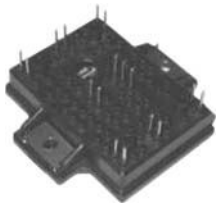
# Dual Mode PFC, 60 A



EMIPAK2

## FEATURES

- NPT Warp2 PFC IGBT with low $V_{CE(ON)}$
- Silicon carbide PFC diode
- Antiparallel FRED Pt® fast recovery
- 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

| PRODUCT SUMMARY | |
|---|---|
| $V_{CES}$ | 600 V |
| $V_{CE(ON)}$ typical at $I_C$ = 50 A | 1.8 V |
| $I_C$ at $T_C$ = 98 °C | 50 A |

## DESCRIPTION

VS-EMG050J60N is an integrated solution for dual stage PFC converter 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** |
| Maximum 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 |
| **PFC IGBT Q1 - Q2** | | | | |
| 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 | |
| **ANTIPARALLEL DIODE D1 - D2** | | | | |
| Diode continuous forward current | $I_F$ | $T_C$ = 25 °C | 16 | A |
| | | $T_C$ = 80 °C | 11 | |
| Single pulse forward current | $I_{FSM}$ | 10 ms sine or 6 ms rectangular pulse, $T_J$ = 25 °C | 80 | A |
| Power dissipation | $P_D$ | $T_C$ = 25 °C | 29 | W |
| | | $T_C$ = 80 °C | 16 | |
| **PFC DIODE D3 - D4** | | | | |
| Repetitive peak reverse voltage | $V_{RRM}$ | | 600 | V |
| Diode continuous forward current | $I_F$ | $T_C$ = 25 °C | 25 | A |
| | | $T_C$ = 80 °C | 17 | |
| Single pulse forward current | $I_{FSM}$ | 10 ms sine or 6 ms rectangular pulse, $T_J$ = 25 °C | 80 | A |
| Power dissipation | $P_D$ | $T_C$ = 25 °C | 74 | W |
| | | $T_C$ = 80 °C | 41 | |

**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

| **ELECTRICAL SPECIFICATIONS** ($T_J$ = 25 °C unless otherwise noted) | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **TEST CONDITIONS** | **MIN.** | **TYP.** | **MAX.** | **UNITS** |
| **PFC IGBT Q1 - Q2** | | | | | | |
| 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 | - | 3 | 100 | µA |
| | | $V_{GE}$ = 0 V, $V_{CE}$ = 600 V, $T_J$ = 125 °C | - | 0.170 | 3 | mA |
| Gate to emitter leakage current | $I_{GES}$ | $V_{GE}$ = ± 20 V, $V_{CE}$ = 0 V | - | | ± 200 | nA |
| **ANTIPARALLEL DIODE D1 - D2** | | | | | | |
| Forward voltage drop | $V_F$ | $I_F$ = 20 A | - | 2.19 | 2.4 | V |
| | | $I_F$ = 20 A, $T_J$ = 125 °C | - | 1.93 | 2.15 | |
| **PFC DIODE D3 - D4** | | | | | | |
| Cathode to anode breakdown voltage | $V_{BR}$ | $I_R$ = 500 µA | 600 | - | - | V |
| Reverse leakage current | $I_{RM}$ | $V_R$ = 600 V | - | 27 | 250 | µA |
| | | $V_R$ = 600 V, $T_J$ = 125 °C | - | 0.1 | 1 | mA |
| Forward voltage drop | $V_F$ | $I_F$ = 10 A | - | 1.34 | 1.63 | V |
| | | $I_F$ = 10 A, $T_J$ = 125 °C | - | 1.36 | 1.65 | |

| **SWITCHING CHARACTERISTICS** ($T_J$ = 25 °C unless otherwise noted) | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **TEST CONDITIONS** | **MIN.** | **TYP.** | **MAX.** | **UNITS** |
| **PFC IGBT Q1 - Q2 (WITH FREEWHEELING D3 - D4 PFC DIODE)** | | | | | | |
| Total gate charge (turn-on) | $Q_g$ | $I_C$ = 70 A<br>$V_{CC}$ = 400 V<br>$V_{GE}$ = 15 V | - | 480 | 720 | nC |
| Gate to emitter 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<br>$V_{CC}$ = 400 V<br>$V_{GE}$ = 15 V<br>$R_g$ = 4.7 Ω<br>L = 500 µH<br>$T_J$ = 25 °C (1) | - | 0.155 | - | mJ |
| Turn-off switching loss | $E_{OFF}$ | | - | 0.471 | - | |
| Total switching loss | $E_{TOT}$ | | - | 0.626 | - | |
| Turn-on delay time | $t_{d(on)}$ | | - | 196 | - | ns |
| Rise time | $t_r$ | | - | 29 | - | |
| Turn-off delay time | $t_{d(off)}$ | | - | 220 | - | |
| Fall time | $t_f$ | | - | 67 | - | |

