

<Full SiC Power Modules>

# FMF400BX-24B

HIGH POWER SWITCHING USE  
INSULATED TYPE



fourpack

Drain current  $I_D$  ..... **400 A**  
 Drain-Source voltage  $V_{DSX}$  ..... **1200 V**  
 Maximum junction temperature  $T_{vjmax}$  ..... **175 °C**

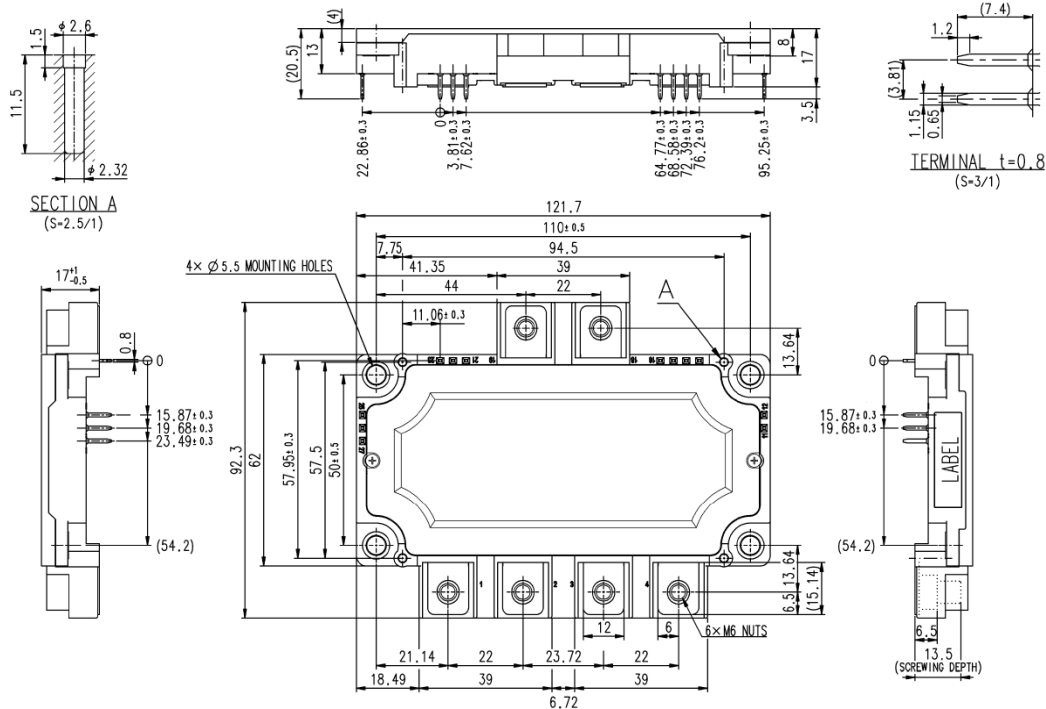
- Silicon Carbide MOSFET + Silicon Carbide Schottky Barrier Diode
- Flat base Type
- Copper base plate
- RoHS Directive compliant
- Recognized under UL1557, File E323585

## APPLICATION

AC Motor Control, Motion/Servo Control, Power supply, etc.

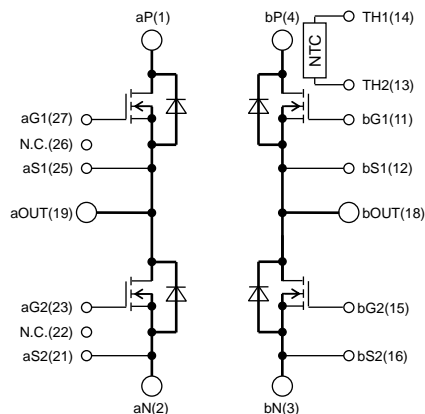
## OUTLINE DRAWING & INTERNAL CONNECTION

Dimension in mm



## INTERNAL CONNECTION

Terminal code



1	aP	16	bS2
2	aN	18	bOUT
3	bN	19	aOUT
4	bP	21	aS2
11	bG1	22	N.C.
12	bS1	23	aG2
13	TH2	25	aS1
14	TH1	26	N.C.
15	bG2	27	aG1

Tolerance otherwise specified

Division of Dimension	Tolerance
0.5 to 3	±0.2
over 3 to 6	±0.3
over 6 to 30	±0.5
over 30 to 120	±0.8
over 120 to 400	±1.2

## FMF400BX-24B

HIGH POWER SWITCHING USE  
INSULATED TYPEMAXIMUM RATINGS ( $T_{vj}=25\text{ }^{\circ}\text{C}$ , unless otherwise specified)

Symbol	Item	Conditions	Rating	Unit
$V_{DSX}$	Drain-source voltage	$V_{GS}=-15\text{ V}$	1200	V
$V_{GSS}$	Gate-source voltage	D-S short-circuited	$\pm 20$	V
$I_D$	Drain current	DC, $T_C=60\text{ }^{\circ}\text{C}$ (Note.2)	400	A
$I_{DRM}$		Pulse, Repetitive (Note.3), $T_{vj}=150\text{ }^{\circ}\text{C}$ (Note.4)	800	
$P_{tot}$	Total power dissipation	$T_C=25\text{ }^{\circ}\text{C}$ (Note.2)	1560	W
$I_S$ (Note.1)	Source current	DC	400	A
$I_{SRM}$ (Note.1)		Pulse, Repetitive (Note.3), $T_{vj}=150\text{ }^{\circ}\text{C}$	800	
$V_{isol}$	Isolation voltage	Terminals to base plate, RMS, $f=60\text{ Hz}$ , AC 1 min	5000	V
$T_{vjmax}$	Maximum junction temperature	Instantaneous event (overload) (Note.11)	175	$^{\circ}\text{C}$
$T_{vjop}$	Operating junction temperature	Continuous operation (under switching) (Note.11)	$-40\sim+150$	$^{\circ}\text{C}$
$T_{cmax}$	Maximum case temperature	(Note.2, 10)	125	$^{\circ}\text{C}$
$T_{stg}$	Storage temperature	-	$-40\sim+125$	$^{\circ}\text{C}$

