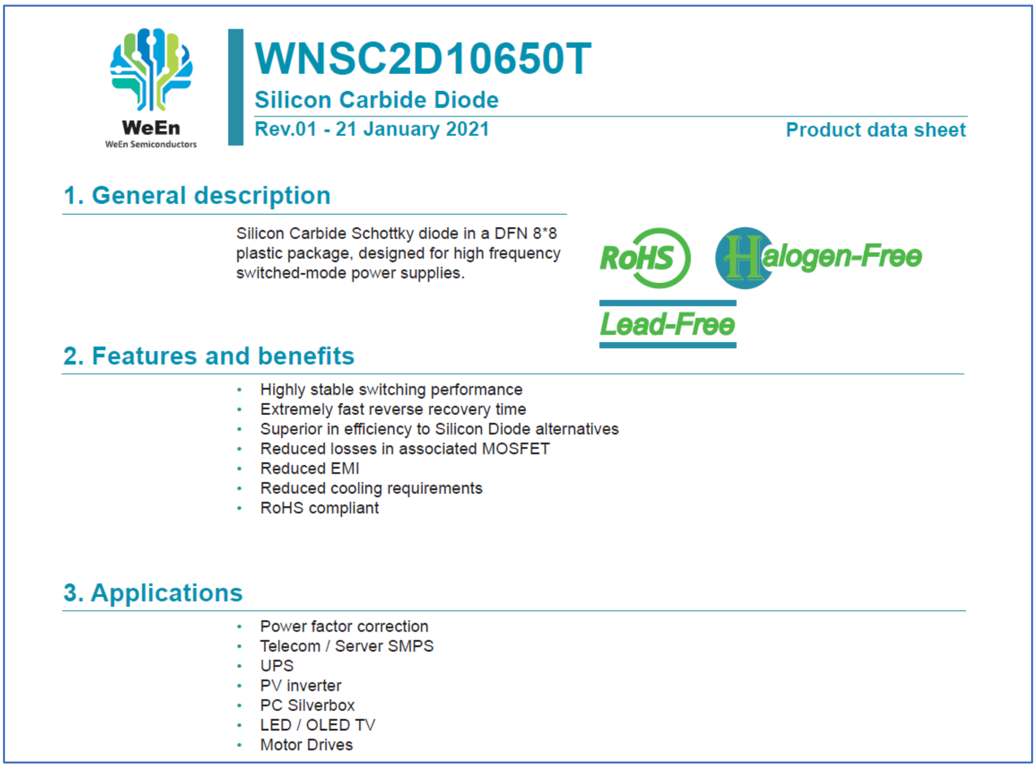
1. Introduction

Datasheets are not required to be created to a fixed international standard. This means datasheets must be read and interpreted carefully to ensure that parameter descriptions and values are correctly understood. There are product datasheets for single and dual diodes for differing technology platforms: Silicon diodes (hyperfast, ultrafast etc.,), Schottky diodes and Silicon Carbide diodes.

WDN007 looks at the parameters defined and described in WeEn datasheets for Silicon Carbide diodes. The other technology platforms are described in WDN006, "Understanding the diode datasheet".

2. Datasheet product profile

All WeEn's datasheets have the product name and type, revision number and publication date on the first page heading. This is followed by three sections, "General description", "Features and benefits" and "Applications". These sections describe the product to allow the reader to quickly understand its technology, main advantages and uses.


WeEn
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WNSC2D10650T
Silicon Carbide Diode
Rev.01 - 21 January 2021 — Product data sheet

1. General description

Silicon Carbide Schottky diode in a DFN 8*8 plastic package, designed for high frequency switched-mode power supplies.

RoHS — Halogen-Free — Lead-Free

2. Features and benefits

- Highly stable switching performance
- Extremely fast reverse recovery time
- Superior in efficiency to Silicon Diode alternatives
- Reduced losses in associated MOSFET
- Reduced EMI
- Reduced cooling requirements
- RoHS compliant

3. Applications

- Power factor correction
- Telecom / Server SMPS
- UPS
- PV inverter
- PC Silverbox
- LED / OLED TV
- Motor Drives

Fig. 1. Example of a datasheet product profile (WNSC2D10650T)

The “Quick reference data” section highlights some important parameters for the product found in the main body of the datasheet.

4. Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions	Values			Unit
Absolute maximum rating						
V_{RRM}	repetitive peak reverse voltage			650		V
$I_{F(AV)}$	average forward current	δ = 0.5 ; square-wave pulse; $T_c \leq 138$ °C; Fig. 1; Fig. 2; Fig. 3		10		A
T_j	junction temperature			175		°C
Symbol	**Parameter**	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Static characteristics						
V_F	forward voltage	I_F = 10 A; T_j = 25 °C; Fig. 5	-	1.5	1.7	V
		I_F = 10 A; T_j = 150 °C; Fig. 5	-	1.8	2.2	V
Dynamic characteristics						
Q_r	recovered charge	I_F = 10 A; dI_F/dt = 500 A/µs; V_R = 400 V; T_j = 25 °C; Fig. 7	-	14	-	nC

Fig. 2. Example of a datasheet product profile (WNSC2D10650T)

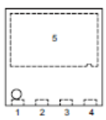
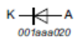
“Pinning information” contains a table and diagram to aid the correct identification of the product’s electrical terminals and package type.

“Ordering information” gives the product’s part number and package version.

The “Marking” section gives data on the labelling printed on the device and data on the packing method.

5. Pinning information

Table 2. Pinning information

Pin	Symbol	Description	Simplified outline	Graphic symbol
1	n.c.	not connected		
2	n.c.	not connected		
3	A	anode		
4	A	anode		
5	K	mounting base; connected to cathode		

6. Ordering information

Table 3. Ordering information

Type number	Package name	Orderable part number	Packing method	Small packing quantity	Package version	Package issue date
WNSC2D10650T	DFN8*8	WNSC2D10650TJ	Tape	3000	DFN8X8N	25-Dec-2019

7. Marking

Table 4. Marking codes

Type number	Marking codes
WNSC2D10650T	WNSC2D 10650T

Fig. 3. Example of a datasheet product profile (WNSC2D10650T)

3. Datasheet "Limiting Values"

7. Limiting values

Table 4. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Fig. 4. Example of "Limiting Values" table heading

"Limiting Values" describe the limiting conditions that can be applied by a circuit without risk of damage to the diode, and these limiting values reflect the diode's capability. These are the absolute maximum ratings for *the operating and environmental conditions* and circuit designers should ensure these are not exceeded. These values may be maximum or minimum. "Limiting" means that the value specified in the table must not be exceeded otherwise the product may malfunction or even be permanently damaged. A limiting value is defined in accordance with the IEC-60134 international standard, known as the "**Absolute Maximum Rating System**".

3.1 V_{RRM}, V_{RWM} & V_R

8. Limiting values

Table 5. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Values	Unit
V_{RRM}	repetitive peak reverse voltage		650	V
V_{RWM}	crest working reverse voltage		650	V
V_R	reverse voltage	DC	650	V

Fig. 5. Example of diode voltage ratings (WNSC2D10650T)

V_{RRM} is the maximum allowable instantaneous repetitive peak reverse voltage (including transients) that the circuit can apply to the diode. "RRM" describes the voltage as "Reverse", "Repetitive" and "Maximum". Similarly, V_{RWM} is the maximum allowable repetitive crest working voltage including transients with "RWM" meaning "Reverse", "Working" and "Maximum". V_R is the maximum allowable constant (DC) reverse voltage. Sometimes, V_{RSM}, the maximum allowable <u>non-repetitive</u> peak reverse voltage including all non-repetitive transients is included. If the limiting reverse voltage is exceeded and circuit conditions allow a large reverse avalanche current, then diode damage can result.

The rated values of $V_{RRM(max)}$, $V_{RWM(max)}$ and $V_{R(max)}$ may be applied continuously over the entire operating junction temperature range, provided that the thermal resistance between junction and ambient is low enough to avoid the possibility of thermal runaway.

