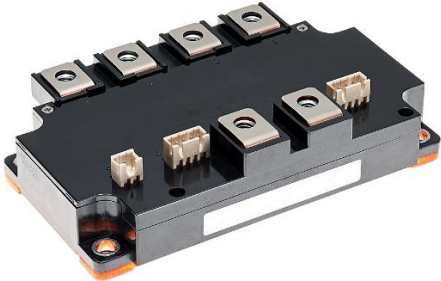


<Full SiC Modules>

# FMF600DX2-24A

**HIGH POWER SWITCHING USE  
INSULATED TYPE**



Dual switch (Half-Bridge)

Drain current  $I_D$  ..... **600 A**  
 Drain-Source voltage  $V_{DSX}$  ..... **1200 V**  
 Maximum junction temperature  $T_{vjmax}$  ..... **150 °C**

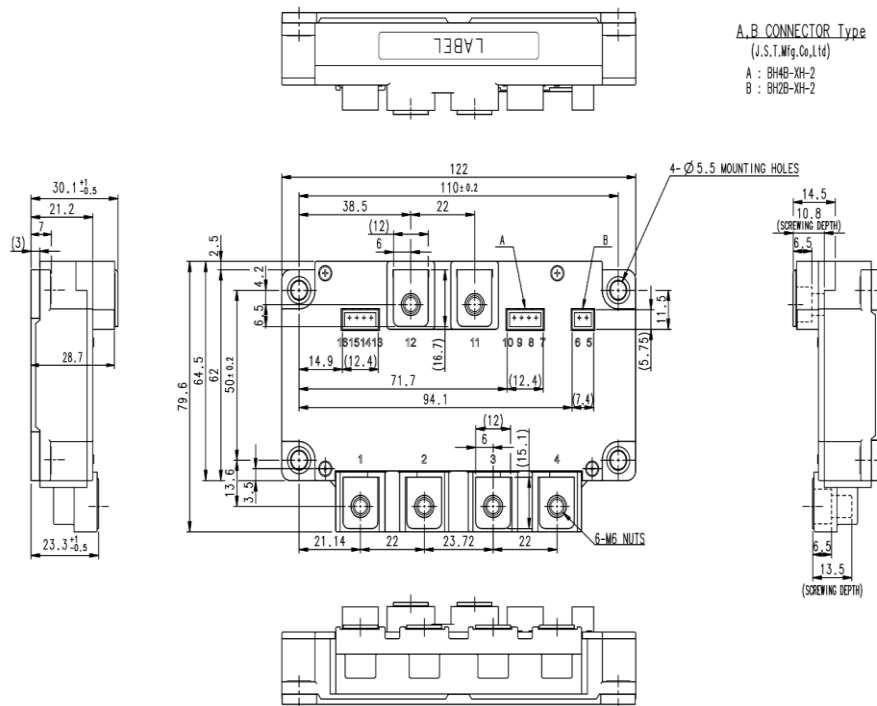
- Silicon Carbide MOSFET + Silicon Carbide Schottky Barrier Diode
- Flat base Type
- Copper base plate
- RoHS Directive compliant
- Recognized under UL1557, File E323585

## APPLICATION

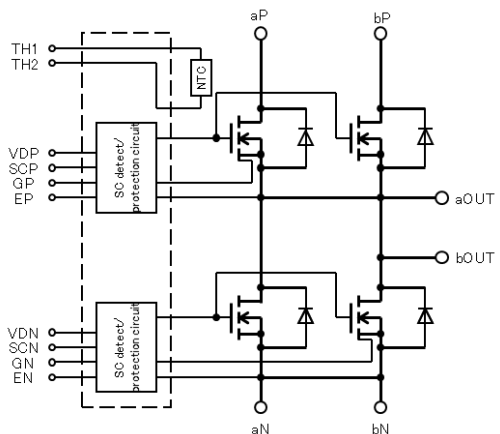
AC Motor Control, Motion/Servo Control, Power supply, etc.

## OUTLINE DRAWING & INTERNAL CONNECTION

Dimension in mm



## INTERNAL CONNECTION



## Terminal code

- |    |      |
|----|------|
| 1  | aP   |
| 2  | aN   |
| 3  | bN   |
| 4  | bP   |
| 5  | TH1  |
| 6  | TH2  |
| 7  | VDN  |
| 8  | SCN  |
| 9  | GN   |
| 10 | EN   |
| 11 | bOUT |
| 12 | aOUT |
| 13 | EP   |
| 14 | GP   |
| 15 | SCP  |
| 16 | VDP  |

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

aP and bP, aN and bN must be connected externally.

SCP, SCN are terminal for drain current sensing. The ratio of SCP/EP, SCN/EN is approximately 1:61500

## FMF600DX2-24A

HIGH POWER SWITCHING USE

INSULATED TYPE

**MAXIMUM RATINGS (T<sub>vj</sub>=25 °C, unless otherwise specified)**

Symbol	Item	Conditions	Rating	Unit
V <sub>DSX</sub>	Drain-source voltage	V <sub>GS</sub> =-15 V	1200	V
V <sub>GSS</sub>	Gate-source voltage	D-S short-circuited	±20	V
I <sub>D</sub>	Drain current	DC, T <sub>c</sub> =30°C(Notes.2)	600	A
I <sub>DRM</sub>		Pulse, Repetitive (Notes.3), T <sub>vj</sub> =150°C(Notes.4)	900	
P <sub>tot</sub>	Total power dissipation	T <sub>c</sub> =25 °C (Note. 2.)	2190	W
I <sub>S</sub> (Note.1)	Source current	DC	600	A
I <sub>SRM</sub> (Note.1)		Pulse, Repetitive (Notes.3), T <sub>vj</sub> =150°C	900	
V <sub>isol</sub>	Isolation voltage	Terminals to base plate, RMS, f=60 Hz, AC 1 min	4000	V
T <sub>vjmax</sub>	Maximum junction temperature	Instantaneous event (overload)	150	°C
T <sub>cmax</sub>	Maximum case temperature	(Notes.2)	125	°C
T <sub>vjop</sub>	Operating junction temperature	Continuous operation (under switching)	-40~+150	°C
T <sub>stg</sub>	Storage temperature	-	-40~+125	°C