ELECTRICAL CHARACTERISTICS ( $T_{vj}=25\text{ }^{\circ}\text{C}$ , unless otherwise specified)

Symbol	Item	Conditions <sup>(note10)</sup>	Limits			Unit	
			Min.	Typ.	Max.		
I <sub>DSX</sub>	Drain-source cut-off current	V <sub>DS</sub> =V <sub>DSX</sub> , V <sub>GS</sub> =-15 V	-	-	4	mA	
		V <sub>DS</sub> =800V, V <sub>GS</sub> =-15 V	-	-	0.4		
V <sub>GS(th)</sub>	Gate-source threshold voltage	I <sub>D</sub> =113 mA, V <sub>DS</sub> =10 V	1.8	2.5	3.2	V	
I <sub>GSS</sub>	Gate-source leakage current	V <sub>GS</sub> =V <sub>GSS</sub> , D-S short-circuited	-	-	0.5	μA	
V <sub>DS(on)</sub> (terminal)	Drain-source on-state voltage	I <sub>D</sub> =400 A, V <sub>GS</sub> =15V <sup>(Note.6)</sup>	T <sub>vj</sub> =25 °C	-	1.65	2.30	V
			T <sub>vj</sub> =125 °C	-	2.10	-	
			T <sub>vj</sub> =150 °C	-	2.20	-	
V <sub>DS(on)</sub> (chip)	Drain-source on-state voltage	I <sub>D</sub> =400 A, V <sub>GS</sub> =15V <sup>(Note.6)</sup>	T <sub>vj</sub> =25 °C	-	1.35	-	V
			T <sub>vj</sub> =125 °C	-	1.80	-	
			T <sub>vj</sub> =150 °C	-	1.90	-	
r <sub>DS(on)</sub> (chip)	Drain-source on-state resistance	I <sub>D</sub> =400 A, V <sub>GS</sub> =15V <sup>(Note.6)</sup>	T <sub>vj</sub> =25 °C	-	3.4	-	mΩ
			T <sub>vj</sub> =125 °C	-	4.5	-	
			T <sub>vj</sub> =150 °C	-	4.8	-	
C <sub>iss</sub>	Input capacitance	V <sub>DS</sub> =10 V, V <sub>GS</sub> =0V	-	34	-	nF	
C <sub>oss</sub>	Output capacitance		-	24	-		
C <sub>rss</sub>	Reverse transfer capacitance		-	1.7	-		
Q <sub>G</sub>	Gate charge	V <sub>DD</sub> =600 V, I <sub>D</sub> =400 A, V <sub>GS</sub> =0→15 V	-	975	-	nC	
t <sub>d(on)</sub>	Turn-on delay time	V <sub>DD</sub> =600 V, I <sub>D</sub> =400 A, V <sub>GS</sub> =±15 V, T <sub>vj</sub> =150°C, R <sub>G</sub> =3.0Ω, L <sub>s_ext</sub> =25nH, Inductive load, per pulse	-	120	-	ns	
t <sub>r</sub>	Rise time		-	80	-		
t <sub>d(off)</sub>	Turn-off delay time		-	200	-		
t <sub>f</sub>	Fall time		-	30	-		
E <sub>on</sub>	Turn-on switching energy		-	16	-	mJ	
E <sub>off</sub>	Turn-off switching energy		-	7	-		
Q <sub>C</sub>	Drain-source charge			-	2	-	μC
V <sub>SD</sub> <sup>(Note.1)</sup> (terminal)	Source-drain voltage	I <sub>S</sub> =400 A <sup>(Note.6)</sup> V <sub>GS</sub> =-15 V	T <sub>vj</sub> =25 °C	-	1.90	2.45	V
			T <sub>vj</sub> =125 °C	-	2.70	-	
			T <sub>vj</sub> =150 °C	-	2.90	-	
V <sub>SD</sub> <sup>(Note.1)</sup> (chip)	Source-drain voltage	I <sub>S</sub> =400 A <sup>(Note.6)</sup> V <sub>GS</sub> =-15 V	T <sub>vj</sub> =25 °C	-	1.60	-	V
			T <sub>vj</sub> =125 °C	-	2.40	-	
			T <sub>vj</sub> =150 °C	-	2.60	-	
R <sub>DD'+SS'</sub>	Internal lead resistance	aP-aS1, bP-bS1, aOUT-aS2, bOUT-bS2 terminals, per switch	-	0.75	-	mΩ	
L <sub>s</sub>	Internal stray inductance	aP-aN, bP-bN	-	18	-	nH	
r <sub>g</sub>	Internal gate resistance	Per switch	-	1.75	-	Ω	

Caution: Short-circuit capability is not designed.

