3-Levels Half-Bridge Inverter Stage, 60 A/57 A

EMIPAK2

PRODUCT SUMMARY	
1° LEVEL OF HALF-BRIDGE	
V_{CES}	600 V
$V_{CE(ON)}$ typical at I_C = 50 A	1.8 V
I_C at T_C = 98 °C	50 A
2° LEVEL OF HALF-BRIDGE	
V_{CES}	900 V
$V_{CE(ON)}$ typical at I_C = 50 A	2.73 V
I_C at T_C = 93 °C	50 A

FEATURES

- Warp1 and Warp2 PFC IGBT
- FRED Pt® and HEXFRED® antiparallel diodes
- FRED Pt® clamping diodes
- Integrated thermistor
- Square RBSOA
- Operating frequency 60 kHz to 150 kHz
- Low internal inductances
- Low switching loss
- Compliant to RoHS Directive 2002/95/EC

Pb-free
RoHS
COMPLIANT

DESCRIPTION

VS-EMF050J60U is an integrated solution for a multi level inverter half-bridge in a single package. The EMIPAK2 package is easy to use thanks to the solderable terminals and provides improved thermal performance thanks to the exposed substrate. The optimized layout also helps to minimize stray parameters, allowing for better EMI performance.

ABSOLUTE MAXIMUM RATINGS				
PARAMETER	SYMBOL	TEST CONDITIONS	MAX.	UNITS
Operating junction temperature	T_J		150	°C
Storage temperature range	T_{Stg}		- 40 to 125	
RMS isolation voltage	V_{ISOL}	T_J = 25 °C, all terminals shorted, f = 50 Hz, t = 1 s	3500	V
Q1 - Q4 IGBT				
Collector to emitter voltage	V_{CES}		600	V
Gate to emitter voltage	V_{GES}		20	V
Pulsed collector current	I_{CM}		150	A
Clamped inductive load current	I_{LM} (1)		150	A
Continuous collector current	I_C	T_C = 25 °C	88	A
		T_C = 80 °C	60	
Power dissipation	P_D	T_C = 25 °C	338	W
		T_C = 80 °C	189	
Q2 - Q3 IGBT				
Collector to emitter voltage	V_{CES}		900	V
Gate to emitter voltage	V_{GES}		20	V
Pulsed collector current	I_{CM}		150	A
Clamped inductive load current	I_{LM} (2)		150	A
Continuous collector current	I_C	T_C = 25 °C	85	A
		T_C = 80 °C	57	
Power dissipation	P_D	T_C = 25 °C	338	W
		T_C = 80 °C	189	

ABSOLUTE MAXIMUM RATINGS				
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MAX.**	**UNITS**
D1 - D2 CLAMPING DIODE				
Repetitive peak reverse voltage	V_{RRM}		600	V
Single pulse forward current	I_{FSM}	10 ms sine or 6 ms rectangular pulse, T_J = 25 °C	150	A
Diode continuous forward current	I_F	T_C = 25 °C	68	A
		T_C = 80 °C	46	
Power dissipation	P_D	T_C = 25 °C	150	W
		T_C = 80 °C	84	
D3 - D4 AP DIODE				
Single pulse forward current	I_{FSM}	10 ms sine or 6 ms rectangular pulse, T_J = 25 °C	150	A
Diode continuous forward current	I_F	T_C = 25 °C	53	A
		T_C = 80 °C	36	
Power dissipation	P_D	T_C = 25 °C	176	W
		T_C = 80 °C	99	
D5 - D6 AP DIODE				
Single pulse forward current	I_{FSM}	10 ms sine or 6 ms rectangular pulse, T_J = 25 °C	100	A
Diode continuous forward current	I_F	T_C = 25 °C	46	A
		T_C = 80 °C	31	
Power dissipation	P_D	T_C = 25 °C	96	W
		T_C = 80 °C	54	

Notes

- Absolute Maximum Ratings indicate sustained limits beyond which damage to the device may occur.

(1) V_{CC} = 400 V, V_{GE} = 15 V, L = 500 μH, R_g = 22 Ω, T_J = 150 °C

(2) V_{CC} = 720 V, V_{GE} = 15 V, L = 500 μH, R_g = 22 Ω, T_J = 150 °C

ELECTRICAL SPECIFICATIONS (T_J = 25 °C unless otherwise noted)						
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MIN.**	**TYP.**	**MAX.**	**UNITS**
Q1 - Q4 IGBT						
Collector to emitter breakdown voltage	BV_{CES}	V_{GE} = 0 V, I_C = 500 μA	600	-	-	V
Temperature coefficient of breakdown voltage	$\Delta BV_{CES}/\Delta T_J$	V_{GE} = 0 V, I_C = 500 μA (25 °C to 125 °C)	-	0.1	-	V/°C
Collector to emitter voltage	$V_{CE(ON)}$	V_{GE} = 15 V, I_C = 27 A	-	1.44	1.75	V
		V_{GE} = 15 V, I_C = 50 A	-	1.8	2.1	
		V_{GE} = 15 V, I_C = 27 A, T_J = 125 °C	-	1.7	2.05	
		V_{GE} = 15 V, I_C = 50 A, T_J = 125 °C	-	2.2	2.5	
Gate threshold voltage	$V_{GE(th)}$	V_{CE} = V_{GE}, I_C = 250 μA	2.9	3.9	5.3	
Temperature coefficient of threshold voltage	$\Delta V_{GE(th)}/\Delta T_J$	V_{CE} = V_{GE}, I_C = 1 mA (25 °C to 125 °C)	-	- 10	-	mV/°C
Forward transconductance	g_{fe}	V_{CE} = 20 V, I_C = 50 A	-	95	-	s
Transfer characteristics	V_{GE}	V_{CE} = 20 V, I_C = 50 A	-	5.9	-	V
Zero gate voltage collector current	I_{CES}	V_{GE} = 0 V, V_{CE} = 600 V	-	0.003	0.1	mA
		V_{GE} = 0 V, V_{CE} = 600 V, T_J = 125 °C	-	0.170	3	
Gate to emitter leakage current	I_{GES}	V_{GE} = ± 20 V, V_{CE} = 0 V	-	-	± 200	nA

ELECTRICAL SPECIFICATIONS (T_J = 25 °C unless otherwise noted)						
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MIN.**	**TYP.**	**MAX.**	**UNITS**
Q2 - Q3 IGBT						
Collector to emitter breakdown voltage	BV_{CES}	V_{GE} = 0 V, I_C = 500 µA	900	-	-	V
Temperature coefficient of breakdown voltage	$\Delta BV_{CES}/\Delta T_J$	V_{GE} = 0 V, I_C = 500 µA (25 °C to 125 °C)	-	- 8.5	-	V/°C
Collector to emitter voltage	$V_{CE(ON)}$	V_{GE} = 15 V, I_C = 27 A	-	2.45	2.8	V
		V_{GE} = 15 V, I_C = 50 A	-	2.73	3.2	
		V_{GE} = 15 V, I_C = 27 A, T_J = 125 °C	-	2	2.35	
		V_{GE} = 15 V, I_C = 50 A, T_J = 125 °C	-	2.43	2.9	
Gate threshold voltage	$V_{GE(th)}$	V_{CE} = V_{GE}, I_C = 250 µA	2.8	4.5	6.3	
Temperature coefficient of threshold voltage	$\Delta V_{GE(th)}/\Delta T_J$	V_{CE} = V_{GE}, I_C = 1 mA (25 °C to 125 °C)	-	- 11.7	-	mV/°C
Forward transconductance	g_{fe}	V_{CE} = 20 V, I_C = 50 A	-	68	-	s
Transfer characteristics	V_{GE}	V_{CE} = 20 V, I_C = 50 A	-	6.9	-	V
Zero gate voltage collector current	I_{CES}	V_{GE} = 0 V, V_{CE} = 900 V	-	0.006	0.38	mA
		V_{GE} = 0 V, V_{CE} = 900 V, T_J = 125 °C	-	1.4	3	
Gate to emitter leakage current	I_{GES}	V_{GE} = ± 20 V, V_{CE} = 0 V	-	-	± 200	nA
D1 - D2 CLAMPING DIODE						
Cathode to anode blocking voltage	V_{BR}	I_R = 100 µA	600	-	-	V
Forward voltage drop	V_{FM}	I_F = 30 A	-	1.84	2.12	V
		I_F = 30 A, T_J = 125 °C	-	1.37	1.65	
Reverse leakage current	I_{RM}	V_R = 600 V	-	0.002	0.1	mA
		V_R = 600 V, T_J = 125 °C	-	3.2	6	
D3 - D4 AP DIODE						
Forward voltage drop	V_{FM}	I_F = 50 A	-	2.7	3.2	V
		I_F = 50 A T_J = 125 °C	-	2.8	3.3	
D5 - D6 AP DIODE						
Forward voltage drop	V_{FM}	I_F = 30 A	-	1.93	2.37	V
		I_F = 30 A T_J = 125 °C	-	1.48	1.9	

