

# LM4050WG2.5RLQV Neutron Displacement Damage (NDD) Characterization



## ABSTRACT

This report presents the effect of neutron displacement damage (NDD) on the LM4050WG2.5RLQV device. The devices were radiated up to  $1 \times 10^{13}$  n/cm<sup>2</sup> (1-MeV equivalent). A sample size of nine units was exposed to radiation testing per MIL-STD-883(Method 1017 for Neutron Irradiation) and an additional unirradiated sample device was used for correlation. Electrical testing was performed at Texas Instruments before and after neutron irradiation using the production test program for LM4050QML-SP devices.

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## 1 Overview

The LM4050WG2.5RLQV is a radiation-hardness-assured (RHA) 2.5-V shunt voltage reference. The LM4050QML's design eliminates the need for an external stabilizing capacitor while ensuring stability with a capacitive load, thus making the LM4050QML easy to use. The LM4050-2.5QML has a 60  $\mu$ A minimum and 15 mA maximum operating current.

General device information and testing conditions are listed in [Table 1-1](#).

**Table 1-1. Overview Information**

TI Part Number	LM4050QML-SP
Orderable Number	LM4050WG2.5RLQV
Device Function	Shunt Voltage Reference
Die Name	GLLM4050CLEC3A
Package	10-pin CFP (NAC)
Technology	LFAST
A/T Lot Number / Date Code	5405507/1545B
Unbiased Quantity Tested	9 + control
Exposure Facility	VPT Rad
Neutron Fluence (1-MeV equivalent)	$1.0 \times 10^{12}$ , $5.0 \times 10^{12}$ , $1.0 \times 10^{13}$ n/cm <sup>2</sup>
Irradiation Temperature	25°C
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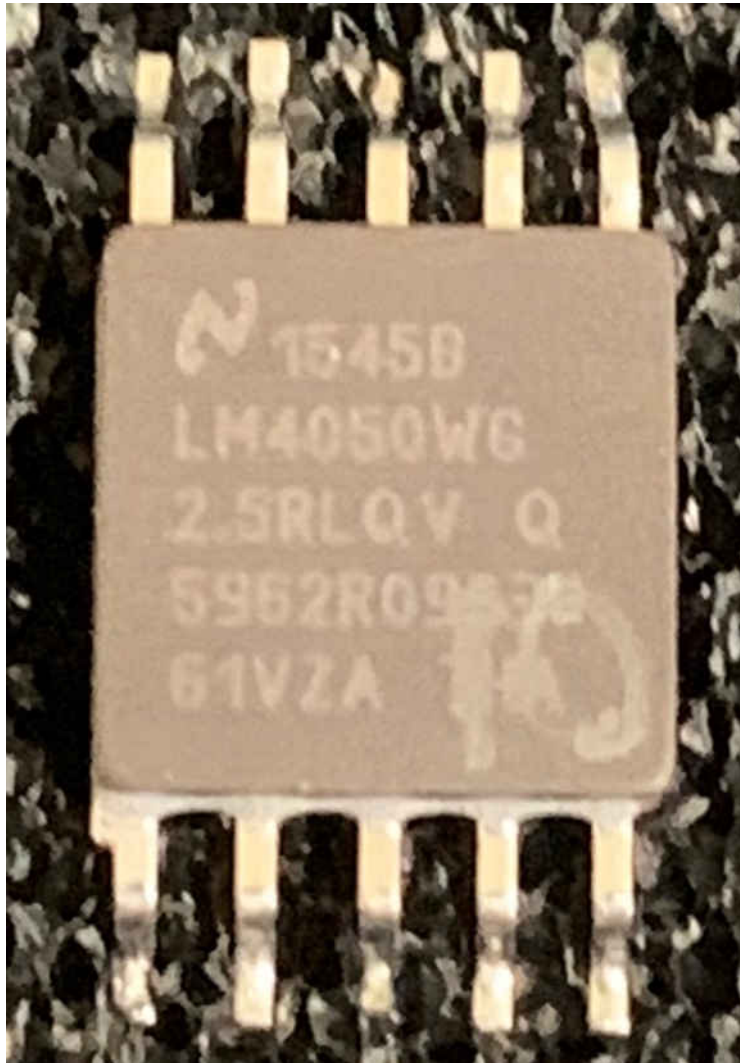
## 2 Test Procedures

The LM4050WG2.5RLQV devices was electrically pre-tested using the production automated test equipment (ATE) program.

