

APPLICATION NOTE
ANxxxx

Understanding the Datasheet of a SiC Power Schottky Diode

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1 – Introduction

A datasheet is an important document to understand the operational functionalities of any product, and due to a large amount of technical information on the document, it is sometimes difficult to comprehend useful data. Therefore, this application note provides a detailed discussion on how to read and interpret the notations, parameters, and diagrams on Genesic Semiconductor's Silicon Carbide (SiC) Power Schottky Diode. It is applicable to the new generation Merged Pin Schottky (MPS™) diodes.

2 – Nomenclature

G **C** **10** **MPS** **12** **252**

G – GeneSiC Semiconductor

B / C – Technology Generation

10 – Maximum Continuous Forward Current (A) Rating at $T_C = 165^\circ\text{C}$, $D = 1$ (Single Die)

MPS – Merged Pin Schottky (MPS™)

12 – Repetitive Peak Reverse Voltage Multiplier * 100 (V)

252 – Package Code

G **C** **2X** **10** **MPS** **12** **247**

G – GeneSiC Semiconductor

B / C – Technology Generation

2X – Number of Dies (2X Signifies 2 Dies)

10 – Maximum Continuous Forward Current (A) Rating at $T_C = 165^\circ\text{C}$, $D = 1$ (A) (Single Die)

MPS – Merged Pin Schottky (MPS™)

12 – Repetitive Peak Reverse Voltage Multiplier * 100 (V)

247 – Package Code

3 – Absolute Maximum Ratings

Repetitive Peak Reverse Voltage (V_{RRM})

V_{RRM} is the maximum allowable repetitive peak reverse voltage of the diode in steady state and transient conditions before it suffers a breakdown. This breakdown limit is rated at an industry standard of 25°C temperature unless stated otherwise. It should also be noted that this breakdown limit might be reduced by approximately 10% at extremely low temperatures like -55°C.

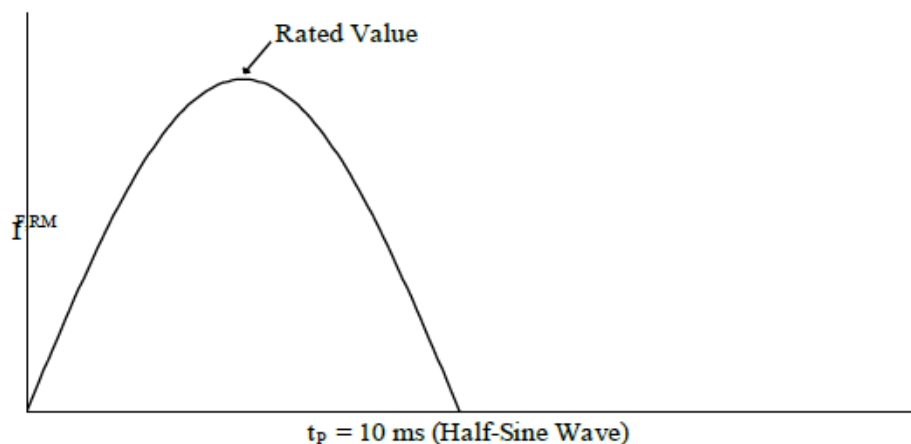
Continuous Forward Current (I_F)

I_F is the maximum allowable continuous forward current rating of the diode for a given value of case temperature (T_C). It is specified as a DC value of continuous duty ($D = 1$) and is strictly not an instantaneous operating limit for any other duty cycles. The typical current derating curve provided in the datasheet should be used to determine this limit at different temperatures and duty cycles.

Non-Repetitive Peak Forward Surge Current, Half Sine Wave ($I_{F,SM}$)

$I_{F,SM}$ is the maximum allowable non-repetitive half sine wave peak forward surge current rating of the diode for a given temperature and pulse time period. It is specified at 25°C and 150°C for a pulse time (t_p) of 10 milli-seconds. This limit is practically derived by incrementally raising the current to failure for any given DUT. For the purpose of the datasheet, this rating is significantly de-rated from the failure point.

