NITRONEX CORPORATION

NPT35015 and NPT25015 Qualification Document

Revision 1

NPT35015 and NPT25015 Qualification Document

Qualification Document for NPT35015 and NPT25015

1.0 Purpose

This document outlines the qualification of the NPT35015 and NPT25015 products.

2.0 Customers and/or Applications

RF products for use in wireless communications infrastructure.

3.0 Qualification by Similarity

All Reliability testing was performed on the NPT35015 device. The NPT25015 product will be qualified by similarity.

4.0 NRF1 Technology Definition

4.1 Technology Features

The Nitronex NRF1 technology was designed to support product development for linear and broadband applications to 3.8 GHz with operational voltage of 28V.

Key features of NRF1 technology include:

- High-resistivity (>10k Ohm-cm) silicon substrate
- Ti/Al/Ni/Au ohmic contacts
- 0.5µm Ni/Au T-gate electrode
- SiN_x passivation and encapsulation layers
- Electroplated gold air-bridge interconnect level
- Through-substrate ground vias
- 150µm final substrate thickness

Mask count consists of 10 photo levels, 9 reticles and 1 contact plate. An optional label feature introduces an additional contact plate to the count.

4.2 Process Performance Results

- Psat > 3.5W/mm with Drain Efficiency > 60% at 2.14GHz and 28V
- Maximum Drain current > 800mA/mm
- Contact Resistance < 0.5 Ω-mm
- Breakdown Voltage > 100V
- Maximum Drain Current drift of less than 5% over 20 years at T_J=150°C, V_{DS}=28V

4.3 In-line Process Data

NRF1 process platform was released in October 2005. Specification limits have been established for inline performance under both DC and RF stimulus. A list of the parameters and limits is given in Table 1 below. To date over 200 wafers have been run through this process flow with high yield.

Table 1: Specification limits for DC and RF inline tests.

Parameter	Description	Units	LSL	TGT	USL
BVDG	Two Terminal Off-State Breakdown Voltage	V	135	160	-
BVDS	Three Terminal Off-State Breakdown Voltage	V	95	130	-
GMX	Maximum Extrinsic Transconductance	mS/mm	250	290	330
IDLK_100	Drain Leakage at V_{DS}=100V, V_{GS}=-8V	mA/mm	-	0.2	1.0
IDMAX	Maximum Open Channel Current	mA/mm	760	830	900
LOG_ISO	Isolation Leakage Current - LOG10	Log(A)	-	-9	-8
RC_TLM	Contact Resistance	Ohm mm	-	0.38	0.55
RDON	On Resistance	Ohm mm	2.4	3.0	3.6
RSH_CRBME	Epitaxial Layer Sheet Resistance	Ohm/sq	440	490	530
VP	Pinchoff Voltage	V	-1.50	-1.25	-1.00
NPSAT_W_MM	Saturated Output Power	W/mm	3.4	3.9	-
DEFF_MAX	Maximum Drain Efficiency	%	57	62.5	-

5.0 NPT35015 Device Definition

5.1 Device Features

The NPT35015 consists of a single 8mm die (0.56mm x 1.665mm chip dimension) with a Ag epoxy die attach to a thin Cu flange. The package is then sealed with an overmolded plastic coating. All packaging is performed by Amkor Technologies. Figure 1 below shows a layout picture of the 8mm product die.

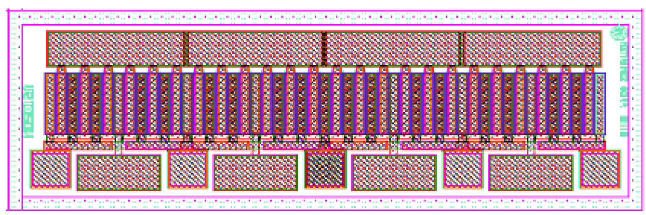


Figure 1: Layout drawing of 8mm product die.

Figure 2 shows a picture of the packaged NPT35015 product device.

