SiC MOSFET module application note Electrical characteristics

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1. Characteristics SiC MOSFET Module

1.1. Scope

The scope of this application note covers the following products.

Table 1.1.1 Product covered in this application note

Part No.	Drain-source voltage rating (V_{DSS})	Drain current (I_D)	Gate-source voltage rating (V_{GSS})	Recommended gate drive voltage ($+V_{GG}$/$-V_{GG}$)
MG600Q2YMS3	1200V	600A	+25V/-10V	+20V/-6V
MG400Q2YMS3	1200V	400A	+25V/-10V	+20V/-6V
MG400V2YMS3	1700V	400A	+25V/-10V	+20V/-6V
MG250V2YMS3	1700V	250A	+25V/-10V	+20V/-6V
MG250YD2YMS3	2200V	250A	+25V/-10V	+20V/-6V
MG800FXF2YMS3	3300V	800A	+25V/-10V	+20V/-6V
MG800FXF1JMS3	3300V	800A	+25V/-10V	+20V/-6V
MG800FXF1ZMS3	3300V	800A	+25V/-10V	+20V/-6V

1.2. Part No. of SiC MOSFET Modules

The part No. of SiC MOSFET module is composed of the contents shown in Fig. 1.2.1.

MG	600	Q	2	Y	M	S	3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Fig. 1.2.1 Part No. of SiC MOSFET Module

(1) Symbol for modules
(2) Value of current rating in amperes
(3) Symbols representing Drain-source voltage (V_{DSS}) (Table1.2.2)
(4) Number of SiC MOSFET in one module
(5) Symbols representing internal circuit (Table1.2.3)
(6) Symbol for Nch MOSFET
(7) Symbol for SiC
(8) Sequence number

Table1.2.2 Symbols for Drain-Source Voltage （V_{DSS} ）

Symbol	Drain-Source Voltage （V_{DSS} ）
Q	1200V
V	1700V
YD	2200V
FXF	3300V

Table 1.2.3 Symbols representing internal circuit

Symbol	Internal circuit
Y	Dual (half-bridge)
J	Low-side MOS chopper (High-side: SBD、Low-side: MOSFET)
Z	High-side MOS chopper (High-side: MOSFET、Low-side: SBD)

2. Absolute Maximum Ratings

Absolute maximum ratings are specified for each item which must not be exceeded during operation even instantaneously.

The maximum allowable values of the current and the voltage that can be applied to SiC MOSFET are specified as the absolute maximum ratings. Recognizing the absolute maximum ratings in designing circuits is very important not only for the effective operation of SiC MOSFET but also for reliable operation that is sufficiently high for the target operating hours.

When designing a circuit, pay attention to fluctuations in the supply voltage, variations in the characteristics of electrical components, the stress higher than the absolute maximum ratings at the time of circuit adjustment, changes in ambient temperature, fluctuations in the input signal, etc.

However, even if the product is used within allowable operating limits (operating temperature, current, voltage, etc.), if the product is used continuously under high loads (high temperature, high current, high voltage, large temperature change, etc.), the reliability of the product may be significantly reduced. Therefore, in order to ensure reliability, we recommend an appropriate reliability design considering de-rating.

Absolute maximum ratings specified in the datasheet are explained by individual items.

Table 2.1 Absolute maximum ratings

Item	Symbol	Description
Drain-source voltage	V_{DSS}	The maximum voltage allowed between the drain and the source with the short-circuited gate and source
Gate-source voltage	V_{GSS}	The maximum voltage allowed between the gate and the source with the short-circuited drain and source
Drain current (DC)	I_D	The maximum allowable DC current from the drain to the source
Drain current (pulsed)	I_{DP}	The maximum allowable peak drain current for pulsed operation
Drain power dissipation	P_D	The maximum power that can be dissipated by the SiC MOSFET
Source current (DC)	I_S	The maximum allowable DC current from the source to the drain
Source current (pulsed)	I_{SP}	The maximum allowable peak source current for pulsed operation
Channel temperature	T_{ch}	The maximum allowable chip temperature while in operation
Storage temperature	T_{stg}	The temperature range in which a MOSFET can be stored without voltage applied
Isolation voltage	V_{isol}	The isolation voltage between the base plate and the internal circuit or terminals.
Isolation voltage (thermistor terminal-other terminal)	V_{isol}(therm)	The maximum voltage at which a MOSFET can maintain isolation between one thermistor terminal and other terminals (non-thermistor)
Mounting torque	TOR	The maximum torque that can be applied when tightening a screw

2.1. Drain-source voltage V_{DSS}

V_{DSS} is the maximum drain-to-source voltage with the SiC MOSFET gate and source short-circuited. If a voltage exceeding the rating is applied, there is a risk of SiC MOSFET failure due to its entering the breakdown mode. Also, do not use the gate open from the source. The SiC MOSFET has a high input-impedance and may be destroyed if they fall into an on-state due to a voltage between the gate and the source caused by noise.

2.2. Gate-source voltage V_{GSS}

V_{GSS} is the maximum voltage allowed between the gate-to-source with the SiC MOSFET drain and source short-circuited. This rating is attributed to the withstand capacity of the gate oxide, but the value is determined in consideration of the practical voltage and reliability.

V_{GSS} rating of SiC MOSFET may differ for positive and negative. Refer to the datasheet of the products for the V_{GSS} value and make sure that gate to source voltage (V_{GS}) does not exceeded absolute maximum rating due to noises, etc.

2.3. Drain current I_D, I_{DP}

I_D is the maximum continuous (DC) current that the SiC MOSFET can flow under the ideal heat dissipation condition in the direction of the drain to the source (forward). Whereas the pulsed current that the SiC MOSFET can flow forward-direction is specified as I_{DP}.

However, the maximum current values in the forward direction are limited by the heat dissipation condition. The maximum allowable current values are specified so that the channel temperature will not exceed the absolute maximum rating T_{ch}.

2.4. Drain power dissipation P_D

P_D is the maximum power that the MOSFET can dissipate continuously under the specified thermal conditions.

The allowable power dissipation varies with the conditions under which the MOSFET is used. Use the SiC MOSFET under the condition that the channel temperature does not exceed T_{ch}.