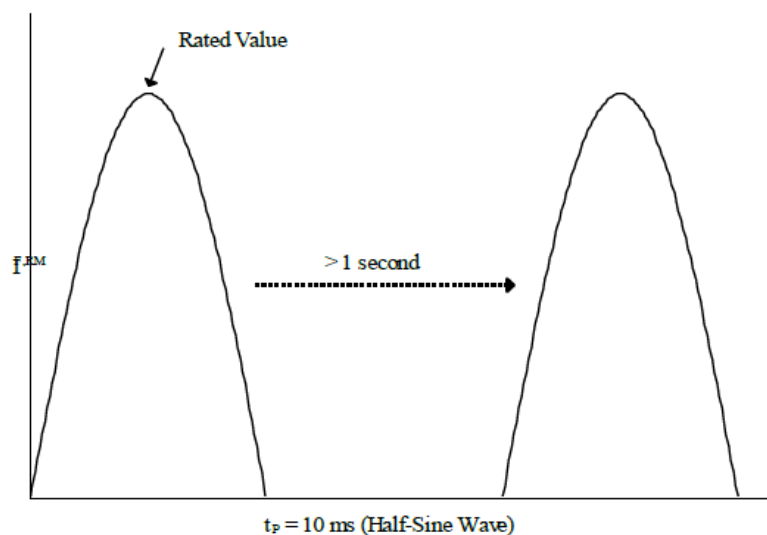
During the test, the junction is allowed to exceed the maximum junction temperature rating of the device for the duration of the test current pulse and then allowed sufficient time to attain thermal equilibrium in order to re-verify the DUT for its rated electrical and mechanical characteristics. It should also be noted that this rating is not based upon the transient thermal impedance of the package.



Repetitive Peak Forward Surge Current, Half Sine Wave ($I_{F,RM}$)

$I_{F,RM}$ is the maximum allowable repetitive half sine wave peak forward surge current rating of the diode for a given temperature and pulse time period. It is specified at 25°C and 150°C for a pulse time (t_p) of 10 milli-seconds.

During the test, the DUT is repetitively stressed under the specified conditions for more than 100 current surges and no reverse voltages are applied (V_R). After each current surge, the junction is allowed to attain thermal equilibrium and it is always kept under the maximum rated value of T_j . It is then checked for any degradation in the electrical and mechanical parameters. The specified value is a de-rated test current specified according to the package transient thermal impedance.



Non-Repetitive Peak Forward Surge Current ($I_{F,max}$)

$I_{F,Max}$ is the maximum allowable non-repetitive peak forward DC surge current rating of the diode at the given temperature and pulse time period. It is specified at 25°C for a single DC current pulse of 10 μs period. After the test, the junction is allowed to attain thermal equilibrium before verifying it for its rated electrical and mechanical characteristics. Here also, the value is de-rated for the purpose of the datasheet.

i^2t Value ($\int i^2 dt$)

$\int i^2 dt$ represents the square of the surge on-state current integrated over the time period. When stressed to high $\int i^2 dt$ values, diodes lose their reverse blocking capability partially or entirely until the junction temperature falls down below its permissible absolute maximum rating. The absolute maximum rating of this parameter serves to determine the diode's short circuit current protection and its capability to retain electrical and mechanical properties after surge stresses.

Non-Repetitive Avalanche Energy (E_{AS})

E_{AS} (Energy in Avalanche, Single Pulse) represents the absolute maximum single pulse avalanche energy that can be absorbed by the diode during Unclamped Inductive Switching (UIS) functions before it suffers an avalanche breakdown. This specification is useful to determine the diode's capability to withstand inductively induced over-voltage spikes during fast turn-off switching transitions. The rating is specified at the continuous current rating of the diode (I_{AV}) as it is the worst case condition. The E_{AS} capability of the diode will vary over a range of load currents and inductive loads.

Diode Ruggedness (dV/dt)

The dV/dt ruggedness of a power diode is used to indicate the diode's capability to handle voltage over-shoot transients during switching and therefore, this rating determines the maximum switching speed in hard switched applications.