SWITCHING CHARACTERISTICS (T_J = 25 °C unless otherwise noted)						
PARAMETER	SYMBOL	TEST CONDITIONS	MIN.	TYP.	MAX.	UNITS
Q1 - Q4 IGBT (WITH FREEWHEELING D1 - D2 CLAMPING DIODE)						
Total gate charge (turn-on)	Q_g	I_C = 70 A V_{CC} = 400 V V_{GE} = 15 V	-	480	720	nC
Gate to ermitter charge (turn-on)	Q_{ge}		-	82	164	
Gate to collector charge (turn-on)	Q_{gc}		-	160	260	
Turn-on switching loss	E_{ON}	I_C = 50 A V_{CC} = 400 V V_{GE} = 15 V R_g = 4.7 Ω L = 500 μH (1)	-	0.11	-	mJ
Turn-off switching loss	E_{OFF}		-	0.76	-	
Total switching loss	E_{TOT}		-	0.87	-	
Turn-on delay time	$t_{d(on)}$		-	182	-	ns
Rise time	t_r		-	46	-	
Turn-off delay time	$t_{d(off)}$		-	207	-	
Fall time	t_f		-	92	-	
Turn-on switching loss	E_{ON}	I_C = 50 A V_{CC} = 400 V V_{GE} = 15 V R_g = 4.7 Ω L = 500 μH T_J = 125 °C (1)	-	0.25	-	mJ
Turn-off switching loss	E_{OFF}		-	0.88	-	
Total switching loss	E_{TOT}		-	1.13	-	
Turn-on delay time	$t_{d(on)}$		-	183	-	ns
Rise time	t_r		-	47	-	
Turn-off delay time	$t_{d(off)}$		-	211	-	
Fall time	t_f		-	101	-	
Input capacitance	C_{ies}	V_{GE} = 0 V V_{CC} = 30 V f = 1 MHz	-	9500		pF
Output capacitance	C_{oes}		-	780		
Reverse transfer capacitance	C_{res}		-	116		
Reverse bias safe operating area	RBSOA	T_J = 150 °C, I_C = 150 A V_{CC} = 400 V, V_P = 600 V R_g = 22 Ω, V_{GE} = 15 V to 0 V		Fullsquare		
Q2 - Q3 IGBT (WITH FREEWHEELING D3 - D4 AP DIODE)						
Total gate charge (turn-on)	Q_g	I_C = 50 A V_{CC} = 400 V V_{GE} = 15 V	-	320	480	nC
Gate to emitter charge (turn-on)	Q_{ge}		-	38	58	
Gate to collector charge (turn-on)	Q_{gc}		-	106	160	
Turn-on switching loss	E_{ON}	I_C = 50 A V_{CC} = 720 V V_{GE} = 15 V R_g = 4.7 Ω L = 500 μH (1)	-	0.56	-	mJ
Turn-off switching loss	E_{OFF}		-	0.68	-	
Total switching loss	E_{TOT}		-	1.24	-	
Turn-on delay time	$t_{d(on)}$		-	152	-	ns
Rise time	t_r		-	48	-	
Turn-off delay time	$t_{d(off)}$		-	165	-	
Fall time	t_f		-	100	-	
Turn-on switching loss	E_{ON}	I_C = 50 A V_{CC} = 720 V V_{GE} = 15 V R_g = 4.7 Ω L = 500 μH T_J = 125 °C (1)	-	0.95	-	mJ
Turn-off switching loss	E_{OFF}		-	2.18	-	
Total switching loss	E_{TOT}		-	3.13	-	
Turn-on delay time	$t_{d(on)}$		-	154	-	ns
Rise time	t_r		-	52	-	
Turn-off delay time	$t_{d(off)}$		-	168	-	
Fall time	t_f		-	360	-	
Input capacitance	C_{ies}	V_{GE} = 0 V V_{CC} = 30 V f = 1 MHz	-	6600	-	pF
Output capacitance	C_{oes}		-	400	-	
Reverse transfer capacitance	C_{res}		-	90	-	
Reverse bias safe operating area	RBSOA	T_J = 150 °C, I_C = 150 A V_{CC} = 720 V, V_P = 900 V R_g = 22 Ω, V_{GE} = 15 V to 0 V		Fullsquare		

SWITCHING CHARACTERISTICS (T_J = 25 °C unless otherwise noted)						
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MIN.**	**TYP.**	**MAX.**	**UNITS**
D1 - D2 CLAMPING DIODE						
Diode reverse recovery time	t_{rr}	V_R = 200 V I_F = 30 A dI/dt = 500 A/μs	-	50	80	ns
Diode peak reverse current	I_{rr}		-	7.5	11	A
Diode recovery charge	Q_{rr}		-	185	440	nC
Diode reverse recovery time	t_{rr}	V_R = 200 V I_F = 30 A dI/dt = 500 A/μs, T_J = 125 °C	-	107	147	ns
Diode peak reverse current	I_{rr}		-	18	22	A
Diode recovery charge	Q_{rr}		-	955	1620	nC
D3 - D4 AP DIODE						
Diode reverse recovery time	t_{rr}	V_R = 400 V I_F = 50 A dI/dt = 500 A/μs	-	114	150	ns
Diode peak reverse current	I_{rr}		-	21	25	A
Diode recovery charge	Q_{rr}		-	1200	1875	nC
Diode reverse recovery time	t_{rr}	V_R = 400 V I_F = 50 A dI/dt = 500 A/μs, T_J = 125 °C	-	170	210	ns
Diode peak reverse current	I_{rr}		-	28	32	A
Diode recovery charge	Q_{rr}		-	2160	3360	nC
D5 - D6 AP DIODE						
Diode reverse recovery time	t_{rr}	V_R = 200 V I_F = 30 A dI/dt = 500 A/μs	-	46	77	ns
Diode peak reverse current	I_{rr}		-	7	11	A
Diode recovery charge	Q_{rr}		-	161	423	nC
Diode reverse recovery time	t_{rr}	V_R = 200 V I_F = 30 A dI/dt = 500 A/μs, T_J = 125 °C	-	106	138	ns
Diode peak reverse current	I_{rr}		-	17	22	A
Diode recovery charge	Q_{rr}		-	900	1518	nC

Note

[1] Energy losses include "tail" and diode reverse recovery.

THERMISTOR ELECTRICAL CHARACTERISTICS (T_J = 25 °C unless otherwise noted)						
PARAMETER	**SYMBOL**	**TEST CONDITIONS**	**MIN.**	**TYP.**	**MAX.**	**UNITS**
Resistance	R_{25}		4500	5000	5500	Ω
	R_{100}	T_J = 100 °C	468	493	518	
B value	B	T_J = 25 °C/T_J = 50 °C	3206	3375	3544	K

THERMAL AND MECHANICAL SPECIFICATIONS					
PARAMETER	**SYMBOL**	**MIN.**	**TYP.**	**MAX.**	**UNITS**
Junction to case Q1 - Q4 IGBT thermal resistance (per switch)	R_{thJC}	-	-	0.37	°C/W
Junction to case Q2 - Q3 IGBT thermal resistance (per switch)		-	-	0.37	
Junction to case D1 - D2 AP diode thermal resistance (per diode)		-	-	0.83	
Junction to case D3 - D4 AP diode thermal resistance (per diode)		-	-	0.71	
Junction to case D5 - D6 AP diode thermal resistance (per diode)		-	-	1.3	
Case to sink, flat, greased surface (per module)	R_{thCS}	-	0.1	-	
Mounting torque (M4)		-	2	3	Nm
Weight		-	39	-	g

