International
IOR Rectifier

# EMP30P06D

iNTERO

## PIM+

## EMP Features:

- **Power Module:**
  - NPT IGBTs 30A, 600V
  - 10us Short Circuit capability
    - Square RBSOA
    - Low $Vce_{(on)}$ (2.05Vtyp @ 30A, 25°C)
    - Positive $Vce_{(on)}$ temperature coefficient
  - Gen III HexFred Technology
    - Low diode $V_F$ (1.34Vtyp @ 30A, 25°C)
    - Soft reverse recovery
  - 5mΩ sensing resistors on all phase outputs and DCbus minus rail
    - Thermal coefficient < 50ppm/°C

## Description

The EMP30P06D is a Power Integrated Module for Motor Driver applications with embedded sensing resistors on all three-phase output currents.

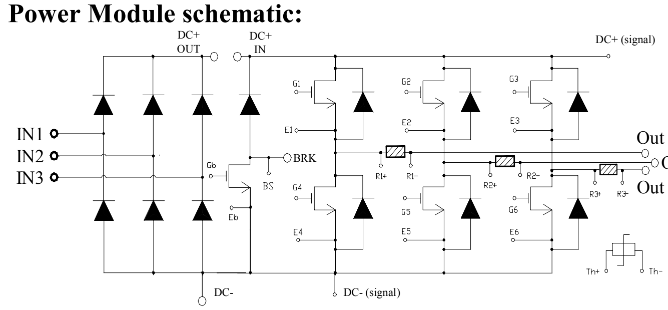
Each sensing resistor's head is directly bonded to an external pin to reduce parasitic effects and achieve high accuracy on feedback voltages.
Since their thermal coefficient is very low, no value compensation is required across the complete operating temperature range.

The device comes in the EMP™ package, fully compatible in length, width and height with EconoPack 2 outline.

**Package:**

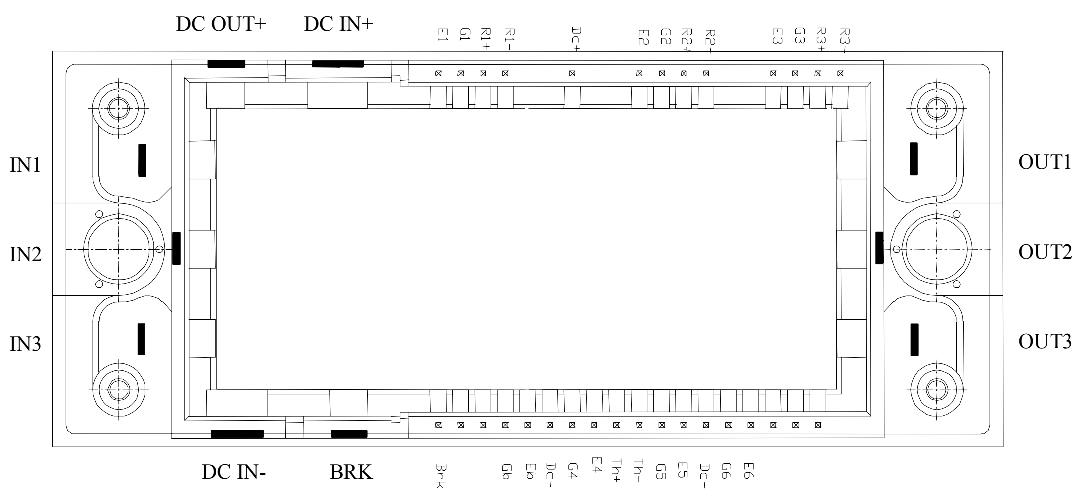

EMP – Bridge Brake inverter (EconoPack 2 outline compatible)

**Power Module schematic:**




Three phase bridge brake inverter with current sensing resistors on all output phases and thermistor

## Power module frame pins mapping



## Pins mapping

| Symbol | Lead Description |
|---|---|
| IN1/2/3 | Diode Bridge power input pins |
| DC OUT+ | DC Bus plus power output pin |
| DC IN+ | DC Bus plus power input pin |
| DC IN- | DC Bus minus power input pin |
| DC + | DC Bus plus signal connection (Kelvin point) |
| DC - | DC Bus minus signal connections (Kelvin points) |
| BRK | Brake power output pin |
| Brk | Brake signal connection (Kelvin point) |
| Th + | Thermal sensor positive input |
| Th - | Thermal sensor negative input |
| G1/2/3 | Gate connections for high side IGBTs |
| E1/2/3 | Emitter connections for high side IGBTs (Kelvin points) |
| Gb | Gate connection for brake IGBT (Kelvin point) |
| Eb | Emitter connection for brake IGBT (Kelvin point) |
| R1/2/3 + | Output current sensing resistor positive input (IGBTs emitters 1/2/3 side, Kelvin points) |
| R1/2/3 - | Output current sensing resistor negative input (Motor side, Kelvin points) |
| G4/5/6 | Gate connections for low side IGBTs |
| E4/5/6 | Emitter connections for low side IGBTs (Kelvin points) |
| OUT1/2/3 | Three phase power output pins |

## *General Description*

The EMP module contains six IGBTs and HexFreds Diodes in a standard inverter configuration. IGBTs used are the new NPT 600V-30A (current rating measured at 80C°), generation V from International Rectifier; the HexFred diodes have been designed specifically as pair elements for these power transistors. Thanks to the new design and technological realization, these devices do not need any negative gate voltage for their complete turn off; moreover the tail effect is also substantially reduced compared to competitive devices of the same family. This feature tremendously simplifies the gate driving stage. Another innovative feature in this type of power modules is the presence of sensing resistors in the three output phases, for precise motor current sensing and short circuit protections, as well as another resistor of the same value in the DC bus minus line, needed only for device protections purposes. A complete schematic of the EMP module is shown on page 1 where all sensing resistors have been clearly evidenced, a thermal sensor with negative temperature coefficient is also embedded in the device structure.

The package chosen is mechanically compatible with the well known EconoPack outline, Also the height of the plastic cylindrical nuts for the external PCB positioned on its top is the same as the EconoPack II, so that, with the only re-layout of the main motherboard, this module can fit into the same mechanical fixings of the standard EconoPack II package thus speeding up the device evaluation in an already existing driver. An important feature of this new device is the presence of Kelvin connections for all feedback and command signals between the board and the module with the advantage of having all emitter and resistor sensing independent from the main power path. The final benefit is that all low power signal from/to the controlling board are unaffected by parasitic inductances or resistances inevitably present in the module power layout. The new package outline is shown on bottom of page 1. Notice that because of high current spikes on those inputs the DC bus power pins are doubled in size compared to the other power pins. Module technology uses the standard and well know DBC (Direct Bondable Copper): over a thick Copper base an allumina ($Al_2O_3$) substrate with a 300µm copper foil on both side is placed and IGBTs and Diodes dies are directly soldered, through screen printing process. These dies are then bonded with a 15 mils aluminum wire for power and signal connections. All components are then completely covered by a silicone gel for mechanical protection and electrical isolation purposes.

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## Absolute Maximum Ratings ($T_C$=25ºC)

Absolute Maximum Ratings indicate sustained limits beyond which damage to the device may occur.
All voltage parameters are absolute voltages referenced to $V_{DC-}$, all currents are defined positive into any lead.
Thermal Resistance and Power Dissipation ratings are measured at still air conditions.

| | Symbol | Parameter Definition | | Min. | Max. | Units |
|---|---|---|---|---|---|---|
| **Inverter and Brake** | $V_{DC}$ | DC Bus Voltage | | 0 | 500 | V |
| | $V_{CES}$ | Collector Emitter Voltage | | 0 | 600 | |
| | $I_{C\ @\ 100°C}$ | IGBTs continuous collector current ($T_C$ = 100 °C, fig. 1) | | | 25 | A |
| | $I_{C\ @\ 80°C}$ | IGBTs continuous collector current ($T_C$ = 80 °C,fig 1) | | | 30 | |
| | $I_{C\ @\ 25°C}$ | IGBTs continuous collector current ($T_C$ = 25 °C,fig 1) | | | 45 | |
| | $I_{CM}$ | Pulsed Collector Current (Fig. 3, Fig. CT.5) | | | 90 | |
| | $I_{F\ @\ 100°C}$ | Diode Continuous Forward Current ($T_C$ = 100 °C) | | | 25 | |
| | $I_{F\ @\ 25°C}$ | Diode Continuous Forward Current ($T_C$ = 25 °C) | | | 45 | |
| | $I_{FM}$ | Diode Maximum Forward Current | | | 90 | |
| | $V_{GE}$ | Gate to Emitter Voltage | | -20 | +20 | V |
| | $P_{D\ @\ 25°C}$ | Power Dissipation (One transistor) | | | 138 | W |
| | $P_{D\ @\ 100°C}$ | Power Dissipation (One transistor, $T_C$ = 100 °C) | | | 55 | |
| **Bridge** | $V_{RRM}$ | repetitive peak reverse voltage ($T_j$ = 150 °C) | | | 1400 | V |
| | $V_{RSM}$ | non repetitive peak reverse voltage | | | 1500 | |
| | $I_o$ | Diode Continuous Forward Current ($T_C$ = 100 °C, 120° Rect conduction angle) | | | 45 | A |
| | $I_{FSM}$ | One-cycle forward. Non-repetitive on state surge current (t=10ms, Initial $T_j$=150°C) | 100% $V_{RRM}$ reapplied | | 225 | |
| | | | No voltage reapplied | | 270 | |
| | $I^2t$ | Current $I^2t$ for fusing (t=10ms, Initial $T_j$=150°C) | 100% $V_{RRM}$ reapplied | | 253 | $A^2s$ |
| | | | No voltage reapplied | | 365 | |
| | $I^2\sqrt{t}$ | Current $I^2\sqrt{t}$ for fusing (t=0.1 to 10ms, no voltage reapplied, Initial $T_j$ = 150°C) | | | 3650 | $A^2\sqrt{s}$ |
| **Power Module** | MT | Mounting Torque | | | 3.5 | Nm |
| | $T_J$ | Operating Junction Temperature | | -40 | +150 | ºC |
| | $T_{STG}$ | Storage Temperature Range | | -40 | +125 | |
| | Vc-iso | Isolation Voltage to Base Copper Plate | | -2500 | +2500 | V |

## Electrical Characteristics: Inverter and Brake

For proper operation the device should be used within the recommended conditions.

