MITSUBISHI ELECTRIC

<Full SiC Power Modules>

# FMF600DXE-24BN

**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 $T_{vjmax}$ ..... **175** °C

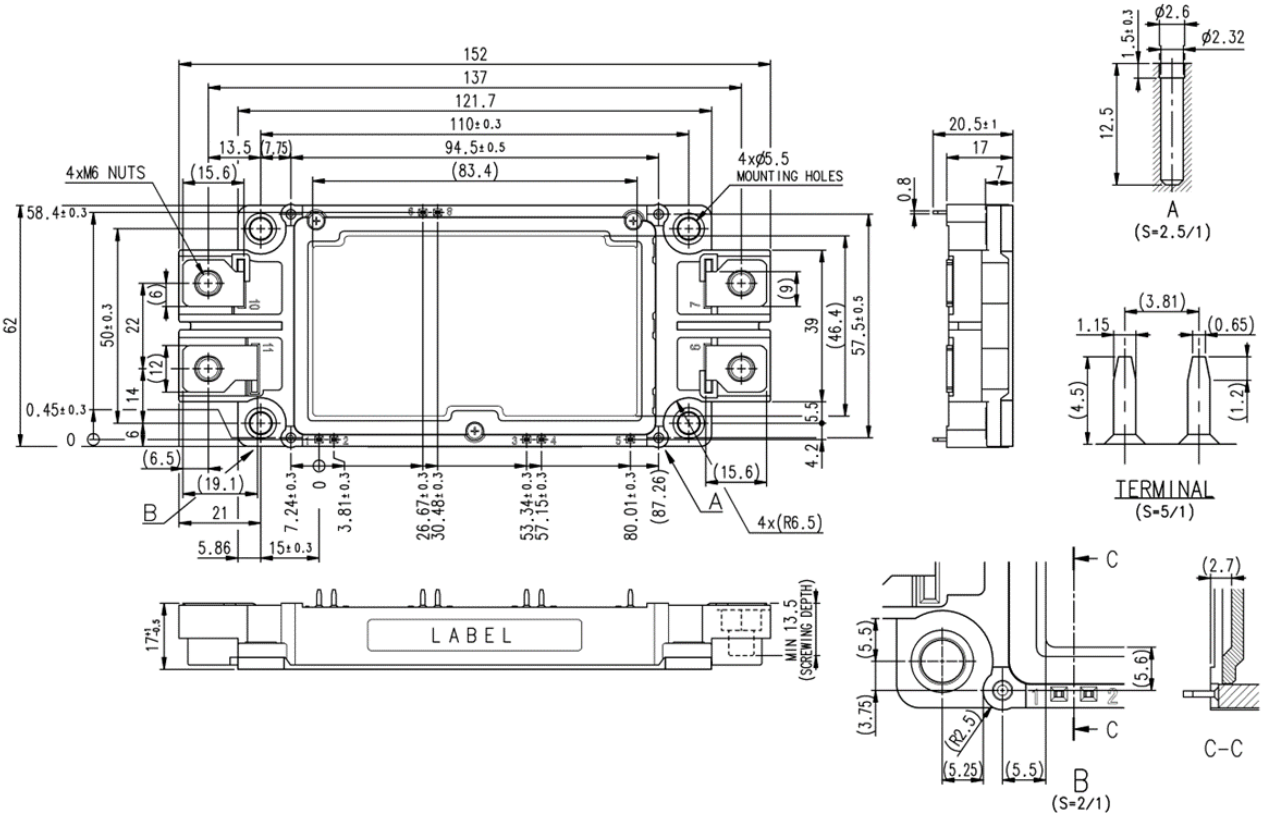
- Silicon Carbide MOSFET
- Flat base Type
- Copper base plate
- RoHS Directive compliant
- Recognized under UL1557, File E323585

## APPLICATION

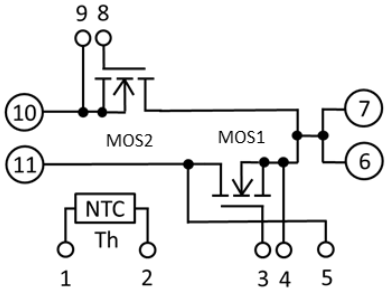
HF converter, Power supply, etc.

## OUTLINE DRAWING & INTERNAL CONNECTION

Dimension in mm




## INTERNAL CONNECTION




| Terminal | code | Terminal | code |
|---|---|---|---|
| 1 | TH1 | 6 | OUT |
| 2 | TH2 | 7 | OUT |
| 3 | G1 | 8 | G2 |
| 4 | S1 | 9 | S2 |
| 5 | D1 | 10 | N |
| | | 11 | P |

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 | $V_{GS}$=-7 V, Measurement terminals position(P-OUT, OUT-N) Refer to Switching characteristics test circuit | 1200 | V |
| $V_{GSS}$ | Gate-source voltage | D-S short-circuited | +20/-12 | V |
| $I_D$ | Drain current | DC, $T_C$=80℃ (Note.2) | 600 | A |
| $I_{DRM}$ | | Pulse, Repetitive (Note.3), $T_{vj}$=150℃(Note.4) | 1200 | |
| $P_{tot}$ | Total power dissipation | $T_C$=25 °C (Note. 2) | 2500 | W |
| $I_S$ (Note1) | Source current | DC | 600 | A |
| $I_{SRM}$ (Note1) | | Pulse, Repetitive (Note.3), $T_{vj}$=150℃(Note.4) | 1200 | |
| $V_{isol}$ | Isolation voltage | Terminals to base plate, RMS, f=60 Hz, AC 1 min | 4000 | V |
| $T_{vjmax}$ | Maximum junction temperature | Instantaneous event (overload) (Note.11) | 175 | °C |
| $T_{vjop}$ | Operating junction temperature | Continuous operation (under switching) (Note.11) | -40～+150 | °C |
| $T_{Cmax}$ | Maximum case temperature | (Note.2, 11) | 125 | °C |
| $T_{stg}$ | Storage temperature | - | -40～+125 | °C |