2.5. Source current I_S, I_{SP}

As with the drain current, the maximum continuous (DC) current that the SiC MOSFET can flow under the ideal heat dissipation condition in the direction of the source to the drain (reverse) is specified as I_S. Whereas the pulsed current that the SiC MOSFET can flow reverse direction is specified as I_{SP}. The maximum allowable current values are specified so that the channel temperature will not exceed the absolute maximum rating T_{ch}.

2.6. Channel temperature T_{ch}

T_{ch} is the allowable maximum temperature of the channel of the SiC MOSFET.

2.7. Storage temperature T_{stg}

T_{stg} is the temperature range in which a SiC MOSFET module can be stored without voltage applied.

2.8. Isolation voltage V_{isol}

V_{isol} is the isolation voltage between the base plate and the internal circuit or terminals.

2.9. Isolation voltage (thermistor terminal-other terminal) V_{isol}(therm)

V_{isol}(therm) is applicable to MG600Q2YMS3 and MG400V2YMS3. This is the isolation voltage between one of the thermistor terminals (terminal 1 and 2) and other terminals (P,N,AC,4,5,7,11 and 12).

2.10. Mounting torque TOR

TOR is the maximum allowable torque for mounting the SiC MOSFET module. Tightening below the recommended torque described in the datasheet may cause loosening during use.

Unbalanced screwing or tightening above the TOR may cause damage to the SiC MOSFET module.

3. Thermal Resistance Characteristics

Thermal resistance is the ability of a material to resist the flow of thermal energy.

The power consumed by the SiC MOSFET chips is converted into heat, which is transferred to the heatsink through the case. An increase in power dissipation (P_w) causes a further increase in the SiC MOSFET temperature (ΔT).

ΔT can be calculated as $\Delta T = R_{th} \times P_W$. Here, R_{th} is a constant defining a relationship between ΔT and P_W. This constant is called thermal resistance.

Table 3.1 Thermal resistance characteristics

Item	Symbol	Unit	Description
Thermal resistance (channel-to-case)	$R_{th(ch-c)}$	K/W	Thermal resistance from the channel to the case.
Thermal resistance (case-to-fin)	$R_{th(c-f)}$	K/W	Thermal resistance from the case to the fin (heatsink).

3.1. Thermal resistance (channel-to-case) $R_{th(ch-c)}$

$R_{th(ch-c)}$ is the thermal resistance between the channel and the case when they are at thermal equilibrium. The temperature difference $\Delta T_{(ch-c)}$ can be expressed by the equation (3.1.1) using $R_{th(ch-c)}$ and P_w. Note that $R_{th(ch-c)}$ is the value per SiC MOSFET (Denoted as "The value per half a module" in the datasheet).

$$\Delta T_{(ch-c)} = R_{th(ch-c)} \times P_W \qquad \cdots(3.1.1)$$

Transient thermal resistance $r_{th(ch-c)}$ is the thermal resistance between the channel and the case when they are at thermal equilibrium. $r_{th(ch-c)}$ is the function of time when the SiC MOSFET module is affected by thermal capacitance. Figure 3.1.2 shows an example of the $r_{th(ch-c)}$ versus time t.

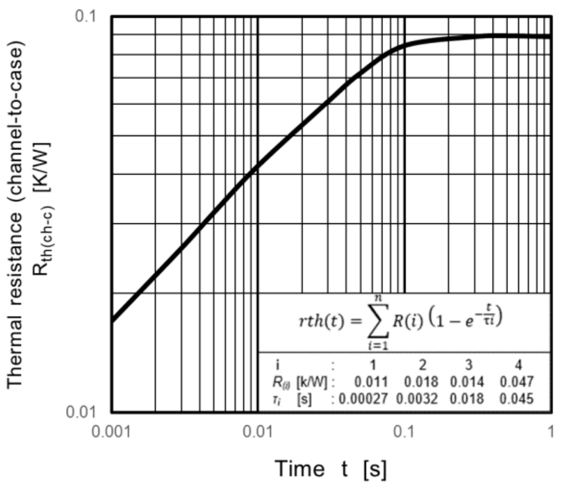


Fig. 3.1.2 An example of $r_{th(ch-c)}$-t characteristics

$r_{th(ch-c)}$ is expressed by the equation (3.1.3) as a function of time. Here, $R(i)$ is a parameter that expresses the ease of heat transfer within a substance. τi is a parameter related the time of heat transfer.

$$rth(t) = \sum_{i=1}^{n} R(i)(1 - e^{-\frac{t}{\tau i}}) \qquad \cdots(3.1.3)$$

3.2. Thermal resistance (case to fin) $R_{th(c\text{-}f)}$

$R_{th(c\text{-}f)}$ is the thermal resistance from the case to the fin. The temperature difference $\Delta T_{(c\text{-}f)}$ can be expressed by the equation (3.2.1) using $R_{th\ (c\text{-}f)}$ and P_w. Note that $R_{th\ (c\text{-}f)}$ is the value per module whereas $R_{th(ch\text{-}c)}$ is the value for per SiC MOSFET. (Denoted as "The value per module." in the datasheet).

$$\Delta T_{(c\text{-}f)} = R_{th(c\text{-}f)} \times P_W \qquad \cdots(3.2.1)$$

4. Static Electrical Characteristics

Static electrical characteristics specified in the datasheet are explained by individual items.