General test procedures were IAW MIL-STD-883, Method 1017 for Neutron Irradiation of LM4050WG2.5RLQV.

**Table 2-1. Neutron Irradiation Conditions**

Group	Sample Qty	Neutron Fluence (n/cm <sup>2</sup> )	Bias
A	3	$1.0 \times 10^{12}$	Unbiased
B	3	$5.0 \times 10^{12}$	Unbiased
C	3	$1.0 \times 10^{13}$	Unbiased



**Figure 2-1. LM4050WG2.5RLQV Device**

The LM4050WG2.5RLQV is packaged in a 10-pin ceramic flat pack package (NAC) as shown in [Figure 2-1](#) .

### 3 Facility

VPT Rad performs all neutron displacement damage irradiations in a low-enriched, open-pool, water moderated, thermal neutron reactor. It utilizes flat-plate type fuel and has a maximum thermal energy output of up to 1 MW. The Fast Neutron Irradiator (FNI) faces one side of the reactor core. The FNI design produces a geometrical planar *beam* of fast neutrons that is approximately uniform over an area of 12 in × 20 in. Lead and thermal neutron absorbing compounds are combined to filter out both fission gammas and thermal neutrons. The ratio of fast-to-thermal neutrons is approximately 400:1, with a gamma exposure of up to 1401 rad(Si) for a 1E13 n/cm<sup>2</sup> (1-MeV(Si) equivalent) exposure. The FNI can accommodate a sample or samples with size up to 30 cm in diameter and 15-cm thick including packaging materials. The minimum neutron fluence rate is 1E6 n/cm<sup>2</sup>-s. The maximum neutron fluence rate is approximately 1.0E11 n/cm<sup>2</sup>-s (both values are 1-MeV(Si) equivalent).

The neutron fluence rate is determined using the previously-measured neutron radiation field for the FNI, performed in accordance with ASTM standards (ASTM F1190), and correlated to the measured reactor power level. The neutron dose is timed to meet the customer-specified fluence for the irradiation. Neutron dosimetry meeting ASTM standards (ASTM E265) is utilized to track and ensure irradiations meet the required minimum. The facility retains *source-suitability* with the Defense Logistics Agency (DLA) Laboratory Suitability Program for ASTM Test Method 1017. The DUTS are typically irradiation in an unbiased condition as per TM1017. If bias conditions are required, they can be maintained via dry thimbles connected to the irradiation volume.

## 4 Results

There were failures at all tested neutron fluence levels. At the  $1 \times 10^{12}$  n/cm<sup>2</sup> level were marginal and only appeared in one device. At the  $5 \times 10^{12}$  n/cm<sup>2</sup> fluence levels, failures were present in all three devices. At the  $1 \times 10^{13}$  n/cm<sup>2</sup> fluence levels, failures were present in all three devices. The full parameter list and graphs are found in [Appendix A](#).

[Table 4-1](#) lists the LM4050QML-SP specification compliance matrix.

**Table 4-1. LM4050QML-SP Specification Compliance Matrix**

PARAMETER	TEST CONDITION	LM4050QML-SP DATA SHEET (SNVS627G)				ATE TEST #
		MIN	TYP	MAX	UNIT	
Minimum Operating Current				60	μA	3.1
Reverse Breakdown Voltage	I <sub>R</sub> = 100 μA		2.5		V	4.2
Reverse Breakdown Voltage Tolerance	I <sub>R</sub> = 60 μA			±2.5	mV	5.3
	I <sub>R</sub> = 100 μA			±2.5		4.2
	I <sub>R</sub> = 1 mA			±3.75		6.4
	I <sub>R</sub> = 10 mA			±10		9.7
	I <sub>R</sub> = 15 mA			±13		8.6

## 5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

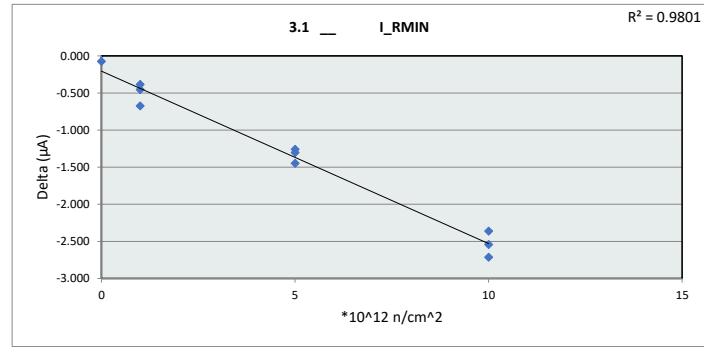
DATE	REVISION	NOTES
April 2022	*	Initial release