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

| Symbol | Item | Conditions (note10) | | Limits | | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | Min. | Typ. | Max. | |
| $I_{DSX}$ | Drain-source cut-off current | $V_{DS}$=$V_{DSX}$, $V_{GS}$=-7 V | | - | - | 1.0 | mA |
| | | $V_{DS}$=800V, $V_{GS}$=-7 V | | - | - | 1.0 | |
| $V_{GS(th)}$ | Gate-source threshold voltage | $I_D$=217 mA, $V_{DS}$=10 V | | 1.8 | 2.2 | 3.2 | V |
| $I_{GSS}$ | Gate-source leakage current | $V_{GS}$=$V_{GSS}$, D-S short-circuited | | - | - | 0.5 | μA |
| $V_{DS(on)}$ (terminal) | Drain-source on-state voltage | $I_D$=600 A, $V_{GS}$=15V (Note.6) | $T_{vj}$=25 °C | - | 1.37 | 1.95 | V |
| | | | $T_{vj}$=125 °C | - | 1.63 | - | |
| | | | $T_{vj}$=150 °C | - | 1.88 | - | |
| $V_{DS(on)}$ (chip) | Drain-source on-state voltage | $I_D$=600 A, $V_{GS}$=15V (Note.6) | $T_{vj}$=25 °C | - | 1.10 | - | V |
| | | | $T_{vj}$=125 °C | - | 1.36 | - | |
| | | | $T_{vj}$=150 °C | - | 1.61 | - | |
| $r_{DS(on)}$ (chip) | Drain-source on-state resistance | $I_D$=600 A, $V_{GS}$=15V (Note.6) | $T_{vj}$=25 °C | - | 1.83 | - | mΩ |
| | | | $T_{vj}$=125 °C | - | 2.27 | - | |
| | | | $T_{vj}$=150 °C | - | 2.68 | - | |
| $C_{iss}$ | Input capacitance | $V_{DS}$=10 V, $V_{GS}$=0V | | - | 53 | - | nF |
| $C_{oss}$ | Output capacitance | | | - | 28 | - | |
| $C_{rss}$ | Reverse transfer capacitance | | | - | 3.3 | - | |
| $Q_G$ | Gate charge | $V_{DD}$=600 V, $I_D$=600 A, $V_{GS}$=0→15 V | | - | 1550 | - | nC |
| $t_{d(on)}$ | Turn-on delay time | $V_{DD}$=600 V, $I_D$=600 A, $V_{GS}$=+15 / -7 V, $T_{vj}$=150℃, $R_{G(on/off)}$=1.6 / 1.0 Ω, $L_{s\_ext}$=13.2 nH, Inductive load, per pulse | | - | 160 | - | ns |
| $t_r$ | Rise time | | | - | 85 | - | |
| $t_{d(off)}$ | Turn-off delay time | | | - | 270 | - | |
| $t_f$ | Fall time | | | - | 55 | - | |
| $t_{rr}$ (Note1) | Reverse recovery time | | | - | 95 | - | |
| $E_{on}$ | Turn-on switching energy | | | - | 25 | - | mJ |
| $E_{off}$ | Turn-off switching energy | | | - | 15 | - | |
| $E_{rr}$ (Note1) | Reverse recovery energy | | | - | 7 | - | |
| $Q_{rr}$ (Note1) | Reverse recovery charge | | | - | 17 | - | μC |
| $V_{SD}$ (Note.1) (terminal) | Source-drain voltage | $I_S$=600 A(Note.6) $V_{GS}$=-7 V | $T_{vj}$=25 °C | - | 4.40 | 5.70 | V |
| | | | $T_{vj}$=125 °C | - | 4.10 | - | |
| | | | $T_{vj}$=150 °C | - | 4.00 | - | |
| $V_{SD}$ (Note.1) (chip) | Source-drain voltage | $I_S$=600 A (Note.6) $V_{GS}$=-7 V | $T_{vj}$=25 °C | - | 4.13 | - | V |
| | | | $T_{vj}$=125 °C | - | 3.83 | - | |
| | | | $T_{vj}$=150 °C | - | 3.73 | - | |

Caution: Short-circuit capability is not 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 | - | - | 60 | K/kW |
| $R_{th(c-s)}$ | Contact thermal resistance(Note.2) | Case to heat sink, per 1 module, Thermal grease applied (Note.8, 11) | - | 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 (Note.2) ,$R_{100}$=493 Ω | -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 |

**MODULE**

| 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 | N·m |
| $e_c$ | Flatness of base plate | On the centerline X, Y (Note.5) | 0 | - | +100 | μm |

| Symbol | Item | Conditions | Value | Unit |
|---|---|---|---|---|
| m | mass | - | 415 | g |
| $d_a$ | Clearance | Terminal to terminal | 10.0 | mm |
| | | Terminal to base plate | 8.2 | |
| $d_s$ | Creepage distance | Terminal to terminal | 17.4 | mm |
| | | Terminal to base plate | 16.0 | |
| $R_{DD'+SS'}$ | Internal lead resistance | P-S1, OUT-S2 terminals, per switch | 0.45 | mΩ |
| $L_s$ | Internal stray inductance | P-N | 9 | nH |
| $r_g$ | Internal gate resistance | Per switch | 0.95 | Ω |

*: 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.

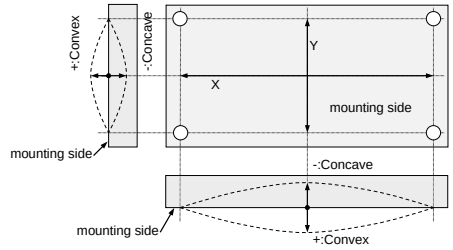
Note1. Represent ratings and characteristics of the MOSFET body diode.