**ELECTRICAL CHARACTERISTICS (T<sub>vj</sub>=25 °C, unless otherwise specified)**

Symbol	Item	Conditions (Note.9)	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	-	-	33	mA	
		V <sub>DS</sub> =800V, V <sub>GS</sub> =-15 V	-	-	1.0		
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>GS(th)</sub>	Gate-source threshold voltage	I <sub>D</sub> =203 mA, V <sub>DS</sub> =10 V	0.5	1	1.6	V	
r <sub>DS(on)</sub> (Chip)	Static drain-source On-state resistance	I <sub>D</sub> =600 A, V <sub>GS</sub> =15V (Note.6)	T <sub>vj</sub> =25 °C	-	2.2	-	mΩ
			T <sub>vj</sub> =150 °C	-	3.7	-	
V <sub>DS(on)</sub> (chip)	Static drain-source On-state voltage	I <sub>D</sub> =600 A, V <sub>GS</sub> =15V (Note.6)	T <sub>vj</sub> =25 °C	-	1.31	-	V
			T <sub>vj</sub> =125 °C	-	2.02	-	
			T <sub>vj</sub> =150 °C	-	2.21	-	
V <sub>DS(on)</sub> (terminal)	Static drain-source On-state voltage	I <sub>D</sub> =600 A, V <sub>GS</sub> =15V (Note.6)	T <sub>vj</sub> =25 °C	-	1.66	2.30	V
			T <sub>vj</sub> =125 °C	-	2.38	-	
			T <sub>vj</sub> =150 °C	-	2.56	-	
C <sub>iss</sub>	Input capacitance	V <sub>DS</sub> =10 V, V <sub>GS</sub> =0V	-	53	-	nF	
C <sub>oss</sub>	Output capacitance		-	19	-		
C <sub>rss</sub>	Reverse transfer capacitance		-	1.5	-		
Q <sub>G</sub>	Gate charge	V <sub>DD</sub> =600 V, I <sub>D</sub> =600 A, V <sub>GS</sub> =15 V	-	2100	-	nC	
t <sub>d(on)</sub>	Turn-on delay time	V <sub>DD</sub> =600 V, I <sub>D</sub> =600 A, V <sub>GS</sub> =±15 V R <sub>G</sub> =2.0Ω, Inductive load	-	100	-	ns	
t <sub>r</sub>	Rise time		-	60	-		
t <sub>d(off)</sub>	Turn-off delay time		-	350	-		
t <sub>f</sub>	Fall time		-	60	-		
Q <sub>C</sub>	Drain-source charge		-	3	-		μC
V <sub>SD</sub> (Note.1) (Chip)	Source-drain voltage	I <sub>S</sub> =600 A (Note.6) V <sub>GS</sub> =-15 V	T <sub>vj</sub> =25 °C	-	1.7	-	V
			T <sub>vj</sub> =125 °C	-	2.2	-	
			T <sub>vj</sub> =150°C	-	2.4	-	
V <sub>SD</sub> (Note.1) (terminal)	Source-drain voltage	I <sub>S</sub> =600 A (Note.6) V <sub>GS</sub> =-15 V	T <sub>vj</sub> =25 °C	-	2.05	2.45	V
			T <sub>vj</sub> =125 °C	-	2.55	-	
			T <sub>vj</sub> =150°C	-	2.75	-	
E <sub>on</sub>	Turn-on switching energy per pulse	V <sub>DD</sub> =600 V, I <sub>D</sub> /I <sub>S</sub> =600 A,	-	9.7	-	mJ	
E <sub>off</sub>	Turn-off switching energy per pulse	V <sub>GS</sub> =±15 V, R <sub>G</sub> =2.0Ω, T <sub>vj</sub> =125°C	-	26.2	-		
E <sub>rec</sub> (Note.1)	Diode switching energy per pulse	Inductive load	-	0.8	-		
R <sub>DD'+SS'</sub>	Internal lead resistance	P-N, T <sub>c</sub> =25°C(Notes.2)	-	0.5	-	mΩ	
r <sub>g</sub>	Internal gate resistance	Per switch	-	0.72	-	Ω	
L <sub>s</sub>	Internal stray inductance	P-N	-	10	-	nH	

**FMF600DX2-24A**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	-	-	57	K/kW
$R_{th(j-c)D}$		Junction to case, per inverter FWD	-	-	82	
$R_{th(c-s)}$	Contact thermal resistance <sup>(Note.2)</sup>	Case to heat sink, per 1 module, Thermal grease applied <sup>(Note.8)</sup>	-	15	-	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	k $\Omega$
$\Delta R/R$	Deviation of resistance	$R_{100}=493\ \Omega$ , $T_C=100\text{ }^\circ\text{C}$ <sup>(Note.2)</sup>	-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

# FMF600DX2-24A

HIGH POWER SWITCHING USE  
INSULATED TYPE

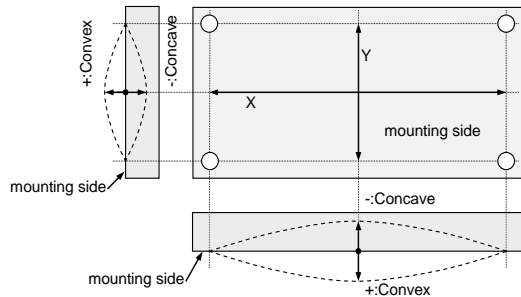
## MECHANICAL CHARACTERISTICS

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	3.5	
$d_s$	Creepage distance	-	17	-	-	mm
$d_a$	Clearance	-	10	-	-	mm
$m$	mass	-	-	454	-	g
$e_c$	Flatness of base plate	On the centerline X, Y (Note.5)	$\pm 0$	-	+100	$\mu\text{m}$

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

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

- 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.
- Pulse width and repetition rate should be such that the device junction temperature ( $T_{vj}$ ) does not exceed  $T_{vjmax}$  rating.
- Junction temperature ( $T_{vj}$ ) should not increase beyond  $T_{vjmax}$  rating.
- 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. Refer to the figure of test circuit.

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

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

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

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

9. Per switch (ex. Tr1 chips total in page.6)

## 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
$V_D$	DC supply voltage(control)	Applied across VDP-EP/VDN-EN terminals	13.5	15	16.5	V
$V_{GS(+)}$	Gate-Source positive drive voltage	Applied across GP-EP,GN-EN terminals	13.5	15	16.5	V
$V_{GS(-)}$	Gate-Source negative drive voltage	Applied across GP-EP/GN-EN terminals	-16.5	-15	-9	V
$R_G$	External gate resistance (Note.10)	Per switch	2.0	-	10	$\Omega$
$t_{d(SCoff)}$	Gate cutoff delay time after SC output	$V_{GS}=15\text{V}$ , $R_G=2.0\ \Omega$ , $T_{vj}=150^\circ\text{C}$	-	-	3	$\mu\text{s}$
$f_c$	Switching frequency	$V_{GS}=\pm 15\text{V}$ , $R_G=2.0\ \Omega$ , $V_{DD}=600\text{V}$ , $T_{vj}=150^\circ\text{C}$	-	-	100	kHz