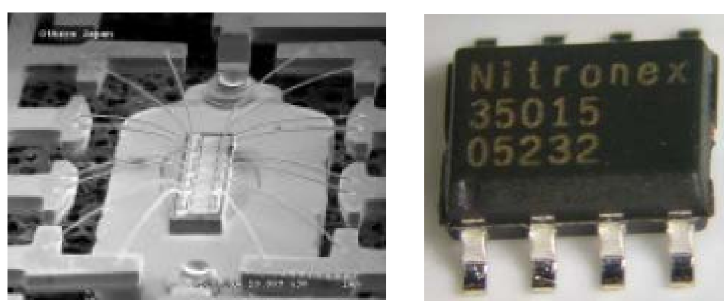


Figure 2: Picture of the NPT35015.

5.2 Device Performance Results

- OFDM Performance at V_{DS}=28V and P_{out}=1.5W from 3.3-3.8GHz:
  - EVM < 2.0%
  - Gain > 10.5dB
  - Drain Eff. > 18%
- CW saturated performance of 18W and 50% at 3.5GHz and 28V.

5.3 Final Device Data

A battery of RF tests were performed on a nominal set of devices to obtain typical characteristics for the NPT35015 product. Multiple devices from 3 process lots were put through CW, Pulsed, 2-tone PEP, and OFDM testing. Results are as follows.

5.3.1 CW, Pulsed, and PEP Performance

CW, pulsed (100μs pulse width, 1% duty cycle), and 2-tone PEP (100khz spacing) measurements were taken with V_{DS}=28V, I_{DQ}=200mA, and Frequency=3.5GHz. A typical CW plot and a comparison of CW, pulsed, and PEP power is shown in Fig. 3.

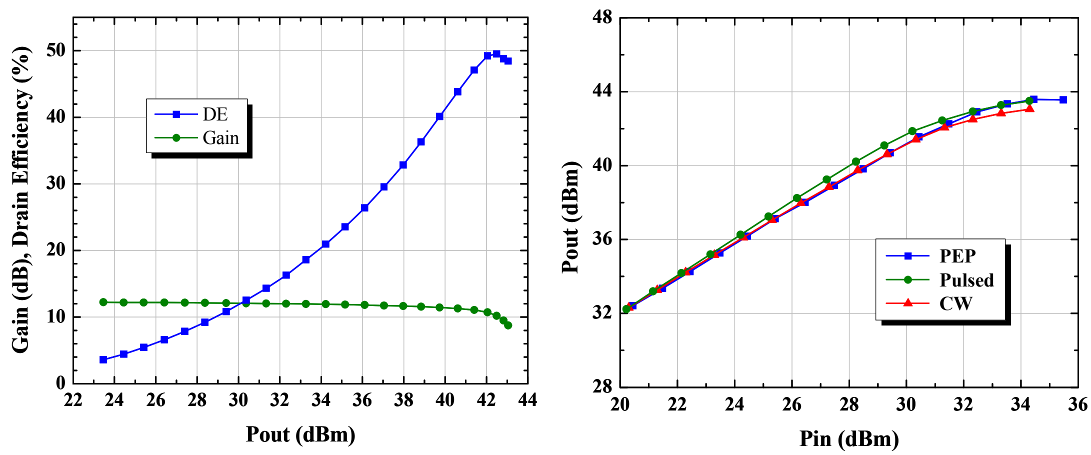


Figure 3: CW power sweep at 3.5GHz (left) and comparison of CW, Pulsed, and PEP power (right).

5.3.2 OFDM Performance

OFDM performance is measured over the frequency range of 3.3GHz to 3.8GHz with a single carrier OFDM waveform (64-QAM ¾, 8 burst, 3.5MHz channel bandwidth, 10.3dB PAR @ 0.01% probability). All measurements are taken with a bias point of V_{DS}=28V and I_{DQ}=200mA. Figure 4 shows the EVM performance versus frequency and a plot of EVM performance versus power for 3.4 and 3.6GHz.

