

## Low Side Chopper 600 V, 400 A, DIAP IGBT Power Module (Trench Field Stop IGBT)



Dual INT-A-PAK

**FEATURES**

- Trench Field Stop IGBT technology
- 6  $\mu$ s short circuit capability
- Low  $V_{CE(on)}$
- Square RBSOA
- FRED Pt® antiparallel diode with ultrasoft reverse recovery characteristics
- Industry standard package
- $Al_2O_3$  DBC
- UL pending
- Designed for industrial level
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)


**RoHS**  
COMPLIANT

**BENEFITS**

- Increased operating efficiency
- Direct mounting on heatsink
- Very low junction to case thermal resistance

PRIMARY CHARACTERISTICS	
<b>IGBT Q1</b>	
$V_{CES}$	600 V
$I_C$ DC at 80 °C	375 A
$V_{CE(on)}$ (typical) at 400 A, 25 °C	1.67 V
<b>CHOPPER DIODE D2</b>	
$V_{RRM}$	600 V
$I_F$ DC at 80 °C	278 A
$V_{FM}$ (typical) at 400 A, 25 °C	1.61 V
$t_{rr}$ at 400 A, 25 °C	141 ns
<b>ANTIPARALLEL DIODE D1</b>	
$V_{RRM}$	600 V
$I_F$ DC at 80 °C	142 A
$V_{FM}$ (typical) at 200 A, 25 °C	1.56 V
$t_{rr}$ at 200 A, 25 °C	120 ns
Package	Dual INT-A-PAK
Circuit	Low side chopper

ABSOLUTE MAXIMUM RATINGS				
PARAMETER	SYMBOL	TEST CONDITIONS	MAX.	UNITS
<b>IGBT Q1</b>				
Collector to emitter voltage	$V_{CES}$		600	V
Continuous collector current	$I_C$ <sup>(1)</sup>	$T_C = 25\text{ °C}$	492	A
		$T_C = 80\text{ °C}$	375	
Pulsed collector current	$I_{CM}$	$T_p = 6\text{ ms, square pulse}$	850	
Clamped inductive load current	$I_{LM}$		693	
Gate to emitter voltage	$V_{GE}$		$\pm 20$	V
Maximum power dissipation	$P_D$	$T_C = 25\text{ °C}$	1363	W
		$T_C = 80\text{ °C}$	864	
<b>DIODE D2</b>				
Chopper diode continuous forward current	$I_F$	$T_C = 25\text{ °C}$	374	A
		$T_C = 80\text{ °C}$	278	
Single pulse forward current	$I_{FSM}$	10 ms sine or 6 ms rectangular pulse, $T_J = 25\text{ °C}$	1415	
Maximum power dissipation	$P_D$	$T_C = 25\text{ °C}$	652	W
		$T_C = 80\text{ °C}$	413	
<b>DIODE D1</b>				
Antiparallel diode continuous forward current	$I_F$	$T_C = 25\text{ °C}$	192	A
		$T_C = 80\text{ °C}$	142	
Single pulse forward current	$I_{FSM}$	10 ms sine or 6 ms rectangular pulse, $T_J = 25\text{ °C}$	725	
Maximum power dissipation	$P_D$	$T_C = 25\text{ °C}$	312	W
		$T_C = 80\text{ °C}$	198	
RMS isolation voltage	$V_{ISOL}$	Any terminal to case ( $V_{RMS} t = 1\text{ s, } T_J = 25\text{ °C}$ )	3500	V
Storage temperature range	$T_{STG}$		-40 to 150	°C
Operating junction temperature range	$T_J$		-40 to +175	°C

**Note**

<sup>(1)</sup> Maximum continuous collector current must be limited to 500 A to do not exceed the maximum temperature of terminals



<b>ELECTRICAL SPECIFICATIONS</b> ( $T_J = 25\text{ }^\circ\text{C}$ unless otherwise specified)						
PARAMETER	SYMBOL	TEST CONDITIONS	MIN.	TYP.	MAX.	UNITS
<b>IGBT Q1</b>						
Collector to emitter breakdown voltage	$V_{BR(CES)}$	$V_{GE} = 0\text{ V}, I_C = 500\text{ }\mu\text{A}$	600	-	-	V
Collector to emitter voltage	$V_{CE(on)}$	$V_{GE} = 15\text{ V}, I_C = 300\text{ A}$	-	1.48	-	
		$V_{GE} = 15\text{ V}, I_C = 400\text{ A}$	-	1.67	2.0	
		$V_{GE} = 15\text{ V}, I_C = 300\text{ A}, T_J = 125\text{ }^\circ\text{C}$	-	1.64	-	
		$V_{GE} = 15\text{ V}, I_C = 400\text{ A}, T_J = 125\text{ }^\circ\text{C}$	-	1.93	-	
Gate threshold voltage	$V_{GE(th)}$	$V_{CE} = V_{GE}, I_C = 6.4\text{ mA}$	4.6	5.9	7	
		$V_{CE} = V_{GE}, I_C = 6.4\text{ mA}, T_J = 125\text{ }^\circ\text{C}$	-	4.6	-	
Temperature coefficient of threshold voltage	$\Delta V_{GE(th)}/\Delta T$	$V_{CE} = V_{GE}, I_C = 6.4\text{ mA}, (25\text{ }^\circ\text{C to } 125\text{ }^\circ\text{C})$	-	-13	-	mV/ $^\circ\text{C}$
Forward transconductance	$g_{fe}$	$V_{CE} = 20\text{ V}, I_C = 400\text{ A}$	-	70	-	mS
Transfer characteristics	$V_{GE}$	$V_{CE} = 20\text{ V}, I_C = 400\text{ A}$	-	9.1	-	V
Collector to emitter leakage current	$I_{CES}$	$V_{GE} = 0\text{ V}, V_{CE} = 600\text{ V}$	-	0.2	20	$\mu\text{A}$
		$V_{GE} = 0\text{ V}, V_{CE} = 600\text{ V}, T_J = 150\text{ }^\circ\text{C}$	-	1.6	-	mA
Gate to emitter leakage current	$I_{GES}$	$V_{GE} = \pm 20\text{ V}$	-	-	$\pm 1200$	nA
<b>DIODE D1</b>						
Antiparallel diode forward voltage drop	$V_{FM}$	$I_{FM} = 100\text{ A}$	-	1.32	-	V
		$I_{FM} = 200\text{ A}$	-	1.56	1.82	
		$I_{FM} = 100\text{ A}, T_J = 150\text{ }^\circ\text{C}$	-	1.1	-	
		$I_{FM} = 200\text{ A}, T_J = 150\text{ }^\circ\text{C}$	-	1.42	-	
<b>DIODE D2</b>						
Blocking voltage	$V_{RRM}$	$I_R = 500\text{ }\mu\text{A}$	600	-	-	V
Leakage current	$I_{RRM}$	$V_R = 600\text{ V}$	-	0.2	15	$\mu\text{A}$
		$V_R = 600\text{ V}, T_J = 150\text{ }^\circ\text{C}$	-	2.8	-	mA
Chopper diode forward voltage drop	$V_{FM}$	$I_{FM} = 300\text{ A}$	-	1.48	-	V
		$I_{FM} = 400\text{ A}$	-	1.61	1.92	
		$I_{FM} = 300\text{ A}, T_J = 150\text{ }^\circ\text{C}$	-	1.34	-	
		$I_{FM} = 400\text{ A}, T_J = 150\text{ }^\circ\text{C}$	-	1.51	-	