**$T_J$ = 25°C (unless otherwise specified)**

| Symbol | Parameter Definition | Min. | Typ. | Max. | Units | Test Conditions | Fig. |
|---|---|---|---|---|---|---|---|
| $V_{(BR)CES}$ | Collector To Emitter Breakdown Voltage | 600 | | | V | $V_{GE}$ = 0V, $I_C$ = 250µA | |
| $\Delta V_{(BR)CES / \Delta T}$ | Temperature Coeff. of Breakdown Voltage | | 0.67 | | V/°C | $V_{GE}$ = 0V, $I_C$ = 1mA (25 - 125 °C) | |
| $V_{CE(on)}$ | Collector To Emitter Saturation Voltage | | 1.91 | 2.2 | V | $I_C$ = 25A, $V_{GE}$ = 15V | 5, 6 |
| | | | 2.46 | 2.87 | | $I_C$ = 45A, $V_{GE}$ = 15V | 7, 9 |
| | | | 2.19 | 2.55 | | $I_C$ = 25A, $V_{GE}$ = 15V, $T_J$ = 125 °C | 10, 11 |
| $V_{GE(th)}$ | Gate Threshold Voltage | 4 | 4.46 | 5 | V | $V_{CE}$ = $V_{GE}$, $I_C$ = 250µA | 12 |
| $\Delta V_{GE(th) / \Delta Tj}$ | Temp. Coeff. of Threshold Voltage | | -10 | | mV/°C | $V_{CE}$ = $V_{GE}$, $I_C$ = 1mA (25 – 125 °C) | |
| $g_{fe}$ | Forward Trasconductance | | 18 | | S | $V_{CE}$ = 50V, $I_C$ = 30A | |
| $I_{CES}$ | Zero Gate Voltage Collector Current | | | 250 | µA | $V_{GE}$ = 0V, $V_{CE}$ = 600V | |
| | | | 368 | 580 | | $V_{GE}$ = 0V, $V_{CE}$ = 600V, $T_J$ = 125 °C | |
| | | | | 2000 | | $V_{GE}$ = 0V, $V_{CE}$ = 600V, $T_J$ = 150 °C | |
| $V_{FM}$ | Diode Forward Voltage Drop | | 1.29 | 1.48 | V | $I_C$ = 25A | 8 |
| | | | 1.25 | 1.5 | | $I_C$ = 25A, $T_J$ = 125 °C | |
| $I_{GES}$ | Gate To Emitter Leakage Current | | | ±100 | nA | $V_{GE}$ =± 20V | |
| R1/2/3 | Sensing Resistors | 4.95 | 5 | 5.05 | mΩ | | |

## Electrical Characteristics: Bridge

For proper operation the device should be used within the recommended conditions.

**$T_J$ = 25°C (unless otherwise specified)**

| Symbol | Parameter Definition | Min. | Typ. | Max. | Units | Test Conditions | Fig. |
|---|---|---|---|---|---|---|---|
| $V_{FM}$ | Forward Voltage Drop | | | 1.45 | V | $t_p$ = 400µs, $I_{pk}$ = 45A | 24 |
| $V_{F(TO)}$ | Threshold voltage | | 0.78 | | V | $T_J$ = 125 °C | |
| $I_{rm}$ | Reverse Leakage Current | | | 5 | mA | $T_J$ = 125 °C   $V_R$ = 1200V | |

## Switching Characteristics: Inverter and Brake

For proper operation the device should be used within the recommended conditions.

**$T_J$ = 25°C (unless otherwise specified)**

| Symbol | Parameter Definition | Min | Typ | Max | Units | Test Conditions | Fig. |
|---|---|---|---|---|---|---|---|
| $Q_g$ | Total Gate Charge (turn on) | | 102 | 153 | nC | $I_C$ = 30A | 23 |
| $Q_{ge}$ | Gate – Emitter Charge (turn on) | | 14 | 21 | | $V_{CC}$ = 400V | |
| $Q_{gc}$ | Gate – Collector Charge (turn on) | | 44 | 66 | | $V_{GE}$ = 15V | CT1 |
| $E_{on}$ | Turn on Switching Loss | | 0.469 | 0.779 | mJ | $I_C$ = 30A, $V_{CC}$ = 400V, $T_J$ = 25 °C | CT4 |
| $E_{off}$ | Turn off Switching Loss | | 0.338 | 0.507 | | $V_{GE}$ = 15V, $R_G$ =10Ω, L = 800µH | WF1 |
| $E_{tot}$ | Total Switching Loss | | 0.807 | 1.281 | | Tail and Diode Rev. Recovery included | WF2 |
| $E_{on}$ | Turn on Switching Loss | | 0.631 | 0.946 | mJ | $I_C$ = 30A, $V_{CC}$ = 400V, $T_J$ = 125 °C | 13, 15 |
| $E_{off}$ | Turn off Switching Loss | | 0.604 | 0.906 | | $V_{GE}$ = 15V, $R_G$ =10Ω, L = 800µH | CT4 WF1 |
| $E_{tot}$ | Total Switching Loss | | 1.235 | 1.852 | | Tail and Diode Rev. Recovery included | WF2 |
| td (on) | Turn on delay time | | 101 | 152 | ns | $I_C$ = 30A, $V_{CC}$ = 400V, $T_J$ = 125 °C | 14,16 |
| Tr | Rise time | | 25 | 38 | | | CT4 |
| td (off) | Turn off delay time | | 130 | 195 | | $V_{GE}$ = 15V, $R_G$ =10Ω, L = 800µH | WF1 |
| Tf | Fall time | | 105 | 156 | | | WF2 |
| $C_{ies}$ | Input Capacitance | | 1750 | | pF | $V_{CC}$ = 30V | 22 |
| $C_{oes}$ | Output Capacitance | | 160 | | | $V_{GE}$ = 0V | |
| $C_{res}$ | Reverse Transfer Capacitance | | 60 | | | f = 1MHz | |
| RBSOA | Reverse Bias Safe Operating Area | FULL SQUARE | | | | $T_J$ = 150 °C, $I_C$ =90A, $V_{GE}$ = 15V to 0V<br>$V_{CC}$ = 500V, $V_p$ = 600V, $R_G$ = 10Ω | 4<br>CT2 |
| SCSOA | Short Circuit Safe Operating Area | 10 | | | µs | $T_J$ = 150 °C, $V_{GE}$ = 15V to 0V<br>$V_{CC}$ = 360V, Vp= 600V, $R_G$ = 10Ω | CT3<br>WF4 |
| $E_{REC}$ | Diode reverse recovery energy | | 925 | 1165 | µJ | $T_J$ = 125 °C | 17,18 19,20 |
| Trr | Diode reverse recovery time | | 77 | | ns | $I_F$= 30A, $V_{CC}$ = 400V, | 21 CT4 |
| Irr | Peak reverse recovery current | | 62 | 93 | A | $V_{GE}$ = 15V, $R_G$ =10Ω, L = 800µH | WF3 |
| $Rth_{J-C\_T}$ | Each IGBT to copper plate thermal resistance | | 0.806 | 0.9 | °C/W | See also fig. 25 and 26 | |
| $Rth_{J-C\_D}$ | Each Diode to copper plate thermal resistance | | 1.06 | 1.22 | °C/W | | |
| $Rth_{C-H}$ | Module copper plate to heat sink thermal resistance. Silicon grease applied = 0.1mm | | 0.03 | | °C/W | | |
| Pdiss | Total Dissipated Power | | 23 | | W | $I_C$ = 3.3A, $V_{DC}$ = 300V, fsw = 8kHz, $T_C$ = 55 °C | PD1 |
| | | | 40 | | | $I_C$ = 6A, $V_{DC}$ = 300V, fsw = 8kHz, $T_C$ = 55 °C | PD2 |
| | | | 61 | | | $I_C$ = 6A, $V_{DC}$ = 300V, fsw = 16kHz $T_C$ = 55 °C, | |
| | | | 95 | | | $I_C$ = 14A, $V_{DC}$ = 300V, fsw = 4kHz, $T_C$ = 55°C | PD3 |