Power Dissipation (P_{tot})

P_{tot} expresses the maximum power that can be dissipated by the diode at a case temperature of 25°C. It is derived from the junction-case thermal resistance (R_{thJC}) and the maximum power dissipation at different temperatures can be derived from the power derating curve on the datasheet. Here, it is assumed that the case temperature is constantly maintained at the stated value while the power is being dissipated from the diode. However, in practical applications, the method of cooling derates the maximum power dissipation, and under any conditions, it cannot be greater than the value specified by the power derating curve.

Operating and Storage Temperature (T_j and T_{stg})

These specify the allowable range of operating junction temperature (T_j) and storage temperature (T_{stg}). In most of the cases, both the ratings are same and typically for GeneSiC Semiconductor's diodes the range is -55°C and 175°C. Operation beyond this range is strictly not recommended.

4 – Electrical Characteristics

The specifications provided in this section of the datasheet are static (or DC) characteristics for the stated conditions and are presented as typical and/or maximum ratings. Such static characteristics might vary between the typical and maximum ratings during production. However, most of the parts are ensured to have these characteristics at the typical ratings and it is always verified that these characteristics do not exceed their maximum ratings during production.

Diode Forward Current (V_F)

V_F is the diode's forward voltage drop specified as a function of the continuous forward current (I_F) and junction temperature (T_j). The typical values of V_F at different conditions of I_F and T_j can be derived from the typical forward characteristics curve in the datasheet.

Reverse Current (I_R)

I_R is the reverse leakage current of the diode when a reverse voltage (V_R) is applied across it. A SiC Schottky diode is a majority carrier device and therefore has no minority carriers stored in the drift layer during the forward operating mode, resulting in a zero reverse recovery current. However, the thinner and more heavily doped voltage blocking layer in a SiC Schottky diode typically possesses a higher junction capacitance as compared to a Si PIN diode of the same voltage rating. As a result, there is a small yet finite reverse recovery current in SiC Schottky diodes due to the capacitive displacement current. However, unlike the reverse recovery characteristics displayed by Si PIN diodes, the capacitive recovery characteristics observed in SiC Schottky diodes are very less dependent of forward current level and turn-off dI/dt . I_R is dependent on the reverse voltage (V_R) and junction temperature (T_j). Moreover, the datasheet provides a typical reverse characteristics curve which can be used by the designer to determine the typical values of I_R for different conditions of V_R and T_j .

Total Capacitive Charge (Q_C)

Q_C signifies the typical total capacitive charge required to force the diode in to forward conduction mode when a voltage is applied to it. With SiC Schottky diodes, the absence of minority charge carries has reduced this charge to the order of a few tens of nano-coulomb (nC) and thereby making it very suitable for high frequency switching circuits. This information is useful to designers in understanding the dynamic behavior of the diode in such applications and is provided in the datasheet at $T_j = 175^\circ\text{C}$ for a given dI_F/dt value.

Switching Time (t_s)

The switching time (t_s) can be defined as the maximum time taken by the diode to be forced in to forward conduction mode. This characteristic is related to the presence of Q_C and also useful in understanding the behavior in switching circuits. SiC Schottky diodes can attain very fast switching speed due to use of majority charge carriers and thus, an absence of recombination time.

Total Capacitance (C)

C represents the total junction capacitance as a monotonically decreasing function of the reverse voltage (V_R) applied to the diode. As this capacitance is highly dependent on the area of the depletion region (which varies with V_R), it is measured at a 1 MHz frequency over a wide range of V_R . The typical measurements are shown in the typical junction capacitance vs. reverse voltage characteristics curve in the datasheet. With SiC Schottky diodes, the value of C is small due to smaller junction areas and moreover, no significant variation in C is observed at high voltages.

5 – Thermal / Mechanical Characteristics

Thermal Resistance, Junction-Case (R_{thJC})

R_{thJC} is the resistance against heat flow measured between the diode's junction and the base plate of the diode's case. This is an important factor that decides the power that can be dissipated by the diode and therefore it is expressed in °C/W. This characteristic of the device is independent of the circuit board conditions and is generated by the power loss in the device itself.

Mounting Torque

It is the maximum allowable mounting torque in N-m that can be applied to the mounting structure. It is dependent upon the type of the package and its ruggedness. At GeneSiC Semiconductor, the diodes offered in industry standard packages like TO-220 and TO-247 will have this specification.