## FMF400BX-24B

HIGH POWER SWITCHING USE  
INSULATED TYPE

## THERMAL RESISTANCE CHARACTERISTICS

Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
$R_{th(j-c)Q}$	Thermal resistance <sup>(Note. 2)</sup>	Junction to case, per inverter switch	-	-	96	K/kW
$R_{th(j-c)D}$		Junction to case, per inverter FWD	-	-	126	
$R_{th(c-s)}$	Contact thermal resistance <sup>(Note. 2)</sup>	Case to heat sink, per 1 module, Thermal grease applied <sup>(Note. 8, 11)</sup>	-	12	-	K/kW

## NTC THERMISTOR PART

Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
$R_{25}$	Zero-power resistance	$T_C=25\text{ }^{\circ}\text{C}$ <sup>(Note. 2)</sup>	4.85	5.00	5.15	kΩ
$\Delta R/R$	Deviation of resistance	$T_C=100\text{ }^{\circ}\text{C}$ <sup>(Note. 2)</sup> , $R_{100}=493\text{ }\Omega$	-7.3	-	+7.8	%
$B_{(25/50)}$	B-constant	Approximate by equation <sup>(Note. 7)</sup>	-	3375	-	K
$P_{25}$	Power dissipation	$T_C=25\text{ }^{\circ}\text{C}$ <sup>(Note. 2)</sup>	-	-	10	mW

## MECHANICAL CHARACTERISTICS

Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
$M_t$	Mounting torque	Main terminals M 6 screw	3.5	4.0	4.5	N·m
$M_s$		Mounting to heat sink M 5 screw	2.5	3.0	6.0	
$m$	mass	-	-	423	-	g
$d_a$	Clearance	Terminal to terminal	10.0	-	-	mm
		Terminal to base plate	7.2	-	-	
$d_s$	Creepage distance	Terminal to terminal	14.4	-	-	mm
		Terminal to base plate	11.9	-	-	
$e_c$	Flatness of base plate	On the centerline X, Y <sup>(Note. 5)</sup>	-100	-	+100	μm

\*: This product is compliant with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) directive 2011/65/EU and (EU)2015/863.

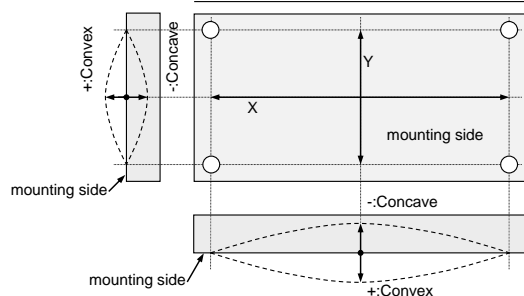
Note1. Represent ratings and characteristics of the anti-parallel, source-drain free wheeling diode (FWD).

2. Case temperature ( $T_C$ ) and heat sink temperature ( $T_s$ ) are defined on the each surface (mounting side) of base plate and heat sink just under the chips.  
Refer to the figure of chip location.

3. Pulse width and repetition rate should be such that the device junction temperature ( $T_{vj}$ ) does not exceed  $T_{vj\max}$  rating.

4. Junction temperature ( $T_{vj}$ ) should not increase beyond  $T_{vj\max}$  rating.

5. The base plate (mounting side) flatness measurement points (X, Y) are as follows of the following figure.



6. Pulse width and repetition rate should be such as to cause negligible temperature rise.

$$7. B_{(25/50)} = \ln\left(\frac{R_{25}}{R_{50}}\right) / \left(\frac{1}{T_{25}} - \frac{1}{T_{50}}\right)$$

$R_{25}$ : resistance at absolute temperature  $T_{25}$  [K];  $T_{25}=25\text{ }^{\circ}\text{C}+273.15=298.15\text{ [K]}$

$R_{50}$ : resistance at absolute temperature  $T_{50}$  [K];  $T_{50}=50\text{ }^{\circ}\text{C}+273.15=323.15\text{ [K]}$

8. Typical value is measured by using thermally conductive grease of  $\lambda=0.9\text{ W/(m}\cdot\text{K)}/D_{(C-S)}=100\mu\text{m}$ .

9. Use the following screws when mounting the printed circuit board (PCB) on the standoffs.

"φ2.6×10 or φ2.6×12, B1 tapping screw"

The length of the screw depends on the thickness (t1.6) of the PCB.