| **SWITCHING CHARACTERISTICS** ($T_J$ = 25 °C unless otherwise noted) | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **TEST CONDITIONS** | **MIN.** | **TYP.** | **MAX.** | **UNITS** |
| Turn-on switching loss | $E_{ON}$ | $I_C$ = 50 A<br>$V_{CC}$ = 400 V<br>$V_{GE}$ = 15 V<br>$R_g$ = 4.7 Ω<br>L = 500 µH<br>$T_J$ = 125 °C (1) | - | 0.182 | - | mJ |
| Turn-off switching loss | $E_{OFF}$ | | - | 0.615 | - | |
| Total switching loss | $E_{TOT}$ | | - | 0.797 | - | |
| Turn-on delay time | $t_{d(on)}$ | | - | 198 | - | ns |
| Rise time | $t_r$ | | - | 29 | - | |
| Turn-off delay time | $t_{d(off)}$ | | - | 227 | - | |
| Fall time | $t_f$ | | - | 75 | - | |
| Input capacitance | $C_{ies}$ | $V_{GE}$ = 0 V<br>$V_{CC}$ = 30 V<br>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<br>$V_{CC}$ = 400 V, $V_P$ = 600 V<br>$R_g$ = 22 Ω, $V_{GE}$ = 15 V to 0 V | Fullsquare | | | |
| **ANTIPARALLEL DIODE D1 - D2** | | | | | | |
| Diode reverse recovery time | $t_{rr}$ | $V_R$ = 200 V<br>$I_F$ = 20 A<br>dI/dt = 500 A/µs, $T_J$ = 25 °C | - | 65 | 110 | ns |
| Diode peak reverse current | $I_{rr}$ | | - | 11 | 15 | A |
| Diode reverse charge | $Q_{rr}$ | | - | 350 | 825 | nC |
| Diode reverse recovery time | $t_{rr}$ | $V_R$ = 200 V<br>$I_F$ = 20 A<br>dI/dt = 500 A/µs, $T_J$ = 125 °C | - | 83 | 130 | ns |
| Diode peak reverse current | $I_{rr}$ | | - | 15 | 20 | A |
| Diode reverse charge | $Q_{rr}$ | | - | 587 | 1300 | nC |
| **PFC DIODE D3 - D4** | | | | | | |
| Diode reverse recovery time | $t_{rr}$ | $V_R$ = 200 V<br>$I_F$ = 10 A<br>dI/dt = 200 A/µs, $T_J$ = 25 °C | - | 43 | - | ns |
| Diode peak reverse current | $I_{rr}$ | | - | 2.13 | - | A |
| Diode reverse charge | $Q_{rr}$ | | - | 45.5 | - | nC |
| Diode reverse recovery time | $t_{rr}$ | $V_R$ = 200 V<br>$I_F$ = 10 A<br>dI/dt = 200 A/µs, $T_J$ = 125 °C | - | 44 | - | ns |
| Diode peak reverse current | $I_{rr}$ | | - | 2.14 | - | A |
| Diode reverse charge | $Q_{rr}$ | | - | 46.5 | - | 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 PFC IGBT thermal resistance | $R_{thJC}$ | - | - | 0.37 | °C/W |
| Junction to case PFC diode thermal resistance | | - | - | 1.69 | |
| Junction to case AP diode thermal resistance | | - | - | 4.29 | |
| Case to sink, flat, greased surface (per module) | $R_{thCS}$ | - | 0.1 | - | |
| Mounting torque (M4) | | - | 2 | 3 | Nm |
| Weight | | - | 39 | - | g |

