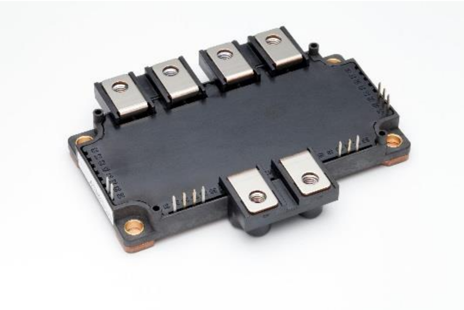
MITSUBISHI ELECTRIC

<Full-SiC Modules>

FMF400BX-24A

HIGH POWER SWITCHING USE
INSULATED TYPE



4in1

Drain current I_D .... 400 A
Drain-Source voltage V_{DSX} .... 1200 V
Maximum junction temperature T_{vjmax} .... 150 °C

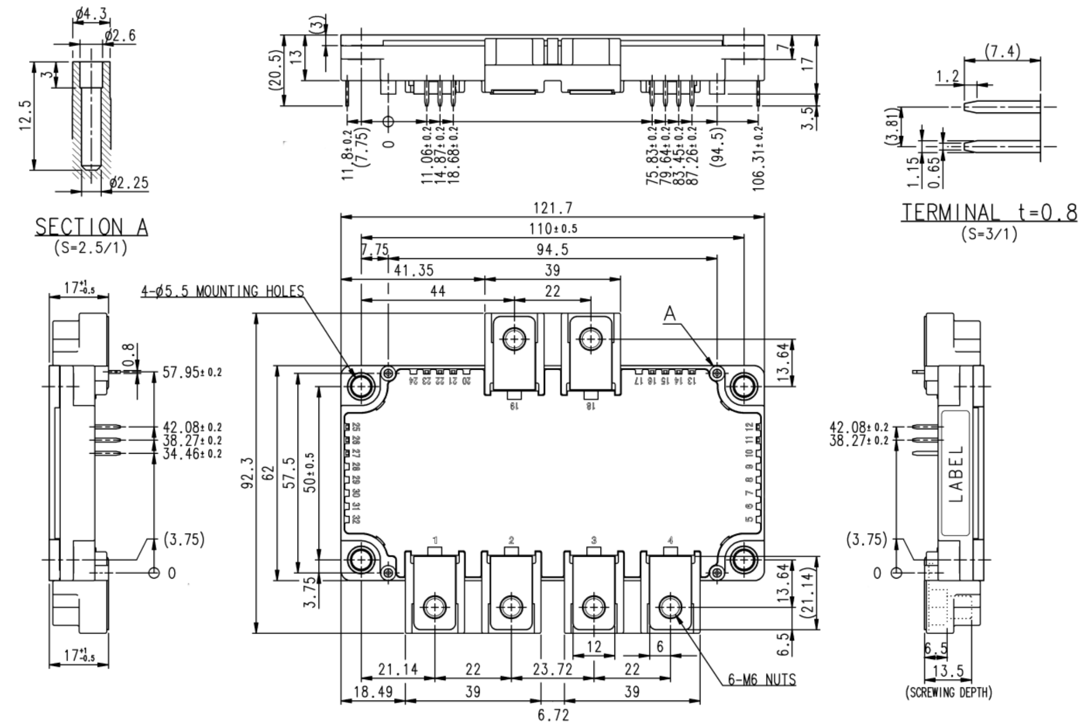
- ●Silicon Carbide MOSFET + Silicon Carbide Schottky Barrier Diode
- ●Flat base Type
- ●Copper base plate
- ●RoHS Directive compliant
- ●Recognized under UL1557, File E323585

APPLICATION

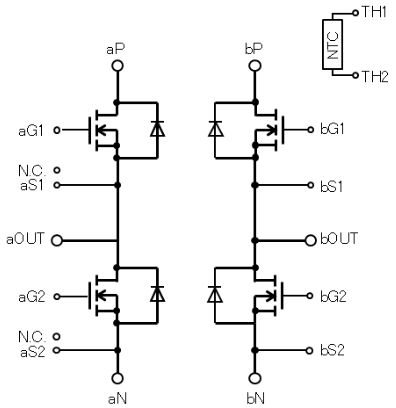
AC Motor Control, Motion/Servo Control, Power supply, etc.

OUTLINE DRAWING & INTERNAL CONNECTION

Dimension in mm



INTERNAL CONNECTION



Terminal code

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

MAXIMUM RATINGS (T_{vj}=25 °C, unless otherwise specified)

Symbol	Item	Conditions	Rating	Unit
V_{DSX}	Drain-source voltage	V_{GS}=-15 V	1200	V
V_{GSS}	Gate-source voltage	D-S short-circuited	± 20	V
I_D	Drain current	DC	400	A
I_{DRM}		Pulse, Repetitive, T_{vj}=150℃ (Note.3)	800	
P_{tot}	Total power dissipation	T_C=25 °C (Note.2, 4)	1485	W
I_S (Note.1)	Source current	DC	400	A
I_{SRM} (Note.1)		Pulse, Repetitive, T_{vj}=150℃ (Note.3)	800	
V_{isol}	Isolation voltage	Terminals to base plate, RMS, f=60 Hz, AC 1 min	4000	V
T_{vjmax}	Maximium junction temperature	Instantaneous event (overload)	150	°C
T_{Cmax}	Maximum case temperature	(Note.2)	125	
T_{vjop}	Junction temperature	Continuous operation (under switching)	-40 ~ +150	
T_{stg}	Storage temperature	-	-40 ~ +125	

ELECTRICAL CHARACTERISTICS (T_{vj}=25 °C, unless otherwise specified)