<b>SWITCHING CHARACTERISTICS</b> ( $T_J = 25\text{ }^\circ\text{C}$ unless otherwise specified)							
PARAMETER	SYMBOL	TEST CONDITIONS	MIN.	TYP.	MAX.	UNITS	
<b>IGBT Q1</b>							
Total gate charge (turn-on)	$Q_g$	$I_C = 400\text{ A}, V_{CC} = 480\text{ V}, V_{GE} = 15\text{ V}$	-	1970	-	nC	
Gate to emitter charge (turn-on)	$Q_{ge}$		-	144	-		
Gate to collector charge (turn-on)	$Q_{gc}$		-	1240	-		
Turn-off switching energy	$E_{off}$	$R_{g(off)} = 1\text{ }\Omega$	$I_C = 300\text{ A}, V_{CC} = 300\text{ V}, V_{GE} = \pm 15\text{ V}, L = 500\text{ }\mu\text{H}, T_J = 25\text{ }^\circ\text{C}$	-	12.9	-	mJ
Turn-off delay time	$t_{d(off)}$			-	594	-	ns
Fall time	$t_f$			-	77	-	ns
Turn-on switching energy	$E_{on}$			-	12.8	-	mJ
Turn-on delay time	$t_{d(on)}$	$R_{g(on)} = 6.8\text{ }\Omega$	$I_C = 300\text{ A}, V_{CC} = 300\text{ V}, V_{GE} = \pm 15\text{ V}, L = 500\text{ }\mu\text{H}, T_J = 25\text{ }^\circ\text{C}$	-	337	-	ns
Rise time	$t_r$			-	197	-	ns
Turn-off switching energy	$E_{off}$	$R_{g(off)} = 1\text{ }\Omega$	$I_C = 300\text{ A}, V_{CC} = 300\text{ V}, V_{GE} = \pm 15\text{ V}, L = 500\text{ }\mu\text{H}, T_J = 125\text{ }^\circ\text{C}$	-	14.7	-	mJ
Turn-off delay time	$t_{d(off)}$			-	638	-	ns
Fall time	$T_f$			-	91	-	ns
Turn-on switching energy	$E_{on}$	$R_{g(on)} = 6.8\text{ }\Omega$	$I_C = 300\text{ A}, V_{CC} = 300\text{ V}, V_{GE} = \pm 15\text{ V}, L = 500\text{ }\mu\text{H}, T_J = 125\text{ }^\circ\text{C}$	-	13.4	-	mJ
Turn-on delay time	$t_{d(on)}$			-	339	-	ns
Rise time	$t_r$			-	204	-	ns