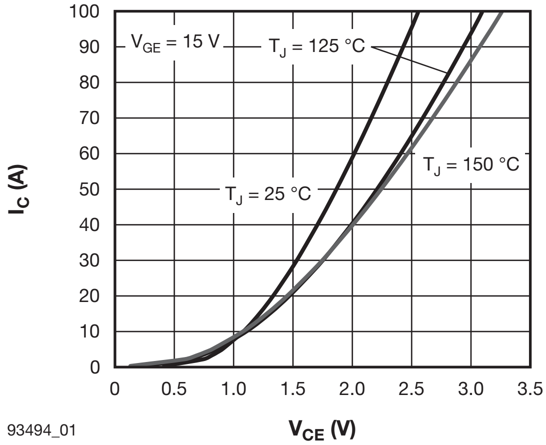


Fig. 1 - Typical Q1 - Q4 IGBT Output Characteristics

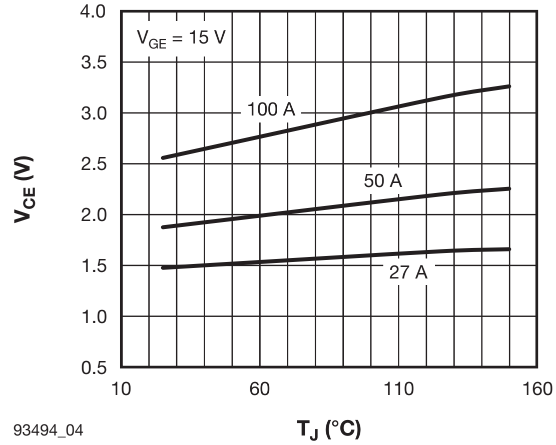


Fig. 4 - Typical Q1 - Q4 IGBT Collector to Emitter Voltage vs. Junction Temperature

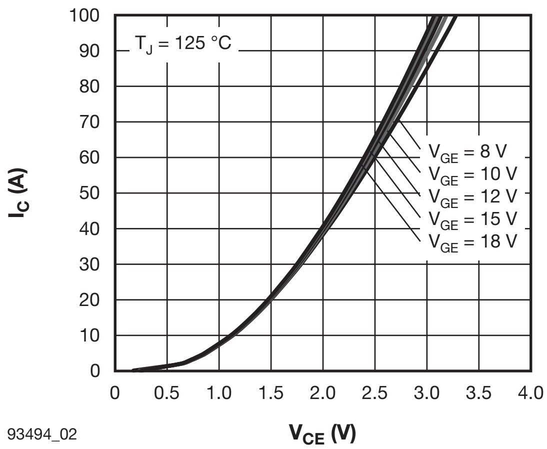


Fig. 2 - Typical Q1 - Q4 IGBT Output Characteristics

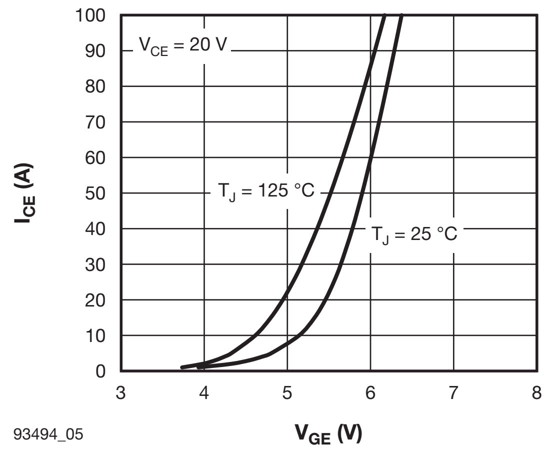


Fig. 5 - Typical Q1 - Q4 IGBT Transfer Characteristics

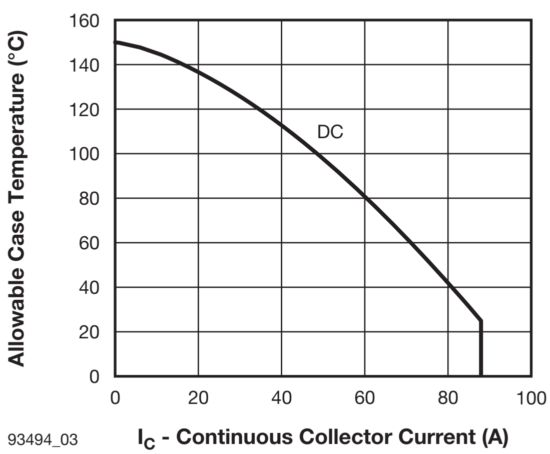


Fig. 3 - Maximum DC Q1 - Q4 IGBT Collector Current vs. Case Temperature per Junction

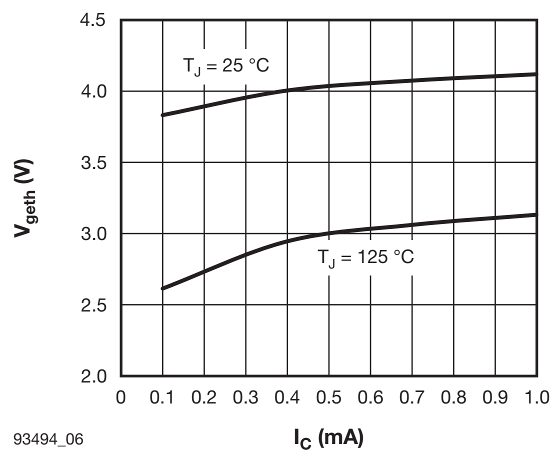


Fig. 6 - Typical Q1 - Q4 IGBT Gate Threshold Voltage

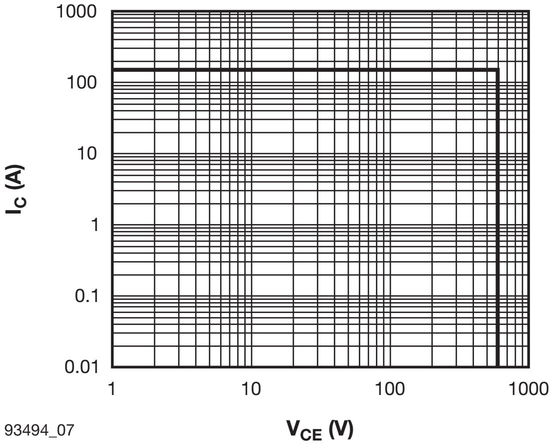


Fig. 7 - Q1 - Q4 IGBT Reverse Bias SOA
T_J = 150 °C, V_{GE} = 15 V, R_g = 22 Ω

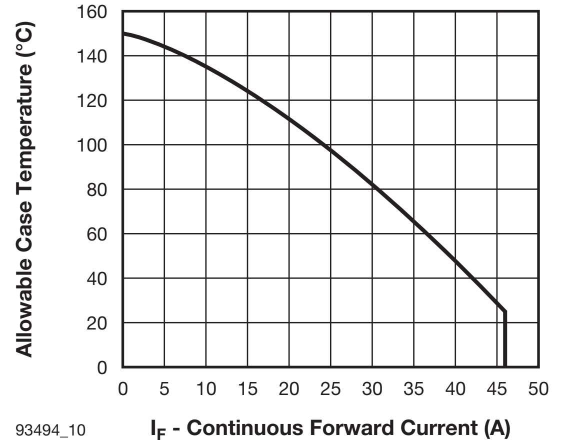


Fig. 10 - Maximum DC D5 - D6 Antiparallel Diode Forward Current vs. Case Temperature per Junction

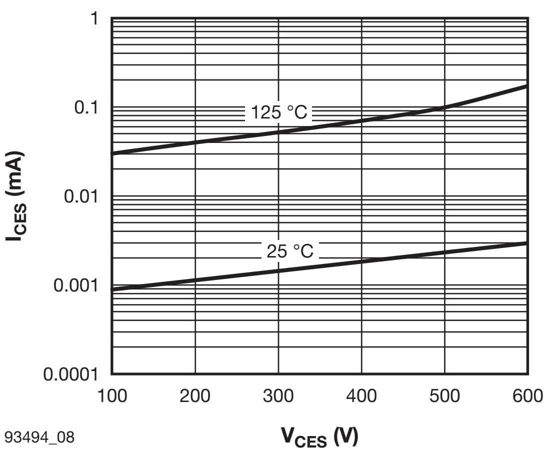


Fig. 8 - Typical Q1 - Q4 IGBT Zero Gate Voltage Collector Current

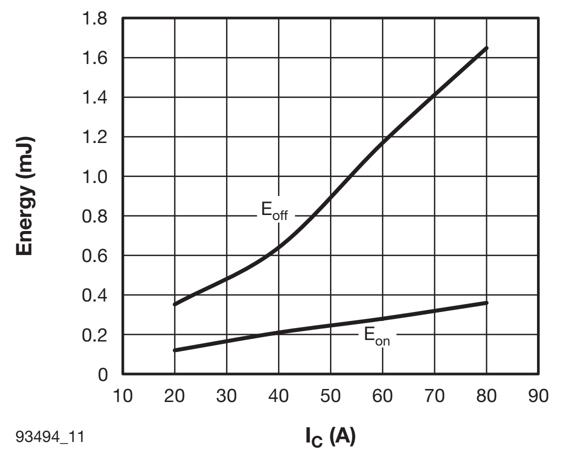


Fig. 11 - Typical Q1 - Q4 IGBT Energy Loss vs. I_C
(with Freewheeling D1 - D2 Clamping Diode)
V_{CC} = 400 V, R_g = 4.7 Ω, V_{GE} = 15 V, L = 500 µH