Symbol	Item	Conditions (note10)		Limits Min.	Typ.	Max.	Unit
I_{DSX}	Drain-source cut-off current	V_{DS}=V_{DSX}, V_{GS}=-15V		-	-	22	mA
		V_{DS}=800V, V_{GS}=-15V		-	-	0.5	
I_{GSS}	Gate-source leakage current	V_{GS}=V_{GSS}, D-S short-circuited		-	-	0.5	μA
$V_{GS(th)}$	Gate-source threshold voltage	I_D=135 mA, V_{DS}=10 V		0.5	1	1.6	V
$r_{DS(on)}$ (chip)	Static drain-source On-state resistance	I_D=400 A, V_{GS}=15 V (Note.6)	T_{vj}=25 °C	-	3.2	-	mΩ
			T_{vj}=150 °C	-	5.6	-	
$V_{DS(on)}$ (chip)	Static drain-source On-state voltage	I_D=400 A, V_{GS}=15 V (Note.6)	T_{vj}=25 °C	-	1.3	-	V
			T_{vj}=125 °C	-	2.02	-	
			T_{vj}=150 °C	-	2.2	-	
$V_{DS(on)}$ (terminal)	Static drain-source On-state voltage	I_D=400 A, V_{GS}=15 V (Note.6)	T_{vj}=25 °C	-	1.66	2.3	V
			T_{vj}=125 °C	-	2.38	-	
			T_{vj}=150 °C	-	2.56	-	
C_{iss}	Input capacitance	V_{DS}=10 V, V_{GS}=0V		-	35	-	nF
C_{oss}	Output capacitance			-	13	-	
C_{rss}	Reverse transfer capacitance			-	1	-	
Q_G	Gate charge	V_{DD}=600 V, I_D=400 A, V_{GS}=15 V		-	1400	-	nC
$t_{d(on)}$	Turn-on delay time	V_{DD}=600 V, I_D=400 A, V_{GS}=±15 V, R_G=4.4Ω, Inductive load		-	120	-	ns
t_r	Rise time			-	80	-	
$t_{d(off)}$	Turn-off delay time			-	420	-	
t_f	Fall time			-	60	-	
Q_C	Drain-source charge			-	2	-	μC
V_{SD} (Note.1) (chip)	Source-drain voltage	I_S=400 A (Note.6) V_{GS}=-15 V	T_{vj}=25 °C	-	1.7	-	V
			T_{vj}=125 °C	-	2.2	-	
			T_{vj}=150 °C	-	2.4	-	
V_{SD} (Note.1) (terminal)	Source-drain voltage	I_S=400 A (Note.6) V_{GS}=-15 V	T_{vj}=25 °C	-	2.05	2.45	V
			T_{vj}=125 °C	-	2.55	-	
			T_{vj}=150 °C	-	2.75	-	
E_{on}	Turn-on switching energy per pulse	V_{DD}=600 V, I_D/I_S=400 A, V_{GS}=±15 V, R_G=4.4Ω, T_{vj}=125 °C, Inductive load		-	11	-	mJ
E_{off}	Turn-off switching energy per pulse			-	20	-	
E_{rec} (Note.1)	Diode switching energy per pulse			-	0.5	-	
$R_{DD'+SS'}$	Internal lead resistance	P-N, T_C=25 °C (Note.2)		-	1.0	-	mΩ
r_g	Internal gate resistance	per Tr1a chips total, per Tr1b chips total, per Tr2a chips total, per Tr2b chips total (internal connection in page 5.)		-	1.1	-	Ω
L_s	Internal stray inductance	P-N		-	18	-	nH

Caution; No short-circuit capability is designed.

THERMAL RESISTANCE CHARACTERISTICS

Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
$R_{th(j-c)Q}$	Thermal resistance (Note.2)	Junction to case, per Tr1a chips total, per Tr1b chips total, per Tr2a chips total, per Tr2b chips total, (internal connection in page 5.)	-	-	84	K/kW
$R_{th(j-c)D}$		Junction to case, per Di1a chips total, per Di1b chips total, per Di2a chips total, per Di1b chips total, (internal connection in page 5.)	-	-	122	
$R_{th(c-s)}$	Contact thermal resistance (Note.2)	Case to heat sink, Thermal grease applied (Note.8)	-	15	-	K/kW

NTC THERMISTOR PART

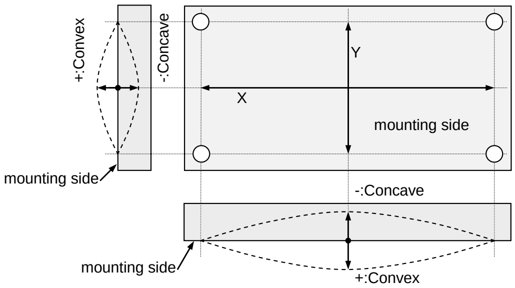
Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
R_{25}	Zero-power resistance	T_C=25 °C (Note.2)	4.85	5.00	5.15	kΩ
ΔR/R	Deviation of resistance	T_C=100 °C, R_{100}=493 Ω (Note.2)	-7.3	-	+7.8	%
$B_{(25/50)}$	B-constant	Approximate by equation (Note.7)	-	3375	-	K
P_{25}	Power dissipation	T_C=25 °C (Note.2)	-	-	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	3.5	
d_s	Creepage distance	Terminal to terminal		12	-	-	mm
		Terminal to base plate		13.6	-	-	
d_a	Clearance	Terminal to terminal		10	-	-	mm
		Terminal to base plate		12.3	-	-	
m	mass	-		-	390	-	g
e_c	Flatness of base plate	On the centerline X, Y (Note.5)		±0	-	+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.

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}) dose not exceed T_{vjmax} rating.
4. Junction temperature (T_{vj}) should not increase beyond T_{vjmax} 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. Refer to the figure of test circuit.
7. $B_{(25/50)} = \ln(\frac{R_{25}}{R_{50}})/(\frac{1}{T_{25}}-\frac{1}{T_{50}})$

R_{25}: resistance at absolute temperature T_{25} [K]; T_{25}=25 [°C]+273.15=298.15 [K]
R_{50}: resistance at absolute temperature T_{50} [K]; T_{50}=50 [°C]+273.15=323.15 [K]
8. Typical value is measured by using thermally conductive grease of λ=0.9 W/(m·K).
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 (ex. Tr1 chips total in page.5)