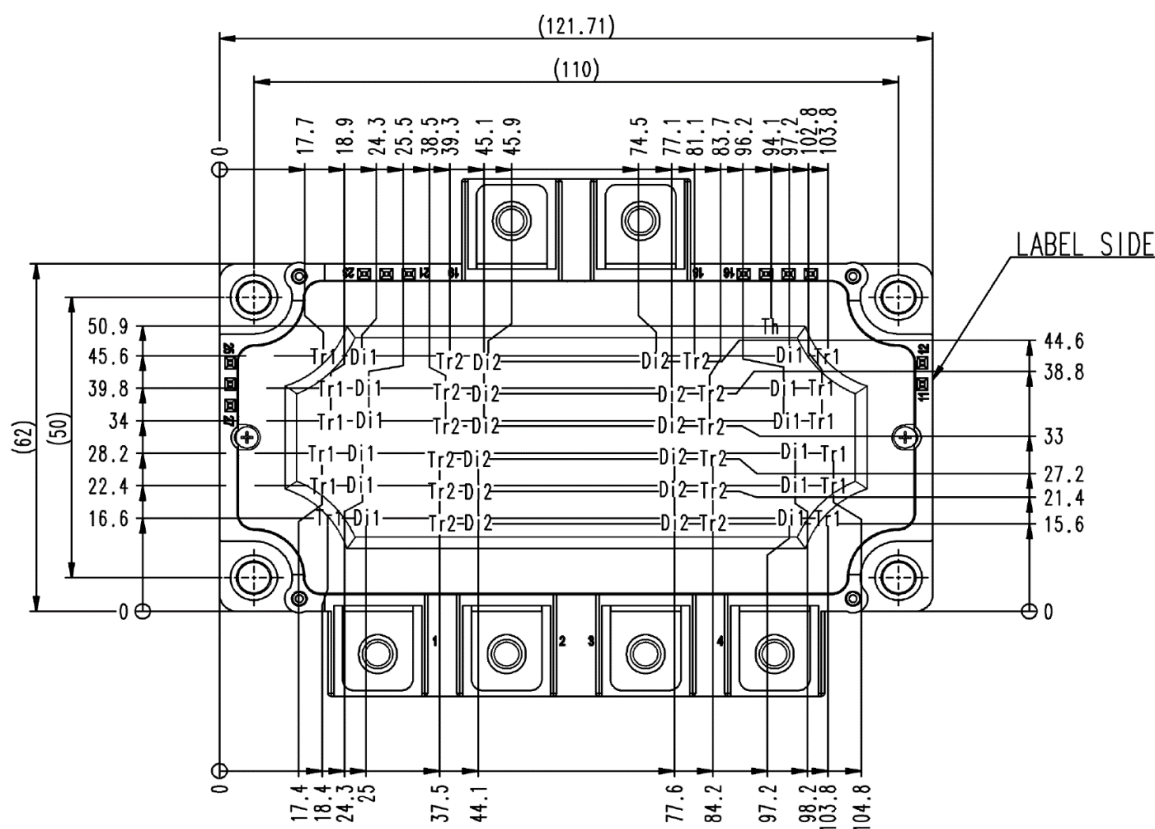
10. Per switch

11. Long term performance related to thermal conductive grease (including but not limited to aspects such as the increase of thermal resistance due to pumping out, etc.) should be verified under your specific application conditions. Each temperature condition ( $T_{vj\max}$ ,  $T_{vj\text{op}}$ ,  $T_{C\max}$ ) must be maintained below the maximum rated temperature throughout consideration of the temperature rise even for long term usage.

**FMF400BX-24B**HIGH POWER SWITCHING USE  
INSULATED TYPE**RECOMMENDED OPERATING CONDITIONS**

Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
$V_{DD}$	(DC) Supply voltage	Applied across aP -aN, bP -bN terminals	-	600	850	V
$V_{GS(+)}$	Gate-Source positive drive voltage	Applied across aG1-aS1, bG1-bS1, aG2-aS2, bG2-bS2 terminals	13.5	15.0	16.5	V
$V_{GS(-)}$	Gate-Source negative drive voltage	Applied across aG1-aS1, bG1-bS1, aG2-aS2, bG2-bS2 terminals	-16.5	-15.0	-7.0	V
$R_G$	External gate resistance (Note.12)	Per switch	3.0	-	15.0	$\Omega$
$f_c$	Switching frequency	$V_{GS(+)}=15V$ , $R_G=3.0\Omega$	$V_{GS(-)} < -10V$	-	-	50
		$V_{DD}=600V$ , $T_{vj}=150^\circ C$	$V_{GS(-)} \geq -10V$	-	-	100

Note 12. The value of external gate resistance should be considered the surge voltage not to exceed the rating voltage in the worst system condition.

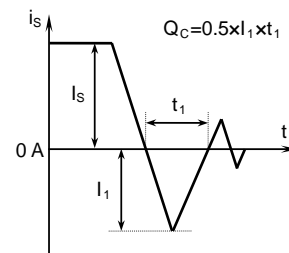
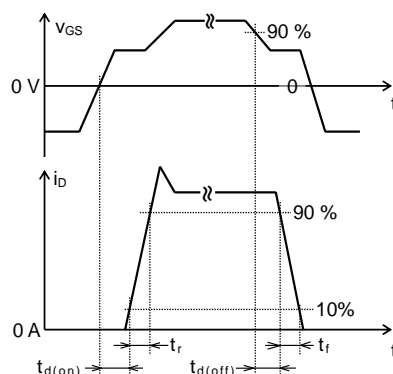
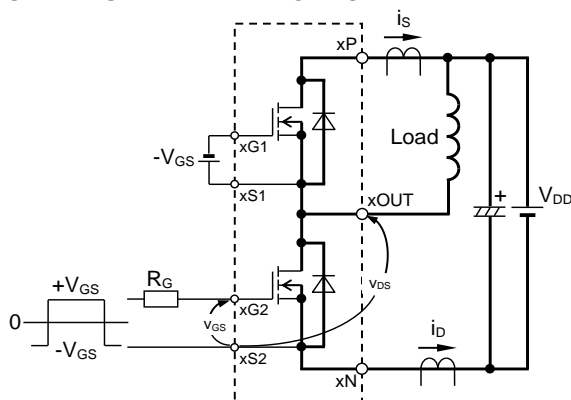
**CHIP LOCATION (Top view)**Dimension in mm, tolerance:  $\pm 1$  mm

Tr1,Tr2: SiC-MOSFET, Di1,Di2: SiC-SBD, Th: NTC thermistor

# FMF400BX-24B

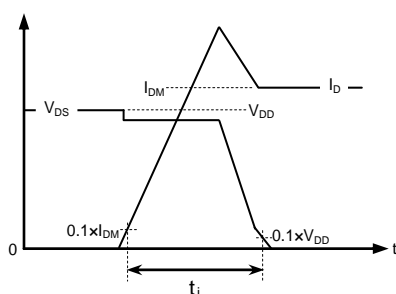
HIGH POWER SWITCHING USE  
INSULATED TYPE

## TEST CIRCUIT AND WAVEFORMS

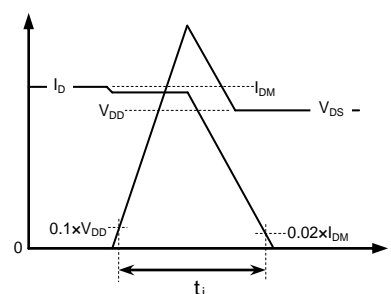


Switching characteristics test circuit and waveforms(x: a or b)

Q<sub>c</sub> test waveform



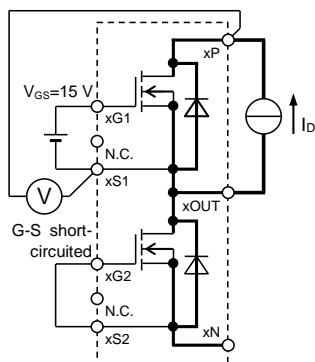
MOSFET Turn-on switching energy



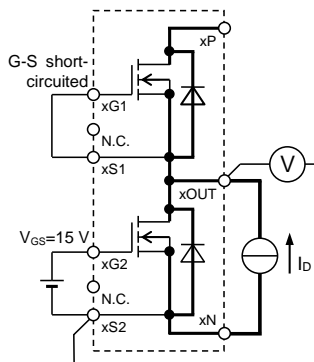
MOSFET Turn-off switching energy

Turn-on / Turn-off switching energy test waveforms (Integral time instruction drawing)

