MITSUBISHI ELECTRIC

<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

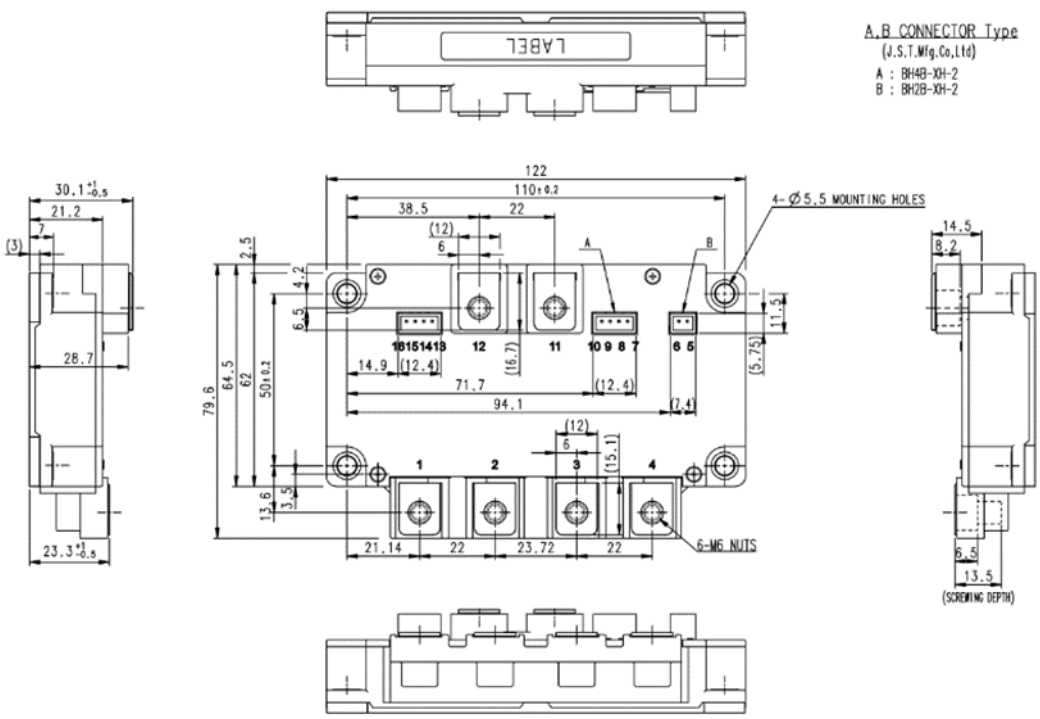
- ●Silicon Carbide MOSFET + Silicon Carbide Schottky Barrier Diode
- ●Flat base Type
- ●Copper base plate
- ●RoHS Directive compliant
- ●Recognized under UL1557, File E323585

APPLICATION

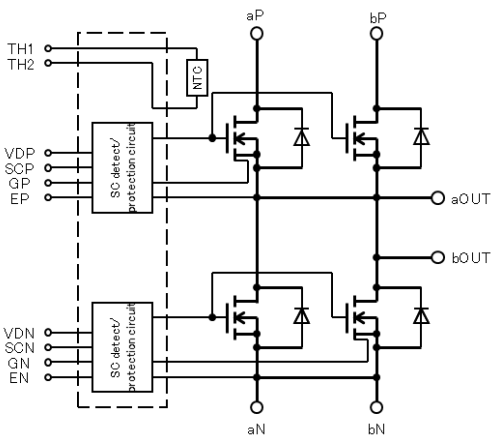
AC Motor Control, Motion/Servo Control, Power supply, etc.

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 should be connected externally.

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

<Full SiC Modules>

FMF600DX2-24A

HIGH POWER SWITCHING USE
INSULATED TYPE

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, T_c=30℃ (Note.2)	600	A
I_{DRM}		Pulse, Repetitive (Note.3), T_{vj}=150℃ (Note.4)	900	
P_{tot}	Total power dissipation	T_C=25 °C (Note. 2,)	2190	W
I_S (Note.1)	Source current	DC	600	A
I_{SRM} (Note.1)		Pulse, Repetitive (Note.3), T_{vj}=150℃	900	
V_{isol}	Isolation voltage	Terminals to base plate, RMS, f=60 Hz, AC 1 min	4000	V
T_{vjmax}	Maximum junction temperature	Instantaneous event (overload)	150	°C
T_{cmax}	Maximum case temperature	(Note.2)	125	°C
T_{vjop}	Operating junction temperature	Continuous operation (under switching)	-40～+150	°C
T_{stg}	Storage temperature	-	-40～+125	°C

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

Symbol	Item	Conditions (Note.10)		Limits			Unit
				Min.	Typ.	Max.	
I_{DSX}	Drain-source cut-off current	V_{DS}=V_{DSX}, V_{GS}=-15 V		-	-	33	mA
		V_{DS}=800V, V_{GS}=-15 V		-	-	1.0	
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=203 mA, V_{DS}=10 V		0.5	1	1.6	V
$r_{DS(on)}$ (Chip)	Static drain-source On-state resistance	I_D=600 A, V_{GS}=15V (Note.6)	T_{vj}=25 °C	-	2.2	-	mΩ
			T_{vj}=150 °C	-	3.7	-	
$V_{DS(on)}$ (chip)	Static drain-source On-state voltage	I_D=600 A, V_{GS}=15V (Note.6)	T_{vj}=25 °C	-	1.31	-	V
			T_{vj}=125 °C	-	2.02	-	
			T_{vj}=150 °C	-	2.21	-	
$V_{DS(on)}$ (terminal)	Static drain-source On-state voltage	I_D=600 A, V_{GS}=15V (Note.6)	T_{vj}=25 °C	-	1.66	2.30	V
			T_{vj}=125 °C	-	2.38	-	
			T_{vj}=150 °C	-	2.56	-	
C_{iss}	Input capacitance	V_{DS}=10 V, V_{GS}=0V		-	53	-	nF
C_{oss}	Output capacitance			-	19	-	
C_{rss}	Reverse transfer capacitance			-	1.5	-	
Q_G	Gate charge	V_{DD}=600 V, I_D=600 A, V_{GS}=15 V		-	2100	-	nC
$t_{d(on)}$	Turn-on delay time	V_{DD}=600 V, I_D=600 A, V_{GS}=±15 V R_G=2.0Ω, Inductive load		-	100	-	ns
t_r	Rise time			-	60	-	
$t_{d(off)}$	Turn-off delay time			-	350	-	
t_f	Fall time			-	60	-	
Q_C	Drain-source charge			-	3	-	μC
V_{SD} (Note.1) (Chip)	Source-drain voltage	I_S=600 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=600 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=600 A, V_{GS}=±15 V, R_G=2.0Ω, T_{vj}=125℃ Inductive load		-	9.7	-	mJ
E_{off}	Turn-off switching energy per pulse			-	26.2	-	
E_{rec} (Note.1)	Diode switching energy per pulse			-	0.8	-	
$R_{DD'+SS'}$	Internal lead resistance	P-N, T_C=25℃ (Note.2)		-	0.5	-	mΩ
r_g	Internal gate resistance	Per switch		-	0.72	-	Ω
L_s	Internal stray inductance	P-N		-	10	-	nH