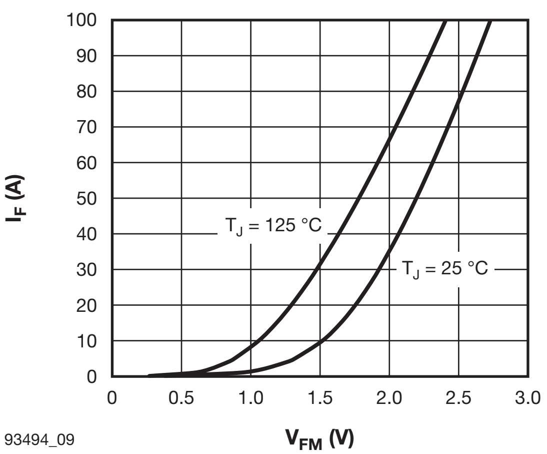


Fig. 9 - Typical D5 - D6 Antiparallel Diode Forward Characteristics

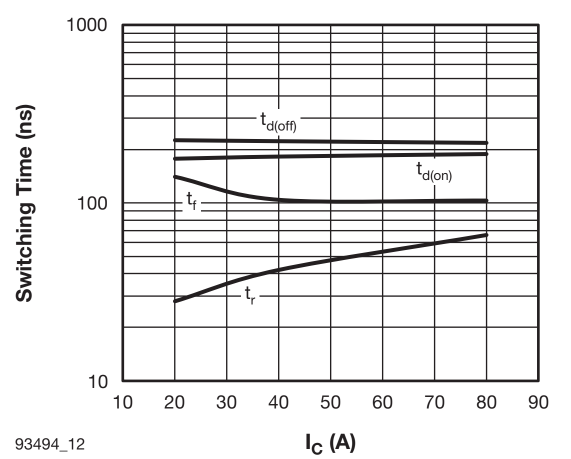


Fig. 12 - Typical Q1 - Q4 IGBT Switching Time vs. I_C
(with Freewheeling D1 - D2 Clamping Diode)
T_J = 125 °C, V_{CC} = 400 V, R_g = 4.7 Ω, V_{GE} = 15 V, L = 500 µH

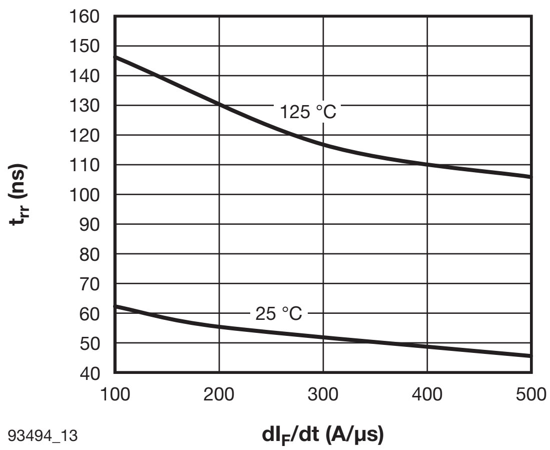


Fig. 13 - Typical D5 - D6 Antiparallel Diode Reverse Recovery Time vs. dI_F/dt
V_R = 200 V, I_F = 30 A

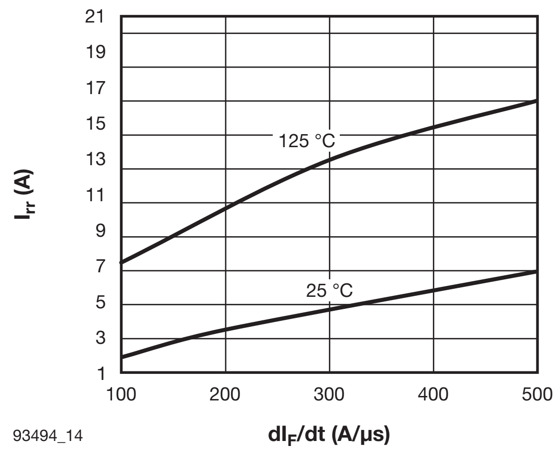


Fig. 14 - Typical D5 - D6 Antiparallel Diode Reverse Recovery Current vs. dI_F/dt
V_R = 200 V, I_F = 30 A

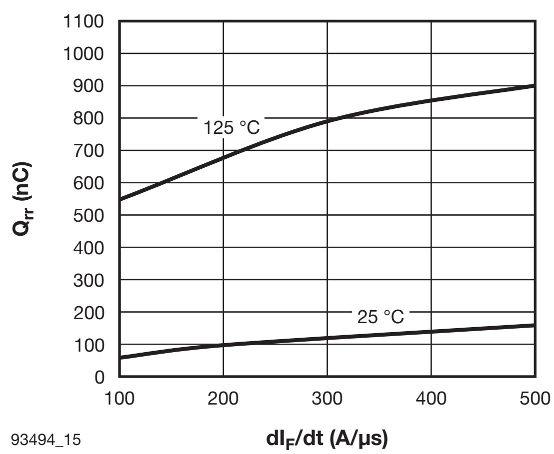


Fig. 15 - Typical D5 - D6 Antiparallel Diode Reverse Recovery Charge vs. dI_F/dt
V_R = 200 V, I_F = 30 A

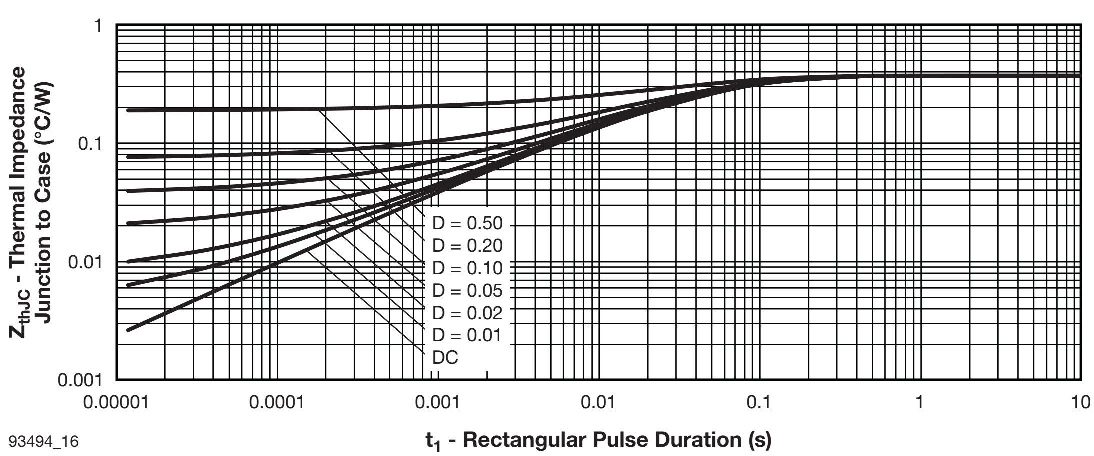


Fig. 16 - Maximum Thermal Impedance Z_{thJC} Characteristics (Q1 - Q4 IGBT)

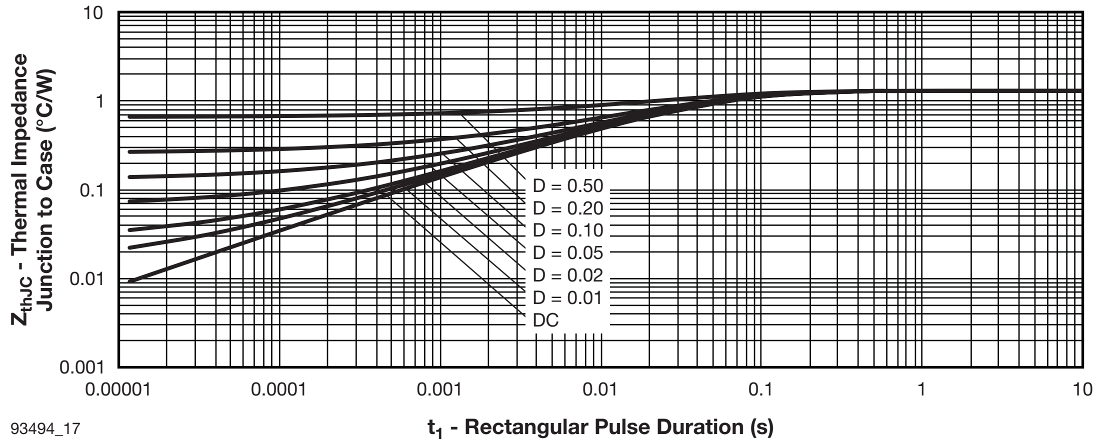


Fig. 17 - Maximum Thermal Impedance Z_{thJC} Characteristics (D5 - D6 Antiparallel Diode)