## TEST CIRCUIT

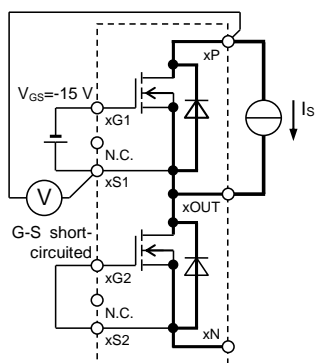


Tr1

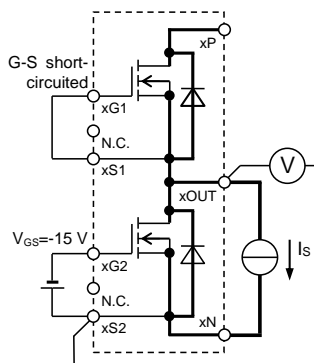


Tr2

V<sub>DS(on)</sub> test circuit (x: a or b)

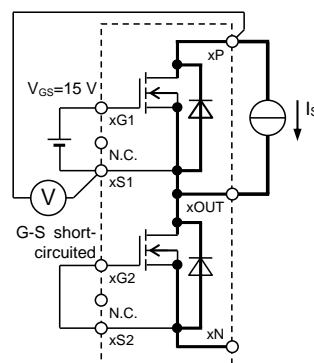


Di1

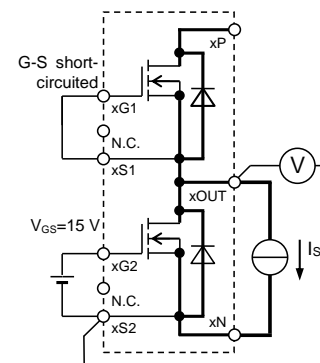


Di2

V<sub>SD</sub> test circuit, V<sub>GS</sub>=-15V (x: a or b)



Tr1&Di1



Tr2&Di2

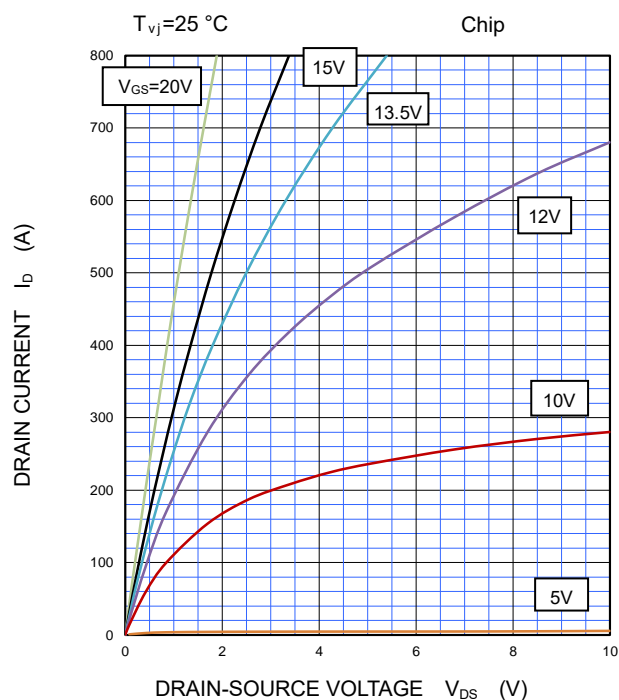
V<sub>SD</sub> test circuit, V<sub>GS</sub>=15V (x: a or b)

## FMF400BX-24B

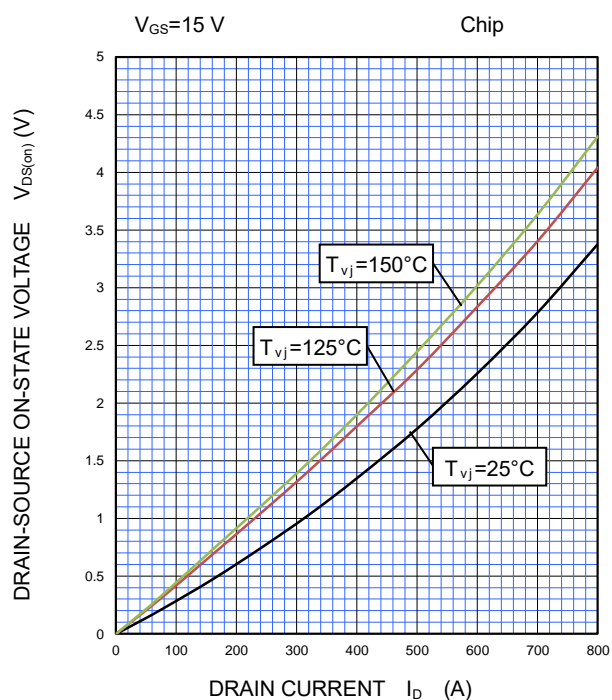
HIGH POWER SWITCHING USE  
INSULATED TYPE