Caution; No short-cirtcuit capabitily 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 inverter switch	-	-	57	K/kW
$R_{th(j-c)D}$		Junction to case, per inverter FWD	-	-	82	
$R_{th(c-s)}$	Contact thermal resistance (Note.2)	Case to heat sink, per 1 module, 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	R_{100}=493 Ω, T_C=100 °C (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

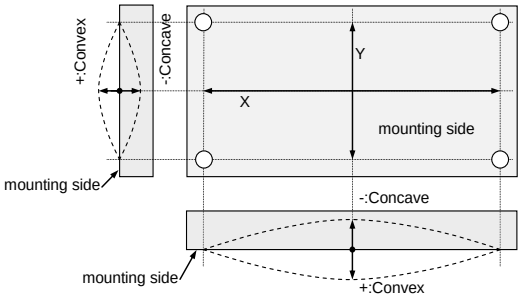
MECHANICAL CHARACTERISTICS

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	-	17	-	-	mm
d_a	Clearance	-	10	-	-	mm
m	mass	-	-	454	-	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}) does 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]

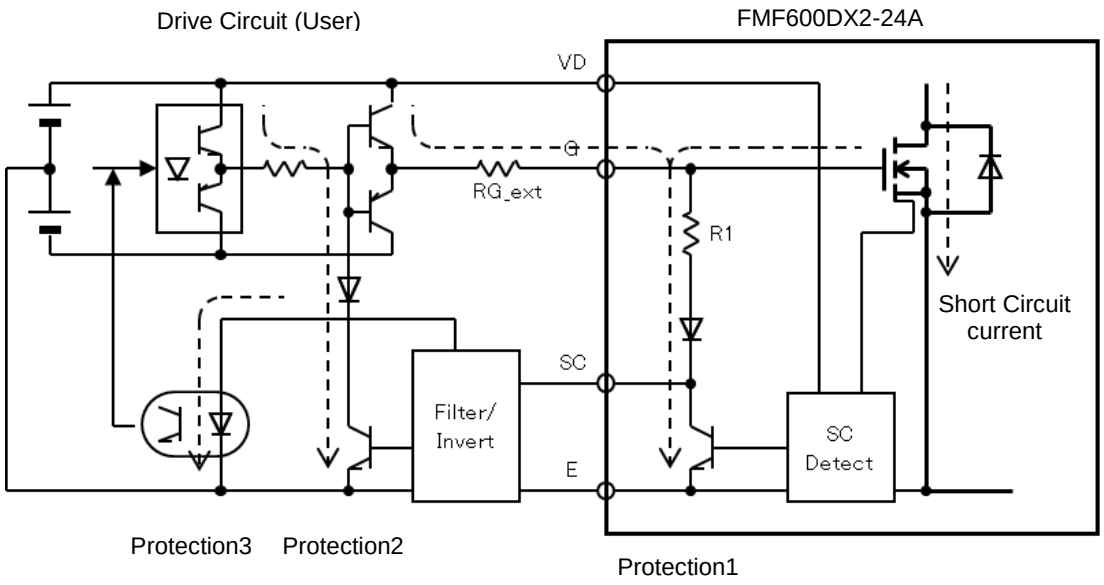
   R_{50}: resistance at absolute temperature T_{50} [K]; T_{50}=50 [°C]+273.15=323.15 [K]
8. Typical value is measured by using thermally conductive grease of λ=0.9 W/(m·K).
9. Use the following screws when mounting the printed circuit board (PCB) on the standoffs.
   "φ2.6×10 or φ2.6×12, B1 tapping screw"
   The length of the screw depends on the thickness (t1.6) of the PCB.
10. Per switch (ex. Tr1 chips total in page.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.11)	Per switch	2.0	-	10	Ω
$t_{d(SCoff)}$	Gate cutoff delay tiem after SC output	V_{GS}=15V, R_G=2.0Ω, T_{vj}=150℃	-	-	3	μs
f_c	Switching frequency	V_{GS}=±15V, R_G=2.0Ω, V_{DD}=600V, T_{vj}=150℃	-	-	100	kHz

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.