Fig. 1 – Maximum DC collector Current vs. case temperature

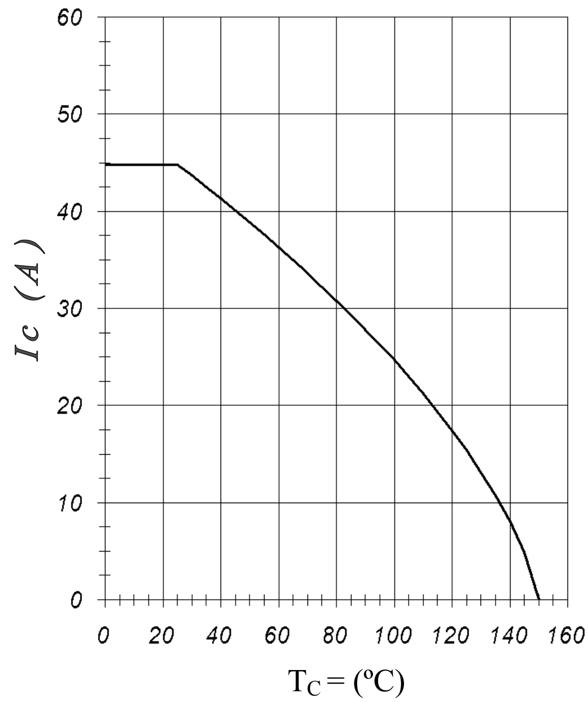



Fig. 2 – Power Dissipation vs. Case Temperature

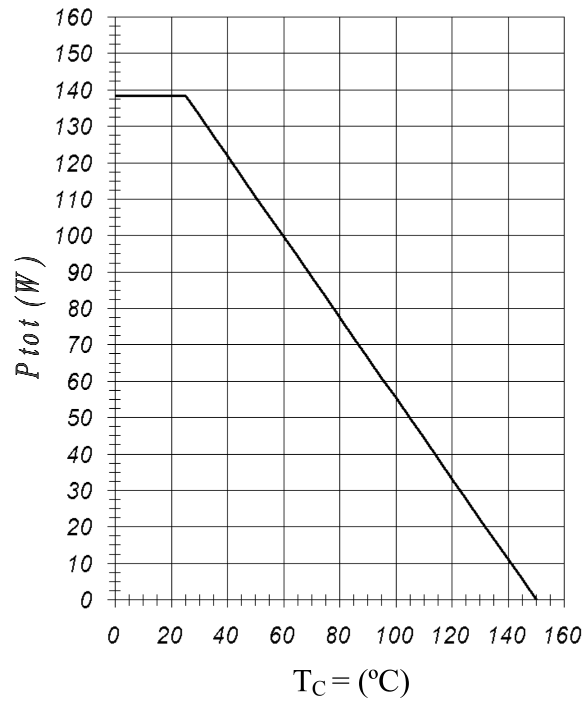



Fig. 3 – Forward SOA
$T_C$ = 25ºC; Tj ≤ 150ºC

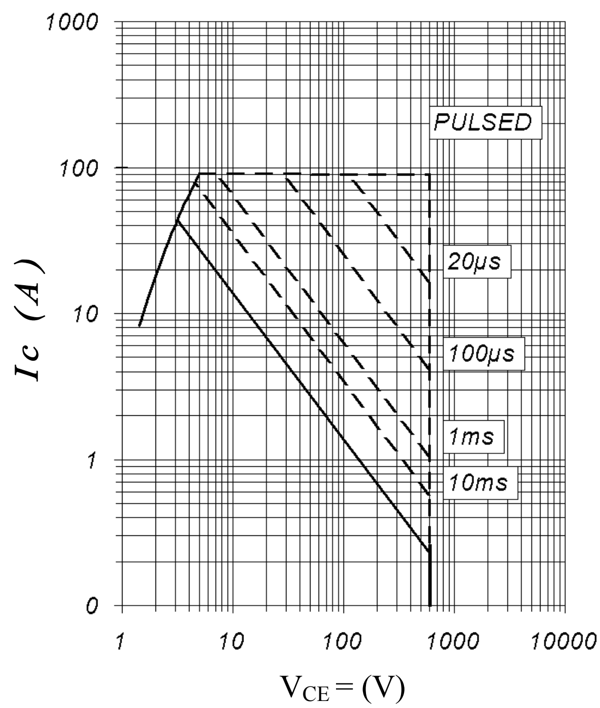



Fig. 4 – Reverse Bias SOA
Tj = 150ºC, $V_{GE}$ = 15V

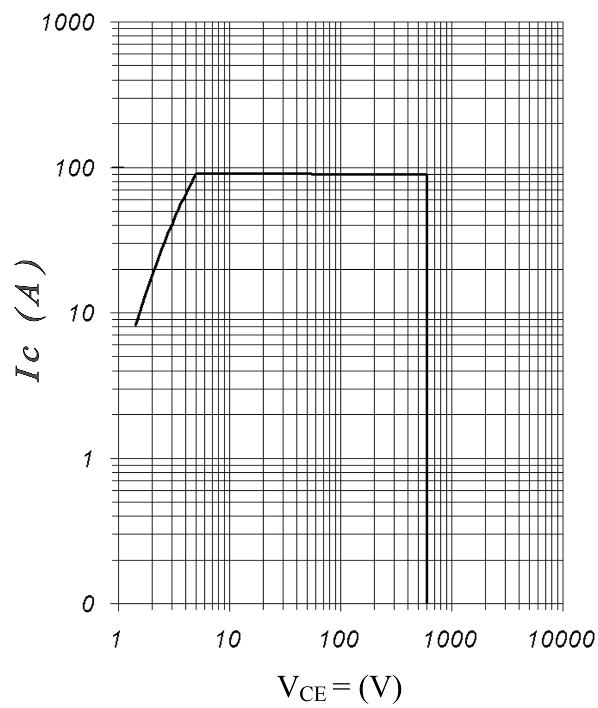


Fig. 5 – Typical IGBT Output Characteristics
Tj = - 40ºC; tp = 500µs

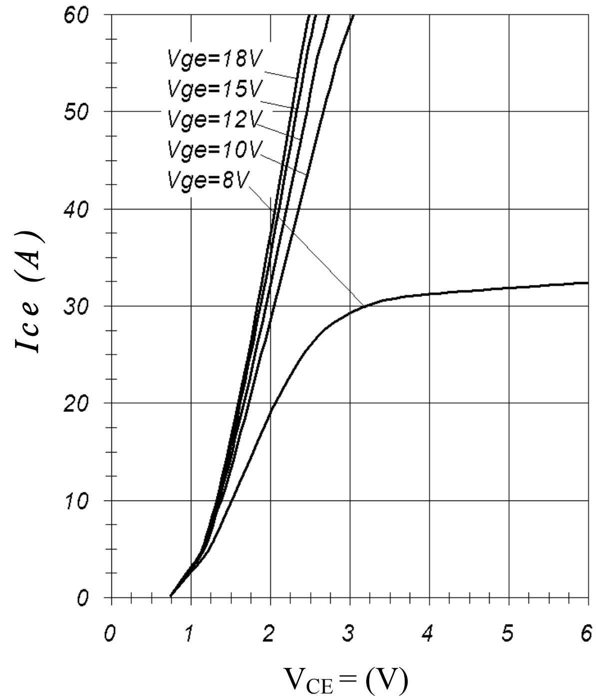



Fig. 6 – Typical IGBT Output haracteristics
Tj = 25ºC; tp = 500µs

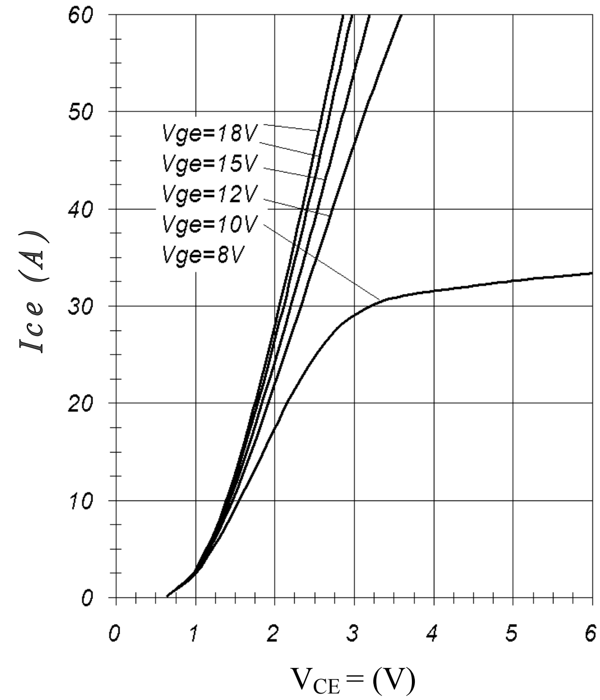