Table 4.1 Static characteristics

Item	Symbol	Description
Gate-source leakage current	I_{GSS}	The leakage current when the specified voltage is applied between the gate and the source with the drain and the source are short-circuited
Drain-source cut-off current	I_{DSS}	The leakage current when the specified voltage is applied between the drain and the source with the gate and the source are short-circuited
Gate threshold voltage	V_{th}	The gate-voltage when a specified current described in the datasheet flows from the drain to the source.
Drain-source on-voltage (sense)	$V_{DS(on)sense}$	The voltage between the drain sense terminal and the source sense terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the drain to the source.
Drain-source on-voltage (terminal)	$V_{DS(on)terminal}$	The voltage between the drain main terminal and the source main terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the drain to the source.
Source-drain on-voltage (sense)	$V_{SD(on)sense}$	The voltage between the source sense terminal and the drain sense terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the source to the drain.
Source-drain on-voltage (terminal)	$V_{SD(on)terminal}$	The voltage between the source main terminal and the drain main terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the source to the drain.
Source-drain off-voltage (sense)	$V_{SD(off)sense}$	The voltage between the source sense terminal and the drain sense terminal, when the SiC MOSFET is off and the specified current described in the datasheet flows from the source to the drain.
Source-drain off-voltage (terminal)	$V_{SD(off)terminal}$	The voltage between the source main terminal and the drain main terminal, when the SiC MOSFET is off and the specified current described in the datasheet flows from the source to the drain.
Input capacitance	C_{iss}	The capacitance of the gate of the SiC MOSFET. It affects switching speed of the SiC MOSFET.
Internal gate resistance	r_{ig}	The internal gate resistance of the SiC MOSFET module.

4.1. Gate-source leakage current I_{GSS}

I_{GSS} is the leakage current when a specified voltage is applied between the gate and the source with the drain and the source are short-circuited.
I_{GSS} may differ for positive and negative depending on the direction of the applied voltage.

4.2. Drain-source cut-off current I_{DSS}

I_{DSS} is the leakage current when a specified voltage is applied between the drain and the source with the gate and the source are short-circuited.

4.3. Gate threshold voltage V_{th}

V_{th} is the gate-voltage when a specified current flows between the drain and the source. V_{th} has negative temperature coefficient, which makes it easier to turn on with lower voltages in high temperature environment. It is necessary to check for malfunctions due to noise or misfiring for the whole temperature range of when the SiC MOSFET is used.

4.4. Drain-source on-voltage (sense) $V_{DS(on)sense}$

$V_{DS(on)sense}$ is the voltage between the drain sense terminal and the source sense terminal when the SiC MOSFET is on and the specified current described in the datasheet flows from the drain to the source.

$V_{DS(on)sense}$ is gate-voltage dependent. If positive-bias gate-voltage $+V_{GS}$ becomes low, V_{DS} increases and heat generation increases, resulting in SiC MOSFET breakdown.

Use $+ V_{GS}$ with +15V or higher.

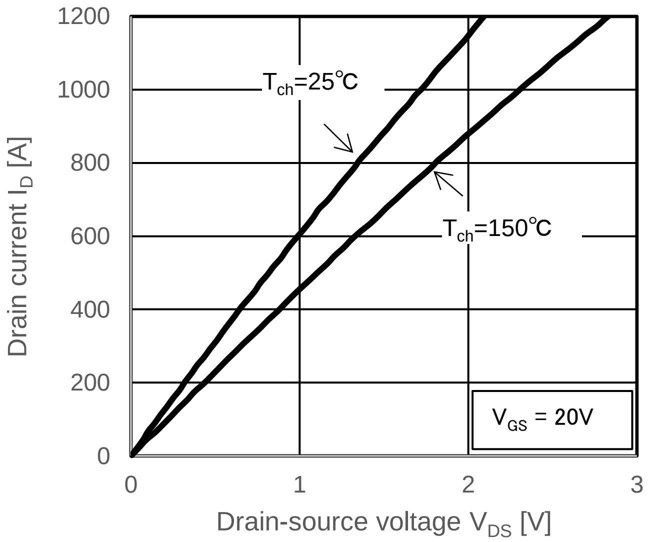


Fig. 4.4.1 An example of I_D-$V_{DS(on)sense}$ characteristics

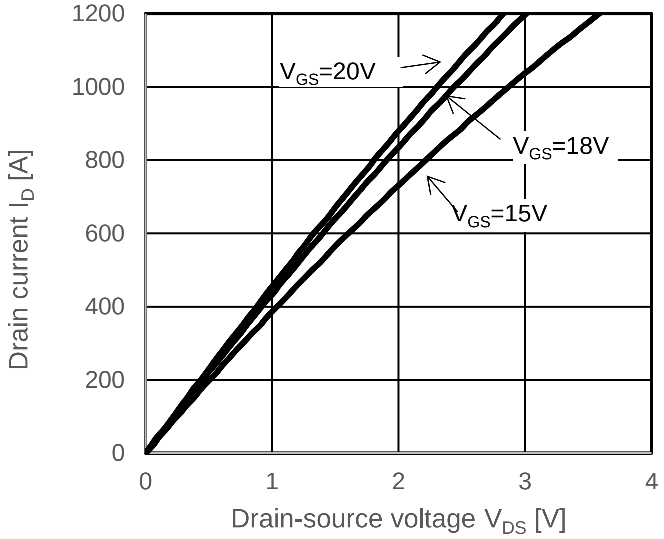


Fig. 4.4.2 An example of gate-voltage dependency on I_D-$V_{DS(on)sense}$ characteristics

4.5. Drain-source on-voltage (terminal) $V_{DS(on)terminal}$

$V_{DS(on)terminal}$ is the voltage between the drain main terminal and the source main terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the drain to the source.

4.6. Source-drain on-voltage (sense) $V_{SD(on)sense}$

$V_{SD(on)sense}$ is the voltage between the source sense terminal and the drain sense terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the source to the drain.

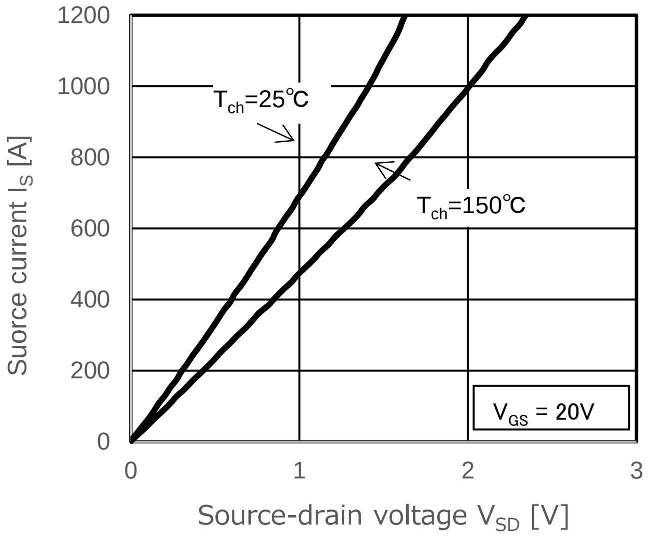


Fig. 4.6.1 An example of I_S-$V_{SD(on)sense}$ characteristics (V_{GS}: positive bias)

4.7. Source-drain on-voltage (terminal) $V_{SD(on)terminal}$

$V_{SD(on)terminal}$ is the voltage between the source main terminal and the drain main terminal, when the SiC MOSFET is on and the specified current described in the datasheet flows from the source to the drain.