### PERFORMANCE CURVES

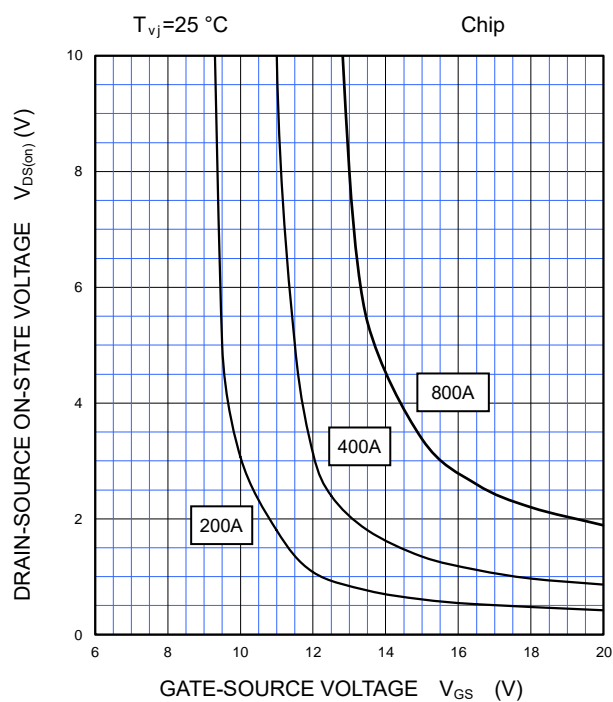
OUTPUT  
CHARACTERISTICS  
(TYPICAL)



DRAIN-SOURCE ON STATE VOLTAGE  
CHARACTERISTICS  
(TYPICAL)



DRAIN-SOURCE ON STATE VOLTAGE  
CHARACTERISTICS  
(TYPICAL)

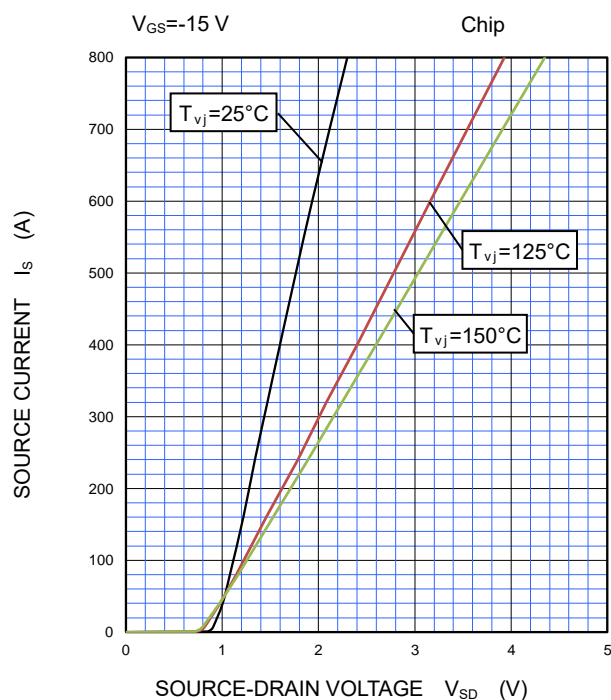


## FMF400BX-24B

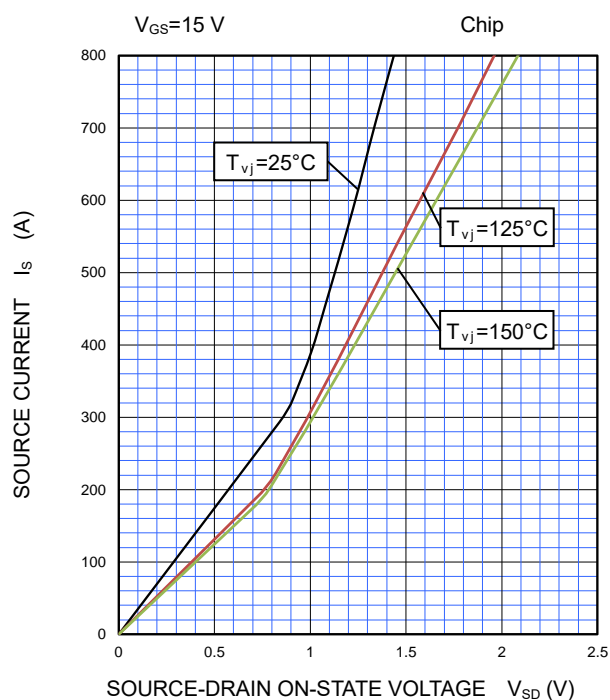
HIGH POWER SWITCHING USE  
INSULATED TYPE

### PERFORMANCE CURVES

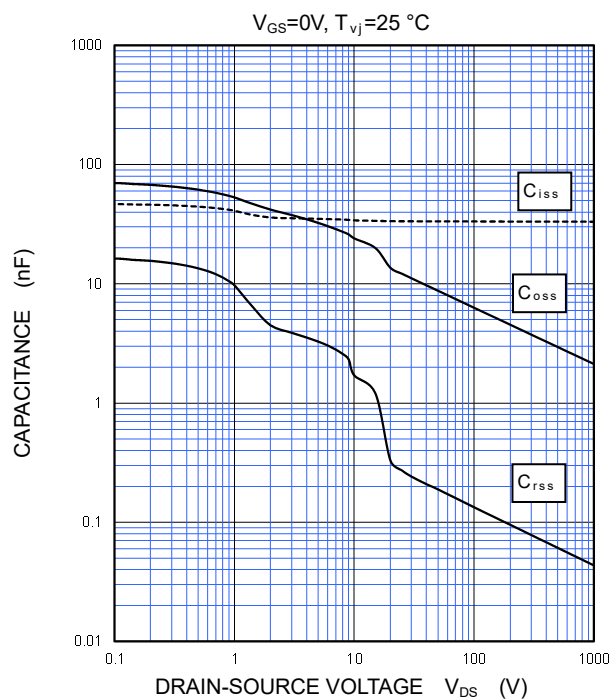
FREE WHEELING DIODE  
FORWARD CHARACTERISTICS  
(TYPICAL)