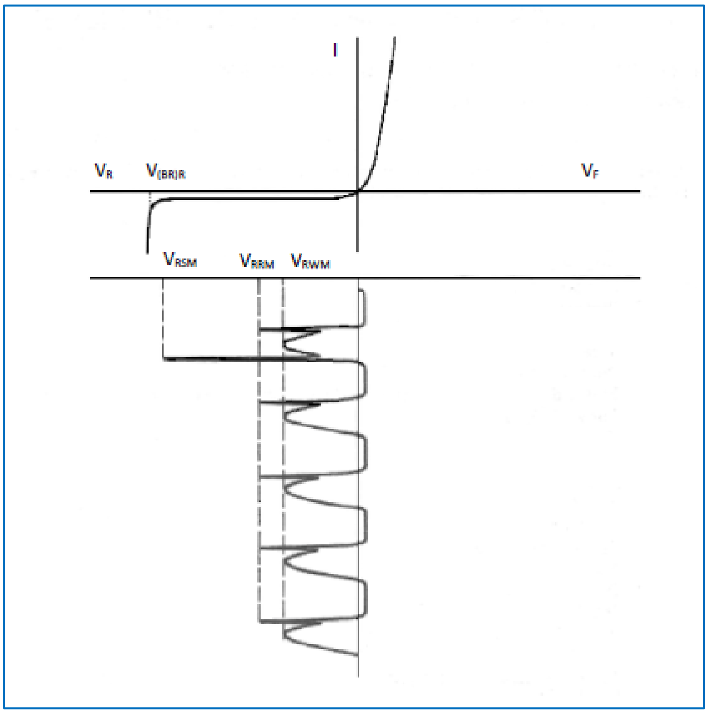


Fig. 6. Diode voltage definitions

3.2 $I_{F(AV)}$ & I_{FRM} [$I_{F(peak)}$]

$I_{F(AV)}$	average forward current	δ = 0.5; square-wave pulse; $T_c \leq 138$ °C; Fig. 1; Fig. 2; Fig. 3	10	A
I_{FRM}	repetitive peak forward current	δ = 0.5; t_p = 25 µs; $T_c \leq 138$ °C; square-wave pulse	20	A

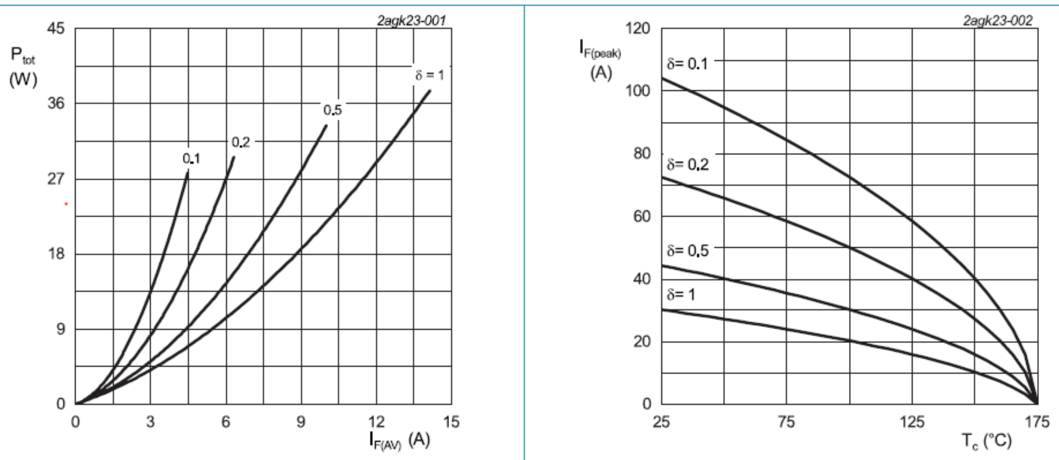
Fig. 7. Example of forward current ratings (WNSC2D10650T)

$I_{F(AV)}$ is the value of current for the diode which under steady state conditions results in the rated temperature $T_{j(max)}$ being reached for a given package-related temperature condition. This temperature condition is specified as T_{mb} for “mounting-base” or “tab” type packages (e.g. WNSC2D10650D), T_c for “DFN” type packages (e.g. WNSC2D10650T) and T_h for plastic packages for “heatsink” mounting (e.g. WNSC2D10650X).

$I_{F(AV)}$ is related to the $I_{F(RMS)}$ current parameter by the equations, $I_{F(AV)} = I_{F(RMS)} \times \sqrt{(\delta)}$, where δ is the duty cycle factor for square wave current.