4.8. Source-drain off-voltage (sense) $V_{SD(off)sense}$

$V_{SD(off)sense}$ is the voltage between the source sense terminal and the drain sense terminal, when the SiC MOSFET is off and the specified current described in the datasheet flows from the source to the drain.

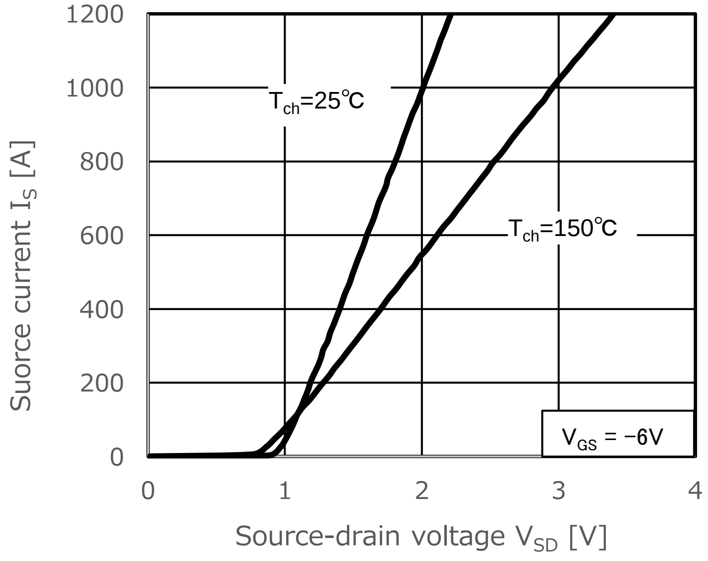


Fig. 4.8.1 An example of I_s-$V_{SD(off)sense}$ characteristics (V_{GS}: negative bias)

4.9. Source-drain off-voltage (terminal) $V_{SD(off)terminal}$

$V_{SD(off)terminal}$ is the voltage between the source main terminal and the drain main terminal, when the SiC MOSFET is off and the specified current described in the datasheet flows from the source to the drain.

4.10. Capacitance Characteristics C_{iss}, C_{oss}, C_{rss}

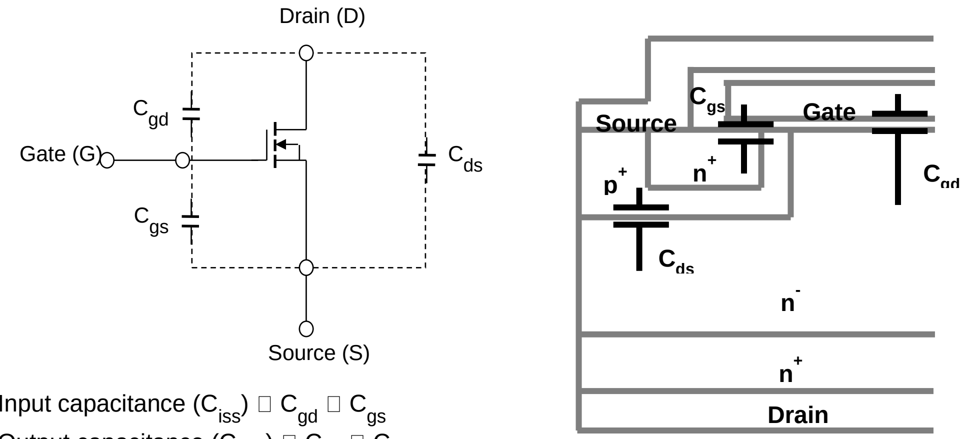
The gate of the SiC MOSFET is insulated by a thin silicon oxide film. Therefore, the SiC MOSFET has capacitances between the gate-drain, the gate-source and the drain-source terminals as shown in figure 4.10.1.

The gate-drain capacitance C_{gd} and the gate-source capacitance C_{gs} are determined by the structure of the gate electrode, while the drain-source capacitance C_{ds} is determined by the capacitance of the p-n junction. For the SiC MOSFET, the input capacitance ($C_{iss} = C_{gd} + C_{gs}$), the output capacitance ($C_{oss} = C_{ds} + C_{gd}$) and the reverse transfer capacitance ($C_{rss} = C_{gd}$) are important characteristics.

Figure 4.10.2 shows the dependency of C_{iss}, C_{rss} and C_{oss} on drain-source voltage V_{DS}.

Switching characteristics of the SiC MOSFET are affected by the input capacitance C_{iss} and the output impedance of the gate drive circuit.

The gate current flows to charge the input capacitance during switching, the lower the output impedance of the gate drive circuit, the larger the gate current and the faster the switching speed.



Input capacitance (C_{iss}) = C_{gd} + C_{gs}
Output capacitance (C_{oss}) = C_{ds} + C_{gd}
Reverse transfer capacitance (C_{rss}) = C_{gd}

Fig. 4.10.1 Capacitance equivalent circuit

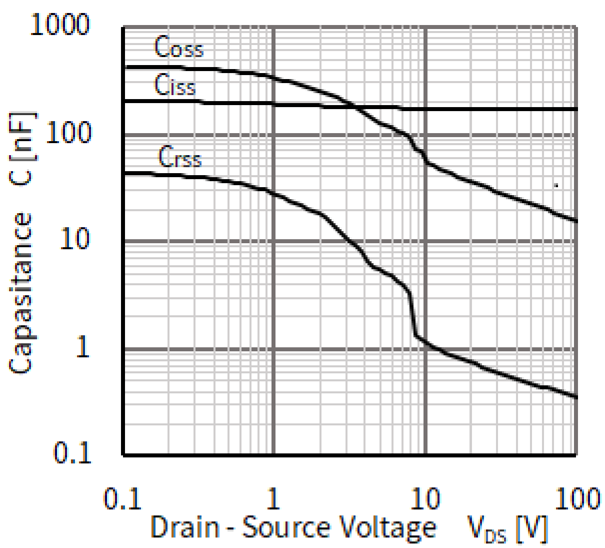


Fig. 4.10.2 An example of C - V_{DS} characteristics

4.11. Gate Resistance r_{ig}

r_{ig} is the gate resistance inside the SiC MOSFET module.