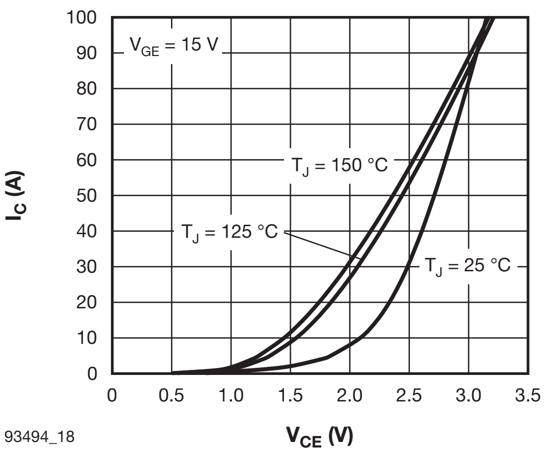


Fig. 18 - Typical Q2 - Q3 IGBT Output Characteristics

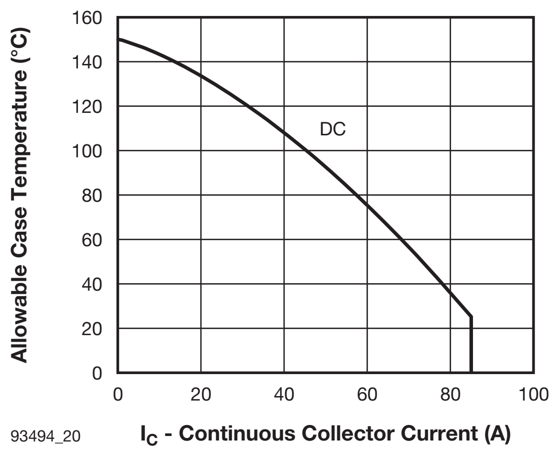


Fig. 20 - Maximum DC Q2 - Q3 IGBT Collector Current vs. Case Temperature per Junction

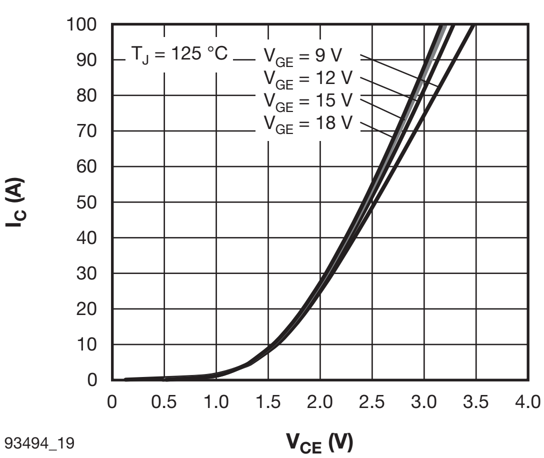


Fig. 19 - Typical Q2 - Q3 IGBT Output Characteristics

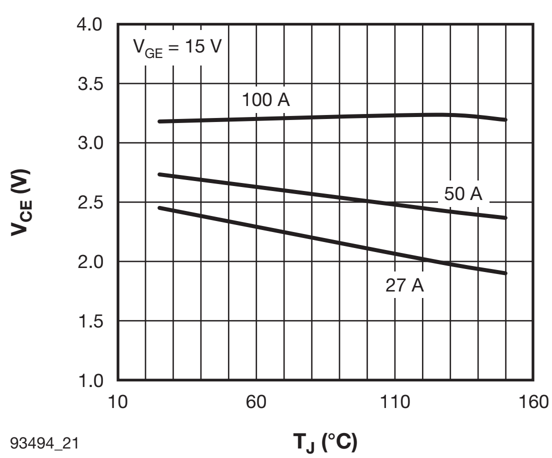


Fig. 21 - Typical Q2 - Q3 IGBT Collector to Emitter Voltage vs. Junction Temperature