In WeEn datasheets the I_{FRM} rating is defined such that it is an ***additional clarification*** of the $I_{F(AV)}$ rating in the condition of continuous current conduction. I_{FRM} is the maximum allowable repetitive peak forward current [$I_{F(peak)}$] including transients which occur every cycle. The junction temperature should not exceed $T_{j(max)}$ during repetitive current transients. The “I_{FRM}” rating for square waves with durations no more than 25µs is relevant in real applications and meaningful to the user.

The I_{FRM} rating and its definition is discussed further in the WDN001, “Understanding I_{FRM} for power diodes”. This parameter is defined differently by various manufacturers.



$I_{F(AV)} = I_{F(RMS)} \times \sqrt{\delta}$
V_o = 1.024 V; R_s = 0.1156 Ω

Fig. 1. Forward power dissipation as a function of average forward current; square waveform; maximum values

Fig. 2. Current derating as a function of case temperature

Fig. 8. Examples of $P_{(tot)}$ vs $I_{F(AV)}$ & $I_{F(peak)}$ vs T_c graphics (WNSC2D10650T)

The current derating graph indicates the reduction of the maximum current recommended for temperatures that may exceed T_c = 138 °C (for this WNSC2D10650T example).

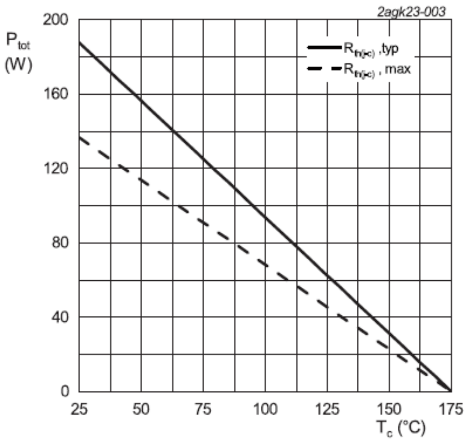


Fig. 3. Total power dissipation as a function of case temperature

Fig. 9. Example of power dissipation graphic (WNSC2D10650T)

Operating the diode at $I_{F(AV)}$ values above the rated limiting value will lead to exceeding the maximum allowable junction temperature $T_{j(max)}$. This can reduce the long-term reliability of the diode or cause immediate failure.

The average junction temperature rise can be calculated by multiplying the power dissipation at the rated average current by the thermal resistance (e.g. $R_{th(j-mb)}$ or $R_{th(j-h)}$). By subtracting this average junction temperature rise from the maximum allowable temperature, $T_{j(max)}$, the maximum allowable mounting base or heatsink temperature is obtained. This is the value shown in the datasheet text and value indicated on the derating graphics.

It should be remembered that to operate the diode under these conditions means the external heatsinking and cooling arrangements need to dissipate the generated power to the ambient surroundings. *This may mean devices in real applications are derated from the maximum $I_{F(AV)}$ conditions in the datasheet, especially devices surface-mounted on PCBs which usually have high thermal resistance to ambient values.* This derating in real applications holds for all manufacturers of diodes whatever the datasheet specification.

3.3 I_{FSM}

I_{FSM}	non-repetitive peak forward current	t_p = 10 ms; $T_{j(init)}$ = 25 °C; sine-wave pulse	50	A
		t_p = 10 µs; $T_{j(init)}$ = 25 °C; square-wave pulse	450	A

Fig. 10. Example of peak forward current ratings (WNSC2D10650T)

I_{FSM} is the maximum non-repetitive peak forward surge current that may be applied to the diode. It is specified for a single half-sine wave pulse applied to a device at an initial junction temperature of 25 °C before surge, for the duration specified (10ms and 10µs in this case), but may also be specified at 8.3ms to reflect usage at 60 Hz. The shorter the time period of the surge (higher frequency), the higher the I_{FSM} capability. Exceeding the I_{FSM} rating may damage the diode.

3.4 I^2t

I^2t	I^2t for fusing	t_p = 10 ms; $T_{j(init)}$ = 25 °C; sine-wave pulse	12.5	A^2s

Fig. 11. Example of I^2t for fusing rating (WNSC2D10650T)

The rating of this parameter serves to determine the diode's *short circuit* current capability i.e. its capability to retain its electrical and mechanical property integrity after surge stress. This rating is numerically linked with the I_{FSM} rating by the equation:

$$I^2t = (I_{FSM}^2/2) \times t_p \equiv I_{FSM}^2/200$$

This is for t_p = 10ms (50Hz half-sine duration) fusing time.