## A Appendix: NDD Test Results

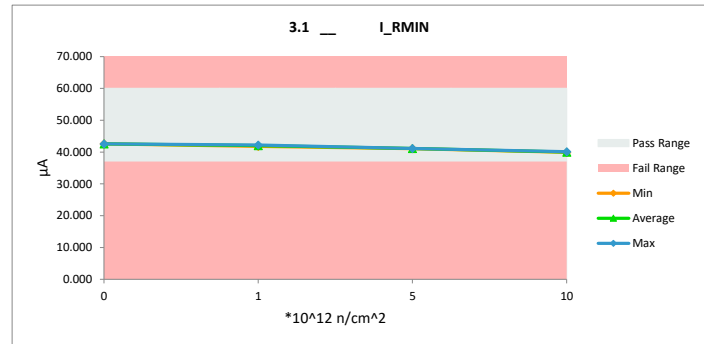
This appendix contains the detailed NDD test results.

# NDD Report LM4050WG2.5RLQV

		3.1 I_RMIN		
Test Site				
Tester				
Test Number				
Unit		µA	µA	
Max Limit		60	60	
Min Limit		37	37	
*10 <sup>12</sup> n/cm <sup>2</sup>	Serial #	PRE	POST	Delta
1	33.1	42.650	42.197	-0.453
1	34.1	42.478	42.094	-0.384
1	35.1	42.494	41.819	-0.675
5	36.1	42.303	41.043	-1.260
5	37.1	42.444	41.140	-1.303
5	38.1	42.572	41.125	-1.447
10	39.1	42.697	39.983	-2.714
10	40.1	42.478	39.936	-2.542
10	41.1	42.481	40.121	-2.360
0	42.1	42.660	42.585	-0.075
Max		42.697	42.585	-0.075
Average		42.526	41.204	-1.321
Min		42.303	39.936	-2.714
Std Dev		0.120	0.964	0.951



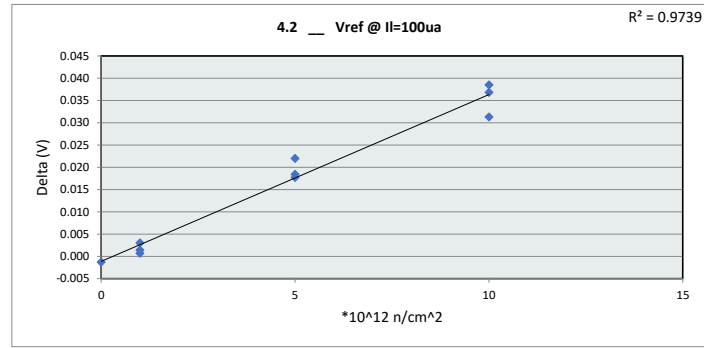
		3.1 I_RMIN			
Test Site					
Tester					
Test Number					
Max Limit		60	µA		
Min Limit		37	µA		
*10 <sup>12</sup> n/cm <sup>2</sup>		0	1	5	10
LL		37.000	37.000	37.000	37.000
Min		42.585	41.819	41.043	39.936
Average		42.585	42.037	41.103	40.013
Max		42.585	42.197	41.140	40.121
UL		60.000	60.000	60.000	60.000



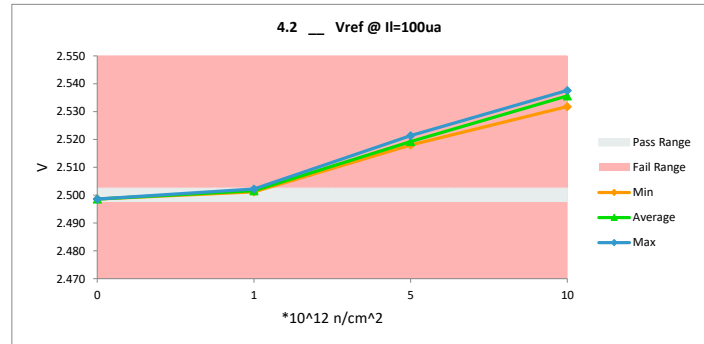
# NDD Report LM4050WG2.5RLQV

4.2 __ Vref @ Il=100ua	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	2.5025
Min Limit	2.4975