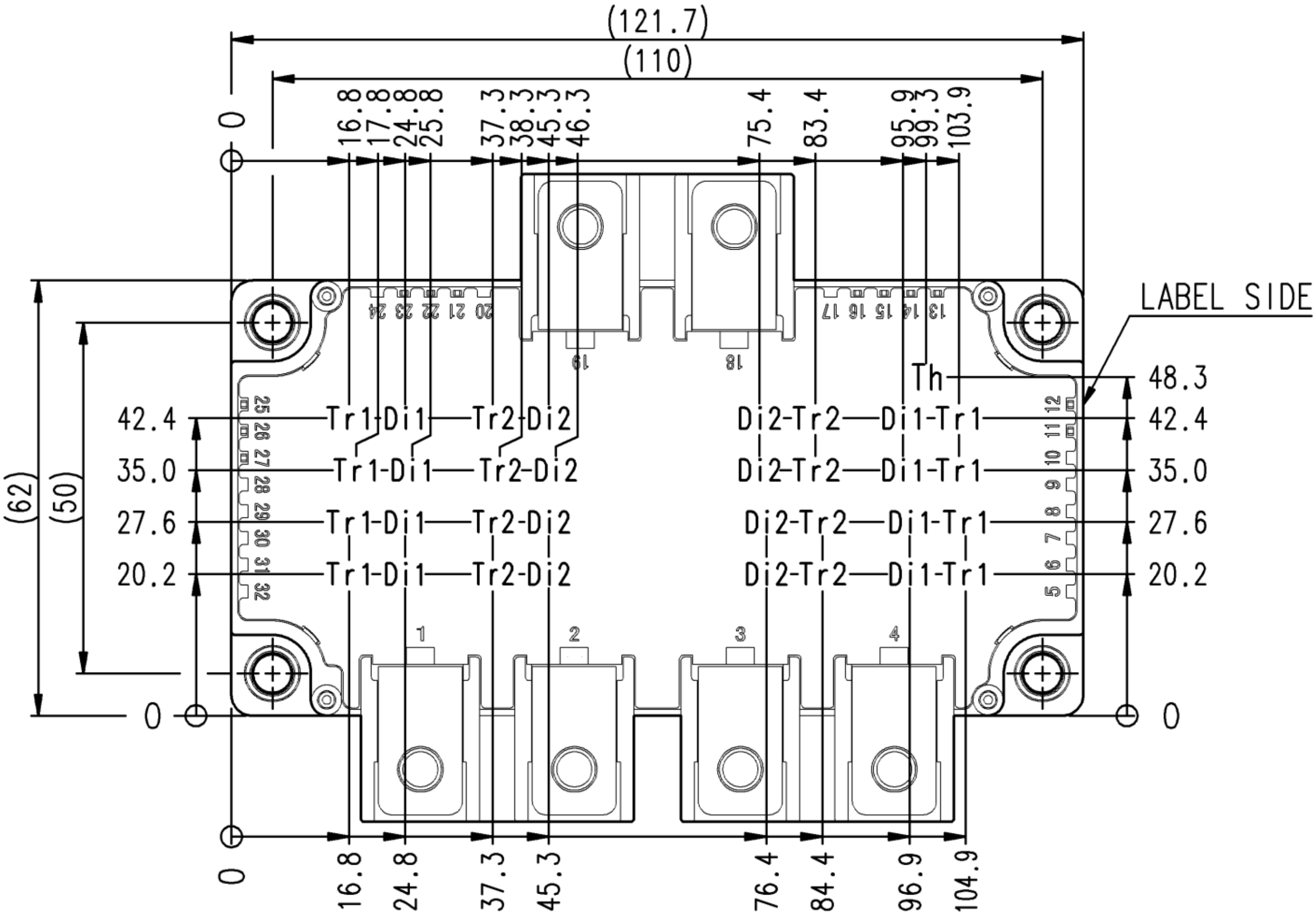
RECOMMENDED OPERATING CONDITIONS

Symbol	Item	Conditions	Limits			Unit
			Min.	Typ.	Max.	
V_{DD}	(DC) Supply voltage	Applied across aP/bP-aN/bN	-	600	850	V
$V_{GS(+)}$	Gate (-source drive) voltage (positive)	Applied across aG1-aS1/bG1-bS1/ aG2-aS2/bG2-bS2	13.5	15	16.5	V
$V_{GS(-)}$	Gate (-source drive) voltage (negative)	Applied across aG1-aS1/bG1-bS1/ aG2-aS2/bG2-bS2	-16.5	-15.0	-9	V
R_G	External gate resistance (Note.11)	Per switch	2.2	-	18	Ω

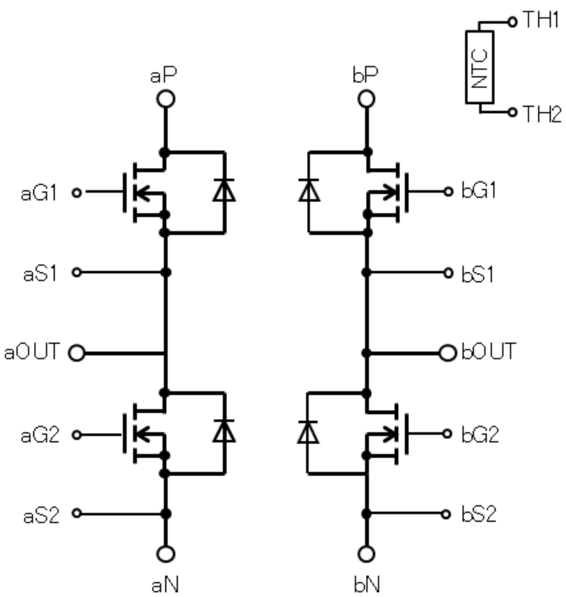
Note 11. The value of external gate resistance should be considered the surge voltage not to exceed the rating voltage in the worst system condition.

CHIP LOCATION (Top view)

Dimension in mm, tolerance: ±1 mm



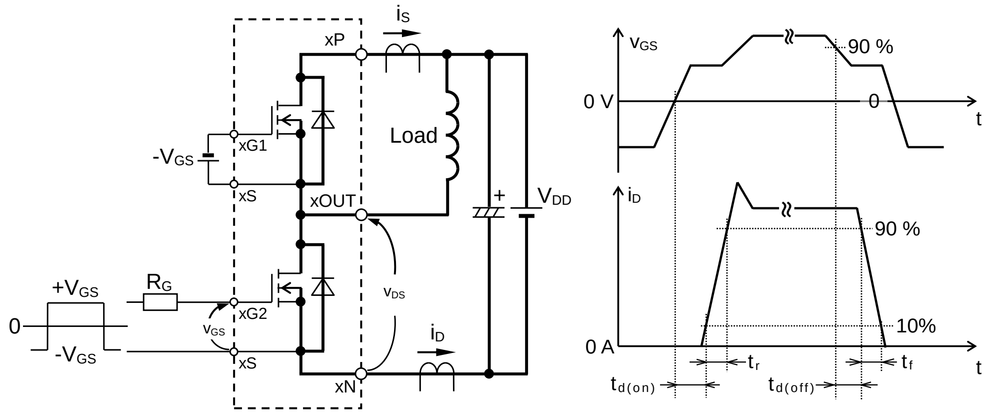
Tr1/Tr2: SiC-MOS, Di1/Di2: SiC-SBD, Th: NTC thermistor