The value of the internal gate resistance r_{ig} is used when designing the gate drive circuit. For more information, see SiC MOSFET Module Application Note Gate drive 2. Gate drive circuit

4.12. Gate Charge Q_g

Q_g is the amount of the charge stored in the gate capacitance while the gate voltage changes. Q_{gtotal} is the stored charge in the gate of the SiC MOSEFT from $-V_{GG}$ to $+V_{GG}$, and it can be read from the figure 4.12.1. Refer to the datasheet of the products for the V_{GS}-Q_g characteristic curve. The gate charge Q_{gtotal} is used when designing the gate drive circuit. For more information, see SiC MOSFET Module Application Note Gate drive Chapter 2.

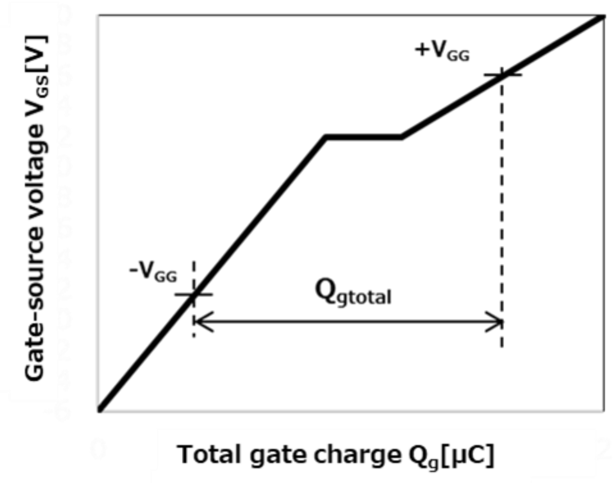


Fig. 4.12.1 Definition of Q_{gtotal}

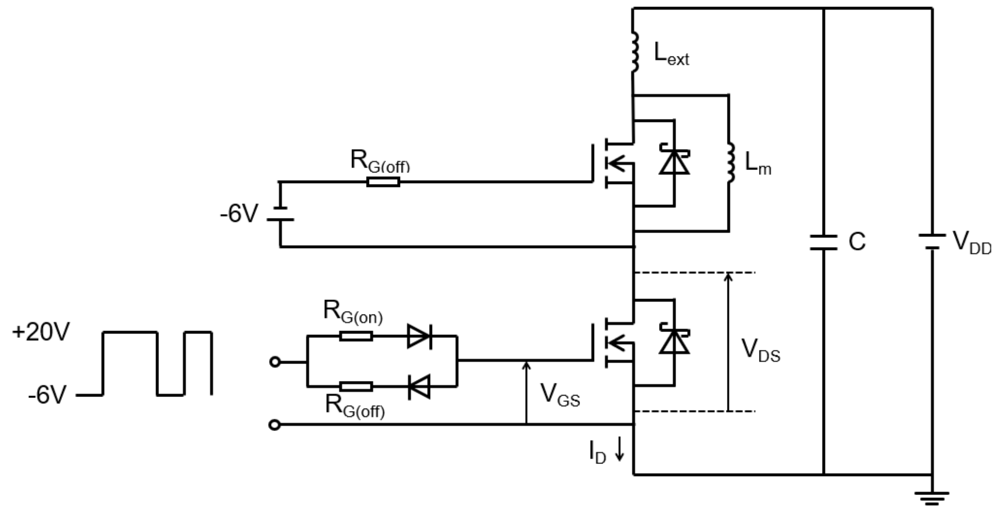
5. Dynamic characteristics (switching characteristics)

Dynamic electrical characteristics of the MOSFET (switching) specified in the datasheet are explained by individual items.

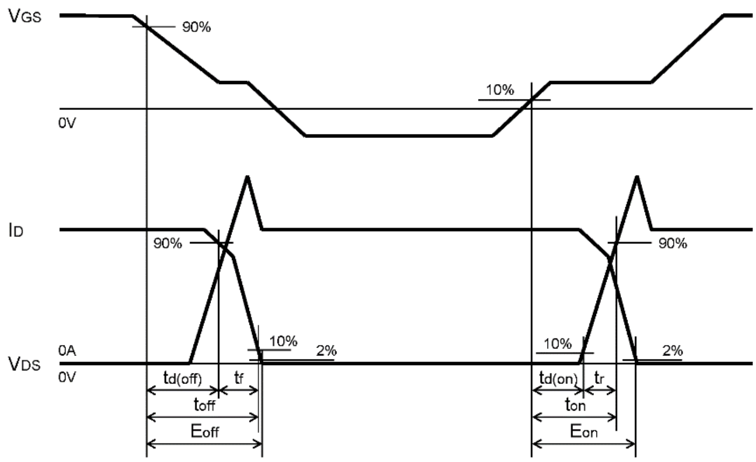
Table 5.1 Dynamic characteristics (switching)

Item	Symbol	Description
Switching time (turn-on delay time)	$t_{d(on)}$	The time from when the voltage between the gate and the source reaches 10% of the set voltage at turn-on until the drain current rises to 10% of the set current.
Switching time (rise time)	t_r	The time from when the drain current reaches at 10% of the set current until it rises to 90% of the set current during turn-on.
Switching time (turn-on time)	t_{on}	The time from when the voltage between the gate and the source reaches 10% of the set voltage at turn-on until the drain current rises to 90% of the set current. t_{on} is the sum of $t_{d(on)}$ and t_r.
Switching time (turn-off delay time)	$t_{d(off)}$	The time from when the voltage between the gate and the source reaches 90% of the set voltage at turn-off until the drain current falls to 90% of the set current.
Switching time (fall time)	t_f	The time from when the drain current reaches at 90% of the set current until it falls to 10% of the set current during turn-off.
Switching time (turn-off time)	t_{off}	The time from when the voltage between the gate and the source reaches 90% of the set voltage at turn-off until the drain current falls to 10% of the set current. t_{off} is the sum of $t_{d(off)}$ and t_f.
Turn-on switching loss	E_{on}	The energy loss during the period when the voltage between the gate and the source reaches 10% of the set voltage at turn-on and the voltage between the drain and the source drops to 2% of the set value.
Turn-off switching loss	E_{off}	The energy loss during the period when the voltage between the gate and the source reaches 90% of the set voltage at turn-off and the drain current falls to 2% of the set value.