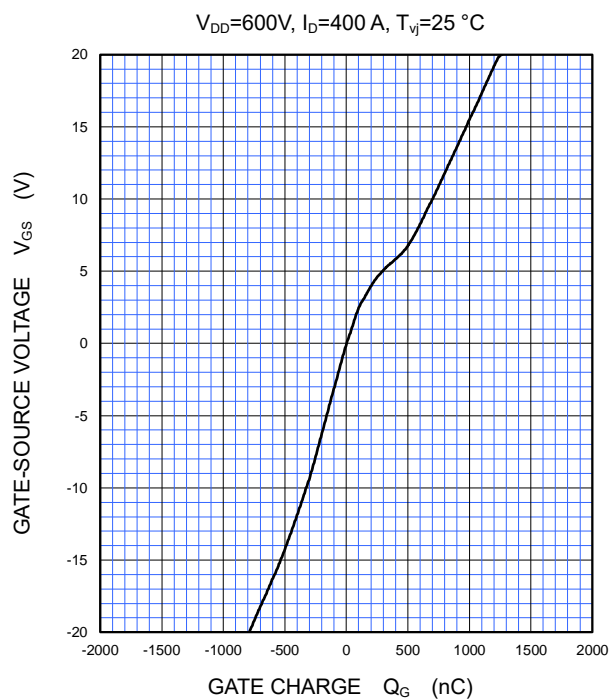
SOURCE-DRAIN ON STATE VOLTAGE  
CHARACTERISTICS  
(TYPICAL)



CAPACITANCE  
CHARACTERISTICS  
(TYPICAL)



GATE CHARGE  
CHARACTERISTICS  
(TYPICAL)



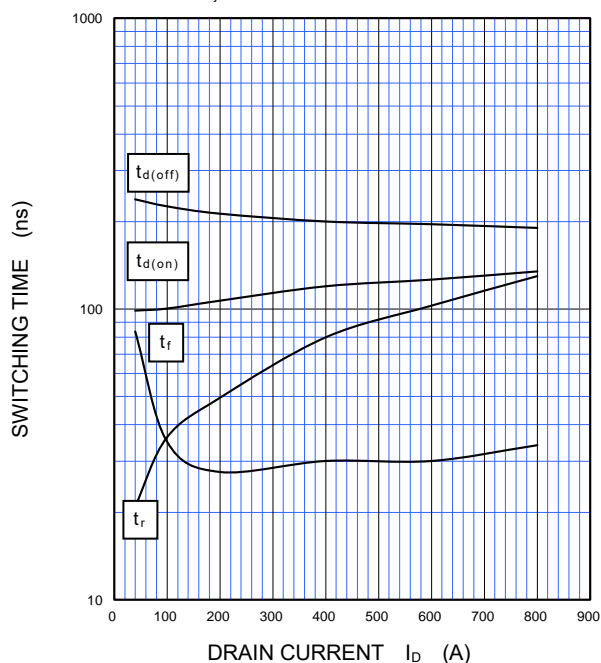
# FMF400BX-24B

HIGH POWER SWITCHING USE  
INSULATED TYPE

## PERFORMANCE CURVES

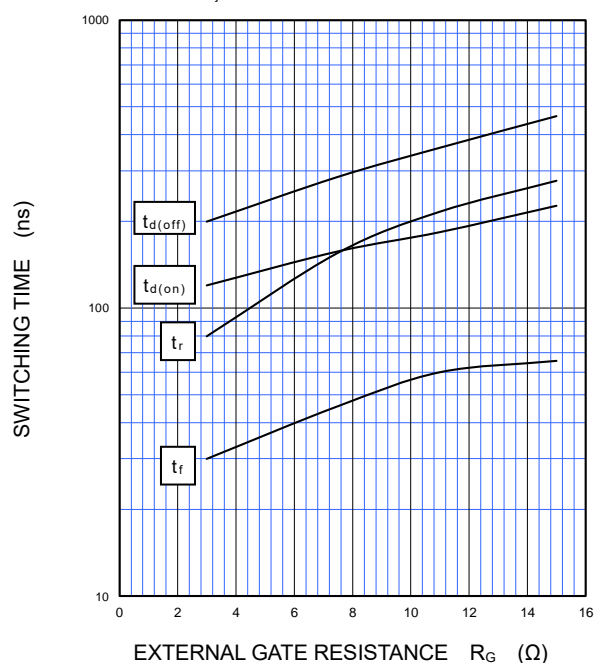
HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $R_G=3.0\Omega$ ,  $L_{s\_ext}=25\text{ nH}$   
 $T_{vj}=150\text{ }^\circ\text{C}$ , INDUCTIVE LOAD



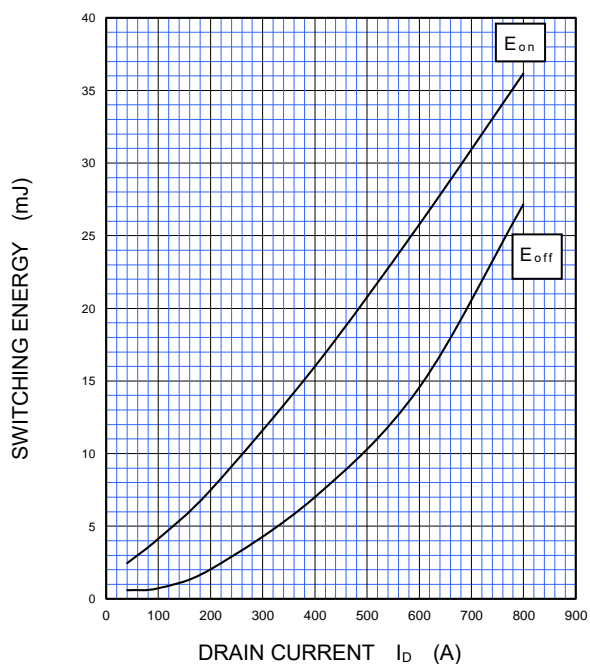
HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $I_D=400\text{ A}$ ,  $L_{s\_ext}=25\text{ nH}$   
 $T_{vj}=150\text{ }^\circ\text{C}$ , INDUCTIVE LOAD