Fig. 7 – Typical IGBT Output Characteristics
Tj = 125ºC; tp = 500µs

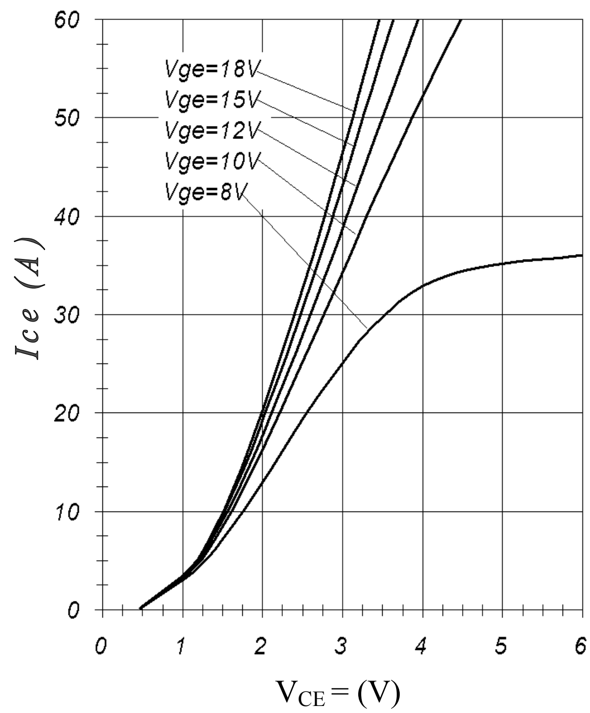



Fig. 8 – Typical Diode Forward
Characteristics tp = 500µs

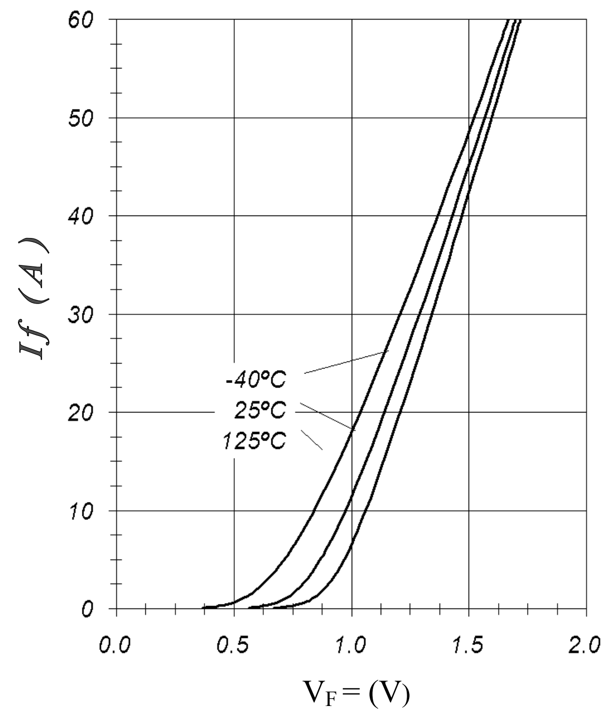
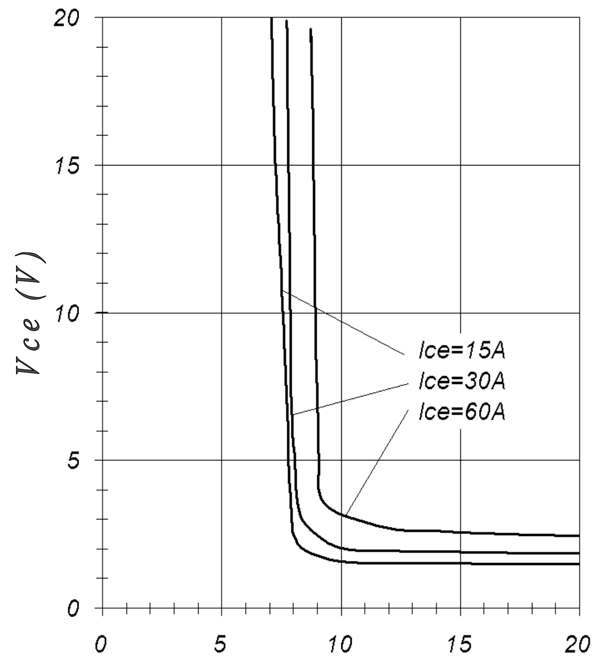
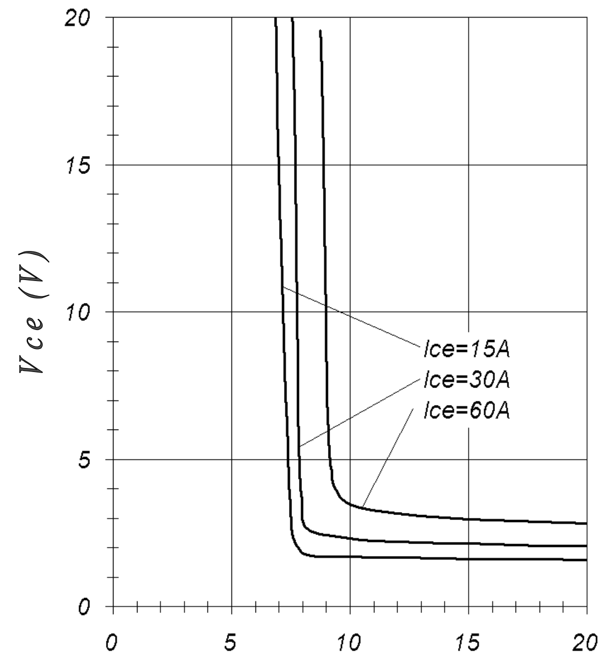


Fig. 9 – Typical $V_{CE}$ vs. $V_{GE}$
Tj = - 40ºC



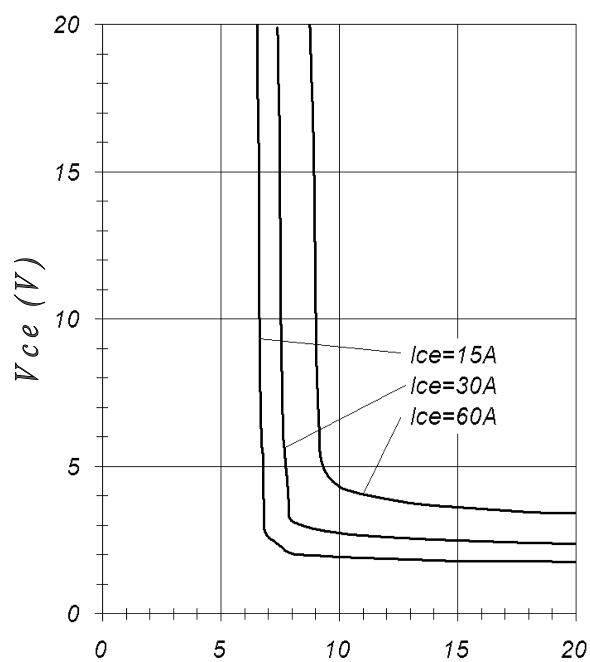

$V_{GE}$ = (V)

Fig. 10 – Typical $V_{CE}$ vs. $V_{GE}$
Tj = 25ºC



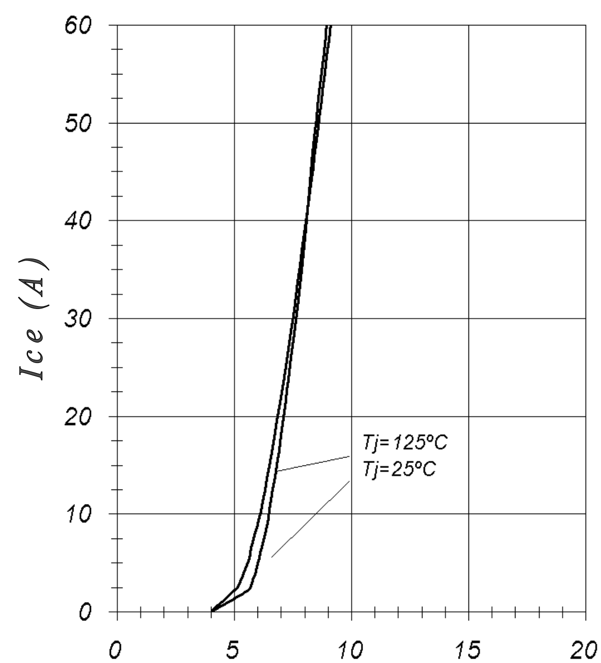

$V_{GE}$ = (V)

Fig. 11 – Typical $V_{CE}$ vs. $V_{GE}$
Tj = 125ºC



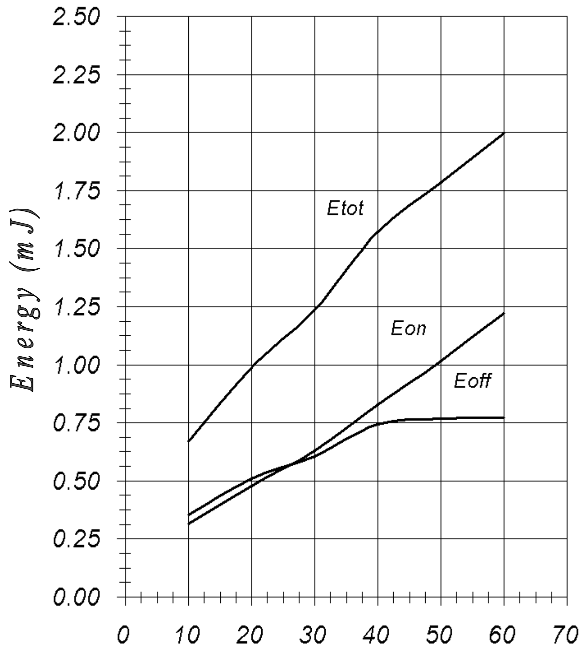

$V_{GE}$ = (V)