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.

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. Reference value. 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.

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 ($T_{vj\,max}$, $T_{vj\,op}$, $T_{C\,max}$) must be maintained below the maximum rated temperature throughout consideration of the temperature rise even for long term usage.

<Full SiC Power Modules>

# FMF600DXE-24BN

HIGH POWER SWITCHING USE
INSULATED TYPE

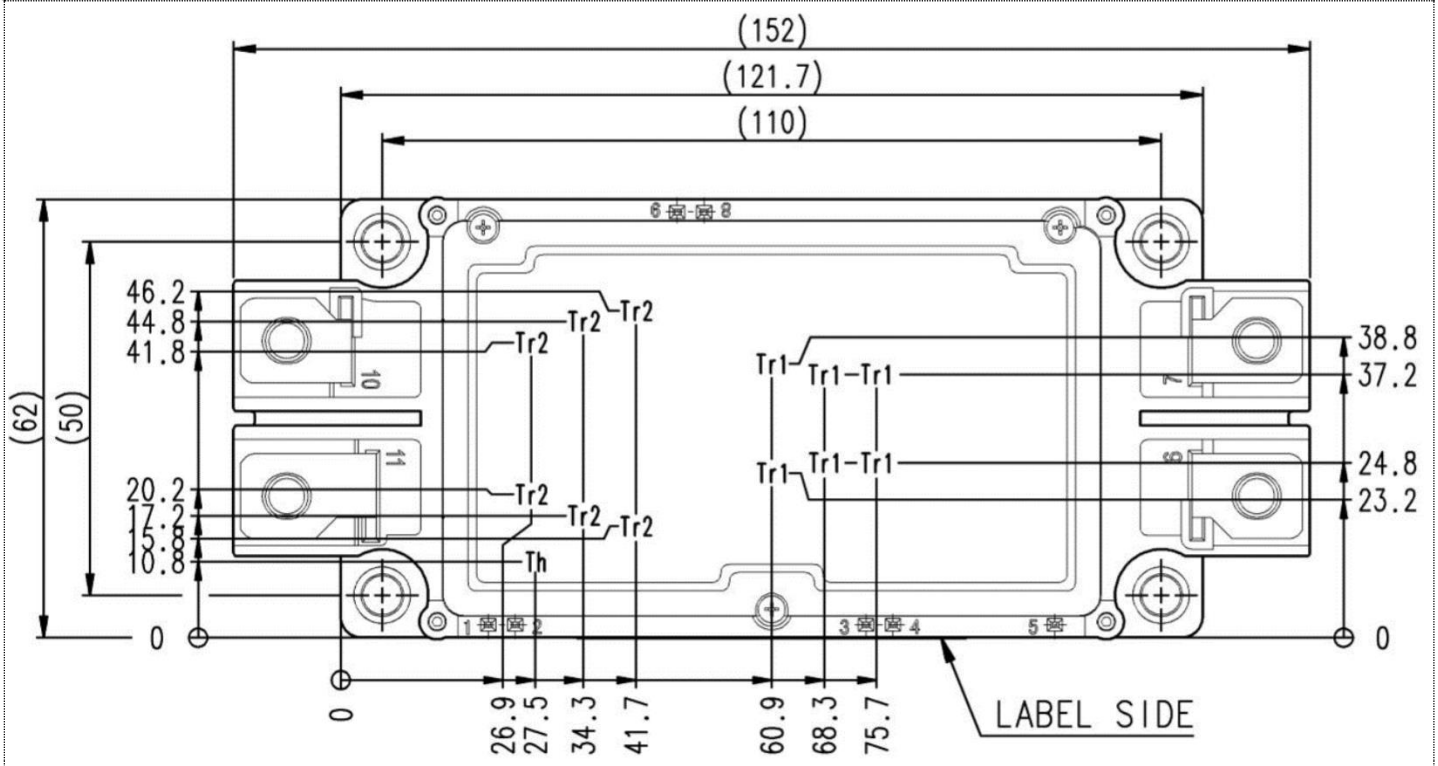
RECOMMENDED OPERATING CONDITIONS

| Symbol | Item | Conditions | Limits | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| $V_{DD}$ | (DC) Supply voltage | Applied across P-N terminals | - | 600 | 850 | V |
| $V_{GS(+)}$ | Gate-Source drive positive voltage | Applied across G1-S1, G2-S2 terminals | 13.5 | 15 | 16.5 | V |
| $V_{GS(-)}$ | Gate-Source drive negative voltage | Applied across G1-S1, G2-S2 terminals | -8.5 | -7 | -5.5 | V |
| $R_{G(on)}$ | External gate turn-on resistance (Note.12) | Per switch | 1.6 | - | 8.0 | Ω |
| $R_{G(off)}$ | External gate turn-off resistance (Note.12) | | 1.0 | - | 8.0 | |

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.