SWITCHING CHARACTERISTICS (T <sub>J</sub> = 25 °C unless otherwise specified)								
PARAMETER	SYMBOL	TEST CONDITIONS		MIN.	TYP.	MAX.	UNITS	
Turn-off switching energy	E <sub>off</sub>	R <sub>g (off)</sub> = 1 Ω	I <sub>C</sub> = 400 A, V <sub>CC</sub> = 300 V, V <sub>GE</sub> = ± 15 V, L = 500 μH, T <sub>J</sub> = 25 °C	-	19.3	-	mJ	
Turn-off delay time	t <sub>d(off)</sub>			-	593	-	ns	
Fall time	t <sub>f</sub>			-	82	-		
Turn-on switching energy	E <sub>on</sub>	R <sub>g (on)</sub> = 6.8 Ω		I <sub>C</sub> = 400 A, V <sub>CC</sub> = 300 V, V <sub>GE</sub> = ± 15 V, L = 500 μH, T <sub>J</sub> = 25 °C	-	15.6	-	mJ
Turn-on delay time	t <sub>d(on)</sub>				-	354	-	ns
Rise time	t <sub>r</sub>				-	238	-	
Turn-off switching energy	E <sub>off</sub>	R <sub>g (off)</sub> = 1 Ω	I <sub>C</sub> = 400 A, V <sub>CC</sub> = 300 V, V <sub>GE</sub> = ± 15 V, L = 500 μH, T <sub>J</sub> = 125 °C		-	21.2	-	mJ
Turn-off delay time	t <sub>d(off)</sub>				-	631	-	ns
Fall time	T <sub>f</sub>				-	92	-	
Turn-on switching energy	E <sub>on</sub>	R <sub>g (on)</sub> = 6.8 Ω		I <sub>C</sub> = 400 A, V <sub>CC</sub> = 300 V, V <sub>GE</sub> = ± 15 V, L = 500 μH, T <sub>J</sub> = 125 °C	-	17.2	-	mJ
Turn-on delay time	t <sub>d(on)</sub>				-	365	-	ns
Rise time	t <sub>r</sub>				-	246	-	
Reverse bias safe operating area	RBSOA	T <sub>J</sub> = 175 °C, I <sub>C</sub> = 693 A, R <sub>g</sub> = 10 Ω, V <sub>GE</sub> = 15 V to 0 V, V <sub>CC</sub> = 400 V, V <sub>p</sub> = 600 V			Fullsquare			
Short circuit safe operating area <sup>(1)(2)</sup>	SCSOA	T <sub>J</sub> = 150 °C, V <sub>CC</sub> = 360 V, V <sub>GE</sub> = 15 V			-	-	6	μs
<b>DIODE D2</b>								
Diode reverse recovery time	t <sub>rr</sub>	I <sub>F</sub> = 400 A, V <sub>CC</sub> = 400 V, T <sub>J</sub> = 25 °C, di/dt = 1000 A/μs,	-	141	-	ns		
Diode peak reverse current	I <sub>rr</sub>		-	41	-	A		
Diode recovery charge	Q <sub>rr</sub>		-	3.2	-	μC		
Diode reverse recovery time	t <sub>rr</sub>	I <sub>F</sub> = 400 A, V <sub>CC</sub> = 400 V, T <sub>J</sub> = 125 °C, di/dt = 1000 A/μs,	-	230	-	ns		
Diode peak reverse current	I <sub>rr</sub>		-	77	-	A		
Diode recovery charge	Q <sub>rr</sub>		-	10.2	-	μC		
<b>DIODE D1</b>								
Diode reverse recovery time	t <sub>rr</sub>	I <sub>F</sub> = 200 A, V <sub>R</sub> = 400 V, T <sub>J</sub> = 25 °C, di/dt = 1000 A/μs,	-	120	-	ns		
Diode peak reverse current	I <sub>rr</sub>		-	28	-	A		
Diode recovery charge	Q <sub>rr</sub>		-	2.2	-	μC		
Diode reverse recovery time	t <sub>rr</sub>	I <sub>F</sub> = 200 A, V <sub>R</sub> = 400 V, T <sub>J</sub> = 125 °C, di/dt = 1000 A/μs,	-	165	-	ns		
Diode peak reverse current	I <sub>rr</sub>		-	90	-	A		
Diode recovery charge	Q <sub>rr</sub>		-	9.1	-	μC		

**Notes**

- (1) Not subject to production test - verified by design / characterization
- (2) Allowed number of short circuits: < 1000; time between short circuits: > 1 s

THERMAL AND MECHANICAL SPECIFICATIONS						
PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNITS	
Operating junction temperature range	T <sub>J</sub>	-40	-	175	°C	
Storage temperature range	T <sub>Stg</sub>	-40	-	150		
Thermal resistance, junction to case per leg	Q1 IGBT	R <sub>thJC</sub>	-	-	0.11	°C/W
	D1 diode		-	-	0.48	
	D2 diode		-	-	0.23	
Thermal resistance, case to sink per module	R <sub>thCS</sub>	-	0.05	-		
Mounting torque	Power terminal screw: M6	2.5	-	5.0	Nm	
	Mounting screw: M6	3.0	-	5.0		
Weight		-	300	-	g	