SC DETECTION & PROTECTION



Example of application (SC detection & protection)

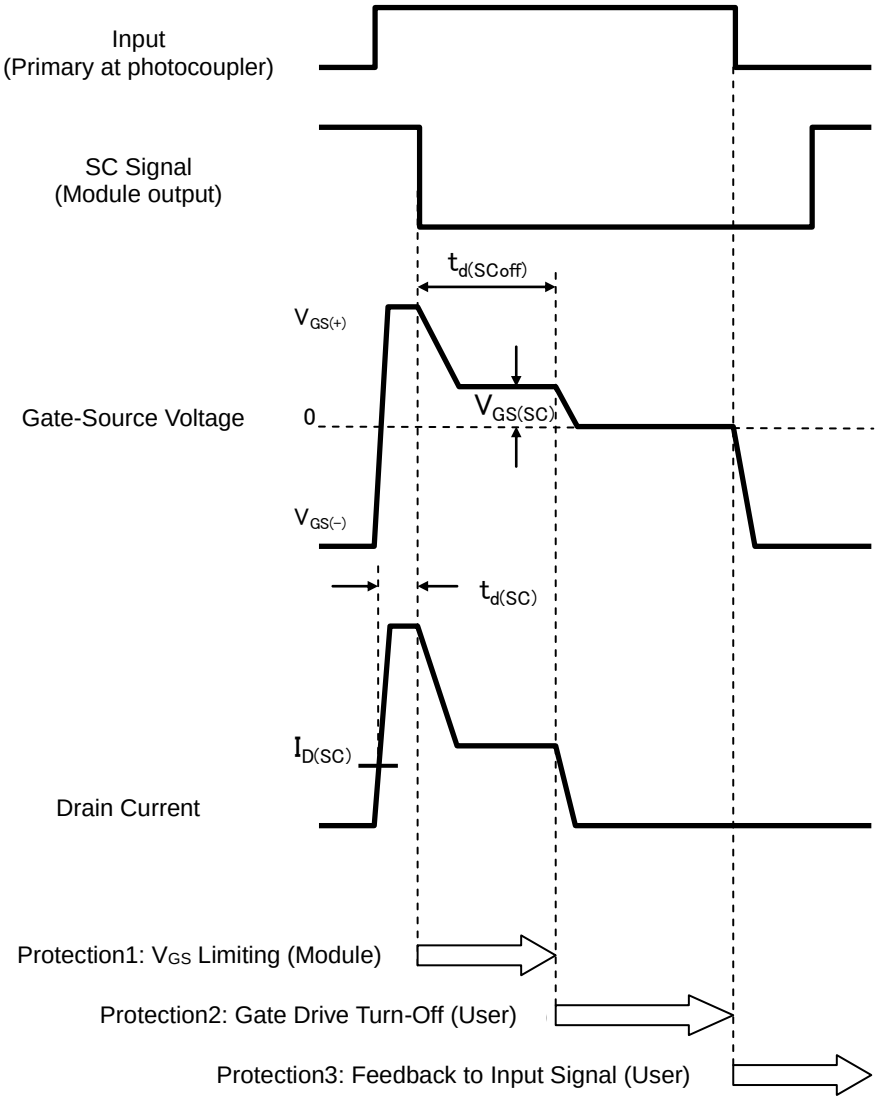
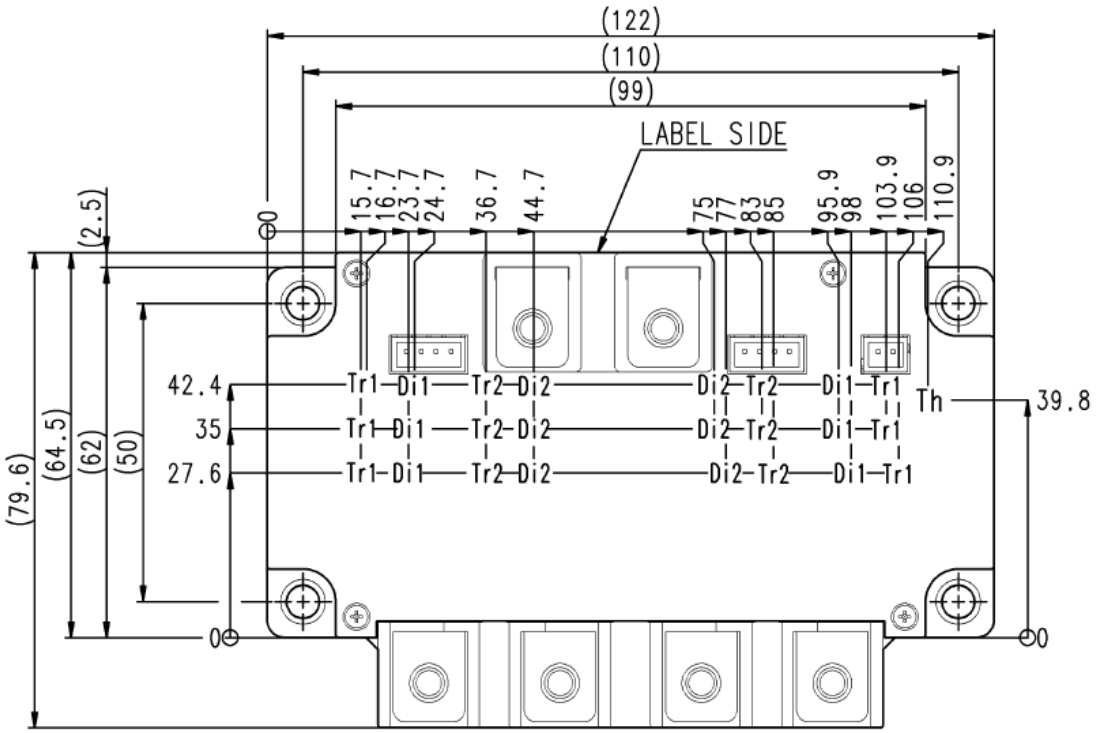