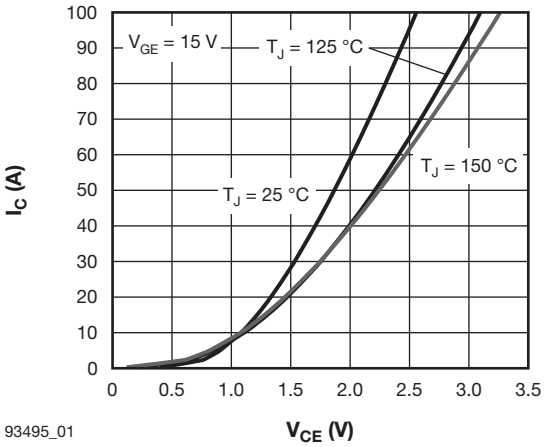



Fig. 1 - Typical PFC IGBT Output Characteristics

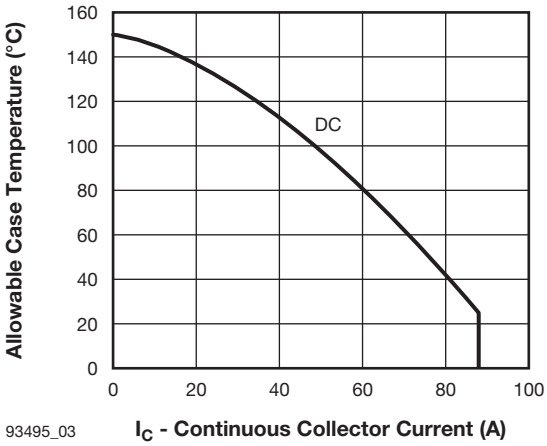



Fig. 3 - Maximum DC PFC IGBT Collector Current vs. Case Temperature per Junction

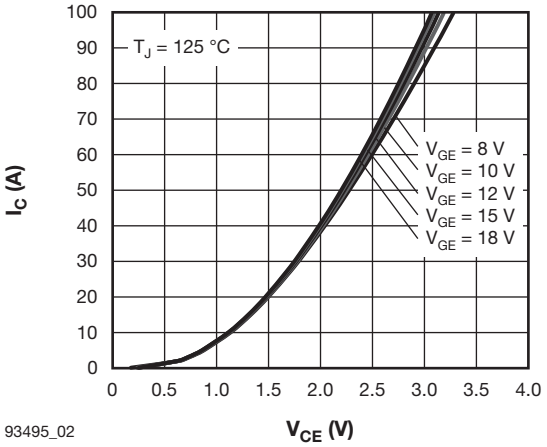



Fig. 2 - Typical PFC IGBT Output Characteristics

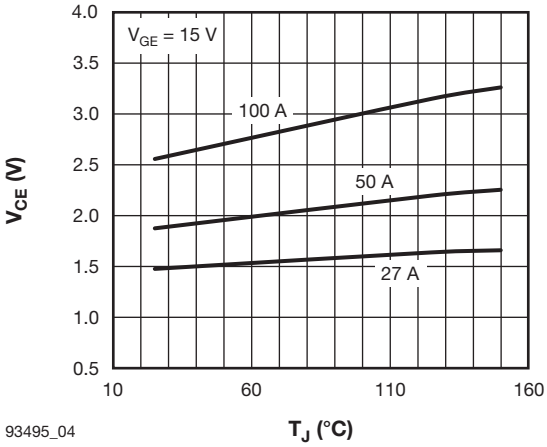



Fig. 4 - Typical PFC IGBT Collector to Emitter Voltage vs. Junction Temperature

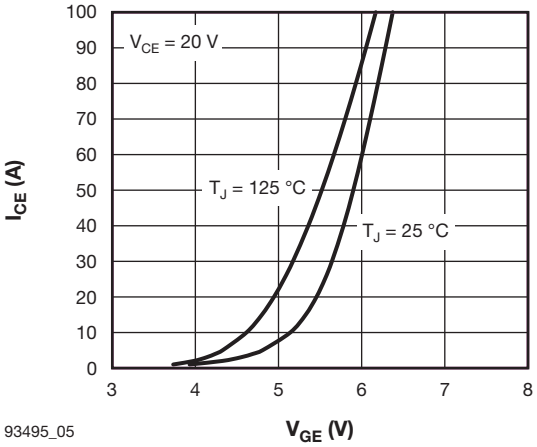



Fig. 5 - Typical PFC IGBT Transfer Characteristics