Fig. 12 – Typical Transfer Characteristics
$V_{CE}$ = 20V; tp = 20µs



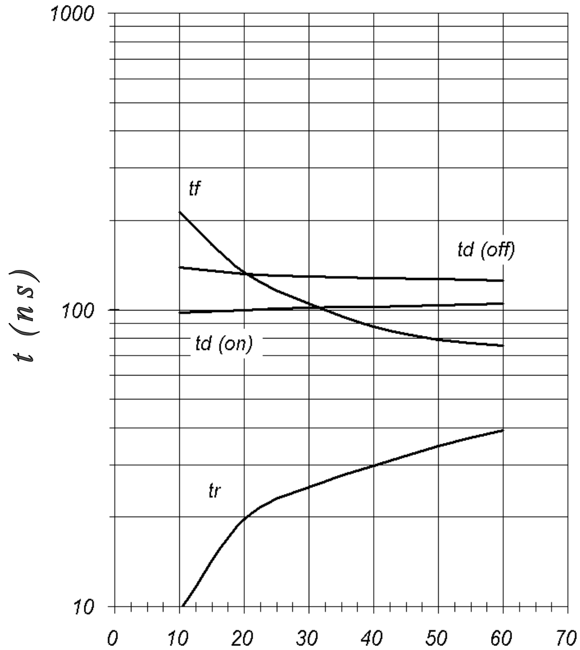

$V_{GE}$ = (V)

Fig. 13 – Typical Energy Loss vs. $I_C$
Tj = 125ºC; L = 800µH; $V_{CE}$ = 400V;
Rg = 10Ω; $V_{GE}$ = 15V



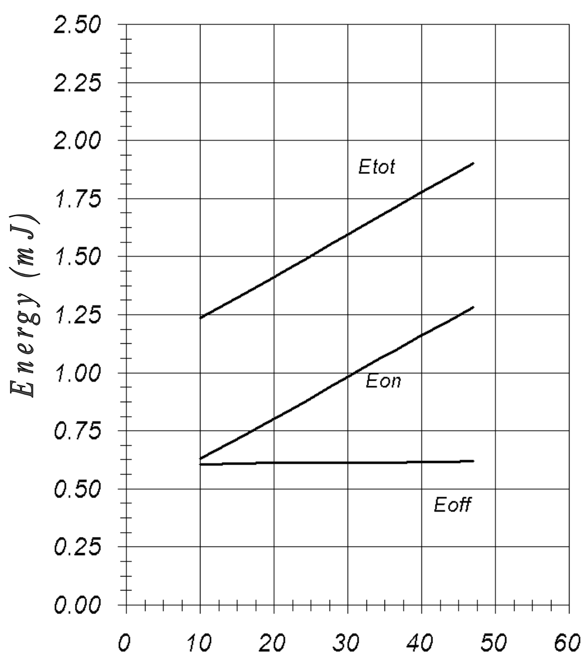

$I_C$ = (A)

Fig. 14 – Typical Switching Time vs. $I_C$
Tj = 125ºC; L = 800µH; $V_{CE}$ = 400V;
Rg = 10Ω; $V_{GE}$ =15V



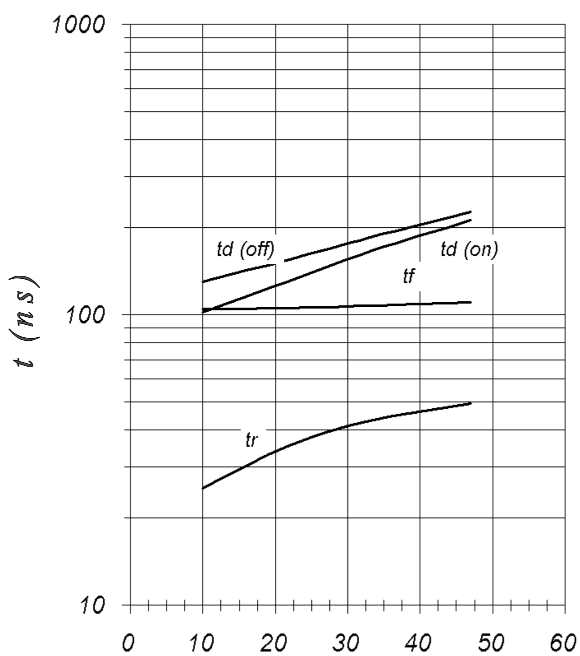

$I_C$ = (A)

Fig. 15 – Typical Energy Loss vs. Rg
Tj = 125ºC; L = 800µH; $V_{CE}$ = 400V;
$I_{CE}$ = 30A; $V_{GE}$ = 15V



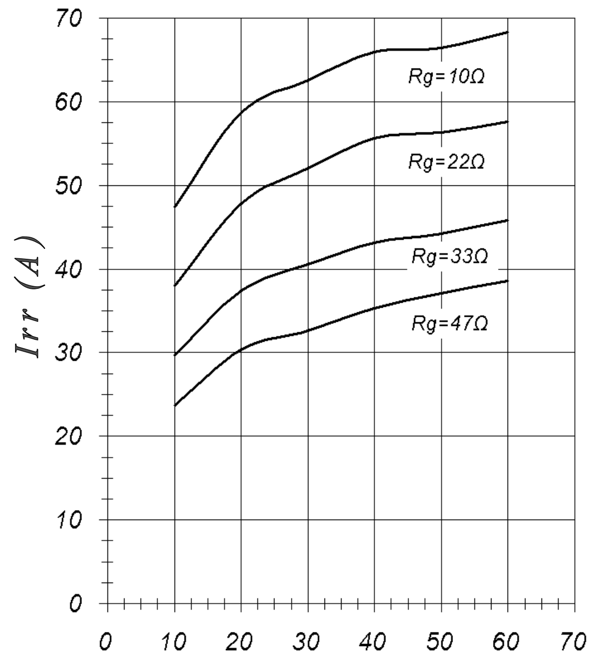

Rg = (Ω)

Fig. 16 – Typical Switching Time vs. Rg
Tj = 125ºC; L = 800µH; $V_{CE}$ = 400V;
$I_{CE}$ = 30A; $V_{GE}$ = 15V



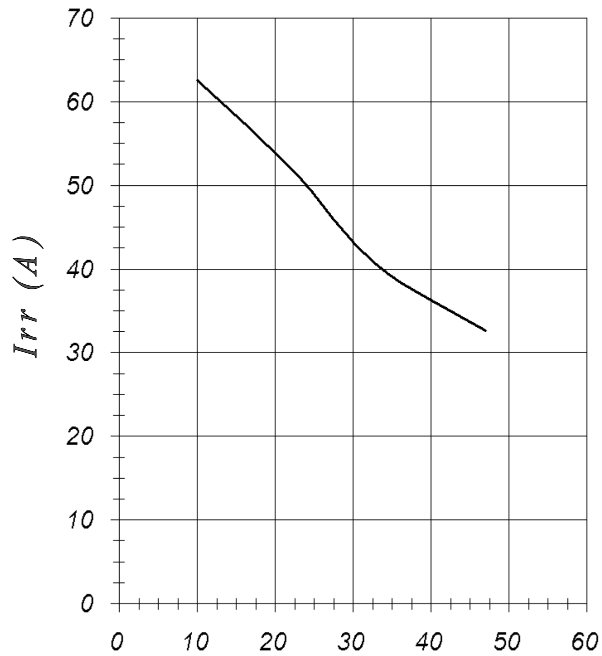

Rg = (Ω)

Fig. 17 – Typical Diode $I_{RR}$ vs. $I_F$
Tj = 125ºC



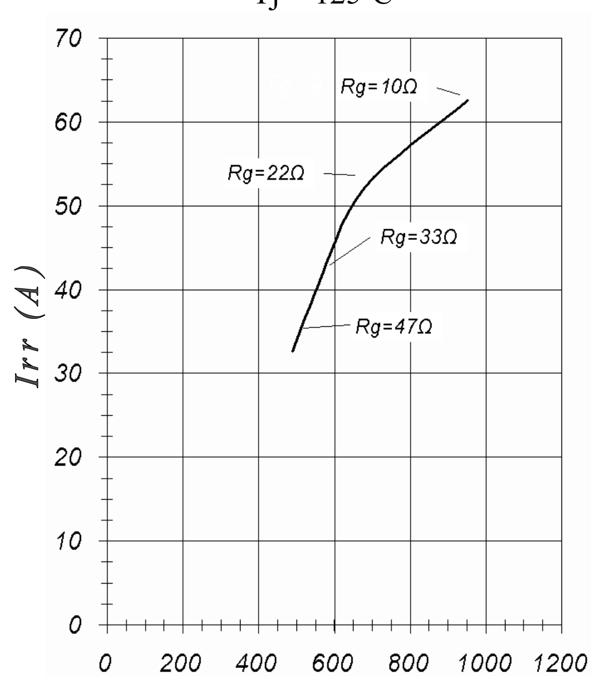

$I_F$ = (A)

Fig. 18 – Typical Diode $I_{RR}$ vs. Rg
$I_F$ = 30A; Tj = 125ºC



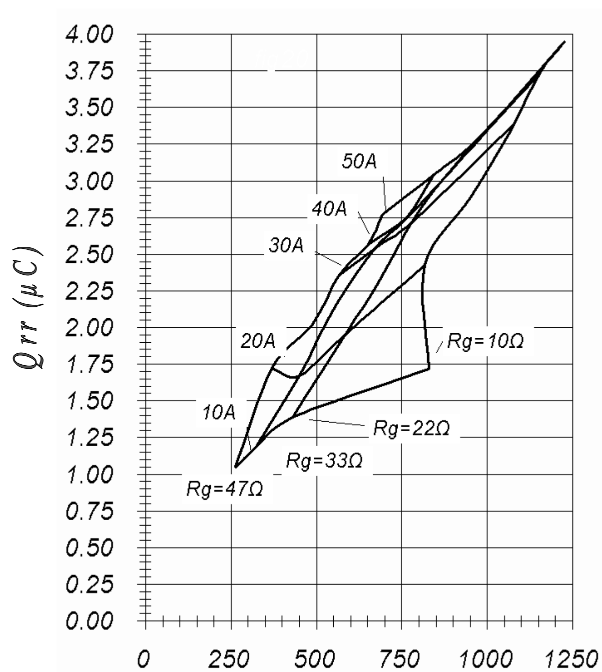

Rg = (Ω)