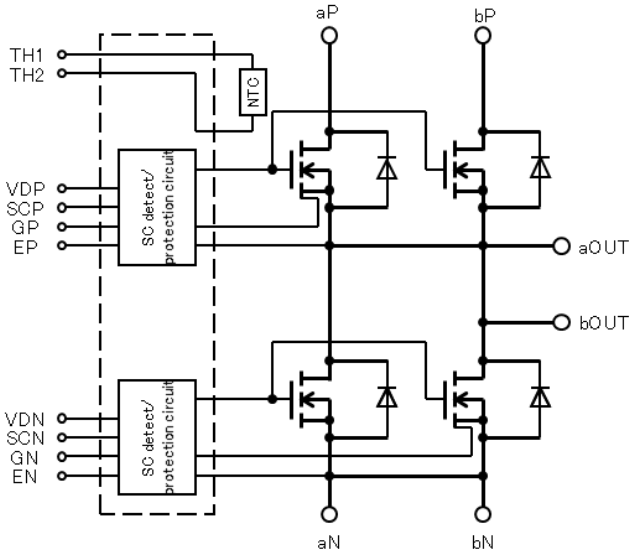
Diagram of SC detection & protection

CHIP LOCATION (Top view)

Dimension in mm, tolerance: ±1 mm



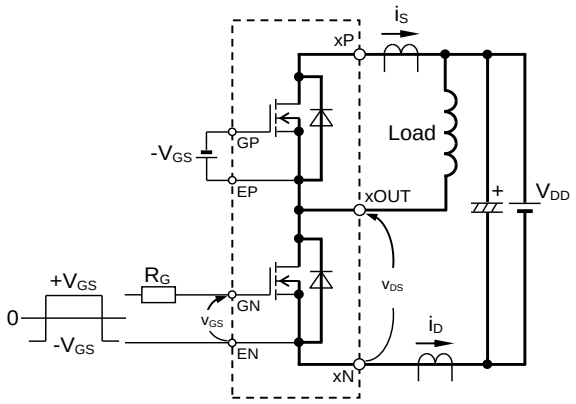
Tr1/Tr2: SiC-MOS, Di2/Di2: SiC-SBD, Th: NTC thermistor

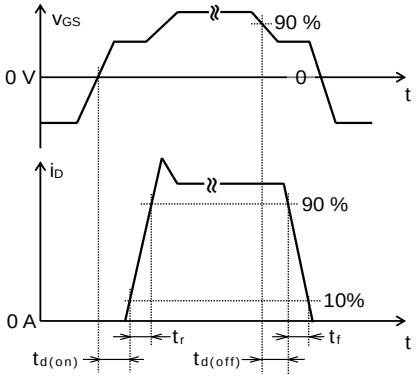


- The terminal aP-bP, aN-bN, aOUT-bOUT must be connected with each other.
- When the current sensor is not used, SCP-EP, SCN-EN must be short-circuited.

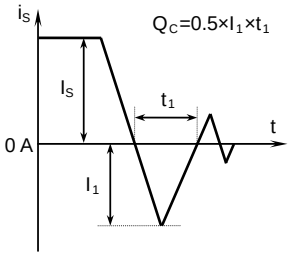
Internal connection

TEST CIRCUIT AND WAVEFORMS

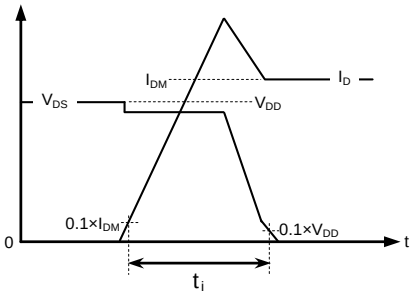




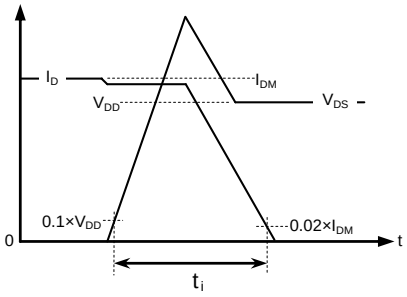
Switching characteristics test circuit and waveforms(x: connected a* and b*)



