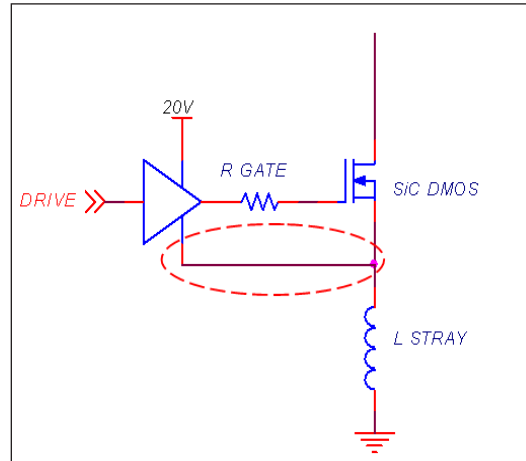
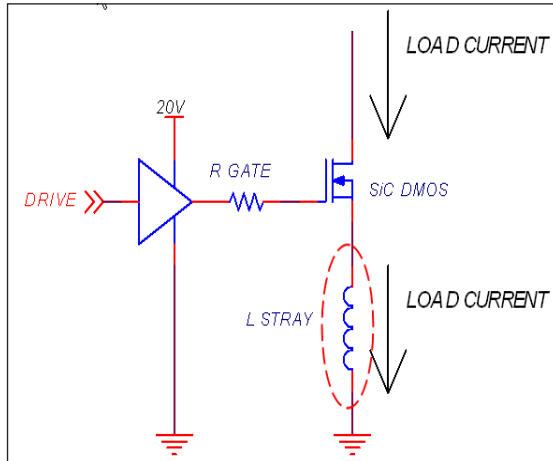


The two stage current transformer first stage consists of 10 turns of AWG 30 wire on a small high permeability core. A Ferroxcube 3E27 material is recommended. The second stage is a small wide bandwidth current transformer, such as the Tektronix CT-2. Lastly, a separate source return should be used for the gate drive as shown below:

Stray inductance on source lead causes load  $di/dt$  to be fed back into gate drive which causes the following:

- Switch  $di/dt$  is limited
- Could cause oscillation

*Kelvin gate connection with separate source return is highly recommended*



A significant benefit of the SiC DMOSFET is the elimination of the tail current observed in silicon IGBTs. However, it is very important to note that the current tail does provide a certain degree of parasitic dampening during turn-off. Additional ringing and overshoot is typically observed when silicon IGBTs is replaced with SiC DMOSFETs. The additional voltage overshoot can be high enough to destroy the device. Therefore, it is critical to manage the output interconnection parasitics (and snubbers) to keep the ringing and overshoot from becoming problematic.

## ESD RATINGS

ESD Test	Total Devices Sampled	Resulting Classification
ESD-HBM	All Devices Passed 1000V	2 (>2000V)
ESD-MM	All Devices Passed 400V	C (>400V)
ESD-CDM	All Devices Passed 1000V	IV (>1000V)