The same value for I^2t is calculated when t_p = 8.33ms (60Hz half-sine duration) using the corresponding I_{FSM} rating at 60Hz.

3.5 T_{stg} and T_j

T_{stg}	storage temperature		-55 to 175	°C
T_j	junction temperature		175	°C

Fig. 12. Example of temperature ratings (WNSC2D10650T)

T_{stg} gives the values for the range of temperature allowable for storage (dispatching, handling, warehousing) of the diode. $T_{j(max)}$ is the maximum operating junction temperature for the diode in the on-state or blocking state. Although the junction temperature may transiently exceed $T_{j(max)}$ without damage, (e.g. during exceptional, brief, non-repetitive overload, or fault conditions), for repetitive operation the peak junction temperature must remain below the absolute maximum rating.

4. Datasheet "Characteristics"

"Characteristics" are the inherent measurable parameters for the diode and are often stated with minimum or maximum values or both. Sometimes typical values are given. The limits define a range of values for the diode's inherent parameter characteristics. These values are useful to the designer for optimizing the circuit and ensuring reliable operation.

4.1 Thermal characteristics, R_{th} and Z_{th}

Table 6. Thermal characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$R_{th(j-c)}$	thermal resistance from junction to case	Fig. 4		-	0.8	1.1	K/W
$R_{th(j-a)}$	thermal resistance from junction to ambient free air	in free air		-	50	-	K/W

Fig. 13. Example of thermal characteristics (WNSC2D10650T)

Maximum steady-state thermal resistance values are given in the datasheet and are used to specify the diode's current and power ratings. As previously mentioned, the average junction temperature rise for a given power dissipation is the mathematical product of the average dissipation and the thermal resistance.

A typical value of junction to ambient thermal resistance is given which assumes that through-hole leaded devices are mounted vertically on a PCB in free air. The value for surface mount packages is for a device soldered to a pad area on a given PCB material.

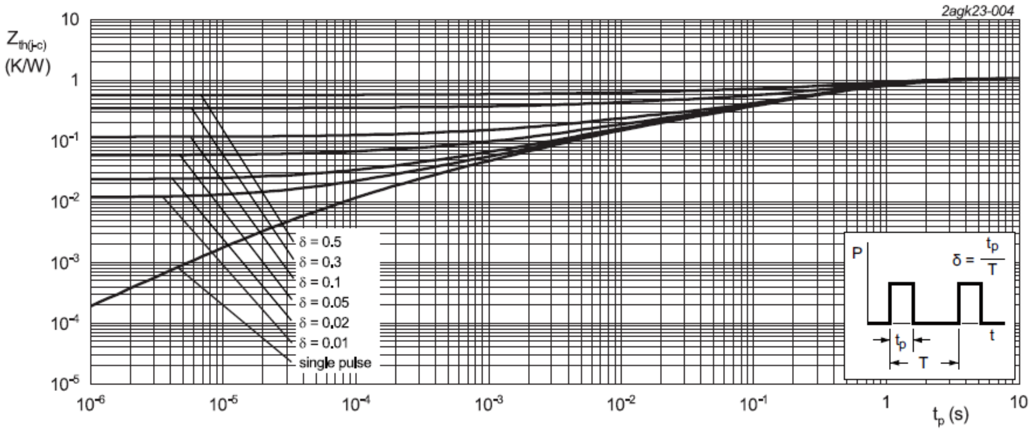


Fig. 4. Transient thermal impedance from junction to case as a function of pulse duration

Fig. 14. Example of transient thermal impedance graphic (WNSC2D10650T)

Although average junction temperature rise may be calculated from the thermal resistance value, the peak junction temperature calculation requires knowledge of the current waveform and the transient thermal impedance curve. This curve in the datasheet is based on rectangular power pulses. Increasing the pulse duration results in higher transient thermal impedance (Z_{th}) until the steady-state, thermal resistance (R_{th}) is reached. If the application operates under transient (pulse) conditions, then Z_{th} instead of R_{th} should be considered since R_{th} is applicable only to steady state, continuous operation. The temperature rise is calculated as the mathematical product of peak dissipation during the pulse by the thermal impedance for the given pulse width.