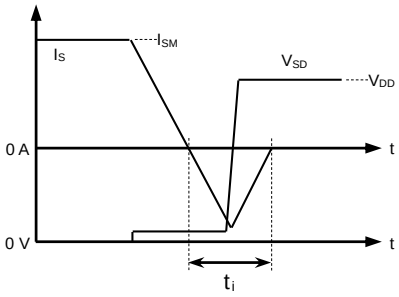
Q_C test waveform



MOSFET Turn-on switching energy



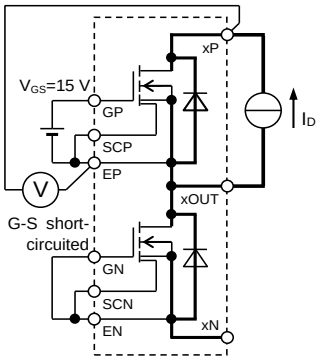
MOSFET Turn-off switching energy



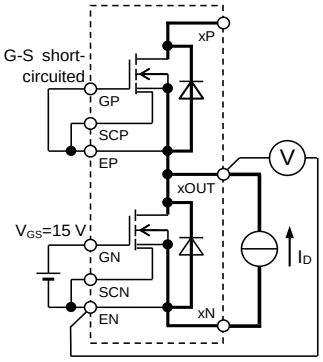
Diode switching energy

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

TEST CIRCUIT

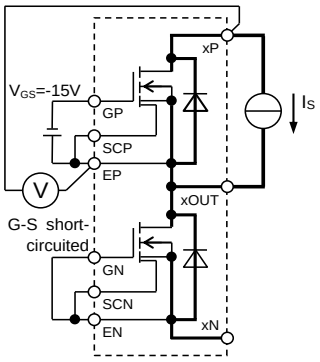


Tr1

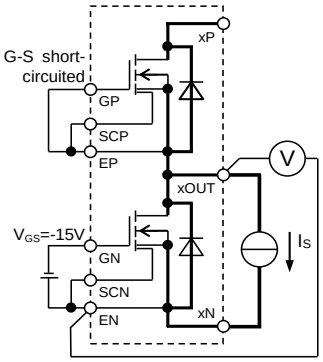


Tr2

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

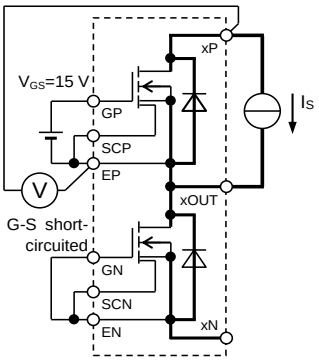


Di1

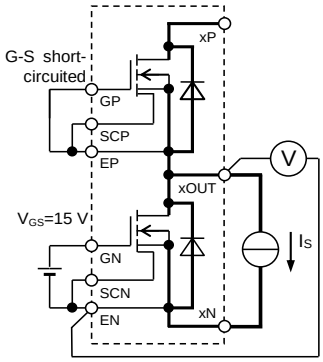


Di2

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



Tr1&Di1

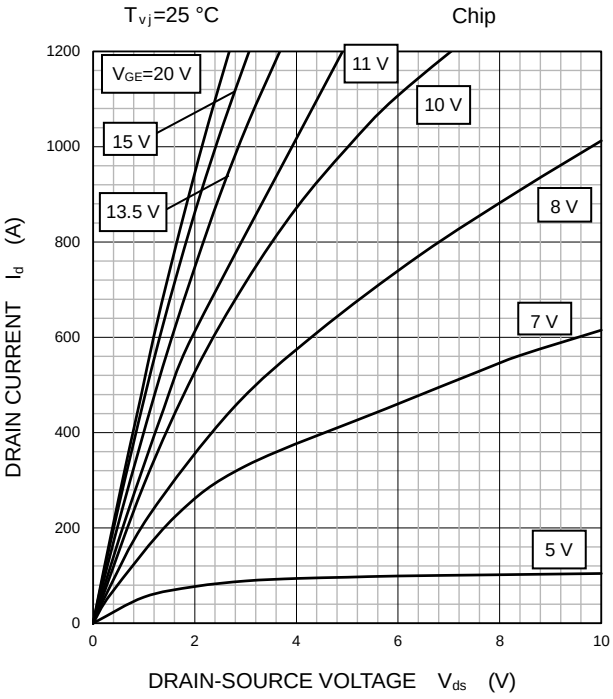


Tr2&Di2

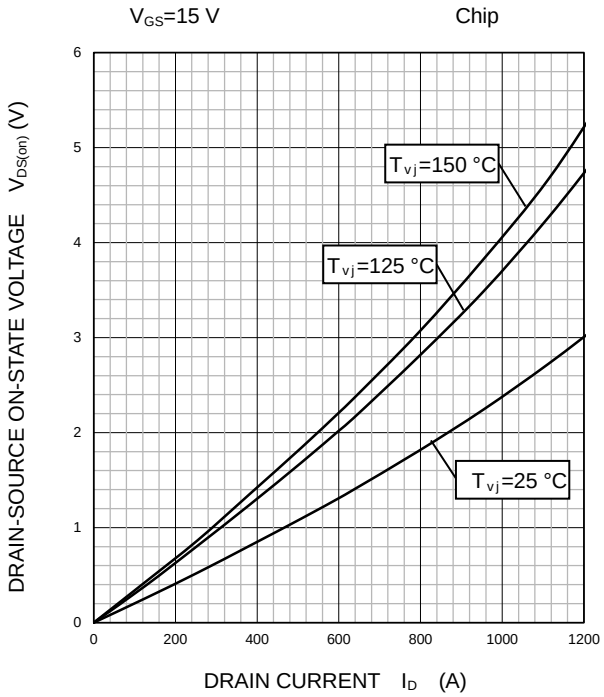
V_{SD} test circuit (x: Connected a* and b*), V_{GS}=15V

PERFORMANCE CURVES

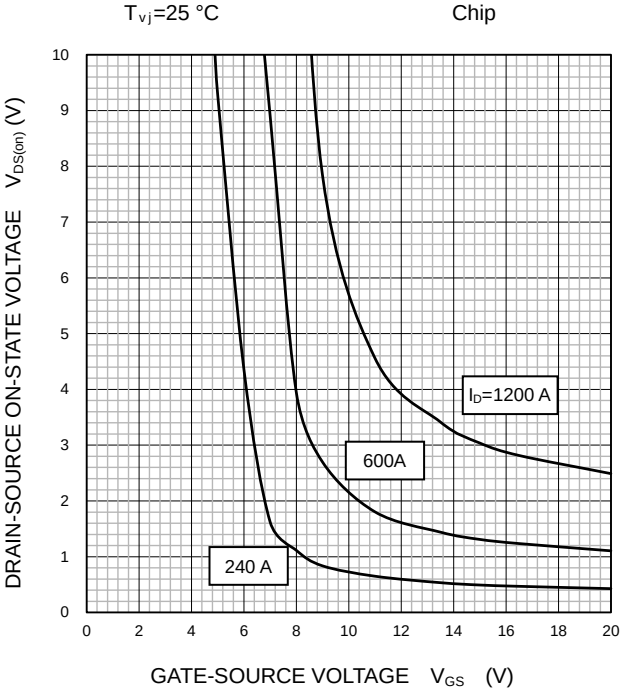
OUTPUT CHARACTERISTICS (TYPICAL)



DRAIN-SOURCE ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)