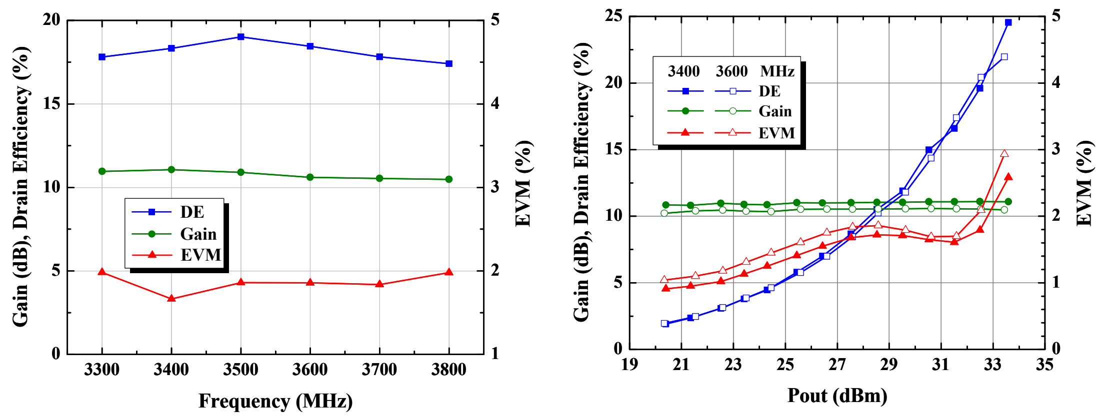


Figure 4: OFDM performance vs frequency at P_{out}=1.5W (left) and EVM curves at 3.4 and 3.6GHz (right).

6.0 NPT25015 Device Definition

6.1 Device Features

The NPT25015 utilizes the same die and packaging technology described in section 5.1.

6.2 Device Performance Results

- OFDM Performance at V_{DS}=28V and P_{out}=1.5W from 2.5-2.7GHz:
  - EVM < 2.0%
  - Gain > 14dB
  - Drain Eff. > 23%
- CW saturated performance of 25W and 55% at 2.5GHz and 28V.

6.3 Final Device Data

A battery of RF tests were performed on a nominal set of devices to obtain typical characteristics for the NPT25015 product. Multiple devices from 3 process lots were put through CW and OFDM testing. Results are as follows.

6.3.1 CW Performance

CW measurements were taken with V_{DS}=28V, I_{DQ}=200mA, and Frequency=2.5GHz. A typical CW plot is shown in Fig. 5.

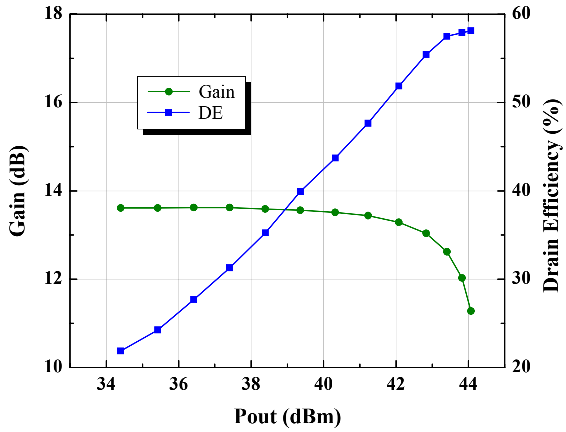


Figure 5: CW power sweep at 2.5GHz.

6.3.2 OFDM Performance

OFDM performance is measured over the frequency range of 2.5GHz to 2.7GHz with a single carrier OFDM waveform (64-QAM ¾, 8 burst, 3.5MHz channel bandwidth, 10.3dB PAR @ 0.01% probability). All measurements are taken with a bias point of V_{DS}=28V and I_{DQ}=200mA. Figure 6 shows the EVM performance versus frequency and a plot of EVM performance versus power for 2.5 and 2.7GHz