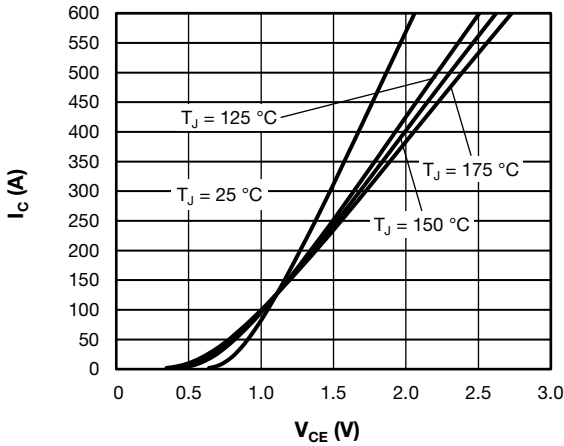


Fig. 1 - Typical IGBT Output Characteristics,  $V_{GE} = 15\text{ V}$

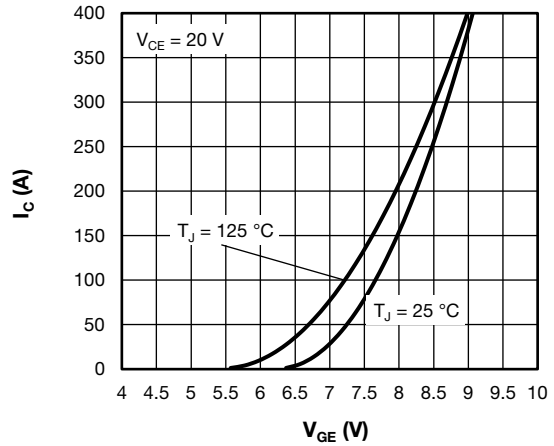


Fig. 4 - Typical IGBT Transfer Characteristics

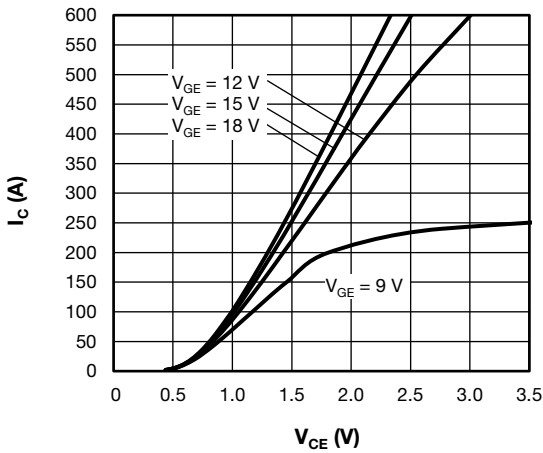


Fig. 2 - Typical IGBT Output Characteristics,  $T_J = 125\text{ °C}$

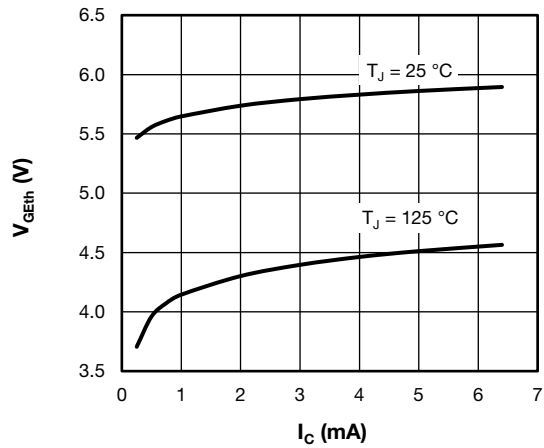


Fig. 5 - Typical IGBT Gate Threshold Voltage

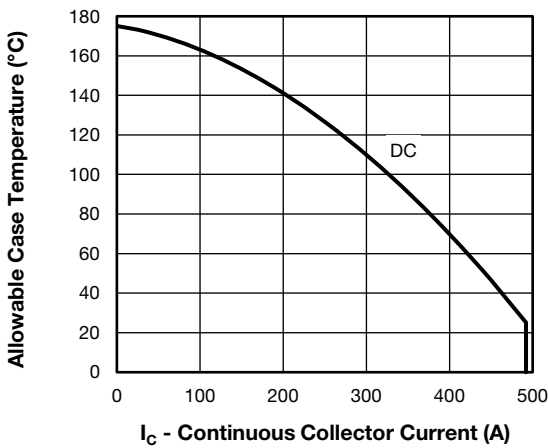


Fig. 3 - Maximum IGBT Continuous Collector Current vs. Case Temperature

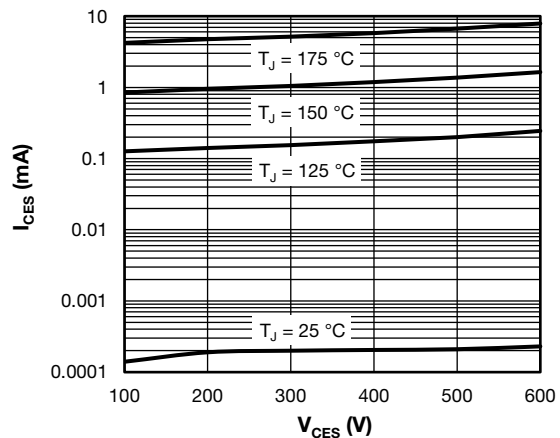


Fig. 6 - Typical IGBT Zero Gate Voltage Collector Current

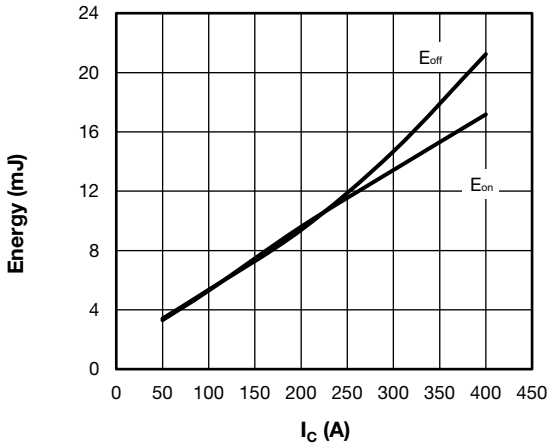


Fig. 7 - Typical IGBT Energy Loss vs.  $I_C$  with Freewheeling Diode  
 $T_J = 125\text{ }^\circ\text{C}$ ,  $V_{CC} = 300\text{ V}$ ,  $R_{g(on)} = 6.8\ \Omega$ ,  $R_{g(off)} = 1\ \Omega$   
 $V_{GE} = +15\text{ V}/-15\text{ V}$ ,  $L = 500\ \mu\text{H}$

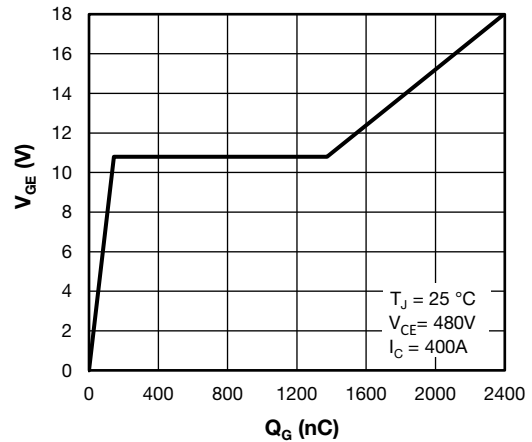


Fig. 10 - Typical Trench IGBT Gate Charge vs. Gate to Emitter Voltage  
 $T_J = 25\text{ }^\circ\text{C}$   
 $V_{CE} = 480\text{ V}$   
 $I_C = 400\text{ A}$

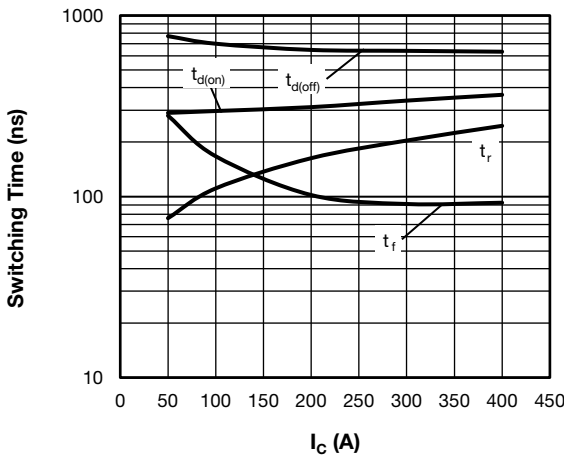


Fig. 8 - Typical Trench IGBT Switching Time vs.  $I_C$  with Freewheeling Diode  
 $T_J = 125\text{ }^\circ\text{C}$ ,  $V_{CC} = 300\text{ V}$ ,  $R_{g(on)} = 6.8\ \Omega$ ,  $R_{g(off)} = 1\ \Omega$ ,  
 $V_{GE} = +15\text{ V}/-15\text{ V}$ ,  $L = 500\ \mu\text{H}$