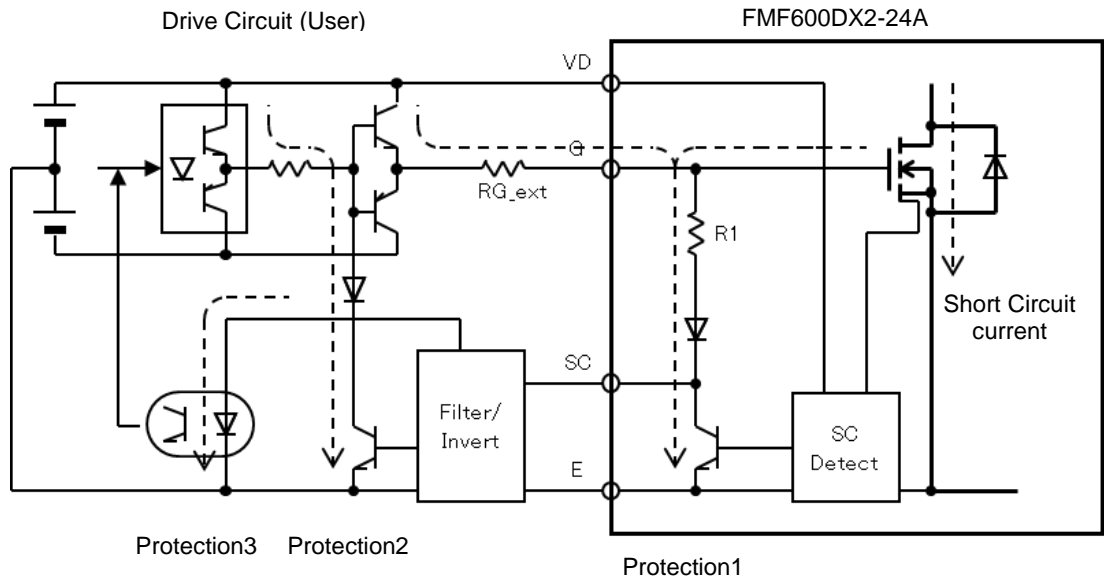
Note 10. The value of external gate resistance should be considered the surge voltage not to exceed the rating voltage in the worst system condition.

# FMF600DX2-24A

HIGH POWER SWITCHING USE

INSULATED TYPE

## SC DETECTION & PROTECTION



Example of application (SC detection & protection)