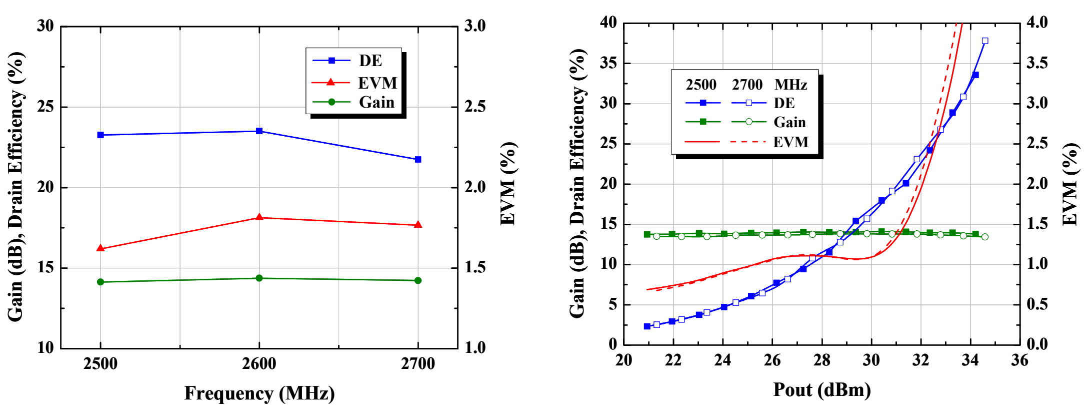


Figure 6: OFDM performance vs frequency at P_{out}=1.5W (left) and EVM curves at 2.5 and 2.7GHz (right).

7.0 Qualification Data

Section 7 presents the qualification data for the NPT35015 product. The first section details the plan approved by the Technology Qualification Review Board (TQRB). The second section contains results from all the reliability tests.

7.1 Reliability plan

Qualification is divided into 4 blocks:

- Product Device Tests
- Product Assembly Tests
- Other packaged tests
- Intrinsic Device Tests

The flow chart in Fig. 7 below details which tests are included in each block.

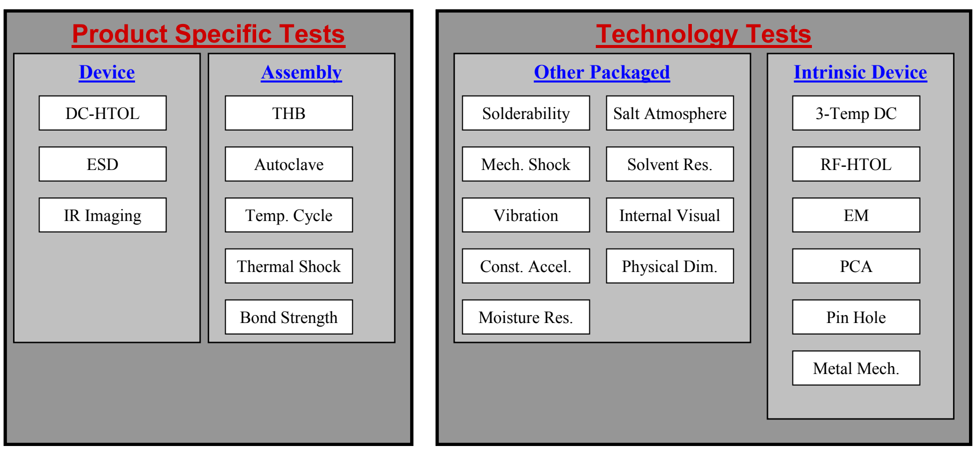


Figure 7: Flow chart detailing different test blocks and specific tests.

7.1.1 Sample Sizes

A minimum of 3 lots will be used in all samples sets. The number of samples and allowed failures are based on LTPD statistics (90% confidence) and are given in the test descriptions that follow.

7.1.2 NPT35015 Reliability Plan

The NPT35015 leveraged a fully qualified process platform which was verified through testing of all the fundamental technology tests such as 3-temp DC, RF-HTOL, etc. Highlights of the technology qualification included an activation energy of 2.0eV and a MTTF > 10^7 hours at 150°C. Details of these results can be found in the NRF1 Process Qualification Document. For the NPT35015 qualification the focus was on product specific tests. The process was divided into three phases. Phase 1 consisted of mechanical verification of the overmolded packaged process and was performed by Amkor Technologies using their standard Qual B flow. Phase 2 was also performed by Amkor and consisted of Moisture Resistance, unbiased HAST, and Temperature Cycling. Phase 3 testing was performed at Nitronex and consisted of DC-HTOL, ESD, Thermal Imaging, and VSWR testing.