Fig. 19 – Typical Diode $I_{RR}$ vs. $dI_F/dt$
$V_{DC}$ = 400V; $V_{GE}$ = 15V; $I_F$ = 30A;
Tj = 125ºC



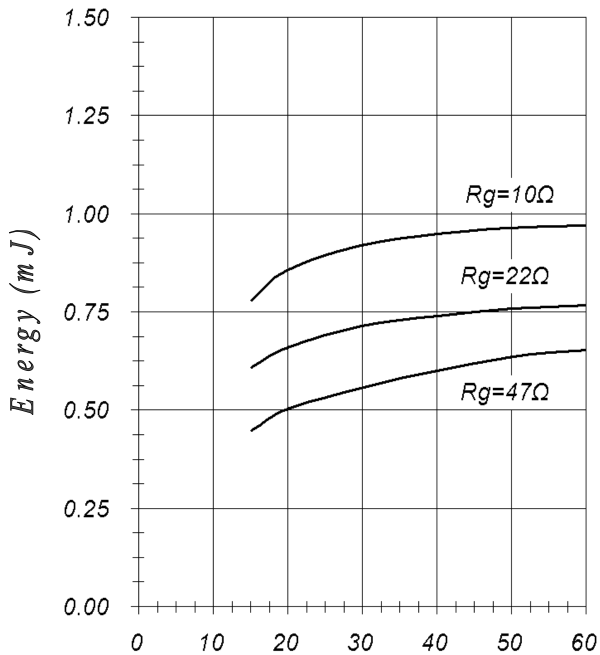

$dI_F/dt$ (A/µs)

Fig. 20 – Typical Diode $Q_{RR}$
$V_{DC}$ = 400V; $V_{GE}$ = 15V; Tj = 125ºC




$dI_F/dt$ (A/µs)

Fig. 21 – Typical Diode $E_{REC}$ vs. $I_F$
Tj = 125ºC




$I_F$ = (A)

Fig. 22 – Typical Capacitance vs. $V_{CE}$
$V_{GE}$ = 0V; f = 1MHz

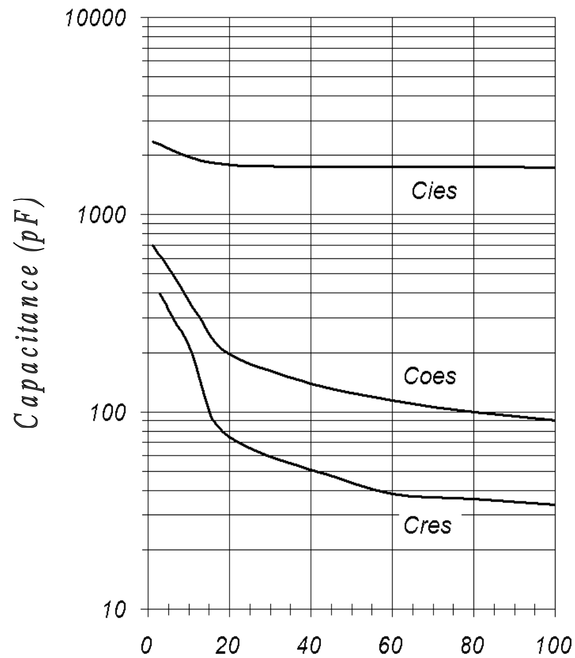
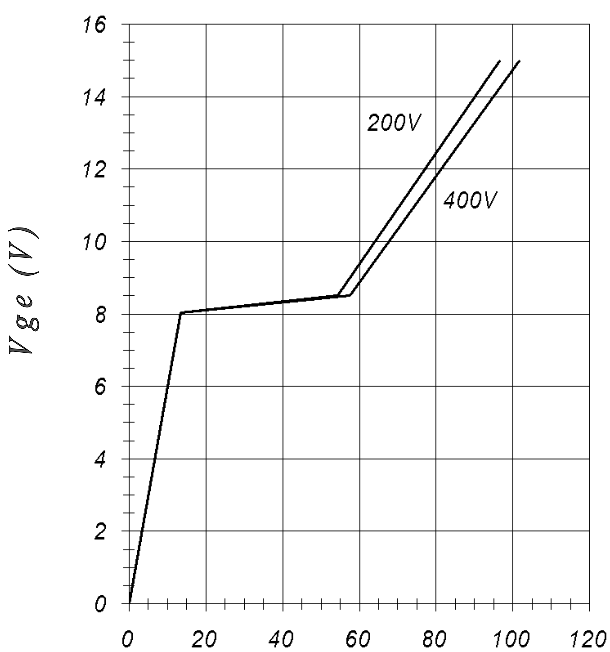
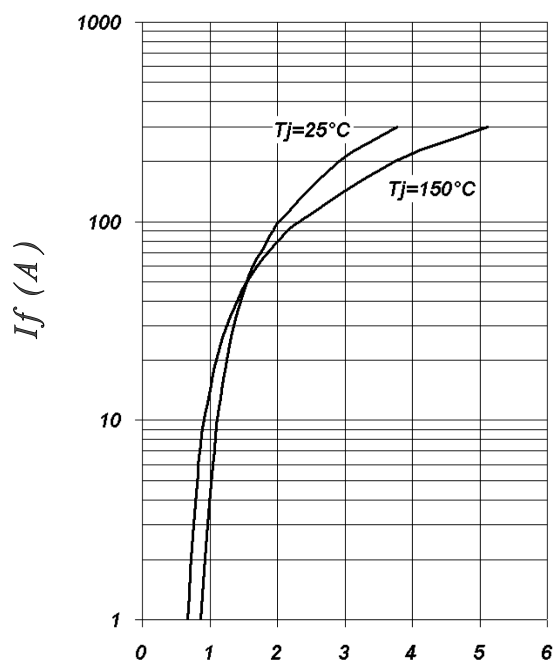



Fig. 23 – Typical Gate Charge vs. $V_{GE}$
$I_C$ = 30A; L = 600µH; $V_{CC}$ = 400V




$Q_G$ = (nC)

Fig. 24 – On state Voltage Drop
characteristic $V_{FM}$ vs $I_F$ $t_p$ = 400µs




$V_{FM}$ = (V)

Fig. 25 – Normalized Transient Impedance, Junction-to-copper plate (IGBTs)

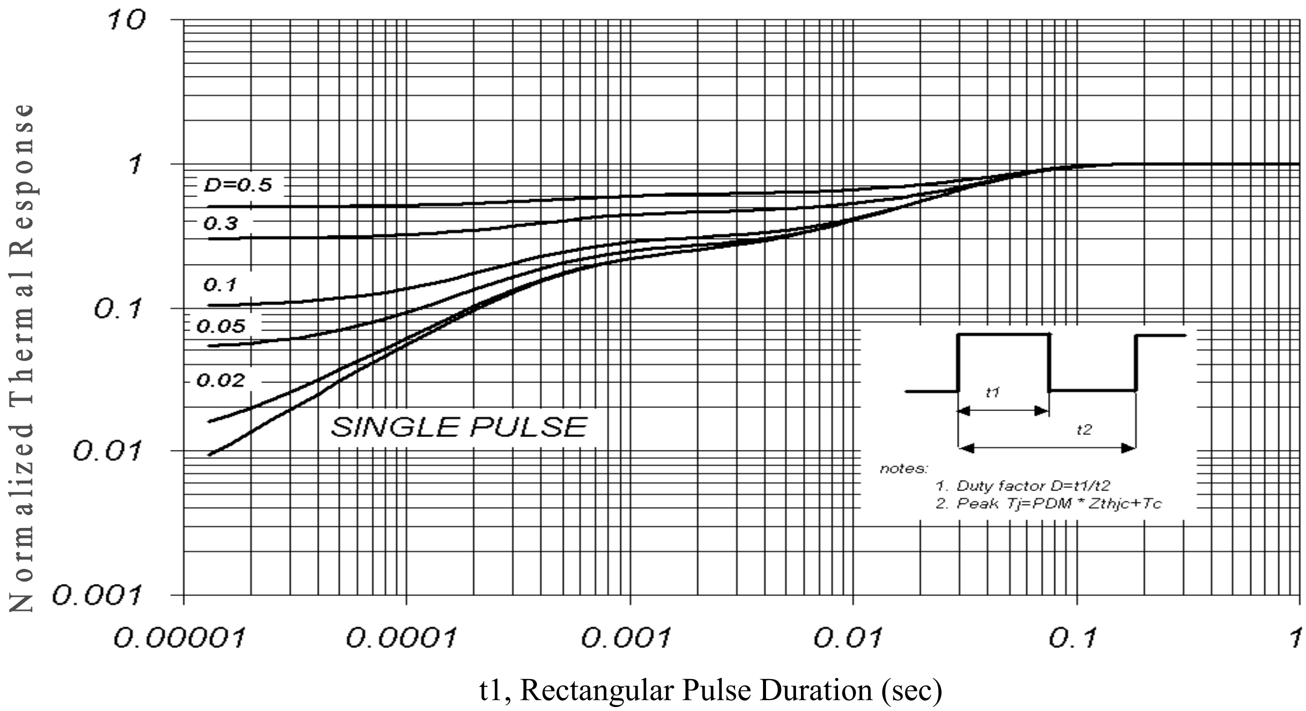



Fig. 26 – Normalized Transient Impedance, Junction-to-copper plate (FRED diodes)

