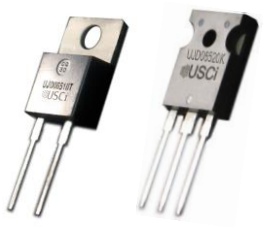
650 V xR SiC Series
650 V-10A, 8A, 6A, 4A / 20A, 16A Schottky Diodes

Product Qualification Report



Summary

This report delineates the reliability and qualification tests applied to the 650 V SiC Schottky Diode product family from USCi packaged in 2 lead TO-220 or 3 lead TO-247 discrete platform. USCi continuously strives for excellence by performing the harshest of reliability tests as outlined below in Table 1. A total of 1155 units of the 10A-650V devices in 2 lead TO-220 were tested in 3 lots where the testing and failure criteria are based on *Stress Test Qualification for Automotive Grade Discrete Semiconductors* (AEC-Q101-REV-C) and the *Stress-Test-Driven Qualification of Integrated Circuits* (JESD471I). Additionally, 77 units each of the 8A-650V, 6A-650V, and 4A-650V devices in 2 lead TO-220, and 77 units each of the 20A-650V, and 16A-650V devices in 3 lead TO-247, were tested for 168 hours under High Temperature Reverse Bias (HTRB). All reliability tests were performed in an ISO 9001 certified facility.

Table 1: USCi's Standard Reliability Qualification Tests
A: Tests Performed on 1155 Units of 10A-650V Devices

Test	Conditions	Sample Size	Reference Document
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 1000 Hrs, V=80% V_{max}	3 Lots of 231 devices (77pcs/Lot)	JESD22-A108C
Intermittent Operational Lifetime (IOL)	ΔTj ≥100ºC, 8572 cycles (3.5 minutes on/ 3.5 minutes off)	3 Lots of 231 devices (77pcs/Lot)	AECQ101C & MIL-STD-750D METHOD 1036,1037
Temperature Humidity Bias Life Test (H3TRB)	85ºC/85% RH, V=100 V 1000 Hrs	3 Lots of 231 devices (77pcs/Lot)	JESD22-A101C
Accelerated Moisture Resistance Unbiased Autoclave (AC)	T_{amb}=121ºC, 100% rh, 205 Kpa, 96 Hrs	3 Lots of 231 devices (77pcs/Lot)	JESD22-A102C
Temperature Cycling (TC)	-55ºC to +150ºC 2 cycles/Hr, 1000 cycles	3 Lots of 231 devices (77pcs/Lot)	JESD22-A104D, Cond H, Soak Mode 2

B: Tests Performed on 77 Units Each of 8A-650V, 6A-650V, and 4A-650V Devices

Test	Conditions	Sample Size	Reference Document
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	JESD22-A108C

C: Tests Performed on 77 Units Each of 20A/16A-650V Devices in 3 Lead TO-247

Test	Conditions	Sample Size	Reference Document
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	JESD22-A108C

High Temperature Reverse Bias (HTRB)

The HTRB test for Schottky Diodes is designed to accelerate the failure modes at the Schottky interface as well as the edge termination process under reverse bias by testing the device at steady state reverse voltage and increasing the ambient temperature. The device junction temperature is related to the ambient temperature and the leakage current through:

$$T_j = (R_{th,case} + R_{th,heatsink}) I_{leak} V_r + T_{Amb}$$

Intermittent Operational Lifetime (IOL)

Intermittent operational lifetime testing is aimed at accelerating failure modes associated with the stresses on all bonds and interfaces between the chip and mounting surfaces by subjecting the devices to repeated turn on and off of current. Self-heating within the device creates a junction temperature rise given by:

$$\Delta T_j = (R_{th,case} + R_{th,heatsink}) I_f V_f$$

Temperature Humidity Bias Life Test (H3TRB)

High-humidity, high-temperature reverse bias (H3TRB) testing is performed to evaluate the reliability of non-hermetic packaged devices in humid environments while undergoing reverse bias. H3TRB is designed to accelerate failure modes associated with moisture penetration through the external protective material (encapsulant or potting), and includes internal corrosion, internal oxidation.

Accelerated Moisture Resistance Unbiased Autoclave (AC)

Unbiased autoclave testing evaluates the moisture resistance integrity of non-hermetic packaged solid state devices using a moisture condensing environment under high pressure. The test accelerates moisture penetration through the external protective material (encapsulant or potting) or along the interface between the external protective material and the metal conductors passing through it.

Temperature Cycling (TC)

Temperature cycling is to evaluate the robustness of the whole package when undergoing extreme temperature swings while the devices are unbiased. Temperature cycling is used to identify failure modes associated from a mismatch in the coefficient of thermal expansion (CTE) between dissimilar materials of all the materials in the complete package.

Failure Criteria

Test failure criteria are defined by the AECQ101-REV C and JESD47I documents, summarized below as any device exhibiting the following:

1. Devices not meeting the electrical test limits defined in the device datasheet specification after performing each stress test.
2. Devices not remaining within ± 20% of the initial reading of each test after completion of environmental testing.
3. Any device exhibiting external physical damage attributable to the environmental test.

For any failure found, the root cause is found by implementing a Failure Mode Effect Analysis (FMEA) and is used to determine if the failure results from mishandling, ESD, test-equipment failure, or a data-acquisition failure. Any device failing for these reasons will be removed from the test and not counted as a qualification failure.

Summary of Reliability Qualification Results

Table 2 and Table 3 show the summaries of the Pre- and Post-Stress Parametric Verification Results at 25°C of all the 650V devices used for the qualification tests. Table 4 summarizes the failures and results for each test condition.