7.1.3 Product Device Level Tests

7.1.3.1 DC High Temperature Operating Life (DC-HTOL)

Testing will be performed under DC stress at V_{ds}=28V and T_j=150°C for 1000 hours in accordance with JESD22A108A. CW power sweeps are performed before and after the 1000 hours of stress..

Sample Size: To reach an LTPD level of 5, requires either 45 samples with 0 failures or 77 samples with 1 failure. Samples will be taken randomly from a minimum of 3 processed lots.

7.1.3.2 Electrostatic Discharge – Human Body Model (ESD-HBM)

Three devices per voltage per wafer will be stressed according to 1020/Mil-Std-750. Voltages of 250V, 500V, and 1000V wiill be attempted. For each voltage all pin combination will be stressed with 3 ESD pulses. The ESD-HBM threshold will be the highest passing voltage.

7.1.3.3 Electrostatic Discharge - Machine Model (ESD-MM)

Three devices per voltage per wafer will be stressed according to 1020/Mil-Std-750. Voltages of 50V, 100V, 200V, and 400V will be attempted. For each voltage all pin combination will be stressed with 3 ESD pulses. The ESD-MM threshold will be the highest passing voltage.

7.1.3.4 Thermal Impedance

Thermal impedance will be characterized on a minimum of 5 samples using IR microscopy under a baseplate temperature of 80°C. Whenever possible thermal impedance test conditions will mimic actual fixturing and bias conditions used during life test.

7.1.3.5 VSWR Testing

Output of device is terminated with 10:1 mismatch and line stretcher used to rotate mismatch through all angles. Device is held at operating output power during stress.

7.1.4 Product Assembly Level Tests

7.1.4.1 Unbiased HAST

HAST testing will be carried out at 131°C, 85%RH, for 96 hours per JESD22A110B. DC testing will be carried out before and after the stress.

Sample Size: A total of 231 samples were tested, 77 each from 3 process lots.

7.1.4.2 Temperature Cycle

Temperature Cycling will consist of air-to-air cycling between –65°C and 150°C per Mil-Std-750. There will be a total of 500 cycles. CSAM results before and after stress are used to inspect parts.

Sample Size: A total of 231 samples were tested, 77 each from 3 process lots.

7.1.4.3 Moisture Resistance

Moisture Resistance will be test per Mil-Std-833-1004. The failure criteria for this test is visual inspection and this is considered a destructive test.

Sample Size: A total of 66 samples were tested, 22 each from 3 process lots.

7.2 Reliability Results

Reliability testing was performed according to the plan in section 7.1, details of individual tests are shown in the following sections.

7.2.1 Amkor Qual B Mechanical Tests

Over 1000 NPT35015 devices were put through the standard Qual B flow at Amkor Technologies with no failures seen on any tests. Table 2 summarizes all the tests and a full test report is available upon request.

Table 2: Summary of Amkor Qual B Tests

Process	Spec No.	Test Item	Sample Size	Status
Saw	001-0507-2002	Saw Visual	100	Passed
		Kerf Width	10	Passed
Die Attach	001-0510-2042	Die Bond Visual	100	Passed
		Epoxy Void	10	Passed
		Adhesive Thickness	10	Passed
Wirebond	001-0511-2044	Wire bond visual	100	Passed
		Loop Height	10	Passed
		Crater Test	10	Passed
		Wire Pull Test	45	Passed
		Ball Shear Test	45	Passed
Mold	011-0517-2447	Mold Visual	100	Passed
		Wiresweep	1	Passed
		Internal Void	1	Passed
Lead Finish	001-0522-2571	Plating Visual	100	Passed
		Solerability	10	Passed
		Thickness	10	Passed
Marking	001-0516-2060	Mark Visual	100	Passed
TFS	001-0521-2014	T/F Visual	100	Passed
		Seating Plane Height	10	Passed
		Lead Tip to Tip	10	Passed
		Coplanarity	10	Passed
		Microgap/crack	50	Passed

