NITRONEX CORPORATION

NPT1010B and NPT1010P

Qualification Document

Revision 1.0

1.0 Purpose

This document outlines the qualification of the NPT1010B and NPT1010P devices.

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2.0 Reference Documents

The reliability plan is based on industry- and military-accepted standard documents and references therein, primarily:

JESD47F, "Stress-Driven Qualification of Integrated Circuits," (revision January 2007)
MIL-STD-883G, "Test Method Standard – Microcircuits," (revision February 2006)

This document generally follows the structure of JESD47. Tests were added and sample sizes were adjusted to also cover the military applications.

3.0 Reliability Qualification

3.1 Objective

The objective of this reliability qualification is to qualify NPT1010B and NPT1010P devices produced with the NRF1 technology to meet a generally accepted set of stress test driven qualification requirements for industrial and military applications.

3.2 Test Vehicle and Qualification family

The NPT1010 GaN power transistor is a depletion mode high electron mobility transistor (HEMT) fabricated using the qualified Nitronex NRF1 GaN-on-Si process technology and mask set N05013. The device consists of one 36mm die of 2 mil thickness, with AuSn die attach in a thermally-enhanced AC360CM-F2 air cavity package with copper flange and ceramic lid.

3.3 Qualification plan: stress tests and lot sampling

Table 1 lists the stress tests performed per the qualification plan. The mechanical reliability tests are to verify the reliability performance of packaging and die-packaging interaction. HTOL was performed for 168 hours both to confirm device intrinsic reliability performance in the early life of the device, and to check for any die-package interactions. The wear-out intrinsic reliability performance of the NPT1010 is qualified by similarity to the NPT25100 and NPT35050A products. All of these products are based on the qualified Nitronex NRF1 process technology, which has demonstrated intrinsic reliability performance for 20 year product lifetime, through three-temperature DC life testing and RF high temperature operating life (RF-HTOL), as described in the Nitronex documents NGD-007, "NPT35050A Qualification Document," and NGD-025, "NPT25100B Qualification Document."

The devices sampled for test are composed of approximately equal numbers from:

- Two wafer lots for HTOL, sampled from the frozen process of record, to encompass process variability
- Three wafer lots for electrostatic discharge (ESD) sensitivity, sampled from the frozen process of record, to encompass process variability
- Three packaging lots for temperature cycling, to encompass packaging and die-packaging interaction variability
- Two packaging lots for mechanical shock, to encompass packaging and die-packaging interaction variability
- One packaging lot for moisture resistance (MR) and salt atmosphere (SA)
- One packaging lot for solvent resistance (SR)
- One packaging lot for solderability (SLDR) for pill option (NPT1010P)

Table 1. Required stress tests for product qualification. Resistance to solvents testing required only on devices using inks or paints as a marking medium. Salt atmosphere will be performed at condition "A". Solderability is only required for earless pill style packages.

Stress	Abbr.	Reference	Stress Conditions	DUT Failure Criterion	# of lots	Units/Lot	Total units	Acceptance criterion
High temperature operating life	HTOL	JESD22-A108, JESD85	VDS=28V, TJ~200C, 168 hrs	10X change in leakage/15% degradation on other parameters or catastrophic fail	2	20+19	39	0 fail
ESD Human Body Model	ESD-HBM	JESD22-A114	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	2	3	6	Classification
ESD Charged Device Model	ESD-CDM	JESD22-C101	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	3	3	9	Classification
ESD Machine Model	ESD-MM	JESD-A115	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	3	3	9	Classification
Temperature cycling	TC	JESD22-A104	-65/+150C	10X change in leakage/15% degradation on other parameters or catastrophic fail	3	25	75	0 fail
Mechanical shock + vibration variable frequency + constant acceleration	MS+VVF+CA	JESD22-B104(M2002) + -B103(M2007) + M2001	See reference	10X change in leakage and or 15% degradation on other parameters or catastrophic fail	2	20	40	0 fail
Moisture resistance	MR	M-883-1004	See reference	Visual inspection per MIL spec only (mechanical samples)	1	15	15	0 fail
Salt atmosphere	SA	M-883-1009	see reference	Visual inspection per MIL spec only (mechanical samples)	1	15	15	0 fail
Solvent resistance	SR	M-883-2015	see reference	Visual inspection per MIL spec only (mechanical samples)	1	3	3	0 fail
Solderability (Pill option only)	SLDR	M-883-2013	see reference	Visual inspection per MIL spec only (mechanical samples)	1	22	22	0 fail

3.4 Qualification Results

3.4.1 Transistor Reliability – HTOL

A 39 piece sample was placed under DC-HTOL stress at Tj = 200°C for 168 hours. Quantile box plots showing the distributions for the 38 devices at 168 hours are shown for maximum drain current, VP, RDON, IDLK at 60 volts, G_SS, DEFF_MAX and P_SAT in Fig. 1, Fig. 2 and Fig. 3 below. The data is consistent with that shown during the 1000 hour DC-HTOL test performed as part of the process qualification. The post HTOL electrical testing results indicate that the zero to 168 hours shifts on critical parameters are relatively minor and are well within the product specifications and allowable shifts per qualification plan.