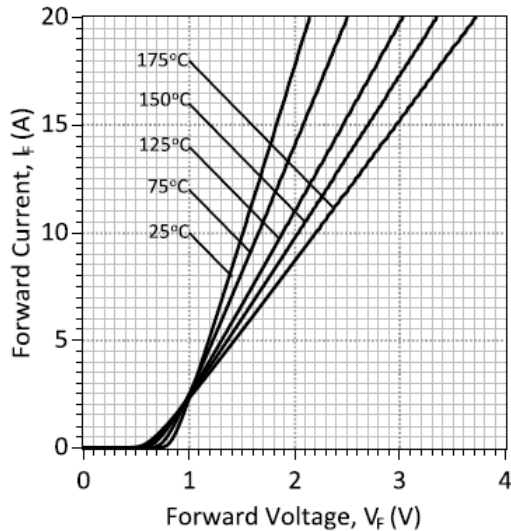
Package Weight (W_T)

W_T specifies the weight of the part and is expressed in grams (g).

6 – Typical Performance Curves

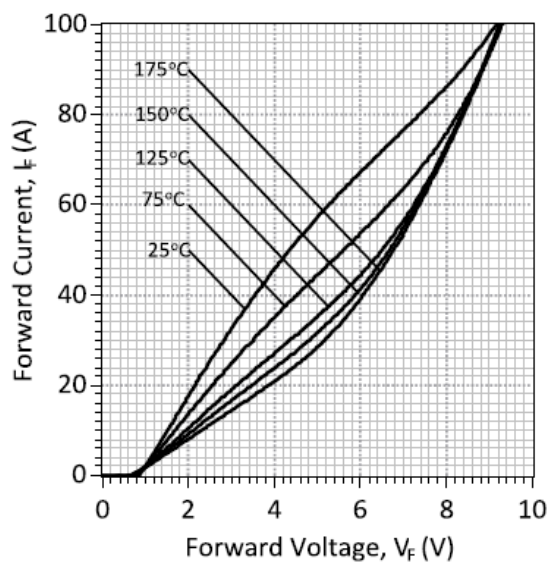
This section provides an explanation to the typical characteristic performance curves specified in the datasheet and an understanding of how to interpret parameters from them for different operating conditions. The performance curves of **GC10MPS12-252** are used as a reference here.

Typical Forward Characteristics



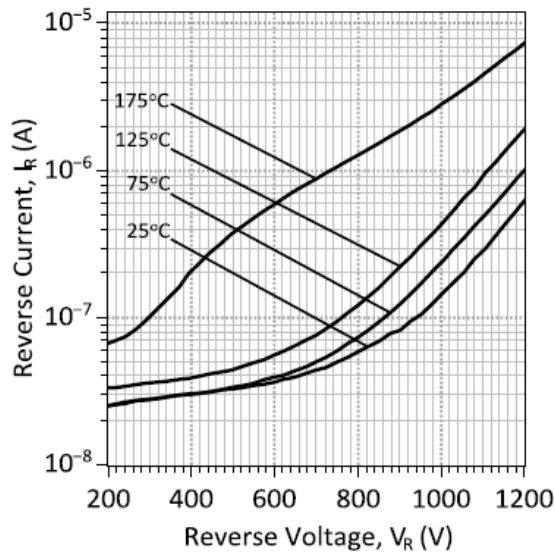
This curve provides the forward conduction transfer characteristics of the diode as a function of the junction temperature. At a constant forward current (I_F), the typical intrinsic forward voltage drop of a SiC diode increases significantly as T_j increases. Such a characteristic of these SiC diodes allows designers to easily parallel diodes and share large values of forward currents. The typical forward characteristic of a conventional Si diode is quite different due to a dominating negative temperature coefficient region.