7.2.2 Product Assembly Level Tests

Over 500 NPT35015 devices were used for Moisture Resistance, unbiased HAST, and Temperature Cycling tests at Amkor Technologies with no failures seen on any tests. Table 3 summarizes all the tests and a full test report is available upon request

Table 3: Summary of Product Assembly Level Tests

Test	Spec No.	Sample Size	Status
Moisture Sensitivity	001-0228-2531	66	Passed
Temperature Cycling	001-0234-2150	231	Passed
HAST (unbiased)	001-0234-2150	231	Passed

7.2.3 Product Device Level Tests

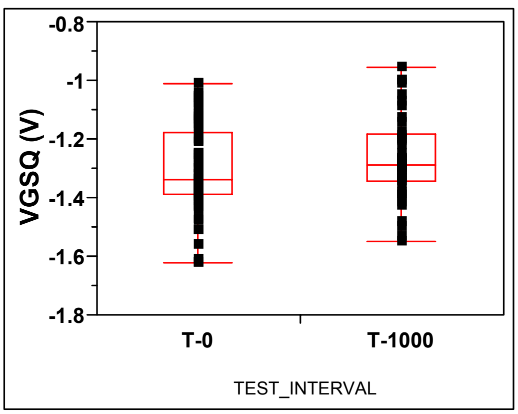
Results for Device level reliability tests are summarize in Table 4 below.

Table 4: Summary of Reliability Test Data

Test Name	Test Standard	Sample Set	Status
DC-HTOL	JESD22-A108	45 devices, 1000 hours	**Complete**
ESD-HBM	M-750-1020	9	**Complete**
ESD-MM	M-750-1020	9	**Complete**
VSWR	10:1 VSWR	5	**Passed**
Thermal Impedance	IR imaging	9	**Complete**

7.2.4 DC-HTOL Results

A 45 piece sample was placed under DC-HTOL stress at V_{DS}=28V and T_j=200°C for 1000 hours as planned. CW testing was performed at 28V and 3.5GHz before and after the 1000 hours of stress. Figure 8 below shows box plots for V_{gsq} and small-signal gain before and after the stress. Minimal shift is seen for both parameters proving the robustness of the device.



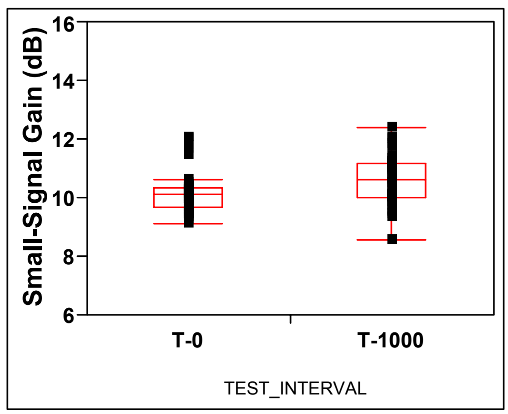


Figure 8: DC-HTOL results for V_{gsq} (left) and small-signal gain (right).

7.2.5 ESD-HBM Results

ESD testing was carried out using the HBM waveform on 3 devices each from 3 different wafers. Each pin combination (-GS, +GS, -GD, +GD) was stressed with 3 test pulses and full DC characterization was performed before and after stress. Figure 9 shows results after a HBM voltage stress of 250V and 500V. There was no damage seen after 250V, while one failure was seen at 500V. This leads to an ESD classification of 1A.