Of the 39 parts, one of the parts suffered a catastrophic failure during post-168 hour characterization assignable to ESD damage from handling. This part showed typical behavior of gate bias voltage drift during the 168 hour HTOL exonerating any intrinsic reliability problems associated with that device.

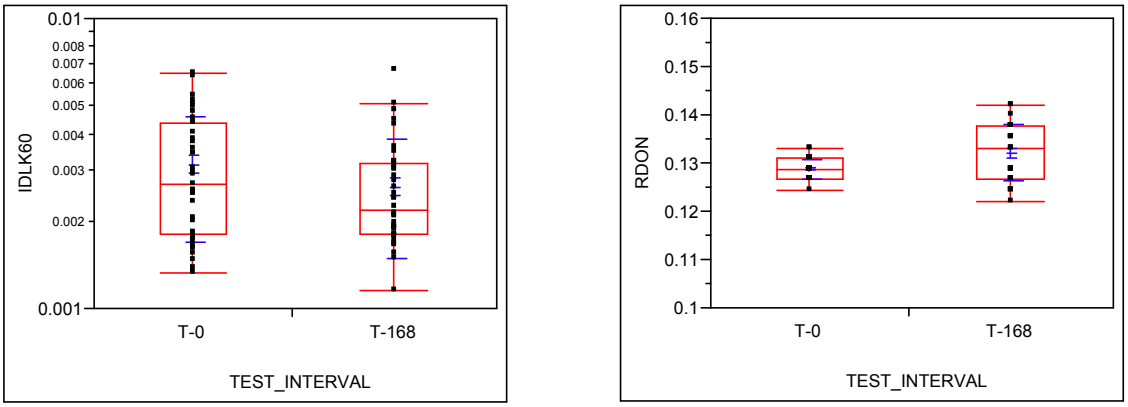

Figure 1: HTOL results for IDLK60 (left) and RDON (right)

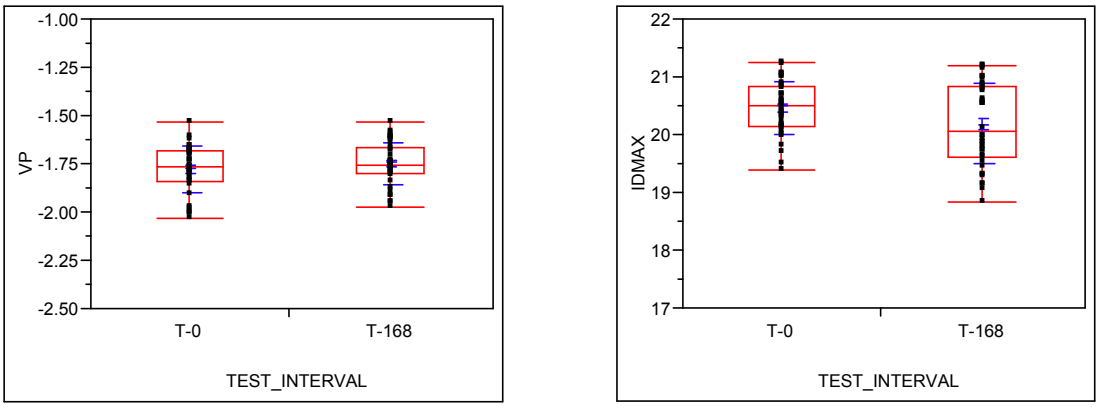

Figure 2: HTOL results for VP (left) and maximum drain current (right)