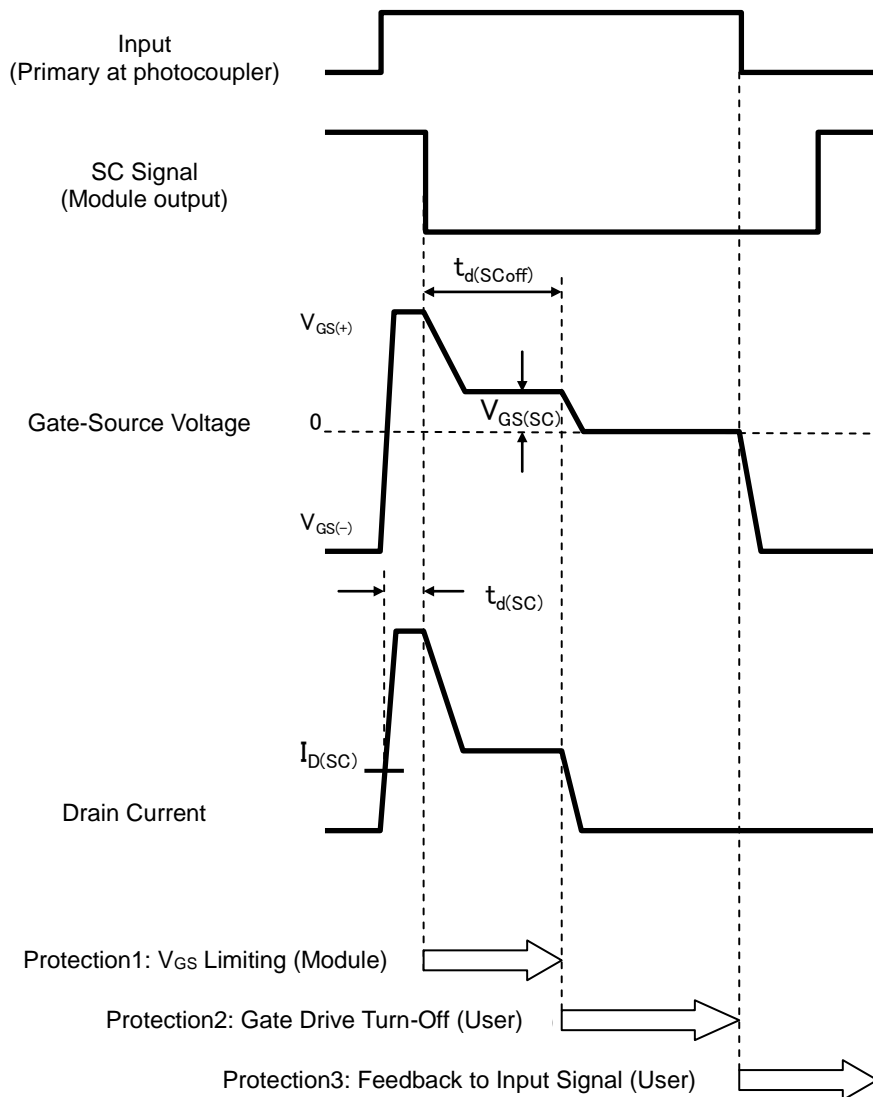


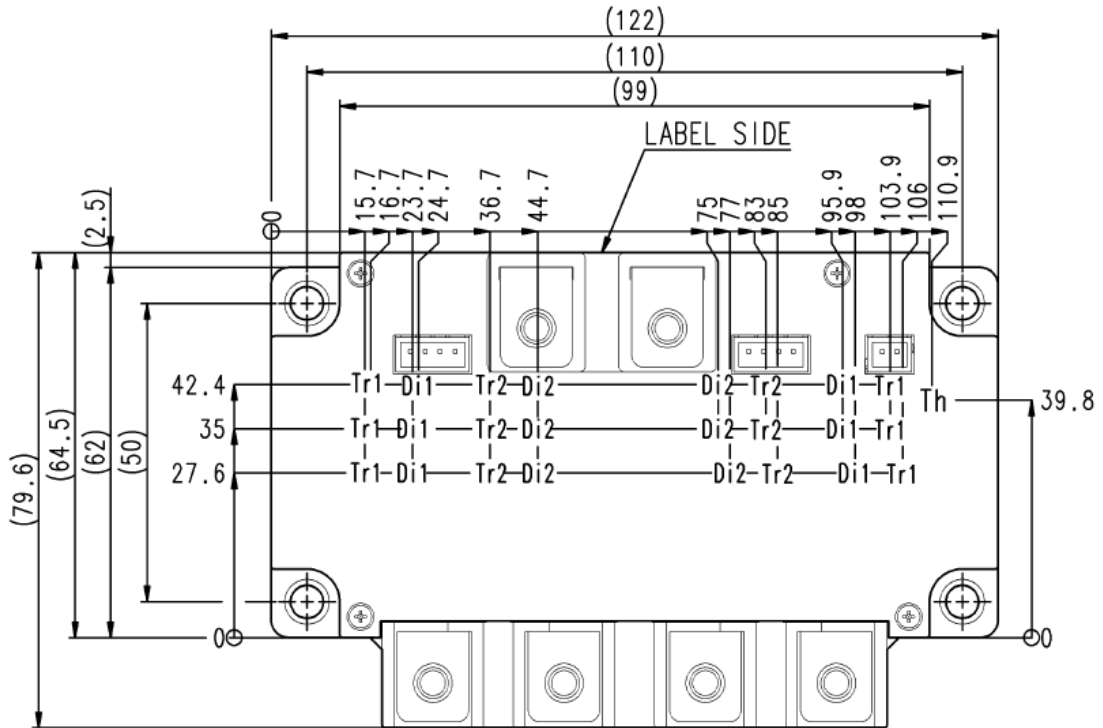
Diagram of SC detection & protection

# FMF600DX2-24A

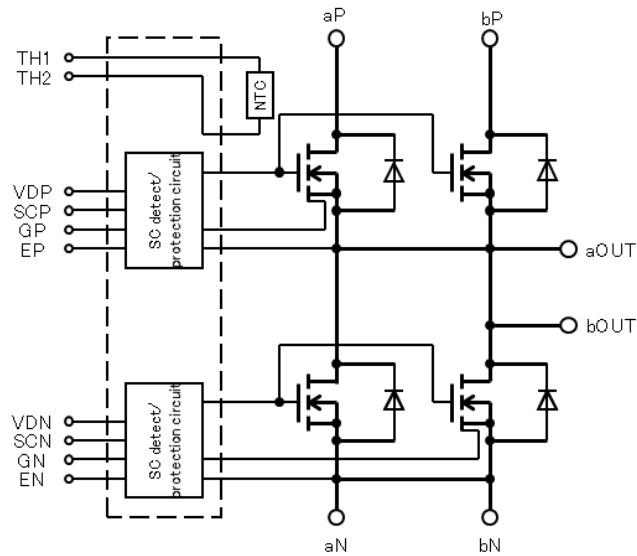
HIGH POWER SWITCHING USE  
INSULATED TYPE

## CHIP LOCATION (Top view)

Dimension in mm, tolerance:  $\pm 1$  mm



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



- The terminal aP-bP, aN-bN, aOUT-bOUT must be connected with each other.
- When the current sensor is not used, SCP-EP, SCN-EN must be short-circuited.

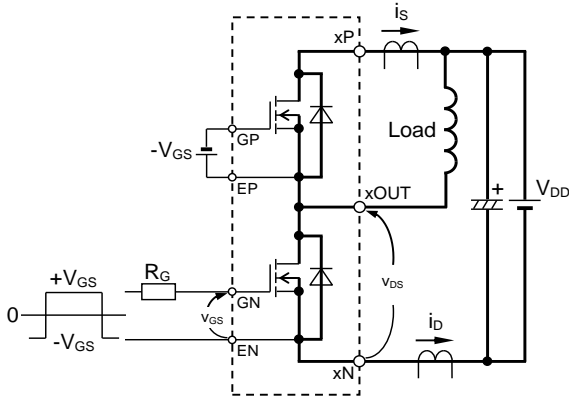
Internal connection

# FMF600DX2-24A

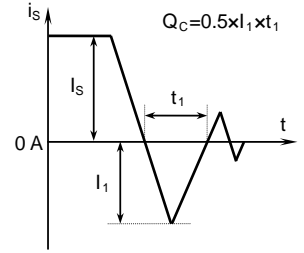
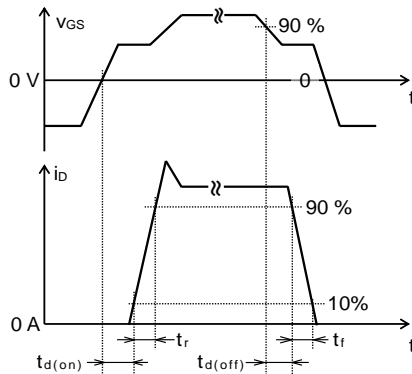
HIGH POWER SWITCHING USE

INSULATED TYPE

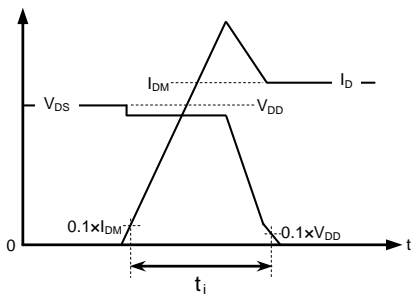
## TEST CIRCUIT AND WAVEFORMS



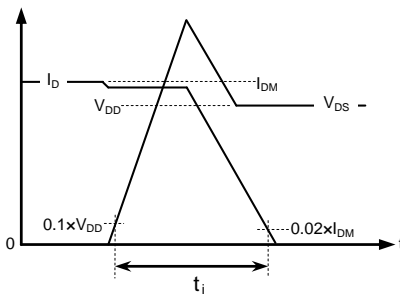
Switching characteristics test circuit and waveforms(x: connected a\* and b\*)