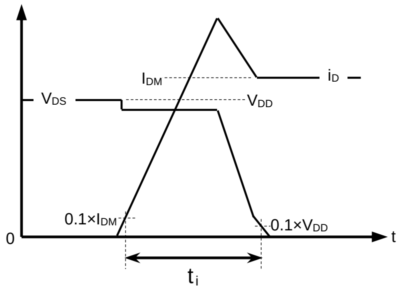
Terminal	code
1	aP
2	aN
3	bN
4	bP
11	bG1
12	bS1
13	TH2
14	TH1
15	bG2
16	bS2
18	bOUT
19	aOUT
21	aS2
22	N.C.
23	aG2
25	aS1
26	N.C.
27	aG1

Internal connection

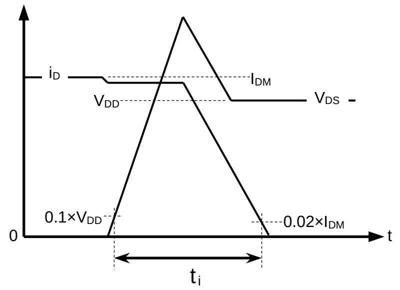
TEST CIRCUIT AND WAVEFORMS



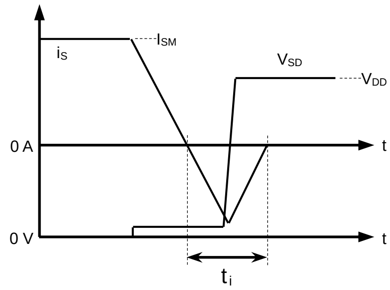
Switching test circuit and waveforms (x: Connected a* or b*)



MOSFET Turn-on switching energy



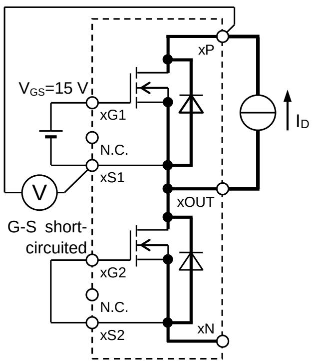
MOSFET Turn-off switching energy



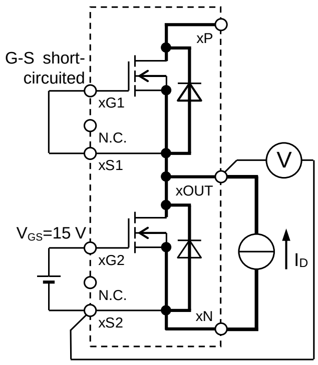
Diode switching energy

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

TEST CIRCUIT

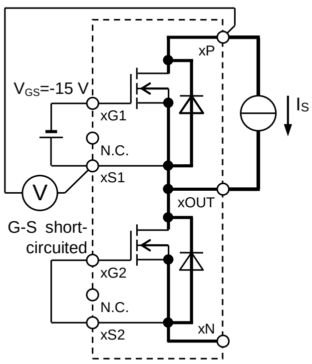


Tr1

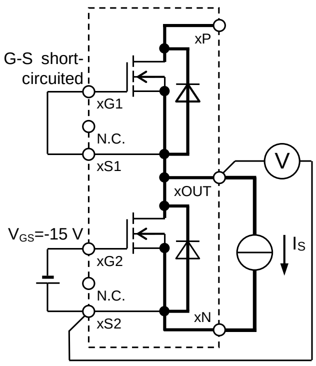


Tr2

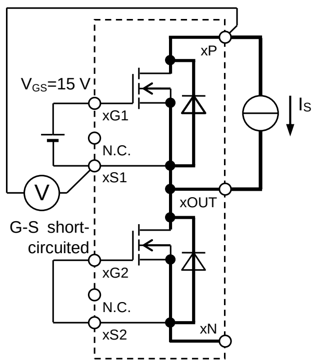
$V_{DS(on)}$ test circuit (x: Connected a* or b*)



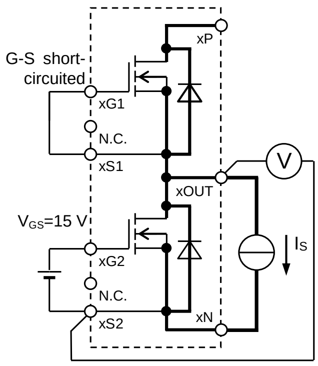
Di1



Di2



Tr1&Di1



Tr2&Di2

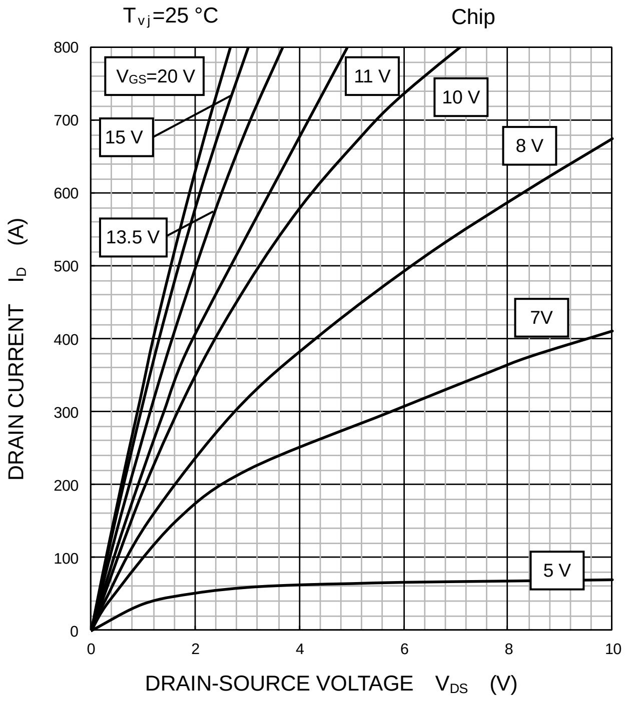
V_{SD} test circuit ,V_{GS}=-15V (x: Connected a* or b*)