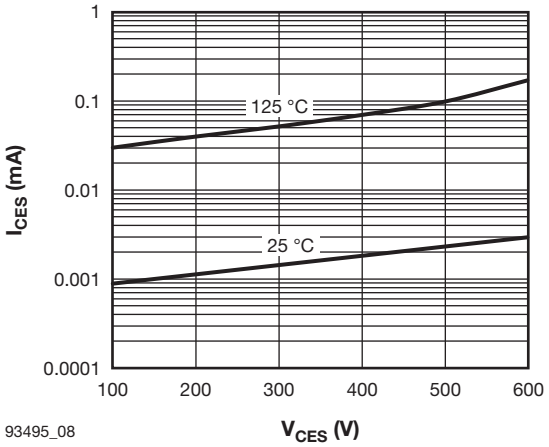



Fig. 8 - Typical PFC IGBT Zero Gate Voltage Collector Current

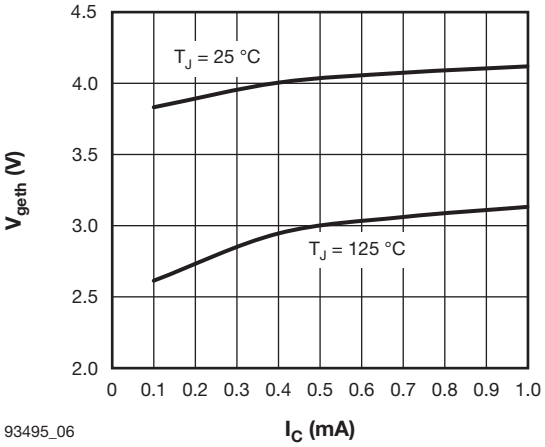



Fig. 6 - Typical PFC IGBT Gate Threshold Voltage

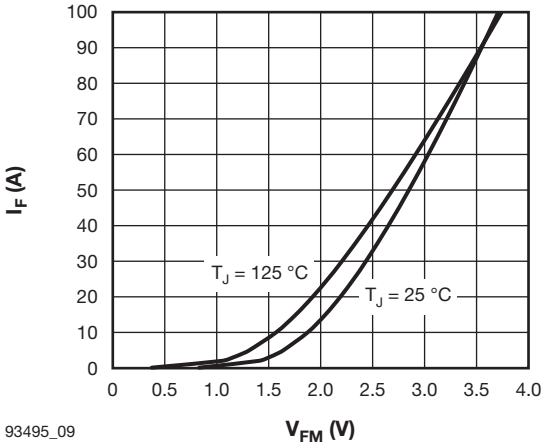



Fig. 9 - Typical Antiparallel Diode Forward Characteristics

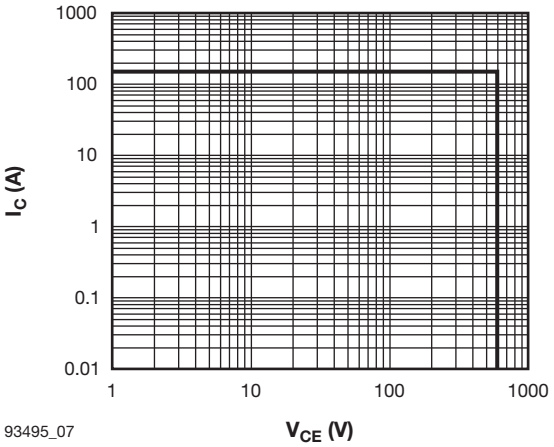



Fig. 7 - IGBT Reverse Bias SOA
$T_J$ = 150 °C, $V_{GE}$ = 15 V, $R_g$ = 22 Ω

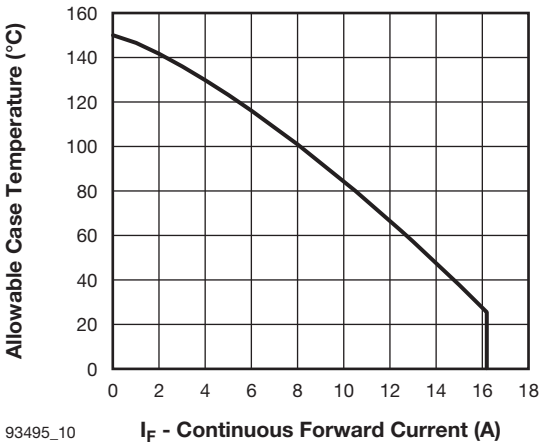



Fig. 10 - Maximum DC Antiparallel Diode Forward Current vs. Case Temperature per Junction