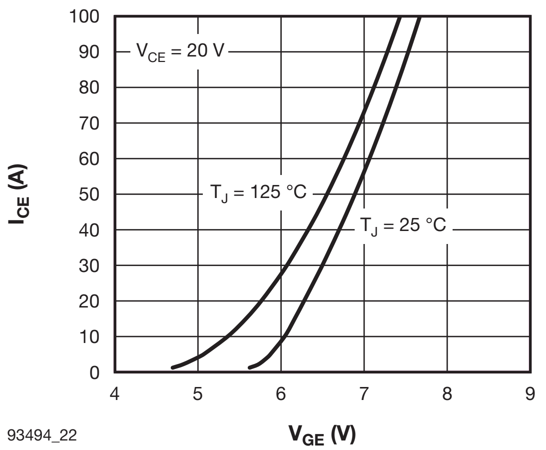


Fig. 22 - Typical Q1 - Q4 IGBT Transfer Characteristics

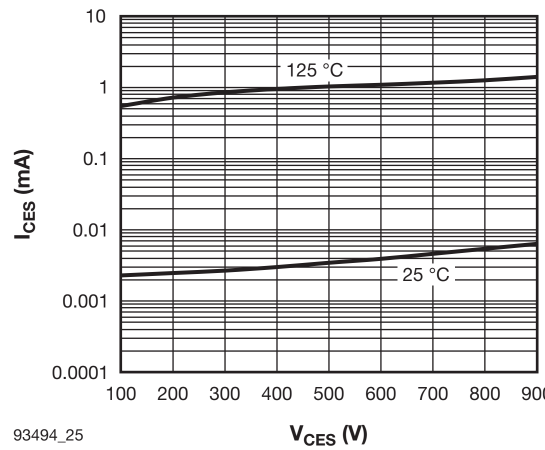


Fig. 25 - Typical Q2 - Q3 IGBT Zero Gate Voltage Collector Current

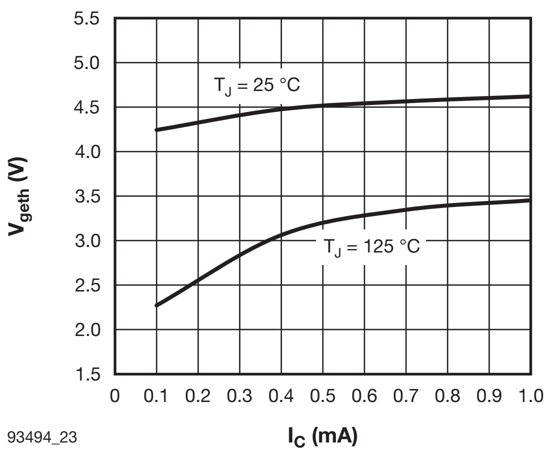


Fig. 23 - Typical Q2 - Q3 IGBT Gate Threshold Voltage

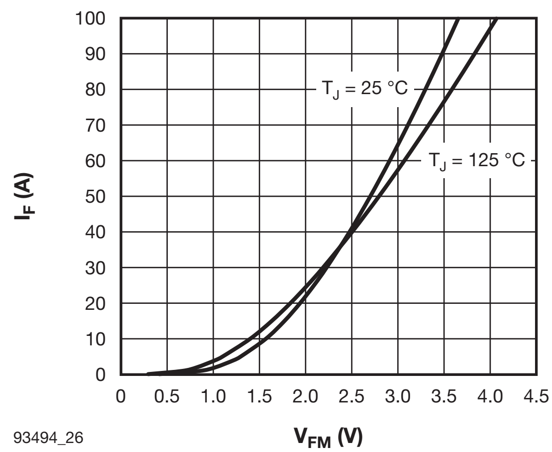


Fig. 26 - Typical D3 - D4 Antiparallel Diode Forward Characteristics

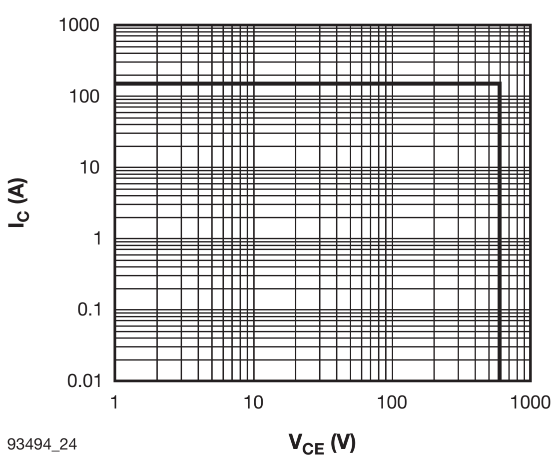


Fig. 24 - Q2 - Q3 IGBT Reverse Bias SOA
T_J = 150 °C, V_{GE} = 15 V, R_g = 22 Ω

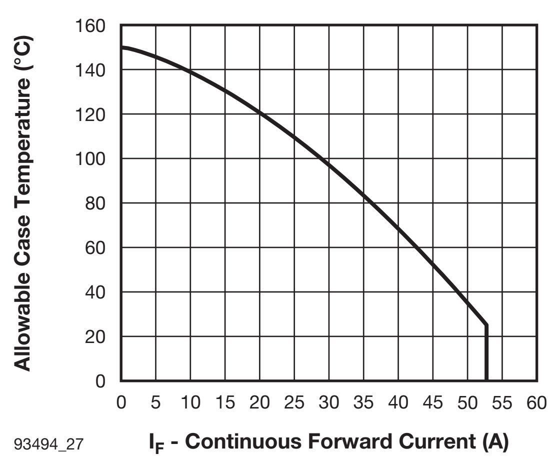


Fig. 27 - Maximum DC D3 - D4 Antiparallel Diode
Forward Current vs. Case Temperature per Junction

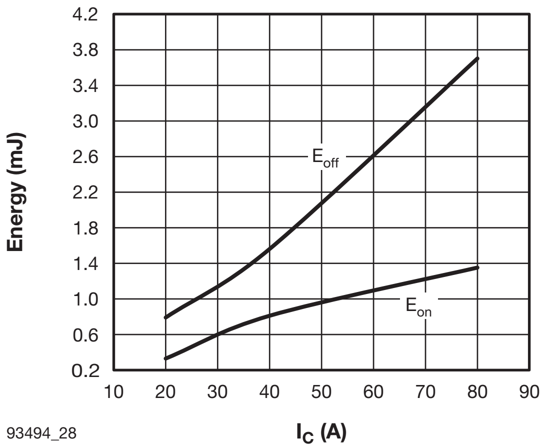


Fig. 28 - Typical Q2 - Q3 IGBT Energy Loss vs. I_C
(with Freewheeling D2 - D3 AP Diode)
V_{CC} = 720 V, R_g = 4.7 Ω, V_{GE} = 15 V, L = 500 μH

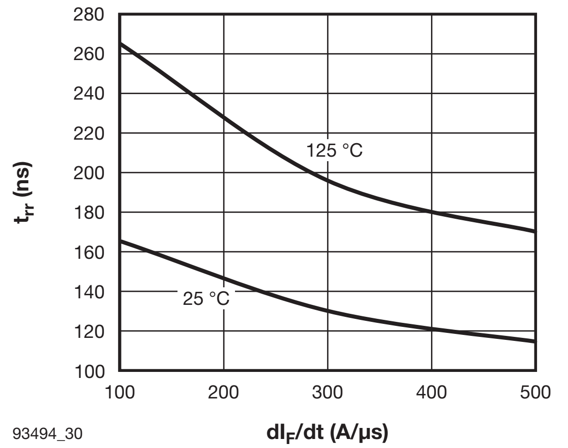


Fig. 30 - Typical D3 - D4 Antiparallel Diode Reverse Recovery Time vs. dI_F/dt
V_R = 400 V, I_F = 50 A

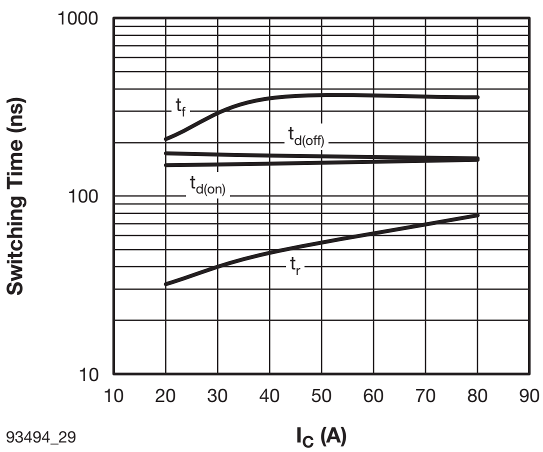


Fig. 29 - Typical Q2 - Q3 IGBT Switching Time vs. I_C
(with Freewheeling D2 - D3 AP Diode)
T_J = 125 °C, V_{CC} = 720 V, R_g = 4.7 Ω, V_{GE} = 15 V, L = 500 μH

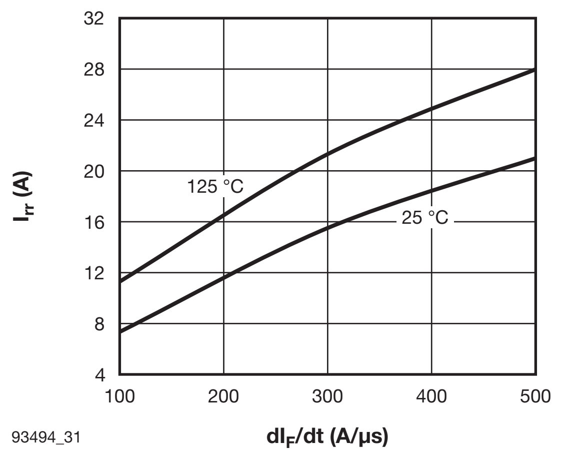


Fig. 31 - Typical D3 - D4 Antiparallel Diode Reverse Recovery Current vs. dI_F/dt
V_R = 400 V, I_F = 50 A

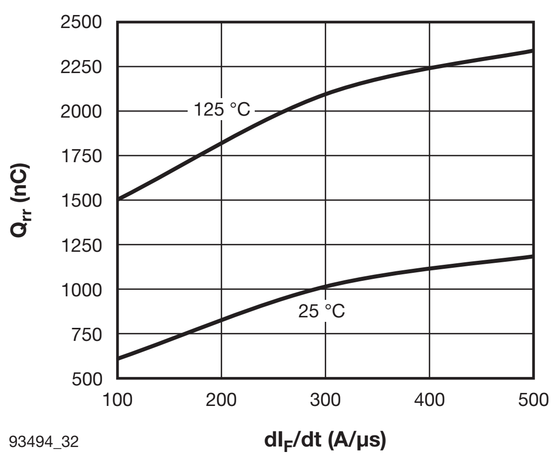


Fig. 32 - Typical D3 - D4 Antiparallel Diode Reverse Recovery Charge vs. dI_F/dt
V_R = 400 V, I_F = 50 A

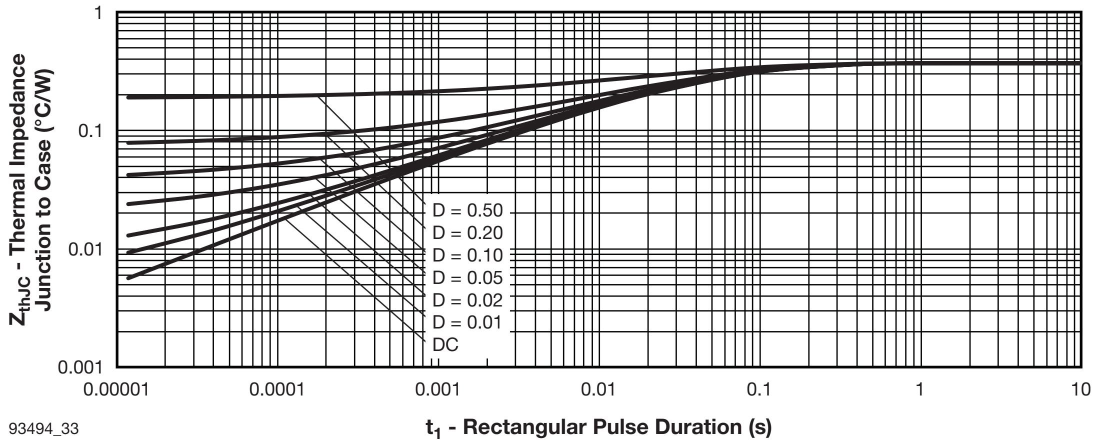


Fig. 33 - Maximum Thermal Impedance Z_{thJC} Characteristics (Q2 - Q3 IGBT)