$V_{SD(on)}$ test circuit ,V_{GS}=+15V (x: Connected a* or b*)

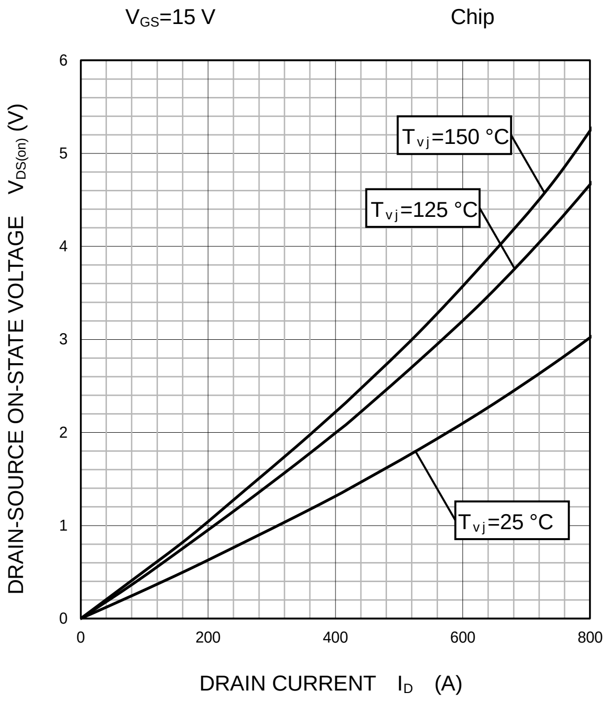
Note: The characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

PERFORMANCE CURVES

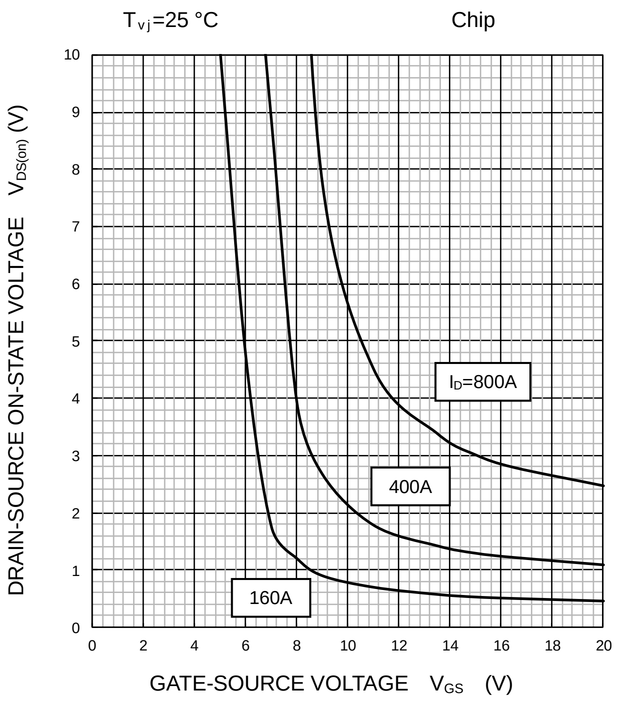
OUTPUT
CHARACTERISTICS
(TYPICAL)



DRAIN-SOURCE ON STATE VOLTAGE
CHARACTERISTICS
(TYPICAL)

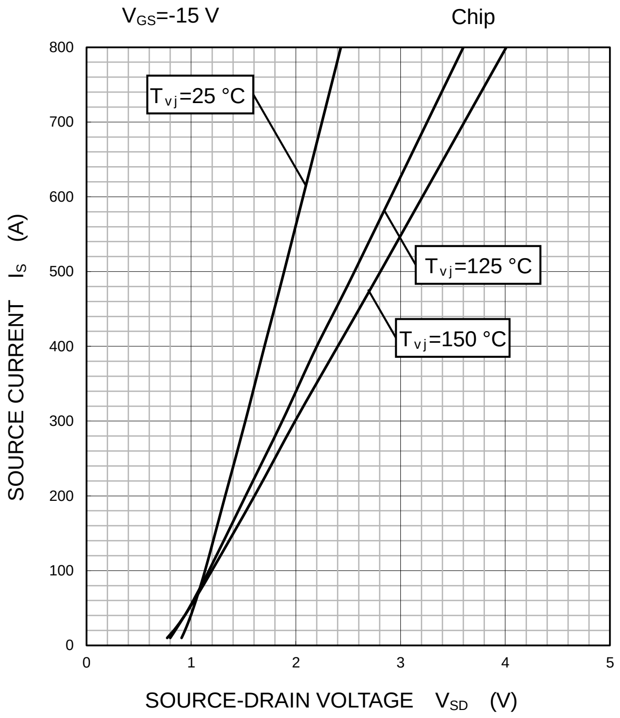


DRAIN-SOURCE ON STATE VOLTAGE
CHARACTERISTICS
(TYPICAL)