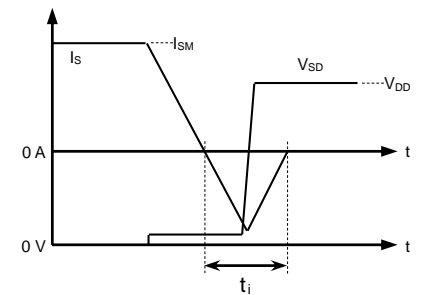
Qc test waveform



MOSFET Turn-on switching energy



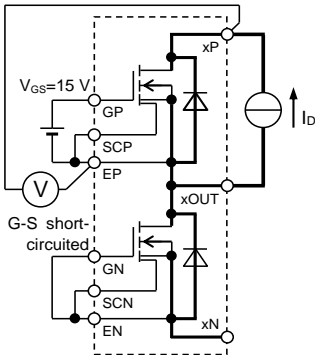
MOSFET Turn-off switching energy



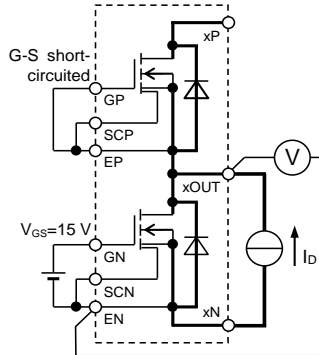
Diode switching energy

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

## TEST CIRCUIT

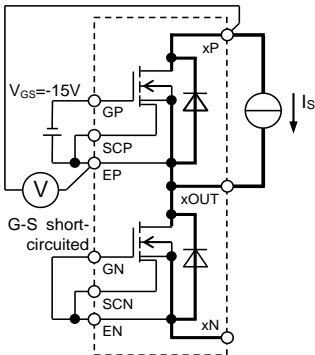


Tr1

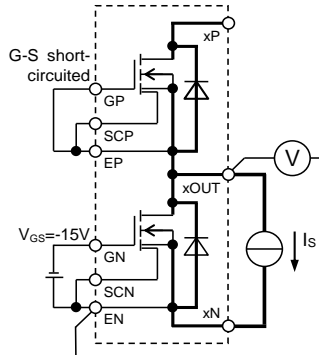


Tr2

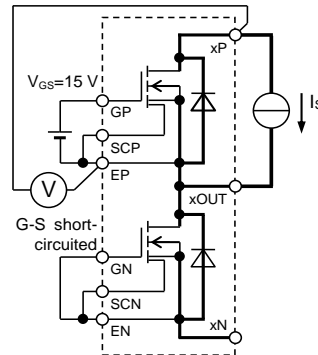
V<sub>DS(on)</sub> test circuit (x: Connected a\* and b\*)



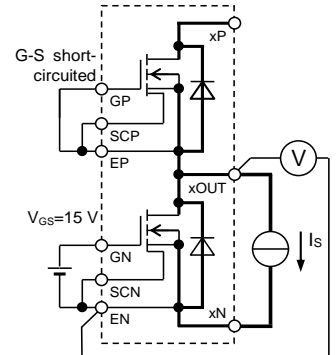
Di1



Di2



Tr1&Di1



Tr2&Di2

V<sub>SD</sub> test circuit (x: Connected a\* and b\*), V<sub>GS</sub>=-15V

V<sub>SD</sub> test circuit (x: Connected a\* and b\*), V<sub>GS</sub>=15V

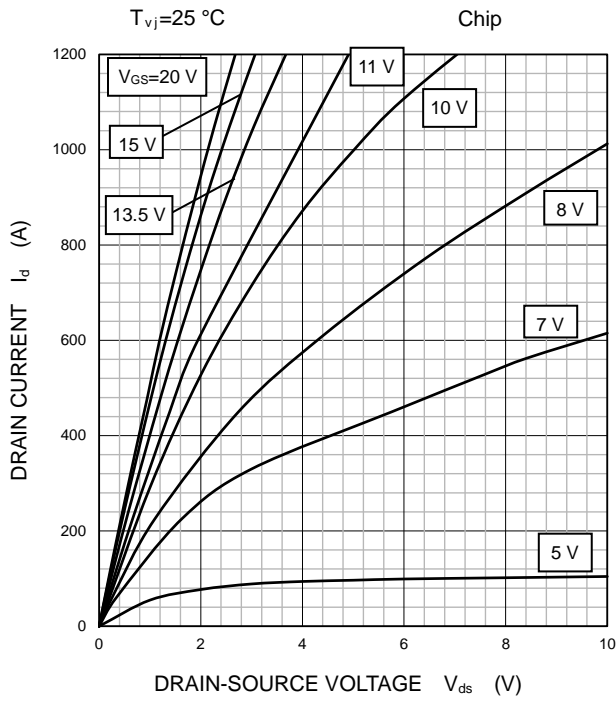
# FMF600DX2-24A

HIGH POWER SWITCHING USE

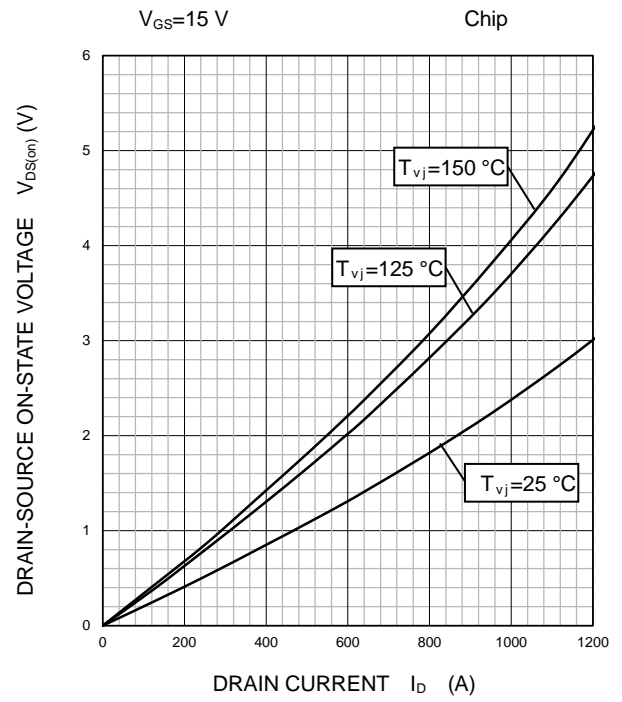
INSULATED TYPE

## PERFORMANCE CURVES

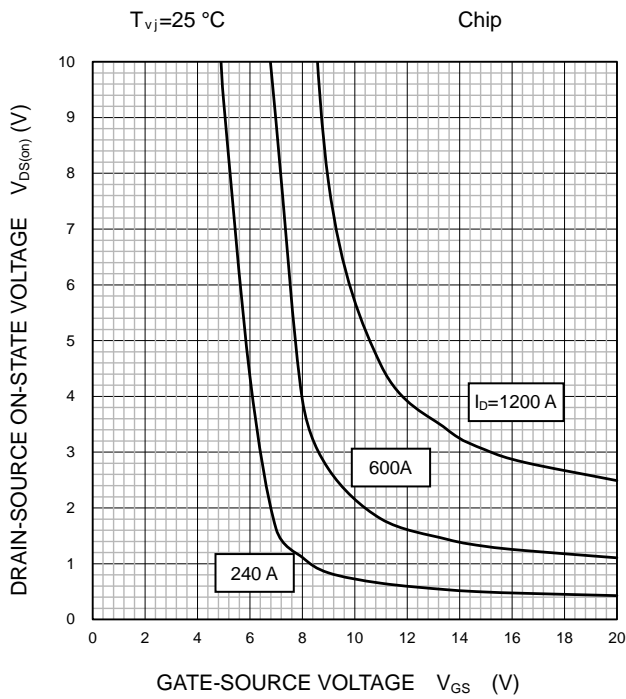
OUTPUT CHARACTERISTICS (TYPICAL)