Typical High Current Forward Characteristics



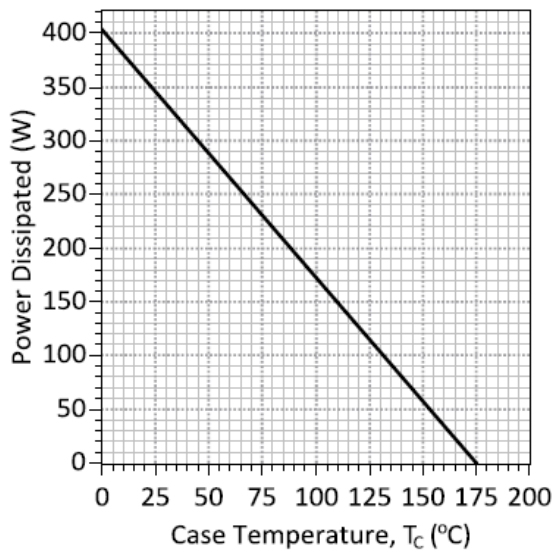
This curve provides the typical forward transfer characteristics for high values of forward current. It is useful in determining the transient surge performance characteristics of the diode

Typical Reverse Characteristics



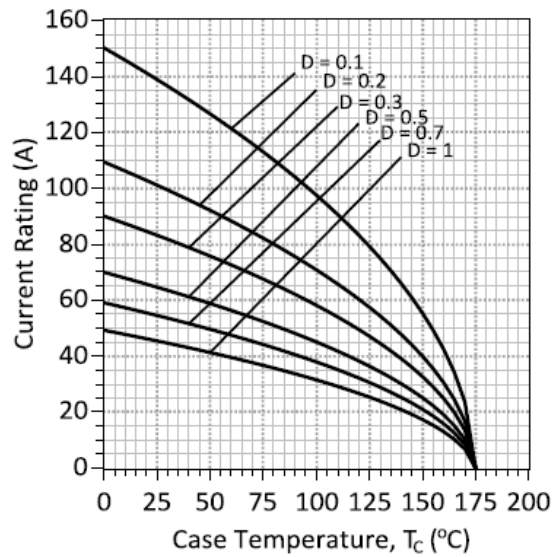
This curve provides the typical reverse leakage current (I_R) as a function of the reverse voltage (V_R) and the junction temperature (T_j). It can be easily seen from the characteristics that the reverse leakage current is very low for SiC diodes due to the absence of minority charge carriers and increases with with V_R and T_j .

Power Derating Curve



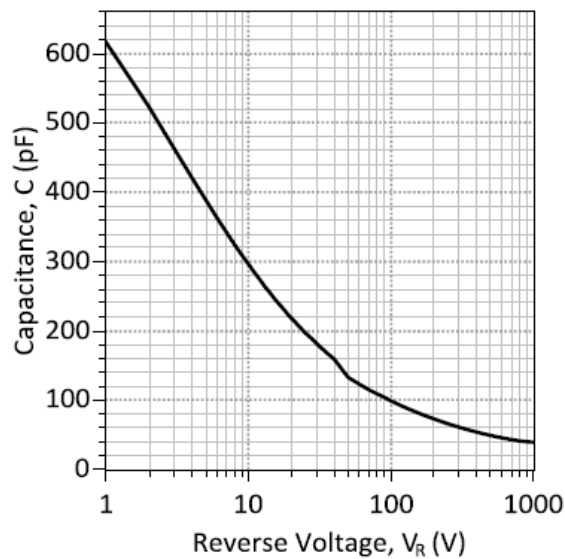
The power derating curve is an important characteristic to determine the absolute maximum power dissipation of the device for a given case temperature (T_c). In practical applications, a reliable cooling mechanism is required to maintain T_c at a desired value.

Current Derating Curves



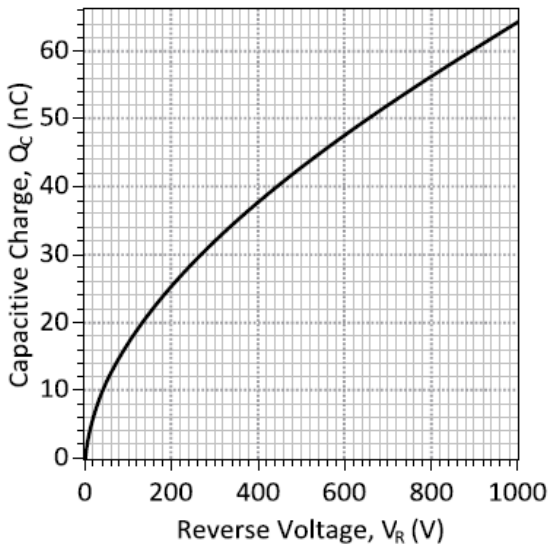
The current derating curves enlist the maximum average DC current that can flow through the diode for a given case temperature (T_c). This information is provided at different duties ($D = 0.1$ to $D = 1$) for a given ON time of the pulse and is based on the thermal resistance (R_{thJC}) of the diode and its forward transfer characteristics. These values will differ for different duty cycles (D) and can be easily estimated from this curve.