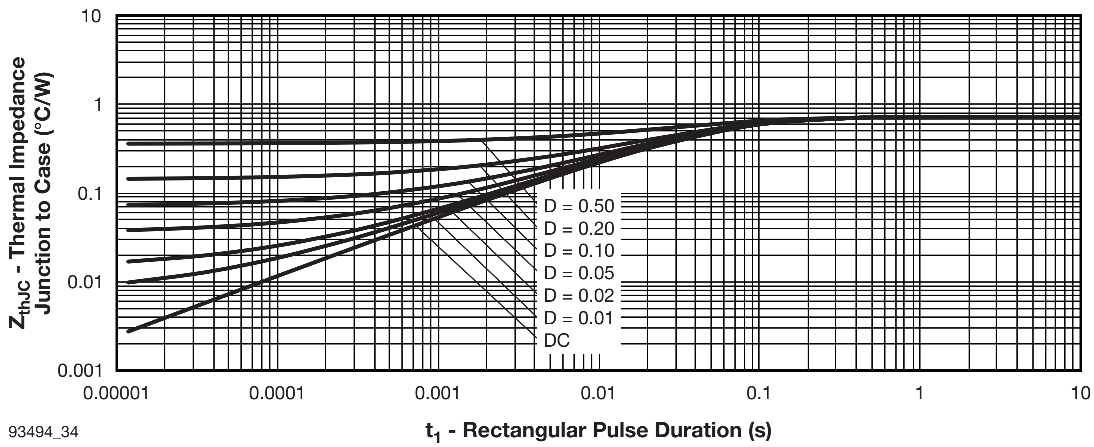


Fig. 34 - Maximum Thermal Impedance Z_{thJC} Characteristics (D3 - D4 Antiparallel Diode)

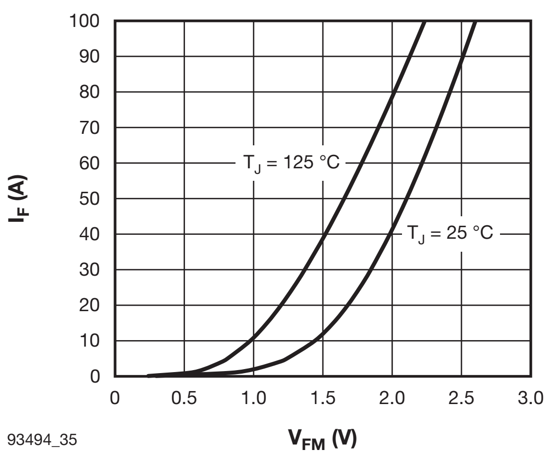


Fig. 35 - Typical D1 - D2 Clamping Diode Forward Characteristics

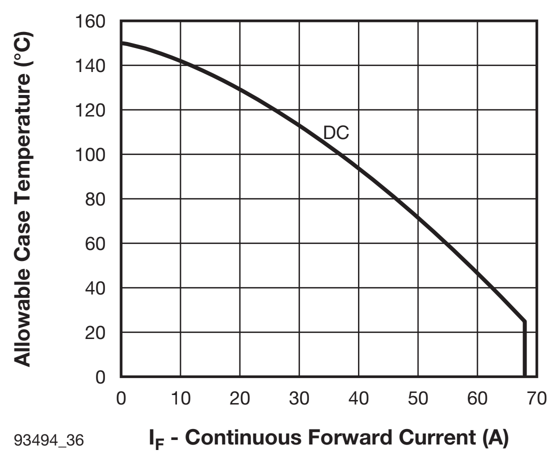


Fig. 36 - Maximum DC D1 - D2 Clamping Diode Forward Current vs. Case Temperature per Junction

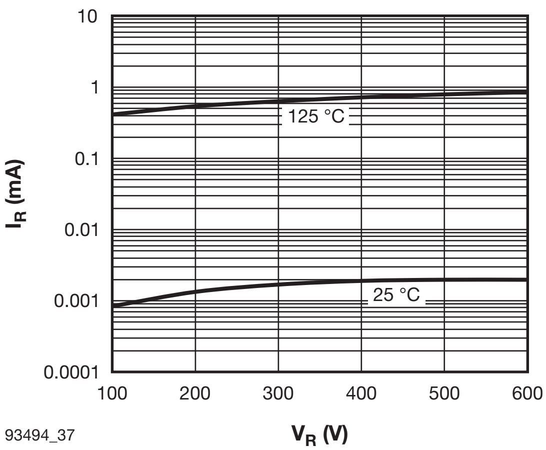


Fig. 37 - Typical D1 - D2 Clamping Diode Reverse Leakage Current

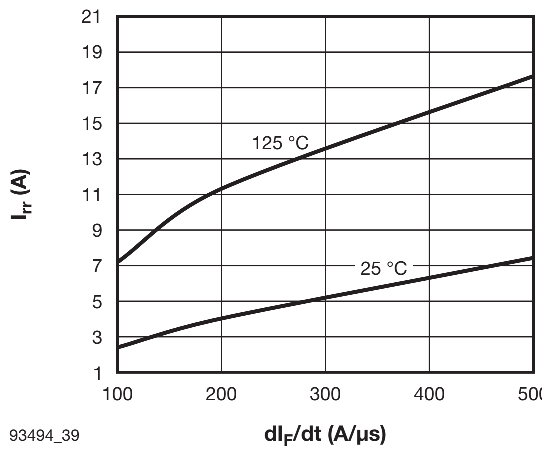


Fig. 39 - Typical D1 - D2 Clamping Diode Reverse Recovery Current vs. dI_F/dt
V_R = 200 V, I_F = 30 A

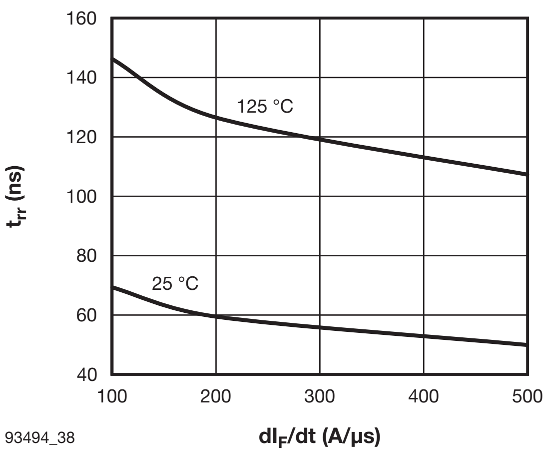


Fig. 38 - Typical D1 - D2 Clamping Diode Reverse Recovery Time vs. dI_F/dt
V_R = 200 V, I_F = 30 A

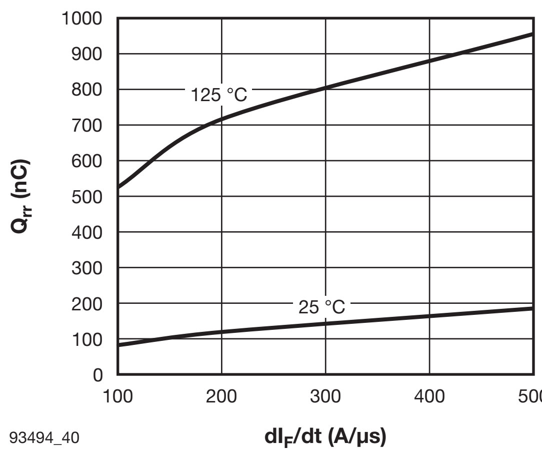


Fig. 40 - Typical D1 - D2 Clamping Diode Reverse Recovery Charge vs. dI_F/dt
V_R = 200 V, I_F = 30 A