*10 <sup>12</sup> n/cm <sup>2</sup>	Serial #	PRE	POST	Delta
1	33.1	2.499	2.502	0.003
1	34.1	2.500	2.501	0.001
1	35.1	2.500	2.501	0.001
5	36.1	2.499	2.521	0.022
5	37.1	2.500	2.518	0.018
5	38.1	2.500	2.518	0.018
10	39.1	2.501	2.538	0.037
10	40.1	2.500	2.532	0.031
10	41.1	2.499	2.537	0.038
0	42.1	2.500	2.499	-0.001
Max		2.501	2.538	0.038
Average		2.500	2.517	0.017
Min		2.499	2.499	-0.001
Std Dev		0.001	0.015	0.015



4.2 __ Vref @ Il=100ua		0	1	5	10
Test Site					
Tester					
Test Number					
Max Limit	2.5025	V			
Min Limit	2.4975	V			
LL	2.498	2.498	2.498	2.498	2.498
Min	2.499	2.501	2.518	2.532	2.532
Average	2.499	2.502	2.519	2.536	2.536
Max	2.499	2.502	2.521	2.538	2.538
UL	2.503	2.503	2.503	2.503	2.503

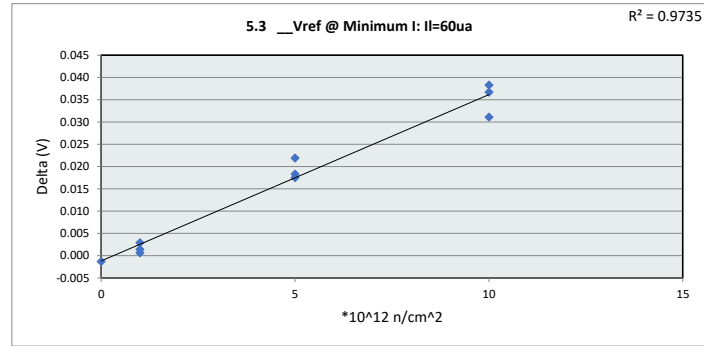




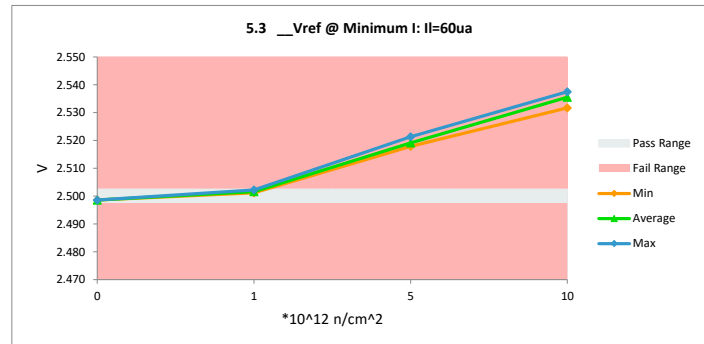
# NDD Report LM4050WG2.5RLQV

5.3 __Vref @ Minimum I: Il=60u	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	2.5025
Min Limit	2.4975

*10 <sup>12</sup> n/cm <sup>2</sup>	Serial #	PRE	POST	Delta
1	33.1	2.499	2.502	0.003
1	34.1	2.501	2.501	0.001
1	35.1	2.500	2.501	0.001
5	36.1	2.499	2.521	0.022
5	37.1	2.501	2.518	0.017
5	38.1	2.500	2.518	0.018
10	39.1	2.501	2.537	0.037
10	40.1	2.501	2.532	0.031
10	41.1	2.499	2.537	0.038
0	42.1	2.500	2.499	-0.001
Max		2.501	2.537	0.038
Average		2.500	2.517	0.017
Min		2.499	2.499	-0.001
Std Dev		0.001	0.015	0.015



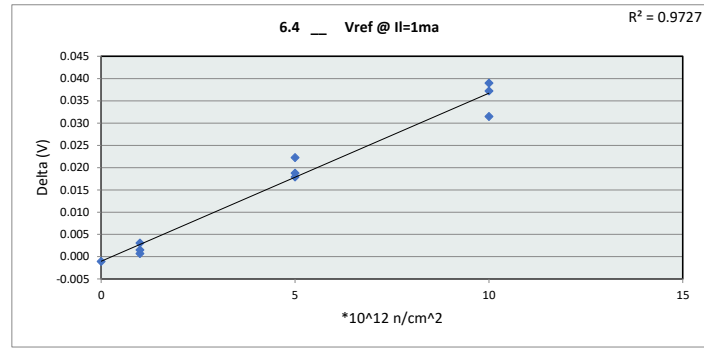
5.3 __Vref @ Minimum I: Il=6				
Test Site				
Tester				
Test Number				
Max Limit	2.5025	V		
Min Limit	2.4975	V		
*10 <sup>12</sup> n/cm <sup>2</sup>	0	1	5	10
LL	2.498	2.498	2.498	2.498
Min	2.499	2.501	2.518	2.532
Average	2.499	2.502	2.519	2.536
Max	2.499	2.502	2.521	2.538
UL	2.503	2.503	2.503	2.503