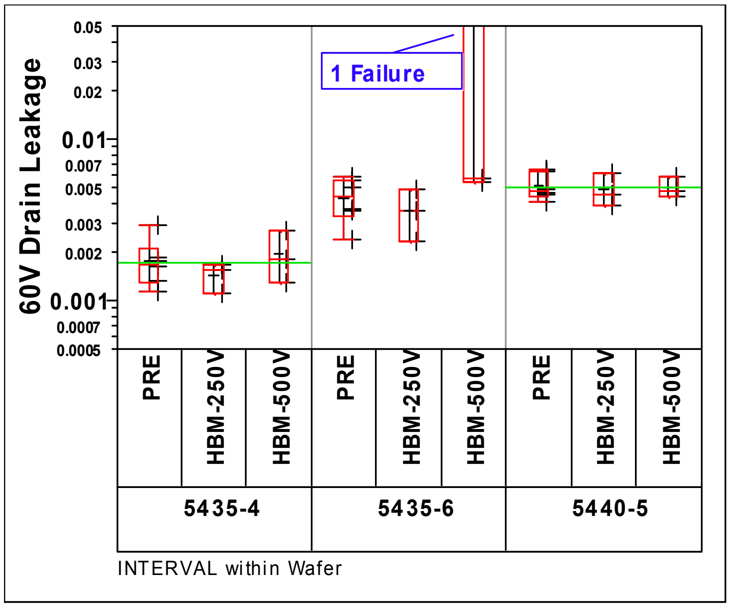


Figure 9: 60V Drain leakage shown on 3 wafers before stress and after stimulus with HBM voltages of 250V and 500V. No failures or significant shifts in performance.

7.2.6 ESD-MM Results

ESD testing was also carried out using the MM waveform on 3 devices each from 3 different wafers. Each pin combination (-GS, +GS, -GD, +GD) was stressed with 3 test pulses and full DC characterization was performed before and after stress. Figure 10 shows results after a MM voltage stress of 50V. There was no damage seen after 50V, while one failure was seen at 100V. This leads to an ESD classification of M1.

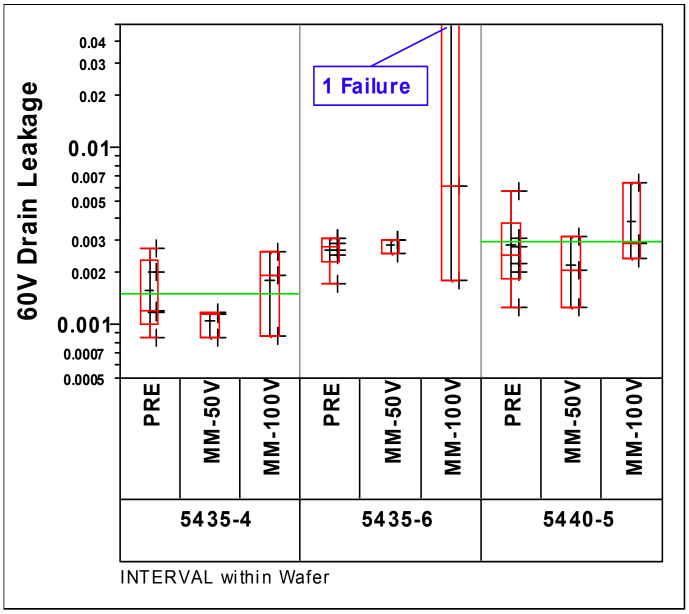


Figure 10: 60V Drain leakage shown on 3 wafers before stress and after stimulus with HBM voltages of 50V and 100V. No failures or significant shifts in performance.

7.2.7 Thermal Impedance Results

Thermal impedance measurements were made using a QFI Infrascope II infrared thermal imaging microscope. The measurement was made with the heat sink temperature at 80°C. The bias condition was V_{DS}=28V and I_{DS}=250mA for each device, which is equal to the power dissipated under the RF operating point of P_{out}=1.5W and Efficiency = 18%. A total of 5 samples were measured from 3 wafers with all 5 devices at or below the datasheet spec of 6.25°C/W. Table 3 summaries the results.

Table 5: Thermal Resistance on NPT35015: Rth Specification = 6.25°C/W.