DRAIN-SOURCE ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)



DRAIN-SOURCE ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)





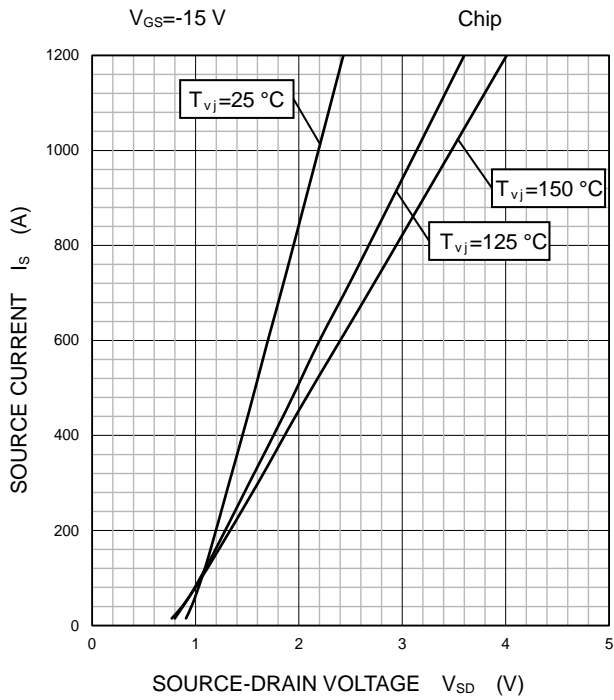
# FMF600DX2-24A

HIGH POWER SWITCHING USE

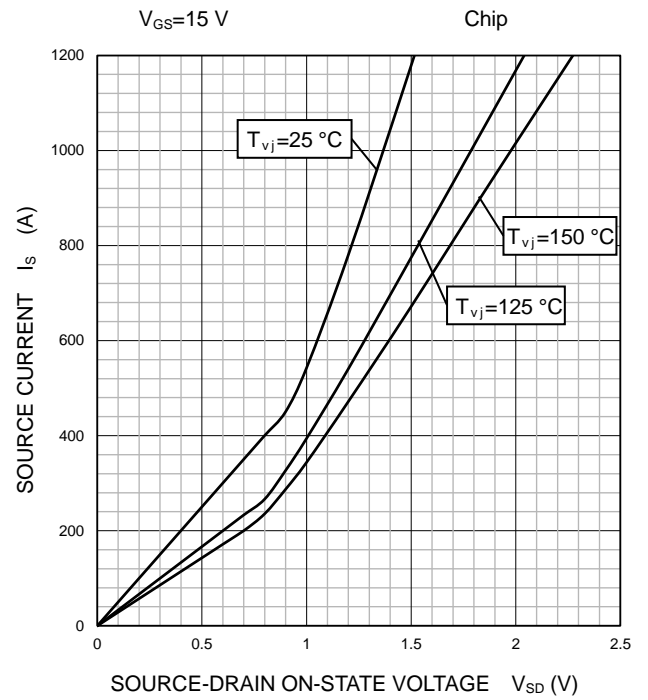
INSULATED TYPE

## PERFORMANCE CURVES

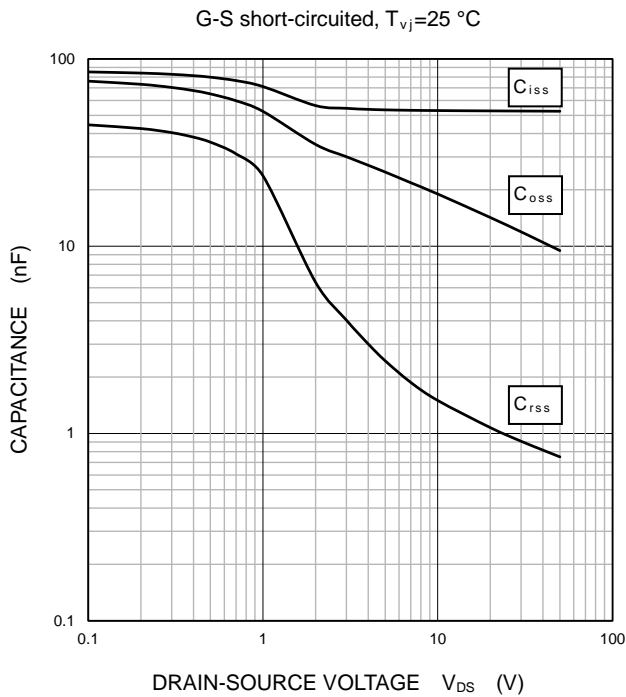
FREE WHEELING DIODE  
FORWARD CHARACTERISTICS  
(TYPICAL)



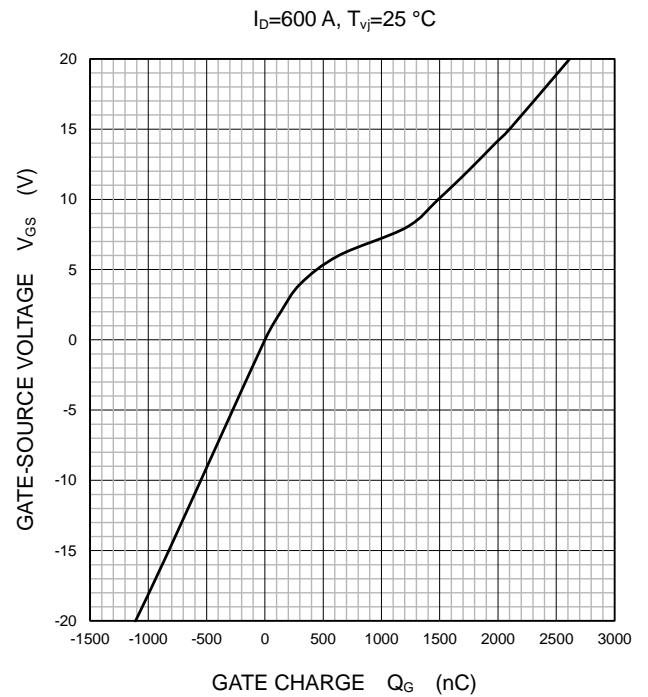
SOURCE-DRAIN ON STATE VOLTAGE  
CHARACTERISTICS  
(TYPICAL)



CAPACITANCE  
CHARACTERISTICS  
(TYPICAL)



GATE CHARGE  
CHARACTERISTICS  
(TYPICAL)