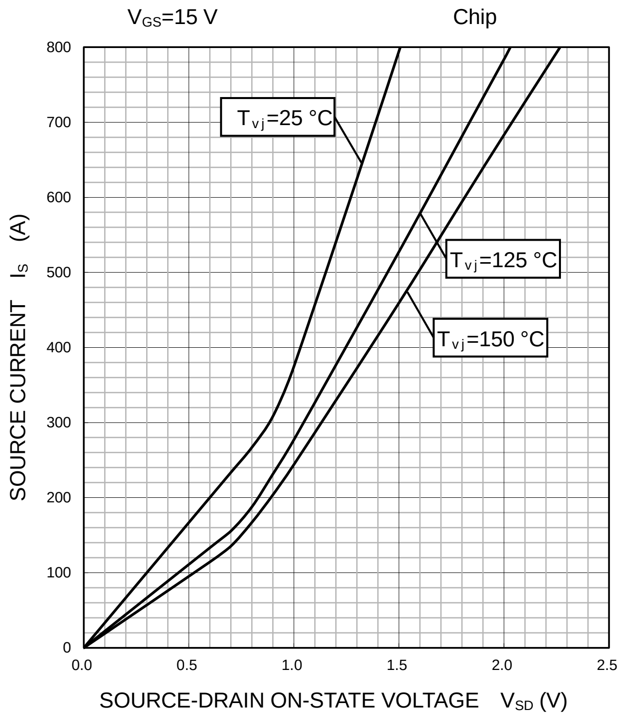


PERFORMANCE CURVES

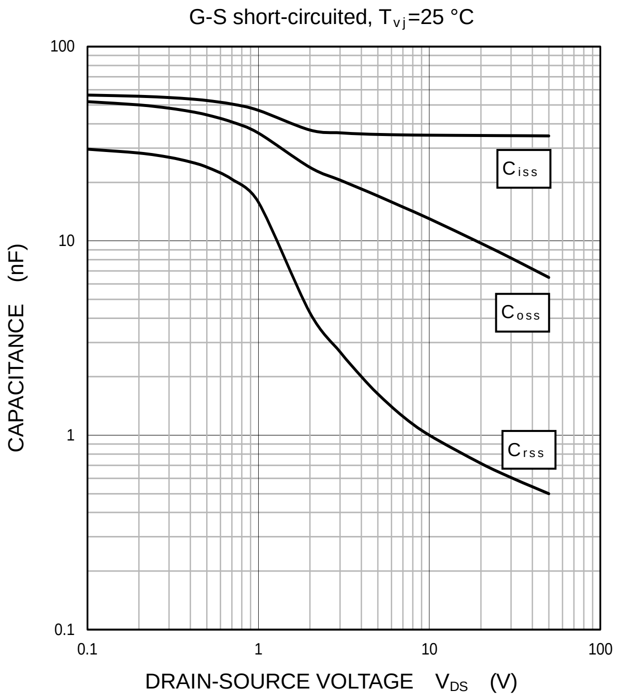
FREE WHEELING DIODE FORWARD CHARACTERISTICS (TYPICAL)



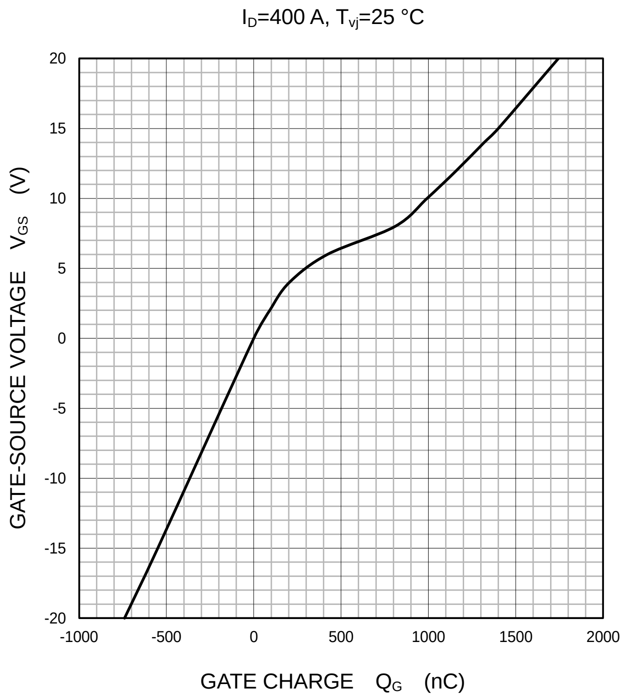
SOURCE-DRAIN ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)



CAPACITANCE CHARACTERISTICS (TYPICAL)



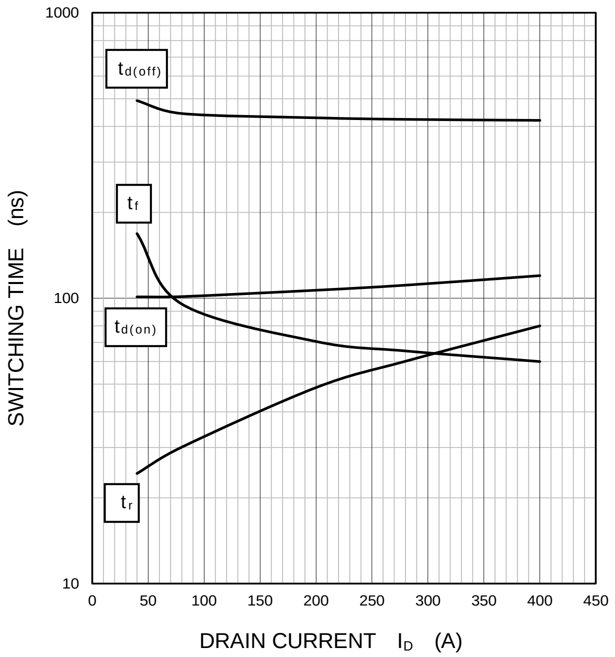
GATE CHARGE CHARACTERISTICS (TYPICAL)



PERFORMANCE CURVES

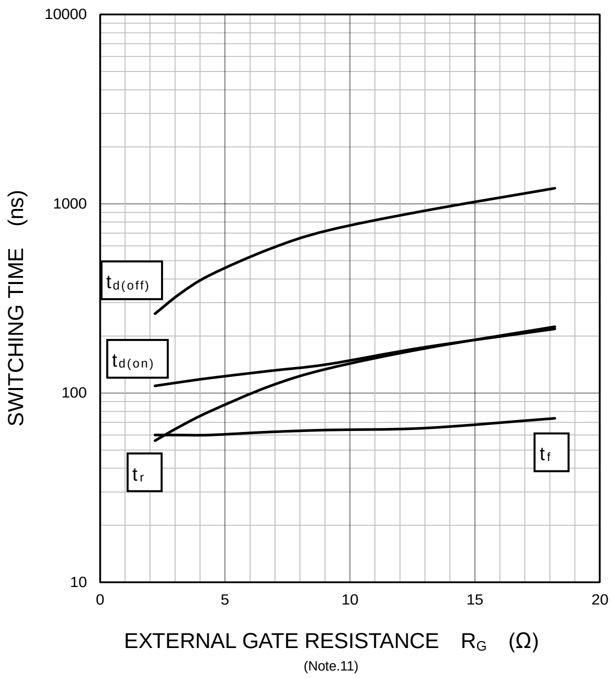
HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