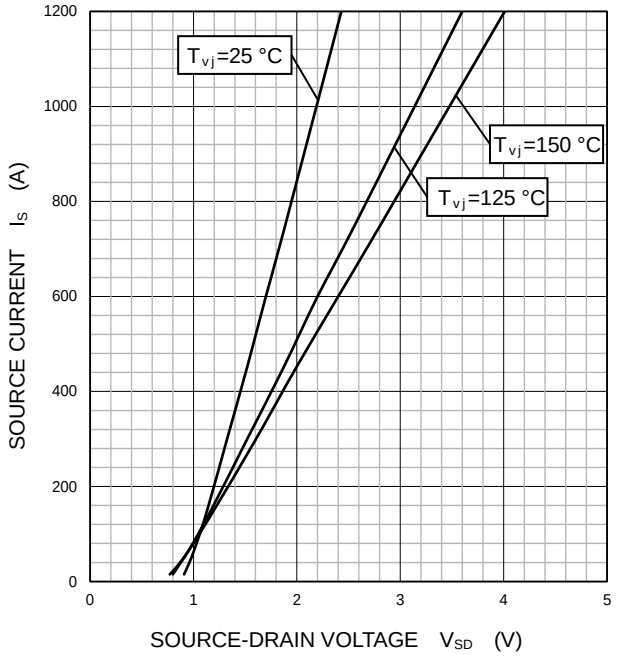
DRAIN-SOURCE ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)



PERFORMANCE CURVES

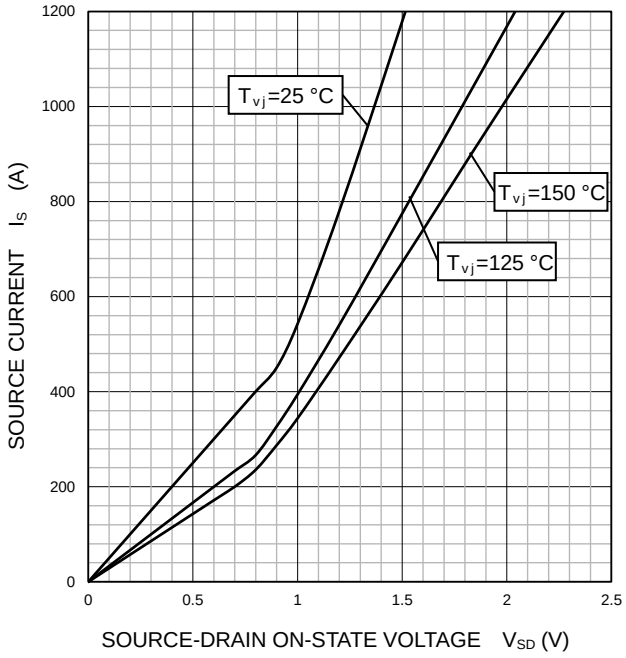
FREE WHEELING DIODE
FORWARD CHARACTERISTICS
(TYPICAL)

V_{GS}=-15 V Chip



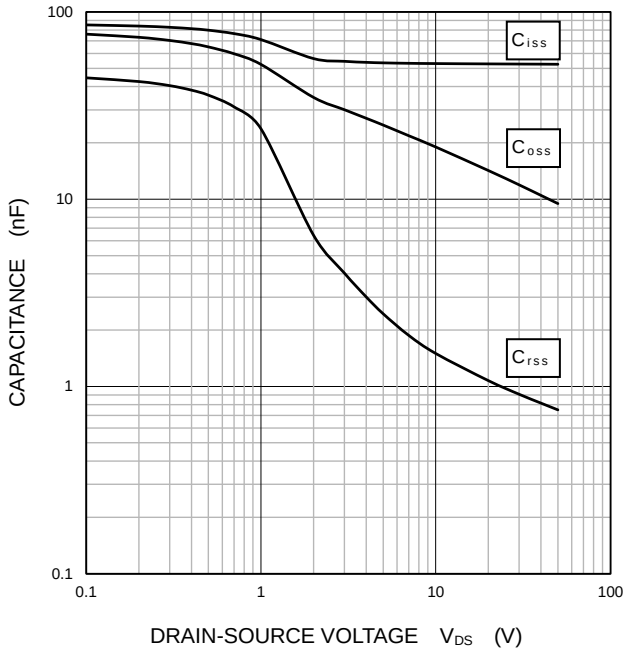
SOURCE-DRAIN ON STATE VOLTAGE
CHARACTERISTICS
(TYPICAL)

V_{GS}=15 V Chip



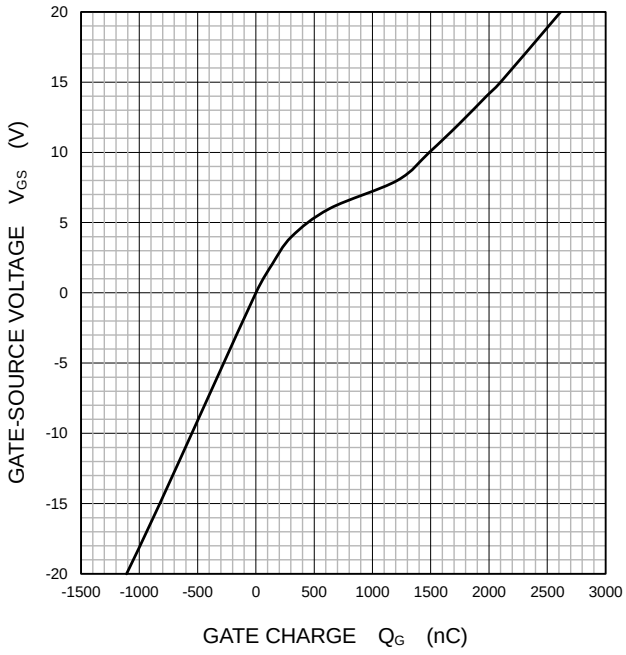
CAPACITANCE
CHARACTERISTICS
(TYPICAL)

G-S short-circuited, T_{vj}=25 °C



GATE CHARGE
CHARACTERISTICS
(TYPICAL)