Typical Junction Capacitance vs. Reverse Voltage Characteristics



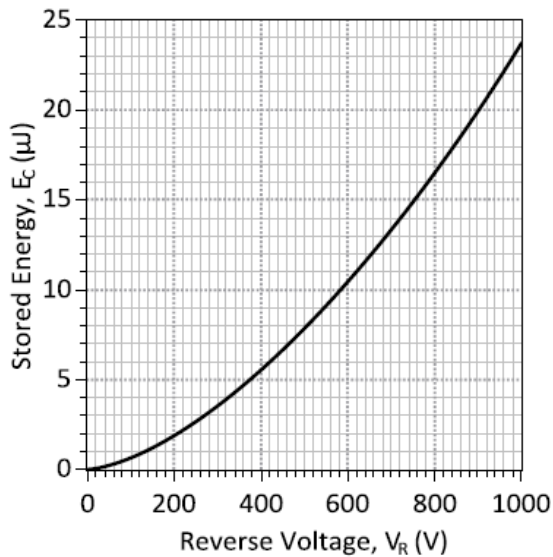
This curve provides the typical junction capacitance of the diode in reverse blocking mode. It is a decreasing function of the DC reverse voltage (V_R) and measured at 1 MHz frequency at $T_j = 25^\circ\text{C}$. In SiC diodes, C retains a constant value for high DC reverse voltages.

Typical Capacitive Charge vs. Reverse Voltage Characteristics



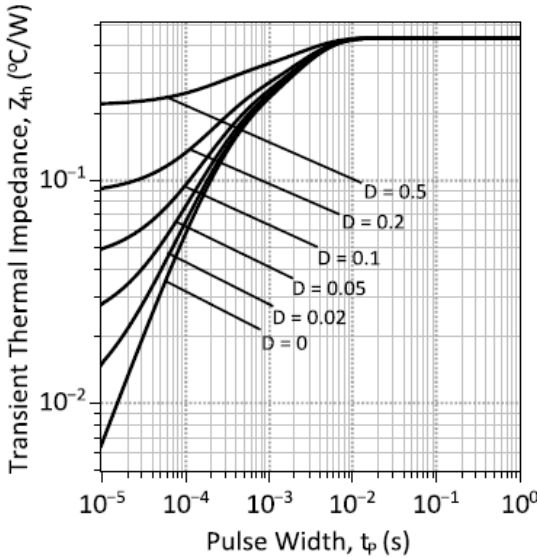
The capacitive charge (Q_C) is a monotonically increasing function of the DC reverse voltage (V_R) and typically ranges up to a few tens of nC. These values are based upon the typical junction capacitance measurements and therefore, specified at a frequency of 1 MHz and $T_j = 25^\circ\text{C}$.

Typical Capacitive Energy vs. Reverse Voltage Characteristics



This curve provides the typical capacitive energy (E_C) stored in the junction capacitance and therefore, it is also a function of V_R . It is useful in determining the switching losses of the diode.