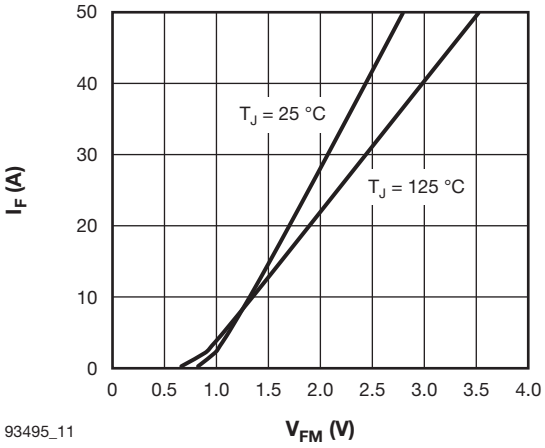



Fig. 11 - Typical PFC Diode Forward Characteristics

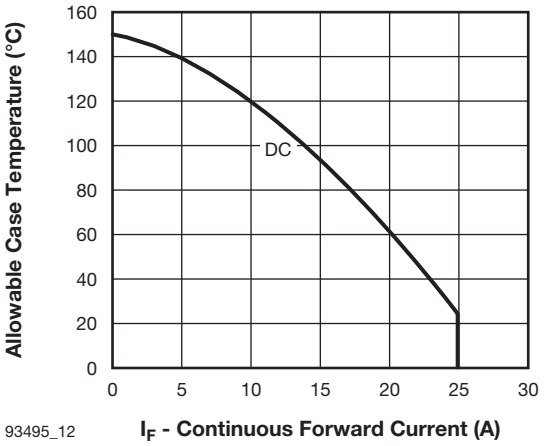



Fig. 12 - Maximum DC PFC Diode Forward Current vs. Case Temperature per Junction

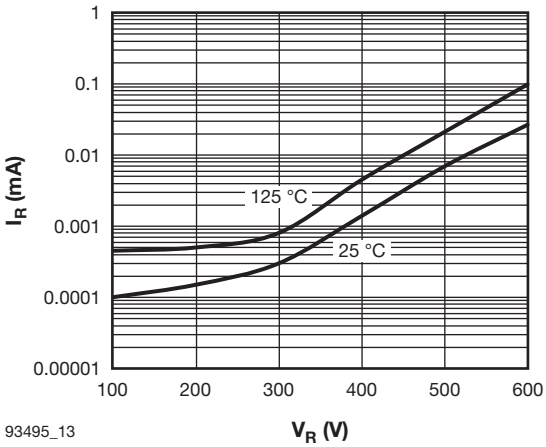



Fig. 13 - Typical PFC Diode Reverse Leakage Current

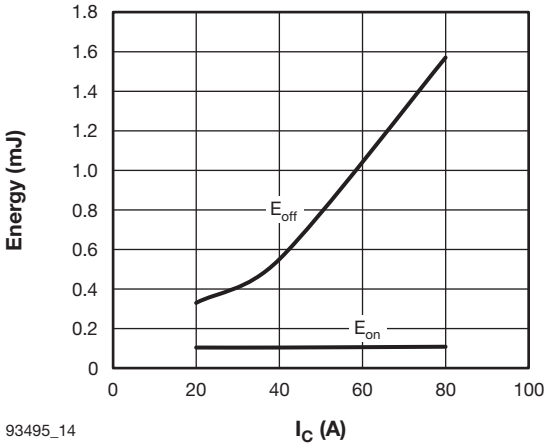



Fig. 14 - Typical PFC IGBT Energy Loss vs. $I_C$
(with Freewheeling D3 - D4 PFC Diode)
$T_J$ = 125 °C, $V_{CC}$ = 400 V, $R_g$ = 4.7 Ω, $V_{GE}$ = 15 V, L = 500 µH

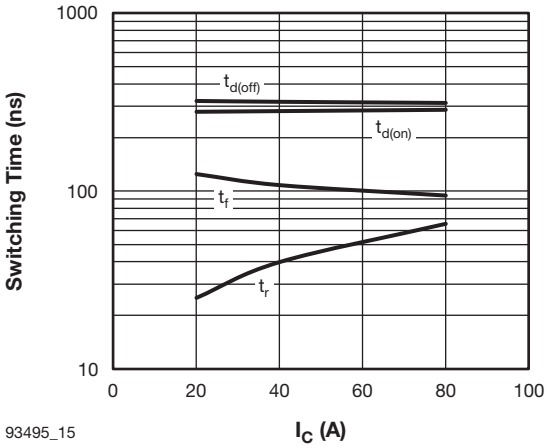



Fig. 15 - Typical PFC IGBT Switching Time vs. $I_C$
(with Freewheeling D3 - D4 PFC Diode)
$T_J$ = 125 °C, $V_{CC}$ = 400 V, $R_g$ = 4.7 Ω, $V_{GE}$ = 15 V, L = 500 µH

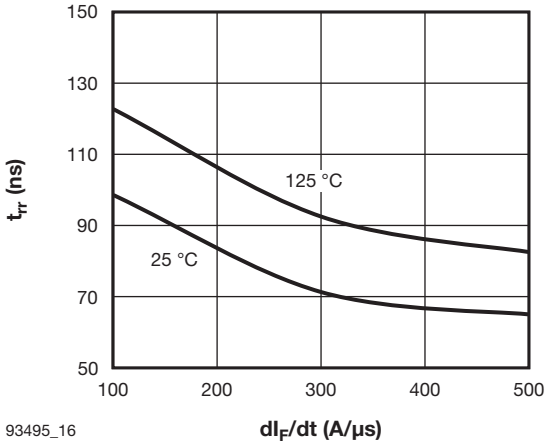



Fig. 16 - Typical Antiparallel Reverse Recovery Time vs. $dI_F/dt$
$V_R$ = 200 V, $I_F$ = 20 A

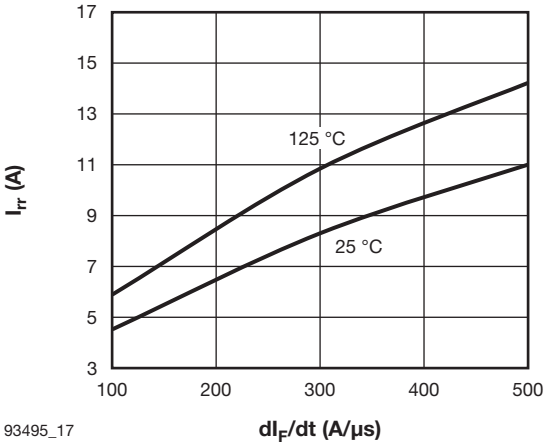



Fig. 17 - Typical Antiparallel Reverse Recovery Current vs. $dI_F/dt$
$V_R$ = 200 V, $I_F$ = 20 A

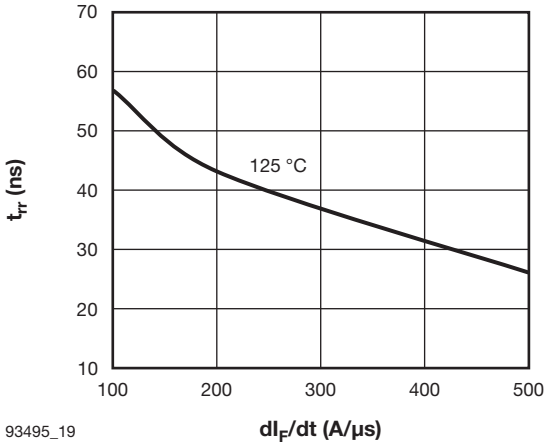



Fig. 19 - Typical PFC Diode Reverse Recovery Time vs. $dI_F/dt$
$V_R$ = 200 V, $I_F$ = 10 A