DUT	T_{case} (°C)	$T_{junction}$ (°C)	R_{TH} (°C/W)	Pass/Fail
1	108.00	150.13	5.47	PASS
2	108.00	155.13	6.12	PASS
3	108.00	152.13	5.73	PASS
4	108.00	148.00	5.19	PASS
5	108.00	155.00	6.10	PASS
AVG	**108.00**	**152.08**	**5.72**	
STD DEV	**0.00**	**3.09**	**0.40**	

7.2.8 VSWR Robustness Testing

VSWR mismatch was presented to devices under operating conditions of V_{DS}=28V, I_{DQ}=200mA, P_{out}=31.8dBm and Frequency=3.5GHz with OFDM modulation applied. A total of 5 devices were stressed and characterization before and after stress shows no significant shift in performance as seen in Fig. 11.

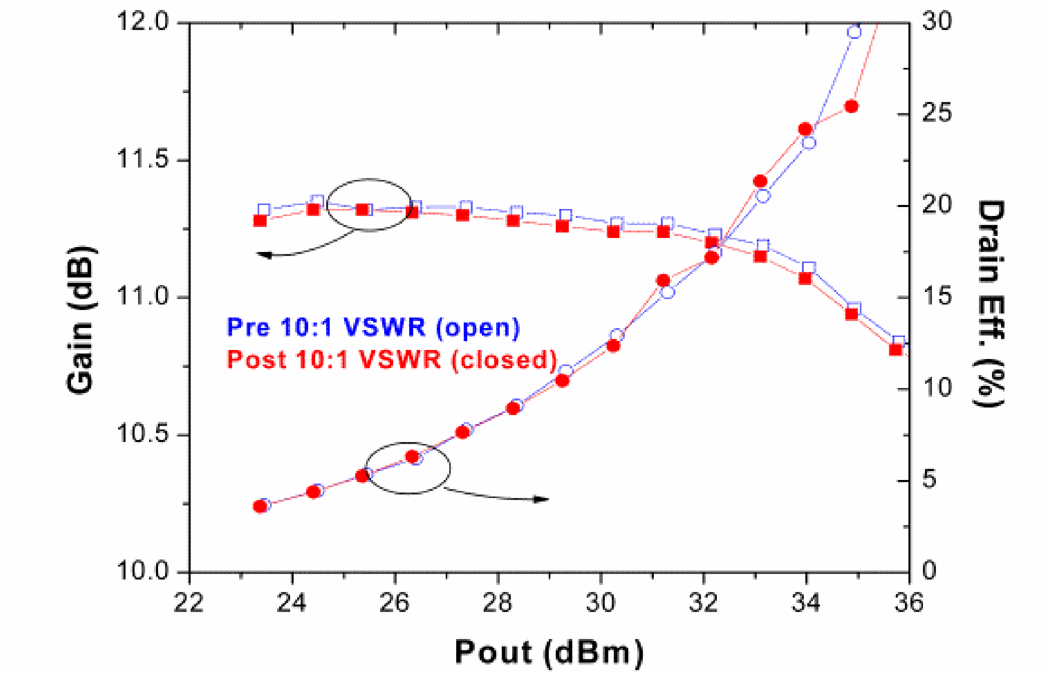


Figure 11: RF power sweep for typical device before and after stress with 10:1 VSWR mismatch.

8.0 Summary

This document outlined qualification of the NPT35015 and NPT25015 devices. Product qualification leveraged a consistent and reliable process platform, NRF1. Devices from the NRF1 process platform were built in plastic overmold packages and produced good CW and OFDM performance In both the 3.3 to 3.8GHz band and the 2.5 to 2.7GHz band. The NPT35015 device was then put through an extensive battery of device and package reliability tests including DC-HTOL, ESD, thermal impedance, and VSWR testing at Nitronex. Additionally, Amkor's standard Qual B was successfully completed. The NPT35015 demonstrated reliable operation by passing all qualification tests and was officially qualified by the Nitronex TQRB on October 6, 2006. The NPT25015 device was qualified by similarity.