Transient Thermal Impedance

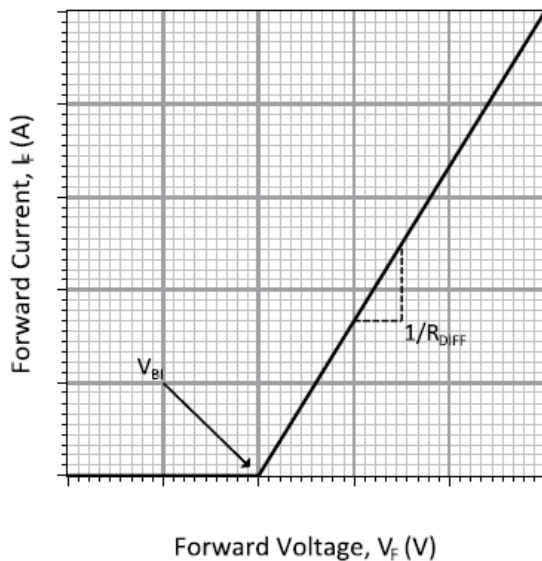


The transient thermal impedance (Z_{thJC}) curve is one of the most useful curves on the datasheet and provides the Z_{thJC} measurements as a function of pulse width (t_p) and duty (D). Z_{thJC} is composed of two components - thermal resistance (R_{thJC}) and thermal capacitance / heat capacity (C_{thJC}). While R_{thJC} affects the heat flow generated by the diode itself, Z_{thJC} takes also the C_{thJC} in to consideration. This is significantly used to estimate the temperature rise during a transient power loss. Thus, the heat to be dissipated from the device has to flow from these several layers of characteristic resistances and capacitances, and depending on the pulse width, either R_{thJC} or C_{thJC} will dominate the behavior.

The increase in the junction temperature can be calculated by the following equation:

$$T_{j,Final} = T_{j,Initial} + \Delta T_j = T_{j,Initial} + Z_{thJC}(t_p, D) * P_{Dissipation}$$

Forward Curve Model



The forward curve model is useful for design engineers to calculate the Built-In Voltage (V_{BI}), often known as the Turn-On Voltage, and the Differential Resistance (R_{DIFF}) of the diode. V_{BI} is a linear decreasing function of the junction temperature and the constants 'm' and 'b' define the slope and line constant of the function. R_{DIFF} is a quadratic increasing function of the junction temperature where 'a', 'b' and 'c' are the constants.

$$I_F = (V_F - V_{BI}) / R_{DIFF}$$

$$V_{BI}(T_j) = (m * T_j) + b$$

$$R_{DIFF}(T_j) = (a * T_j^2) + (b * T_j) + c$$

7 – Package Outline

This section provides the package dimensions and recommended solder pad layout to the designer. The information differs by package types. The dimensions do not include end flash, mold flash and material protrusions.

8 – Compliance

GeneSiC Semiconductor Inc. values the quality of the products and therefore, gives a great importance to their compliance. More details regarding this can be found on the datasheet itself.

9 – SPICE Model Parameters

This section briefly describes the information provided for the SPICE model of the device based on LTSpiceIV. It is provided to the designer in the form of a SPICE derivative which can be copied from the datasheet itself. It should be noted that these parameters will replicate the diode’s SPICE performance as described in the datasheet and should strictly not be changed.

The package lead inductance is modeled for high accuracy of the simulation of our device and the list below describes the diode parameters used in the model.

Parameter	Description	Unit
IS	Saturation Current	A
RS	Ohmic Resistance	Ohm
N	Emission Coefficient	-
IKF	High Injection Knee Current	A
EG	Energy Gap	eV
XTI	Temperature Exponent of IS	-
TRS1	Linear Temperature Coefficient of RS	-
TRS2	Quadratic Temperature Coefficient of RS	-
CJO	Zero-Bias Junction Capacitance	F
VJ	Contact Potential	V
M	Junction Capacitance Grading Coefficient	-
FC	Junction Capacitance Forward-Bias Coefficient	-
TT	Forward Transit Time	s
BV	Reverse Breakdown Voltage	V
IBV	Reverse Current at BV	A
VPK	Peak Forward Voltage	V
IAVE	Continuous Average Forward Current	A
TYPE	Technology Series (SiC_MPS™)	-
MFG	Manufacturer (GeneSiC Semiconductor Inc.)	-

To import the model in to SPICE, copy the SPICE directive in to the circuit simulator and place a Schottky diode from the components window. Use Ctrl + Right Click on this component to open the ‘Component Attribute Editor’ tab and set the ‘SpiceModel’ value equal to the ‘Part Number’ (Example: ‘GC10MPS12’).

Additional Information

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