# FMF600DX2-24A

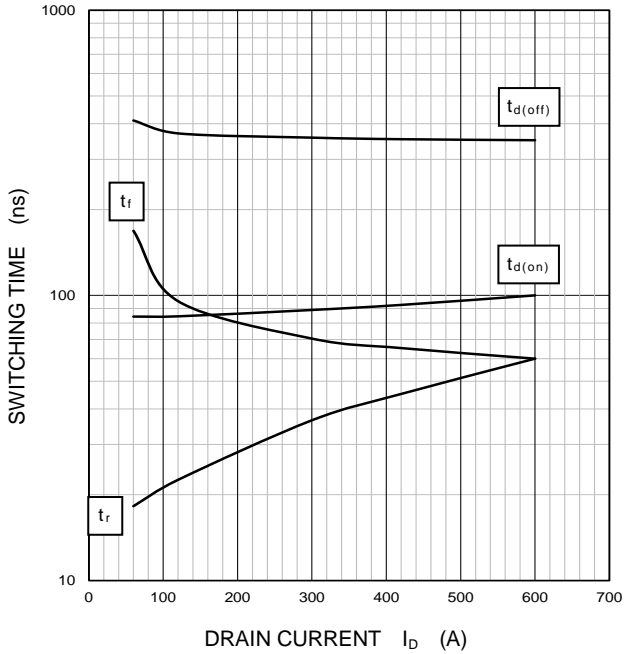
HIGH POWER SWITCHING USE

INSULATED TYPE

## PERFORMANCE CURVES

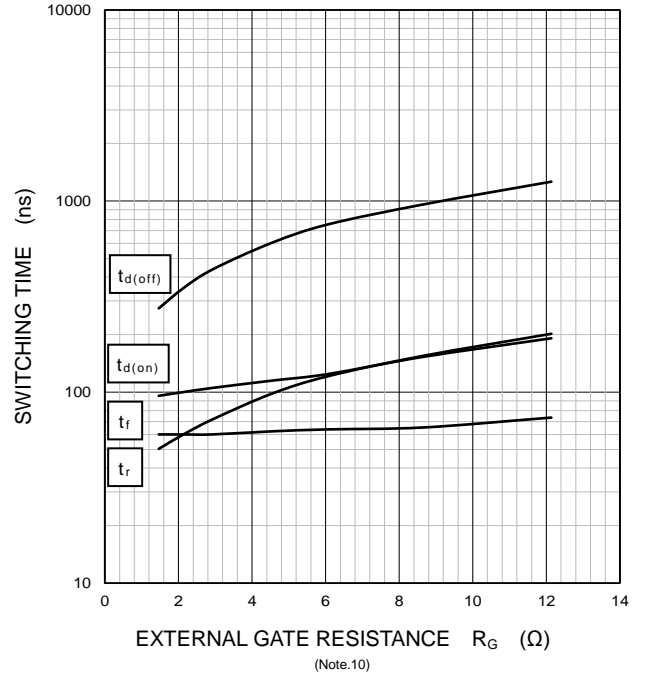
HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $R_G=2.0\ \Omega$ ,  
 $T_{vj}=125\text{ }^\circ\text{C}$ , INDUCTIVE LOAD



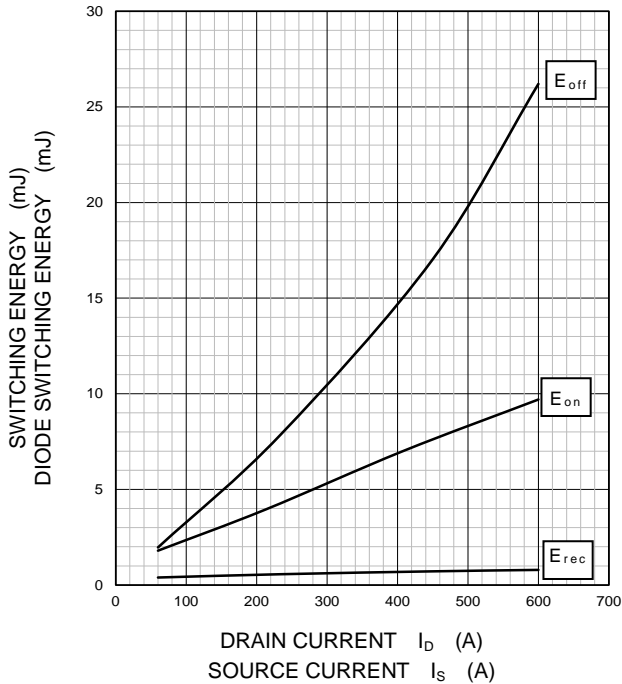
HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $I_D=600\text{ A}$ ,  
 $T_{vj}=125\text{ }^\circ\text{C}$ , INDUCTIVE LOAD



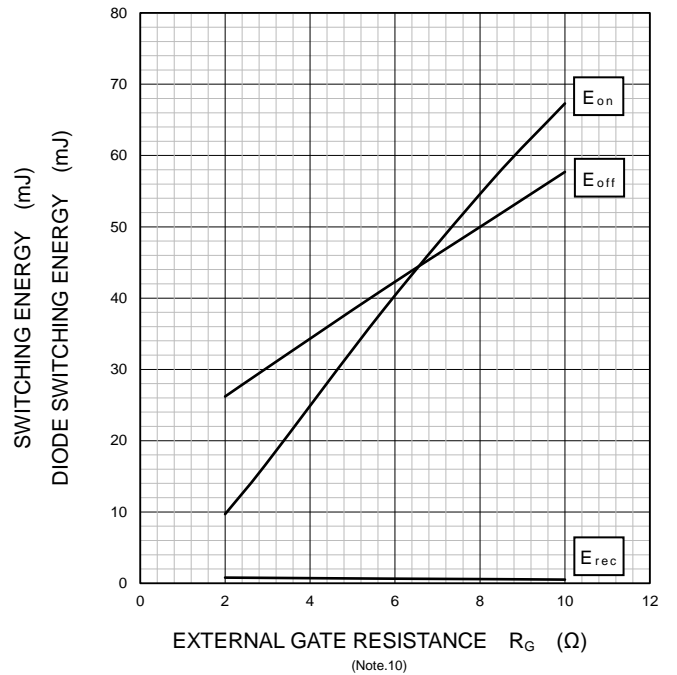
HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $R_G=2.0\ \Omega$ ,  $T_{vj}=125\text{ }^\circ\text{C}$ ,  
INDUCTIVE LOAD, PER PULSE



HALF-BRIDGE  
SWITCHING CHARACTERISTICS  
(TYPICAL)

$V_{DD}=600\text{ V}$ ,  $V_{GS}=\pm 15\text{ V}$ ,  $I_D/I_S=600\text{ A}$ ,  $T_{vj}=125\text{ }^\circ\text{C}$ ,  
INDUCTIVE LOAD, PER PULSE