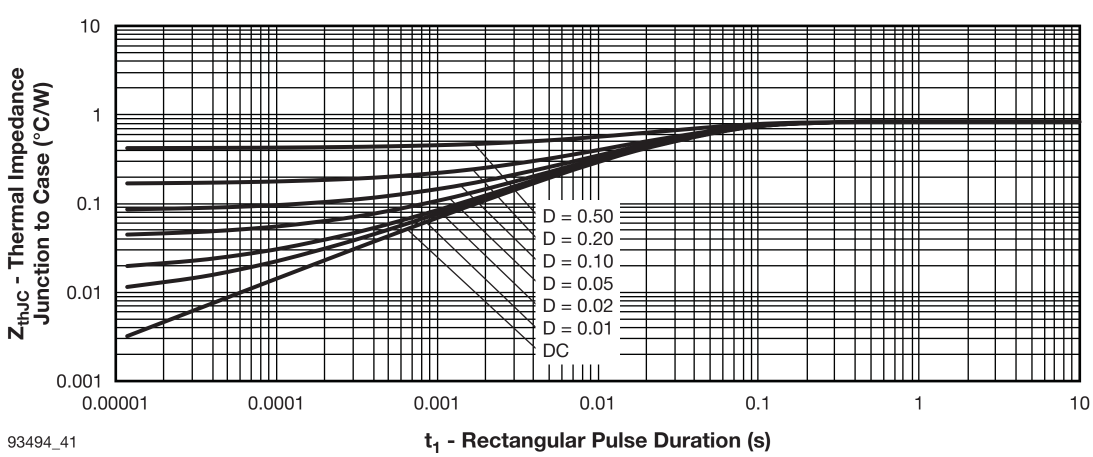


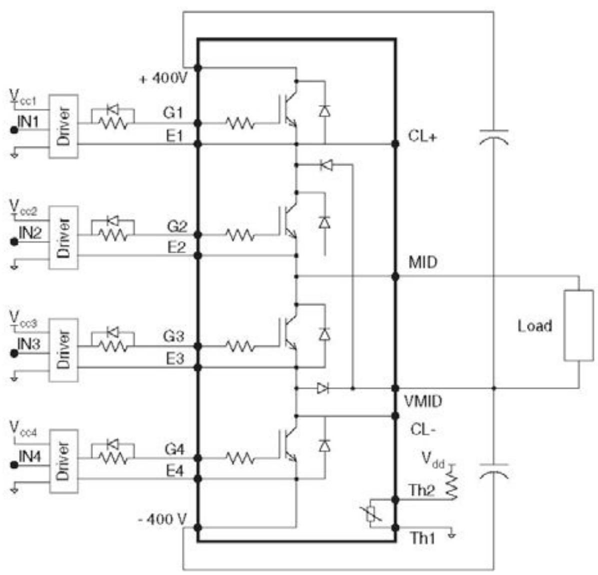
Fig. 41 - Maximum Thermal Impedance Z_{thJC} Characteristics (D1 - D2 Clamping Diode)

ORDERING INFORMATION TABLE

Device code	VS-	EM	F	050	J	60	U
	1	2	3	4	5	6	7

1	-	Vishay Semiconductors product
2	-	Package indicator (EM = EMIPAK2)
3	-	Circuit configuration (F = 3-levels half-bridge inverter stage)
4	-	Current rating (050 = 50 A)
5	-	Die technology (J = Warp2 IGBT)
6	-	Voltage rating (60 = 600 V)
7	-	U = Ultrafast

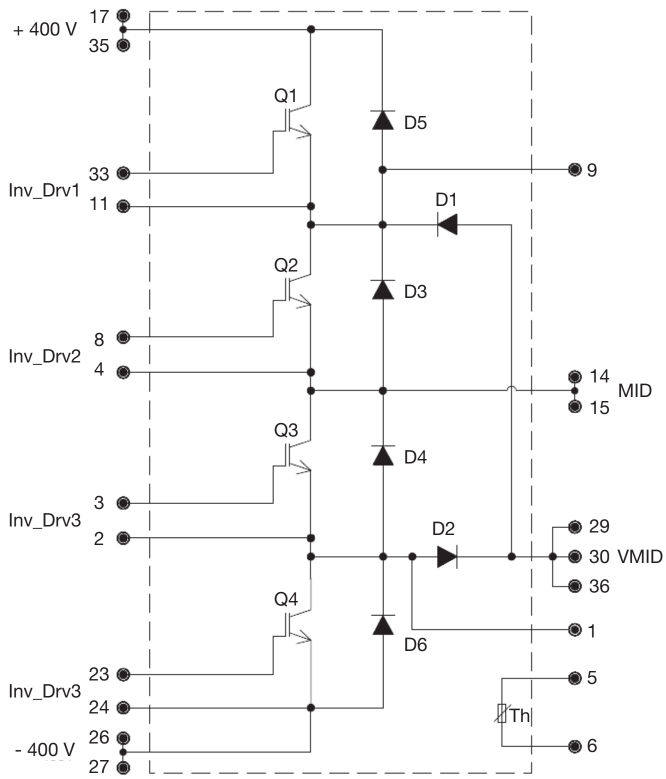
TYPICAL CONNECTION



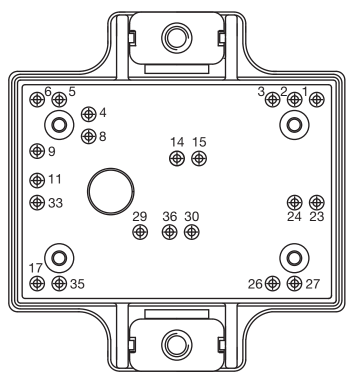
Note

- Please refer to lead assignment for correct pin configuration. This diagram shows electrical connections only.

CIRCUIT CONFIGURATION



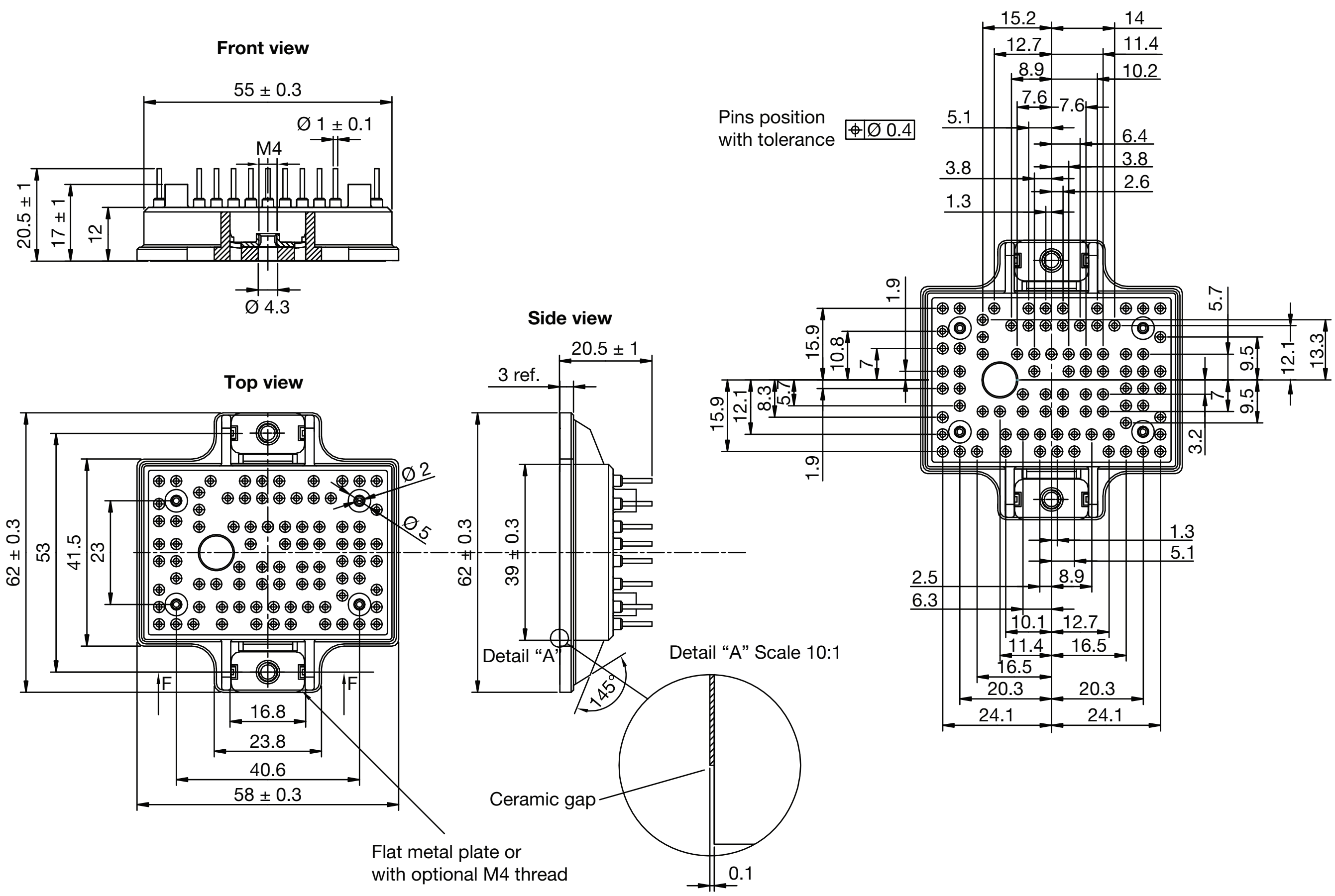
PACKAGE



LINKS TO RELATED DOCUMENTS	
Dimensions	www.vishay.com/doc?95436

EMIPAK2

DIMENSIONS in millimeters



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