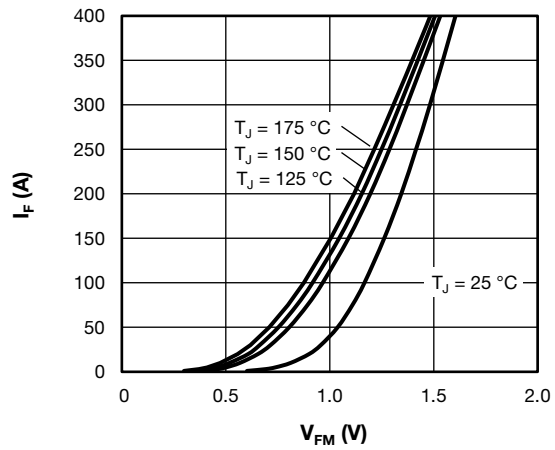


Fig. 11 - Typical D2 Diode Forward Characteristics

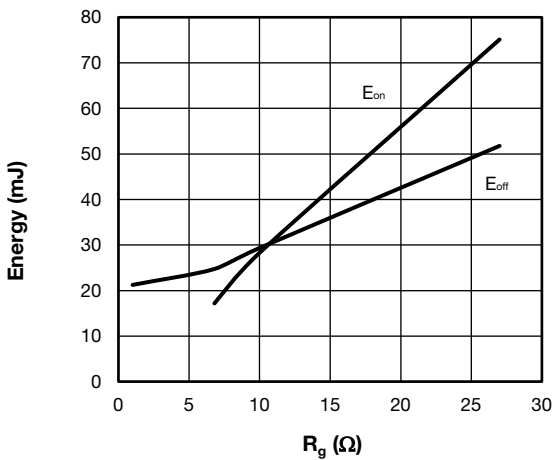


Fig. 9 - Typical Trench IGBT Energy Loss vs.  $R_g$  with Freewheeling Diode  
 $T_J = 125\text{ }^\circ\text{C}$ ,  $V_{CC} = 300\text{ V}$ ,  $I_C = 400\text{ A}$ ,  $V_{GE} = +15\text{ V}/-15\text{ V}$ ,  $L = 500\ \mu\text{H}$

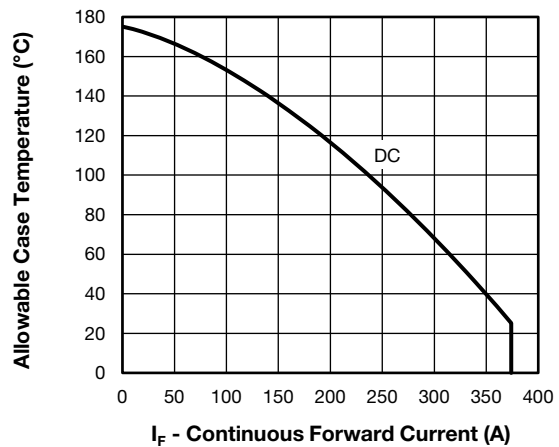


Fig. 12 - Maximum D2 Diode Continuous Forward Current vs. Case Temperature

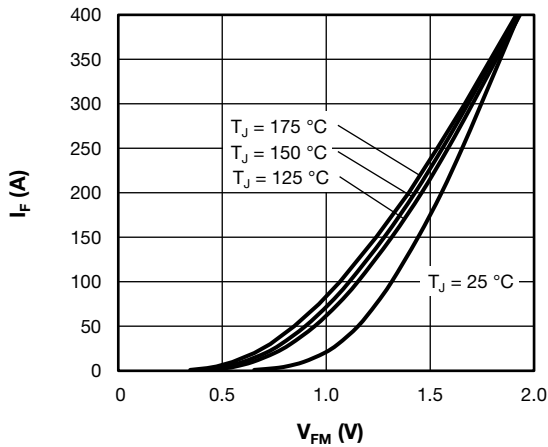


Fig. 13 - Typical D1 Diode Forward Characteristics

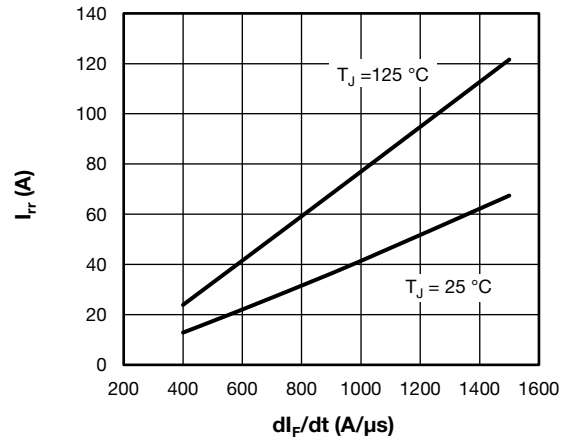


Fig. 16 - Typical Diode Reverse Recovery Current vs.  $di_F/dt$   
 $I_F = 400 \text{ A}, V_{CC} = 400 \text{ V}$