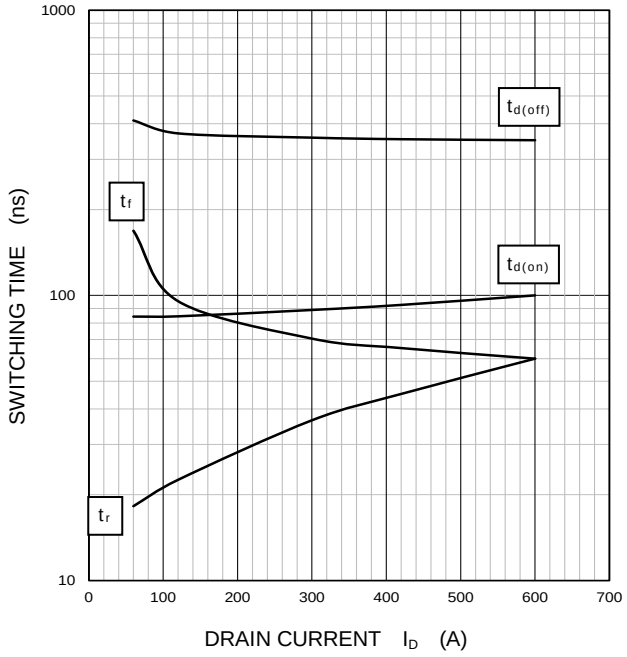
I_D=600 A, T_{vj}=25 °C



PERFORMANCE CURVES

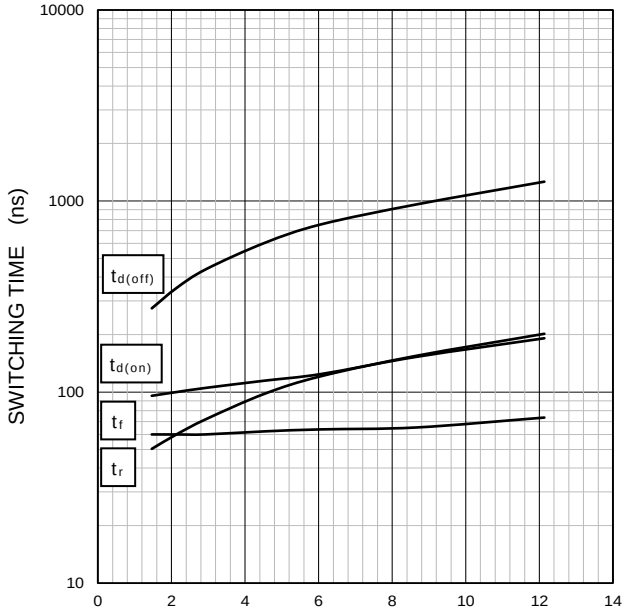
HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

V_{DD}=600 V, V_{GS}=±15 V, R_G=2.0 Ω,
T_{vj}=125 °C, INDUCTIVE LOAD



HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

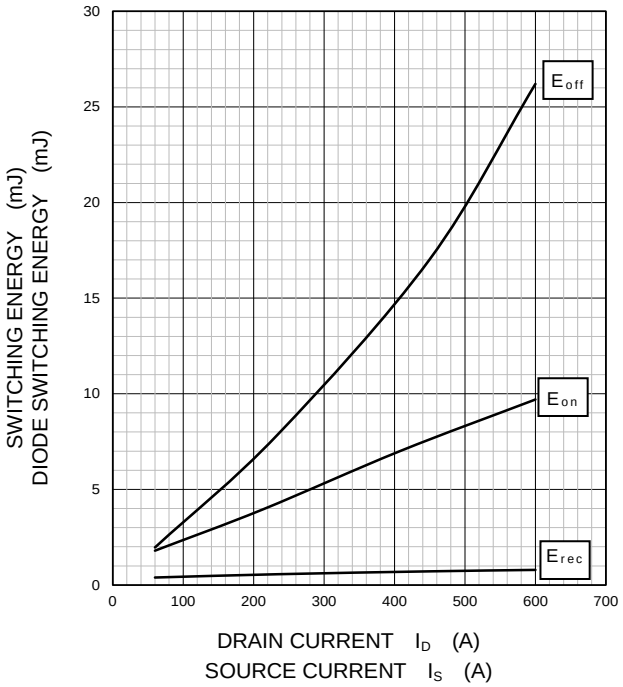
V_{DD}=600 V, V_{GS}=±15 V, I_D=600 A,
T_{vj}=125 °C, INDUCTIVE LOAD



(Note.11)

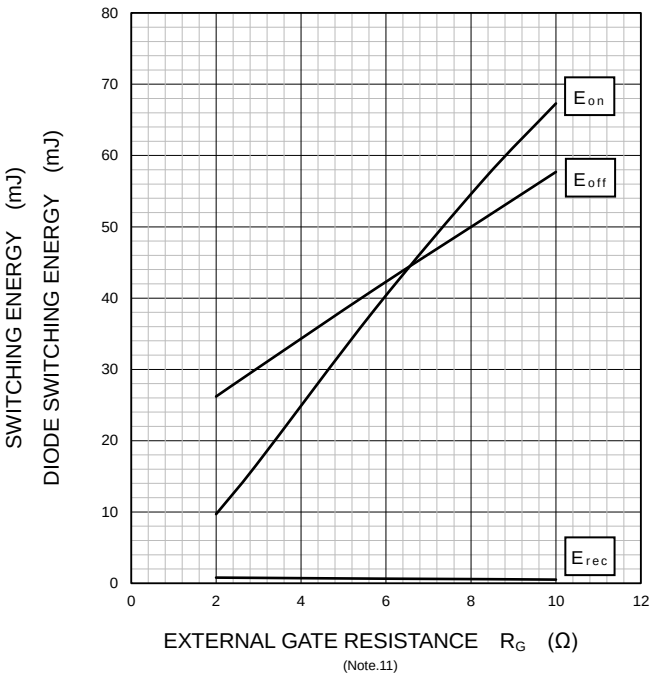
HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)

V_{DD}=600 V, V_{GS}=±15 V, R_G=2.0Ω, 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=600 A, T_{vj}=125 °C,
INDUCTIVE LOAD, PER PULSE