In practice, a power device must frequently handle composite waveforms rather than a simple rectangular pulse. This type of pulse can be simulated by superimposing several rectangular pulses which have a common time period but with both positive and negative amplitudes. Similarly, a burst of pulses can be treated as a composite waveform. Triangular, trapezoidal, and sinusoidal waveforms can also be approximated by a series of rectangles. This analysis is covered elsewhere.

4.2 Isolation Characteristics

10. Isolation characteristics

Table 7. Isolation characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$V_{isol(RMS)}$	RMS isolation voltage	from all terminals to external heatsink; sinusoidal waveform; clean and dust free; 50 Hz ≤ f ≤ 60 Hz; T_h = 25 °C; RH ≤ 65 %		-	-	2500	V

Fig. 15. Example of Isolation rating (WNSC2D10650X)

The isolation voltage in this example is for the T0220F "full pack" plastic package.

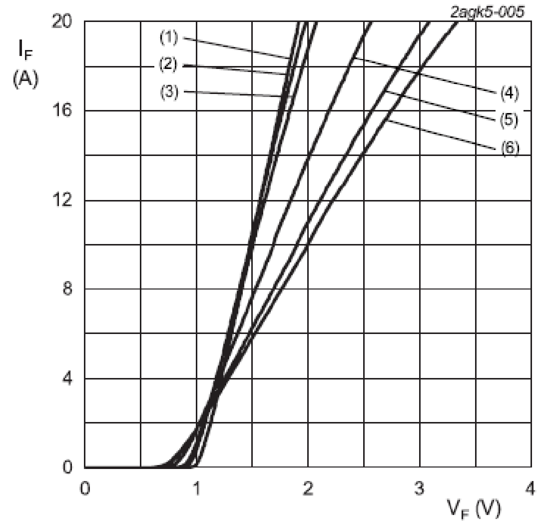
4.3 V_F

Static characteristics							
V_F	forward voltage	I_F = 10 A; T_j = 25 °C; Fig. 5		-	1.5	1.7	V
		I_F = 10 A; T_j = 150 °C; Fig. 5		-	1.8	2.2	V
		I_F = 10 A; T_j = 175 °C; Fig. 5		-	2	2.3	V

Fig. 16. Example of V_F characteristics (WNSC2D10650T)

V_F is the forward voltage for the diode at a specified load current and junction temperature condition. This is the maximum instantaneous forward voltage measured under pulse conditions to avoid excessive power dissipation. It is important to check the specified current and temperature values and whether these are typical or maximum. These values along with V_F / I_F curves at 25 °C and $T_{j(max)}$, enable fair comparison of device specifications between manufacturers. V_F is lower at smaller current values.

The datasheet V_F / I_F graphic has typical curves measured at the rated operating temperature (175 °C in this example) down to -55 °C. The "maximum" curve is used to calculate the power dissipation for a given average current in most cases.



V_o = 1.024 V; R_s = 0.1156 Ω
(1) T_j = -55 °C; typical values
(2) T_j = 0 °C; typical values
(3) T_j = 25 °C; typical values
(4) T_j = 100 °C; typical values
(5) T_j = 150 °C; typical values
(6) T_j = 175 °C; typical values

Fig. 5. Forward current as a function of forward voltage; typical values

Fig. 17. Example I_F & V_F graphic (WNSC2D10650T)

V_0 is the "knee voltage" and R_s is the slope resistance and their values are usually shown in the V_F / I_F graphic in the datasheet (See Fig. 17). These values are sometimes also shown in the power dissipation graphics.

If values for V_0 and R_s are not given in the datasheet, these can be approximated using the V_F / I_F graphic. Points can be chosen on the $T_{J(max)}$ curve, connected with a line, and the line extrapolated to yield V_0 and R_s.

The forward characteristic may be approximated by a linear model and the forward voltage is then given by the equation: $V_F = V_0 + I_F.R_s$ and the instantaneous power dissipation is given by $P_F = V_0.\ I_F + I_F^2.R_s$ where I_F is the instantaneous forward current.