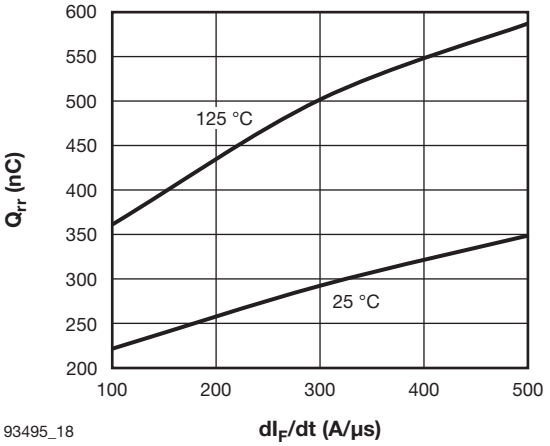



Fig. 18 - Typical Antiparallel Reverse Recovery Charge vs. $dI_F/dt$
$V_R$ = 200 V, $I_F$ = 20 A

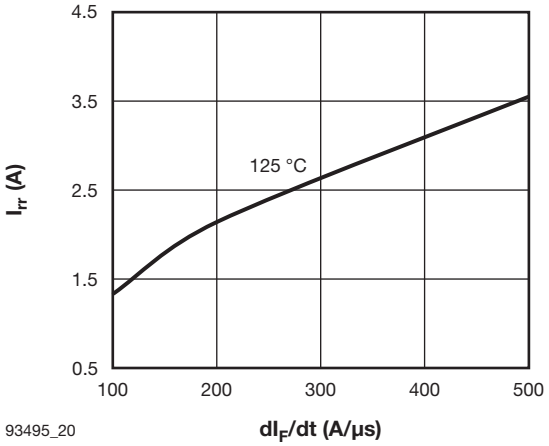



Fig. 20 - Typical PFC Diode Reverse Recovery Current vs. $dI_F/dt$
$V_R$ = 200 V, $I_F$ = 10 A

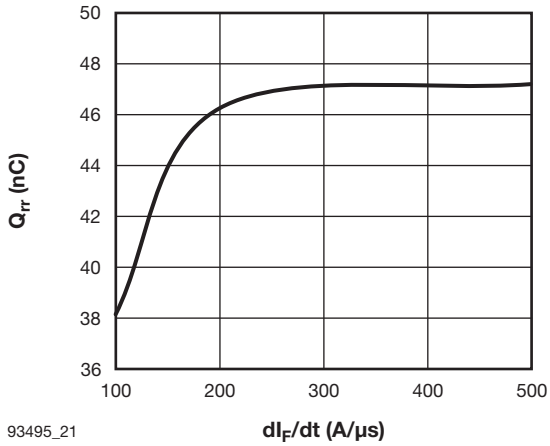



Fig. 21 - Typical PFC Diode Reverse Recovery Charge vs. $dI_F/dt$
$V_R$ = 200 V, $I_F$ = 10 A

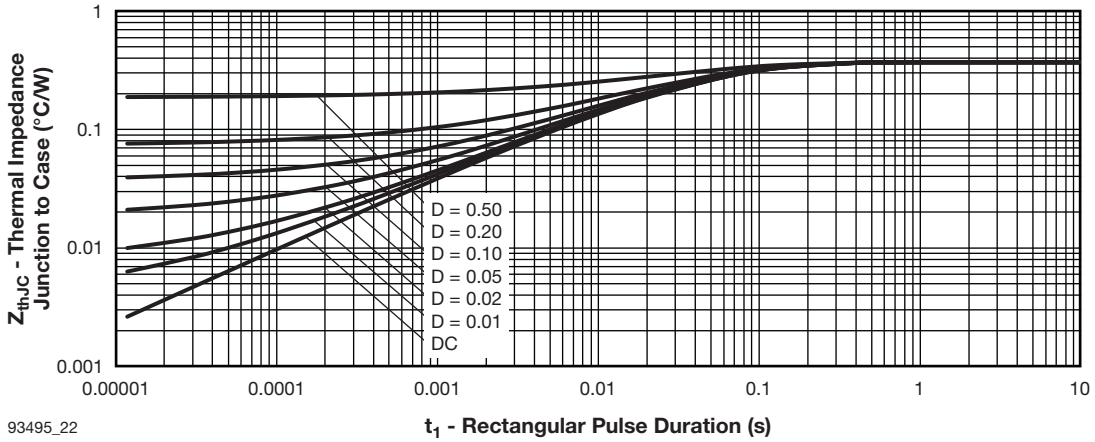



Fig. 22 - Maximum Thermal Impedance $Z_{thJC}$ Characteristics (IGBT)