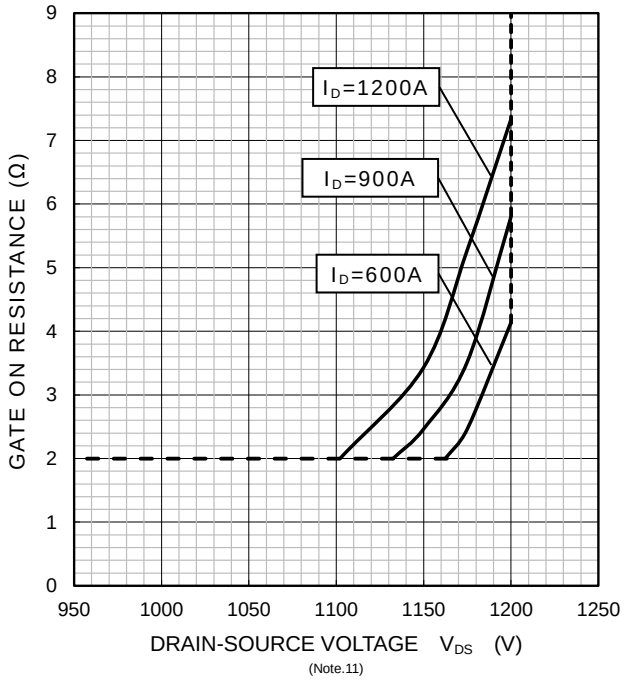


(Note.11)

PERFORMANCE CURVES

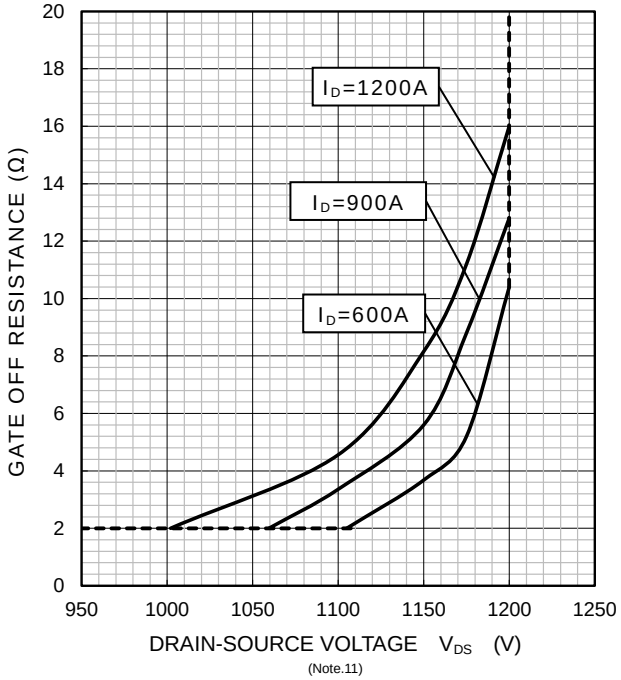
RECOMMENDED GATE RESISTANCE (MINIMUM)

TURN ON, V_{GS}=±15 V



RECOMMENDED GATE RESISTANCE (MINIMUM)

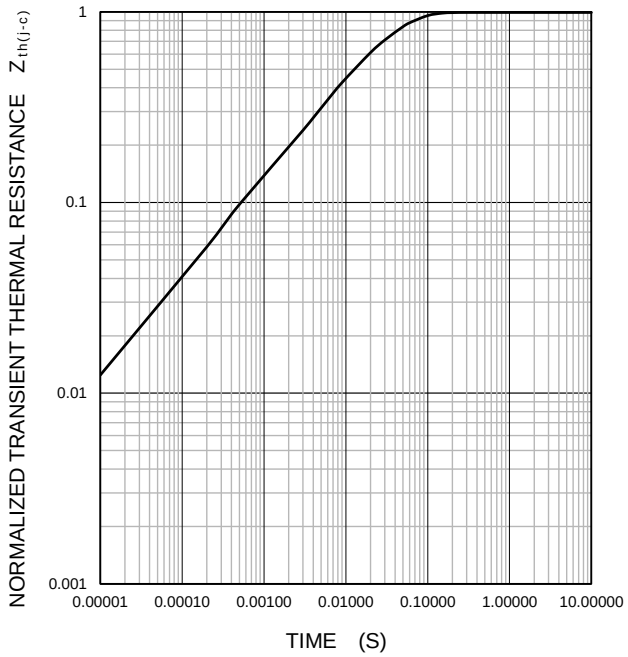
TURN OFF, V_{GS}=±15 V



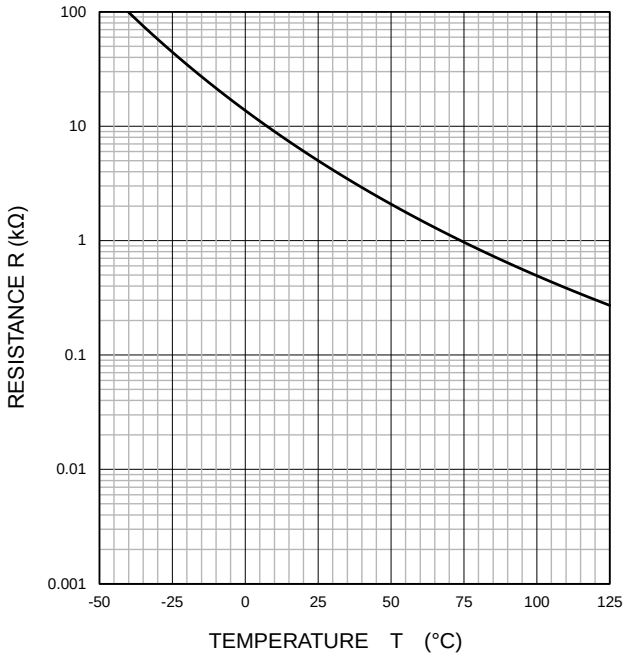
NTC thermistor part

TRANSIENT THERMAL IMPEDANCE CHARACTERISTICS (MAXIMUM)

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



TEMPERATURE CHARACTERISTICS (TYPICAL)



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

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