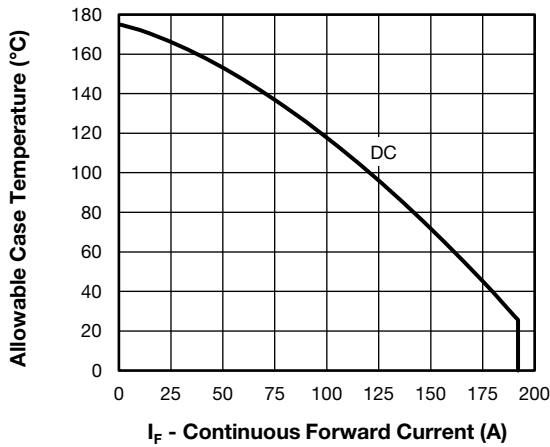


Fig. 14 - Maximum D1 Diode Continuous Forward Current vs. Case Temperature

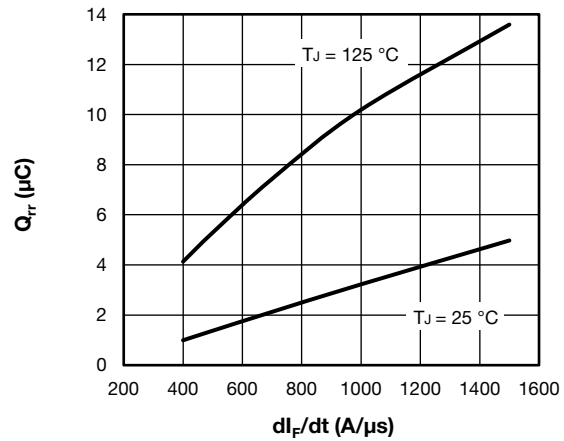


Fig. 17 - Typical Diode Reverse Recovery Charge vs.  $di_F/dt$   
 $I_F = 400 \text{ A}, V_{CC} = 400 \text{ V}$

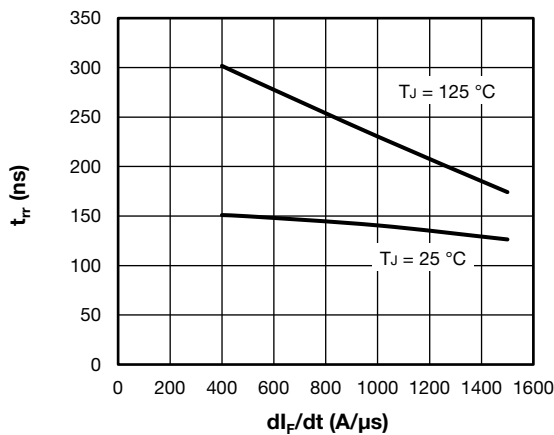


Fig. 15 - Typical Diode Reverse Recovery Time vs.  $di_F/dt$   
 $I_F = 400 \text{ A}, V_{CC} = 400 \text{ V}$

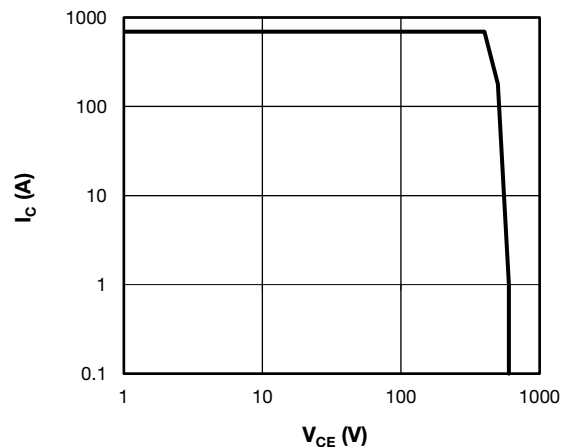


Fig. 18 - IGBT Reverse BIAS SOA  
 $T_J = 175 \text{ °C}, I_C = 693 \text{ A}, R_g = 10 \text{ } \Omega, V_{GE} = +15 \text{ V} / 0 \text{ V},$   
 $V_{CC} = 400 \text{ V}, V_p = 600 \text{ V}$