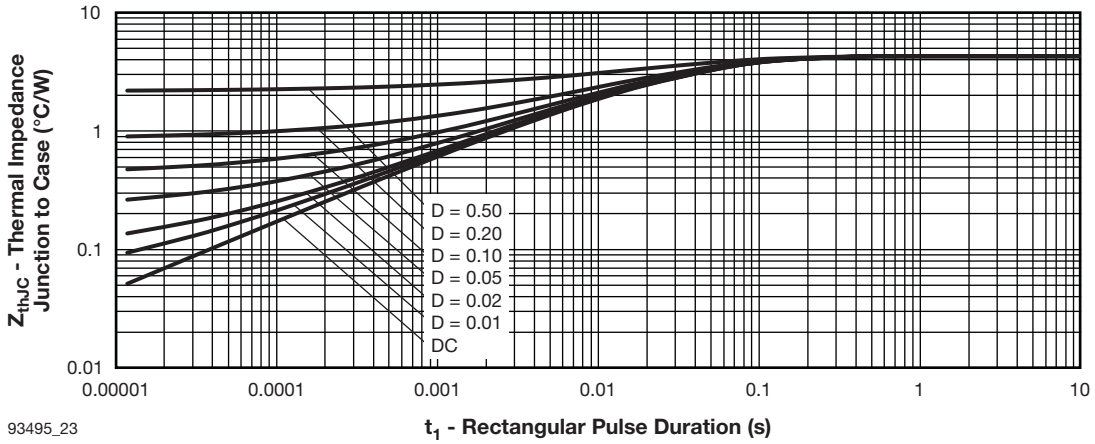



Fig. 23 - Maximum Thermal Impedance $Z_{thJC}$ Characteristics (Antiparallel Diode)

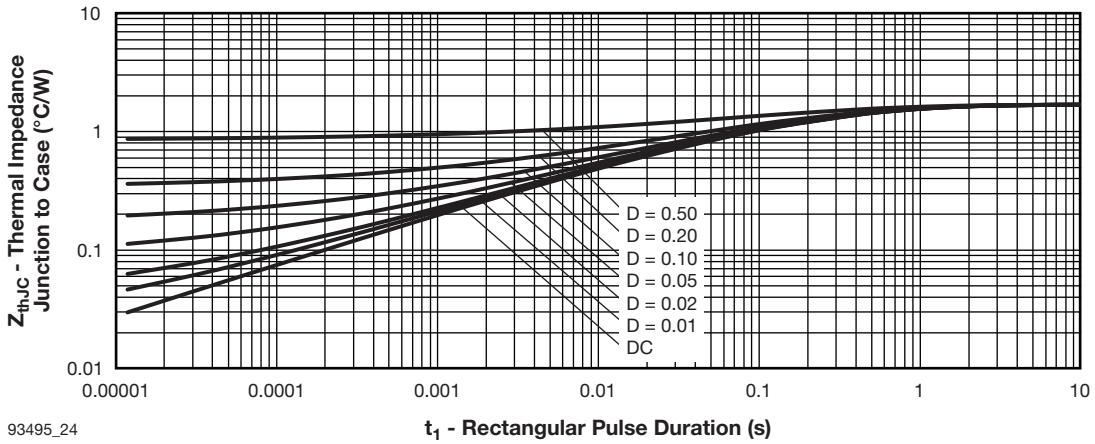



Fig. 24 - Maximum Thermal Impedance $Z_{thJC}$ Characteristics (PFC Diode)

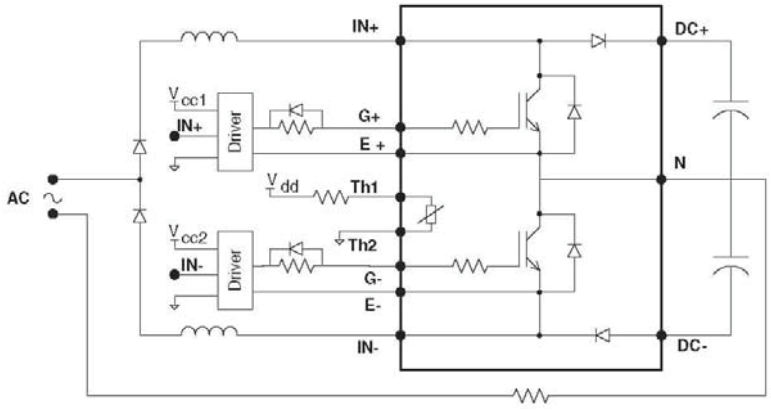
## ORDERING INFORMATION TABLE

Device code

| VS- | EM | G | 050 | J | 60 | N |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

| | | |
|---|---|---|
| 1 | - | Vishay Semiconductors product |
| 2 | - | Package indicator (EM = EMIPAK2) |
| 3 | - | Circuit configuration (G = Dual mode PFC) |
| 4 | - | Current rating (050 = 50 A) |
| 5 | - | Die technology (J = Warp2 IGBT) |
| 6 | - | Voltage rating (60 = 600 V) |
| 7 | - | N = Ultrafast |