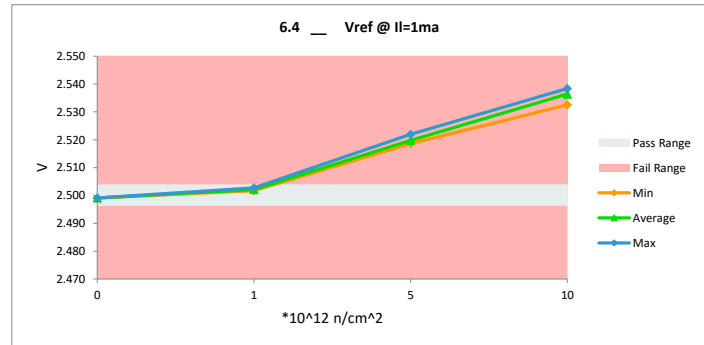
# NDD Report LM4050WG2.5RLQV

6.4 Vref @ Il=1ma	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	2.50375
Min Limit	2.49625

*10 <sup>12</sup> n/cm <sup>2</sup>	Serial #	PRE	POST	Delta
1	33.1	2.500	2.503	0.003
1	34.1	2.501	2.502	0.001
1	35.1	2.500	2.502	0.002
5	36.1	2.500	2.522	0.022
5	37.1	2.501	2.519	0.018
5	38.1	2.500	2.519	0.019
10	39.1	2.501	2.538	0.037
10	40.1	2.501	2.533	0.032
10	41.1	2.499	2.538	0.039
0	42.1	2.500	2.499	-0.001
Max		2.501	2.538	0.039
Average		2.500	2.517	0.017
Min		2.499	2.499	-0.001
Std Dev		0.001	0.016	0.015



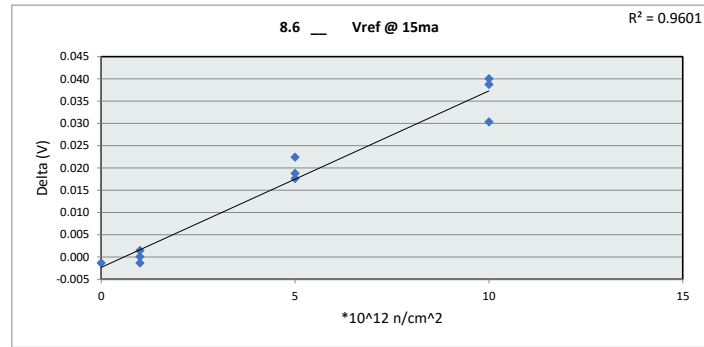
6.4 Vref @ Il=1ma		0	1	5	10
Test Site					
Tester					
Test Number					
Max Limit	2.50375	V			
Min Limit	2.49625	V			
*10 <sup>12</sup> n/cm <sup>2</sup>		0	1	5	10
LL		2.496	2.496	2.496	2.496
Min		2.499	2.502	2.519	2.533
Average		2.499	2.502	2.520	2.536
Max		2.499	2.503	2.522	2.538
UL		2.504	2.504	2.504	2.504



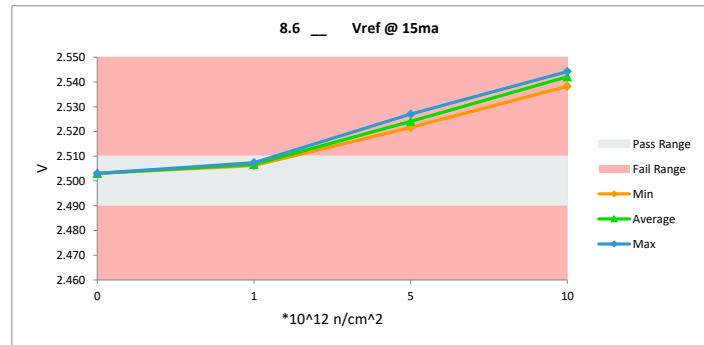
# NDD Report LM4050WG2.5RLQV

		8.6 ___ Vref @ 15ma	
Test Site			
Tester			
Test Number			
Unit		V	V
Max Limit		2.51	2.51
Min Limit		2.49	2.49