It can be shown mathematically that the average forward dissipation for any current waveform is given by the equation, $P_{F(AV)} = V_0.\ I_{F(AV)} + I_{F(RMS)}^2.R_s$, where $I_{F(AV)}$ is the forward average current and $I_{F(RMS)}$ is the RMS value of the forward current.

Therefore, for the diode datasheet, the graph for forward dissipation can be calculated as a function of average current. Square waveforms are assumed, and the graphs usually show the dissipation for various duty cycles. (See Fig. 8).

Similar details for the derivation of V_0, R_s and power calculations are presented in WAN004, "Triac power and thermal calculations".

4.4 I_R

I_R	reverse current	V_R = 650 V; T_j = 25 °C; Fig. 6		-	0.5	50	µA
		V_R = 650 V; T_j = 175 °C; Fig. 6		-	25	250	µA

Fig. 18. Example of I_R characteristic (WNSC2D10650T)

I_R is the reverse leakage current with typical and maximum values for maximum operating junction temperature and maximum reverse voltage (see Fig.18).

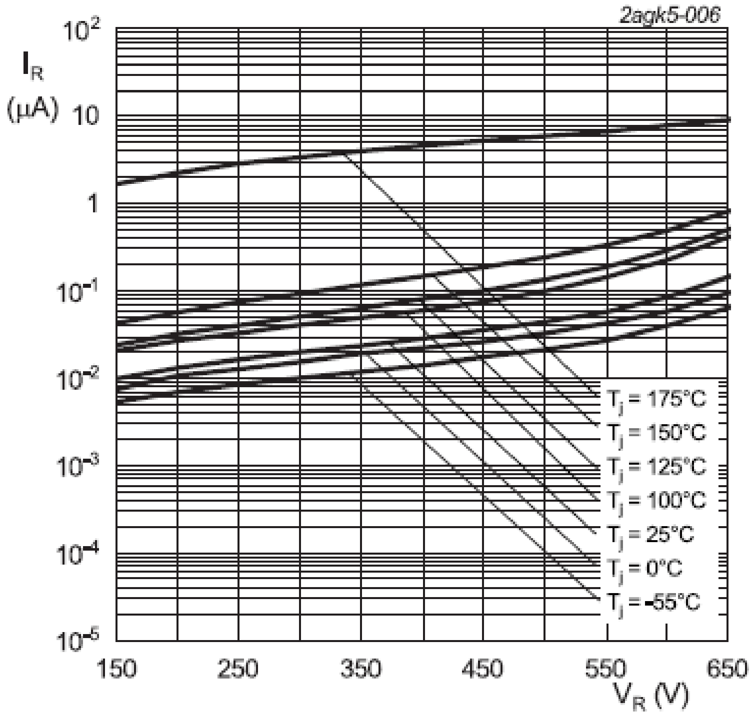


Fig. 6. Reverse leakage current as a function of reverse voltage; typical value

Fig. 19. Example of I_R graphic including junction temperature (WNSC2D10650T)

4.5 Dynamic characteristics: Q_r, C_d & E_{AS}

"Dynamic characteristics" show how diodes cope with fast-changing conditions in a circuit. These are not to be mistakenly understood as limiting values. "Dynamic" means continuous changes in voltage and current.

Dynamic characteristics							
Q_r	recovered charge	I_F = 10 A; V_R = 400 V; dI_F/dt = 500 A/µs; T_j = 25 °C; Fig. 7		-	14	-	nC
C_d	diode capacitance	f = 1 MHz; V_R = 1 V; T_j = 25 °C		-	310	-	pF
		f = 1 MHz; V_R = 300 V; T_j = 25 °C		-	36	-	pF
		f = 1 MHz; V_R = 600 V; T_j = 25 °C		-	32	-	pF
E_{as}	non-repetitive avalanche energy	I_R = 5.5 A; $T_{j(init)}$ = 25 °C; L = 5 mH		75	-	-	mJ

Fig. 20. Example of dynamic characteristics data (WNSC2D10650T)

4.5.1 Recovered charge, Q_r

Silicon Carbide diodes are majority carrier devices and as such do not have significant stored charge that needs to be extracted like bipolar PN diodes after forward conduction. This means that the Q_r curve is flat for all temperatures and so SiC diodes have an excellent temperature-independent switching performance. Bipolar PN diodes whether hyperfast, ultrafast etc., have significant stored charge to be extracted after conducting forward current and so additional reverse recovery characteristics are stated in their datasheets. (see WDN006, "Understanding the diode datasheet")