# FMF600DX2-24A

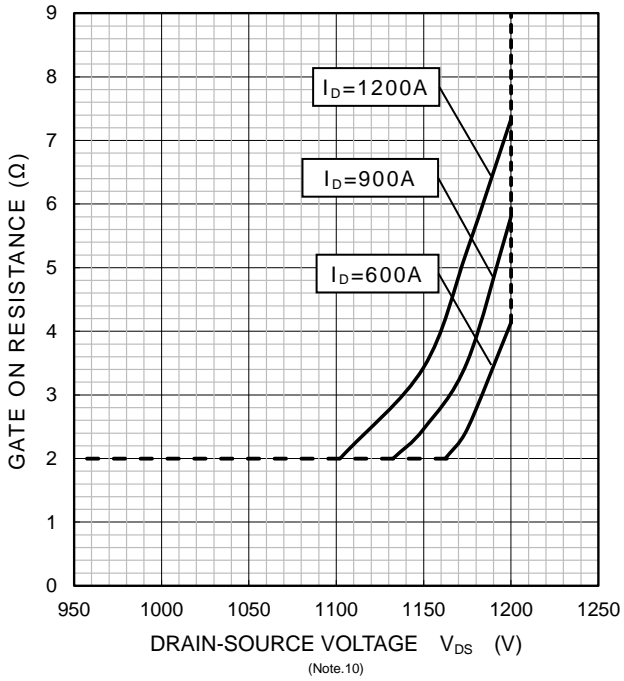
HIGH POWER SWITCHING USE

INSULATED TYPE

## PERFORMANCE CURVES

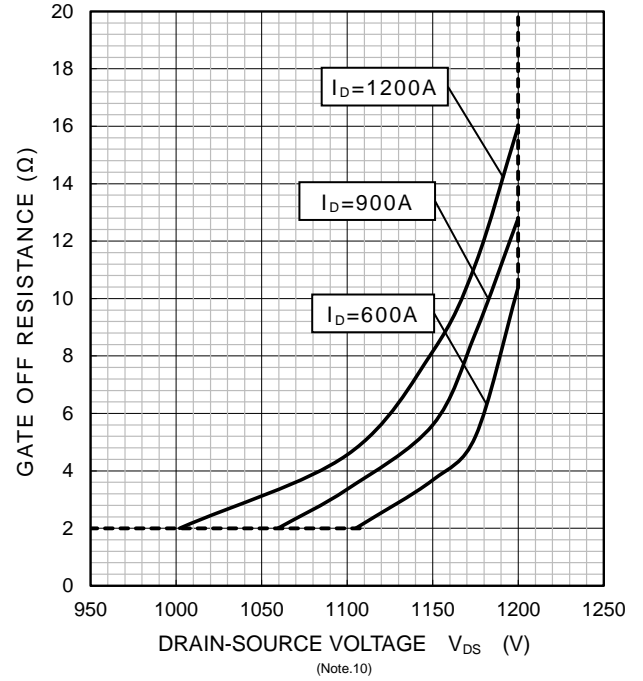
RECOMMENDED GATE RESISTANCE (MINIMUM)

TURN ON,  $V_{GS} = \pm 15\text{ V}$



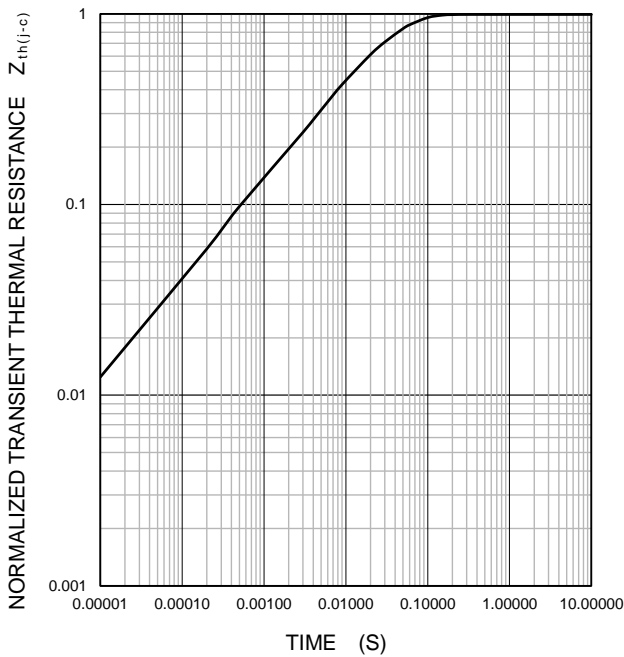
RECOMMENDED GATE RESISTANCE (MINIMUM)

TURN OFF,  $V_{GS} = \pm 15\text{ V}$



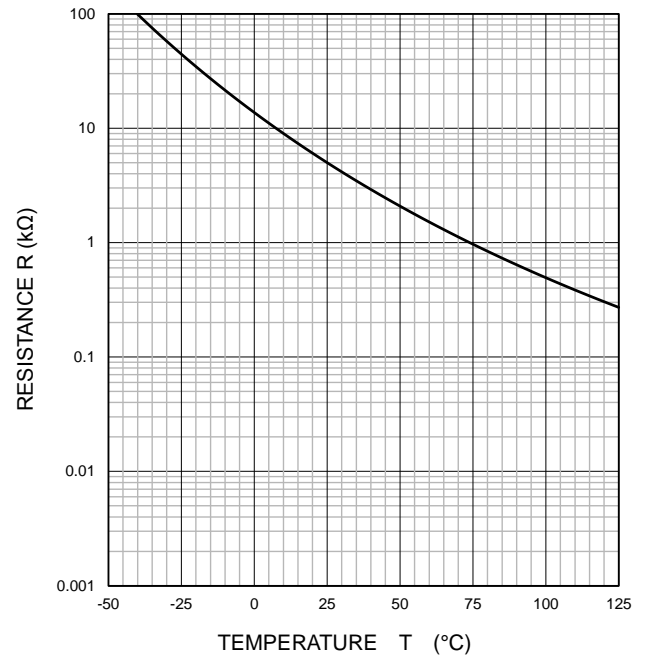
TRANSIENT THERMAL IMPEDANCE CHARACTERISTICS (MAXIMUM)

Single pulse,  $T_C = 25\text{ }^\circ\text{C}$   
 $R_{th(j-c)Q} = 57\text{K/kW}$ ,  $R_{th(j-c)D} = 82\text{K/kW}$



NTC thermistor part

TEMPERATURE CHARACTERISTICS (TYPICAL)



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

## FMF600DX2-24A

HIGH POWER SWITCHING USE  
INSULATED TYPE

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

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In the customer's research and development, please evaluate it not only with a single semiconductor product but also in the entire system, and judge whether it's applicable. Furthermore, 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 (e.g. appropriate fuse or circuit breaker between a power supply and semiconductor products), (ii) use of non-flammable material or (iii) prevention against any malfunction or mishap.

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