Figure 5.2 shows the switching time measurement circuit and the definition of the waveform.



a) Inductive Load Switching Test Circuit (Low side Switching)



b) Switching Timing Chart

Fig. 5.2 Definition of switching measurement circuit, and switching waveform and switching items

5.1. Switching time (turn-on delay time) $t_{d(on)}$

$t_{d(on)}$ is the time from when the voltage between the gate and the source reaches 10% of the set voltage at turn-on until the drain current rises to 10% of the set current. It is strongly affected by the gate resistor $R_{G(on)}$ and becomes longer as $R_{G(on)}$ increases.

5.2. Switching time (rise time) t_r

t_r is the time from when the drain current reaches at 10% of the set current until it rises to 90% of the set current during turn-on. It is strongly affected by the gate resistor $R_{G(on)}$ and becomes longer as $R_{G(on)}$ increases.

5.3. Switching time (turn-on time) t_{on}

t_{on} is the time from when the voltage between the gate and the source reaches 10% of the set voltage at turn-on until the drain current rises to 90% of the set current. t_{on} is the sum of $t_{d(on)}$ and t_r.

5.4. Switching time (turn-off delay time) $t_{d(off)}$

$t_{d(off)}$ is the time from when the voltage between the gate and source reaches 90% of the set voltage at turn-off until the drain current falls to 90% of the set current. It is strongly affected by the gate resistor $R_{G(off)}$ and becomes longer as $R_{G(off)}$ increases.

5.5. Switching time (fall time) t_f

t_f is the time from when the drain current reaches at 90% of the set current until it falls to 10% of the set current during turn-off. It is strongly affected by the gate resistor $R_{G(off)}$ and becomes longer as $R_{G(off)}$ increases.

5.6. Switching time (turn-off time) t_{off}

t_{off} is the time from when the voltage between the gate and the source reaches 90% of the set voltage at turn-off until the drain current falls to 10% of the set current. t_{off} is the sum of $t_{d(off)}$ and t_f.

5.7. Turn-on switching loss E_{on}

E_{on} is the temperature dependent energy loss during the period when the voltage between the gate and the source reaches 10% of the set voltage at turn-on and the voltage between the drain and the source drops to 2% of the set value.

E_{on} is strongly affected by the gate resistor $R_{G(on)}$. E_{on} increases as $R_{G(on)}$ increases.

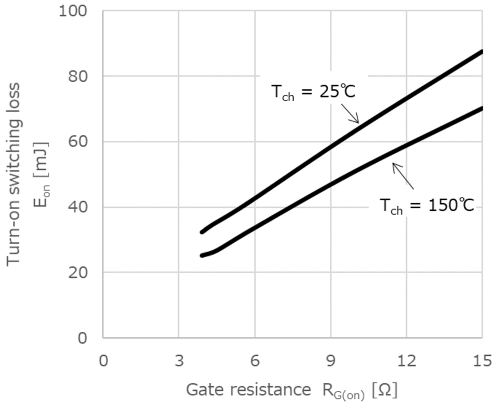


Fig. 5.7.1 An example of E_{on}-$R_{G(on)}$ characteristics

E_{on} increases as turn-on drain current I_D increases.

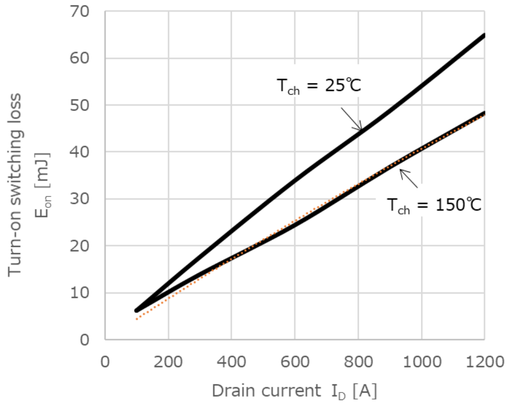


Fig. 5.7.2 An example of E_{on}-I_D characteristics

5.8. Turn-off switching loss E_{off}

E_{off} is the temperature dependent energy loss during the period voltage between the gate and the source reaches 90% of the set voltage at turn-on and the drain current falls to 2% of the set value.

E_{off} is strongly affected by the gate resistor $R_{G(off)}$. E_{off} increases as $R_{G(off)}$ increases.

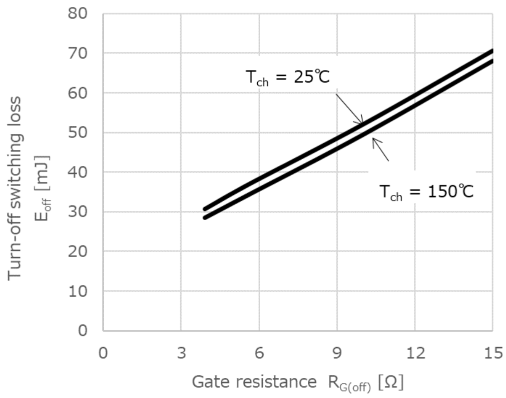


Fig. 5.8.1 An example of E_{off}-$R_{G(off)}$ characteristics

E_{off} increases as turn-off drain current I_D increases.