Table 2 Summary of Pre-stress Data
A: 1155 Units of 10A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.61	0.02	1.56	1.69
Reverse Leakage, IR (Rated Voltage)	μA		250	50.5	26.8	0.5	180.0
Breakdown Voltage, VBR (350 μA)	V	650		759	38	687	913

B: 77 Units of 8A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.57	0.02	1.54	1.61
Reverse Leakage, IR (Rated Voltage)	μA		230	26.5	6.0	18.3	54.9
Breakdown Voltage, VBR (350 μA)	V	650		770	10	750	791

C: 77 Units of 6A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.58	0.01	1.56	1.60
Reverse Leakage, IR (Rated Voltage)	μA		200	58.0	15.9	24.6	84.0
Breakdown Voltage, VBR (350 μA)	V	650		726	14	705	768

D: 77 Units of 4A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.50	0.02	1.46	1.53
Reverse Leakage, IR (Rated Voltage)	μA		170	14.1	10.3	2.5	51.0

E: 77 Units of 20A-650V Devices in 3 Lead TO-247

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.52	0.02	1.48	1.55
Reverse Leakage, IR (Rated Voltage)	μA		500	36.1	8.1	24.0	74.3

F: 77 Units of 16A-650V Devices in 3 Lead TO-247

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.44	0.02	1.42	1.48
Reverse Leakage, IR (Rated Voltage)	μA		460	152.2	57.1	65.9	287.4
Breakdown Voltage, VBR (8 mA)	V	650		910	18	859	941

Table 3 Summary of Post-stress Data
A: 1155 Units of 10A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.62	0.02	1.48	1.70
Reverse Leakage, IR (Rated Voltage)	μA		250	31.8	20.2	0	165.9
Breakdown Voltage, VBR (350 μA)	V	650		803	77	691	1029

B: 77 Units of 8A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.57	0.02	1.54	1.61
Reverse Leakage, IR (Rated Voltage)	μA		230	2.2	1.8	0.7	14.9
Breakdown Voltage, VBR (350 μA)	V	650		948	14	892	967

C: 77 Units of 6A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.58	.01	1.56	1.60
Reverse Leakage, IR (Rated Voltage)	μA		200	4.75	3.96	0.5	18.5
Breakdown Voltage, VBR (350 μA)	V	650		928	37	779	992

D: 77 Units of 4A-650V Devices in 2 Lead TO-220

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.50	0.02	1.46	1.53
Reverse Leakage, IR (Rated Voltage)	μA		170	8.7	3.5	2.5	19.5

E: 77 Units of 20A-650V Devices in 3 Lead TO-247

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.51	0.02	1.49	1.55
Reverse Leakage, IR (Rated Voltage)	μA		500	17.9	4.3	10.4	28.5

F: 77 Units of 16A-650V Devices in 3 Lead TO-247

Parameter	Unit	LSL	USL	Mean	STD.DEV.	Min	Max
Forward Voltage, VF (Rated Current)	V		1.7	1.44	0.02	1.42	1.48
Reverse Leakage, IR (Rated Voltage)	μA		460	151.1	56.7	65.7	286.0
Breakdown Voltage, VBR (8 mA)	V	650		911	18	860	942

Table 4: Summary of Qualification Results

A: 1155 Units of 10A-650V Devices in 2 Lead TO-220

Test	Conditions	Sample Size	Failed
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 1000 Hrs, V=80% V_{max}	3 Lots of 231 devices (77pcs/Lot)	0
Intermittent Operational Lifetime (IOL)	ΔTj ≥100ºC, 8572 cycles (7 min cycle)	3 Lots of 231 devices (77pcs/Lot)	0
Temperature Humidity Bias Life Test (H3TRB)	85C/85% RH, V=100 V 1000 Hrs	3 Lots of 231 devices (77pcs/Lot)	0
Accelerated Moisture Resistance Unbiased Autoclave (AC)	T_{amb}=121ºC, 100% RH, 205 KPa, 96 Hrs	3 Lots of 231 devices (77pcs/Lot)	0
Temperature Cycling (TC)	-55ºC to +150ºC 2 cycles/Hr, 1000 cycles	3 Lots of 231 devices (77pcs/Lot)	0

B: 77 Units of 8A-650V Devices in 2 Lead TO-220

Test	Conditions	Sample Size	Failed
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	0

C: 77 Units of 6A-650V Devices in 2 Lead TO-220

Test	Conditions	Sample Size	Failed
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	0

D: 77 Units of 4A-650V Devices in 2 Lead TO-220

Test	Conditions	Sample Size	Failed
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	0

E: 77 Units of 20A-650V Devices in 3 Lead TO-247

Test	Conditions	Sample Size	Failed
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	0

F: 77 Units of 16A-650V Devices in 3 Lead TO-247

Test	Conditions	Sample Size	Failed
High Temperature Reverse Bias (HTRB)	T_{amb}=175ºC for 168 Hrs, V=80% V_{max}	1 Lot of 77 devices (77pcs/Lot)	0

USCi's xR 650 V Schottky Diode products were selected and stress tested in an ISO 9001 certified facility according to *JESD47I* and *AECQ101-Rev C* guidelines as outlined in this report. The devices tested met all electrical performance requirements, and no failures were observed in any of the qualification tests. Based on these results, USCi's xR 650 V Schottky Diode products UJD06510T, UJD06508T, UJD06506T, UJD06504T, UJD06520K, and UJD06516K, are certified† as qualified product according to USCi's internal requirements.

† This report and its conclusions do not imply any guarantee, warranty, or suitability for any purpose regarding the products mentioned. Results represent the particular devices tested, which were randomly selected according to the sampling plan described herein.