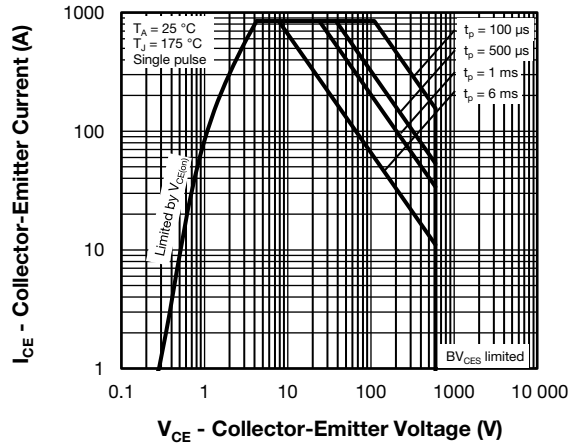


Fig. 19 - IGBT Safe Operating Area

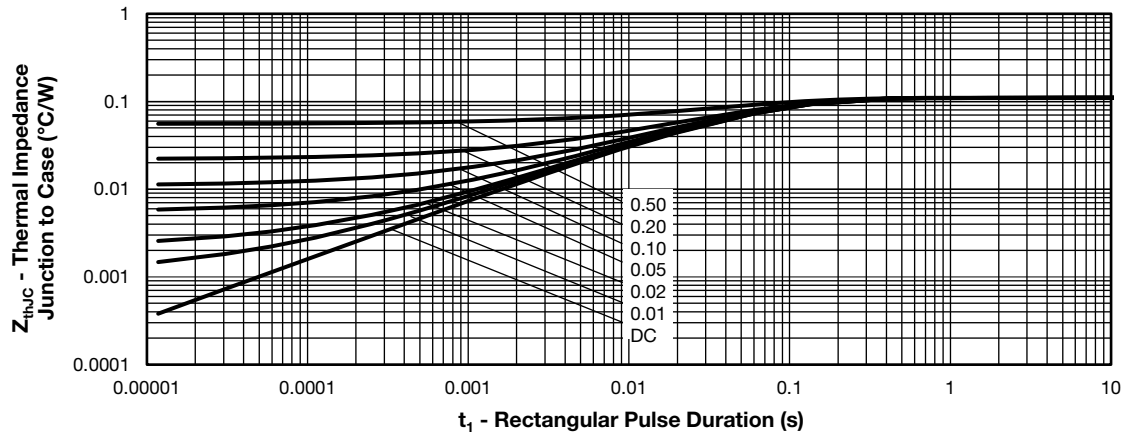


Fig. 20 - Maximum IGBT Thermal Impedance  $Z_{thJC}$  Characteristics

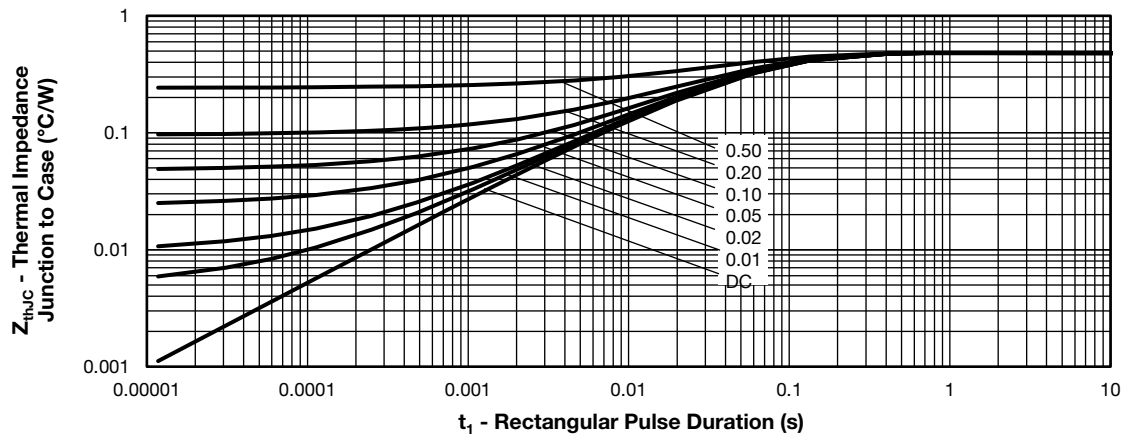


Fig. 21 - Maximum D1 Diode Thermal Impedance  $Z_{thJC}$  Characteristics

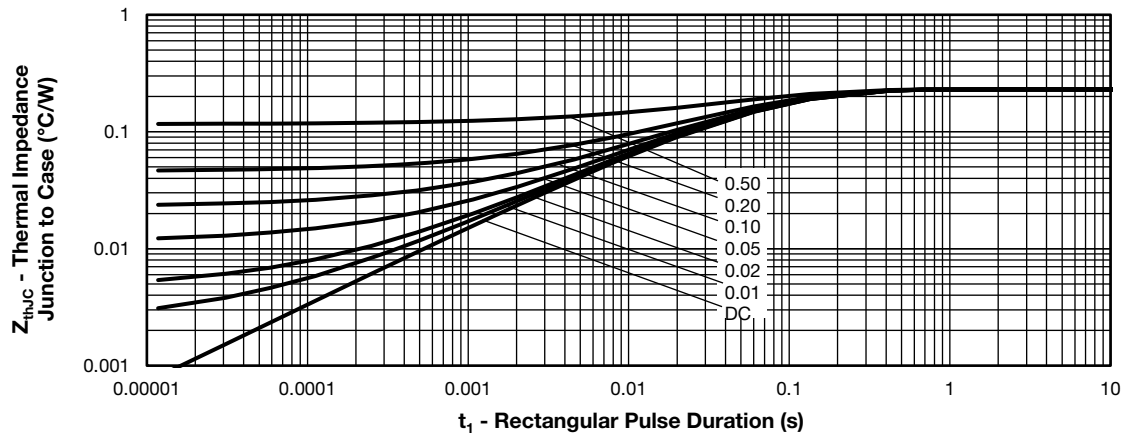


Fig. 22 - Maximum D2 Diode Thermal Impedance  $Z_{thJC}$  Characteristics

**ORDERING INFORMATION TABLE**

Device code	<b>VS-</b>	<b>G</b>	<b>T</b>	<b>400</b>	<b>L</b>	<b>H</b>	<b>060</b>	<b>N</b>
	①	②	③	④	⑤	⑥	⑦	⑧

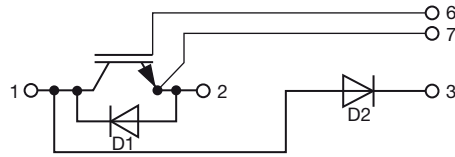
- 1** - Vishay Semiconductors product
- 2** - Insulated gate bipolar transistor (IGBT)
- 3** - T = Trench Field Stop IGBT technology
- 4** - Current rating (400 = 400 A)
- 5** - Circuit configuration (L = low side chopper)
- 6** - Package indicator (H = Dual INT-A-PAK)
- 7** - Voltage rating (060 = 600 V)
- 8** - N = none

LINKS TO RELATED DOCUMENTS	
Dimensions	<a href="http://www.vishay.com/doc?95525">www.vishay.com/doc?95525</a>
Application Note	<a href="http://www.vishay.com/doc?95553">www.vishay.com/doc?95553</a>