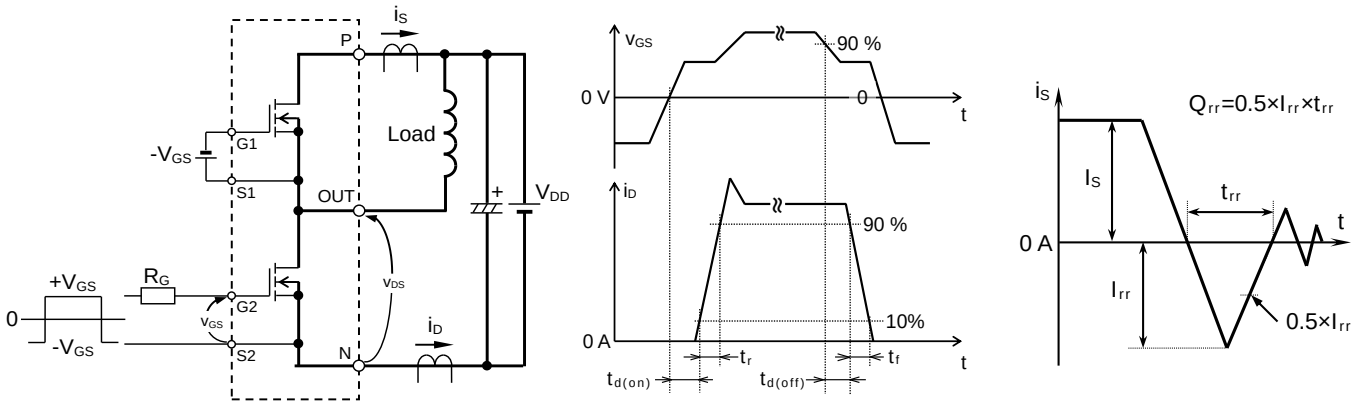
CHIP LOCATION (Top view)

Dimension in mm, tolerance: ±1 mm



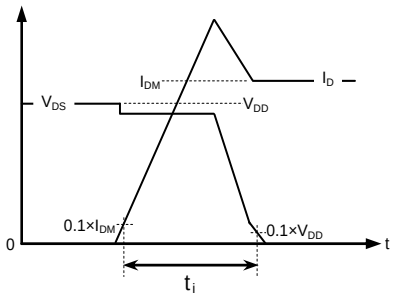

Tr1,Tr2: SiC-MOSFET, Th: NTC thermistor

**TEST CIRCUIT AND WAVEFORMS**

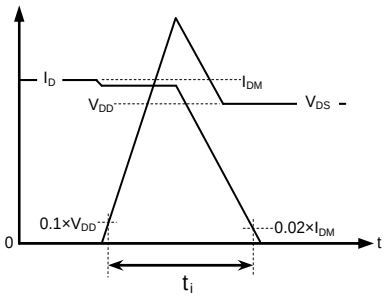



Switching characteristics test circuit and waveforms

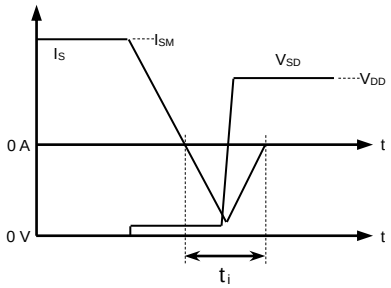
$t_{rr}$, $Q_{rr}$ test waveform




MOSFET Turn-on switching energy



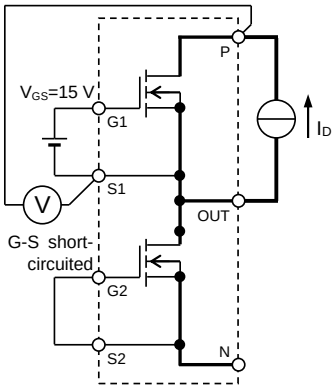

MOSFET Turn-off switching energy



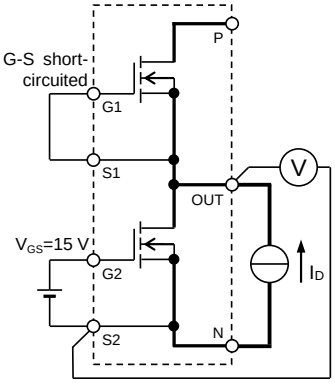

MOSFET body diode Reverse recovery energy

Switching energy and Reverse recovery energy test waveforms (Integral time instruction drawing)