V_{DD}=600 V, V_{GS}=±15 V, R_G=4.4Ω,
T_{vj}=125 °C, INDUCTIVE LOAD



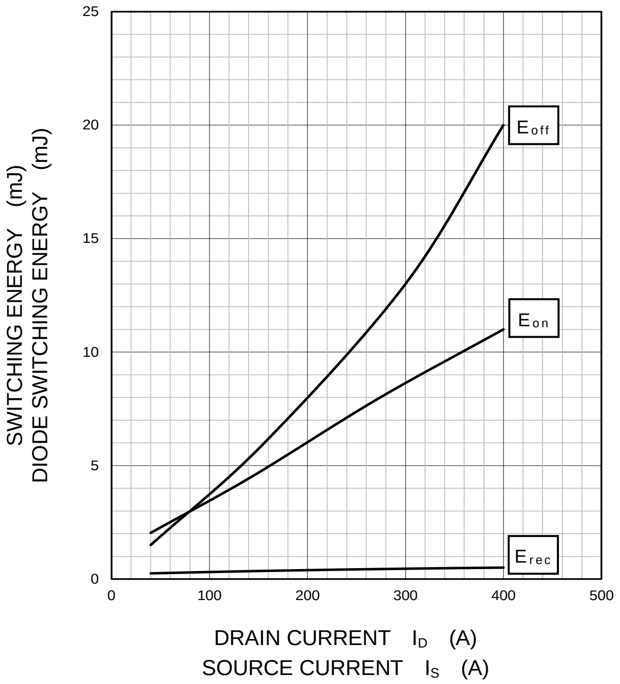
HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

V_{DD}=600 V, V_{GS}=±15 V, I_D=400 A,
T_{vj}=125 °C, INDUCTIVE LOAD



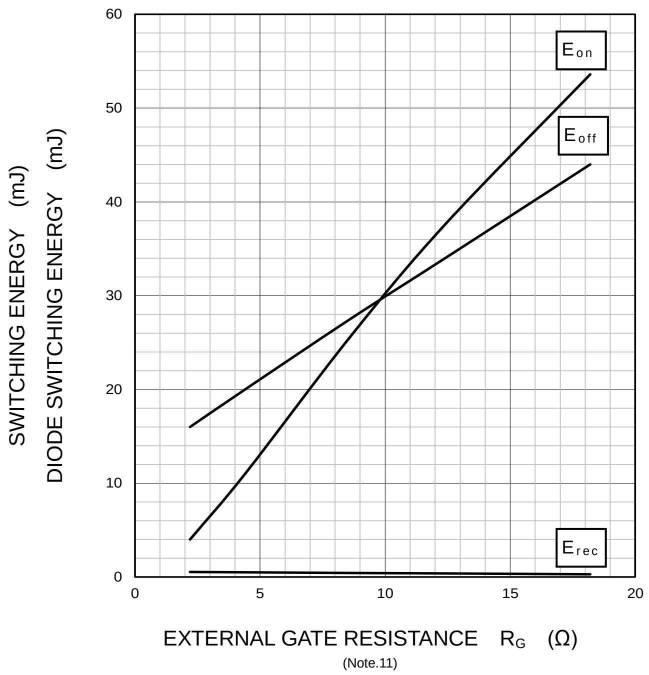
HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

V_{DD}=600 V, V_{GS}=±15 V, R_G=4.4Ω, T_{vj}=125 °C,
INDUCTIVE LOAD, PER PULSE



HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

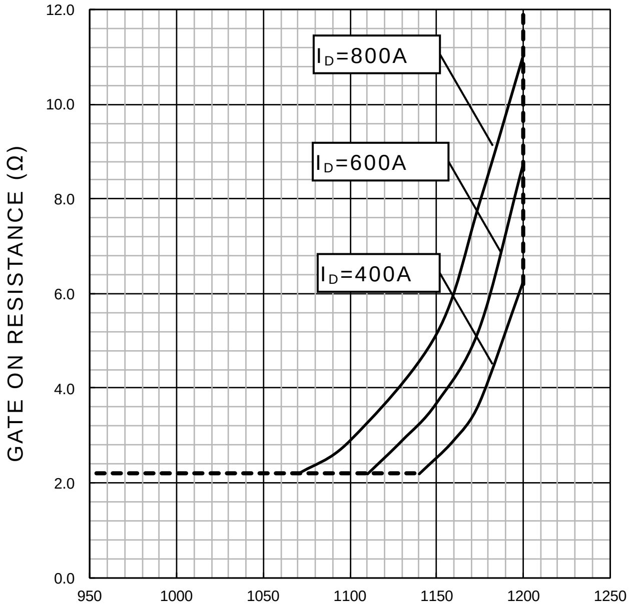
V_{DD}=600 V, V_{GS}=±15 V, I_D/I_S=400 A, T_{vj}=125 °C,
INDUCTIVE LOAD, PER PULSE



PERFORMANCE CURVES

RECOMMENDED GATE RESISTANCE
(MINIMUM)

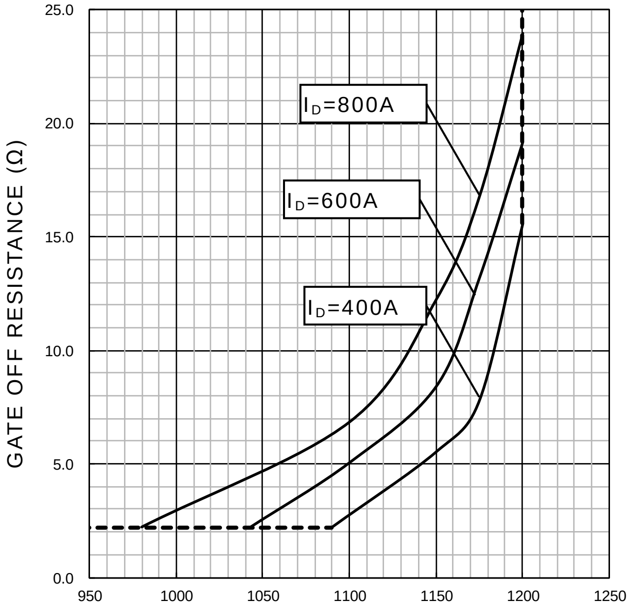
TURN ON, V_{GS}=±15 V



DRAIN-SOURCE VOLTAGE V_{DS} (V)
(Note.11)