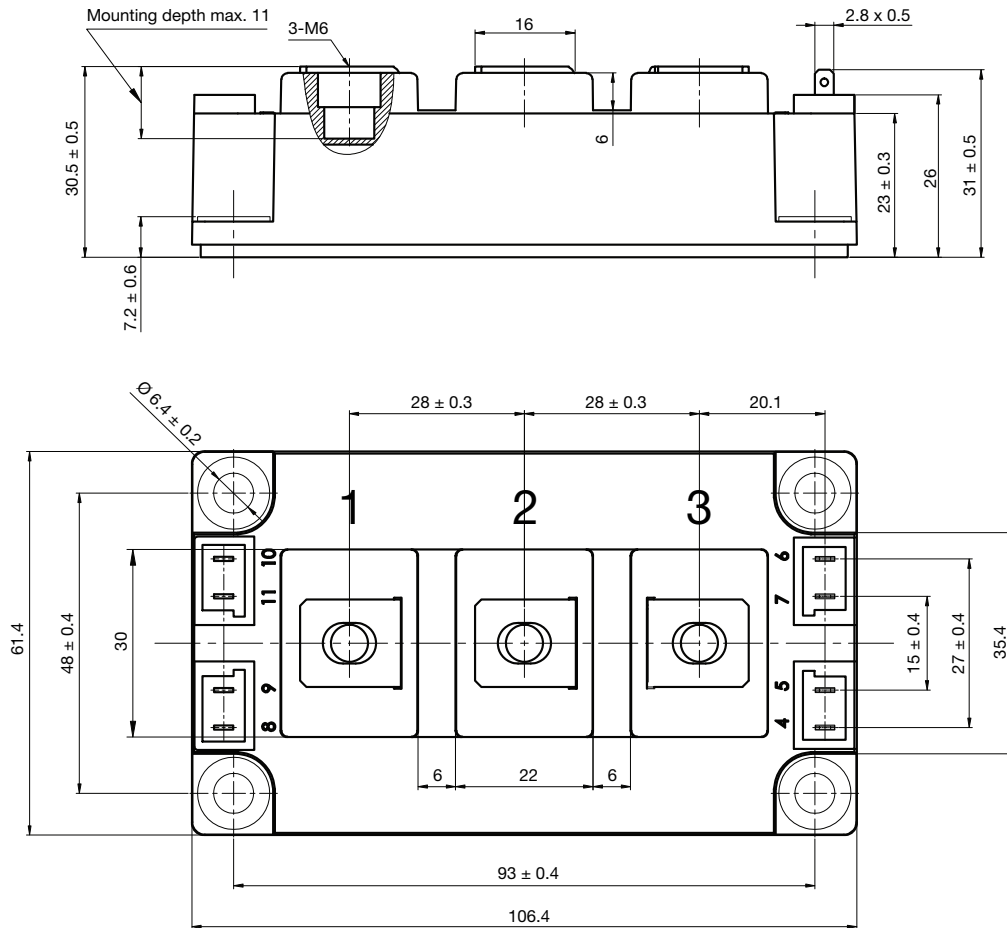




**CIRCUIT CONFIGURATION**



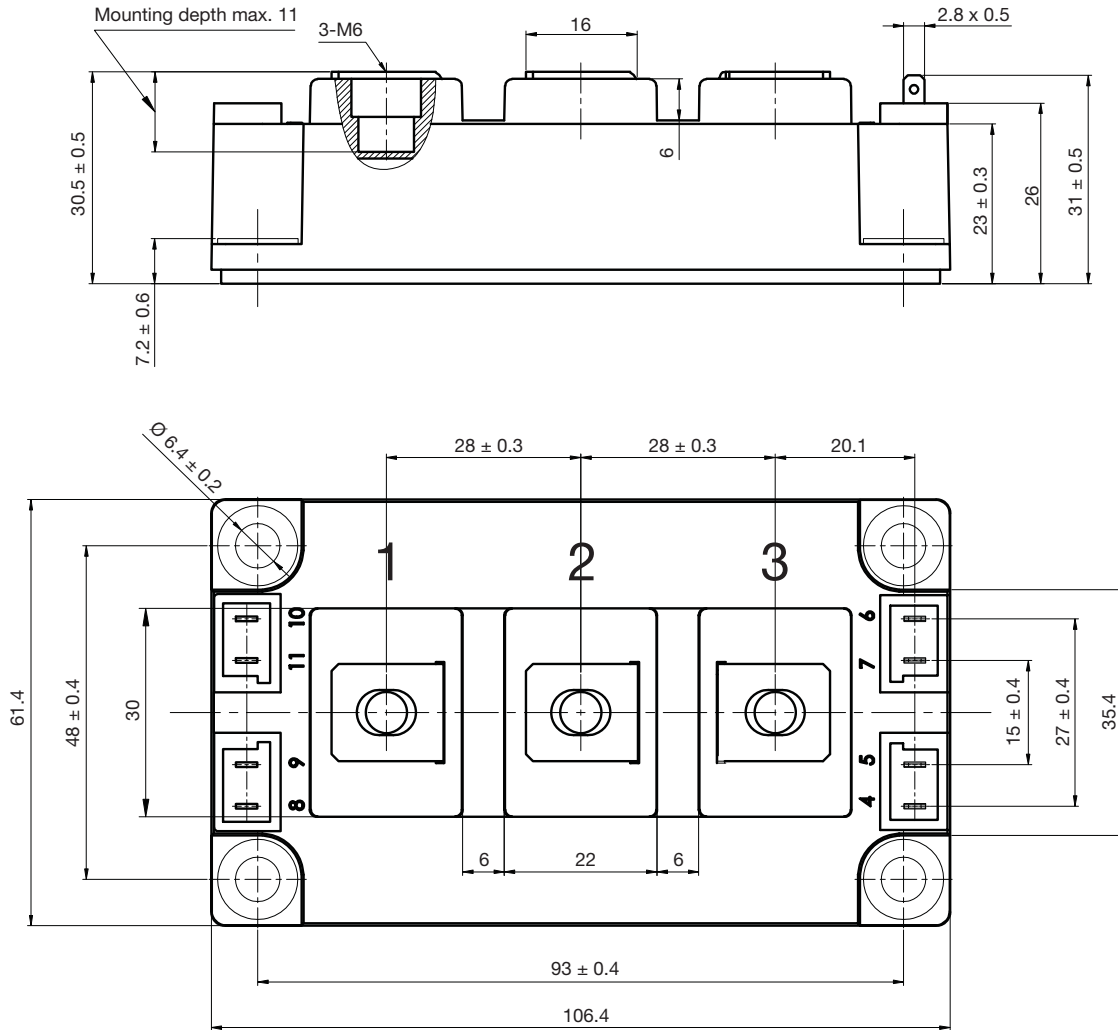
**DIMENSIONS** in millimeters





## Double INT-A-PAK

**DIMENSIONS** in millimeters (inches)





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