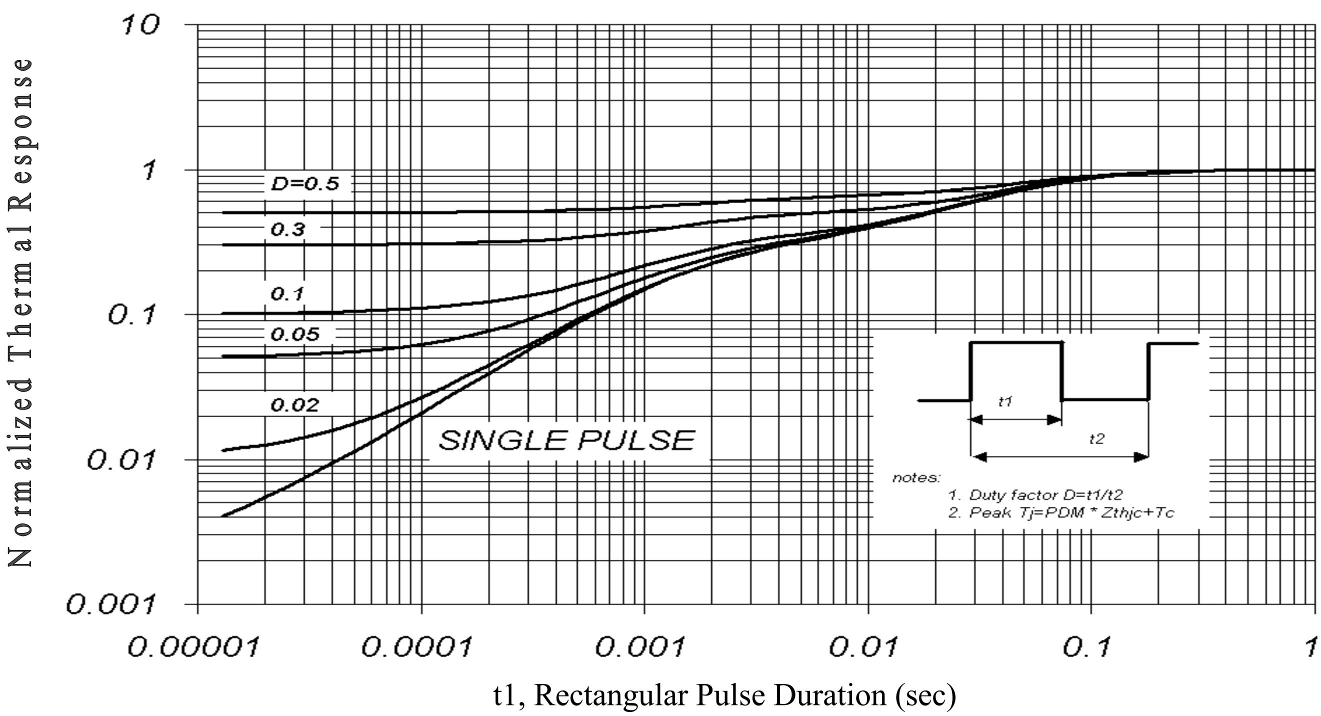


**Fig. CT.1 - Gate Charge Circuit (turn-off)**

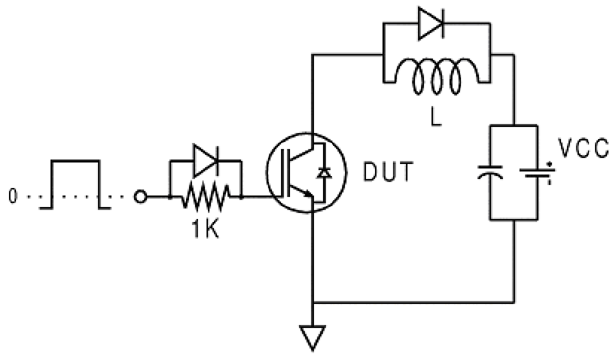



**Fig. CT.2 - RBSOA Circuit**

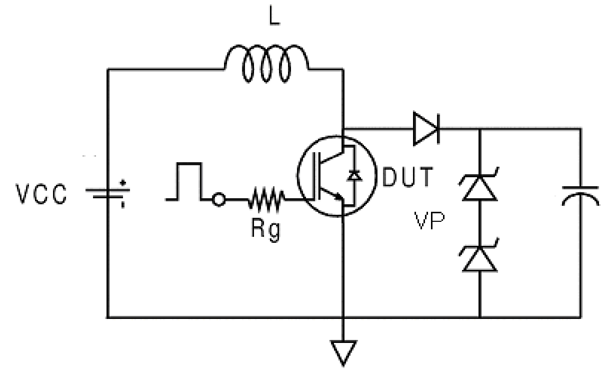



**Fig. CT.3 - S.C. SOA Circuit**

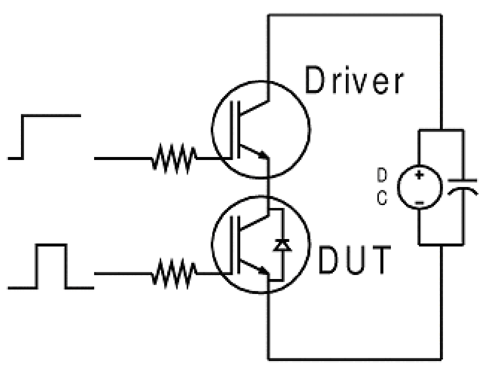



**Fig. CT.4 - Switching Loss Circuit**

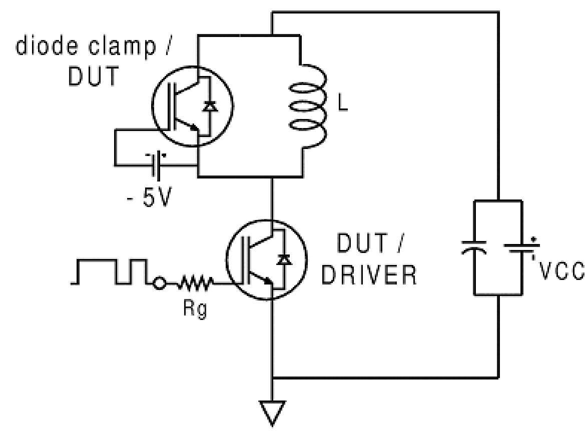



**Fig. CT.5 - Resistive Load Circuit**

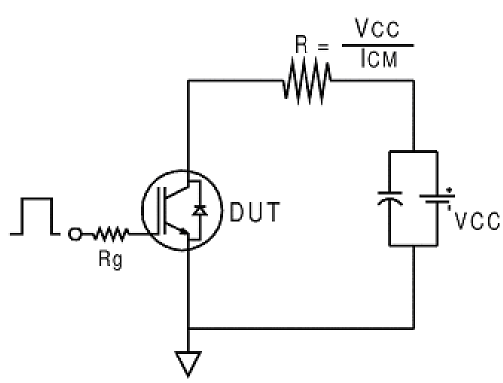


Fig. WF1- Typ. Turn-off Loss Waveform
@ $T_J$ = 150°C using Fig. CT.4

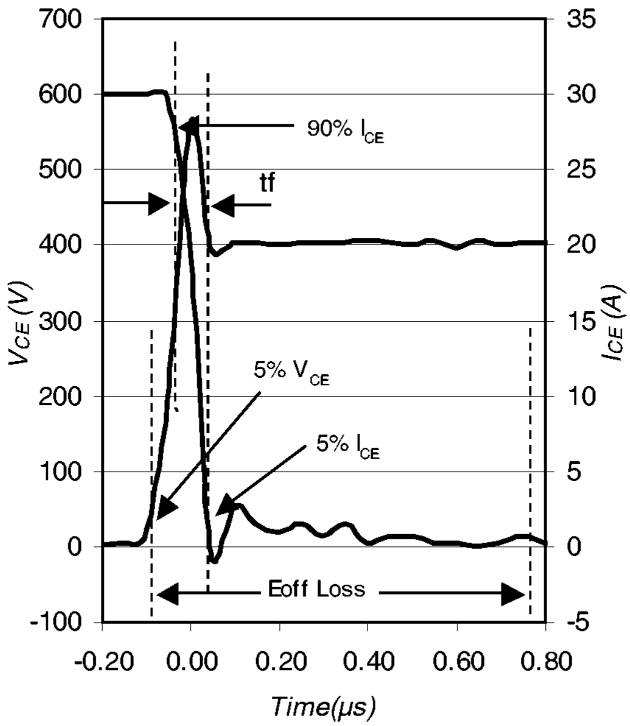



Fig. WF2- Typ. Turn-on Loss Waveform
@ $T_J$ = 150°C using Fig. CT.4

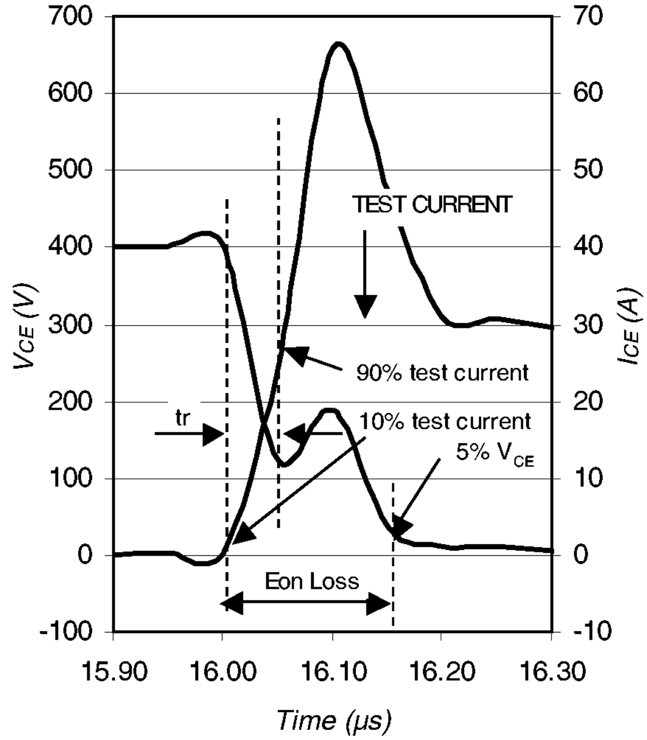



Fig. WF3- Typ. Diode Recovery Waveform
@ $T_J$ = 150°C using Fig. CT.4

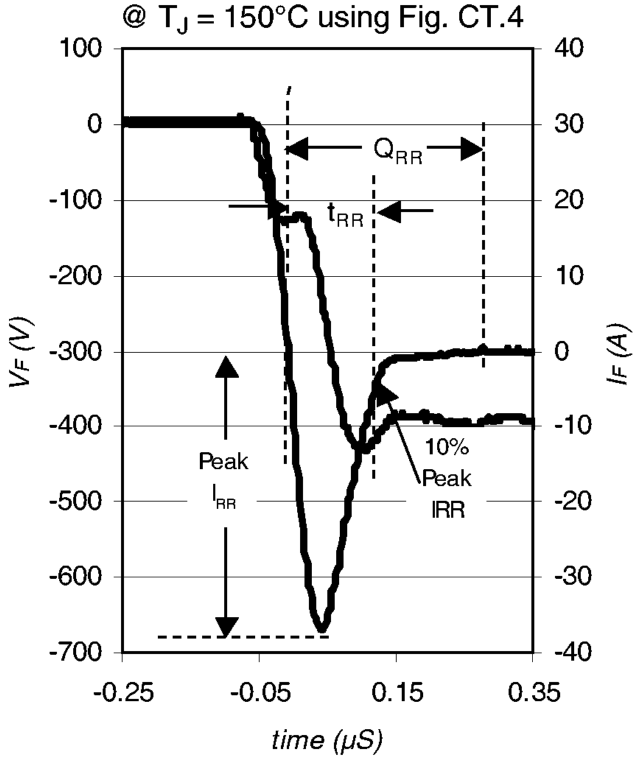
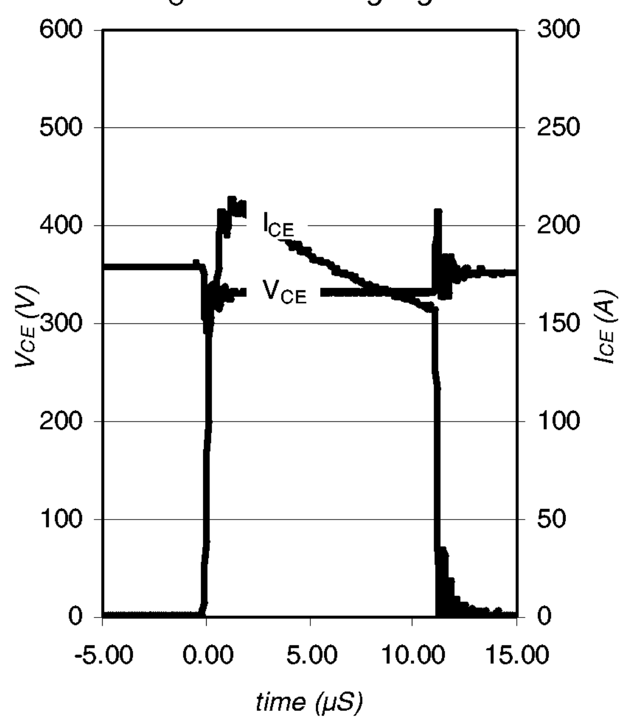