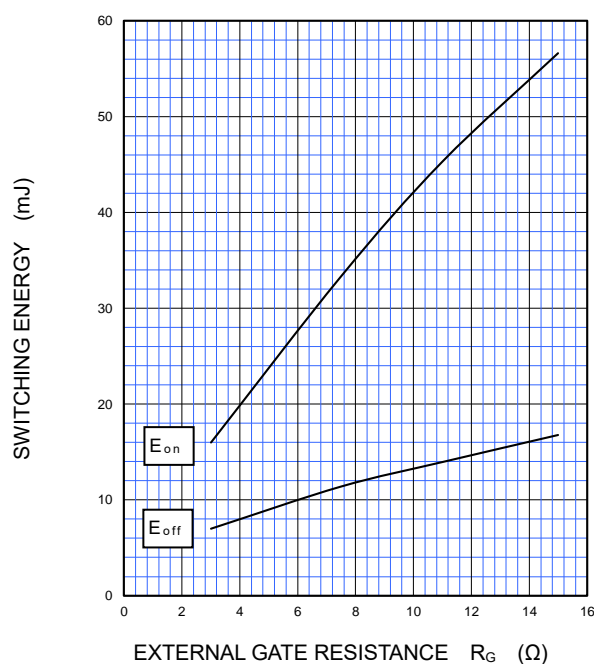
HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $R_G=3.0\Omega$ ,  $T_{vj}=150\text{ }^\circ\text{C}$ ,  $L_{s\_ext}=25\text{ nH}$   
INDUCTIVE LOAD, PER PULSE



HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

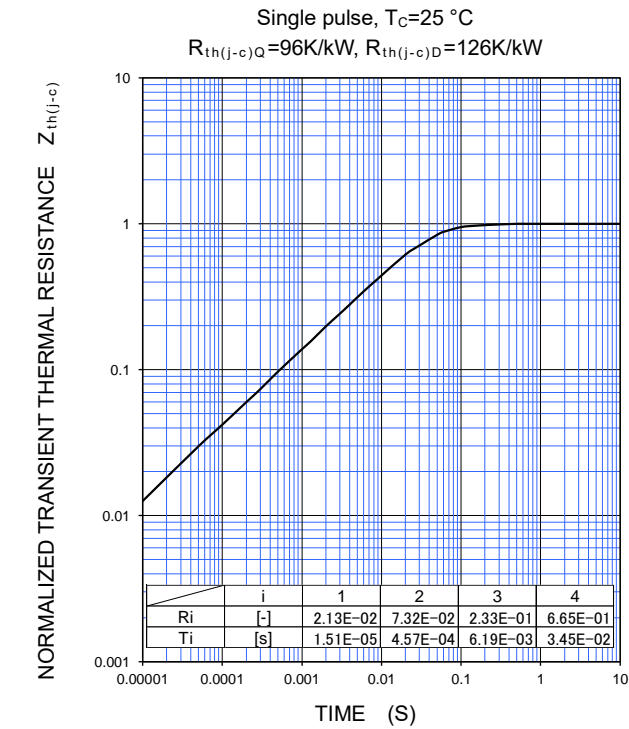
$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $I_D=400\text{ A}$ ,  $T_{vj}=150\text{ }^\circ\text{C}$ ,  $L_{s\_ext}=25\text{ nH}$   
INDUCTIVE LOAD, PER PULSE





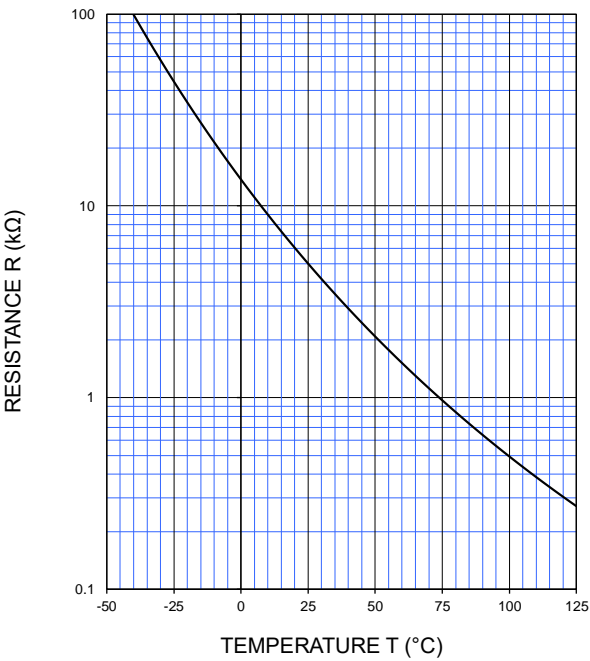
PERFORMANCE CURVES

TRANSIENT THERMAL IMPEDANCE  
CHARACTERISTICS  
(MAXIMUM)



NTC thermistor part

TEMPERATURE  
CHARACTERISTICS  
(TYPICAL)



Note: The characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

### **Important Notice**

The information contained in this datasheet shall in no event be regarded as a guarantee of conditions or characteristics. This product has to be used within its specified maximum ratings, and is subject to customer's compliance with any applicable legal requirement, norms and standards.

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### **Keep safety first in your circuit designs!**

Mitsubishi Electric Corporation puts the maximum effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them. Trouble with semiconductors may lead to personal injury, fire or property damage. Remember to give due consideration to safety when making your circuit designs, with appropriate measures such as (i) placement of substitutive, auxiliary circuits, (ii) use of non-flammable material or (iii) prevention against any malfunction or mishap.

### **Notes regarding these materials**

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