*10 <sup>12</sup> n/cm <sup>2</sup>	Serial #	PRE	POST	Delta
1	33.1	2.506	2.507	0.001
1	34.1	2.508	2.507	-0.001
1	35.1	2.506	2.506	0.000
5	36.1	2.505	2.527	0.022
5	37.1	2.505	2.524	0.019
5	38.1	2.504	2.522	0.018
10	39.1	2.505	2.544	0.039
10	40.1	2.508	2.538	0.030
10	41.1	2.504	2.544	0.040
0	42.1	2.504	2.503	-0.001
Max		2.508	2.544	0.040
Average		2.505	2.522	0.017
Min		2.504	2.503	-0.001
Std Dev		0.001	0.016	0.016



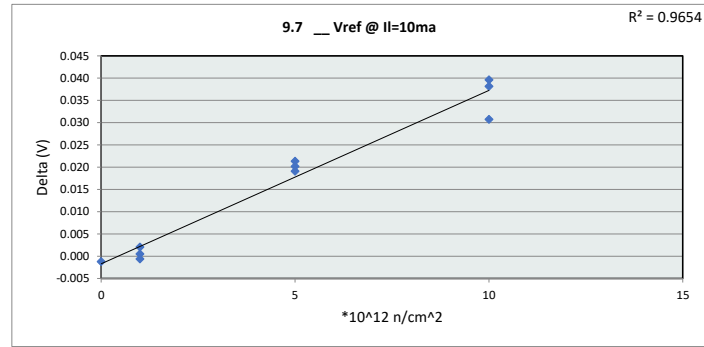
		8.6 ___ Vref @ 15ma			
Test Site					
Tester					
Test Number					
Max Limit		2.51		V	
Min Limit		2.49		V	
*10 <sup>12</sup> n/cm <sup>2</sup>		0	1	5	10
LL		2.490	2.490	2.490	2.490
Min		2.503	2.506	2.522	2.538
Average		2.503	2.507	2.524	2.542
Max		2.503	2.507	2.527	2.544
UL		2.510	2.510	2.510	2.510



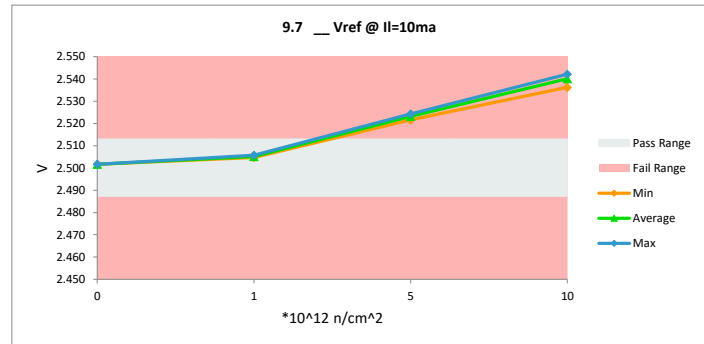
# NDD Report LM4050WG2.5RLQV

9.7 __ Vref @ Il=10ma	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	2.513
Min Limit	2.487

*10 <sup>12</sup> n/cm <sup>2</sup>	Serial #	PRE	POST	Delta
1	33.1	2.504	2.506	0.002
1	34.1	2.505	2.505	-0.001
1	35.1	2.504	2.505	0.001
5	36.1	2.503	2.524	0.021
5	37.1	2.503	2.524	0.020
5	38.1	2.503	2.522	0.019
10	39.1	2.504	2.542	0.038
10	40.1	2.505	2.536	0.031
10	41.1	2.502	2.542	0.040
0	42.1	2.503	2.502	-0.001
Max		2.505	2.542	0.040
Average		2.504	2.521	0.017
Min		2.502	2.502	-0.001
Std Dev		0.001	0.016	0.016



9.7 __ Vref @ Il=10ma					
Test Site					
Tester					
Test Number					
Max Limit	2.513	V			
Min Limit	2.487	V			
*10 <sup>12</sup> n/cm <sup>2</sup>	0	1	5	10	
LL	2.487	2.487	2.487	2.487	
Min	2.502	2.505	2.522	2.536	
Average	2.502	2.505	2.523	2.540	
Max	2.502	2.506	2.524	2.542	
UL	2.513	2.513	2.513	2.513	



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