Fig. WF4- Typ. S.C Waveform
@ $T_C$ = 150°C using Fig. CT.3



# EMP family part number identification

**EMP 30 P 06 D**

| EMP | 30 | P | 06 | D |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

1- Package type

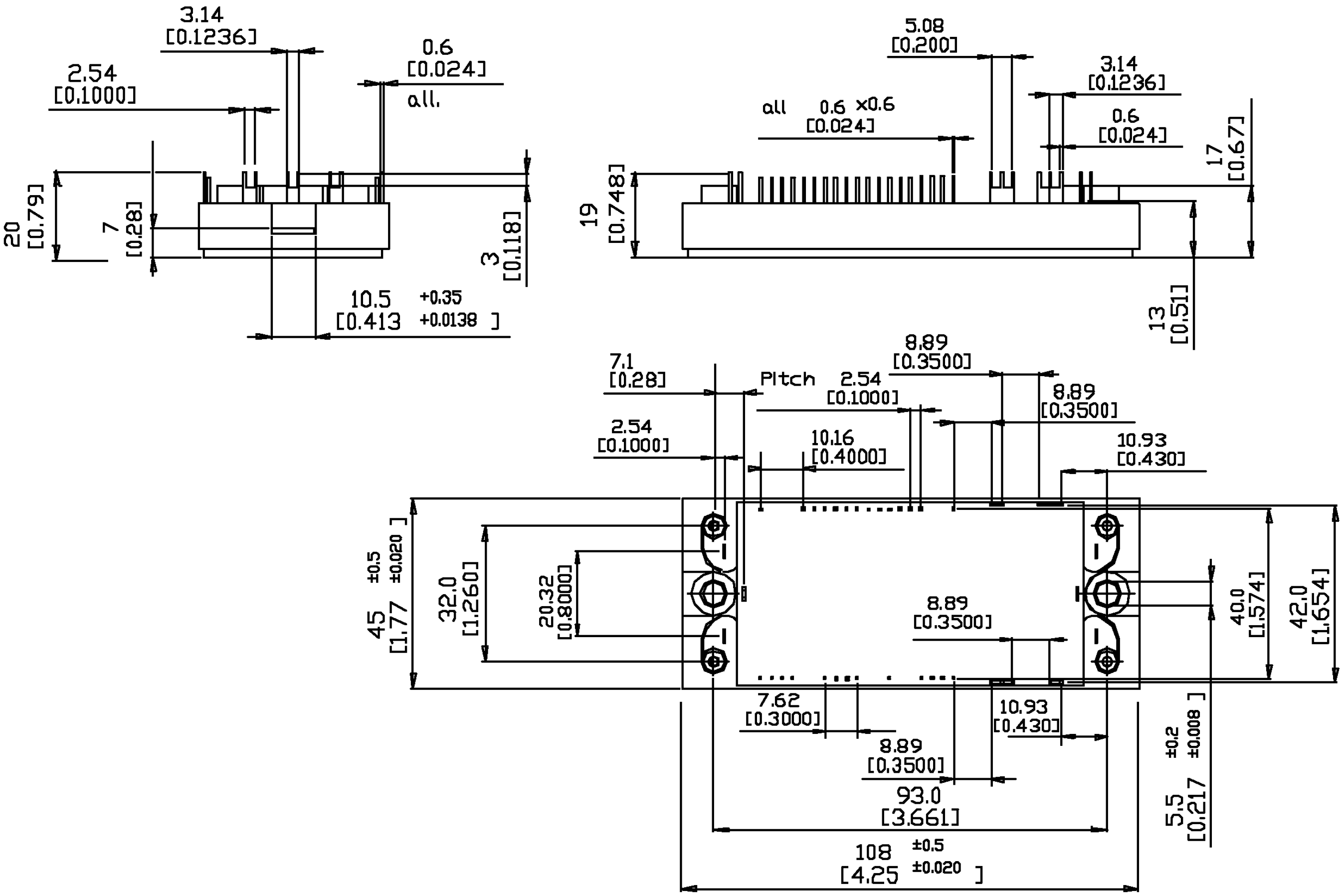
2- Current rating

3- Current sensing configuration
P= on 3 phases
Q= on 2 phases
E= on 3 emitters
F= on 2 emitters
G= on 1 emitter

4- Voltage code: Code x 100 = Vrrm

5- Circuit configuration code
A= Bridge brake
B= Inverter
C= Inverter + brake
D= BBI (Bridge Brake Inverter)
M= Matrix

## EMP30P06D case outline and dimensions




Data and specifications subject to change without notice
This product has been designed and qualified for Industrial Level.
Qualification Standards can be found on IR's Web Site.

International
IOR Rectifier

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