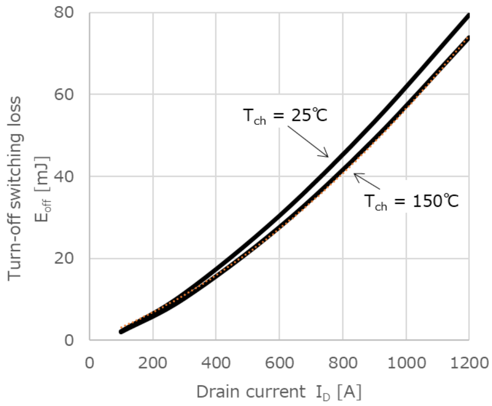


Fig. 5.8.2 An example of E_{off}-I_D characteristics

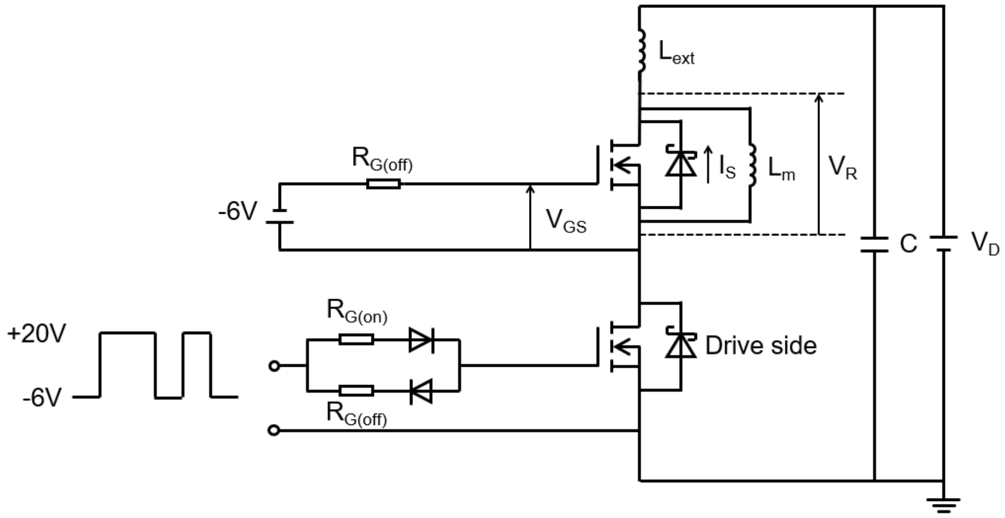
6. Dynamic Characteristics (reverse recovery characteristics)

Dynamic electrical characteristics of the diode (reverse recovery) specified in the datasheet are explained by individual items.

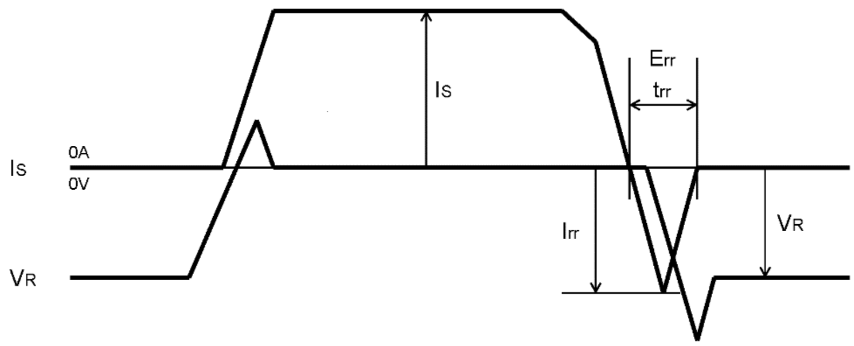
Table 6.1 Dynamic characteristics (reverse recovery characteristics)

Item	Symbol	Description
Reverse recovery time	t_{rr}	The time from when the current starts to flow from the drain to the source direction until it reaches zero in the process of reverse recovery.
Reverse recovery loss	E_{rr}	The energy loss during the current flows in the direction from the drain to the source until it reaches zero in the process of reverse recovery.

Figure 6.2 shows the reverse recovery measurement circuit and the definition of the waveform.



a) Inductive Load Reverse Recovery Test Circuit (Low side Switching)



b) Recovery Timing Chart

Fig. 6.2 Definition of reverse recovery measurement circuit, and reverse recovery waveform and reverse recovery items

6.1. Reverse recovery time, t_{rr}

t_{rr} is the time from the start of the current flow to the direction from the drain to the source until it reaches zero in the reverse-recovery process.

6.2. Reverse recovery loss E_{rr}

E_{rr} is temperature-dependent energy loss during the current flows in the direction from the drain to the source until it reaches zero in the process of reverse recovery.

E_{rr} is strongly affected by $R_{G(on)}$ of the drive-side SiC MOSFET.

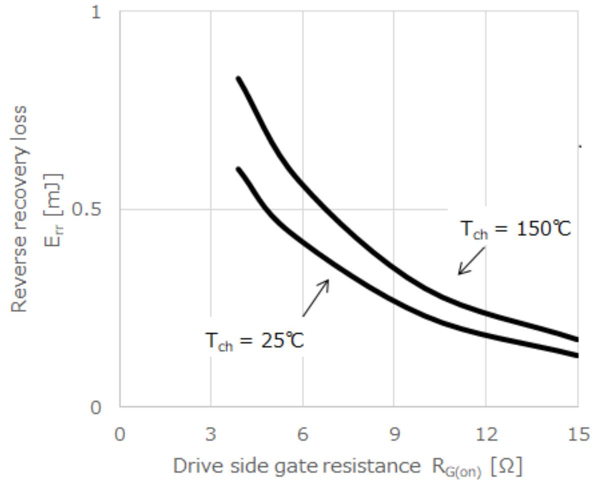


Fig. 6.2.1 An example of E_{rr} - drive side $R_{G(on)}$ characteristics

The reverse recovery loss E_{rr} is affected by the source-current I_S.