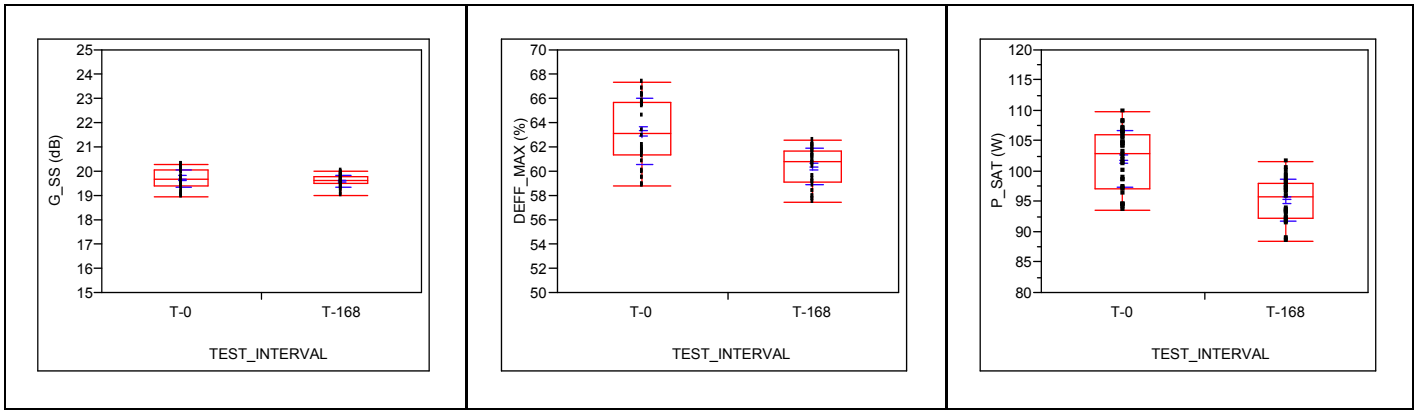

Figure 3: HTOL results for G_SS, DEFF_MAX and P_SAT

3.4.2 ESD

ESD sensitivity testing was performed on burned-in devices that met the target production DC and RF device specifications.

3.4.2.1 ESD-HBM

ESD Human Body Model (HBM) sensitivity testing was carried out in accordance with JEDEC specifications as follows:

- Perform curve traces on each device for as-received devices.
- Apply a positive polarity (200 V) HBM pulse on each device.
- Perform curve traces - device failure is defined as either catastrophic or soft failure (IDLK increases by more than 10x) on the device. Passing devices continue to the next stress level.

- Apply a negative polarity (-200 V) HBM pulse to each device.
- Perform curve traces.
- Repeat positive and negative polarity pulses at 500 V, 1000 V, 2000 V, and 4000 V and curve traces on the same devices until failure is observed on the device.

The results in Table 1 show that all of the devices tested survived pulses up to a level of +/-500 V. The results demonstrate an **ESD-HBM rating of 1B** for the NPT1010.

Table 1. ESD-HBM results by lot. Pre-fail = device met specifications after that cumulative ESD pulse level; post-fail = the device failed after that cumulative ESD pulse level.

Lot number	Device number	Pre-fail (V)	Post-fail (V)
081051D	G090800038	-1000	2000
083143D	G090800052	-500	1000
081051D	G090800037	-1000	1000
083143D	G090800051	-1000	1000
081051D	G090800036	-2000	2000
083143D	G090800043	-1000	2000

3.4.2.2 ESD-CDM

ESD Charged Device Model (CDM) sensitivity testing was carried out in accordance with JEDEC specifications as follows:

- Perform curve traces on each device as-received.
- Apply three positive polarity (100 V) CDM pulses to each device.
- Perform curve traces - device failure is defined as either catastrophic or soft (IDLK increases by more than 10x) on the device. Passing devices continue to the next stress level.
- Apply three negative polarity (-100 V) CDM pulses to each device.
- Perform curve traces.
- Repeat positive and negative polarity pulses at 200 V, 500 V, and 1000 V and curve traces on the same devices until failure is observed in the device.

Table 2: The results show that all 9/9 of the devices tested within specification after through all of the stress levels completed, through 1000 V CDM stress with both polarities. No failures were observed. The results demonstrate an **ESD-CDM rating of "IV"** for the NPT1010.

Lot number	Device number	Device number	Pre-fail V	Post-fail V	Failure
081051D	G084900047	C1	1000	n/a	none
081051D	G084900046	C2	1000	n/a	none
081051D	G084900061	C3	1000	n/a	none
083143D	G084800013	C4	1000	n/a	none
083022D	G084700111	C5	1000	n/a	none
083022D	G084700108	C6	1000	n/a	none
083022D	G084700110	C7	1000	n/a	none
083143D	G084800016	C8	1000	n/a	none
083143D	G084800014	C9	1000	n/a	none

3.4.2.3 ESD-MM

ESD Machine Model (MM) sensitivity testing was carried out in accordance with JEDEC specifications as follows:

- Perform curve traces on each device as-received.
- Apply a positive polarity (100 V) MM pulse to each device.
- Perform curve traces - device failure is defined as either catastrophic or soft (IDLK increases by more than 10x) on the device. Passing devices continue to the next stress level.
- Apply a negative polarity (-100 V) MM pulse to each device
- Perform curve traces.
- Repeat positive and negative polarity pulses at 200 V and 400 V and curve traces on the same devices until failure is observed in the device.