TEST CIRCUIT

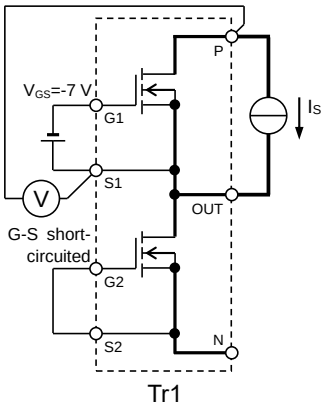



Tr1

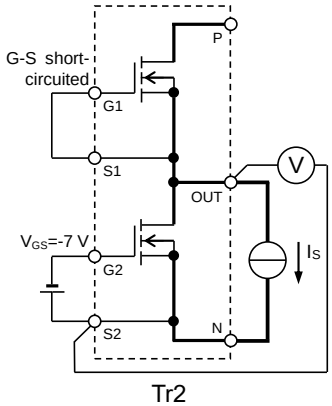



Tr2

$V_{DS(on)}$ test circuit

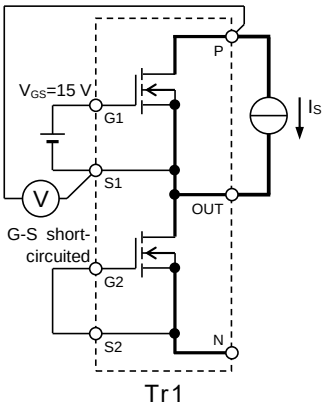



Tr1

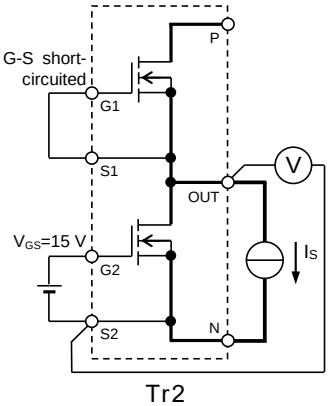



Tr2

$V_{SD}$ test circuit, $V_{GS}$=-7V




Tr1

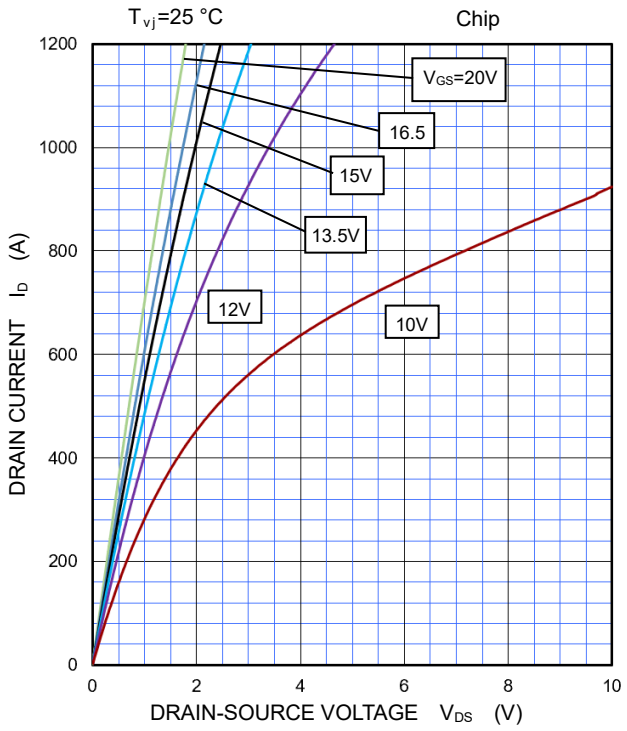



Tr2

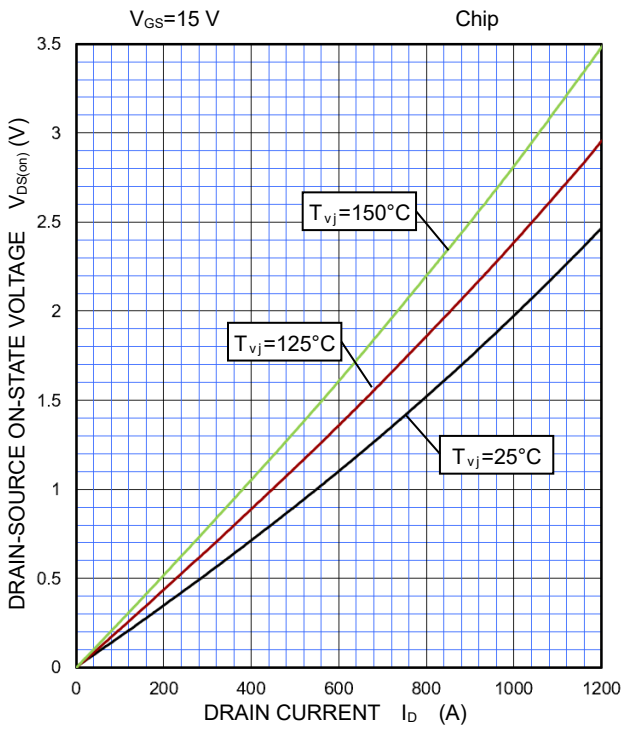
$V_{SD}$ test circuit, $V_{GS}$=15V

**PERFORMANCE CURVES**

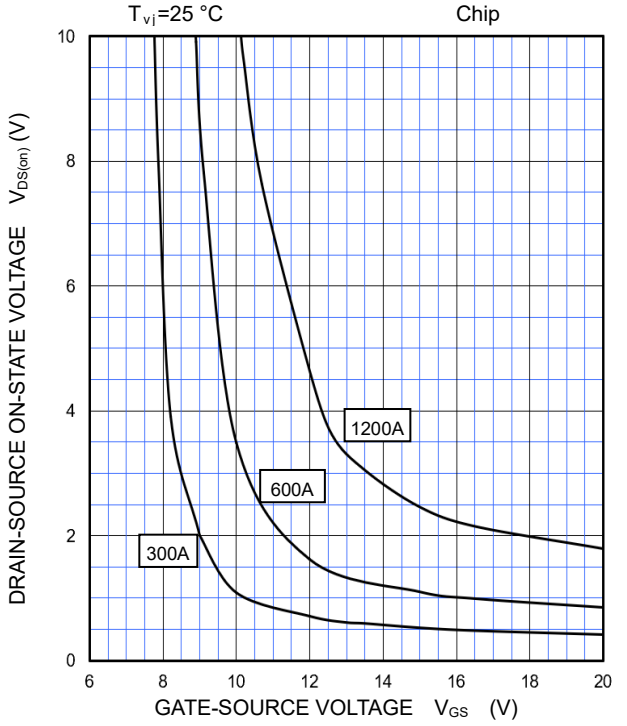
OUTPUT CHARACTERISTICS (TYPICAL)




DRAIN-SOURCE ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)

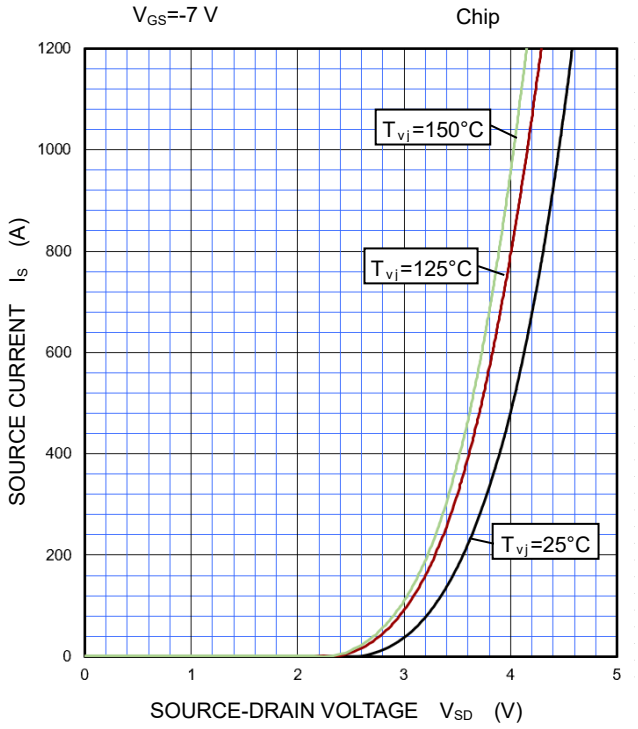



DRAIN-SOURCE ON STATE VOLTAGE CHARACTERISTICS (TYPICAL)