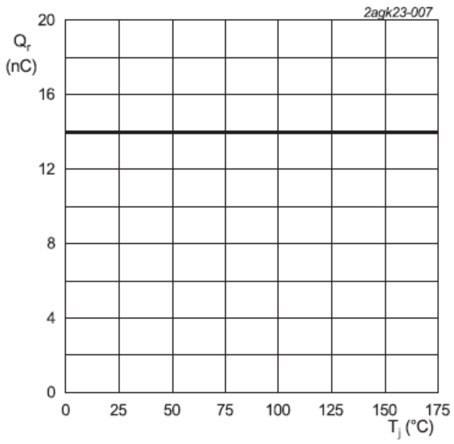


Fig. 7. Recovered charge as a function of junction temperature

Fig. 21. Example of Recovered Charge, Q_r graphic (WNSC2D10650T)

4.5.2 Junction capacitance, C_d

C_d is the junction small signal capacitance of the diode at a specified reverse voltage. Typical values may be given for differing values of V_R or sometimes a graphic may be supplied (see Fig. 20). The higher the current rating of the diode (usually a larger chip), the larger the junction capacitance.

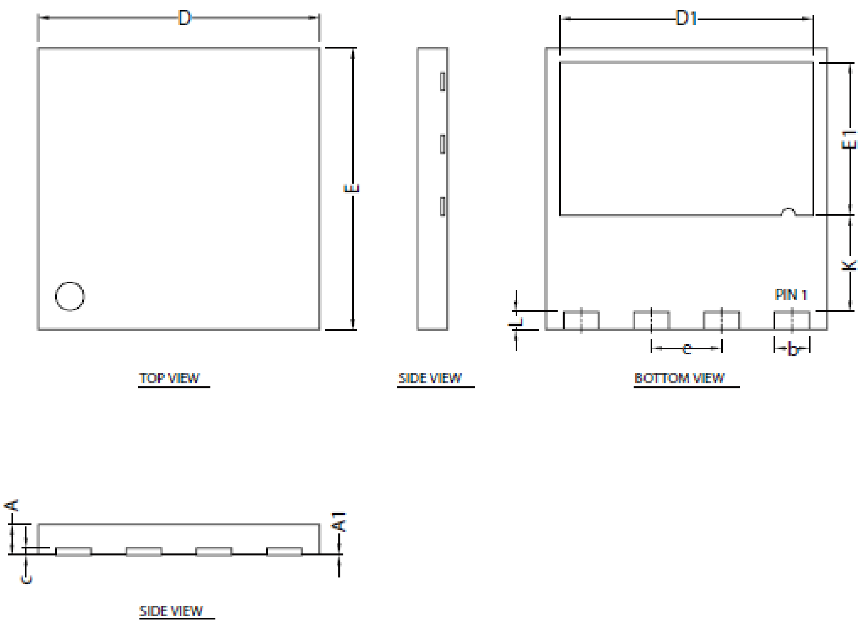
4.5.3 Reverse Avalanche, E_{AS}

This data is helpful in designing circuits which use a diode in free-wheeling mode with an inductive load. As the reverse voltage across a diode is increased a critical value or breakdown voltage is reached which results in an avalanche effect for the leakage current. The reverse energy capability of the diode is specified at 25 °C and this capability may reduce if the diode is at a higher junction temperature just before the avalanche effect begins.

1. Package outline drawing

The datasheet contains a package outline drawing of the device. If a surface mount package is described a soldering pad drawing may also be included.

11. Package outline



UNIT	A	A_1	b	c	D	D_1	E	E_1	e	K	L
mm	0.90 0.80	0.05 0.00	1.10 0.90	0.20 REF	8.10 7.90	7.30 7.10	8.10 7.90	4.45 4.25	2.00 BSC	2.85 2.65	0.60 0.40

Note:
All dimensions do not include mold flash or protrusion.

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Fig. 22. Example of a “DFN” package outline drawing (WNSC2D10650T)

Revision history

Rev	Date	Description
v.01	20210331	initial version

Contact information

For more information and sales office addresses please visit: **http://www.ween-semi.com**

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