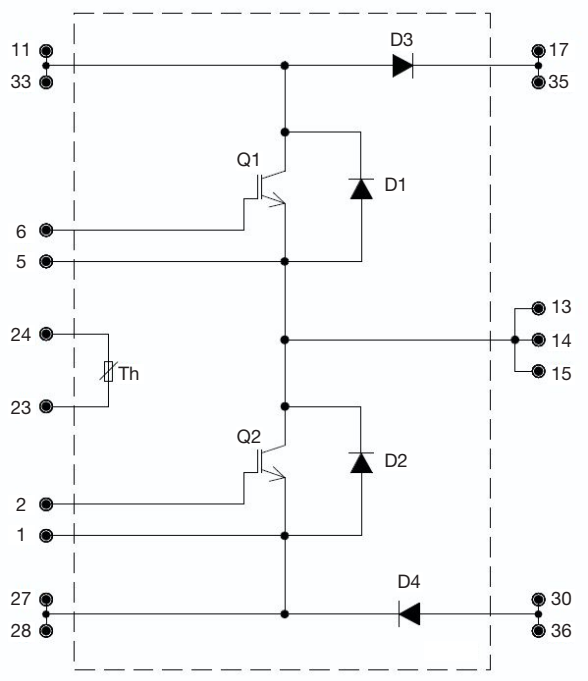
## TYPICAL CONNECTION



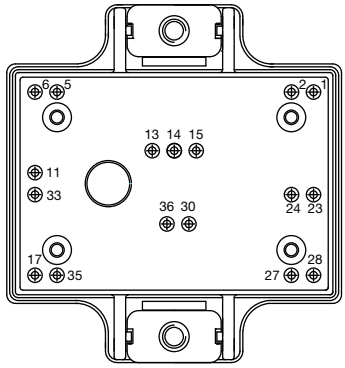

**Note**

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

## CIRCUIT CONFIGURATION



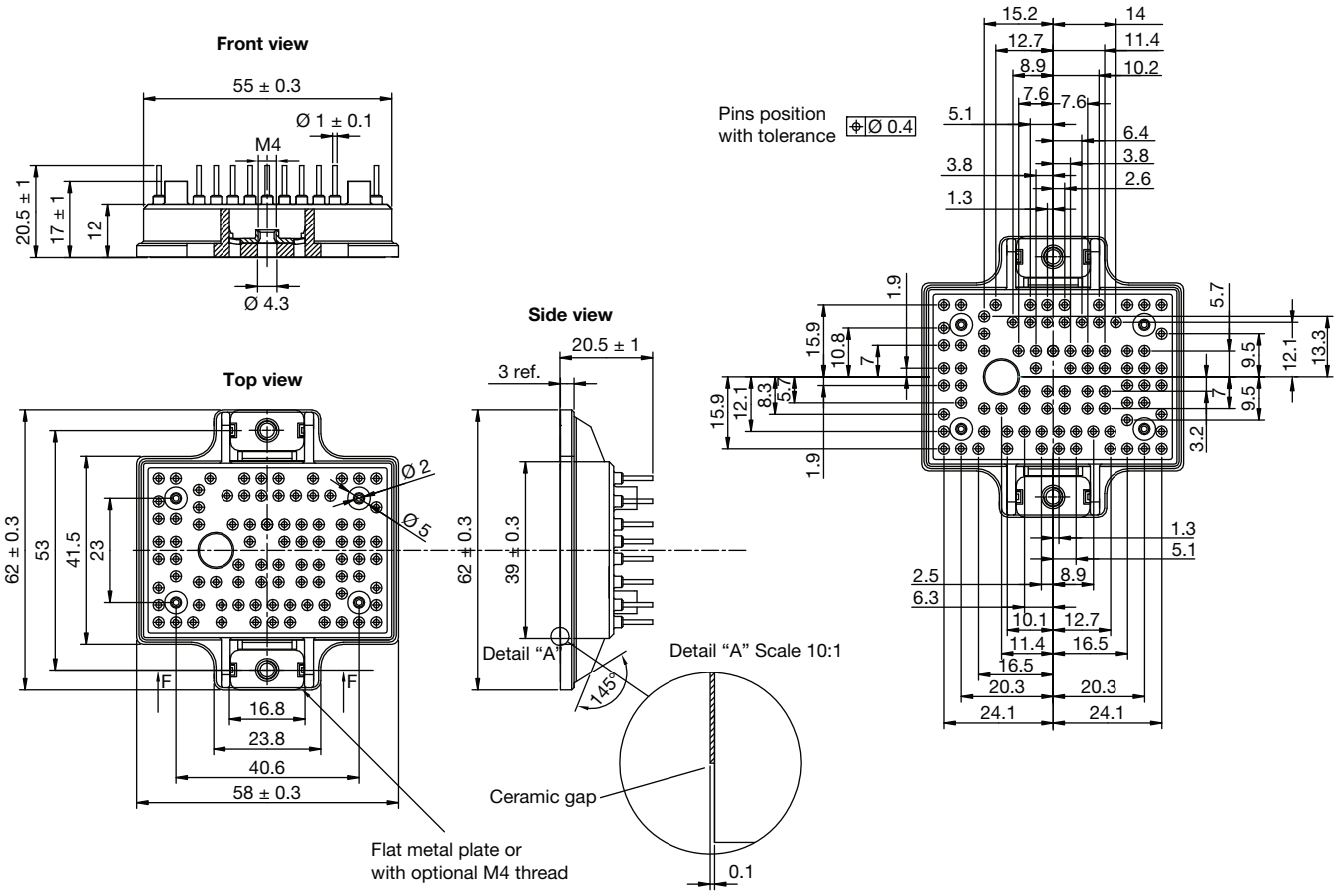

## PACKAGE




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

# EMIPAK2

**DIMENSIONS** in millimeters



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