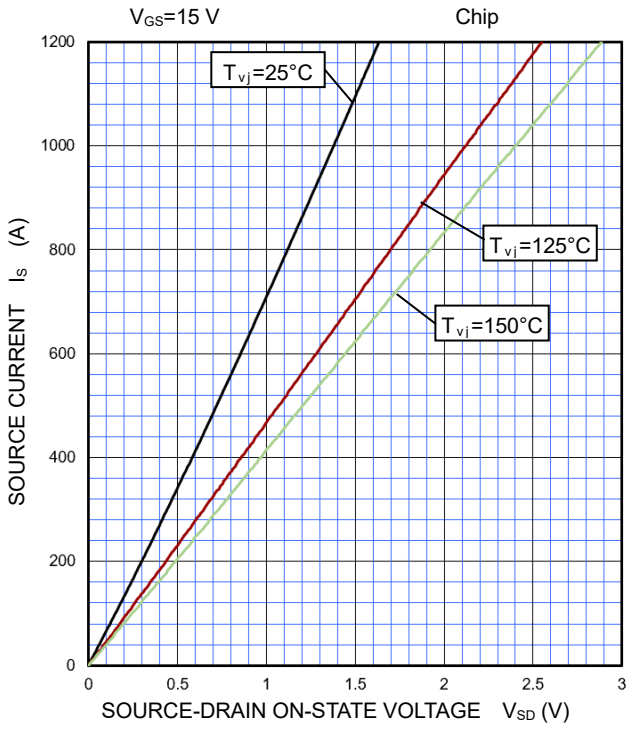


**PERFORMANCE CURVES**

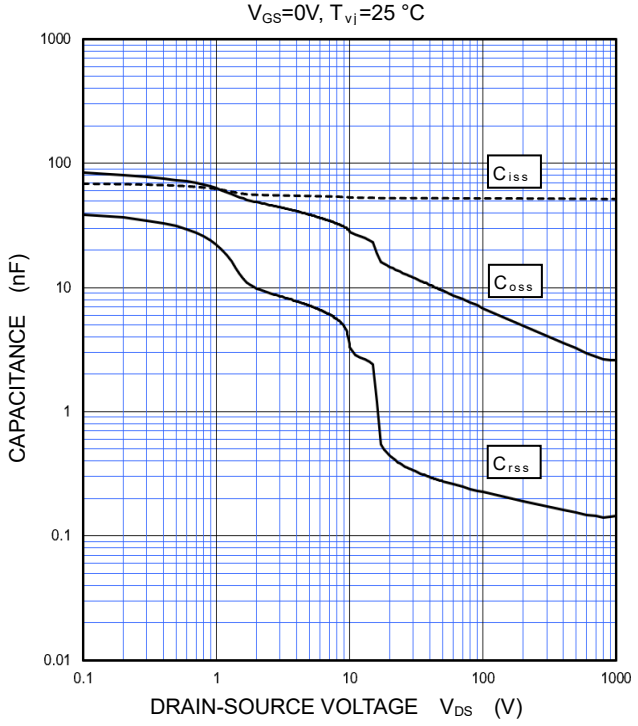
MOSFET BODY DIODE
FORWARD CHARACTERISTICS
(TYPICAL)



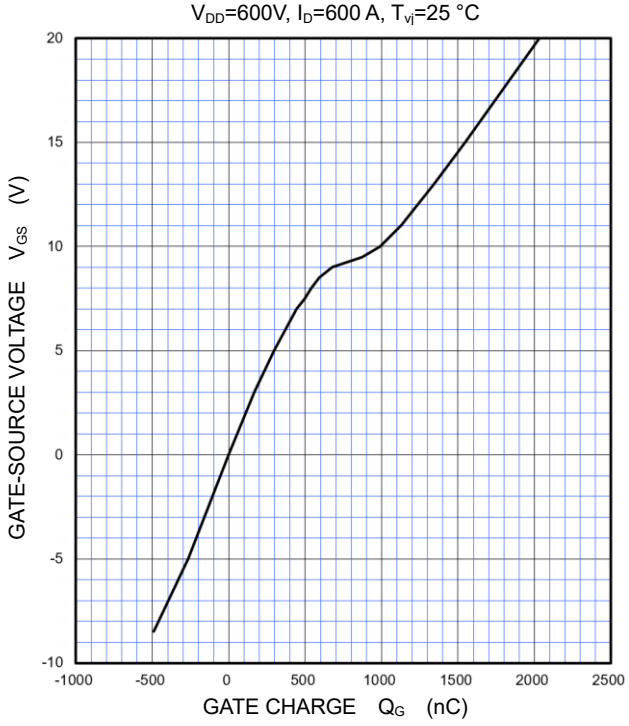

SOURCE-DRAIN ON STATE VOLTAGE
CHARACTERISTICS
(TYPICAL)




CAPACITANCE
CHARACTERISTICS
(TYPICAL)