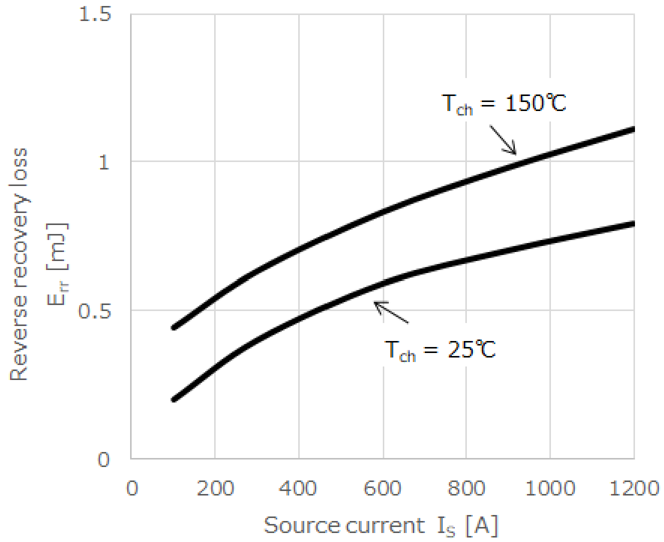


Fig. 6.2.2 An example of E_{rr}-I_s characteristics

7. Stray inductance L_{sPN}

Table 7.1 Stray inductance

Item	Symbol	Unit	Description
Stray inductance	L_{sPN}	nH	The value of package inductance between P and N terminals.

L_{sPN} is the package stray inductance measured between P and N terminals. If the L_{sPN} is large, the peak voltage at turn-off increases, and if the voltage exceeds the area described in "10.1 Reverse Bias Safe Operating Area", there is a risk of the SiC MOSFET module malfunction.

8. Current sensing inductance L_{sCS}

L_{sCS} is applicable to MG800FXF2YMS3,MG800FXF1JMS3 and MG800FXF1ZMS3.

Table 8.1 Current sensing inductance

Item	Symbol	Unit	Description
Current sensing inductance	L_{sCS}	nH	The value of package inductance between terminal 1 and terminal 8.

L_{sCS} can be used to measure transient changes in the current through the SiC MOSFET of the lower arm. The dI_D /dt of the current I_D of the lower arm device can be expressed by the equation (8.2) using the voltage V_{LS} at both ends of the current sense terminals (between terminal 1 and terminal 8).

$$V_{LS} = -L_{sCS}\frac{dI_D}{dt} \cdots (8.2)$$

9. Thermistor

Table 9.1 Thermistor characteristics

Item	Symbol	Unit	Description
Rated NTC resistance	R	Ω	The resistance between thermistor terminals at the specified temperature
NTC B value	B	K	The coefficient of the formula which shows the relationship between resistance and temperature of an NTC thermistor.

The temperature of the module can be monitored by the thermistor. Absolute temperature of the thermistor T can be expressed by the equation (9.2) where thermistor resistance value $R_{(T)}$ is calculated using the NTC B-value and thermistor rated resistance R_{25} as described in the datasheet.

$$R_{(T)} = R_{25} \exp B\left(\frac{1}{T} - \frac{1}{298}\right) \cdots (9.2)$$

Since the thermistor is mounted at a distance from the SiC MOSFET chips and the thermistor itself has a heat capacity, it is not suitable for measuring transient temperature behavior such as short-circuit detection in which the temperature rises in a short time.

Use the thermistor within the maximum ratings. The thermistor has a maximum rated voltage of 7.1V, a maximum rated current of 5mA (recommended current of 100μA), a maximum rated power of 10mW, and an operating temperature range of -40°C to 150°C.

Figure 9.3 shows an example of the circuit and output voltage and current for a thermistor.

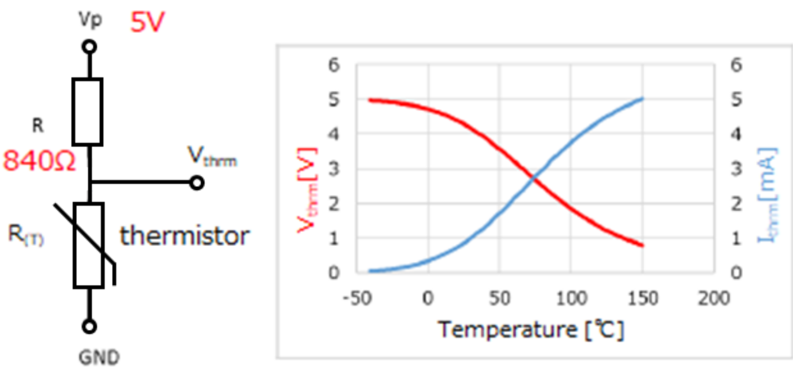


Fig. 9.3 An example of the circuit and output voltage and current for a thermistor

10. Safe Operating Area

The safe operating area of SiC MOSFET modules is defined as the reverse bias safe operating area in the same form as Si IGBTs, taking into account the replacement application of Si IGBTs.

10.1. Reverse Bias Safe Operating Area (RBSOA)

The reverse-bias safe operating area shows the current and voltage areas where SiC MOSFET can be safely turned off. During the process of turning SiC MOSFET from on-state to off-state, a surge-voltage is generated to SiC MOSFET due to the inductance of the circuit. It is necessary to design the circuit so that the turn-off current and surge voltage is within the reverse bias safe operating area during turn-off. (e.g., reducing the inductance of the circuit, adding a surge absorption circuit, or relaxing the turn-off speed).

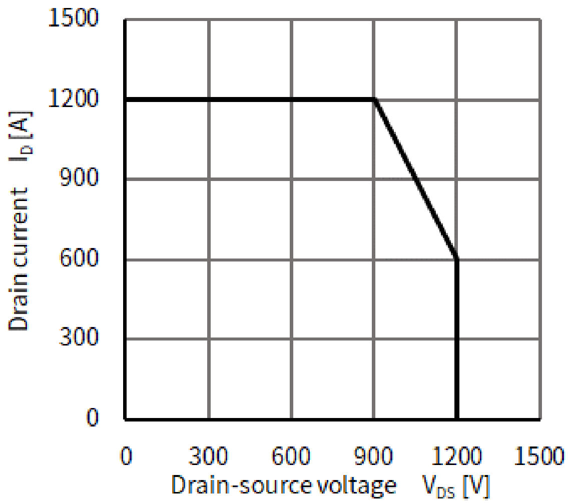


Fig. 10.1.1 An example of reverse bias safe operation area

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