RECOMMENDED GATE RESISTANCE
(MINIMUM)

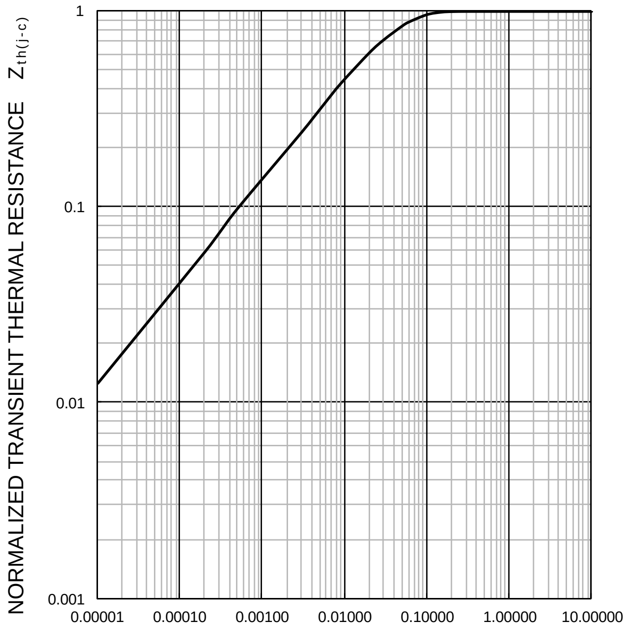
TURN OFF, V_{GS}=±15 V



DRAIN-SOURCE VOLTAGE V_{DS} (V)
(Note.11)

TRANSIENT THERMAL IMPEDANCE
CHARACTERISTICS
(MAXIMUM)

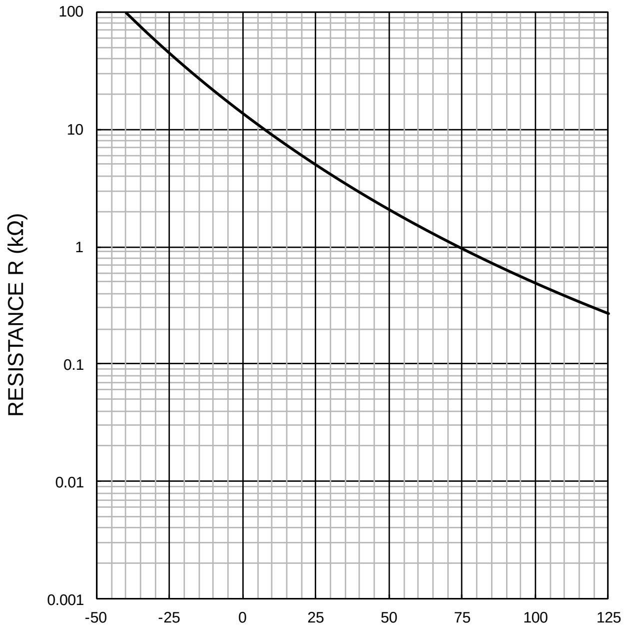
Single pulse, T_C=25 °C
$R_{th(j-c)Q}$=0.84K/W, $R_{th(j-c)D}$=1.22K/W



TIME (S)

NTC thermistor part

TEMPERATURE
CHARACTERISTICS
(TYPICAL)



TEMPERATURE T (°C)

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

Keep safety first in your circuit designs!

This product is designed for industrial application purpose. The performance, the quality and support level of the product is guaranteed by “Customer's Std. Spec.”.
Mitsubishi Electric Corporation puts its reasonable effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them by the reliability lifetime such as Power Cycle, Thermal Cycle or others, or to be used under special circumstances(e.g. high humidity, dusty, salty, highlands, environment with lots of organic matter / corrosive gas / explosive gas, or situation which terminal of semiconductor products is received strong mechanical stress).
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.

Notes regarding these materials

- These materials are intended as a reference to assist our customers in the selection of the Mitsubishi semiconductor product best suited to the customer's application; they do not convey any license under any intellectual property rights, or any other rights, belonging to Mitsubishi Electric Corporation or a third party.
- Mitsubishi Electric Corporation assumes no responsibility for any damage, or infringement of any third-party's rights, originating in the use of any product data, diagrams, charts, or circuit application examples contained in these materials.
- All information contained in these materials, including product data, diagrams and charts represents information on products at the time of publication of these materials, and are subject to change by Mitsubishi Electric Corporation without notice due to product improvements or other reasons. It is therefore recommended that customers contact Mitsubishi Electric Corporation or an authorized Mitsubishi Semiconductor product distributor for the latest product information before purchasing a product listed herein.
  The information described here may contain technical inaccuracies or typographical errors. Mitsubishi Electric Corporation assumes no responsibility for any damage, liability, or other loss rising from these inaccuracies or errors.
  Please also pay attention to information published by Mitsubishi Electric Corporation by various means, including the Mitsubishi Semiconductor home page (www.MitsubishiElectric.com/semiconductors/).
- When using any or all of the information contained in these materials, including product data, diagrams, and charts, please be sure to evaluate all information as a total system before making a final decision on the applicability of the information and products. Mitsubishi Electric Corporation assumes no responsibility for any damage, liability or other loss resulting from the information contained herein.
- Mitsubishi Electric Corporation semiconductors are not designed or manufactured for use in a device or system that is used under circumstances in which human life is potentially at stake. Therefore, this product should not be used in such applications.
  Please contact Mitsubishi Electric Corporation or an authorized Mitsubishi Semiconductor product distributor when considering the use of a product contained herein for any specific purposes, such as apparatus or systems for transportation, vehicular, medical, aerospace, nuclear, or undersea repeater use.
- In the case of new requirement is available, this material will be revised upon consultation.
- The prior written approval of Mitsubishi Electric Corporation is necessary to reprint or reproduce in whole or in part these materials.
- If these products or technologies are subject to the Japanese export control restrictions, they must be exported under a license from the Japanese government and cannot be imported into a country other than the approved destination.
  Any diversion or re-export contrary to the export control laws and regulations of Japan and/or the country of destination is prohibited.
- Please contact Mitsubishi Electric Corporation or an authorized Mitsubishi Semiconductor product distributor for further details on these materials or the products contained therein.