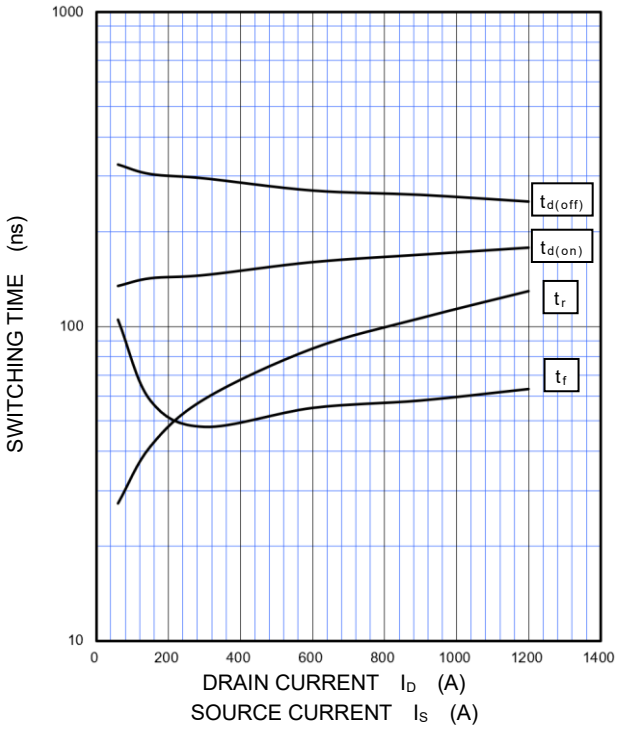



GATE CHARGE
CHARACTERISTICS
(TYPICAL)

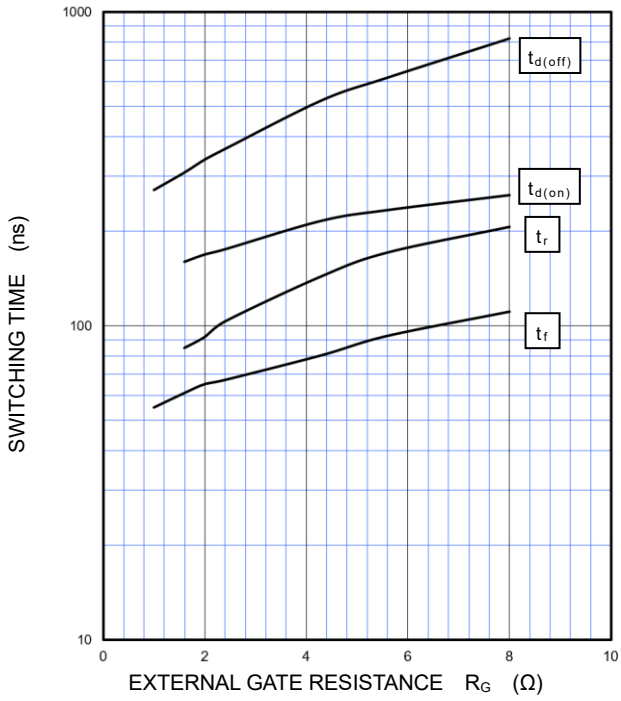


**PERFORMANCE CURVES**

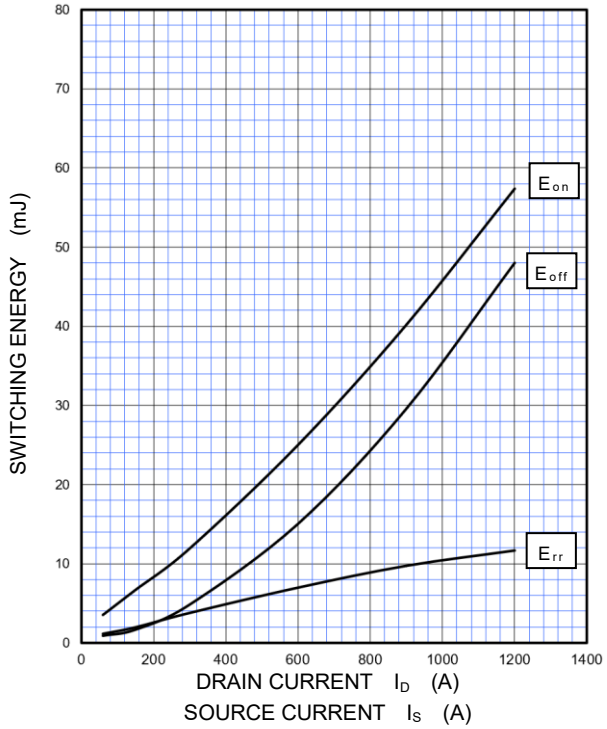
HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)
$V_{DD}$=600 V, $V_{GS}$=15 / -7 V, $R_{G(on/off)}$=1.6 / 1.0Ω,
$T_{vj}$=150 °C, $L_{s\_ext}$=13.2 nH
INDUCTIVE LOAD



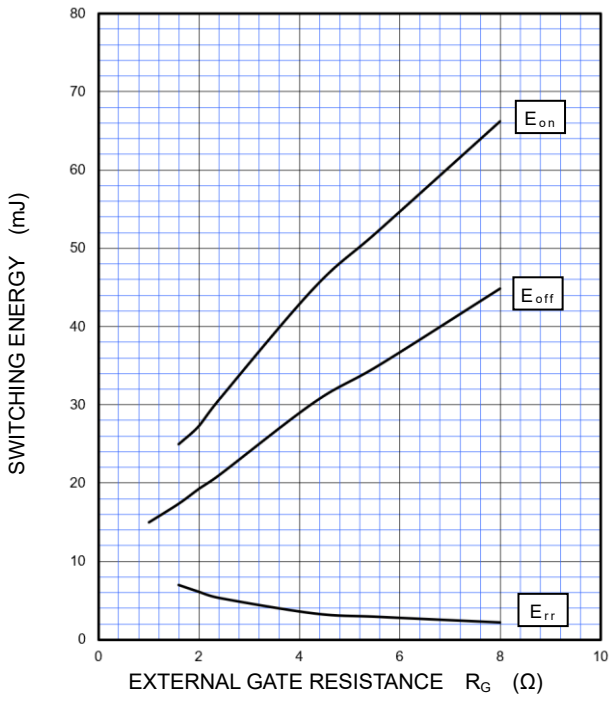

HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)
$V_{DD}$=600 V, $V_{GS}$=15 / -7 V, $I_D$=600 A,
$T_{vj}$=150 °C, $L_{s\_ext}$=13.2 nH
INDUCTIVE LOAD




HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)
$V_{DD}$=600 V, $V_{GS}$=15 / -7 V, $R_{G(on/off)}$=1.6 / 1.0Ω,
$T_{vj}$=150 °C, $L_{s\_ext}$=13.2 nH
INDUCTIVE LOAD, PER PULSE

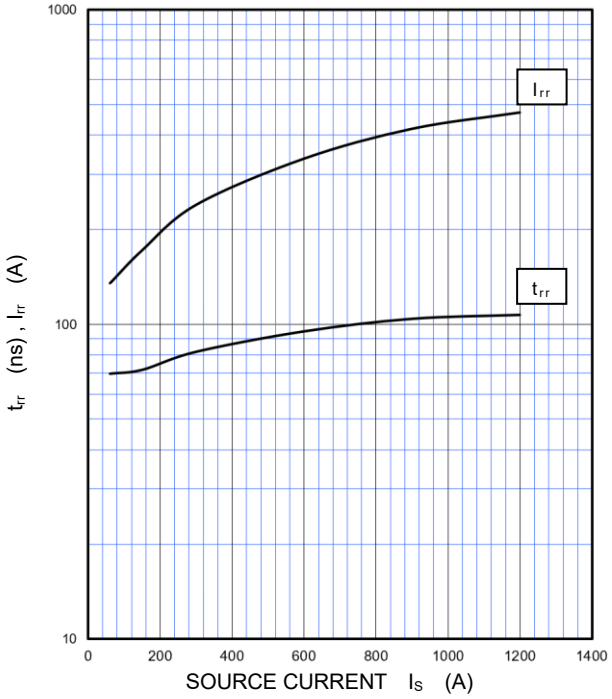



HALF-BRIDGE
SWITCHING CHARACTERISTICS
(TYPICAL)
$V_{DD}$=600 V, $V_{GS}$=15 / -7 V, $I_D$=600 A,
$T_{vj}$=150 °C, $L_{s\_ext}$=13.2 nH
INDUCTIVE LOAD, PER PULSE



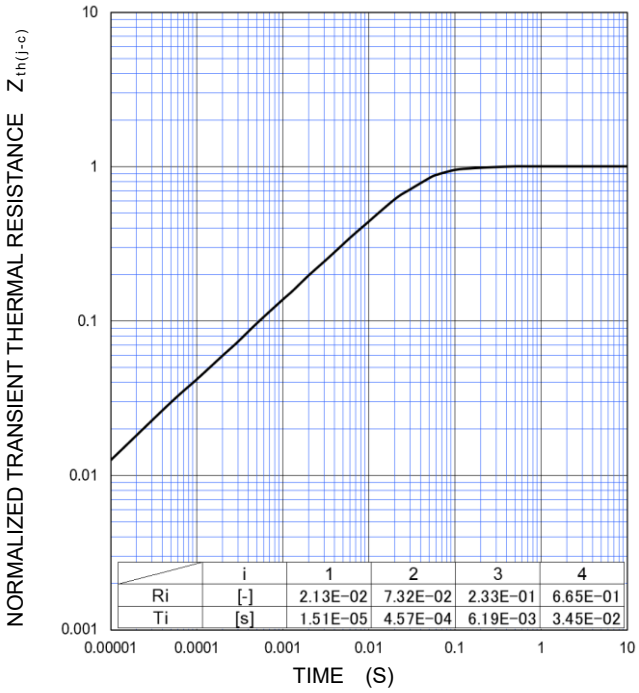
**PERFORMANCE CURVES**

MOSFET BODY DIODE
REVERSE RECOVERY CHARACTERISTICS
**(TYPICAL)**
$V_{DD}$=600 V, $V_{GS}$=15 / -7 V, $R_{G(on/off)}$=1.6 / 1.0Ω,
$T_{vj}$=150 °C, $L_{s\_ext}$=13.2 nH
INDUCTIVE LOAD, PER PULSE



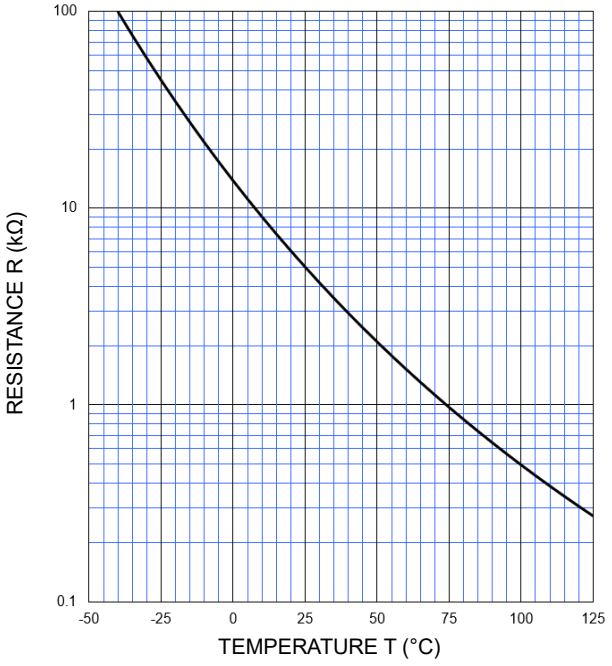

TRANSIENT THERMAL IMPEDANCE
CHARACTERISTICS
(MAXIMUM)

Single pulse, $T_C$=25 °C
$R_{th(j-c)Q}$=60K/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.

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