The results in 3 show that some of the devices tested failed after pulses of 100 V. The results demonstrate an **ESD-MM rating of "A"** for the NPT1010.

Table 3. ESD-MM results by lot. Pre-fail = device met specifications after that cumulative ESD pulse level; post-fail = the device failed after that cumulative ESD pulse level. One device was excluded because the as-received device displayed out-of-specification curve trace results

Lot number	Device number	Pre-fail (V)	Post-fail (V)
083022D	M1	-100	100
083022D	M2	-100	100
083022D	M3	0	100
081051D	M4	200	-200
081051D	M5	200	-200
081051D	M6	-100	200
083143D	M7	-400	n/a
083143D	M8	100	-100
083143D	M9	-100	100

3.4.3 Packaging and Die-Package Reliability

3.4.3.1 Temperature cycling

The device temperature cycling reliability has been demonstrated by showing that 75/75 devices successfully survived 500 cycles from -65 °C to +150 °C, with no significant change in electrical performance. Scanning acoustic microscopy on a sampling of those devices showed no significant die attach void growth or die cracking after temperature cycling.

3.4.3.2 Mechanical shock + vibration + constant acceleration

The device mechanical reliability has been demonstrated by test results showing that 40/40 devices successfully survived the mechanical shock + vibration + constant acceleration suite of stressing, with no significant change in electrical performance.

3.4.3.3 Moisture resistance

The package moisture resistance has been demonstrated by showing that 15/15 packages meet the MIL standard visual inspection acceptance criteria after moisture stress.

3.4.3.4 Salt atmosphere

The package salt atmosphere resistance has been demonstrated by showing that 15/15 packages meet the MIL standard visual inspection acceptance criteria after salt atmosphere stress.

3.4.3.5 Solvent Resistance

The package solvent resistance has been demonstrated by showing that 3/3 packages meet the MIL standard visual inspection acceptance criteria after solvent resistance stress

3.4.3.6 Solderability

The package solderability has been demonstrated by showing that 22/22 meet the JESDC standard visual inspection acceptance criteria after solderability testing.

4.0 Summary

In summary, the NPT1010B and NPT1010P devices meet reliability performance requirements for HTOL, temperature cycling, mechanical shock, vibration, constant acceleration, moisture resistance, salt atmosphere, and solderability stress testing per the qualification plan. The ESD reliability performance has been characterized using the HBM, CDM, and MM methodologies.

Table 4: Qualification Results Summary

Stress Type	Abbr.	Reference	Stress Conditions	DUT Failure Criterion	# of lots	Units/Lot	Total units	Results
High temperature operating life	HTOL	JESD22-A108, JESD85	VDS=28V, TJ~200C, 168 hrs	10X change in leakage/15% degradation on other parameters or catastrophic fail	2	20+19	39	0 fail
ESD Human Body Model	ESD-HBM	JESD22-A114	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	2	3	6	1B Classification (+/- 500V)
ESD Charged Device Model	ESD-CDM	JESD22-C101	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	3	3	9	IV Classification (+/- 1000V)
ESD Machine Model	ESD-MM	JESD-A115	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	3	3	9	A Classification (+/- 100V)
Temperature cycling	TC	JESD22-A104	-65/+150C	10X change in leakage/15% degradation on other parameters or catastrophic fail	3	25	75	0 fail
Mechanical shock + vibration variable frequency + constant acceleration	MS+VVF+CA	JESD22-B104(M2002) + -B103(M2007) + M2001	See reference	10X change in leakage/15% degradation on other parameters or catastrophic fail	2	20	40	0 fail
Moisture resistance	MR	M-883-1004	See reference	Visual inspection per MIL spec only (mechanical samples)	1	15	15	0 fail
Salt atmosphere	SA	M-883-1009	see reference	Visual inspection per MIL spec only (mechanical samples)	1	15	15	0 fail
Solvent resistance	SR	M-883-2015	see reference	Visual inspection per MIL spec only (mechanical samples)	1	3	3	0 fail
Solderability (Pill option only)	SLDR	M-883-2013	see reference	Visual inspection per MIL spec only (mechanical samples)	1	22	22	0 fail

5.0 Approval List

VP, Operations	John Bell	Date
VP, Engineering	Ray Crampton	Date
Director, Technology	Pradeep Rajagopal	Date
Test Manager	Apurva Chaudhari	Date
Quality Manager	Frank Palmieri	Date
Reliability Manager	Anwar Arab	Date